



CIRCE

Coordinated Ionospheric Reconstruction CubeSat Experiment

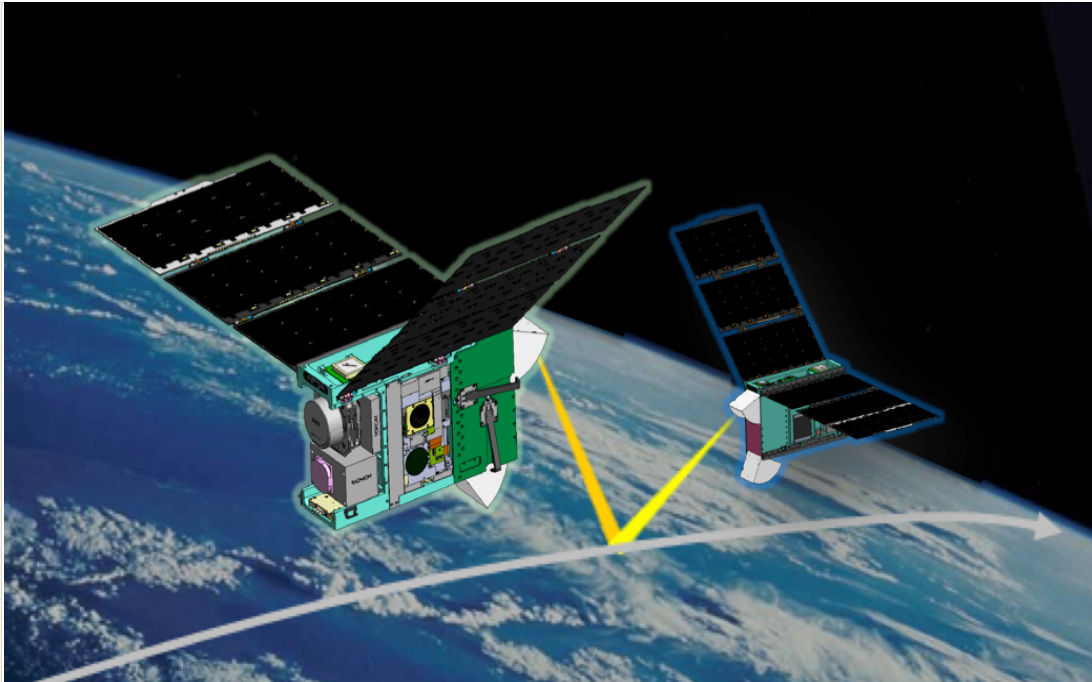
Tri-TIP Optical Calibration

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Bruce Fritz is an NRC Postdoctoral Research Associate at the
U.S. Naval Research Laboratory (NRL)
This work was supported by the Chief of Naval Research.

CIRCE – Mission Concept

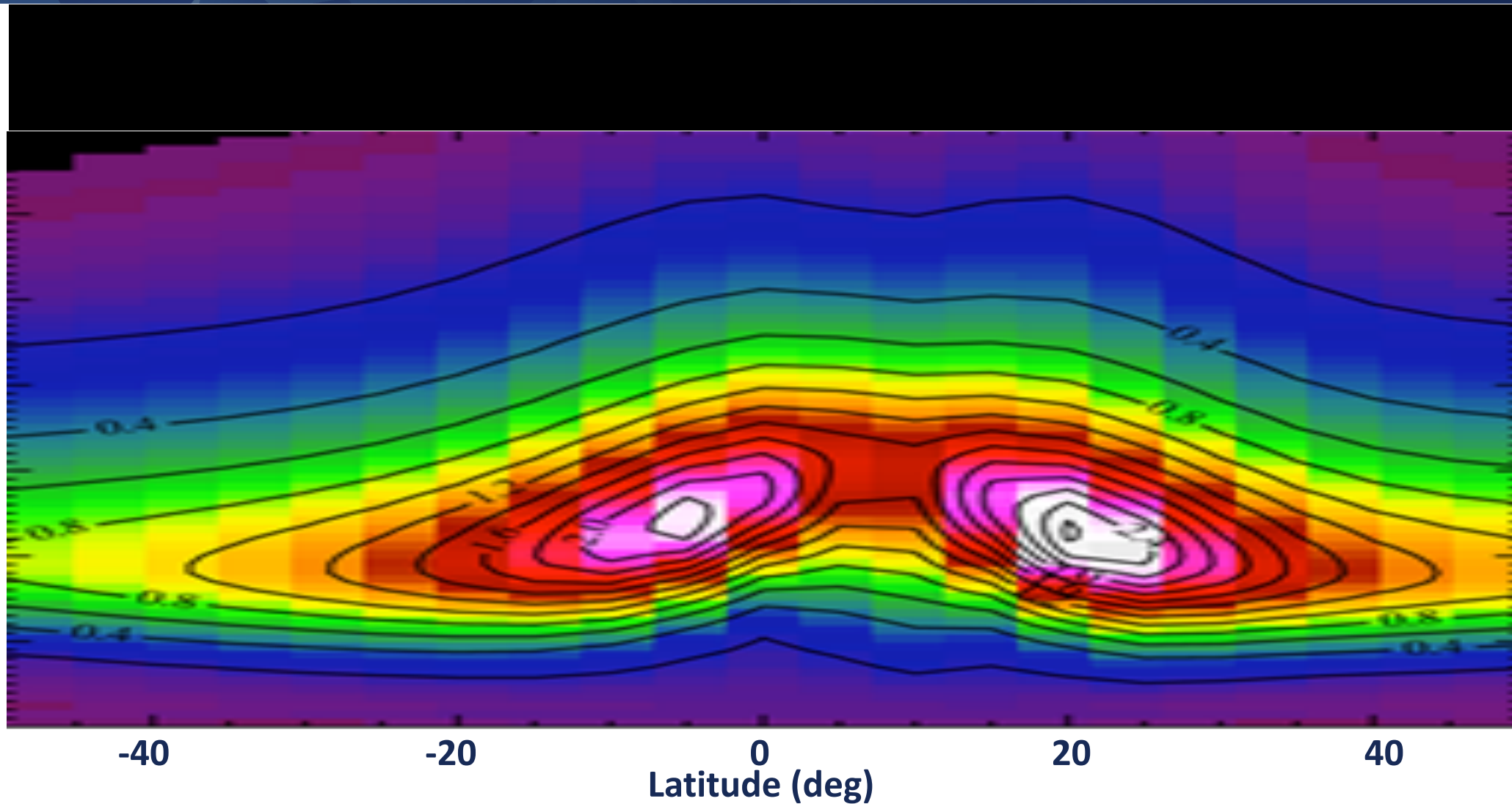
Objective: Provide space-based *tomographic* specification of n_e vs altitude and orbit phase angle derived from ultraviolet (UV) observations of the ionosphere with different viewing angles from multiple CubeSats



