

337 nm CubeSat photometer

Physics 101: a complete companion to the mission study

22 October 2026 | Standalone revision r4

Source altitude 15-18 km; nominal orbit 550 km; simultaneous 337 nm and 777 nm channels.

Measured evidence, conditional calculations and unresolved mission inputs are labeled separately. This document replaces the interpretation of earlier layered revisions.

Fresh finite-cylinder nonspherical-ice calculations were executed. Numerical convergence remains incomplete in flagged cases; they are diagnostics, not validated predictions of real anvil timing.

The original question numbering is retained. Initial denotes the unnumbered transmission question; A-1 is the tool question and A-2 is the timing question; B-4 through G-22 follow the original list.

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Scope and how to read the evidence

The study concerns a nightside two-channel photometer near 550 km, with a 337 nm nitrogen band used to detect blue streamer-like transients and a simultaneous 777 nm channel used to constrain thermal alternatives. The optical-head target is approximately 2-4 kg and 5-10 W. These are requirements under assessment, not a completed hardware design.

The strongest result is a set of corrected physical constraints and reproducible conditional tests. Molecules above 15-18 km remove several percent of the direct 337 nm beam; clouds redirect and delay light; actual photon counts and the entire receiver response govern timing and a red upper limit. The campaign has not supplied an unbiased faint-source population, a polar 337 nm background climatology or accepted flight hardware.

This is a new standalone revision. It replaces interpretation of the earlier layered technical and Physics 101 PDFs. Earlier CloudScat runs are dated conditional heritage; fresh revision analyses are identified by their execution receipts. A run is not described as measured or physically validated merely because it completed or passed algebraic checks.

The original list starts with an unnumbered transmission/Rayleigh question, then tool question 1 and timing question 2, followed by 4-22. The document preserves those scopes as Initial, A-1, A-2, B-4 through G-22. Complete-document numbers 1-22 are navigation only; no missing original question 3 is invented. All 22 scopes have reviewed answers, but the selected mission is not empirically closed.

What is established, and what remains a measurement

A physical principle can be settled while an instrument choice remains open. A calculation can be correct under assumptions while a real cloud or source violates those assumptions. A measurement on another mission is evidence for that hardware and environment, not automatic qualification of ours.

Evidence labels used throughout both companion documents.

Label	Meaning	Does not imply
Measured or manufacturer-specified	Published device, scene or calibration under stated conditions	The proposed complete instrument has that performance
Executed conditional model	Retained code/data, run receipt and numerical checks	Physical validation or a measured scene/population
Method or physical principle	Derivation, conservation law or documented inference procedure	Missing parameters are known
Missing mission evidence	Selected receiver, source, background or exposure still needs data	The physics question has no useful answer

Physics foundations

1. Light can be described as waves and counted as photons

Wavelength is the spacing of a light wave. A nanometre is one billionth of a metre. Our 337 nm band is ultraviolet; 777 nm is deep red/near infrared. A photon is a packet of light energy. Its energy is h times c divided by wavelength, so a 337 nm photon carries about 2.3 times the energy of a 777 nm photon.

This matters when comparing channels. Equal optical watts do not mean equal photon numbers. A detector efficiency is usually a probability that an incoming photon produces a useful signal. A ratio stated in electrical volts, watts or photons is therefore a different ratio unless the conversion is explicit.

Scientific notation is used for very small or large values: $1e-6$ means one millionth; $1e6$ means one million. A value such as $1.4e-16$ is a very small fraction, not a negative number. Always retain the unit and reference plane beside it.

$$E_{\text{ph}} = h c / \lambda; N_{\text{ph}} = \text{energy} / E_{\text{ph}}$$

2. Power, energy, irradiance, radiance and fluence answer different questions

A watt is energy per second. A joule is energy. Irradiance is optical power arriving per square metre at a specified plane. Integrating irradiance over time gives energy fluence in joules per square metre. Photon fluence counts photons per square metre over the event.

Radiance also specifies direction: it is power per projected area per solid angle, and spectral radiance adds per unit wavelength. A steradian measures angular area. A diffuse cloud fills many viewing directions, whereas a compact flash occupies a small region. A wide-field detector therefore needs both spatial/angular acceptance and aperture area to convert scene radiance into counts.

A published waveform already expressed as 337 nm band-integrated irradiance must not be multiplied by 4 nm again. Likewise, light measured at the spacecraft has already undergone the real cloud/air journey. Applying cloud attenuation again would count that loss twice.

$$\text{energy fluence} = \int \text{irradiance}(t) dt$$

3. The source is an excited gas, not a lamp with a fixed wattage

An electric field accelerates charged particles. Energetic electrons can transfer energy to nitrogen molecules, leaving them in excited states. When a molecule returns toward a lower state, it may emit a photon in one of several allowed transitions. The second-positive nitrogen system includes the band near 337 nm.

Nonthermal means that some electrons can have high energies without the entire gas having the temperature of a hot lightning channel. It does not mean no energy or no heating. A streamer and a hot channel can have different spectra, and ordinary lightning can contain several components with different spectra.

An individual excited state can lose energy quickly by radiation or collisions. A millisecond optical event can persist because excitation continues or recurs, not because each molecule stores the energy for a millisecond. This separates molecular lifetime from event duration.

$$\text{excitation history} + \text{radiative decay} + \text{collisional quenching} \text{ determine emitted light}$$

4. Distance and aperture decide how many packets are intercepted

For a hypothetical isotropic point flash, the same total photons spread across a sphere. Doubling the distance spreads them over four times the area. A small entrance aperture intercepts its area divided by that sphere area, on axis in vacuum.

Using a 25 mm circular entrance at roughly 534 km source-to-instrument range gives only about 1.4×10^{-16} of all isotropically emitted photons before atmospheric transport and detection losses. This is a geometry example, not a measured source yield or an aperture requirement. A known spacecraft-plane fluence can be converted directly to aperture photons without guessing total source emission.

Off-axis geometry changes range and projected area. A nonimaging photometer may not know the source position within its field, which creates a brightness/response ambiguity unless another instrument localizes it or a conservative field-wide calibration is used.

$$N_{\text{ap}}/N_{\text{emitted}} = A \cos(\theta) / (4 \pi R^2) \text{ in vacuum}$$

5. Scattering changes direction; absorption removes photon energy from this band

A molecule or cloud particle can redirect light. If energy is absorbed, it is transferred to the material or re-emitted in another form. These are different processes. A photon redirected away from the original beam can still reach another direction or eventually return toward the satellite.

Optical depth is the accumulated chance of interaction along a path. The untouched beam falls as $\exp(-\tau)$. At $\tau = 1$ about 37% remains untouched. This says nothing by itself about how much scattered light ultimately enters the aperture.

Gas molecules are much smaller than the wavelength and produce Rayleigh scattering. Cloud particles are much larger and usually send much light forward. Mie theory describes spheres; real ice crystals can require nonspherical optical models. The angular distribution matters, not just a single scattering strength.

$$\text{direct fraction after interactions} = \exp(-\tau)$$

6. A measured waveform is a chain of physical and instrumental responses

The source has its own time history. The cloud spreads arrival times. Electronics respond over a finite time, and the digitizer integrates or samples at selected instants. The recorded curve is the combined result.

Rise time must be defined. Time from onset to peak differs from the interval between 10% and 90% of peak or plateau. Arrival-time percentiles of an impulse response are another quantity. The report states which definition a calculation uses.

A long event can be easy to detect but hard to classify from its earliest edge. Timing information depends on the photons arriving when the candidate shapes differ, not only on all photons collected over 3 ms.

$$\text{recorded signal} = \text{sampled}(\text{source} * \text{cloud response} * \text{receiver response}) + \text{noise}$$

7. Photon noise remains after a mean background is subtracted

Independent photon arrivals fluctuate. If a window contains an average of 100 background photons, the actual count is not always 100. In the ideal Poisson model, the variance equals 100 and the standard deviation is 10.

Subtracting an estimated background removes the mean level but does not undo the random arrivals. Estimating that mean from a finite preceding interval adds its own uncertainty. Detector false counts and correlated bursts can add more than Poisson fluctuations.

A 5 sigma rule for one fixed window is not automatically safe for continuous searches. Testing many windows creates more opportunities for an accidental event. A validated threshold must state the search family, false-alarm allocation and detection probability.

for ideal Poisson counts: mean = variance; standard deviation = $\sqrt{\text{mean}}$

8. A negative result is an upper limit, not proof of zero

If no red photons are registered, we ask how much red light could still plausibly have been present. Under an ideal known-zero-background Poisson model, zero counts allows an upper mean near 3 counts at 95% one-sided confidence.

That detected-count limit must be converted through efficiency and live time to an incoming photon limit. A finite baseline, uncertain efficiency, dead time or saturation changes the procedure. A quiet overloaded detector is not a trustworthy null.

A statistical confidence interval describes repeated performance of a stated procedure. A likelihood-score gap or selection margin is not automatically a 95% probability that the chosen physical explanation is correct.

$P(\text{zero} \mid \text{mean } S) = \exp(-S)$

9. Gain, efficiency and dead time are different detector properties

Efficiency tells us what fraction of incoming photons produces useful detected events. Gain tells us how large an electrical pulse is produced after detection. Multiplying gain does not recover a photon that was never detected, and gain fluctuations can add noise.

Dead time is a period after an event when another event may not be registered. At high rates, count losses become important. Some electronics can become so overloaded that more incoming activity produces fewer reported events. A mean-rate correction cannot reconstruct the missing individual arrival times.

Detector noise must be measured at the actual wavelength, temperature, bias, area and bandwidth. APMT, a SiPM, an APD and a camera can all be useful, but their catalogue numbers are not interchangeable.

efficiency converts aperture photons to detected events; gain converts detection to output charge

10. Sampling and optical bandwidth are separate kinds of width

Sampling rate tells us how frequently the digitizer records a value. 10 kS/s means 100 microseconds between samples; 50 kS/s means 20 microseconds. Analogue bandwidth describes how fast the electrical chain responds. Noise bandwidth describes how much noise the complete filter/estimator admits.

A digitizer also needs anti-alias filtering: unwanted fast variations can masquerade as slower ones after sampling. At 50 kS/s, the first Nyquist limit is 25 kHz. That is a constraint to design around, not a guarantee that a 25 kHz practical filter is adequate.

Optical bandwidth is different again: it describes admitted wavelengths. A 4 nm optical filter does not mean 4 kHz electronics. The report always keeps wavelength, time and frequency units separate.

sample spacing = $1 / \text{sample rate}$

11. Wide-field collection and narrow color selection compete for volume

A large entrance admits more light. A broad field admits more directions. Passive optics cannot compress both without limit onto a tiny detector. The conserved optical quantity called etendue expresses that area-and-angle requirement.

Interference filters also respond differently to slanted rays. Lenses can reduce ray angles at the filter, but generally need more area or volume. Telecentric optics control chief rays while leaving a finite bundle of marginal rays.

This creates a real engineering trade: aperture, field, detector size, filter width and package size must be selected together. A successful heritage instrument demonstrates one arrangement, not every enlarged version of it.

etendue = refractive-index-squared times projected area-and-angle acceptance

12. Calibration separates a readable number from a physical measurement

A detector output is not yet an absolute measurement. Calibration ties it to known incoming light at a defined plane, with uncertainty. Repeatability describes whether the same experiment gives similar answers; accuracy also includes reference errors, geometry, spectrum, temperature and drift.

A lamp that ages together with a detector can hide a problem. An internal source that bypasses the entrance optics cannot measure dirt on those optics. Several reference paths or independent observables are therefore useful.

Finally, inferring source current or cloud depth from light is an inverse problem. Several physical causes can give similar observations. More precise light measurements help, but cannot eliminate a genuine ambiguity unless additional information constrains the model.

measured light + calibrated response + validated physical model + independent constraints -> bounded inference

The 22 original questions

Initial question - Transmission to nadir at 550 km versus overhead cloud optical depth; cloud-top/above-top source; Rayleigh versus particles.

A photon is one packet of light. Imagine a flash sending packets in all directions. The instrument catches only the tiny fraction whose paths cross its entrance. Distance makes the same flash spread over a larger area. A clear line of sight is therefore not the same as catching every photon.

A cloud mostly changes directions. Some packets continue almost straight, some wander before escaping, and some leave through the sides or bottom. Optical depth measures how likely a packet is to encounter something along a path. An optical depth of 1 leaves about 37% of the original straight-going beam untouched; it does not mean that 63% of all light energy has disappeared.

The high atmosphere is thin, but ultraviolet light is readily scattered by gas molecules. Our reference calculation leaves about 92% of the direct 337 nm beam at 15 km and 95% at 18 km. This is large enough to include in a careful budget. Within a substantial cloud, ice-particle encounters are usually the larger effect.

At cloud top there may be no cloud above the flash. Light sent downward can still bounce through the cloud and return upward later. That gives a prompt component plus a delayed component. The answer therefore needs a cloud shape and a direction of observation, not just a single percentage labeled cloud transmission.

Corrections retained. Direct-beam extinction is not total detected fluence. Cloud-top does not mean vacuum; above-top does not mean no cloud contribution. The 25 mm aperture used in examples is an illustrative design variable, not an established requirement.

Still needed. Event-specific cloud geometry, overhead gas/aerosol/ozone columns, source angular emission and absolute photon output. Validated ice phase/absorption properties and actual aperture/field/time acceptance.

Related fresh calculations: R4-N01, R4-N02, R4-N03, R4-N11.

Sources: [S027]; [S032]; [S034]; [S036]; [S037]; [S097]

A-1 - Which radiative-transfer calculation/tool should be used, and alternatives to CloudScat?

A radiative-transfer program follows the possible journeys of light through air and cloud. In a Monte Carlo calculation, the computer samples many random journeys and estimates how often light reaches the instrument and how late it arrives.

CloudScat is a sensible starting point because its designers had this lightning-to-satellite problem in mind. A second program is valuable as a cross-check, but only if the two programs describe the same experiment. Comparing all escaping light from one program with only nadir light from another would give a disagreement even if both were correct.

More simulated photons make the computer estimate less noisy. They cannot tell us whether a chosen cloud really has the assumed crystal shapes or whether the flash emitted the assumed pulse. This is the difference between numerical precision and physical accuracy.

Some alternatives are excellent at atmospheric spectra or images but do not directly produce the arrival-time history needed here. The useful choice is the tool whose documented source, geometry, phase function and timing can be checked. The report labels a model as executed only when a retained receipt and results support that statement.

The new revision also checked two simple matched cases against CloudScat. They agree within their estimated simulation uncertainty. That is useful progress, but the harder tabulated-ice cases still have

unresolved sampling uncertainty.

Corrections retained. Available documentation, downloaded code, an installed executable and a validated calculation are different states. Do not advertise all named atmospheric tools as equivalent transient 3D solvers.

Still needed. A matched independent transient benchmark using the same real-ice properties and detector estimator. A validated event-specific source/cloud model.

Related fresh calculations: R4-N11.

Sources: [S028]; [S029]; [S030]; [S031]; [S033]; [S038]; [S097]

A-2 - Multiple scattering and temporal profile; robustness of 30-80 us versus >200 us rise-time discrimination.

A cloud is a light-delay machine: wandering photons travel farther than direct photons. Deeper flashes often have more opportunity to wander. That makes rise time a useful clue about depth.

But it is a clue shared by several causes. A slow source can look slow even near cloud top. A deep source with a favorable path can show an early component. Electronics can smooth the pulse, and a detector that misses closely spaced photons can distort its shape. Knowing the pulse lasted milliseconds does not guarantee that enough photons arrived during its first 30 microseconds to measure that rise.

We must also agree on what rise time means. Time from first detectable light to the peak is different from time between 10% and 90% of the peak. Comparing those two definitions as though they were the same would create a false physical conclusion.

Sampling is like taking photographs of a moving hand. One photograph every 100 microseconds cannot directly show the detailed motion during 30 microseconds. Faster samples help, but a useful test must include random alignment of the pulse with the sample clock, actual photon noise, the analogue filter and the fitting rule. The correct next step is to inject plausible shallow and deep waveforms through the complete model and measure the confusion between classes.

One new test detected all 1000 example pulses yet assigned a sufficiently separated fast/slow label to only 21 of them. That is not a failed detector: it shows that recognizing a flash and knowing its leading-edge shape require different amounts of information. The test used invented but explicit pulse families, so it does not certify cloud-depth discrimination.

Corrections retained. Keep intrinsic, cloud-propagated and sampled rise times separate. Keep onset-to-peak and 10-90% definitions separate. A tail or a fast leading edge alone does not uniquely identify depth or discharge class.

Still needed. Consistent rise definitions and independently labeled source depths/classes. Intrinsic pulse families, realistic cloud phases/geometry and calibrated receiver response/noise. Injection-recovery over actual leading-edge counts, background, sample phase and count losses.

Related fresh calculations: R4-N02, R4-N03, R4-N04, R4-N09, R4-N11, R4-N12.

Sources: [S035]; [S066]; [S067]; [S079]; [S099]; [S100]; [S106]; [S107]

B-4 - Absolute nightside 337 nm radiance: quiet airglow, moon, zodiacal light and integrated starlight.

Background is all the light arriving while no target flash is present. It matters even if we subtract its average: the number of background photons fluctuates. A brighter steady background therefore makes a faint flash harder to recognize.

Different instruments measure different kinds of brightness. A wide ultraviolet channel combines many wavelengths. A spectrometer separates them. A ground instrument looks upward through a different atmosphere from a satellite looking down at cloud. Dividing a broad measurement by 100 nm silently assumes the light is evenly distributed across that range; atmospheric emission often is not.

We recovered useful real reference spectra. One ground-based mean gives about 1.8 billionths of a watt per square metre, steradian and nanometre around our 4 nm band after the authors' processing. That is a scale example, not a promised polar background. The starlight map is also useful, but the cloud reflects a whole hemisphere of celestial light with uneven brightness.

The missing result is the distribution of total background for the actual field, orbit, cloud and filter. A noise budget should show separate quiet, moonlit and auroral scenarios with clear assumptions, then replace those scenarios with representative measurements when available.

Corrections retained. Noll pseudo-continuum is not total night sky. Broad UV orbital counts are not a measured 4 nm 337 nm polar radiance. Limb spectra and cloud-reflected nadir brightness require different transfer.

Still needed. A total 337 nm scene distribution with measured components and geometry at high latitudes. Actual filter/field response, cloud directional reflection and gas transmission.

Related fresh calculations: R4-N07.

