KWANSEI GAKUIN

AstroParticle Symposium 2024

Direct measurements with CIBER and future perspectives

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CIBER / CIBER-2 collaboration

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Korea: Korean Astronomy and Space Science Institute, Seoul National University

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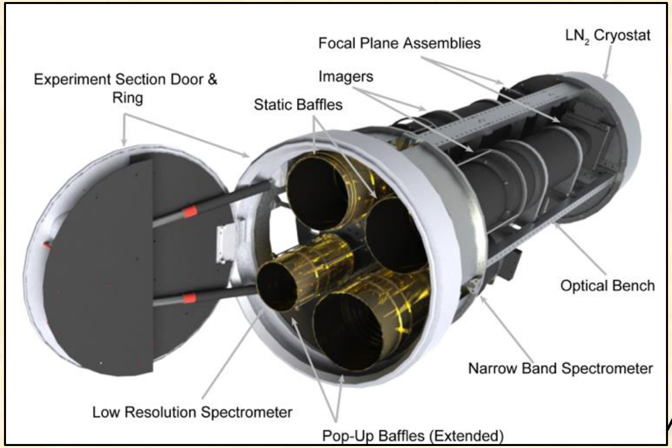
Rocket experiment CIBER

CIBER - Cosmic Infrared Background ExpeRiment

- NASA sounding rocket program (PI: J. Bock)

  Feb 2009, Jul 2010, Mar 2012, and June 2013

CIBER payload



Zemcov et al. (2012)

Observed raw sky brightness

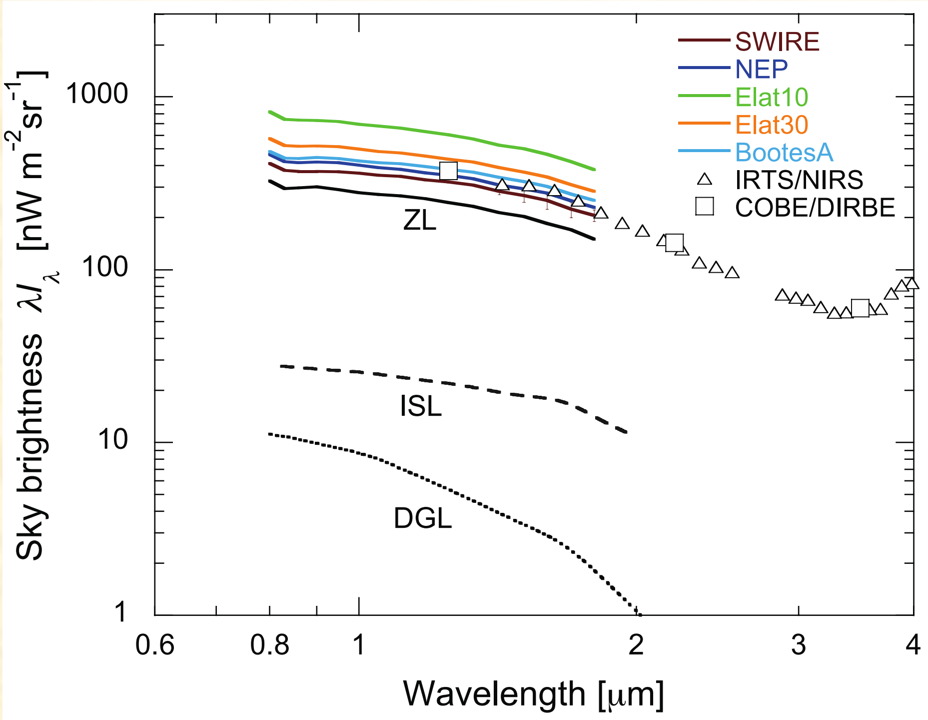
The Sky brightness levels are consistent with previous satellite observations

Extragalactic background

= Sky - foregrounds

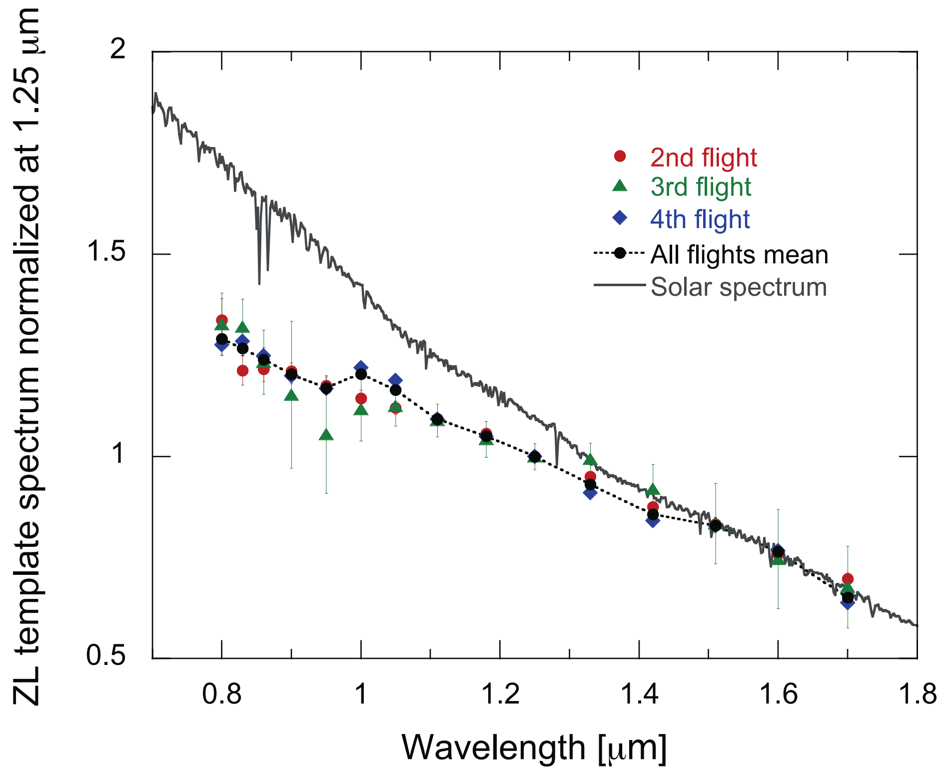
Foregrounds

- zodiacal light (ZL)
- integrated star light (ISL)
- diffuse galactic light (DGL)



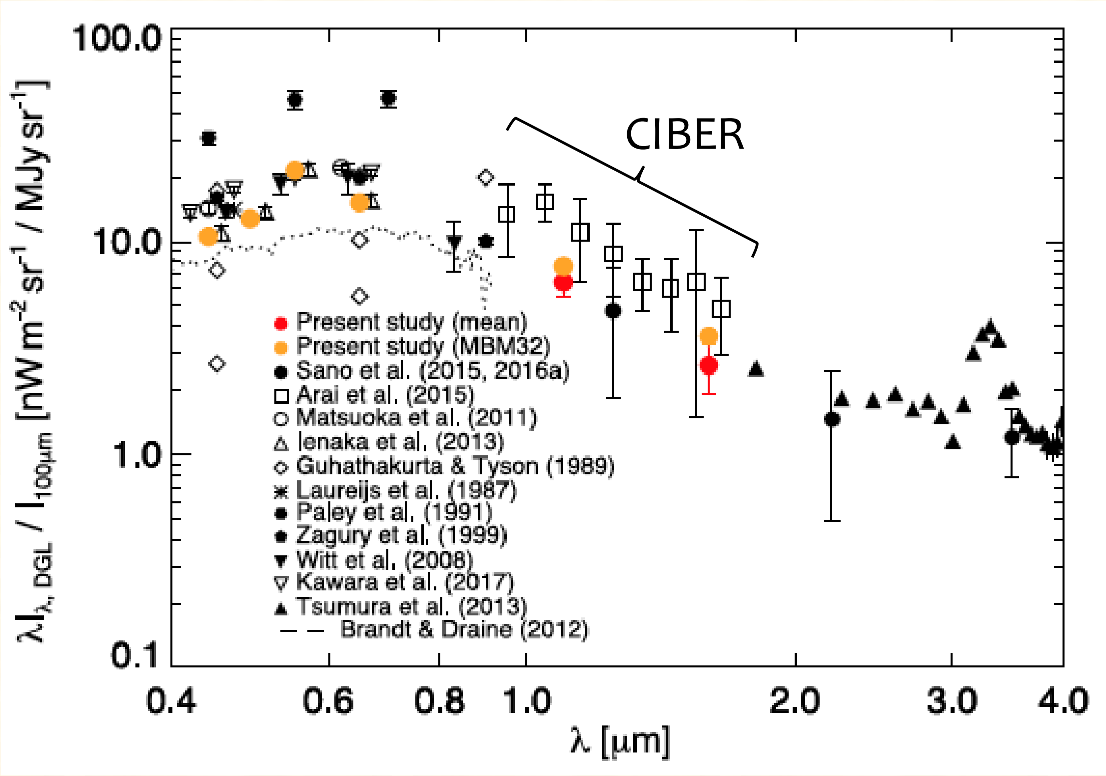
Zodiacal light spectrum

- Obtained by differencing sky spectra (Sky-ISL-DGL) at different ecliptic latitudes, to cancel out any isotropic offset.