Artist conception of CIRCE spacecraft

- ✧ Two 6U CubeSats fly tandem (lead/trail)
 - ✧ 2 Tri-TIP / CubeSat (4 Total)
 - ✧ Coplanar orbit optimized for tomographic reconstruction
- ✧ NRL has heritage from the Tiny Ionospheric Photometer (TIP) on COSMIC & GROUP-C (ISS)

Tri-TIP – Viewing Geometry



Lead

16° down (limb)
17° down (limb)
45° down (wake)

Trail

45° down (ram)
90° down (nadir)

Baseline separation

250 km

***Note this is a very
sparse representation of
the actual FOV for CIRCE

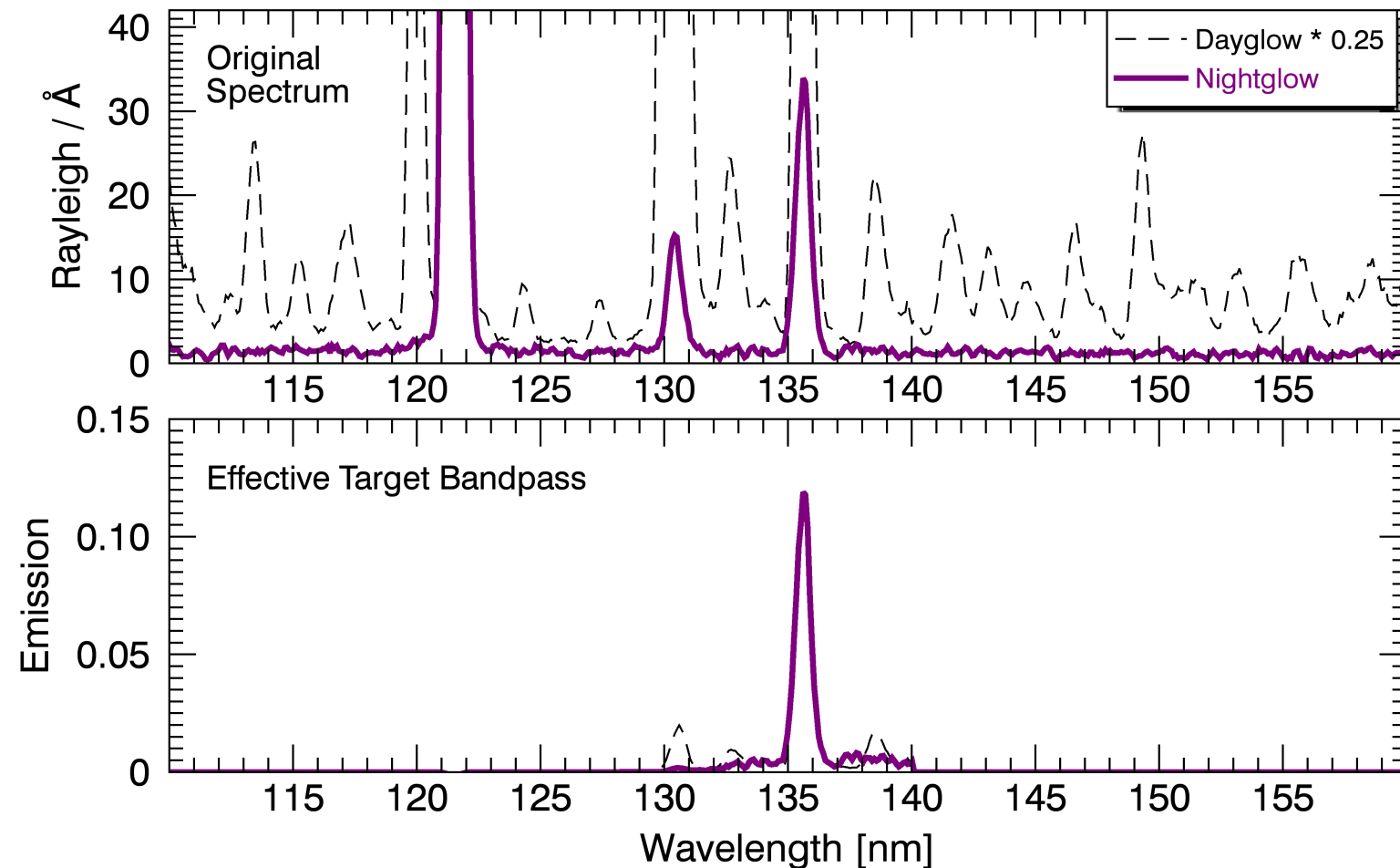
Tri-TIP – Target Measurement

Dayglow spectrum filled
with emission features
(e.g. O, O₂, H, N₂, N)

Nightglow dominated by
only a few species (O, H)