Sources: [S006]; [S011]; [S012]; [S013]; [S017]; [S018]; [S023]

B-5 - Auroral 337 nm 4 nm-band brightness and shot-noise floor during moderate/disturbed conditions.

An auroral 337 nm photon and a discharge 337 nm photon are identical to the detector. Their different origins do not give the filter a way to distinguish them.

A slowly changing glow can be estimated from nearby times and subtracted. But photon arrivals are random: a subtraction cannot remove the fluctuations in how many photons happened to arrive during the flash. This is why aurora can raise the noise floor even when its changing shape is easy to recognize.

An index such as Kp summarizes geomagnetic activity over a broad region and time. It does not tell us exactly whether our field contains a bright narrow arc or a dim patch, or what electron energies produced the emission. That is why a single background number for moderate conditions would claim more knowledge than we have.

We can still make useful engineering calculations: choose explicit received brightnesses, compute the resulting background counts and measure how many flash photons are needed. Those calculations answer what happens if the background is a stated value. They do not tell us how often that value occurs on the proposed orbit. Fast auroral structure and particle artifacts also need controls beyond a simple slow-baseline subtraction.

Corrections retained. Same-wavelength auroral photons cannot be filtered away from the target. Slow mean variability does not eliminate shot noise, and aurora is not universally slow. An imposed precipitation/model case is not a measured Kp-conditioned sky distribution.

Still needed. A calibrated 4 nm 337 nm radiance/time distribution for the actual high-latitude field and scene. Precipitation spectra, arc filling, cloud transfer and actual detector end-of-life noise.

Related fresh calculations: R4-N05.

Sources: [S001]; [S007]; [S008]; [S009]; [S024]; [S025]; [S026]

B-6 - Lunar phase/elevation at which cloud background dominates detector noise.

Moonlight is reflected sunlight. How much reaches our detector depends on how brightly the Moon illuminates the cloud, how the cloud sends that light upward, and how much sky the instrument accepts.

A large field collects more background from many directions. A wider filter accepts more background wavelengths. A warmer detector may generate more false internal counts. Changing any of these can change the Moon condition at which background becomes the main limitation.

The phrase background limited means the random fluctuation in arriving background light exceeds the detector's own fluctuation. It does not mean the background makes detection impossible: a sufficiently

strong flash can still stand out. It also does not identify one lunar phase without a design and a scene model.

We found good lunar calibration work, but precision demonstrated at visible wavelengths must not be copied to 337 nm. The practical next step is to calculate several explicit moonlit-cloud scenarios and identify the maximum received background the receiver can tolerate, then test how often the orbit encounters it.

Corrections retained. Do not transfer visible-band lunar absolute accuracy to 337 nm. Background-limited is a comparison of noise variances for a specified receiver and estimator.

Still needed. Validated 337 nm lunar irradiance versus phase/libration and cloud illumination geometry. Chosen receiver noise/temperature, spectral-angular response and cloud reflection.

Related fresh calculations: R4-N05.

Sources: [S002]; [S003]; [S004]; [S005]; [S010]; [S014]; [S015]; [S016]

C-7 - Detector choice at 337 nm, large area and 10-50 kHz; claimed photodiode/TIA floor.

The detector is the light-to-electricity converter. A photodiode releases a small electrical charge when it absorbs light. A PMT, SiPM or APD multiplies that charge internally, making it easier for later electronics to see.

Internal multiplication is useful, but it is not free sensitivity. The detector can create false signals, multiplication can fluctuate, and a busy detector can miss photons. Making a solid-state sensor larger usually adds false counts and capacitance as well as useful area.

The earlier one-nanoampere floor came from treating one amplifier specification as a law of nature. Better amplifier arrangements exist. The remaining question is whether a real low-noise amplifier still works well with the chosen large detector and in the available power, temperature and radiation environment.

A camera has another trade-off: thousands or millions of small pixels must be read and added. A low-noise pixel does not imply a low-noise full camera at very high speed. The fair comparison uses the same collected photons, field, pulse, temperature and background for each complete receiver. That measurement has not yet selected a winner.

Corrections retained. A vendor gain-bandwidth product is not a universal detector limit. Peak QE at 405, 450 or 570 nm is not measured 337 nm response. Per-pixel noise and minimum exposure do not specify a 50 kHz large-area photometer.

Still needed. Selected sensor/package 337 nm PDE or responsivity, actual sensitive area/capacitance and bias/temperature-dependent dark PSD or correlated-count distribution Complete readout noise, impulse response, power and permitted readout mode; for CMOS, measured full accepted-area cadence and summed read noise, not minimum exposure alone

Related fresh calculations: R4-N08, R4-N12.

Sources: [S055]; [S057]; [S058]; [S059]; [S061]; [S069]; [S085]

C-8 - NEP and aperture photons per event for candidate detectors.

NEP is a way to express detector noise as an equivalent amount of incoming light. It is useful only when we also know the wavelength, bandwidth and measurement method.

Think of listening for a short sound. Noise quoted at one audio frequency is not the same as the total noise heard through a broad microphone. A long average and a quick measurement also have different noise. Optical pulse measurements work the same way.

For a photon counter, an even clearer question is: with this background and these false internal counts, how many extra detected photons are needed to recognize a flash reliably? Then we ask how many aperture photons were required to produce those detected photons. If efficiency is 20%, 500 incoming photons produce 100 detected photons on average, but this is an example conversion, not an established detection threshold.

A proper answer also states how often noise alone is allowed to trigger. Searching continuously creates many opportunities for an accidental pattern. The new statistical studies make those assumptions explicit rather than turning a convenient noise-density number into an unsupported photons-per-event promise.

Corrections retained. Separate spot noise density, integrated RMS, dark current, DCR and detection probability. Do not apply photocathode gain or APD multiplication twice. Aperture photons and registered counts use different reference planes.

Still needed. Actual receiver spectral noise/count statistics, gain/excess noise and target-band throughput at beginning/end of life
Injection-recovery versus aperture photon fluence under relevant backgrounds, integration windows, pulse shapes and false-trigger rules

Related fresh calculations: R4-N05, R4-N08, R4-N09, R4-N10.

Sources: [S057]; [S060]; [S062]; [S065]; [S070]; [S094]

C-9 - DC coupling and preservation of a>3 ms pulse.

DC coupling lets a sustained input remain a sustained output. It can preserve both the fast start and the following milliseconds of a flash, provided the amplifier does not saturate or drift too much.

An AC-coupled analogue signal tends to forget a sustained level. The output jumps at the start, then slides back toward zero even while the light remains on. This is the droop that concerned you, and it is a real design issue.

Counting individual photons works differently. Each photon produces a very short electrical pulse. We can shape that pulse, count it, and ask how the number per time bin changes during the optical event. Shaping each tiny pulse does not necessarily erase the longer envelope made by many arrivals.

The important test is the complete measured response. A detector can appear quiet because it is overloaded, not because light is absent. We therefore need tests that switch between dark, bright and faint illumination and verify both amplitude and recovery.

Corrections retained. Envelope AC coupling and per-photon pulse shaping are different operations. DC feasibility does not certify complete-chain noise, stability or vacuum compatibility.

Still needed. Full-chain optical impulse/step and >3 ms pulse response across faint/background/overload conditions Droop, pedestal, saturation, recovery, discrimination/dead time and pulse-phase bias with actual ADC integration/filtering

Related fresh calculations: R4-N04, R4-N08, R4-N12.

Sources: [S063]; [S064]; [S066]; [S079]; [S088]

C-10 - 2-3 year 550 km polar/SAA radiation effects on dark current and gain.

Radiation damage is not one thing. Some particles leave lasting defects that create false counts. Others make a momentary pulse or upset an electronic state. A detector can keep working electrically while becoming too noisy for a faint measurement.

Silicon detectors often develop more dark counts after energetic particles damage their crystal. Cooling can reduce some of those counts. Heating may repair some defects, but this is a tested procedure with limits, not a free recovery button. PMTs have different vulnerabilities rather than complete immunity.

A satellite at lower altitude, another inclination or a different place inside its spacecraft can receive a different radiation exposure. That is why an observed increase on one mission cannot simply be multiplied by three years for ours.

There is also a classification hazard: a particle can hit only the UV detector or make a window flash. The red channel can remain quiet. We must measure these signatures and use valid health, live-time and recovery checks, rather than assuming every blue-only pulse came from a thunderstorm.

Corrections retained. Operational lifetime is not preserved faint-photon sensitivity. Prompt hits are distinct from cumulative radiation degradation. Cooling, annealing and detector-class ranking remain device/circuit/mission specific.

Still needed. Selected device/lot pre/post proton, TID and SEE tests at intended temperatures, including PDE/gain, noise PSD/DCR, correlated noise and annealing limits Prompt particle/window/coating/electronic pulse shapes and false-event/veto response of the assembled head

Sources: [S077]; [S078]; [S079]; [S080]; [S081]; [S082]; [S083]; [S084]

C-11 - European suppliers for flight or near-flight detectors.

A supplier having built space hardware is useful evidence. It does not mean every part in its catalogue is ready to fly.

We found two particularly relevant routes: ET Enterprises for the PMT approach closest to MMIA, and Photek for custom intensified detectors with independently documented space use. The next step is to specify exactly which tube, window, base, electronics and tests are required.

A hermetic package keeps its interior sealed. That says less about whether the attached circuit, cables, insulation and cooling work in external vacuum. Likewise, an ESA certificate can cover a narrow manufacturing process rather than the optical detector we want.

Country of origin needs equal care. A European office or brand does not show where the sensor wafer or assembled part was made. If European manufacture is a mission requirement, obtain a declaration for the selected part and lot. The report therefore keeps supplier leads separate from accepted flight hardware.

Corrections retained. Do not identify ET catalogue candidates as the unpublished MMIA model. First Sensor MOSFET process approval is not APD certification. Hermetic packaging, supplier heritage and European sales presence are not complete flight qualification or lot origin.

Still needed. Part/lot-specific spectral calibration at 337/777 and accepted qualification/acceptance results for the actual detector, base, HV and readout build

Sources: [S086]; [S087]; [S088]; [S089]; [S090]; [S091]; [S092]; [S093]; [S094]; [S095]; [S096]

D-12 - Maximise nonimaging photometer etendue within roughly 1U.

The entrance aperture is the opening that collects light. The detector is the surface that turns that light into charge. They are not automatically the same size.

A wide field accepts rays from many directions. There is a limit to how much of that light passive optics can squeeze onto a small receiving surface. A funnel can concentrate a narrow set of directions strongly, or accept a broad set with less concentration; it cannot give both without paying elsewhere.

This is why a tiny detector with excellent photon efficiency may still be a poor match to a large, wide-field photometer. A larger detector array can help, but its internal noise and electronics also grow. The optical and detector choices must be made together.

The spacecraft volume matters as well. MMIA's small entrance and large photocathode show one successful arrangement, not proof that a 25 mm entrance with the same narrow filter fits into 1U. We have useful physical lower bounds, but still need an actual optical layout and test.

Corrections retained. The 25 mm MMIA photocathode is not its UV collecting aperture. Conservation of etendue cannot be bypassed by nonimaging optics or high PDE. Circular 60/90 degree and square 80 degree-diagonal fields require different integrals.

Still needed. Assembled field/pupil/wavelength response, vignetting, detector illumination uniformity, throughput and baffle/stray-light rejection

Related fresh calculations: R4-N06, R4-N08.

Sources: [S054]; [S066]; [S073]

D-13 - Maintain narrowband filter response over 60-90 degree full field.

An interference filter selects color using layers of material. Light arriving at a slant sees those layers differently, so the transmitted color shifts.

A wide external field does not force the filter itself to see that same wide angle: lenses can rearrange the rays. But doing so uses optical area and volume. Even when the center ray is well controlled, each bundle still contains a spread of directions.

A graded coating is like tuning different parts of the filter differently. It can help if we know which rays go where, but it cannot make every direction identical. A wider passband is easier to tolerate geometrically, while collecting more unwanted photons.

The useful measurement is therefore a map: which colors pass at every field position, temperature and polarization through the assembled head? That map also affects the blue/red ratio. A source at the edge may otherwise appear fainter or redder simply because the instrument response changed.

Corrections retained. Telecentric does not mean every ray is normal to the filter. Do not infer a PHOT cone or filter diameter from the camera F-number or unscaled CAD.

Still needed. Filter transmission map versus wavelength, actual ray angle/cone, polarization, temperature and vacuum for the selected coating Full-field assembled spectral response including pupil weighting and tolerances

Related fresh calculations: R4-N08.

Sources: [S066]; [S071]; [S074]

D-14 - Is 4 nm FWHM optimal for the N2(0, 0)band and background?

The 337 nm emission is a group of closely spaced colors produced by the same nitrogen transition system. A filter catches some fraction of that group.

Making the filter narrower can reject background, but it can also reject the signal we want. Making it wider can catch more signal until almost all useful light is included; after that, extra width mainly adds unwanted photons. The best choice depends on both curves together.

The shape matters as well as the quoted width. A rounded Gaussian filter and a rectangular 4 nm filter do not pass exactly the same amount of a smooth background. The angle-dependent color shift can matter as much as a small change in nominal width.

We should not optimize hardware using a line spectrum whose positions or populations have not been checked. The new report keeps synthetic spectral examples separate from verified molecular data and leaves the final band choice conditional on source and assembled-filter measurements.

Corrections retained. A nominal band-head wavelength is not a complete emission spectrum. FWHM is not equivalent noise bandwidth. Unvalidated line-list reconstruction and assumed NBE temperatures cannot select the flight filter.

Still needed. Representative source-band spectra or validated physical spectral model constrained by source conditions Scene/background spectra and actual assembled filter/detector response with stable wavelength registration

Related fresh calculations: R4-N07, R4-N08.

Sources: [S013]; [S017]; [S019]; [S020]; [S021]; [S022]; [S072]

D-15 - Required optical density and rejection wavelength range.

A narrow filter is useful only if it also blocks unwanted colors strongly enough. The detector may respond to a much broader range than the nominal science band.

Optical density is a logarithmic blocking measure. OD 6 means one part in a million transmission, but only where that value is actually guaranteed. A guarantee near 337 nm says nothing by itself about a leak near 800 nm.

A tiny leak can matter when the unwanted light is much brighter or occupies many more wavelengths. We therefore compare the total leaked photon rate with the useful band and its noise allowance. The correct answer is a blocking curve plus a wavelength interval, not one impressive number.

A laboratory scan also needs enough dynamic range to verify the claim. Seeing no leak on an insensitive measurement does not prove the leak is absent. The assembled head must be tested because light can scatter around the intended filter path or be generated inside materials.

Corrections retained. Limited-interval OD 6 is not broadband OD 6. A display plot or unverified average blocking claim is not an acceptance measurement.

Still needed. Dynamic-range-qualified leak/blocking scan through detector cutoff, including pinholes, angle/polarization/thermal changes and induced fluorescence Scene spectra sufficient to bound out-of-band photoelectrons and stray light under permitted night/Moon/twilight conditions

Related fresh calculations: R4-N08.

Sources: [S013]; [S014]; [S072]; [S076]; [S078]; [S105]

E-16 - 777.4 nm null-channel detector and comparable photon thresholds.

The red channel is a test of a competing explanation. To trust a negative result, we must first show that the test was capable of seeing the red light in question.

A quiet detector does not mean zero emitted light. It means the data put an upper limit on how much light could have been present. Even a perfectly working detector can miss photons by chance, and a noisy or insensitive channel has a weaker limit.

There are further ways to get a misleading null. The red pulse may arrive later, the source may lie where red throughput is poor, or the detector may be overloaded and failing to count. A particle can also produce only a blue-channel artifact.

The fair blue/red comparison therefore uses calibrated photons at the entrance and measured probabilities of detection. It also needs physical examples of ordinary lightning and target events. Better red sensitivity reduces one source of mistakes, but does not create a universal law saying all thermal discharges must have a particular minimum red ratio.

Corrections retained. Red non-detection is a confidence statement, not zero emission. Red sensitivity must be compared in photon terms through the whole instrument. A blue-first peak does not by itself demonstrate full-event red absence.

Still needed. Both full-chain photon-scale spectral/field response, background/noise, live time and impulse response, including dead time, saturation and recovery Red-channel upper-limit coverage and joint false-negative/false-classification performance using calibrated injections and representative source controls

Related fresh calculations: R4-N04, R4-N09, R4-N10.

Sources: [S053]; [S056]; [S058]; [S066]; [S078]; [S079]; [S103]

E-17 - Cross-calibration of different detector technologies for a trustworthy ratio.

A ratio can look stable even when both channels are wrong in the same way, or change because the channels drift differently. Calibration connects each electrical result to a known number of incoming photons.

We should illuminate both channels with known colors and pulses, through the real entrance path. We then check how much response changes with field position, temperature and brightness. An independent light monitor tells us whether the test source changed while we were measuring.

Timing matters too. If the blue and red electronics respond at different speeds, the ratio at one instant can be wrong even when their integrated light measurements are correct. The instrument must measure those relative delays.

Using the same reference can reduce some uncertainty, but not all. A reference star's uncertainty at one wavelength is not automatically its uncertainty at another, and a wide nonimaging field changes its integrated background when the spacecraft slews. The calibration plan therefore needs both photon

counting and geometry.

Corrections retained. Equal electrical gains are not equal photon response. Single-photoelectron gain calibration does not certify absolute PDE. Shared calibration uncertainty may cancel partly; wavelength/field-specific uncertainty remains.

Still needed. Traceable common-source calibration across each channel spectrum, field, pulse fluence and operating temperature with overlapping attenuation ranges Relative delay/IRF and systematic covariance, plus repeated stability checks and independent reference monitoring

Related fresh calculations: R4-N10.

Sources: [S040]; [S048]; [S066]; [S068]; [S075]

F-18 - On-orbit gain drift, absolute radiometric stability and peak brightness versus current.

Calibration asks whether the same number of incoming photons still gives the same reported answer years later. The detector, electronics, filter and entrance optics can all change.

An internal lamp is valuable, but it can also age. If its reading drops, we need to distinguish a dimmer lamp from a less efficient detector or lower gain. A monitor helps, while its own stability must be checked. A light path that skips the front optics cannot tell us whether those optics became dirty.

Individual photoelectron pulses can reveal multiplication gain under suitable tests. That is different from asking what fraction of incoming photons produces a pulse. We need both quantities to trust absolute brightness.

Even perfectly calibrated brightness does not automatically tell us discharge current. Light is the result of how particles were excited and how the cloud redirected it. Different source sizes, fields and histories can produce similar observed brightness. The route to current is therefore a tested physical model tied to independent observations, not a universal conversion factor.