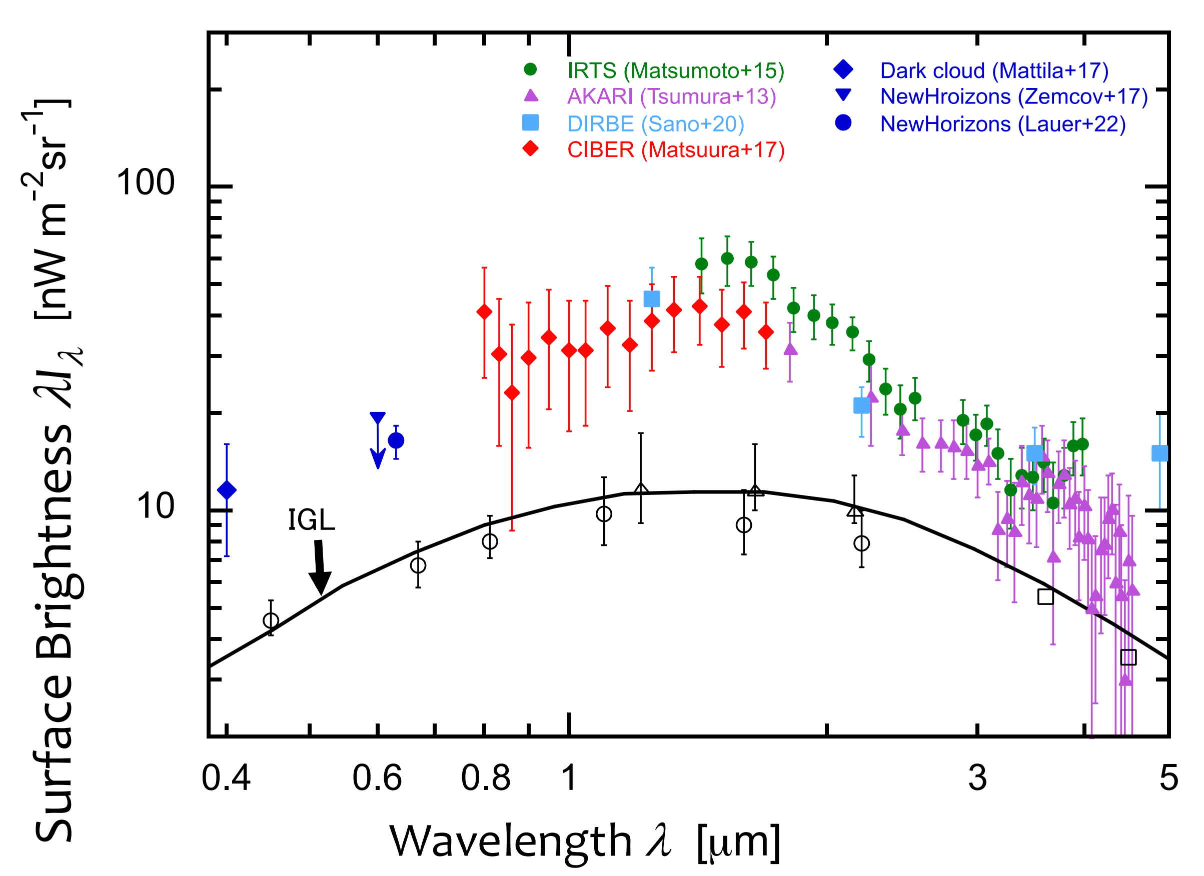
DGL / 100μm correlation

- CIBER LRS vs. SFD100 spectrum compared with the result from the MIRIS satellite



Onishi et al. PASJ 2018

EBL mean intensity spectrum



- Foreground subtracted sky brightness
- ZL subtraction combining the measured spectrum and COBE/DIRBE intensity distribution model.

✓ Nominal result shows agreement with previous satellite results.

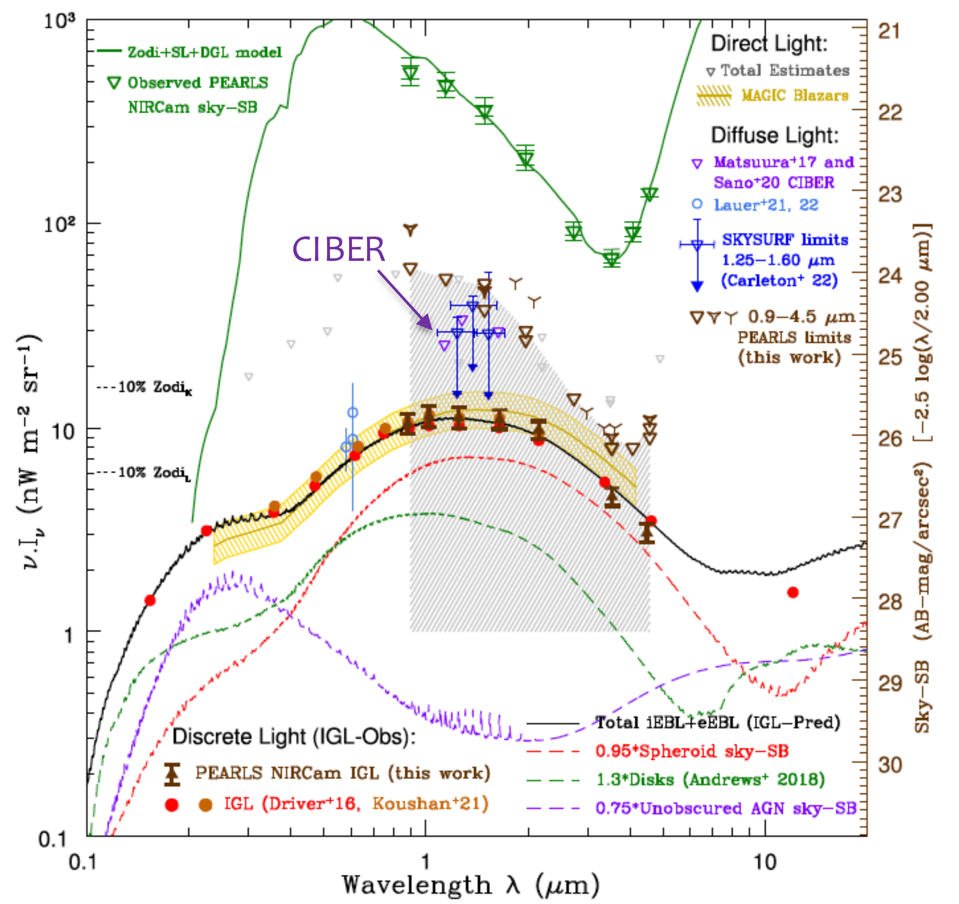
Matsuura et al. 2017, ApJ

NIR EBL measurement with HST & JWST

- HST SKYSURF & JWST PEARLS
- Surface brightness measurement removing AB <26mag sources
- The residual brightness levels are comparable to the CIBER result.

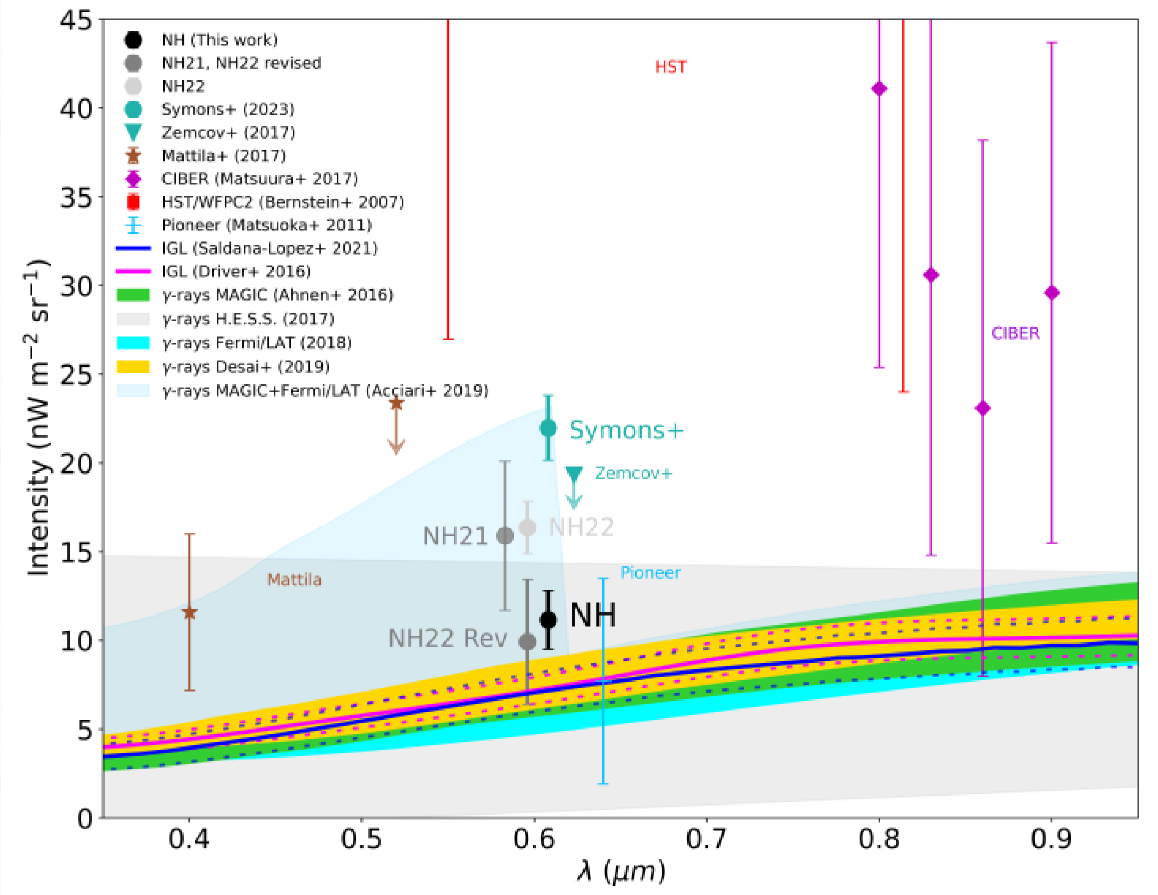
SKYSURF
Carleton et al. 2022
O'Brien et al. 2023