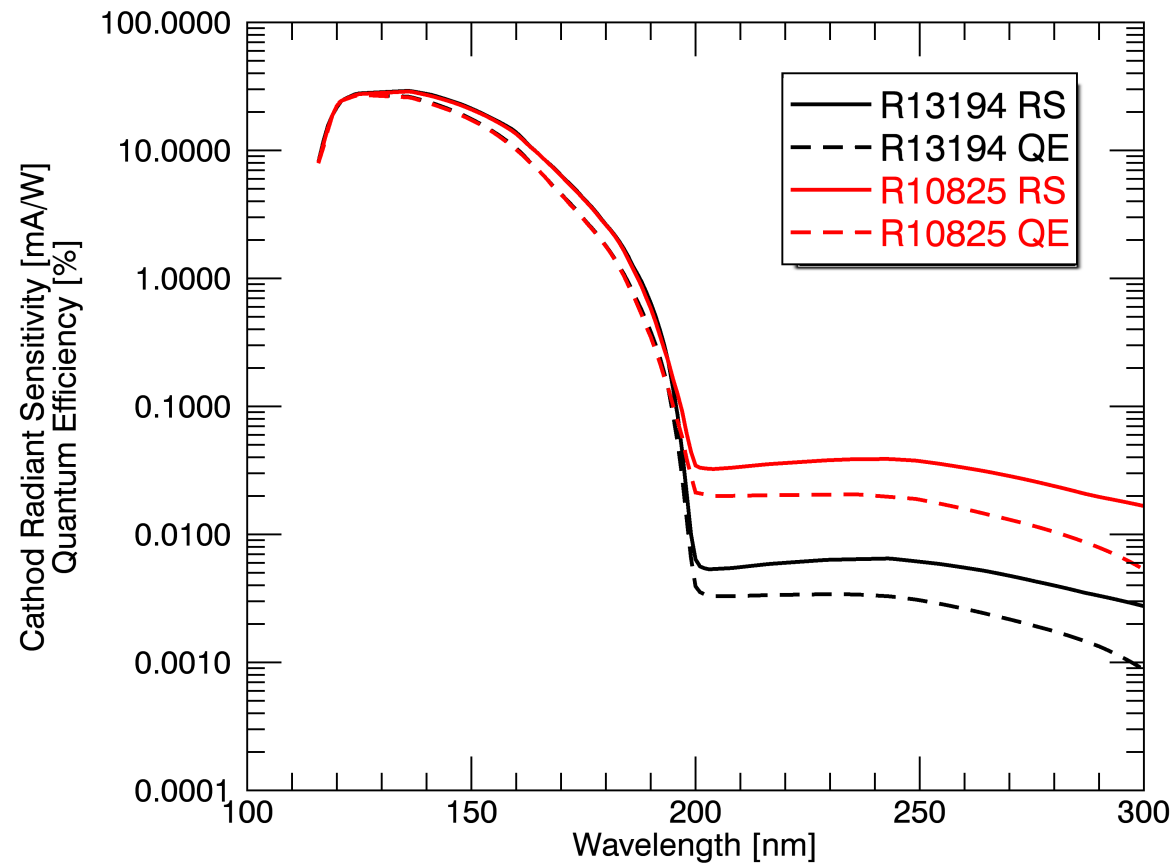
Target measurement is
atomic oxygen

O_I 135.6 nm

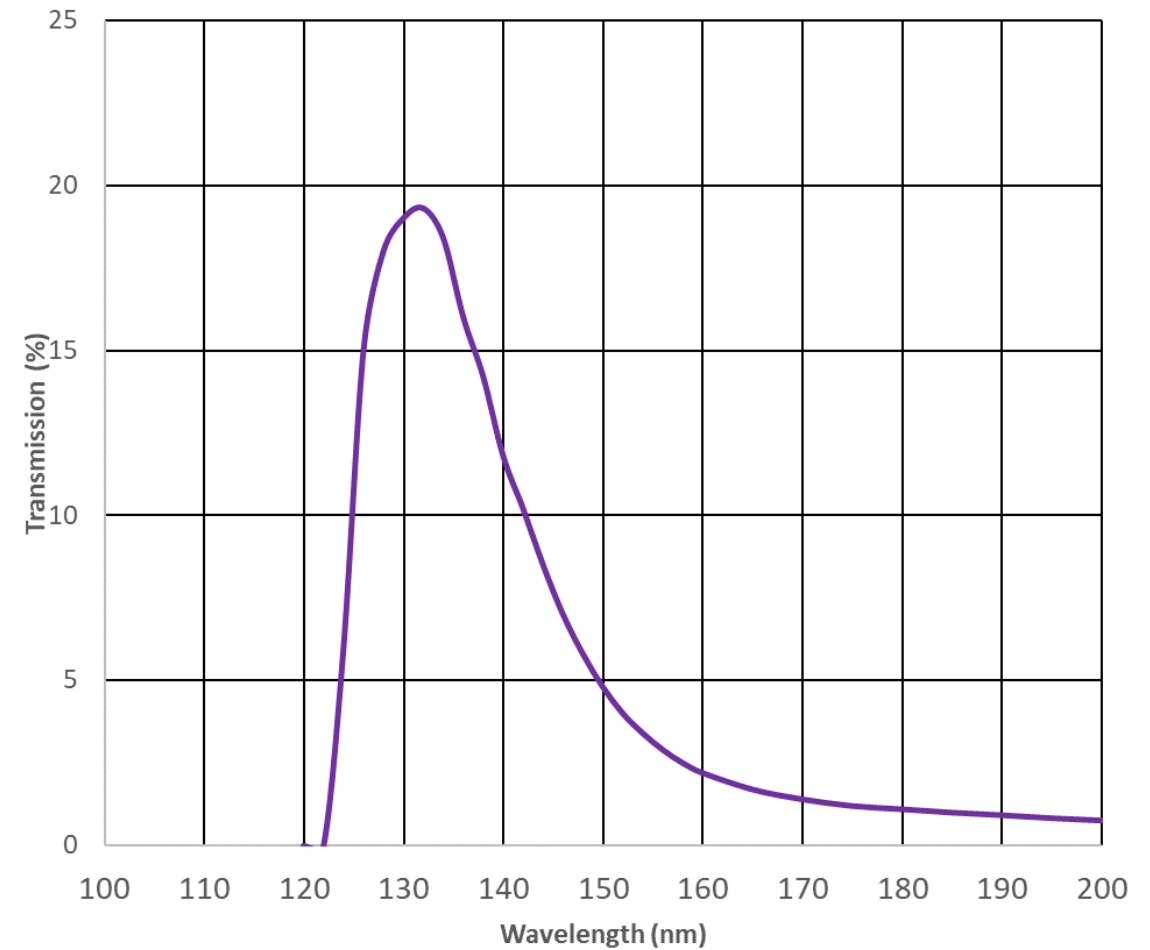


Spectrum taken from UVLIM experiment

Tri-TIP – PMT Passband Challenge