Corrections retained. Internal LED mean response is a product, not a unique gain/PDE measurement. Published visible or reference-wavelength stability is not automatically 337 nm absolute stability. Absolute photons do not alone identify discharge current.

Still needed. Independent optical reference/monitor stability and full-path throughput/PDE drift at science wavelengths, with separate multiplication-gain and offset diagnostics If using stars, actual attitude/path/field response and differential-background covariance; if inferring current, independent current/radio-optical/source-condition calibration

Sources: [S040]; [S043]; [S044]; [S049]; [S050]; [S052]; [S099]; [S104]; [S109]

F-19 - Ground calibration/characterisation and facilities.

A useful ground test asks a known question: we send a measured amount of light through the real entrance and check the reported answer. We repeat it for different colors, directions, temperatures and brightnesses.

Testing only the middle of the field leaves an important hole. This instrument does not form an image, so a flash may arrive from an unknown direction. We need to know how much the response changes across the whole field, and whether the two channels change together.

We also need to test mistakes: light too bright for the detector, a flash during recovery, false bursts in darkness, and a faint pulse on a bright background. Environmental tests should be followed by calibration to see whether sensitivity changed.

Specialist laboratories can provide traceable standards and relevant facilities. Their existence is not a promise that a particular service, uncertainty or booking is available. This report identifies routes and required measurements; it does not claim an institute of its own.

Corrections retained. Facility capability is not an agreed calibration uncertainty or booking. Surviving environmental tests is not the same as preserving calibrated sensitivity.

Still needed. Configuration-specific traceable spectral/angular/pulsed receiver calibration with stated uncertainty Noise/linearity/trigger/timing/bright-light recovery, environmental qualification and contamination/radiation tests for selected build

Sources: [S041]; [S047]; [S048]; [S051]; [S052]; [S075]

F-20 - Laboratory 337 nm source with 30 us rise and >3 ms duration.

The easiest programmable source is probably a UV LED driven by an adjustable current pulse. But the light pulse must be measured directly: an electrical command is not proof that the LED followed it perfectly.

A 340 nm LED emits a spread of colors around its label. Some of its light passes a 337 nm filter and some does not. That is acceptable for certain tests if we measure the spectrum and calibrate how many useful photons entered the instrument.

A 337 nm nitrogen laser matches the color more closely, but its normal short pulses do not automatically match the desired long optical waveform. Color, duration, rise time and stability are separate requirements.

A bright reference photodiode can watch the test source while calibrated attenuation makes the instrument input very faint. We should test many pulse shapes and brightnesses, including overload and recovery. This gives a real measurement of where the instrument detects, classifies or fails.

Corrections retained. A nominal wavelength or driver bandwidth does not certify the emitted optical waveform. The cited LEDD 1 B example is not a demonstrated 30 microsecond source.

Still needed. Optical waveform measured by a sufficiently fast reference at actual drive/temperature: 30 us rise, >3 ms duration, stability and recovery Spectrum/filter capture and calibrated attenuation from faint through overload, with stray-light control

Sources: [S039]; [S042]; [S045]; [S046]

G-21 - Can 2-4 kg/5-10 W deliver a useful event rate at 550 km?

The size and power constraints do not violate an obvious law of physics. Small instruments have measured related optical events in space. That makes the mission worth designing, but it does not yet tell us how many scientifically useful events it will collect.

We now have real observed brightness examples. They show that some events could be very easy to see with a larger aperture, possibly too bright for a simple photon counter. They do not reveal how many much fainter events are missing from the published samples.

The rate question needs two pieces: how often the desired physical events occur in the places and conditions we can observe, and how often our receiver recognizes them correctly. A bigger field sees more territory but also more background and unrelated activity. A larger aperture collects more signal and more background, and may overload on bright events.

The next decision should use a measured receiver threshold and dynamic range, then combine it with a calibrated source/exposure sample. We can present conditional capability curves now. We cannot responsibly promise a useful polar event rate or declare a particular aperture necessary from a selected dozen events.

Corrections retained. Observed spacecraft fluence is not pre-cloud source output and must not be attenuated twice. Selected bright events cannot define the faint population or unbiased orbital rate. Larger aperture also raises background and bright-end saturation.

Still needed. Faint source/dual-band population with calibrated completeness and non-detections. Packaged optical/electronic/thermal/power design, field response, backgrounds and end-of-life injection-recovery. Actual orbit/time/exposure, health/safing, telemetry and false-classification controls.

Related fresh calculations: R4-N06, R4-N09.

Sources: [S066]; [S098]; [S100]; [S101]; [S102]; [S108]; [S110]

G-22 - What assumptions or physics are missing?

We were asking several different questions as though they had one answer: does light escape the cloud, does it hit the aperture, does the detector register it, and does the recorded pulse identify the desired physical event? Each step can fail for a different reason.

A useful way to stay honest is to label what we know. A conservation law can be established. A mathematical model can be solved under its assumptions. A different mission can supply a real measurement. But the proposed instrument still needs its own response and uncertainty measurements.

The new calculations help identify dangerous assumptions and useful tests. They show why cloud reflection can add delayed light, why the same rise can have more than one cause, why a red null needs a confidence limit, and why field size changes both coverage and noise. They do not create the missing faint-event population or certify hardware.

The project can now move from a broad feasibility question to specific measurable requirements. A credible design will say how many photons it needs to detect a flash, how many to measure its rise, how strong a red upper limit it can set, and how those answers change across field, background, temperature, radiation and recovery state. That is the evidence needed before predicting a useful mission yield.

Corrections retained. Do not collapse detection, timing measurement, class identification and current inversion into one threshold. Preserve measurement/model/example/access states and independent cohorts. More decimal places or more papers do not replace missing mission inputs.

Still needed. Selected receiver calibration and end-of-life response. Realistic source/cloud/noise classes and independent physical labels. Unbiased joint population/exposure and validated operational false-event control.

Sources: [S052]; [S066]; [S077]; [S078]; [S097]; [S100]; [S103]; [S109]

Fresh calculations and their limits

These studies answer conditional questions and test algorithms. They do not establish a polar sky climatology, a faint-event population, a physical depth classifier or accepted flight hardware. Counts of cases or packets describe computation, not independent observations.

R4-N01 - Clear-air direct Rayleigh transmission

Even above a high flash, a few percent of the ultraviolet direct beam is scattered. Thin atmosphere does not mean no atmosphere.

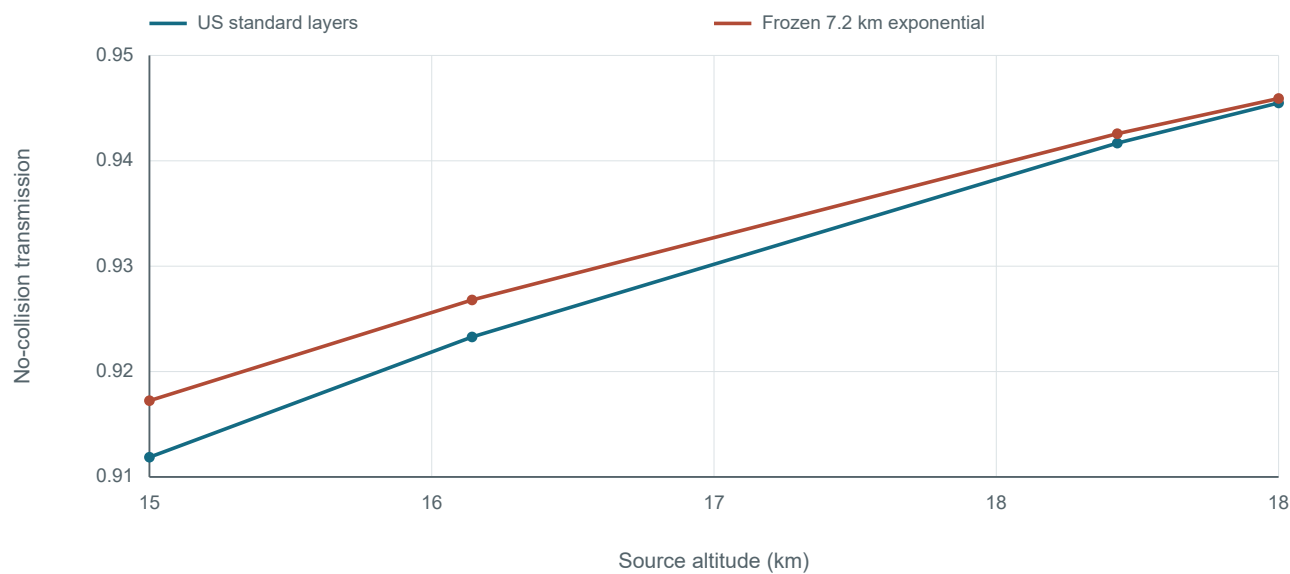
Dry reference vertical column. No cloud, ozone, aerosol or real weather included.

Altitude km	Standard tau_R	Standard direct T	Frozen-exp direct T
15	0.08876	0.9151	0.9206
16	0.07589	0.9269	0.9306
18	0.05549	0.946	0.9469
18.5	0.05132	0.95	0.9504

Direct-only illustrative 25 mm aperture. Standard dry Rayleigh plus stated overhead particle optical depth. Last column adds assumed 20% end-to-end detection probability; it is not photon transmission. No scattered return, ozone or aerosol.

Source km	Cloud tau_above	Direct survival	Aperture photons/emitted	Detected events/emitted
15	0	0.91507	1.2488e-16	2.4977e-17
15	0.1	0.82799	1.13e-16	2.26e-17
15	0.3	0.6779	9.2516e-17	1.8503e-17
15	1	0.33664	4.5942e-17	9.1884e-18
15	3	0.045559	6.2176e-18	1.2435e-18
15	10	4.1544e-05	5.6697e-21	1.1339e-21
18	0	0.94602	1.3057e-16	2.6114e-17
18	0.1	0.85599	1.1814e-16	2.3629e-17
18	0.3	0.70083	9.6727e-17	1.9345e-17
18	1	0.34802	4.8033e-17	9.6067e-18
18	3	0.0471	6.5006e-18	1.3001e-18
18	10	4.2949e-05	5.9278e-21	1.1856e-21

Direct molecular transmission above high sources



Fresh arithmetic; differences reflect reference density profiles, not event-specific weather. No diffuse photons included.

Limits. Direct/ballistic no-collision transmission only. Rayleigh-scattered photons are not all absorbed or necessarily outside the full instrument response. Cloud attenuation can multiply this factor for the direct ray $e^{-\tau_{\text{cloud}}}$ only; total diffuse directional fluence requires radiative transfer and cannot be obtained by this exponential alone. This is a clear dry reference atmosphere; no aerosol, ozone, real polar seasonal weather, source spectrum, or finite-band weighting included.

Sources: [S032]; [S034]

R4-N02 - An above-top reflector can increase nadir light and delay it

A reflecting cloud can send downward light back toward us. Our toy reflector shows why even an above-top flash need not have only direct light. A real cloud also has internal travel and a different angular reflection.

Ideal 15 km plane, 550 km observer, 60 degree circular field, rho 0.8 and 30 us intrinsic 10-90 linear rise.

Height above plane m	Nadir/vacuum fluence	Output rise us	Min reflected delay us
0	2.6	30	0
1	2.6	30	0.006671
100	2.599	30.42	0.6671
1000	2.586	38.78	6.671
3000	2.558	78.71	20.01

Limits. More lower reflectance may add photons; this does not mean more OVERHEAD extinction must increase fluence Factor 3 for rho 1 is this to nadir limit, not universal Mie/ice cloud bound Photon hemisphere escape fraction <= 1 even when directional ratio > 1

Sources: [S112]

R4-N03 - Depth and diffusion strength are not uniquely identifiable

Two different depths can give the same model waveform if the scattering strength changes appropriately. Timing becomes a depth measurement only after the other relevant properties are constrained.

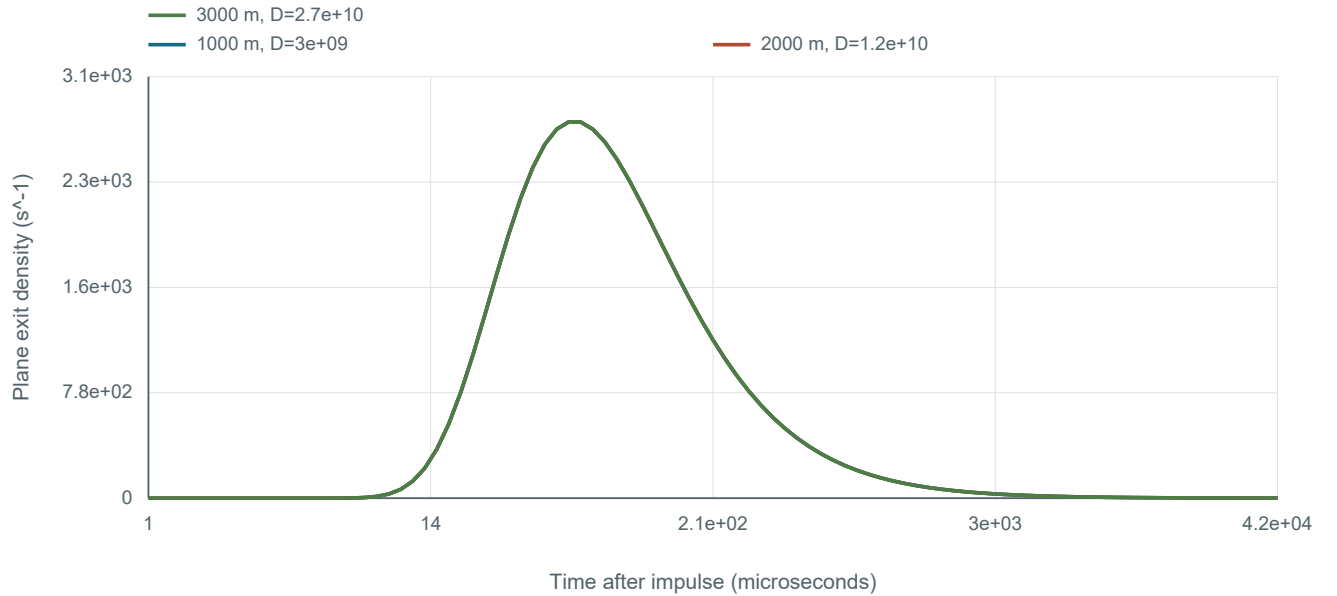
Identical-kernel mathematical counterexample; not three measured clouds.

Depth m	D m 2/s	L 2/D s
1000	3e+09	0.0003333
2000	1.2e+10	0.0003333
3000	2.7e+10	0.0003333

Nonabsorbing diffusion fraction exited within 3 ms at D 3 e 9 m 2/s. It is not aperture capture.

Input 10-90 us	Mode us	Depth m	Exit fraction by 3 ms
5.5	12.33	471.2	0.9116
30	67.27	1100	0.7954
80	179.4	1797	0.6719
200	448.5	2841	0.5031

Different depths, same ideal diffusion kernel



Coincident curves are an exact-model identifiability example. They are not finite-cloud observer signals, and diffusion is unsuitable for the true early ballistic front.

Limits. Parabolic diffusion has a causal non-zero $t_{\text{light precursor}}$; report flags when 10% threshold itself is unphysical. Not an early-time RTE benchmark. Semi-infinite homogeneous medium with absorbing plane and instantaneous delta emission; no finite cloud base, phase function, source extent, upward ballistic term or internal cloud top boundary. $A > 3$ ms observed pulse is not assumed 3 ms intrinsic emission or dwell time; real emission requires convolution

Sources: [S100]

R4-N04 - Raw dead time can compress an apparent rise

A busy counter misses photons. That changes pulse shape as well as brightness. A mean correction can help only when its detector model is valid and uncertainty is propagated.

Limits. Only RAW uncorrected mean waveform shape; published corrected MMIA waveforms cannot be accused of this bias from this diagnostic. No actual source brightness distribution or detector selected. No afterpulsing, paralyzable holdoff, discriminator walk, gain sag, baseline estimation, electronics/sampling or count likelihood

Sources: [S066]

R4-N05 - Auroral/background amplitude scenarios and exact Poisson thresholds

The same steady sky brightness produces more random counts through a bigger aperture. We can calculate what that would cost in required flash photons, but these scenarios do not tell us how often the sky is that bright.

Assumed received band brightness; 60 degree circular field, 30 us window, eta 0.2, dark 50/s. High dead-time occupancy invalidates literal ideal-counter use.

Aperture mm	Band R	Rate PE/s	Signal PE 95%	r x 17 ns
1.0	15.0	1473	11.8	2.503e-05
1.0	2270.0	2.229e+05	34	0.003789
25.0	15.0	9.204e+05	57.79	0.01565
25.0	2270.0	1.393e+08	556.8	2.368

Limits. No Kp class or occurrence assigned. No extrapolation from 10 degree aircraft FOV to full 60/90 degree arc. No cloud reflection or limb to nadir transfer computed.

Sources: [S025]; [S026]; [S113]

R4-N06 - Field size versus an unknown source-brightness law

A wider field sees more storms but makes each faint-event search noisier. Whether it helps depends on how many additional faint sources exist, which is exactly the missing population information.

Hypothetical $3e-9 \text{ W m}^{-2} \text{ sr}^{-1} \text{ nm}^{-1}$ background, 25 mm, 17 km source shell; no cloud loss. Not events/day.

Assumed cumulative slope alpha	90/60 relative yield	90 degree edge/axis threshold
0.5	2.233	3.093
1	1.597	3.093
1.5	1.167	3.093
2	0.8711	3.093
2.5	0.6632	3.093
3	0.5139	3.093

Limits. No actual NBE brightness distribution, geomagnetic/cloud frequency, radio-optical selection or occurrence rate. No optical étendue feasibility for chosen entrance/detector/filter; separately qualified constraints still apply. Fixed source collected $A \cos(\theta)$, no extra unknown $C(\theta)$ map or vignetting.

Sources: [S110]

R4-N07 - Actual reference continuum and starlight data folds

These calculations use useful real reference data while retaining what those data leave out. Adding them blindly would mix different geometries and corrections.

Noll processed mean through ideal top-hats centered at 337.1 in the table convention.