PEARLS
Windhorst et al. 2023



No EBL excess in the optical

- Results from the NH observations @51 au without ZL contamination
- Latest analysis shows little or no EBL excess

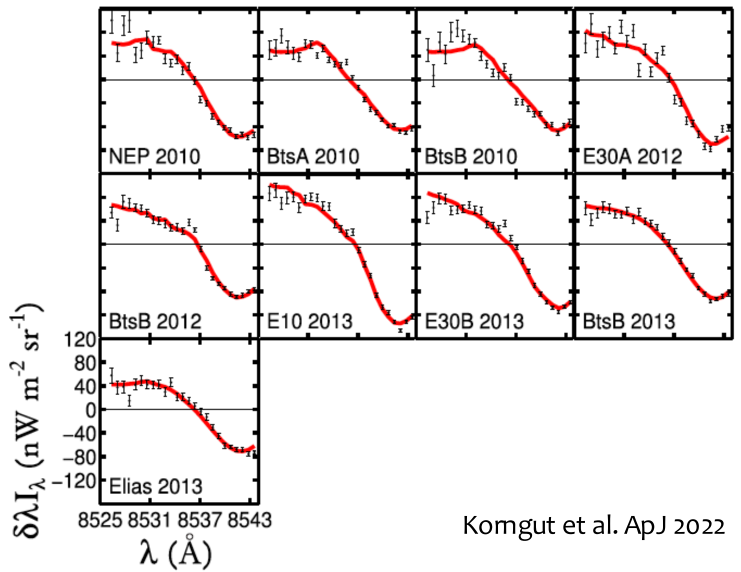


Postman et al. ApJ 2024

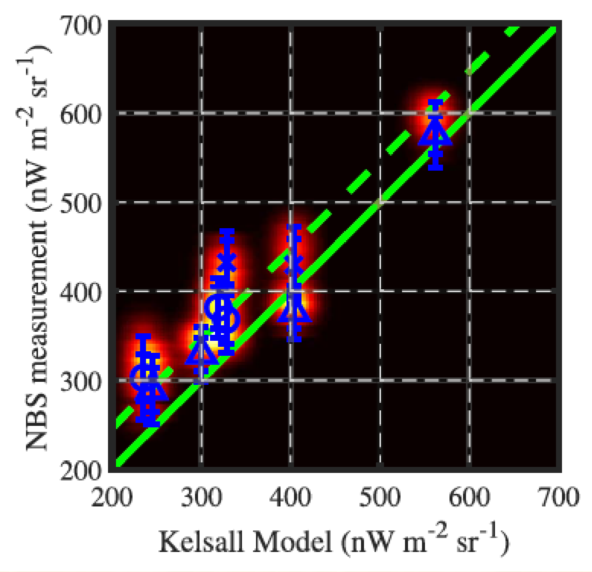
Fraunhofer line measurement

CIBER NBS instrument (Korngut et al. 2013 & 2022)

- Absolute ZL intensity determination from the Ca+ 854 nm absorption depth
- Found isotropic offset component from the Kelsall ZL model extrapolated to 1.25um of 46+/-19 $nWm^{-2}sr^{-1}$



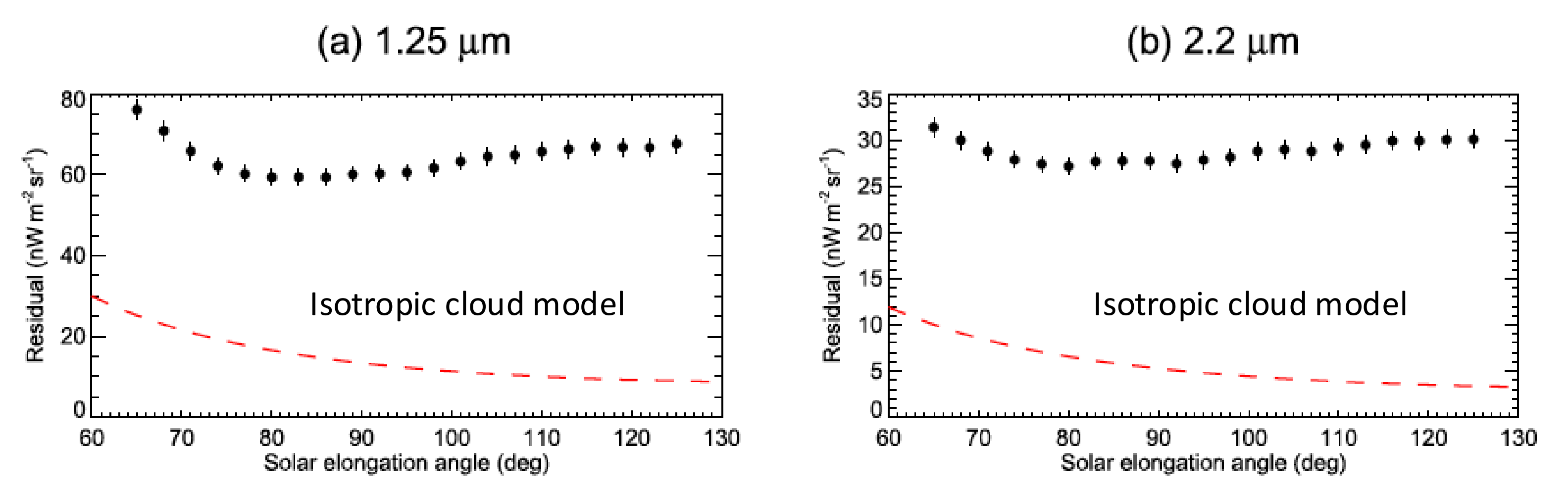
Korngut et al. ApJ 2022



Isotropic zodiacal cloud from the DIRBE analysis

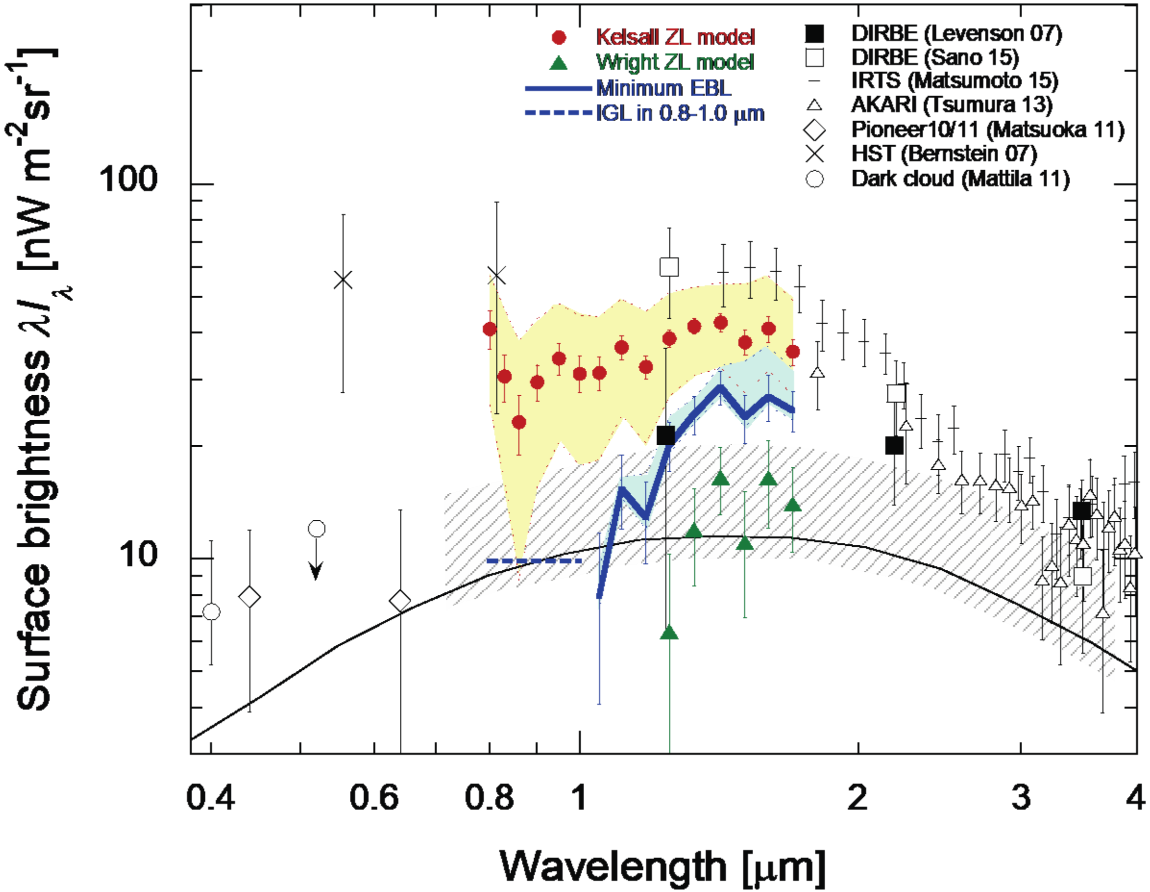
DIRBE/COBE weekly map analysis (Sano et al. 2020)