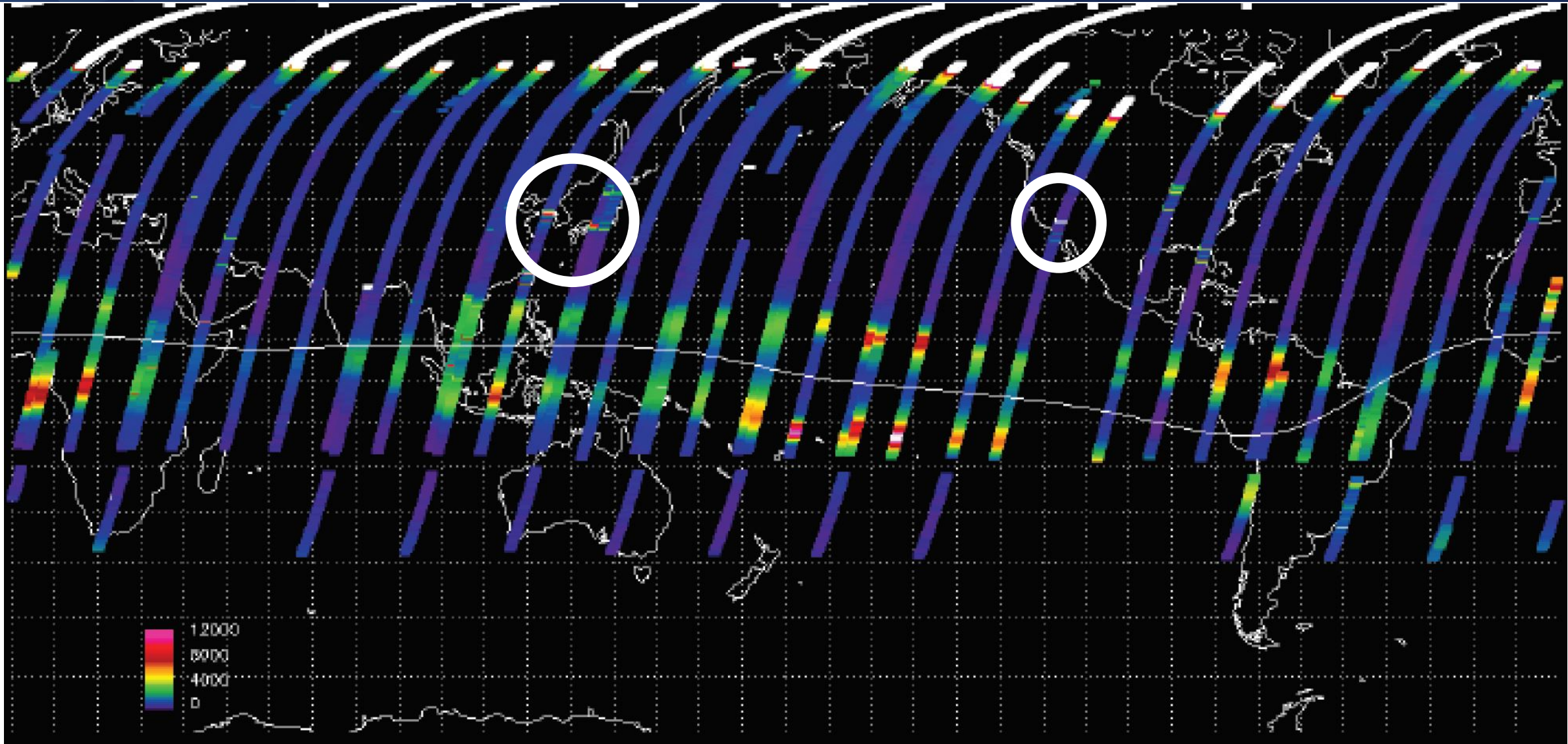
TIP used the Hamamatsu R10825 PMT
Tri-TIP uses the R13194 PMT



Example of a commercial FUV
bandpass filter

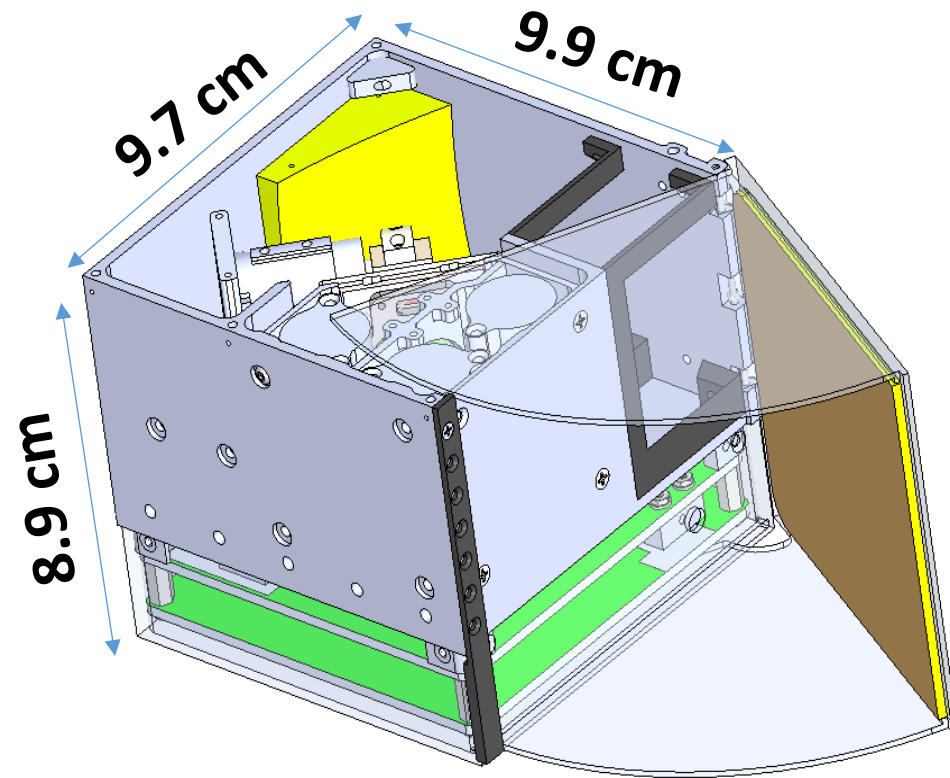
**Excludes Lyman- α (121.6 nm)