Width nm	Integrated Wm ⁻² sr ⁻¹	Band mean Wm ⁻² sr ⁻¹ nm ⁻¹
1	2.032e-09	2.032e-09
2	3.933e-09	1.966e-09
4	7.08e-09	1.77e-09
8	1.258e-08	1.573e-09

Limits. Mean 10633 selected 2009-2019 Cerro Paranal spectra, >=10 min exposure; Moonabovehorizonwithillumination>50% excluded. Not a polar or microsecond distribution. Continuum extracted by median/percentile filters; strong resolved lines removed, unresolved O2 UV bands retained partly. Extraterrestrial components modeled/subtracted; extinction and van Rhijn 90 km corrected. Not total night sky or total 777 line background. Header only says wavelengthnm. Official ESO says Xshooter pipeline wavelength in air; authors could have subsequently converted, not explicitly verified here. Fold centre 337.1 uses table convention; photonenergyuses nominal wavelength with <0.03% air/vac sensitivity.

Sources: [S013]; [S017]; [S018]

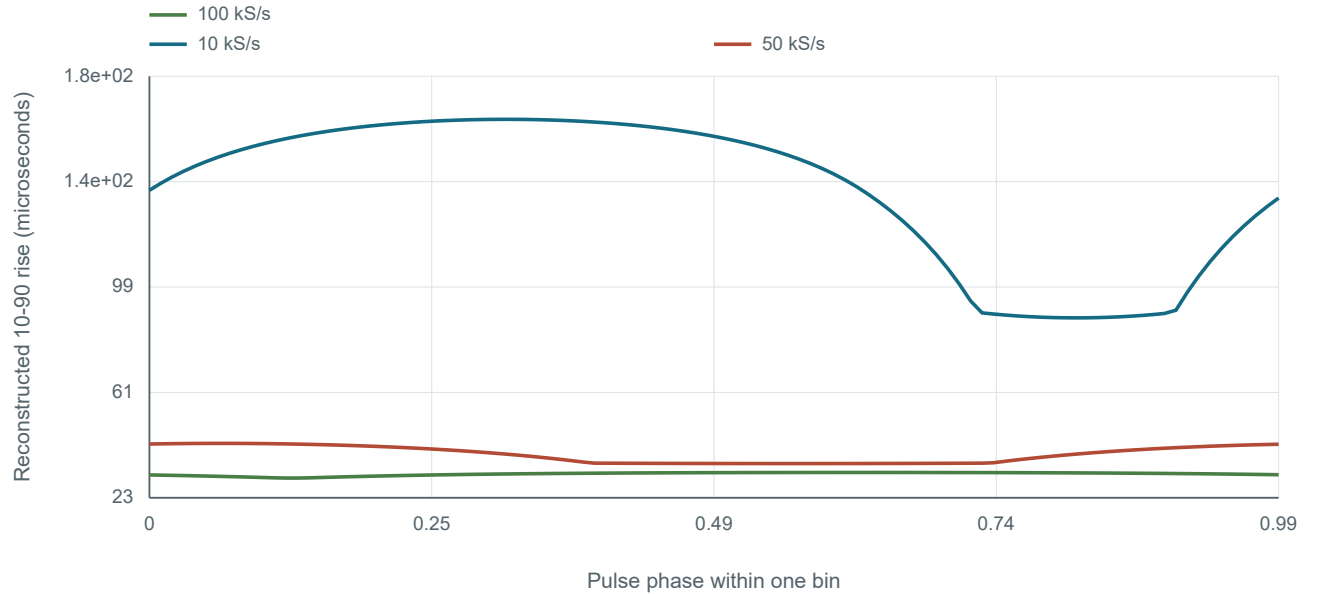
R4-N08 - Optical/electronic design algebra with explicit assumptions

These small models make trade-offs visible without pretending a catalogue sensor or ideal filter is the completed spacecraft.

Ideal air etendue: 25 mm entrance and 10 degree internal filter half-angle.

Full circular field	Minimum detector mm 2	Minimum clear filter mm
30	32.88	37.26
60	122.7	71.98
80	202.8	92.54
90	245.4	101.8

Noiseless bin-phase bias for a 30 us linear rise



Exact nonoverlapping bin averages with interpolation at bin midpoints. This is a particular noiseless estimator/model, not measured timing performance.

Limits. No flight filter optimum, no measured electronics noise, no hardware qualification and no source-population inference.

Sources: [S073]; [S075]

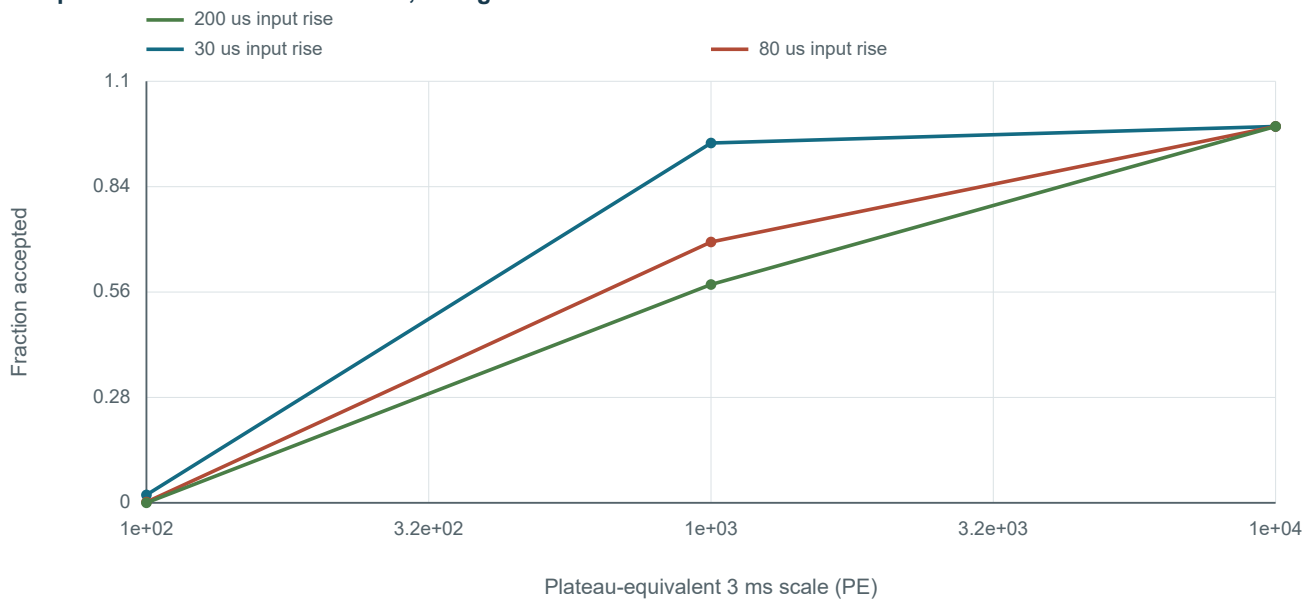
R4-N09 - Detection is easier than trusted morphology classification

A pulse can be detected nearly every time while too little information exists in its leading edge to classify its rise. Rejecting ambiguous classifications is useful, but a low error among a tiny accepted subset is not high mission completeness.

50 kS/s, 1,000 trials per row. Accepted fast/slow labels use the predefined $\ln(19)$ score selection. The last column reports wrong/accepted percentage and an individual two-sided exact 95% interval; it is not a posterior probability.

Scale PE	b/s	Rise us	Actual PE	Detected	Accepted	Wrong/accepted	Error% [95% CI]
100	50	30	99.38	1000	21	0/21	0% [0,16.11]
100	50	80	98.33	1000	2	0/2	0% [0,84.19]
100	50	200	95.83	1000	0	0/0	undefined [n/a, n/a]
1000	50	30	993.8	1000	956	0/956	0% [0,0.3851]
1000	50	80	983.3	1000	693	4/693	0.5772% [0.1575,1.471]
1000	50	200	958.3	1000	580	15/580	2.586% [1.455,4.23]
1000	1e+06	200	958.3	1000	8	5/8	62.5% [24.49,91.48]

Accepted fast/slow labels at 50 kS/s, background 50/s



Synthetic receiver-input shapes, unknown amplitude/onset, finite baseline. Acceptance alone is not correctness; the accompanying table includes errors and exact intervals.

Limits. This is a conditional synthetic receiver-morphology study, not a flight sensitivity/completeness validation. The classes mean 30/80/200 us 10-to 90% rises at a hypothetical linear receiver input after transport; they do not label source depth. Source brightness, cloud transfer, line spectrum, detector PDE and source occurrence population are outside this count-level calculation.

Sources: [S116]; [S113]; [S067]

R4-N10 - Exact counts, finite-baseline limits and search control

If the background was estimated rather than known exactly, our red upper limit changes. We must name the procedure and avoid treating a selection-score threshold as a guarantee.

Exact ideal count controls; limits concern expected detected source counts in the selected window.

Procedure/condition	Upper mean 95%
Zero counts, known zero background	2.99573
Zero on/off, finite baseline, equal alpha split	3.68888

Limits. Registered counts in nonoverlapping on/off windows are independent Poisson variables, before any deadtime/censoring issue. Source expectation $s \geq 0$ is confined to on window; background stationary with common rate and known exposure ratio. Known-background upper bound requires externally known fixed b_{on} , not a finite-baseline plug-in estimate.

Sources: [S113]; [S114]; [S115]

R4-N11 - Independent cylinder transport and the unresolved rare-path test

EXECUTED, BUT NUMERICAL CONVERGENCE INCOMPLETE where flagged. Do not treat these cases as validated ice-cloud predictions.

This is a real new computer experiment, not just a suggestion to run one. We followed 14.4 million model photon histories and compared selected simple cases with CloudScat. Basic geometry, normalization and energy checks passed.

The realistic-looking ice-phase table creates a harder numerical problem: rare paths can contribute disproportionately to the exact nadir estimate. Increasing the sample or changing how initial directions are sampled changed some answers more than a simple error bar suggested. We therefore cannot call those answers converged or use their differences to make a physical claim about ice-cloud timing.

The simpler HG law behaved more steadily in representative controls. That supports a limited implementation check, but it does not make the chosen smooth cloud, source or atmosphere real. The report keeps the uncertain ice results visible as a known gap.

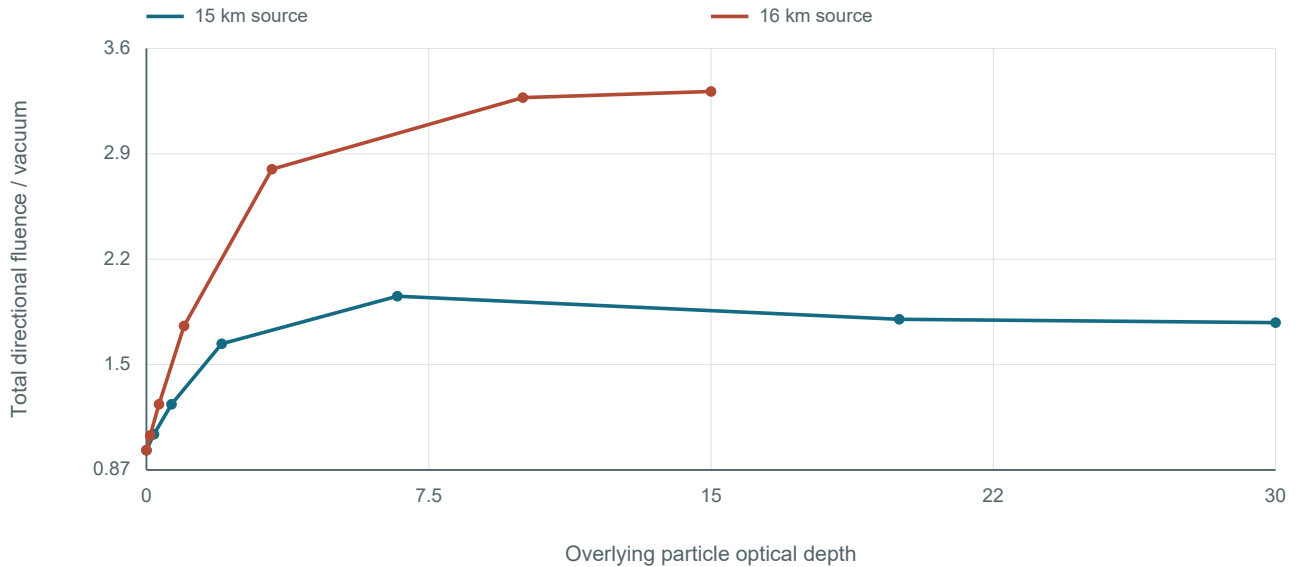
Production and additional source 15 km, total optical depth 10 controls. +/- values are estimated batch SEM, not physical confidence limits. GHM is not uniformly converged.

Phase	Estimator sample	Histories	Nadir/vacuum gain	Estimated SEM
GHM	production	300000	1.6661	0.11797
GHM	larger-packet control	1200000	2.0045	0.098633
HG	production	300000	1.9837	0.008725
HG	larger-packet control	1200000	1.985	0.0053223
GHM	source-cone control	1200000	1.8051	0.13165

Independent-code controls with matched ideal HG and separate geometry: g 0.87098, source 16 km, cloud 12-18 km, radius 20 km.

Overhead tau	CloudScat gain	SE	New gain	SE	Difference / SE
3	2.1996	0.016826	2.1908	0.0134	0.40914
10	3.0824	0.02763	3.1048	0.016895	0.69377

Conditional HG nadir fluence: two fixed source heights



Fresh finite-cylinder model, HG $g=0.77094$, SSA 1. Source 15/16 km in a 14-17 km cylinder, radius 30 km. Whole-cloud density changes in each curve, so cloud below the source also changes. Exterior gas/aerosol absent; not an overhead-only or real-cloud prediction.

Limits. Conditional model comparison, not a universal transmission curve or inversion. Equal g does not fix higher phase-function moments. This grid supplies conditional estimates with MC errors; the current GHM rare-path controls do not establish a physical timing bias. Two matched homogeneous-HG controls from the new engine were compared with retained CloudScat outputs and agree within their combined Monte Carlo errors. This independent-code check does not validate tabulated GHM, atmospheric transport or a real-cloud classifier; own analytic tests are labeled separately.

Sources: [S097]; [S027]; [S111]

R4-N12 - Conditional transported pulse timing and electronics

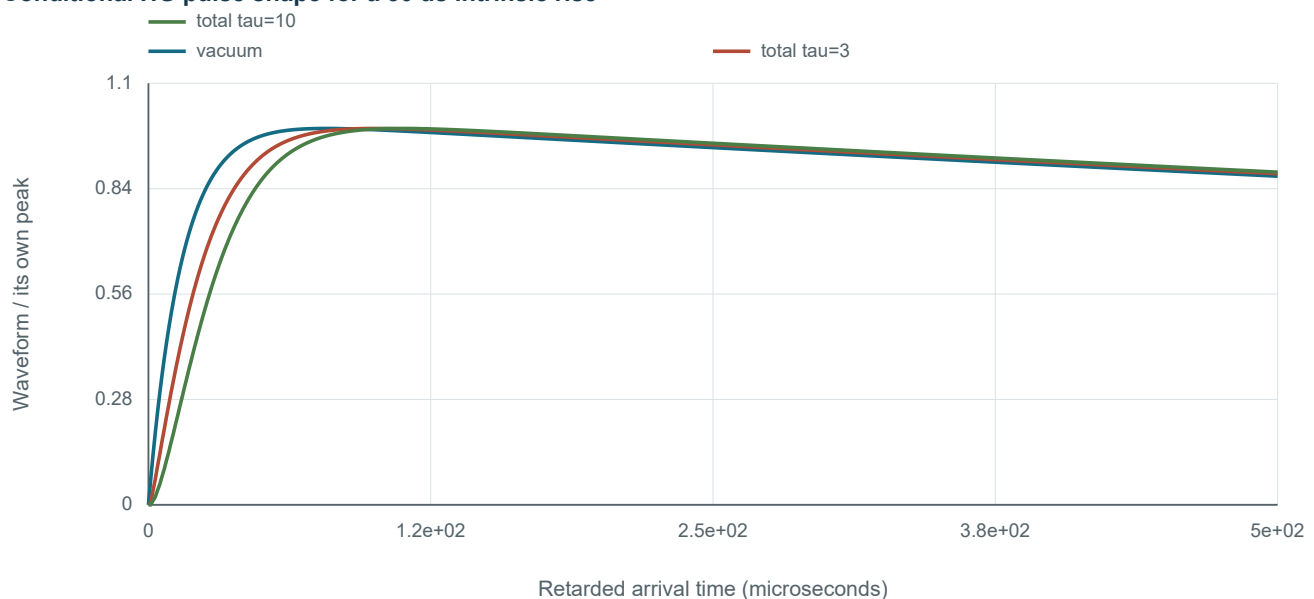
Cloud scattering and electronics can each change the rise. In one explicit smooth-cloud/HG case, a source 2 km below the top still produced a rise in the proposed fast range. Depth alone did not determine the label.

These curves assume we know the source shape and can measure a noiseless curve. The separate photon trials show why actual faint data have a harder problem. Neither study establishes a universal fast=cloudtop rule.

HG g 0.77094, 30 us input 10-90 rise. Gas-free conservative cylinder, not real depth validation.

Source km	Total tau	Above tau	Gain	Gain SEM	Ideal rise us	10 kHz LP rise us
15	0	0	1	0	30	48.036
15	3	2	1.6798	0.0085844	41.617	56.495
15	10	6.6667	1.9837	0.008725	48.227	61.542
15	30	20	1.8364	0.0043262	71.938	82.137
16	0	0	1	0	30	48.036
16	3	1	1.7938	0.0090274	42.948	57.636
16	10	3.3333	2.7951	0.016188	47.674	61.132
16	30	10	3.2524	0.015135	64.721	76.127
17	3	0	1.4624	0.0014462	43.382	58.083
17	10	0	2.0285	0.0041485	46.469	60.382
17	30	0	2.4562	0.004879	46.217	61.239
18	3	0	1.445	0.0030387	54.533	67.652
18	10	0	1.9828	0.005117	58.213	70.222
18	30	0	2.4114	0.007451	58.59	70.581

Conditional HG pulse shape for a 30 us intrinsic rise



Shape only: each curve is normalized to its own output peak. The horizontal coordinate subtracts the direct source-observer flight time $R0/c$; it retains the source onset and excess-path delay. This view does not compare amplitudes. First 0.5 ms shown; timing metrics use the recorded longer window. Conditional homogeneous HG cloud, gas-free conservative transport and an assumed source pulse; no observed source-depth classification is implied.