- ZL subtracted residual sky brightness shows the solar elongation dependence possibly due to an isotropic cloud
- Isotropic cloud brightness is 10-20 $nWm^{-2}sr^{-1}$ at 1.25um



Sano et al. ApJ 2020

EBL mean intensity spectrum



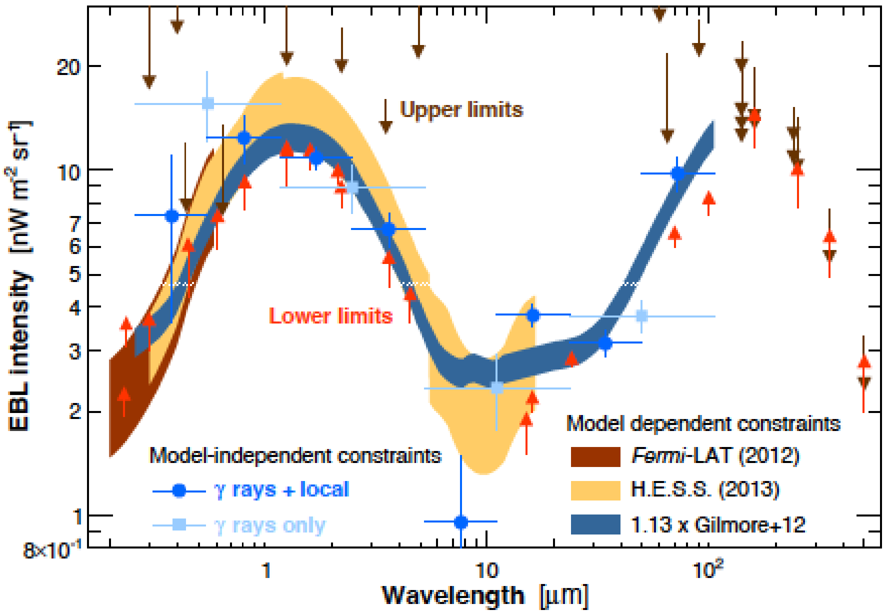
- ✓ Nominal result shows agreement with previous satellite results.
- ✓ A minimum EBL is obtained by taking isotropic ZL into account and assuming no excess in the optical.

Matsuura et al. 2017, ApJ

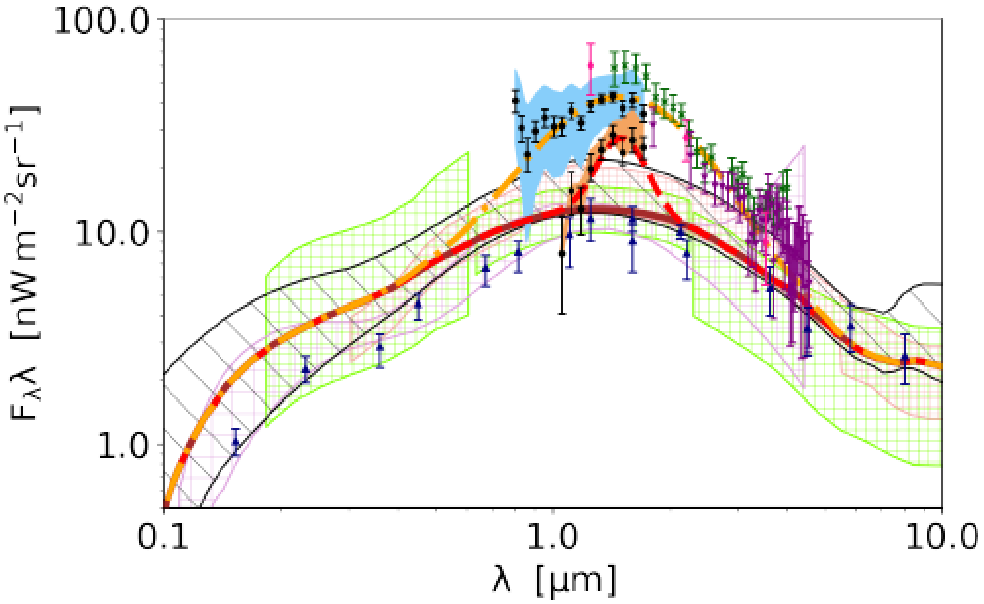
Relaxing the tension to the gamma-ray limit

- There is room to add a narrow spectral feature to EBL to relieve the tension between the gamma-ray limits and the direct measurements.
- Some studies of constraining the Axion-like particle decay with the CIBER EBL limit