Tri-TIP – Red Leak Contamination



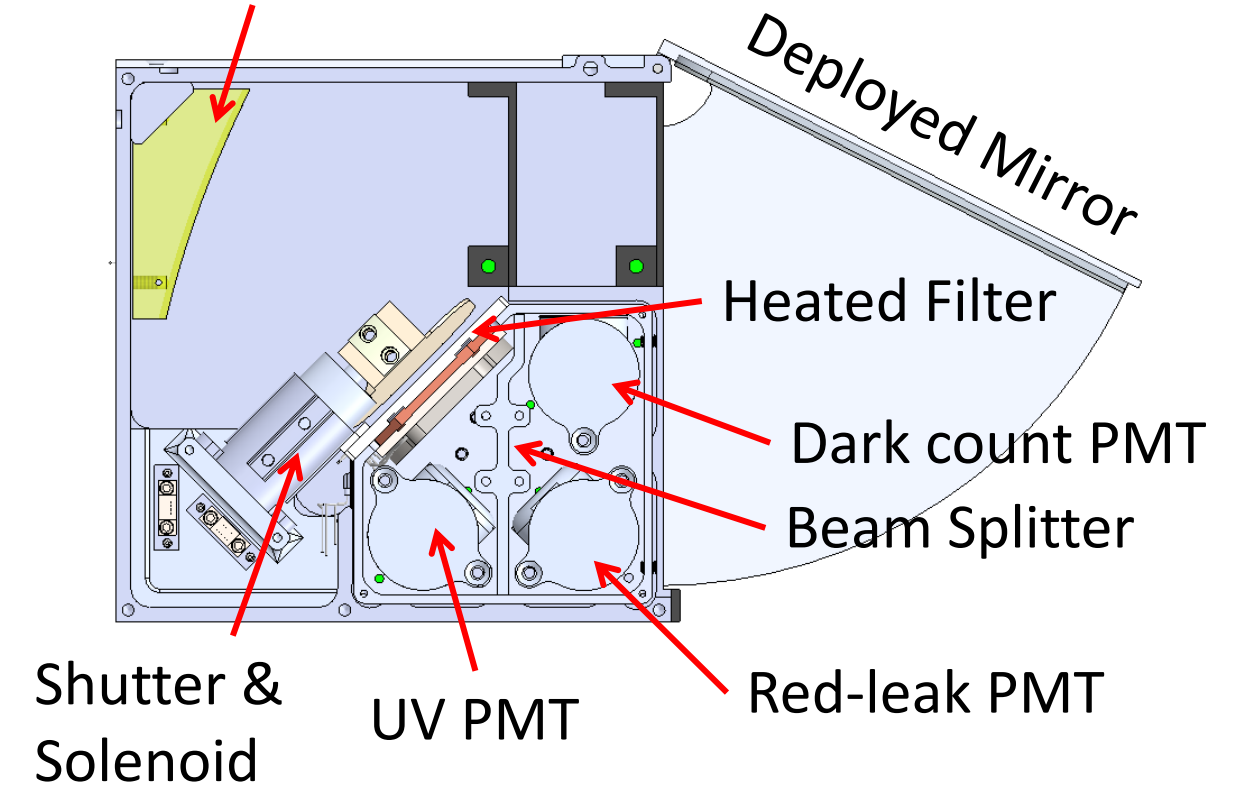
“Solar blind” PMTs see city lights! → Red Leak