Limits. HG is a comparison phase model, not an event-specific ice measurement. GHM timing remains numerically unconverged. Assumed source decay 3 ms is not a universal observed duration. Output normalized to its own peak hides amplitude differences intentionally. Known-model onset, 10-90 rise, arrival quantiles and noisy inferred onset are different quantities.

Sources: [S097]

Minimum remaining validation program

Choose a realizable optical phase-space layout and receiver chain, including field, filter, area, dynamic range, power, thermal and safety states.

Measure traceable 337/777 spectral-angular photon response, noise, time response, count losses and recovery on the full assembled head.

Test source/cloud and artifact alternatives using calibrated pulses and independently labeled physical observations; report both accepted fractions and errors.

Propagate selected-part radiation and contamination effects into end-of-life sensitivity, and validate calibration drift paths.

Acquire a joint faint-source/scene/exposure sample with non-detections, versioned selection and valid observing live time before predicting useful polar yield.

Terms and units

Definitions retain their reference plane and convention.

Term	Meaning
Photon	One packet of light energy.
PDE	Probability that an incident photon produces a useful detected event, with reference plane stated.
QE	Quantum efficiency at a material/device stage; not automatically complete instrument PDE.
Irradiance	Power per unit receiving area.
Radiance	Power per projected area per solid angle; add pernm for spectral radiance.
Fluence	Time-integrated energy or photon number per receiving area.
Optical depth	Dimensionless accumulated extinction along a path.
Phase function	Probability density for scattering into a direction.
Etendue	Optical area-and-angular acceptance, including refractive index.
NEP	Noise-equivalent optical power under a stated spectral/bandwidth convention.
DCR	Dark-count rate at specified temperature, bias and threshold.
ENBW	Equivalent noise bandwidth of the complete filter/estimator.
Dead time	Time-dependent lost-event acceptance following detection.
Confidence limit	A bound from a procedure with stated repeated-sampling coverage.
TID / DDD / SEE	Ionizing dose, displacement damage and individual radiation-induced events.
E/N	Electric field divided by neutral-gas number density; relevant to electron energies.
Current moment	A source quantity involving current and spatial extent; not identical to current.

Sources, access and applicability

116curated cited records include papers, relateddatasets, officialtechnical documentation andmanufacturer sheets. They are not 116independent studies orobserving cohorts. Each record is used only forits stated limitedclaim; access andrights restrictions remain explicit.

Original URLs and DOIs are clickable. Record-specific access statements distinguish inspected full text, selected pages, manufacturer sheets, data/interface audits and limited-access leads. No restricted GLIMS/RAIDS raw data are reproduced. Where no specific license was established, the entry supplies paraphrased findings and an original link only; it does not grant raw-data redistribution rights. Related versions and data products are not independent observing cohorts.

[S001] Introduction to TRE x-ATM V 2.0: A Versatile Model of Auroral Transport and Its Effects in the Ionosphere

Attribution/date: 2026

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2026EA005013>

DOI: [10.1029/2026EA005013](https://doi.org/10.1029/2026EA005013)

Locator: Published model description/optical-output claims; API availability is separately audited in BG 021. No exact 337 numerical result taken from this source..

Access: Open publisher methods, comparison table, inversion tests, uncertainty table and availability inspected

Applicability limits: Model scenario output requires particle inputs and is not a Kp-binned observational climatology. Ground atmospheric corrections cannot be applied blindly to upward/nadir geometry.

[S002] LIME: Lunar Irradiance Model of ESA

OriginalURL: <https://acp.copernicus.org/articles/24/3649/2024/index.html>

DOI: [10.5194/acp-24-3649-2024](https://doi.org/10.5194/acp-24-3649-2024)

Locator: LIME instrument/model band coverage and validation; actual v 2 observed-wavelength archive inspected separately in campaign..

Access: Open primary methods and instrument bands inspected

Applicability limits: An interpolated or extrapolated 337 nm prediction needs an independent UV uncertainty budget; the actual photometer has no 337 nm band.

[S003] Measurements of absolute, SI-traceable lunar irradiance with air-LUSI

OriginalURL:

<https://www.nist.gov/publications/measurements-absolute-si-traceable-lunar-irradiance-airborne-lunar-spectral-irradiance>

DOI: [10.1088/1681-7575/ac64dc](https://doi.org/10.1088/1681-7575/ac64dc)

Locator: Abstract and wavelength-dependent uncertainty results: measured 350-980 nm; <=1% demonstrated 450-970 nm..

Access: NIST primary abstract and instrument/uncertainty summary inspected

Applicability limits: Neither the nominal instrument range nor the stated lowest uncertainty validates 337 nm calibration.

[S004] USGS Lunar Calibration: current mission considerations and uncertainty

OriginalURL: <https://www.usgs.gov/calval/lunar-calibration>

Locator: Official page mission-considerations and uncertainty discussion; lunar viewing/opposition constraints..

Access: Official full page inspected

Applicability limits: These are general mission/calibration characteristics, not a calibrated 337 nm lunar irradiance or a free operational resource.

[S005] The spectral irradiance of the Moon

OriginalURL: <https://pubs.usgs.gov/publication/70029564>

DOI: [10.1086/430185](https://doi.org/10.1086/430185)

Locator: ROLO observed wavelength bands and empirical phase/libration model; lowest fitted band about 350 nm..

Access: Primary USGS publication record and abstract inspected; original paper discovered

Applicability limits: 337 nm lies outside the measured wavelength range; absolute accuracy and fit residual are different quantities.

[S006] TEMPO at Night

OriginalURL: <https://ntrs.nasa.gov/citations/20260001290>

DOI: [10.1029/2024EA004157](https://doi.org/10.1029/2024EA004157)

Locator: PDF§2.1, 2.4, 3, 4.2, 4.3, 4.6, Open Research; NASA metadata publication date 2025-10-01, acquired 2026-02-10.

Access: NASA 27 pageaccepted manuscript: instrument, noise, observingwindows, moon, aurora, lightning and availability inspected; publisher metadata compared

Applicability limits: Do not treat limb examples or visible moon examples as a polar nadir 4 nm 337 climatology. Need raw twilightradiance, postprocessing, errorcovariance and filterfolding. TEMPO does not cover 777.4 nm.

[S007] A Ground-Based Instrument Suite for Integrated High-Time Resolution Measurements of Pulsating Aurora With Arase

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2023JA031527>

DOI: [10.1029/2023JA031527](https://doi.org/10.1029/2023JA031527)

Locator: §2.2 and Table 1; §3.1, Figure 5.

Access: Primary full instrument and calibration sections inspected

Applicability limits: The described bands are 427.8, 844.6, 777.4 and 650-700 nm, not a measured 337 nm profile. Illustrates calibration/energy-ratio degeneracy, not 30μspolar 337 climatology.

[S008] TRE x-ATM V 2: current public API capability audit

OriginalURL: <https://api.phys.ucalgary.ca/docs>

DOI: [10.1029/2026EA005013](https://doi.org/10.1029/2026EA005013)

Locator: Current public Open API response schema and optical output fields, archived during campaign; arbitrary 337/777 outputs not declared..

Access: Actual Open API document fetched 2026-10-21 T 22: 28: 53 Z, 91408 bytes, SHA 256 d 38533 aa 0 dc 168 a 5458 c 2617 df 4 bc 3 b 1 c 906 dff 46 a 9504 ec 0 b 6 d 23 f 52 c 4 7e3 dd

Applicability limits: A paper-level capability is not proof of a callable 337/777 API. Do not send invented flags or relabel 427.8 as 337. This audit corrects the earlier broad BG 006 API availability implication; source code/access or another model must be checked before running 337/777 scenarios.

[S009] GLOW official atmospheric-emission model source and published auroral example

OriginalURL: <https://github.com/NCAR/GLOW>

Locator: model_code/NCAR_GLOW_Glowlicense.txt; model_code/NCAR_GLOW_in.basic.aur; reference_numbers_audit.json.

Access: Pinned source, license, example inputs and output inspected; rounded example integrated locally. No compiler/model execution.

Applicability limits: An imposed precipitation scenario is not a measured moderate-Kp radiance or orbital distribution. Academic research license retained; no fresh atmospheric model run claimed.

[S010] Observations of the moon by GOME: radiometric calibration and lunar albedo

OriginalURL: <https://opg.optica.org/ao/abstract.cfm?uri=ao-37-33-7832>

DOI: [10.1364/AO.37.007832](https://doi.org/10.1364/AO.37.007832)

Locator: Abstract; Table 1.

Access: Primary abstract and Table 1 inspected. Full text and figures are subscription restricted.

Applicability limits: Not justified to say UV lunar measurements do not exist. Actual 337 nm albedo, geometry and error budget have not been extracted from this restricted full text.

[S011] The 1997 reference of diffuse night sky brightness: ultraviolet zodiacal table

OriginalURL: <https://aas.aanda.org/articles/aas/pdf/1998/01/ds1449.pdf>

DOI: [10.1051/aas:1998105](https://doi.org/10.1051/aas:1998105)

Locator: Table 19; Section 8.4; reference_numbers_audit.json.

Access: Primary publisher cached Section 8.4/Table 19 recovered. Direct PDF access 403/timeout, not a fully read local PDF.

Applicability limits: Interpolation choice is not an uncertainty interval. Incident celestial radiance must be integrated over cloud illumination and BRDF; it is not an Earth-filled nadir background.

[S012] RAIDS public calibrated near-UV archive and mission README

OriginalURL: <https://spdf.gsfc.nasa.gov/pub/data/raids/>

Locator: round 04/raids_readme.pdf, pp 1--2; round 04/raids_nuv_qualification.json; round 04/raids_nuv_sample_header.json.

Access: README, Newsletter 6, directory listings and one small public Net CDF inspected; header and geometry audit saved.

Applicability limits: Single commissioning-day limb sample is neither nadir cloud nor polar climatology. No radiance numbers exported. README requests PI authorization and advance draft review before publication/presentation. Private qualification only; no external contact made.

[S013] Low-latitude nightglow pseudo-continuum 300--1800 nm

OriginalURL: <https://acp.copernicus.org/articles/24/1143/2024/>

DOI: [10.5194/acp-24-1143-2024](https://doi.org/10.5194/acp-24-1143-2024)

Locator: Section 2; Section 3; Data availability; round 05/Noll et al.(2024)_primary.xml.

Access: Primary instrument, calibration, continuum-separation, conclusion and data-availability sections inspected; full XML retained.

Applicability limits: Low-latitude ground data need extinction/sky-component separation and satellite illumination geometry. A continuum-only spectrum omits structured O2 bands and must not replace total 337 background or double-count a complete sky model.

[S014] TSIS-1 Hybrid Solar Reference Spectrum version 2 and uncertainty interpretation

OriginalURL: https://lasp.colorado.edu/lisird/data/tsis1_hsrs/

Locator: round 05/HSRS_p 1 nm_v 2.nc; round 05/spectral_geometry_audit.json; Coddington 2021 Section 4.2.

Access: Official variants/metadata inspected; 2.44 MB v 2 HDF 5 file retrieved/hashed and solar-only filter integrations executed; 2021 primary uncertainty text inspected.

Applicability limits: Sunlight is not nightside or lunar irradiance. No absolute Moon flux was derived. 1.3% UV broadband uncertainty is not an independent error for every fine spectral pixel; individual line discrepancies can be larger.

[S015] Alternative hyperspectral Moon phase-reddening model: original LESSSR report

OriginalURL: https://www-cdn.eumetsat.int/files/2021-02/ESS-AMM-RP-001-Rev5_LunarModel_FINAL_EUMETSATwebsite.pdf

Locator: Sections 5.4, 6.3--6.6, 7.2.

Access: Primary 34 page 2019 report selected calibration/model/validation sections inspected.

Applicability limits: No machine-readable coefficient set retrieved yet. UV calibration/polarization features and GOME 2 comparison differences limit an unqualified high-accuracy 337 claim.

[S016] Updated LESSSR lunar model study completed 2024, public overview 2025

OriginalURL: <https://www.eumetsat.int/enhancing-eumetsat-lunar-extended-satellite-simulation-reflectance-model>

Locator: Overview; Table 1; Data resources.

Access: Official full overview, model-range descriptions and data-resources section inspected.

Applicability limits: LCS service scope starts 350 nm and the discussed base-function fit grid starts 350 nm, despite broader model range elsewhere on the same page. Actual 337 nmv 2 coefficients/support need clarification. No claim that coefficients are publicly downloadable or that we ran this model. No external contact made.

[S017] Actual Noll et al.(2024) mean continuum spectral dataset

OriginalURL: <https://zenodo.org/records/8335837>

DOI: [10.5194/acp-24-1143-2024](https://doi.org/10.5194/acp-24-1143-2024)

Locator: Zenodo 8335837 mean continuum table, 0.5 nm grid; processed selection/line-removal conventions in Noll et al.(2024)..

Access: Verifiedranged ZIP centraldirectory and 6 smallmembers CRC 32/SHA checked; whole 151 MBZIP notdownloaded. Actualmean spectrum and README inspected. CC BY 4.0.

Applicability limits: The extracted pseudo-continuum includes many unresolved O2 ultraviolet bands; strong resolved lines were removed. It is not the total polar 337 or 777 nm sky background. Broad extraction windows and a 0.5 nm grid do not establish a sub-nanometre filter optimum.

[S018] Bianchi(2024) Gaia-based direct and diffuse starlight model with actual sky cube

OriginalURL: <https://cdsarc.cds.unistra.fr/viz-bin/cat/J/A+A/691/A330>

DOI: [10.1051/0004-6361/202451086](https://doi.org/10.1051/0004-6361/202451086)

Locator: CDS J/A+A/691/A 330; 99-bin mean intensity table and celestial NESTED Nside64 direct+diffuse sky cube..

Access: Fullauthorarxiv 1 HTML inspected, final CDSR ead Me/99 row Jtable/15.63 MB gzip 49152 x 99 sky cube downloaded andhashed. Finalpublisher directfetch 403; indexedfinaldataavailabilityqualifies CDS route.

Applicability limits: The ultraviolet extension uses stellar-atmosphere/extinction models and an empirical diffuse-light fit, rather than a direct 4 nm measurement at 337 nm. The roughly 13 nm wavelength bracket cannot resolve 4 nm spectral structure. Interpolating it does not provide a new pixel covariance or confidence interval.

[S019] Rovibronic molecular line list for the N2(C 3 Pi_u-B 3 Pi_g) second positive system

OriginalURL: <https://www.osti.gov/servlets/purl/2311352>

DOI: [10.1016/j.jqsrt.2023.108809](https://doi.org/10.1016/j.jqsrt.2023.108809)

Locator: section 2, Eqs 2-3; section 3; Figures 4-6; Tables 1-2; section 4.

Access: Author preprint dated 2023-11-01; all 7 pages text inspected, Figure 6 p 5 visually inspected. Published JQSRT 312(2024)108809.

Conditions/scope: Spectroscopic line-position/strength model validated by author against experimental FTS and SPECAIR under stated laboratory conditions. Not an NBE radiometric calibration.

Applicability limits: Official current ExoMol metadata identifies the 20240705 C-B extension. Public .states/ERJ.trans requests timed out here: this is a local access failure, not global unavailability. Zenodo 5717009 contains the older 20190916 archive, created and modified in 2021; it does not include the Jans et al. 2024 C-B extension.

[S020] The Spectrum of Molecular Nitrogen

OriginalURL: <https://srdb.nist.gov/JPCRD/jpcrd93.pdf>

DOI: [10.1063/1.555546](https://doi.org/10.1063/1.555546)

Locator: section 3.13 printedp 139; Table 29 printedp 226; Appendix A(9) printedp 307.

Access: 195-page scanned official NIST PDF retrieved with SHA 256; selected printedp 113, 115, 117, 123, 139, 226, 306, 307 visually inspected. Not all 195 pages read.

Conditions/scope: Critical spectroscopic compilation; historical source bandheads, not event-specific spectrum.

Applicability limits: A bandhead is not the band centroid or a monochromatic representation. Air/vacuum wavelength conversion does not describe a physical coating passband change in vacuum. Both require explicit metadata.

[S021] Moose / original Massive OES N2CB numericaldata and query-interface audit

OriginalURL: <https://github.com/AntoineTUE/Moose>

Locator: Pinned Moose/original Massive OES data/query audit; lower-state link, energy/J and coordinate checks. These are conditional reconstructions, not an accepted NBE spectrum..

Access: Actual SQL ite 11225088 B and selected sourcefiles retrieved andhashverified. No software installed or outsidepackagecode executed. Own SQL ite/arithmetic audits executed.

Conditions/scope: Numerical spectroscopy implementation and diagnostic, not a measurement.

Applicability limits: The attempted initial v0-v0 filter fold was invalidated; no physical capture fractions from it are retained. Later candidate mappings are conditional diagnostics. Population/spin weights, original line positions and Einstein A values still require independent primary comparison.

[S022] Standard-air wavelength convention and refractivity arithmetic

OriginalURL: <https://emtoolbox.nist.gov/Wavelength/Documentation.asp>

Locator: NIST refractive-index-of-air/wavelength documentation; standard-air coordinate conversion, not a physical filter-vacuum shift..

Access: Official NIST documentation sections IV, VI, VII and Jones 1981Eq 1/introduction printedp 27 inspected throughbrowser. Wholevolume notdownloaded/read.

Conditions/scope: Ownstandardaircoordinatecalculation using publisheddispersion formula; not measured anvil refractivity.

Applicability limits: No nominal wavelength was silently changed in the frozen calculations. NIST discusses air-index models over 300-1700 nm with condition-dependent uncertainty. A nominal dry-air conversion does not certify old table accuracy or an event band centroid.

[S023] Orbital broad UV background cross-check and response-positivity bound

OriginalURL: <https://data.mendeley.com/datasets/57fmn7rh4n/4>

Locator: Dataset wavelength_response.txt and Europe_North Africa_map.txt; Mini-EUSO broad-band response/positivity audit, not a 4 nm measurement..

Access: Cross-stream source package: exact ten-source list/access levels in sourcebranchprimaryreview, not a single independent dataset.

Conditions/scope: Measured broadbandcounts plus calibrationmodels and ownconditionalbound; not measured 4 nm 337 radiance.

Applicability limits: This is not an exposure-weighted polar background distribution or a faint-event rate. Scene conditions, selection, trimming and modal-statistic qualifications must accompany its measurements.