Biteau & Williams 2015



Korochkin+ A&A 2020, Kalashev+ PRD 2019, Kohri & Kodama PRD 2017

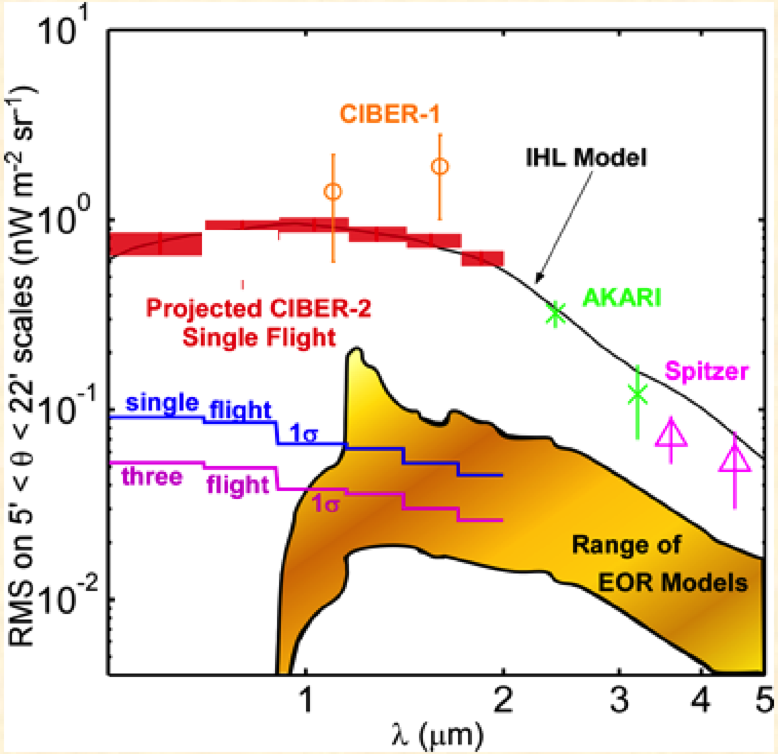


Upgrade experiment CIBER-2

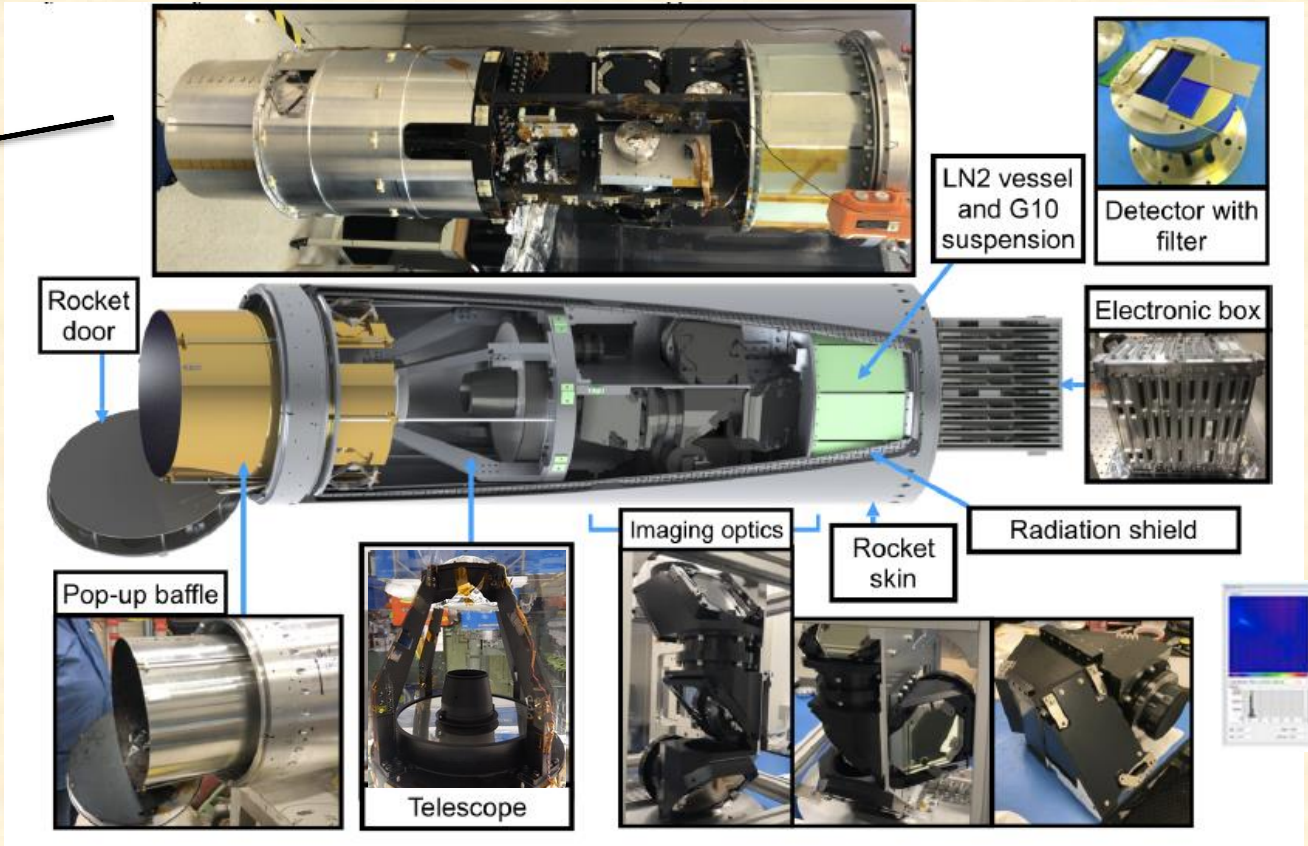
NASA sounding rocket experiment under international collaboration (PI: Zemcov)

New features beyond CIBER

- Larger telescope aperture (28.5 cm)
  → Deeper point source removal (<20 mag)
- Wider FoV (2.3 deg sq.)
  → Several times better sensitivity
- Wider wavelength coverage (0.5 - 2 μm)
  – Fluctuation measurement in 6 bands
  – low-res. spectroscopy of the mean intensity



CIBER-2 payload instruments



FPA: HAWAII-2RG
2k x 2k HgCdTe

GSE/DAQ

All-Al 28.5 cm RC

Wide field camera w/ 2.3 x 2.3 sq.deg FOV

CIBER-2 flights

Launch site – White Sands Missile Range (WSMR), New Mexico

1st flight: June 6, 2021

- Done under the COVID-19 pandemic
- Launch was successful but no scientific achievement due to large contribution of stray light and thermal emission.

2nd flight: April 16, 2023

- solved the problems seen in the 1st flight
- Launched but immediately aborted due to rocket tracking error
- Hard landing with the vacuum door open

- Repaired the payload in a half year for the 3rd flight.

The 3rd flight

- The launch was successfully done on May 5th, 21:32 MDT
- All the instruments were working properly during the flight.
- Payload and the onboard memory data were recovered.

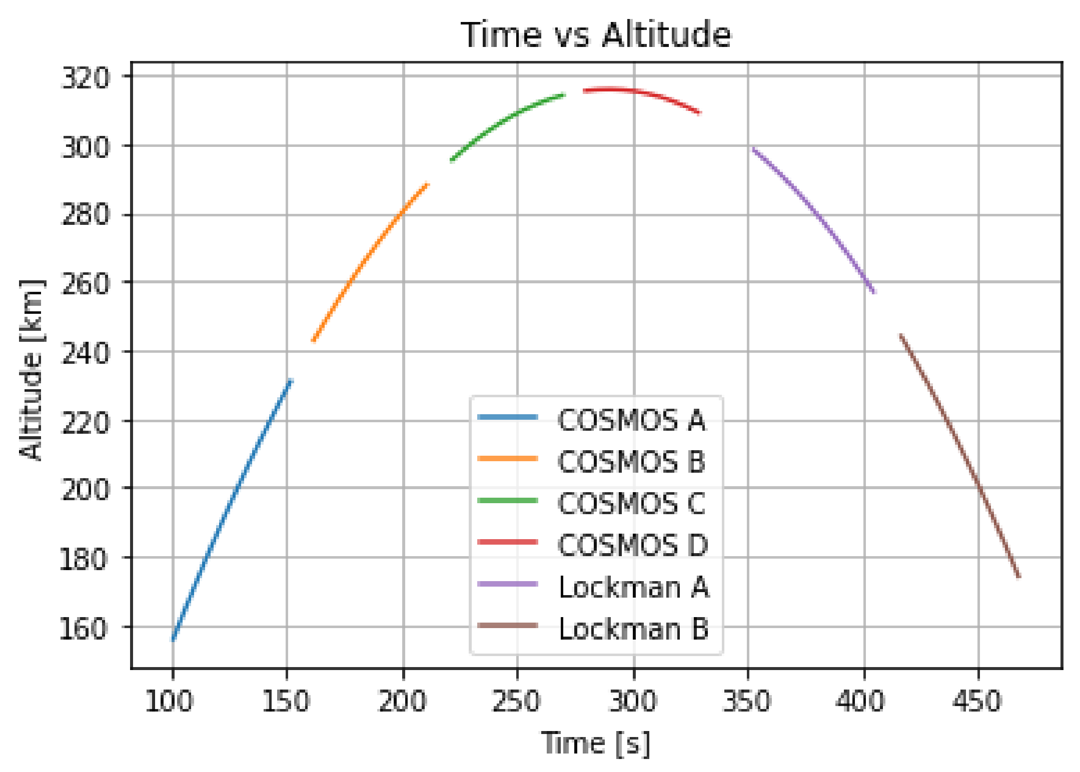
Trajectory and science fields of the 3rd flight

- Apogee: 316 km
- Total observation time:
  6 minutes for *h* >150 km

Target fields

- 4 fields covering COSMOS field
  (RA, Dec) ~ (10^h 0^m, 2d 12m)
- 2 fields towards Lockman hole
  (RA, Dec) ~ (10^h 50^m, 58d 11m)