Tri-TIP – Mechanical Design



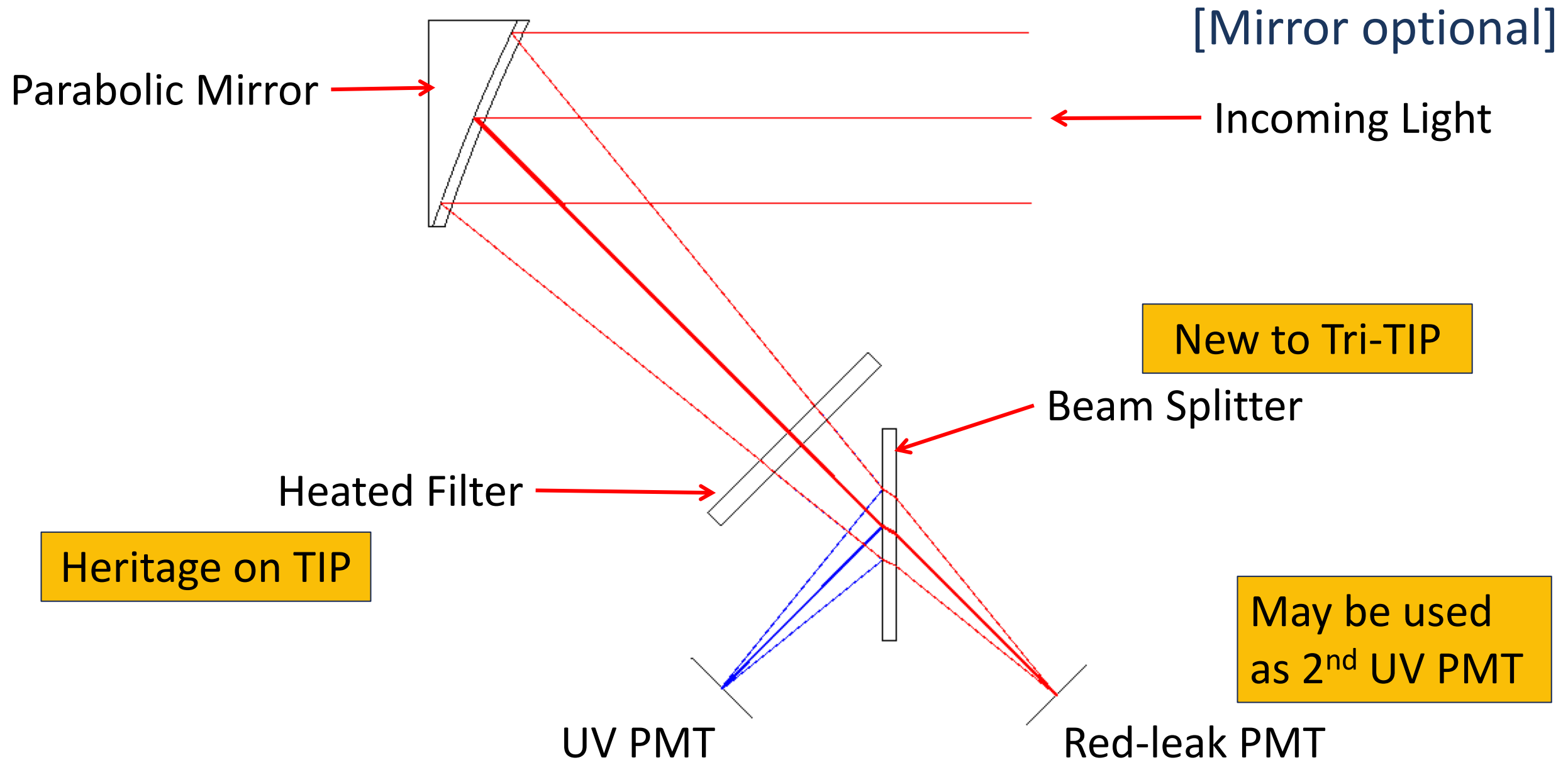
Each Tri-TIP fits within
1U form factor

Parabolic Mirror



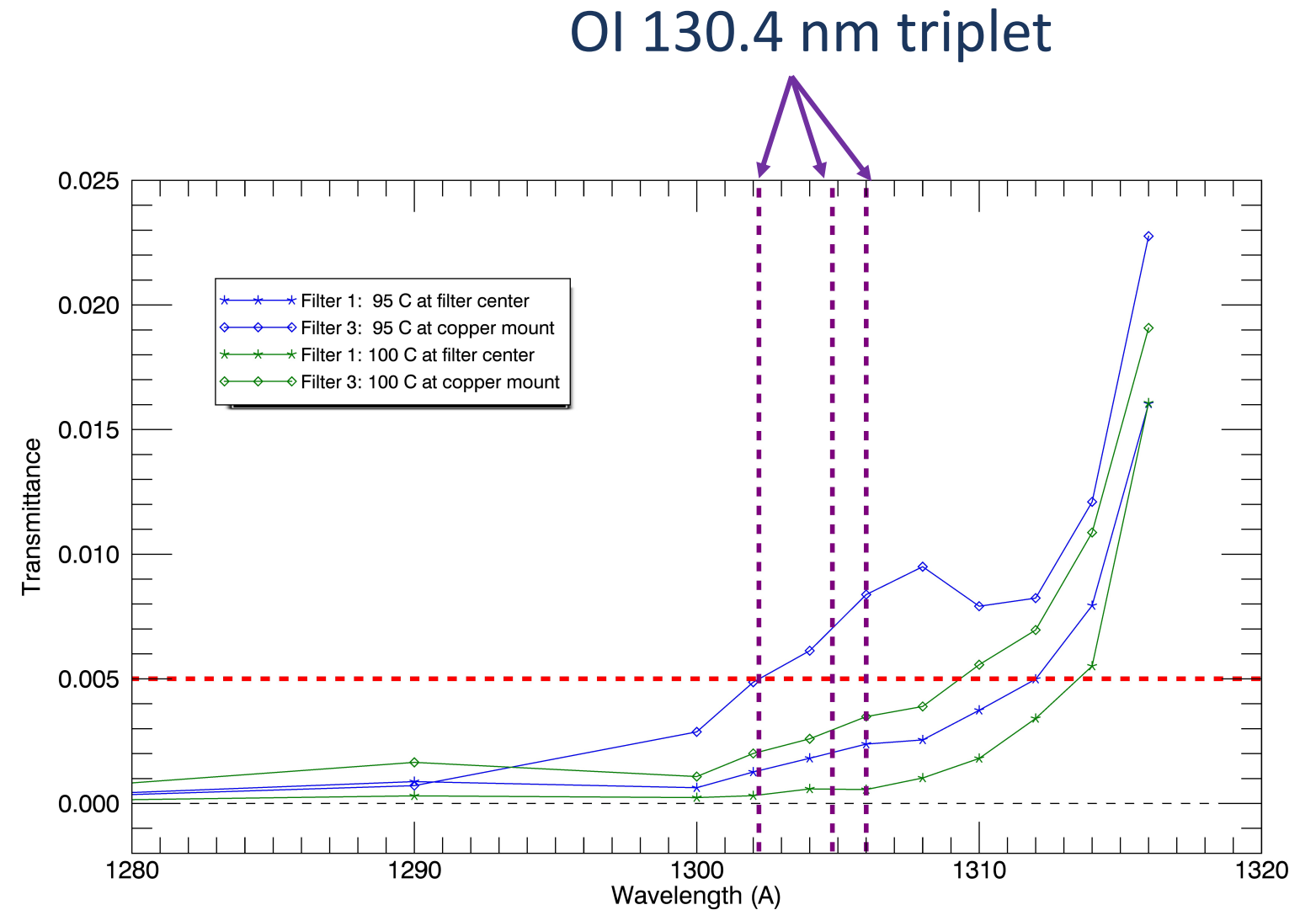
Tri-TIP optical layout

Tri-TIP – Optical Path



Tri-TIP – Heated Filter

- SrF₂ filter substrate
 - Cutoff at ~128 nm (room temperature)
 - Cutoff *shifts* > 131 nm when heated to 100°C
 - Eliminates oxygen triplet at OI 130.4 nm
- Target reduction is 0.5%