[S024] Mesoscale structure of flickering aurora from wide-field high-speed imaging

OriginalURL: <https://angeo.copernicus.org/articles/44/959/2026/>

DOI: [10.5194/angeo-44-959-2026](https://doi.org/10.5194/angeo-44-959-2026)

Locator: sections 2-3; Figure 1; Appendices A, C; Dataavailability.

Access: Primary full HTML methods, results, appendices and data availability inspected; XML/metadata access separate in receipt. No raw image/video download.

Conditions/scope: One unfiltered high-speed ground-observation event; spatial mapping assumes 110 km emission height.

Applicability limits: It supplies neither absolute 337 nm radiance nor a microsecond power spectrum or Kp-conditioned population. Neighboring patches are correlated; independent-cell averaging proportional to $1/\sqrt{N}$ cannot be assumed.

[S025] Some photometer results obtained on the NASA 1969 Airborne Auroral Expedition

Attribution/date: 1971

OriginalURL: <https://ntrs.nasa.gov/citations/19720005652>

Locator: NASA-CR-124719, PDF pp 4-5 filter/calibration; pp 8, 11 selected night observations; page 67 bright sample is midday..

Access: Original 77 page public NASA PDF locally retained; summary/calibration/filter table and selected night/day tables visually verified.

Conditions/scope: Measured filter-channel equivalent brightness, dark-current corrected; not spectrally pure N₂(0, 0).

Applicability limits: Airglow, starlight, moonlight and other features were not removed; the weak-end accuracy at a few tens of Rayleigh is described qualitatively. The inspected 1971 summary does not expose a full filter curve, equivalent bandwidth, formal uncertainty, per-wavelength timestamps or complete zenith extinction correction.

Rights/access: NTRS metadata: Work of USG ov, Public Use Permitted; private working copy.

[S026] Coordinated analysis of various auroral measurements made during NASA 1968 and 1969 airborne auroral expeditions, chapter III

Attribution/date: 1976

OriginalURL: <https://ntrs.nasa.gov/citations/19760014714>

DOI: [10.1029/JA081i034p06046](https://doi.org/10.1029/JA081i034p06046)

Locator: NASA-CR-146857, chapter III; Table 2 printed p 47/PDF 57; calibration printed pp 38-40, 46-50..

Access: Original 102 page public NASA PDF locally retained; printed pp 38-40, 46-50, 54-55, 60 inspected; key calibration/table pages visually verified.

Conditions/scope: Selected auroral spectrum, blend-separated band area and atmosphere-corrected absolute calibration. Chapter title/authors match journal lead; journal full text not obtained for byte/content identity. Not independent observing campaign.

Applicability limits: N₂(C) band intensity is not a measured spectral radiance per nanometre or an actual 4 nm filter fold. A two-minute selected zenith spectrum is not a wide-field orbital distribution or a Kp climatology.

[S027] Spectrally consistent scattering, absorption, and polarization properties of atmospheric ice crystals at wavelengths from 0.2 to 100 μ m

Attribution/date: P. Yang, L. Bi, B. A. Baum, K.-N. Liou, G. W. Kattawar, M. I. Mishchenko, B. Cole 2013

OriginalURL: <https://www.giss.nasa.gov/pubs/abs/ya07100h.html>

DOI: [10.1175/JAS-D-12-039.1](https://doi.org/10.1175/JAS-D-12-039.1)

Locator: NASA GISS publication abstract; NASA abstract last sentence.

Access: author_institution_abstract_only; publisher_fulltext_pending

[S028] MCAR aTS developer documentation version 0.10 and change log 0.10.3

Attribution/date: documentation undated; latest listed release 2016-09-06

OriginalURL: <https://sites.google.com/site/mcarats/>

Locator: Introduction; job namelist Src_mtype Src_apsize; initialization Rad_mplen=3, Rad_ntp, Rad_tpmin/tpmax; initialization namelist Rad_mplen and Rad_tpmin/tpmax; initialization Wld_moptim and Sca_qtfmax; job Rad_mrproj and Rad_difr 0/1; change log 0.10.2; change log 2016-09-06; introduction.

Access: developer_documentation_sections_examined; code_not_downloaded_or_run

[S029] McRALI: a Monte Carlo high-spectral-resolution lidar and Doppler radar simulator for three-dimensional cloudy atmosphere remote sensing

Attribution/date: 2021-01-12

OriginalURL: <https://amt.copernicus.org/articles/14/199/2021/amt-14-199-2021.html>

DOI: [10.5194/amt-14-199-2021](https://doi.org/10.5194/amt-14-199-2021)

Locator: sections 2.1-2.3 and code-availability statement; methods and conclusions; our applicability assessment.

Access: publisher_full_HTML; methods 2.1-2.3, conclusion and code availability examined

[S030] MSCART developer documentation

Attribution/date: documentation build2025-05-06

OriginalURL: <https://intersharp.gitlab.io/mscart-docs/page/index.html>

Locator: feature table; lidar case; input Rad/PR ad/Sca settings.

Access: developer_features, input, case, and_reference pages read

[S031] SMART-G developer README, changelog and license

Attribution/date: versions2.0.0 on2026-09-30,2.0.1 on2026-10-02,2.0.2 on2026-10-08

OriginalURL: <https://github.com/hygeos/smartg>

Locator: README installation/features; changelog 2.0; changelog 2.0.0-2.0.2; LICENSE/README.

Access: complete developer README and selected changelog entries read

[S032] On Rayleigh Optical Depth Calculations

Attribution/date: Barry A. Bodhaine, Norman B. Wood, Ellsworth G. Dutton, James R. Slusser 1999-11-01

OriginalURL: https://web.gps.caltech.edu/~vijay/Papers/Rayleigh_Scattering/Bodhaine-et-al-99.pdf

DOI: [10.1175/1520-0426\(1999\)016<1854:ORODC>2.0.CO;2](https://doi.org/10.1175/1520-0426(1999)016<1854:ORODC>2.0.CO;2)

Locator: sections 1-2, equations 2, 5-6, 9; section 3; Table 2; equation 8.

Access: author/institution_hosted_full_PDF; all 8 pages extracted, sections 1-4 read closely

[S033] mitransient volumetric transient integrator and Mitsuba 3 phase/emitter interfaces

Attribution/date: living developer documentation accessed2026-10-21

OriginalURL: <https://github.com/diegoroyo/mitransient>

Locator: developer integrator/film docs; phase/emitter docs; our applicability assessment; mitransient_volume_interface_audit.json; lines 216-239, 261, 334.

Access: Official docs and source transient_prbvolpath.py read; no renderer installed or executed.

[S034] U S Standard Atmosphere 1976 deeper primary scan and clear-air audit

Attribution/date: 1976-10-01

OriginalURL: <https://ntrs.nasa.gov/api/citations/19770009539/downloads/19770009539.pdf>

Locator: printed 2-3 Tables 2-4, printed 36-39 Tables 18-19; Rayleigh_standard_vs_frozen_337_audit.json; USSA 1976_ozone_above_source_audit.json.

Access: Original 243 pagegovernment PDF privatelyretained; selectedprinted 2-3, 36-39 visuallyread. Scanned OCR ispoor. NASA 2005 Appendix A independentlycrosschecksformulas.

[S035] Exploiting breakdown of the similarity relation for diffuse light transport simultaneous retrieval of scattering anisotropy and diffusion constant

Attribution/date: T. Svensson, R. Savo, E. Alerstam, K. Vynck, M. Burrese, D. S. Wiersma 2013-02-08publisheronline;2013-02-15issue

OriginalURL: <https://arxiv.org/abs/1211.6690>

DOI: [10.1364/OL.38.000437](https://doi.org/10.1364/OL.38.000437)

Locator: preprintpp 2-3, figures 2-3; preprintp 2, figure 1 anddiscussionp 3; ourinterpretationofcontrolledexperiment.

Access: Primary 4-pageauthorpreprintmaintextread, publisherabstractverified. Nojournalpaywallbypass. Preprint PDF dateline 2018-09-03 differsfromv 1 submissionhistory; version URL andhashretained.

[S036] Optical constants of ice from the ultraviolet to the microwave A revised compilation deeper baseline audit

Attribution/date: Stephen G. Warren, Richard E. Brandt 2008-07-31

OriginalURL: https://atmos.uw.edu/ice_optical_constants/Warren_and_Brandt_2008.pdf

DOI: [10.1029/2007JD009744](https://doi.org/10.1029/2007JD009744)

Locator: section 2 paragraphs 6-7, p 2; section 7 paragraph 34, p 7; frozenphase_validation.jsonread-onlyand GHM_ice_absorption_provenance_followup.json.

Access: Primaryauthor 10-page PDF sections 1, 2, 7 read; privatelyretained 644261 Bwith SHA 256.
Originalunderlyingexperimentsnotallreviewed.

[S037] Smoke of extreme Australian bushfires observed in the stratosphere over Punta Arenas, Chile, in January 2020: optical thickness, lidar ratios, and depolarization ratios at 355 and 532 nm

Attribution/date: Kevin Ohneiser et al. 2020-07-10

OriginalURL: <https://acp.copernicus.org/articles/20/8003/2020/>

DOI: [10.5194/acp-20-8003-2020](https://doi.org/10.5194/acp-20-8003-2020)

Locator: table 1 row 10 Jan 2020, 02: 25-04: 20 UTC; table 1 and sections 3-4.

Access: Selected primary methods/results and table 1 read; primary XML retained privately. Actual OASIS table namespace parsed.

[S038] libRadtran current documentation and public MYSTIC availability

Attribution/date: libRadtran developers Live documentation, last modified2024-12-22

OriginalURL: <https://www.libradtran.org/doku.php?id=documentation>

Locator: documentation lines 30 and 49-58; basic_usage MYSTIC section.

Access: Current official documentation and basic-usage pages read; no software installed/run. Manual link advertises 2.0.6, not yet privately retrieved.

[S039] Multi-wavelength calibration procedure for the Pierre Auger Observatory fluorescence detectors

OriginalURL: <https://arxiv.org/pdf/0811.1518>

DOI: [10.1016/j.astropartphys.2009.02.009](https://doi.org/10.1016/j.astropartphys.2009.02.009)

Locator: sections 4.1-5.2; Table 2; Eq.(2).

Access: Full author manuscript v 2 and primary author-institution published-version metadata; Astroparticle Physics 31 (2009) 305-311.

Applicability limits: A bright calibrated photodiode transfer is useful even if a PIN detector is too noisy for the faint science signal. This is not a 1% absolute 337 nm standard or a 30 μ s pulse simulator. Whole-path and piecewise component calibration can differ; narrow mission filters need finer wavelength sampling than this study.

[S040] CALSPEC stellar spectrophotometric standards and current Vega spectrum

OriginalURL: <https://www.stsci.edu/hst/instrumentation/reference-data-for-calibration-and-tools/astronomical-catalogs/calspec>

Locator: CALSPEC composition/cautions/history; FITS primary HISTORY and SCI BINTABLE header.

Access: Official STS cl page and primary FITS file retrieved; header verified, 288000 bytes, SHA 256
7201cd8566d53d384430c3d5fd2ae8d8122e9 a7f765711748b49336f63237672.

Applicability limits: A stellar standard exists at 337 nm, but this does not give a complete 1% receiver calibration. Actual response, backgrounds and pointing remain required. The private Vega fold is an ideal-band photon-statistics illustration; spectral resolution is about 0.55 nm near 337 and 0.98 nm near 777, not a line-resolved nitrogen/oxygen reference.

[S041] Optics and Opto-Electronics Laboratory

OriginalURL: <https://technology.esa.int/lab/optics-and-opto-electronics-laboratory>

Locator: Optical characterization; detector calibration; air-vacuum coating spectral shift.

Access: Official current ESA facility description

Applicability limits: Specific receiver geometry, low-light pulse bandwidth, uncertainty and access terms need confirmation. Coverage of a wavelength is not a demonstrated complete instrument calibration uncertainty.

[S042] Calibration and Characterization of the Ice Cube Photomultiplier Tube

OriginalURL: <https://arxiv.org/pdf/1002.2442>

DOI: [10.1016/j.nima.2010.03.102](https://doi.org/10.1016/j.nima.2010.03.102)

Locator: sections 9.1-9.3, pp.22-27; Table 3; section 11, pp.34-35.

Access: Primary author preprint; journal 2010; automated preprint footer has an inconsistent 2024 date

Conditions/scope: Hamamatsu R 7081-02, 10-inch PMT; laboratory measurements, not a Cube Sat PMT

Applicability limits: Results depend on detector geometry, bias, threshold and individual sample; they are not universal PMT values. The 4 ns nitrogen laser is useful for impulse calibration but does not reproduce the desired 3 ms envelope.

[S043] Sensitivity degradation of ISUAL instruments and its impact on observations

OriginalURL: <https://sprite.phys.ncku.edu.tw/joomla3/images/stories/useruploads/airosprey/1-4.pdf>

DOI: [10.3319/TAO.2011.06.20.01\(AA\)](https://doi.org/10.3319/TAO.2011.06.20.01(AA))

Locator: sections 2-2.1; printed pp.73, 75-76; Tables 1-2.

Access: Full primary team-hosted published article, 2012; 7024538-byte PDF read in memory, extracted text/provenance saved. Shared source with alternative_check; complementary calibration-path qualification.

Applicability limits: These are internal mainly-red LED response trends after preflight voltage-gain correction, not direct 337 nm PDE aging or isolated radiation damage. LED stability is assumed from duty, dose and temperature arguments. The reference pathway does not establish science-wavelength throughput stability. The source-population stream independently retrieved the same paper; cross-link its record rather than count this as independent evidence.

[S044] Predicting electrically generated hydrogen oxides from ultraviolet radiation emissions

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2026JD046463?af=R>

DOI: [10.1029/2026JD046463](https://doi.org/10.1029/2026JD046463)

Locator: sections 2.1, 2.2.1, 2.3.2, 2.4.3, 3.3; Table 1; Figure S16 description.

Access: Primary publisher full HTML verified through af=R; direct full URL initially failed. Supporting DOCX returned 403. Official data recovered independently.

Applicability limits: No instantaneous 337 peak-current law is determined; source conditions differ from 15-18 km NBEs. The corona PMT's 340 nm/12 nm filter and a 10 nm spectral sum are not a 4 nm 337.1 nm receiver.

[S045] LEDD1B and T-Cube LED drivers

OriginalURL: https://www.thorlabs.us/NewGroupPage9_PF.cfm?ObjectGroup_ID=6148

Locator: LEDD1B modulation specifications table and notes.

Access: Official manufacturer specification page.

Applicability limits: This driver is not automatically a 30 μ s optical-rise simulator. Current step, LED load, bias and optical tail must be measured. The driver waveform is not a calibrated optical waveform; use a fast reference detector and verify the complete attenuator/sphere path.

[S046] Mounted LEDs: M340L5

OriginalURL: https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=2692

Locator: M340L5 table row; operating conditions.

Access: Official current manufacturer table.

Applicability limits: It can supply light through a 337 nm passband, but this is not monochromatic 337.1 nm emission. Spectral overlap, attenuated photon number, heating and optical pulse shape require characterization. An exact M337L4 part was not verified; do not recommend that unconfirmed identifier.

[S047] High Accuracy Calibration of Photon-Counting Detectors On Demand

OriginalURL: https://physics.nist.gov/Divisions/Div844/publications/migdall/SPIE65830A_Calibration_On_Demand.pdf

DOI: [10.1117/12.723218](https://doi.org/10.1117/12.723218)

Locator: sections 3-4, pp.3-6.

Access: Primary NIST author conference paper, SPIE 6583, 2007

Applicability limits: Those uncertainty figures are for the demonstrated setups, not a guaranteed 337 nm wide-field two-channel service. A CW efficiency measurement must be checked against actual transient rate, background and detector recovery behavior.

[S048] NPL detector characterisation service

OriginalURL: <https://www.npl.co.uk/products-services/optical/detector-characterisation>

Locator: Calibrating the spectral responsivity of detectors.

Access: Official current full service page inspected.

Applicability limits: The better-than-0.01% cryogenic-radiometer statement applies at specific visible laser wavelengths; it is not a quoted 337 nm receiver uncertainty. A separate routine single-photon-detector service starts at 380 nm. Analog responsivity coverage does not automatically establish 337 nm photon-counting calibration, timing capability, available booking, or an end-to-end uncertainty. No facility affiliation is claimed.

[S049] OMI collection 4: establishing a 17-year-long series of detrended level-1 b data

OriginalURL: <https://amt.copernicus.org/articles/15/3527/2022/>

DOI: [10.5194/amt-15-3527-2022](https://doi.org/10.5194/amt-15-3527-2022)

Locator: sections 4.4-4.6; section 5 and Figures 9-11.

Access: Primary open publisher HTML, 14 June 2022; methods and figures inspected.

Applicability limits: Its large CCD instrument and orbit are not this receiver. Do not import its degradation rate or long-exposure correction performance into microsecond data. The row anomaly is probably external obscuration by loose insulation, not ordinary detector radiation aging. Internal LED constancy alone cannot exclude a blocked entrance path.

[S050] An approach to track instrument calibration and produce consistent products with V 8 TOZ

OriginalURL: <https://amt.copernicus.org/articles/16/2919/2023/>

DOI: [10.5194/amt-16-2919-2023](https://doi.org/10.5194/amt-16-2919-2023)

Locator: Figure 1 and associated introductory calibration paragraphs.

Access: Primary open publisher HTML, 14 June 2023.

Applicability limits: This demonstrates an architecture for separating reference aging from instrument aging, not a universal UV stability guarantee for a Cube Sat. The result is relative temporal stability; initial absolute calibration and retrieval soft-calibration have distinct uncertainties. A single unmonitored LED cannot uniquely separate its own drift from detector gain drift.

[S051] Calibration of radioluminescence detectors for radioactivity measurements

OriginalURL: <https://oar.ptb.de/files/download/EMPIR.19ENV02.PA.20231027.pdf>

DOI: [10.1016/j.nima.2024.169325](https://doi.org/10.1016/j.nima.2024.169325)

Locator: section 3, pp.4-5; reference detector/calibration arrangement.

Access: Primary author manuscript 26 Oct 2023; journal NIMA 1064, 2024

Conditions/scope: DUV340-HL18 W LED, 340 nm, FWHM 8 nm; monitored dual integrating sphere UV radiance source

Applicability limits: Monitor stability is not total absolute calibration uncertainty or multi-year orbital stability. Broad LED spectrum needs spectral-mismatch correction for the N2 band and actual filter.