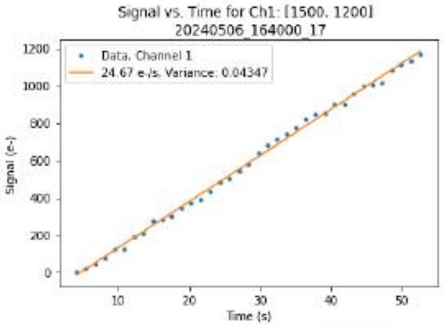
Exposure time in each field is 56 s

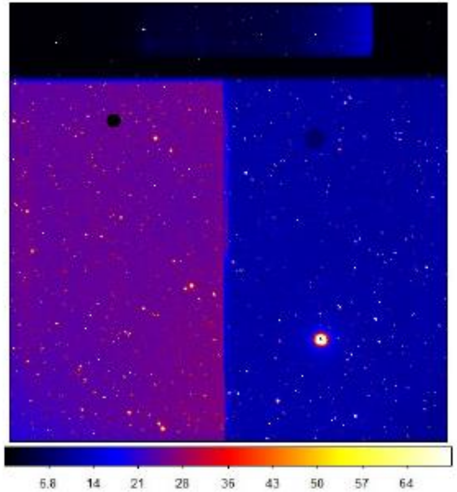


First look at the 3rd flight data

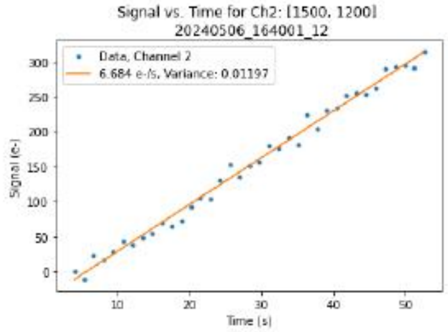
Example @Lockman hole

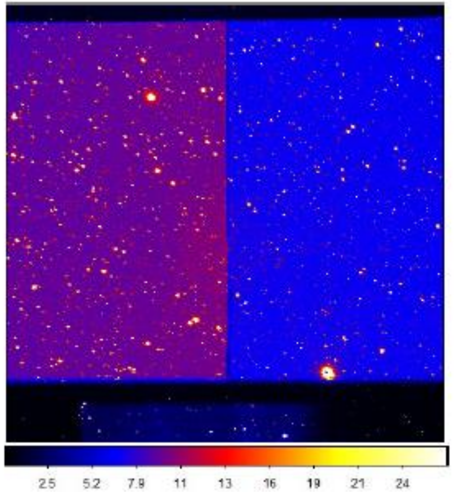
CHANNEL 1 / ARM L



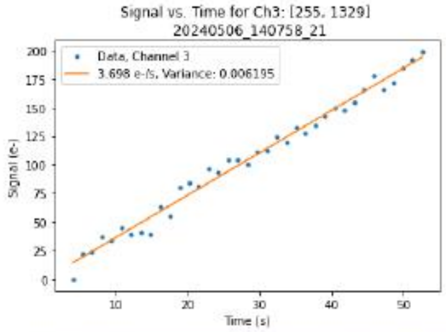


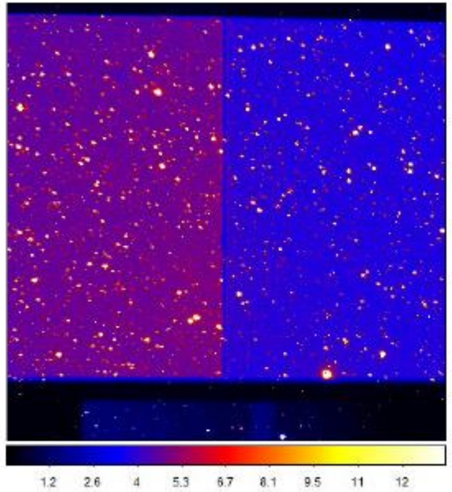
CHANNEL 2 / ARM M





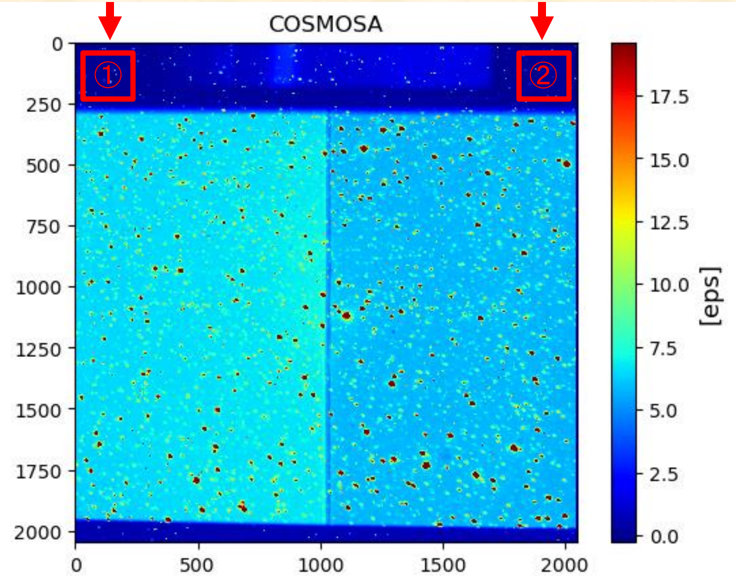
CHANNEL 3 / ARM S

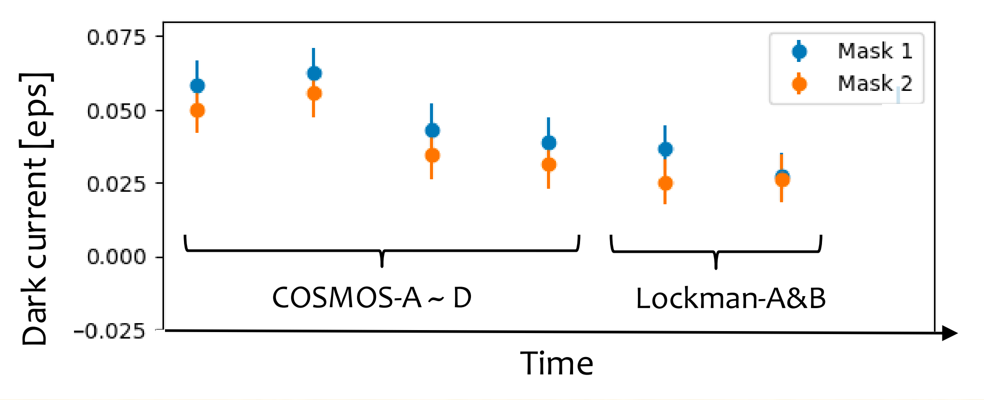




Dark current stability

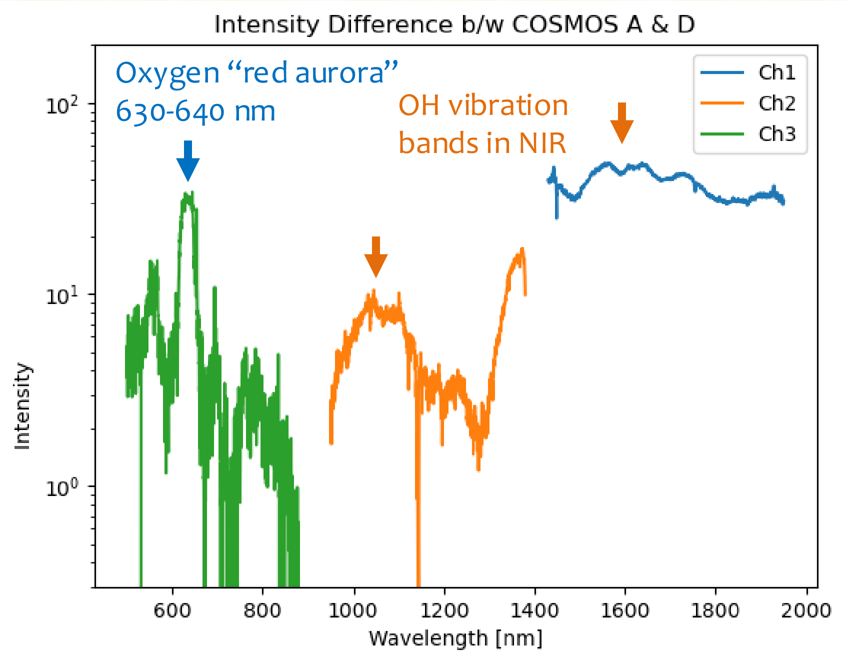
- Use of the dark mask area to trace the dark current trend during obs.
- Possible to correct the dark current drift with an accuracy <0.01 eps, smaller than the expected EBL signal.