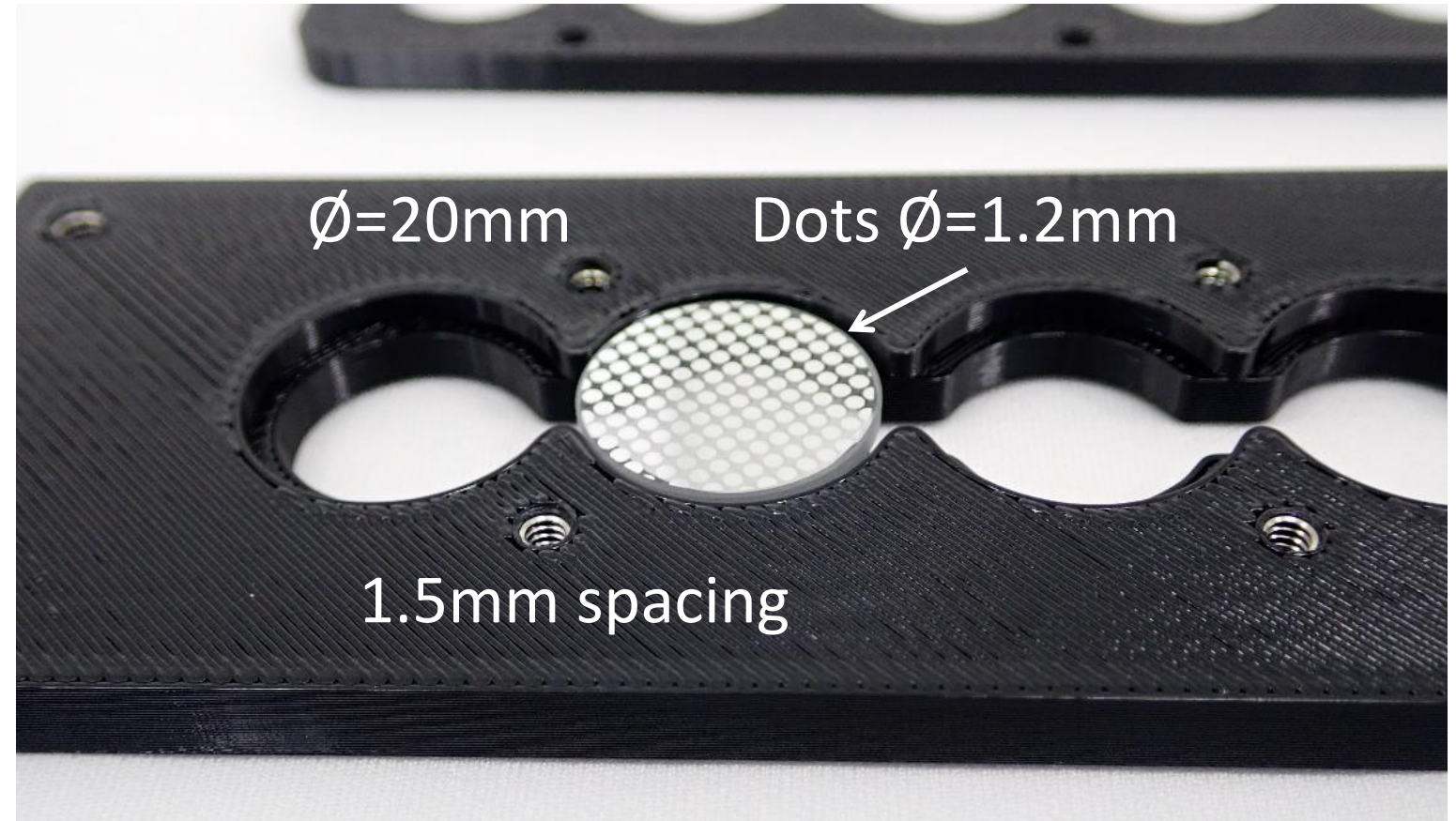


Tri-TIP – Beam Splitter

Two types of substrate:

1. Sapphire (Al_2O_3)
 - Red leak correction
 - Eliminates OI 135.6 nm
2. MgF_2
 - Limb sensor

$\text{Al}+\text{MgF}_2$ reflective coating
uses polka-dot pattern to
minimize geometric effects