[S052] Model independent approach to the single photoelectron calibration of photomultiplier tubes

OriginalURL: <https://arxiv.org/pdf/1602.03150>

DOI: [10.1016/j.nima.2017.02.086](https://doi.org/10.1016/j.nima.2017.02.086)

Locator: sections 3, 5-7; Eqs.(7), (9), (12); Table 1; Figure 9.

Access: Full primary author manuscript v 2, 18 June 2017; NIM A 863, 35-46.

Applicability limits: The equations assume linear independent response and Poisson photoelectrons; background and under-amplified pulses bias occupancy if misclassified. This calibrates charge per collected photoelectron and multiplication noise, not absolute incident-photon PDE. Keep optics/photocathode calibration separate; do not blindly apply to correlated SiPM avalanches or saturated data.

[S053] Raw photodiode and antenna triggers for Leal et al.(2026) multiband return-stroke study

OriginalURL: <https://zenodo.org/records/19209986>

DOI: [10.5281/zenodo.19209986](https://doi.org/10.5281/zenodo.19209986)

Locator: Description; Files; v 1 released 2026-03-24.

Access: Official landing metadata/file inventory verified; API 403. NoPSDATA downloaded.

Applicability limits: Compatible Pico Scope software/export and complete relative calibration are required for waveform reanalysis. ENTLN data require an external request; no contact made. No unrestricted data license established from retrieved landing text.

[S054] Six-Channel Spectrophotometers(PH)Onboard JEM-GLIMS

OriginalURL: https://www.jstage.jst.go.jp/article/ieejfms/131/12/131_12_1000/_pdf

DOI: [10.1541/ieejfms.131.1000](https://doi.org/10.1541/ieejfms.131.1000)

Locator: Table 1, p 1001; sections 2.1-2.2, pp 1001-1002; Figures 3-4.

Access: open primary six-page PDF

Conditions/scope: R 7400-06 UV PMT; R 7400-20 red PMT; S1227-1010BQ broadband PIN Design/preflight paper; 337±5 nm; 42.7 deg UV full FOV; 20 kHz 12-bit; 8 mm PMT photocathode.

Applicability limits: The design sensitivity of 0.1 uW/m2 differs from the later flight table. Telecentric chief-ray control does not establish zero angular spread.

[S055] GSENSE400BSI scientific CMOS image sensor

OriginalURL: https://www.gpixel.com/en/pro_details_1196.html

Locator: specifications and operation modes.

Access: Official current manufacturer product specification.

Applicability limits: A short minimum exposure is not a 50 kHz full-area frame rate. Reducing the ROI changes accepted area/field unless the optics are redesigned. Summed independent read noise scales approximately with square root of pixel count; 1.6 electrons per pixel is not 1.6 electrons for the full receiver. Exact 337 nm QE and flight qualification remain unverified.

[S056] H 16722 series cooled PMT module

OriginalURL: https://www.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SALES_LIBRARY/etd/H16722_TPMO1122E.pdf

Locator: PDF p.1 specifications and footnotes; p.2 cooling and dimensions.

Access: Official datasheet TPMO 1 122E01, October 2022; current H16722-50 product page also verified.

Applicability limits: Red PMTs need not all have only a few percent QE. But a 5 mm cathode imposes an étendue constraint, and thermal rejection in vacuum needs design. No flight qualification or radiation result is given. Dark anode current is not an RMS noise specification.

[S057] S13360 series MPPC electrical and optical characteristics

OriginalURL: https://hep.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SALES_LIBRARY/ssd/s13360_series_kapd1052e.pdf

Locator: p.3 electrical/optical table, footnotes 4-5.

Access: Official manufacturer datasheet; p.3 indexed table and footnotes verified.

Applicability limits: Scaling to a larger mosaic scales dark counts and capacitance too. Bias, package/window, temperature and readout must be retained. A spectrum or separately calibrated PDE is needed at 337.1 and 777 nm; nominal peak PDE cannot be reused.

[S058] S 8664 series Si APD

OriginalURL: https://www.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SALES_LIBRARY/ssd/s8664_series_kapd1012e.pdf

Locator: p.1 table, conditions Ta=25 °C.

Access: Official manufacturer datasheet.

Applicability limits: The 420 nm figures are not calibrated 337 or 777 nm values. Large area trades increased capacitance against collection area; the receiver amplifier must be evaluated with that capacitance. Catalog availability does not imply flight qualification.

[S059] The SiSMUV Project: Development and Characterization of SiPM-Based UV-Light Detectors for Space Telescope Applications

OriginalURL: <https://inspirehep.net/files/475a891bf3046a48d47231575224af93>

DOI: [10.3390/particles8040092](https://doi.org/10.3390/particles8040092)

Locator: sections 3-4 and 6; printed pp.3-5, 8.

Access: Primary open journal PDF; 27 November 2025

Conditions/scope: S13361-3050-NE-08 8 x 8 array, 3 x 3 mm per tile, 50 micrometre cells; RADIOROC/Artix7 prototype 405 nm laser, 25 plus/minus 1 C, 55.2 V representative bias

Applicability limits: 405 nm response is not measured 337 nm response. Quoted reproducibility is not a full absolute uncertainty budget.

[S060] Resolving the signal: precision ADC signal-chain noise questions

OriginalURL: <https://www.ti.com/document-viewer/lit/html/SSZT554/GUID-5FCFDA62-4CDD-403A-969C-EB377113CA8A>

Locator: questions 4-5, 9-10: ENBW, total chain filtering, output-data-rate and clocks.

Access: Official Texas Instruments technical article SSZT 554, Bryan Lizon, January 2019; full text read.

Applicability limits: The article's 6 nV RMS example uses 2.5 samples/s, not 10-50 kS/s; no such low noise is assumed for this photometer. Nonwhite detector/TIA noise and aliased out-of-band noise require PSD integration through the actual chain. A single bandwidth or nominal bit depth does not determine mission photon threshold.

[S061] Transimpedance Amplifier Noise Considerations

OriginalURL: <https://www.analog.com/en/resources/technical-articles/transimpedance-amplifier-noise-considerations.html>

Locator: Noise in TIAs; Achieving Higher Bandwidth with Higher Gain TIAs; Figures 6-9.

Access: official measured circuit/appnote

Conditions/scope: LTC6268 FET-input amplifier; 499 kohm feedback

Applicability limits: Specific low-capacitance setup; not prooflargearea UV receiver reaches equalnoise. Counterexample disproves a universal $1 \text{ e } 10 \text{ V/A} \cdot \text{Hz}$ limit, not fundamental photonbudget limitations.

[S062] Technical note: Si APD

OriginalURL:

https://hep.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SALES_LIBRARY/ssd/si-apd_kapd9007e.pdf

Locator: section 2-1 p.2; section 2-3 equations 2-2 and 2-3 p.3; section 2-5 p.5.

Access: Official manufacturer technical note, full 10-page PDF.

Applicability limits: Multiplying an already multiplied total dark current by M^2 would overestimate the noise incorrectly. A catalog total dark current alone cannot uniquely partition bulk and surface noise. For fixed measured total dark current, the inferred dark PSD lies between 2 qI_D and 2 qMFI_D under this model, not a single universal value.

[S063] CALIPSO lidar Level 1 B data description and quality summary, version 5

OriginalURL: https://ntrs.nasa.gov/api/citations/20260000651/downloads/cal_lid_l1_V5-00_desc_qs.pdf

DOI: [10.5067/CALIPSO/CALIPSO/CAL_LID_L1_Data_Description_Document_V5](https://doi.org/10.5067/CALIPSO/CALIPSO/CAL_LID_L1_Data_Description_Document_V5)

Locator: Appendix 3, printed pp.62-64; Figures A 3-1 to A 3-3.

Access: Official NASA report, 21 January 2026; Appendix 3 updated 5 October 2025.

Applicability limits: A lidar range tail converts to time using 2 d/c . These observations do not establish a 0.2 ms tail for our detector. The useful requirement is amplitude- and duration-dependent impulse/step characterization: cloud timing and receiver timing cannot be separated by assuming a single universal linear kernel.

[S064] Design of photomultiplier output circuits for optimum amplitude or time response

OriginalURL: https://et-enterprises.com/images/technical_papers/rp065_design_of_PMT_output_circuits.pdf

Locator: section 3, printed page 2; Figure 4; section 5.3.

Access: Official ET Enterprises technical reprint R/P 065 by A.G. Wright

Applicability limits: Legacy example amplifiers and nanosecond scintillation pulses are not our chosen receiver. Actual transfer function, saturation and recovery must be measured over the millisecond pulse and background range.

[S065] DLPCA-200 Variable Gain Low Noise Current Amplifier

OriginalURL: <https://www.femto.de/images/pdf-dokumente/de-dlpca-200.pdf>

Locator: p.1 block diagram; p.2 specifications and measurement footnote.

Access: Official manufacturer 5-page PDF, revision R 19, 2 January 2019; current product listing verified.

Applicability limits: Noise at one frequency must not be multiplied by square root of 50 kHz and substituted for the measured integrated figure. Detector capacitance adds voltage-noise current. Bench hardware is not flight qualified; this is a counterexample to the claimed universal gain-bandwidth bound.

[S066] The Modular Multispectral Imaging Array (MMIA) of the ASIM payload

OriginalURL: https://backend.orbit.dtu.dk/ws/files/175725338/The_Modular_Multi.pdf

DOI: [10.1007/s11214-019-0593-y](https://doi.org/10.1007/s11214-019-0593-y)

Locator: section 3.3, printed pp.9-11 and Table 5; section 4.1 p.12.

Access: Primary published author-hosted full manuscript.

Applicability limits: The 250 nm internal check does not establish absolute drift of the whole 337 or 777 nm optical path. Heritage proves an architecture, not the performance of a 25 mm entrance aperture within the same volume and power. Exact PMT part numbers are not published here.

[S067] What the Nyquist criterion means to your sampled data system design

OriginalURL: <https://www.analog.com/media/en/training-seminars/tutorials/MT-002.pdf>

Locator: pp.1, 4-8, Figures 1, 4-7; baseband sampling and antialias filtering.

Access: Official Analog Devices tutorial by Walt Kester; full 12-page PDF, Rev.A 10/08.

Applicability limits: A Nyquist frequency does not specify a practical filter cutoff or its stopband margin. The tutorial's separate bandpass-undersampling examples do not apply directly to a DC-to-transient photometer. Exact sub-sample parameter inference requires pulse-model, phase, noise and filter assumptions; raw cadence alone does not validate rise-time discrimination.

[S068] A Multiband Optical-Radio View of Lightning Return Strokes Exposes Divergent $337/777 \text{ nm}$ Emission Dynamics

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2026GL123245>

DOI: [10.1029/2026GL123245](https://doi.org/10.1029/2026GL123245)

Locator: sections 2.1-2.2, 3.2; Table 1; Figures 3-5.

Access: Full primary publisher HTML now verified using?af=R after initial timeout. Table 1 and relative calibration methods inspected.

Conditions/scope: Thorlabs APD410A2/M 337 nm; APD410A/M 777 nm; Pico Scope 4824 A Ground lightning near Langmuir Lab; approximately 20 deg FOV; 5 MHz 12-bit digitizer; 2 s records, .6 s pretrigger.

Applicability limits: Does not demonstrate faint orbital threshold, absolute photon-number calibration or flight qualification. Cannot reuse ground extinction above 15 km.

[S069] Transimpedance amplifiers: Reaching high gain, low noise and high bandwidth

OriginalURL: <https://doi.org/10.1016/j.measen.2026.102011>

DOI: [10.1016/j.measen.2026.102011](https://doi.org/10.1016/j.measen.2026.102011)

Locator: sections 2.2, 2.4.1, 3.1.3-3.1.4; Tables 1, 3, 4.

Access: Primary publisher search-index full text plus author institution metadata; direct publisher open returned 403. Published online 24 June 2026, volume 46 August 2026.

Applicability limits: This refutes a universal 1 nA amplifier floor, but gives no 337 nm detector-coupled or radiation-qualified result. Actual sensor/cable capacitance matters. The reported average density is RMS divided by square root of nominal bandwidth, not a measured flat white-noise PSD. Its 250 kHz variant has substantially higher 66.18 pA RMS noise.

[S070] Guidelines for accurate evaluation of photodetectors based on emerging semiconductor technologies

OriginalURL: <https://www.repository.cam.ac.uk/items/d1562912-fd22-492e-bbd1-d4f1474ef69f>

DOI: [10.1038/s41566-025-01759-1](https://doi.org/10.1038/s41566-025-01759-1)

Locator: Noise, NEP/detectivity, temporal response and benchmarking sections.

Access: Peer-reviewed consensus article; accepted manuscript available at Cambridge, repository DOI 10.17863/CAM.122981

Applicability limits: Method guidance is not experimental performance of a candidate flight detector. Responsivity and timing measured at bright illumination cannot automatically establish behavior near the faint-event threshold.

[S071] Ultra-narrowband optical bandpass filters with large format and improved temperature stability

OriginalURL: https://alluxa.com/wp-content/uploads/2014/09/Ultra-narrowband-optical-bandpass-filters-with-large-format-and-improved-temperature-stability_2.pdf

Locator: p.2 f/5 modeled cone; p.3 thermal results.

Access: Primary manufacturer-authored 2014 technical paper, 3 pages.

Applicability limits: Neither thermal coefficient is a measured 337 nm property. The result does not solve a 60-90° full field in a compact receiver. Environmental cycling and hard coatings do not by themselves establish radiation, contamination, or vacuum qualification.

[S072] 337-1.5 OD 6 Ultra Narrow Bandpass Filter, SKU 7021

OriginalURL: <https://alluxa.com/optical-filter-catalog/ultra-narrow-bandpass/337-1-1-5-od6-ultra-narrow-bandpass/>

Locator: product specifications table.

Access: Official current catalog, 12.5 mm product; page specifications verified.

Applicability limits: The OD 6 product name does not guarantee visible/NIR blocking. Leakage must be integrated over the detector response, especially for silicon. The 25 mm page did not expose a complete primary specification during this review; secondary reseller values were not transferred. No space qualification follows from the catalog.

[S073] Focal plane optics in far-infrared and submillimeter astronomy

OriginalURL: <https://ntrs.nasa.gov/api/citations/19860004735/downloads/19860004735.pdf>

Locator: printedpp 5-7; equation 1; section 3.

Access: open NASA technicalreport

Applicability limits: The geometrical-optics relation is transferable; the far-infrared materials, bolometer performance and diffraction numbers are not. Finite filter cones and detector acceptance constrain practical ultraviolet throughput.

[S074] Laboratory Calibration of the Optical Transient Detector and the Lightning Imaging Sensor

OriginalURL: https://ghrc.nsstc.nasa.gov/pub/doc/preservation/lis/documents/lis-otd/calibration_data/LabCalofOTDandLIS.pdf

DOI: [10.1175/1520-0426\(2000\)017<0905:LCOTOT>2.0.CO;2](https://doi.org/10.1175/1520-0426(2000)017<0905:LCOTOT>2.0.CO;2)

Locator: printed pp.908-910, sections 4-5; p.912 discussion.

Access: Primary journal article preserved by NASA GHRC

Applicability limits: These are 777 nm imager results, not a ready 4 nm 337 nm Cube Sat design. Passband measurements excluded OOB regions, whose verification was separate vendor testing.

[S075] NIST oxygen persistent lines and wavelength convention

OriginalURL: https://physics.nist.gov/PhysRefData/Handbook/Tables/oxygentable3_a.htm

Locator: O I 7771.94, 7774.17, 7775.39 Å rows; Handbook section A Wavelengths.

Access: Official NIST tables and handbook wavelength convention; full table inspected.

Applicability limits: Source spectra, solar standards, monochromator calibration and filter specification must use a declared common convention. An air-vacuum coordinate conversion is separate from an actual coating passband change when changing ambient pressure. Both require metadata.

[S076] Atomic oxygen photometric temperature of lightning and its sub-processes with SOPAPILLA

OriginalURL: <https://www.nature.com/articles/s41598-025-34189-8>

DOI: [10.1038/s41598-025-34189-8](https://doi.org/10.1038/s41598-025-34189-8)

Locator: Methods: Instruments, Data analysis; Figure 6.

Access: open publisher fulltext

Conditions/scope: PDA100A2 photodiodes; 20 dB gain Ground NIR channels 777/844/926 nm 1 nm filters; 812 nm 10 nm continuum; 20 deg FOV; 800 kHz sampling.

Applicability limits: NIR bright-light conditions do not validate faint 337 nm receiver. Authors average blocking 1 e⁻⁴ from Xray to far IR lacks a source-specific measured blocking curve; do not use as verified optical-density requirement.

[S077] Ice Cube sensitivity for low-energy neutrinos from nearby supernovae

OriginalURL: <https://arxiv.org/pdf/1108.0171>

DOI: [10.1051/0004-6361/201117810](https://doi.org/10.1051/0004-6361/201117810)

Locator: section 3.2, PDF pp.5-6; Figures 2-3.

Access: Primary author manuscript v 2, September 2011; section 3.2 and figures inspected. PDF rendering shows a later automatic 2018 header.

Applicability limits: This is a cold underwater/ice assembly, not a satellite rate prediction or proof that our fused-silica filter will behave identically. It demonstrates that millisecond internal light bursts are physically possible; a >3 ms duration criterion alone is not a universal particle/noise veto. Copying the dead-time cure would impair this mission's rise-time measurement.

[S078] Application of neural networks to classification of data of the TUS orbital telescope

OriginalURL: <https://arxiv.org/pdf/2106.03361>

Locator: section 2 pp.3-4; section 3.1 pp.5-8.

Access: Primary author manuscript v 2, 1 July 2021, full PDF.

Applicability limits: Trigger fractions are selected acquisition statistics, not a transferable probability for this photometer. A UV-chain-only artifact need not appear in a red null channel. The separate first-day high-voltage/daylight fault damaged 51 channels; it must not be presented as cumulative radiation degradation.

[S079] Mitigating radiation damage of single photon detectors for space applications

OriginalURL: <https://link.springer.com/article/10.1140/epjqt/s40507-017-0062-z>

DOI: [10.1140/epjqt/s40507-017-0062-z](https://doi.org/10.1140/epjqt/s40507-017-0062-z)

Locator: sections 2.1-2.2, 3, 4.1-4.2; Figures 3, 5-7; Table 2.

Access: Primary published open-access full text verified.

Applicability limits: Specific bench samples and 780 nm characterization do not predict 337 nm sensitivity or this 550 km mission. PMT sample statistics were small and unaged, with a suspect outlier; no detector-class radiation ranking follows.