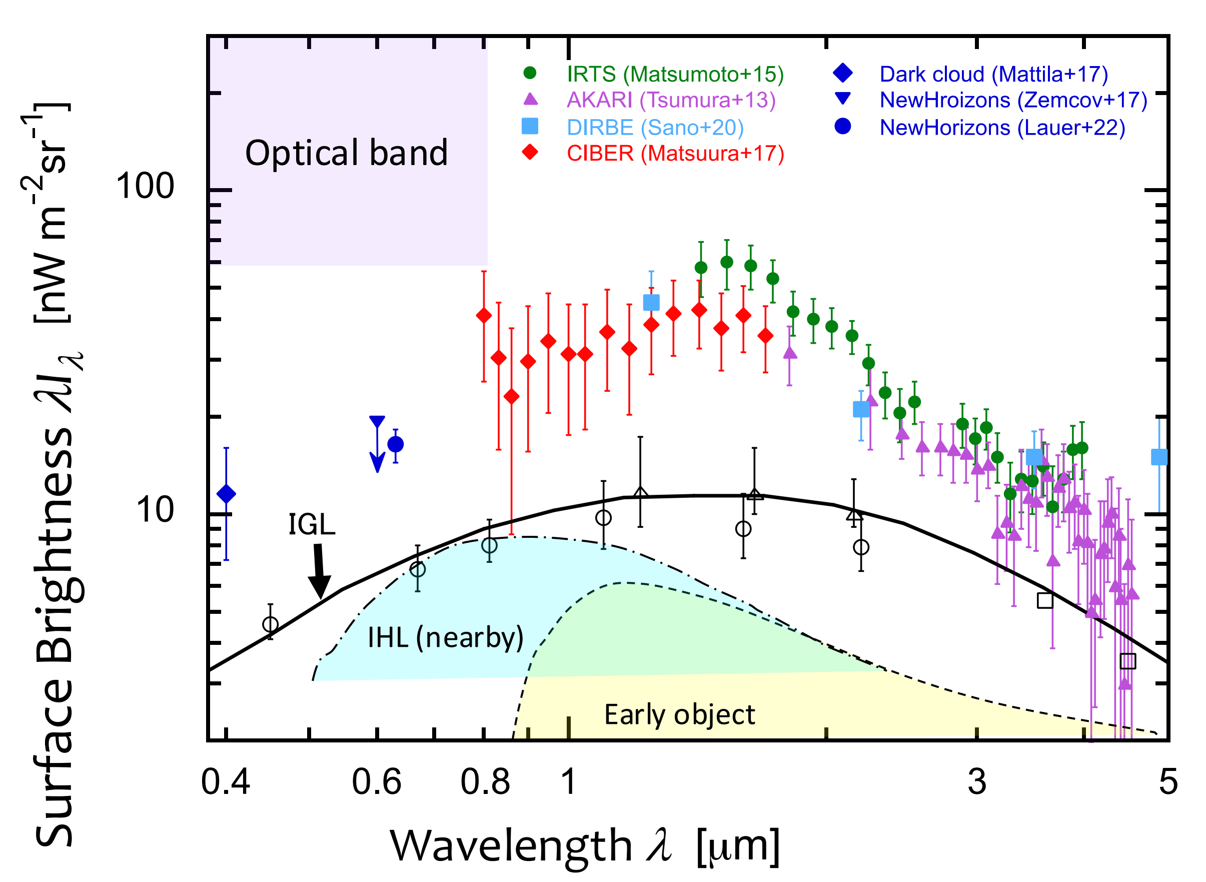
Airglow contamination

- Significant contamination by airglow.
- The airglow spectrum by LVF shows strong spectral lines.
- The data reduction is still in progress.



The optical band is important

- Multiband observation in the optical is important to identify the source of the NIREBL excess.
- Wide area mapping in the optical is also important to accurately assess the ZL and DGL foregrounds.



VERTECS: Cube-Sat mission for EBL

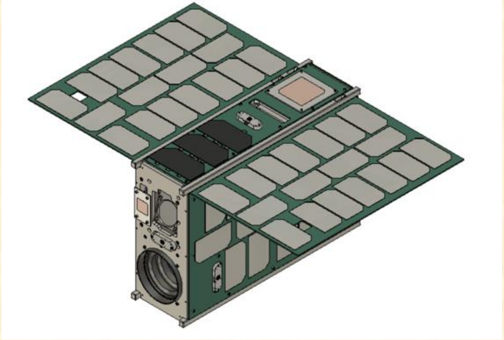
KWANSEI GAKUIN

VERTECS: Visible Extragalactic background RadiaTion Exploration by CubeSat

6U satellite mission for the optical EBL study

JAXA-SMASH (Small Satellite Rush) program

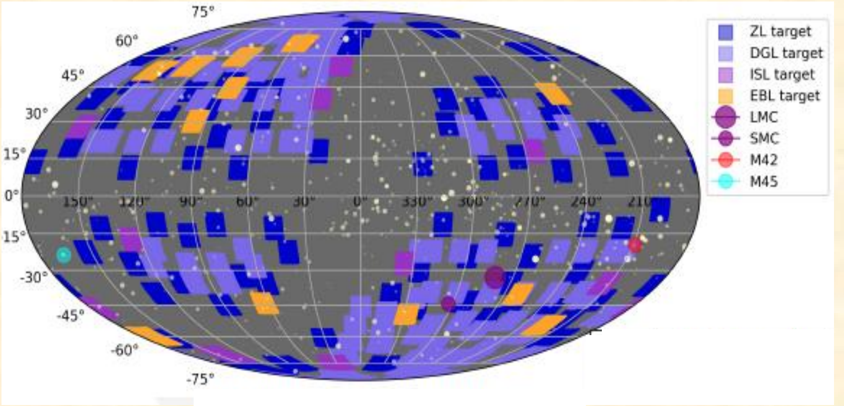
Web site: https://vertecs-project.com



- Mapping 35% of the entire sky in one year from SS Polar Orbit
- 3k x 3k CMOS sensor with 2x2 windowpane filter (400–800 nm)
  - Radiatively cooled to -20 deg C
- 35-mm aperture lens telescope, 6x6 deg^2 FOV, 10 arcsec/pix

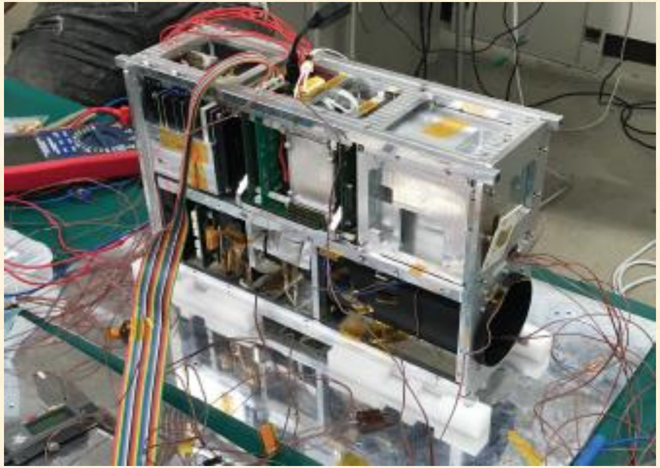
- Detection limit (single 1-min exposure)
  - ZL limited sensitivity
  - Diffuse source ~ 10 nWm^{-2}sr^{-1} (10x10 pix, 1σ)
  - Point source ~ 16 ABmag (5σ)

- Ideal for the ZL and DGL study

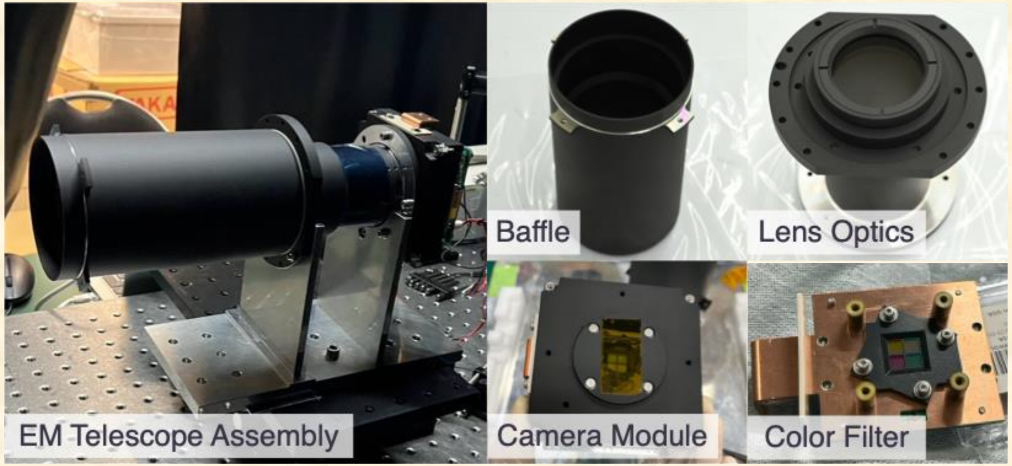


VERTECS development status

- Satellite EM testing for structural, thermal and electrical verification has been completed.
- Design is finalized and FM is in manufacturing.
- To be launched in 2025 by H3 rocket