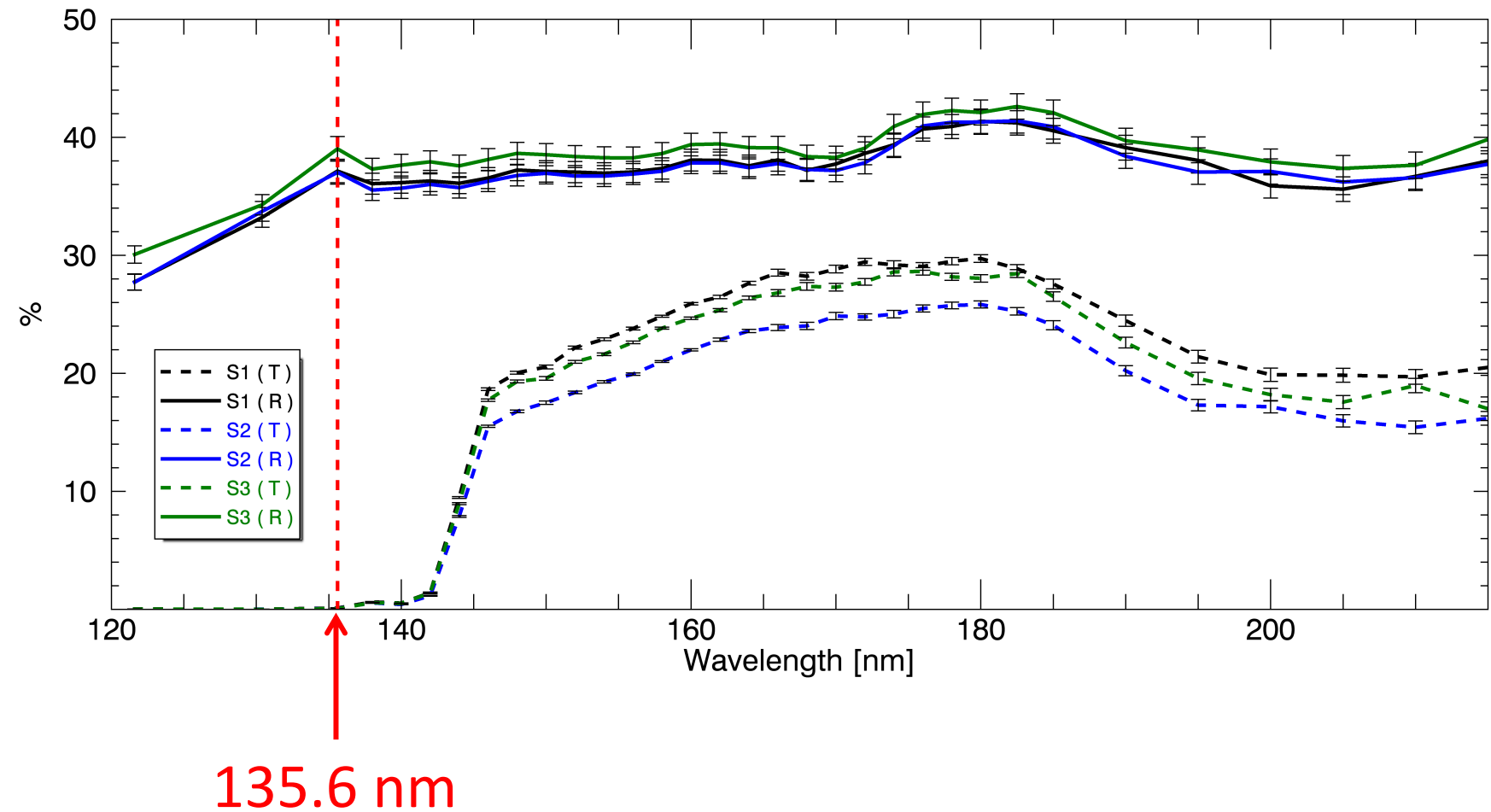


Tri-TIP – Beam splitter characterization

Transmissivity and
reflectivity tested as a
function of wavelength

Substrate successfully
eliminates OI 135.6 nm

Sapphire (Al_2O_3) beam splitters



Tri-TIP – Effective Passband

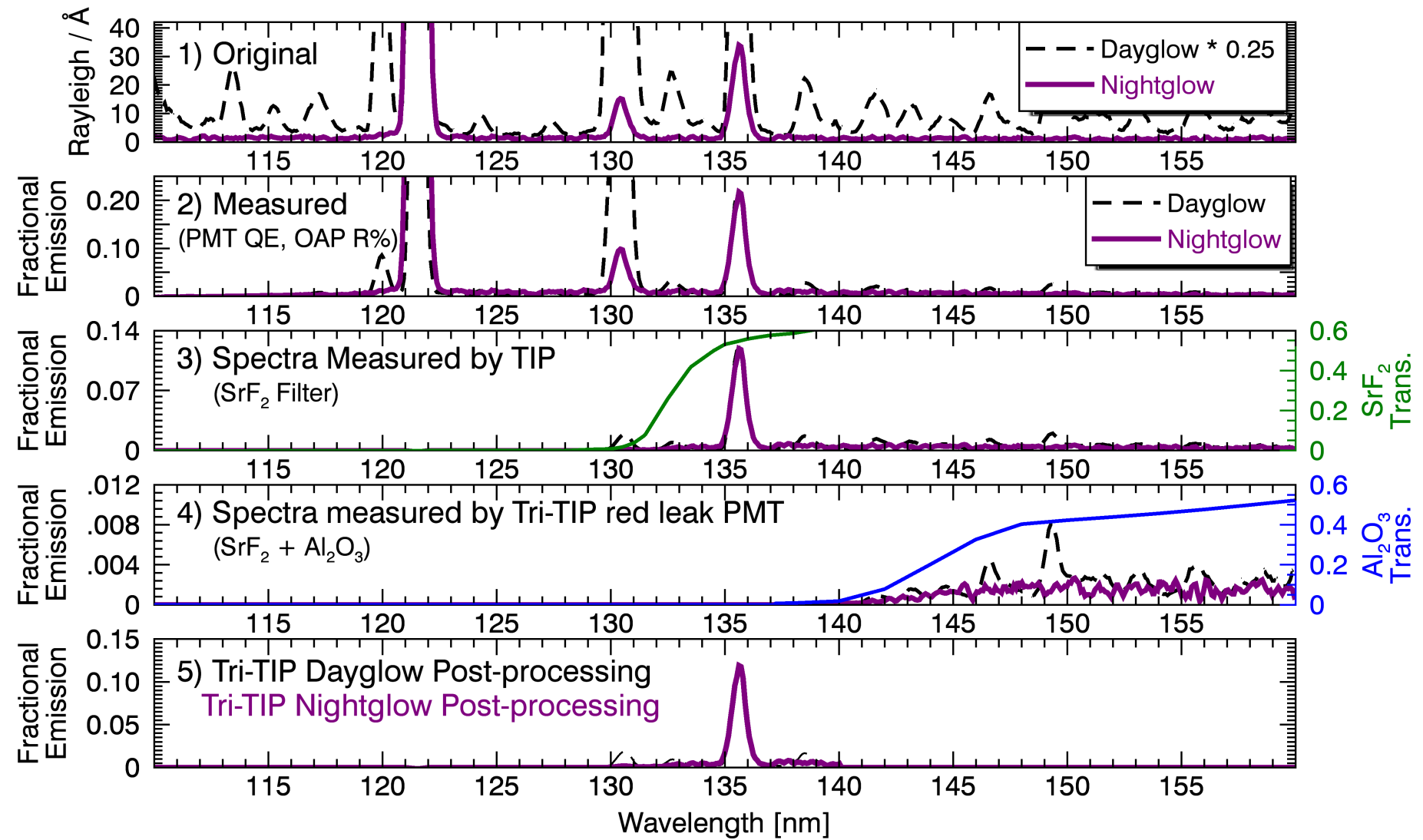
Full Spectrum

What a “Solar Blind”
PMT measures

What TIP measured

What the Red Leak
PMT will measure

Final Tri-TIP Result



Tri-TIP provides compact, high-sensitivity remote sensor in 1U package

- NRL has significant heritage through TIP and other UV remote sensors
- Limb sensor has potential to double observing capability
- Testing underway to characterize and match the UV and Red response of the Hamamatsu PMTs

CIRCE / Tri-TIP data will be analyzed using the VERT method

- CIRCE mission will be able to retrieve ionospheric structure
- Algorithms are tuned as information about observation scenario evolves

Launch expected to LEO as part of the Space Test Program



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Works Cited:

- S. A. Budzien, P. D. Feldman, and R. R. Conway, "Observations of the far ultraviolet airglow by the ultraviolet limb imaging experiment on STS-39," J. Geophys. Res. A Space Phys. 99, 23275–23287 (1994).
- S. A. Budzien et al., "Tiny Ionospheric Photometers on FORMOSAT-3/COSMIC: on-orbit performance," Proc. SPIE 7438, 743813 (2009).
- A. W. Stephan et al., "Evaluation of UVoptics for Triple Tiny Ionospheric Photometers on CubeSat missions," Proc. SPIE 10769, 107690W (2018).
- K. F. Dymond et al., "Low-latitude ionospheric research using the CIRCE Mission: instrumentation overview," Proc. SPIE 10397, 1039719 (2017).
- S. A. Budzien et al., "Three-channel airglow photometer data analysis methodology," Technical Report, US Naval Research Laboratory (2018).
- B. A. Fritz et al., "Ultraviolet beam splitter characterization for use in a CubeSat optical system," Journal of Applied Remote Sensing, DOI: 10.1117/1.JRS.13.032503 (2019)