[S080] Repeated radiation damage and thermal annealing of avalanche photodiodes

OriginalURL: <https://link.springer.com/article/10.1140/epjqt/s40507-021-00103-0>

DOI: [10.1140/epjqt/s40507-021-00103-0](https://doi.org/10.1140/epjqt/s40507-021-00103-0)

Locator: sections 2-4; Figures 3-7; Appendix annealing time.

Access: Primary open-access full text verified; raw datasets available only on author request, which was not made.

Applicability limits: The stated orbital years assume 600 km and 10 mm Al; this is accelerated bench evidence, not flight validation. Conditional versus periodic differences may include small-sample variation. A 2 kcps maintenance threshold chosen for QKD is not a photometer threshold.

[S081] Characterization of more than three years of in-orbit radiation damage of SiPM s on GRBA lpha and VZLUSAT-2 Cube Sats

OriginalURL: <https://arxiv.org/html/2411.00607v2>

DOI: [10.1016/j.nima.2025.170513](https://doi.org/10.1016/j.nima.2025.170513)

Locator: sections 3.1, 3.2, 4.1, 4.2; Figures 9, 11-16; equations 2, 5.

Access: open author manuscript; complete methods inspected

Conditions/scope: Hamamatsu S13360-3050 PE; 4 parallel/channel, 8 total Initial 550 km and 535 km sun-synchronous orbits; 2-2.5 mm PbSb shield; evolving orbit and temperature; 10 us shaping, 15 us processing.

Applicability limits: Reported DCR is not intrinsic primary avalanche DCR. AP8 flux uncertainty factor two; detailed shielding matters.

[S082] In-orbit radiation damage characterization of SiPM s in the GRID-02 Cube Sat detector

OriginalURL: <https://arxiv.org/html/2205.10506v2>

DOI: [10.1016/j.nima.2022.167510](https://doi.org/10.1016/j.nima.2022.167510)

Locator: sections 3, 4; equations 2, 6; device/current figures.

Access: open author manuscript; methods and measured slopes inspected

Conditions/scope: Micro FJ-60035-TSV; 16 parallel/channel, four channels 457×467 km, 97.2 deg; 28.5 V fixed bias; current normalized 5 C; no active cooling.

Applicability limits: Flight altitude is lower than 550 km. Scintillator ke V noise cannot directly become 337 nm optical NEP.

[S083] Comparing a radiation damage model for avalanche photodiodes through in-situ observation of Cube Sat based devices

OriginalURL: <https://www.nature.com/articles/s42005-025-02042-z>

DOI: [10.1038/s42005-025-02042-z](https://doi.org/10.1038/s42005-025-02042-z)

Locator: Methods: Radiation effects on GM-APDs; Results Figs.6-7; Data availability.

Access: Open primary journal article

Conditions/scope: Two SAP500 GM-APDs; free-running passive quench with feedback maintaining excess bias Spoo Qy-1, 51.6 degree inclination, altitude 418 to 378 km during 600 days; DCR comparison normalized to 10 C

Applicability limits: Part-to-part variation and anisotropic geometry prevent transferring a universal growth coefficient to a fixed 550 km polar orbit. Underlying data and code are available on request, not public.

[S084] Total Ionizing Dose Effects on CMOS Image Sensor for the ULTRASAT Space Mission

OriginalURL: <https://arxiv.org/html/2306.15307v1>

Locator: sections 2-5; Figures 2-4.

Access: open author manuscript, NIMA 1054(2023)168463

Conditions/scope: Tower 180 nm 4 Tteststructures similar tofinal CIS Co 60 HZB/CERN; maximumapplicablebias; roomtemperature; measurements up 2 monthsafterirradiation.

Applicability limits: These are test structures, not a final flight device; nominal 300 s exposures differ greatly from a 20 us transient sample. Dark-current random telegraph signals and prompt charge hits require separate treatment. Reported dwell times range from microseconds to weeks.

[S085] SG01D-18S silicon carbide UV photodiode datasheet

OriginalURL: <https://sglux.de/download/photodiodes/SG01D-18S.pdf>

Locator: specification table; spectral-response curve.

Access: Official manufacturer datasheet; revision 7.0

Conditions/scope: sglux SG01D-18S, 0.50 square millimetre SiC photodiode Dark current at 25 C, 1 V reverse bias; peak responsivity at 280 nm

Applicability limits: Peak responsivity must not be applied at 337 nm. No internal multiplication; capacitance and front-end voltage noise remain relevant.

[S086] 9111B series data sheet, Issue 9, 25 January 2016

OriginalURL: https://et-enterprises.com/images/data_sheets/9111B.pdf

Locator: p 1 window/spectral/active-area tables; p 2 ordering and flying-lead drawing.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

[S087] 9113B series data sheet, Issue 7, 7 May 2015

OriginalURL: https://et-enterprises.com/images/data_sheets/9113B.pdf

Locator: p 1 characteristics/window table; p 2 ordering information and 9113FLB drawing.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

[S088] HV2520CN series data sheet

OriginalURL: https://et-enterprises.com/images/data_sheets/HV2520CN.pdf

Locator: p 1 description and schematic; p 2 mating/ordering information.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

[S089] ET Enterprises: Precautions

OriginalURL: <https://et-enterprises.com/support/precautions>

Locator: Photomultiplier Envelope; General Operation; Sockets and Overcaps.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

[S090] Excelitas Canada operations, Vaudreuil-Dorion

OriginalURL: <https://prod.excelitas.com/location/montreal-qc-canada-operations>

Locator: Facility description: silicon and III-V sensors/emitters.

Access: web tool full text, 2026-10-22

[S091] First Sensor APD arrays official selector

OriginalURL: <https://www.first-sensor.com/en/produkte/optische-sensoren/detektoren/avalanche-photodioden-arrays-apd-arrays/>

Locator: Multi-Element Arrays table, order 3005259 and 3001411; evaluation board table.

Access: web tool full text, 2026-10-22

[S092] ESA ESCC Process Capability Approval List entry for First Sensor Lewicki

OriginalURL: <https://escies.org/download/webDocumentFile?id=70759>

Locator: ESCC/RP/HP/PCAL 008 Issue 15, printed pp 24-25, §5.3.2.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

[S093] LASER COMPONENTS Detector Group manufacturing location

OriginalURL: <https://www.lasercomponents.com/en/company/about-us/laser-components-group/laser-components-detector-group/>

Locator: Chandler, Arizona detector manufacturing description.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

[S094] SUR-Series UV-enhanced Silicon Avalanche Photodiode, V 09, 01/20

OriginalURL: https://www.lasercomponents.com/fileadmin/user_upload/home/Datasheets/lc-apd/sur-series.pdf

Locator: p 1 package/active size; p 3 electrical characteristics; p 5 ordering; p 7 cooled versions.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

Conditions/scope: Marked PRELIMINARY throughout; this is the file linked by the current selector, not proof of current guaranteed production acceptance limits

[S095] Photek Photomultiplier Tube DS 006 Rev 05 Oct 21

OriginalURL: <https://www.photek.com/wp-content/uploads/2021/10/PH-DS006-PhotomultiplierTube-Rev05-Oct21.pdf>

Locator: pp 1-2 detector options/QE curves; p 5 environmental testing and ordering table; p 6 UK address.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

[S096] Tandon et al., In-orbit Performance of UVIT and First Results, public author manuscript

OriginalURL: <https://arxiv.org/pdf/1612.00612>

DOI: [10.1007/s12036-017-9445-x](https://doi.org/10.1007/s12036-017-9445-x)

Locator: printed pp 3, 5-6 §2.2; p 11 §3.3; pp 13-14 first VIS images.

Access: Public supplier/reference document, scope qualified by the linked audit; no unrecorded full-text access claimed.

Conditions/scope: Public arXiv 1612.00612 manuscript, posted 2 December 2016; not asserted identical to the 2017 version of record

[S097] Luque et al.2020: Modeling lightning observations from space-based platforms(CloudScat.jl 1.0)

OriginalURL: <https://gmd.copernicus.org/articles/13/5549/2020/>

DOI: [10.5194/gmd-13-5549-2020](https://doi.org/10.5194/gmd-13-5549-2020)

Locator: Sections 2-4: Monte Carlo cloud source/observer implementation and applications.

Access: Open primary article; source/model methods inspected in project and official article reopened 22 October 2026

Rights/access: Article CC BY 4.0. No third-party restricted raw observations reproduced.

[S098] Latitude dependence of narrow bipolar pulse emissions; author dissertation count audit

OriginalURL: <https://www.sciencedirect.com/science/article/abs/pii/S136468261500053X>

DOI: [10.1016/j.jastp.2015.03.005](https://doi.org/10.1016/j.jastp.2015.03.005)

Locator: Ahmad 2014 thesis section 3.3 printedp 43; Ahmad 2015 abstract; Thesispp 43, 46-48; 2015 abstract.

Access: 2015 publisher abstract and snippets; full 2014 Uppsala author dissertation downloaded

[S099] AIRFLY measured pressure, temperature and absolute 337 nm high-energy fluorescence yield

OriginalURL: <https://arxiv.org/abs/1210.6734>

DOI: [10.1016/j.astropartphys.2012.12.006](https://doi.org/10.1016/j.astropartphys.2012.12.006)

Locator: AIRFLY 2013 absolute result; AIRFLY 2007 pressurepaper; AIRFLY 2008 Table 1 and Eq 1-3.

Access: Three openauthor PDFs downloaded, text extracted, SHA 256 saved in emission_kinetics/retrieval.json

Applicability limits: The 216.65 K case is an extrapolation, not a measured flight cloud profile or source electron-energy distribution. A nanosecond excited-state lifetime cannot constrain a continually re-excited source to a nanosecond optical duration.

[S100] Height Determination of a Blue Discharge Observed by ASIM/MMIA on the International Space Station

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022JD037460>

DOI: [10.1029/2022JD037460](https://doi.org/10.1029/2022JD037460)

Locator: Publicfig 5.fig; MATLAB axis YL label properties; fig 5 line 03/02; Section 3 and Figure 3; Section 6 and Supplement Figure S1; Author Figure 5 arrays; analyze_bath_waveform.py.

Access: Public 95.1 MB ZIP inspected by HTTPR ange; selected MATLAB figures retrieved with ZIPCRC checks. Full paper inspected. Numeric figure arrays decoded without executing MATLAB.

[S101] Ordinary/mixed optical-radio context in public BATH-01103 Figure 4

OriginalURL: <https://researchdata.bath.ac.uk/1103/>

DOI: [10.1029/2022JD037460](https://doi.org/10.1029/2022JD037460)

Locator: Published Figure 4 numeric axes andlineobjects.

Access: Selected MATLAB figure entry retrieved by HTTPR ange, ZIPCRC/SHA 256 verified; boundedparser readsnumericdata without executing MATLAB objects

Applicability limits: A useful replay fixture, with no classifier confusion matrix or population completeness.

[S102] Group Data and Detection Efficiency Analysis for the Modular Multispectral Imaging Array

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2025JD045209>

DOI: [10.1029/2025JD045209](https://doi.org/10.1029/2025JD045209)

Locator: Abstract; pbitzer/mmia_groupingv 0.1.1 grouping.pyfind_clusters.

Access: Publisher/full redirects toabstract; abstract anddata statement verified, full methods not obtained. Public source tagv 0.1.1 inspected statically, not executed.

[S103] Global Distribution and Spectral Features of Intense Lightning by the ISUAL Experiment

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022JD036473>

DOI: [10.1029/2022JD036473](https://doi.org/10.1029/2022JD036473)

Locator: Independentparsers ofpublishedcatalogue; matchesall 6 publishedmarginalsexactly; audit_chuang 2022_catalog.py.

Access: Full primary HTML; 18, 338, 400 byte CCBY catalogue retrieved with exact supplied MD 5 verification

Applicability limits: Selected intense limb lightning; changing high voltage and response; fixed 22:30-23:20 local time; assumed 10 km geolocation height. The SP5 band near 774-785 nm differs from the proposed 4 nm filter; no matched photon-threshold comparison is

established.

[S104] Measurement of the electric field distribution in streamer discharges

OriginalURL: <https://pure.tue.nl/ws/portalfiles/portal/350964030/PhysRevResearch.7.013051.pdf>

DOI: [10.1103/PhysRevResearch.7.013051](https://doi.org/10.1103/PhysRevResearch.7.013051)

Locator: Laboratory streamer electric-field method and 70 mbar profiles; optical curves normalized, not an absolute 337 nm-current calibration..

Access: Complete primary main paper; supplemental access failed

[S105] JUICE-MAJIS Earth-flyby lightning spectra

OriginalURL: <https://angeo.copernicus.org/articles/44/435/2026/>

DOI: [10.5194/angeo-44-435-2026](https://doi.org/10.5194/angeo-44-435-2026)

Locator: Instrument/resultssections; Spectralresultfigure/text.

Access: Fullopenprimary HTML

Applicability limits: The stated raw MAJIS data access remains proprietary until about six months after the 2029 EGA3 encounter; no archive spectra were downloaded. No 337/777 ratio, intrinsic line width, source-current calibration or mission population inference follows.

[S106] Blue Flashes as Counterparts to Narrow Bipolar Events: The Optical Signal of Shallow In-Cloud Discharges

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021JD035013>

DOI: [10.1029/2021JD035013](https://doi.org/10.1029/2021JD035013)

Locator: Table 1.

Access: Full publisher HTML inspected; numerical Table 1 retained as published

Applicability limits: Overlaps Liu Nature 2021 twelveeventstudy and 2025 elves subset; do not add counts as independent samples. Shows source population not universally >3 ms. No completeness.

[S107] Multi-Pulse Corona Discharges in Thunderclouds Observed in Optical and Radio Bands

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022GL098938>

DOI: [10.1029/2022GL098938](https://doi.org/10.1029/2022GL098938)

Locator: Section 3.

Access: Full text accessible via publisher web reader; PMC frontpage presented browser challenge

[S108] Night, cloud shadow and spacecraft eclipse are different conditions

OriginalURL: https://gssc.esa.int/navipedia/index.php/Satellite_Eclipses

Locator: audit_night_selection.py.

Access: Primary ESA technical equation plus NASA source and GOLD twilight paper

[S109] Remote Sensing of Source Currents of Narrow Bipolar Events Using Measured Electric Fields

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2023GL107789>

DOI: [10.1029/2023GL107789](https://doi.org/10.1029/2023GL107789)

Locator: Sections 2.2 and 3, equations 7-10; Section 3 Figure 3; Erratum, corrected 29 March 2025.

Access: Full publisher HTML, including March 2025 erratum, inspected. Public code/data DOI 10.26208/xtw 7-zk 59 metadata retrieved; actual archive files not retrieved.

Applicability limits: Forward reproduction demonstrates consistency within the assumed source model, not uniqueness across geometries or current profiles. The paper explicitly says deconvolution non-uniqueness is not addressed. No optical/current calibration or new 337 nm measurements.

[S110] Global Distribution of Key Features of Streamer Corona Discharges in Thunderclouds

OriginalURL: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022JD037535>

DOI: [10.1029/2022JD037535](https://doi.org/10.1029/2022JD037535)

Locator: Figure 5 caption; Figure 6 caption; Table 1; Section 4 paragraph after Figure 6; concluding paragraph; Section 3, Table 1; Figure 10 caption.

Access: Full text accessible through web reader; publisher shell GET previously 403; author-repository PDF also located but not downloaded

[S111] HYGEOS public bulk-ice GHM optical-property table and SMART-G reader

OriginalURL: https://docs.hygeos.com/public.php/webdav/ic_baum_ghm_sol.nc

Locator: Native 330/340 nm, 10 micrometre effective-radius scalar P 11 slice; 594 angle nodes; verified extraction from full Net CDF..

Access: Public model file retrieved and private subset verified against full Net CDF; new revision used retained optical-model input.

Conditions/scope: Scalar phase, linear wavelength interpolation and assumed SSA 1. These are modeled bulk ice properties, not a measured anvil.

Applicability limits: No native phase-grid/habit convergence or actual event validation. Warren-Brandt ultraviolet imaginary-index upper-limit assumptions do not establish real ice/impurity absorption.

Rights/access: Raw full LUT and private subset are not redistributed by these PDFs. Original provider link and derived model diagnostics only.

[S112] Physically Based Rendering, 4 th edition: Diffuse Reflection

OriginalURL: https://www.pbr-book.org/4ed/Reflection_Models/Diffuse_Reflection

Locator: Lambertian reflection model and radiance/irradiance normalization..

Access: Official author-published technical reference used for the ideal reflection law.

Conditions/scope: BRDF= ρ/π ; own finite-FOV/delay integration in this study.

Applicability limits: A real cloud BRDF and internal residence time are not measured by this surface law.

Rights/access: Original technical reference linked; own derived integrals only.

[S113] Sci Py official Poisson distribution API

OriginalURL: <https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.poisson.html>

Locator: Methods sf/logs; Notes PMF.

Access: Official numerical API documentation checked by the statistical study; software versions retained in its receipt.

Conditions/scope: Numerical implementation documentation; web manual 1.18.0, installed library 1.18.1.

Applicability limits: Implementation documentation is not an independent experiment or instrument validation.

Rights/access: Documentation linked; generated statistical results and own derivations only.

[S114] Sci Py official binomial distribution API

OriginalURL: <https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.binom.html>

Locator: Methods sf; Notes binomial PMF.

Access: Official numerical API documentation checked by the statistical study; software versions retained in its receipt.

Conditions/scope: On/off conditional test implementation.

Applicability limits: Implementation documentation is not an independent experiment or instrument validation.

Rights/access: Documentation linked; generated statistical results and own derivations only.

[S115] Sci Py official chi-square distribution API

OriginalURL: <https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.chi2.html>

Locator: Methods ppf/isf.

Access: Official numerical API documentation checked by the statistical study; software versions retained in its receipt.

Conditions/scope: Poisson interval inversion.

Applicability limits: Implementation documentation is not an independent experiment or instrument validation.

Rights/access: Documentation linked; generated statistical results and own derivations only.

[S116] Num Py official Generator.poisson API

OriginalURL: <https://numpy.org/doc/stable/reference/random/generated/numpy.random.Generator.poisson.html>

Locator: Generator.poisson; Notes PMF.

Access: Official numerical API documentation checked by the statistical study; software versions retained in its receipt.

Conditions/scope: Synthetic exact Poisson variate generator; current web manual differs from installed 2.3.5.

Applicability limits: Implementation documentation is not an independent experiment or instrument validation.

Rights/access: Documentation linked; generated statistical results and own derivations only.