Satellite structure

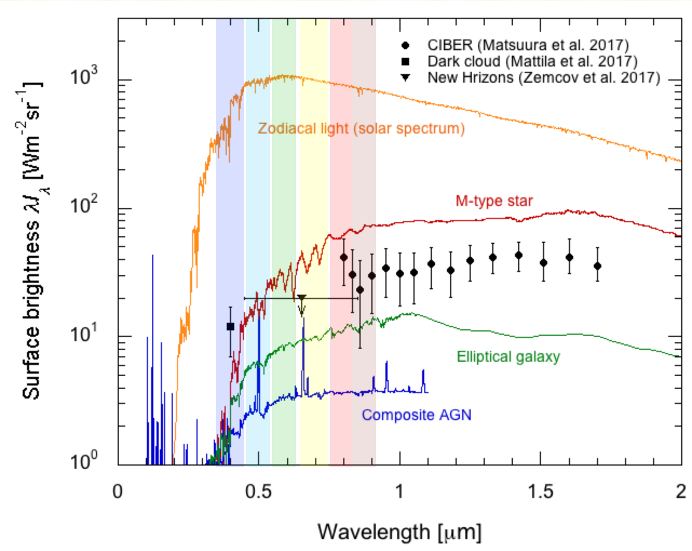


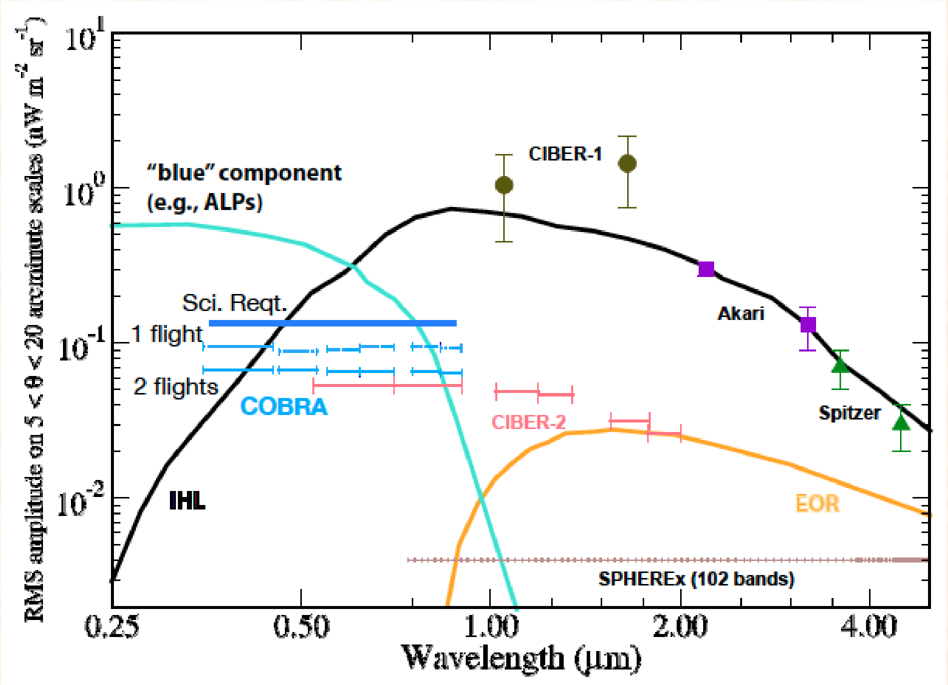
Telescope

The next plan rocket experiment COBRA

COBRA : Cosmic Optical Background Rocket Assay

- SED of the EBL fluctuations and mean intensity in the optical
- Revealing the EBL excess found by New Horizons; proof of IHL and ALPs decay
- NASA program same as CIBER-2
- Modified CIBER-2 design

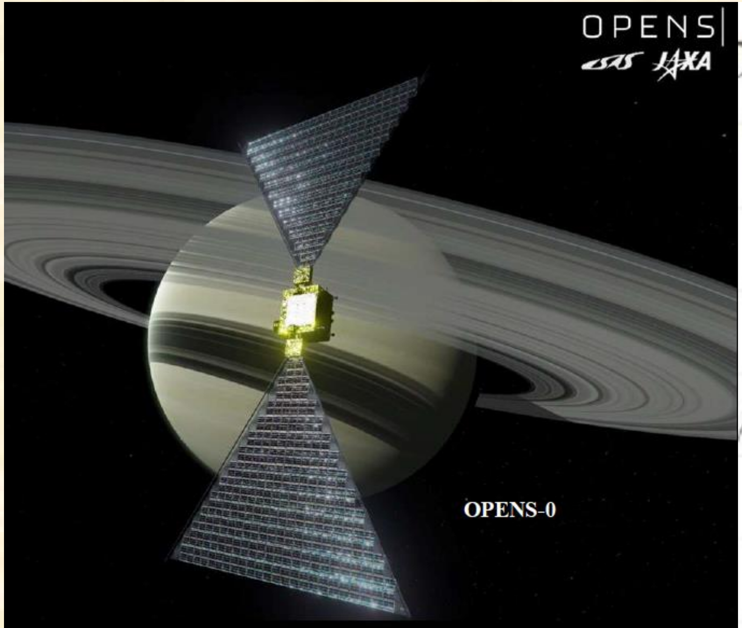


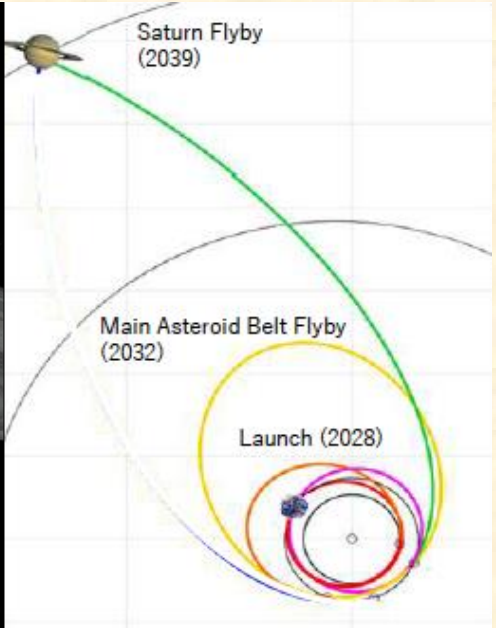


OPENS (Outer Planet Exploration by Novel micro-Spacecraft)

OPENS-0: Tech demo of micro-spacecraft to Saturn

- 100-200 kg payload powered by thin solar cells by JAXA Epsilon-S rocket
- Diffuse background observations with an optical telescope in cruising
- proposed to JAXA in 2024 as the Small Satellite Program

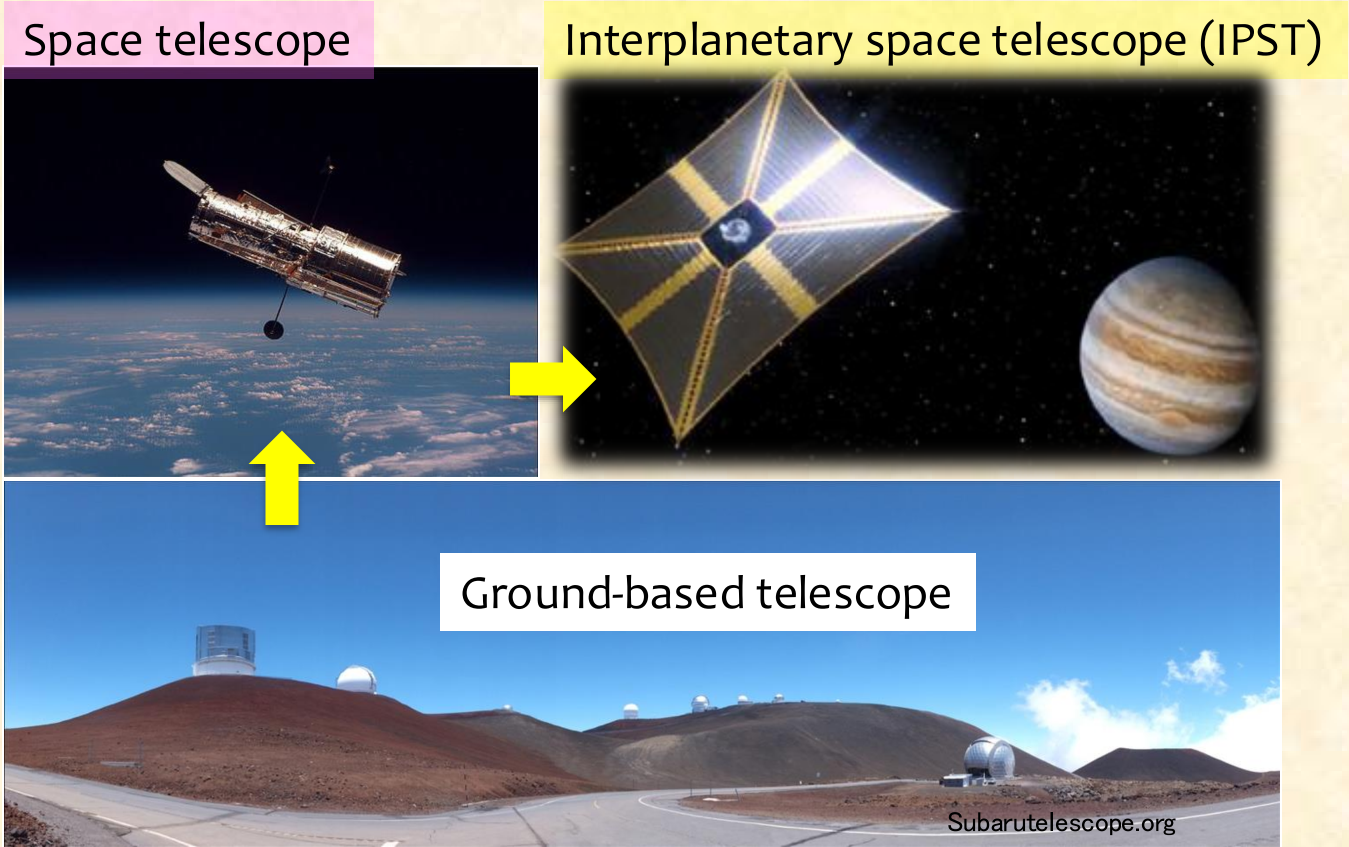




<u>Mission Sequence</u>

2028: Launch
2029: Earth Swing-by
ZL observation
2030: Venus Swing-by
2031: Earth Swing-by
2032: Main Asteroid Belt FB
2039: Saturn Flyby
EBL observation

Telescope evolution for next generation astronomy



Summary

- presented the EBL observations with CIBER and future prospects
- The NIR EBL excess over IGL became certain by years of research.
- The optical EBL was found, but not sure if it's related to the NIR.
- Future series of EBL missions, CIBER-2, COBRA, SPHEREx, VERTECS, and deep space missions would give clear answer to the 3-decades long question,

  "Why is the night sky so bright?".