CIBER Measurements of the Mean Intensity of the NIR background

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for the CIBER Collaboration

Near Infrared Background and the Epoch of Reionization
Austin, Texas
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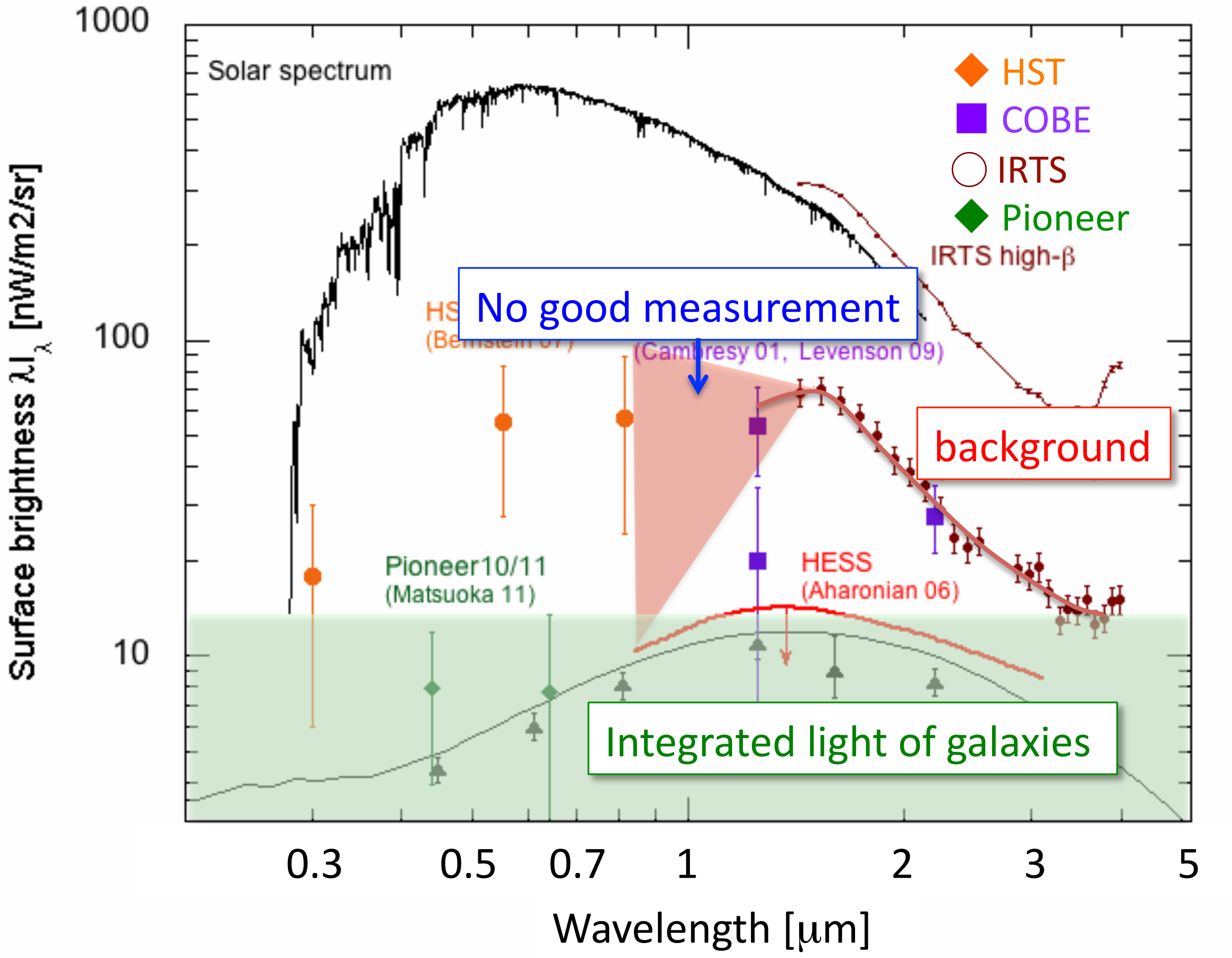
Observational limits on the NIR background

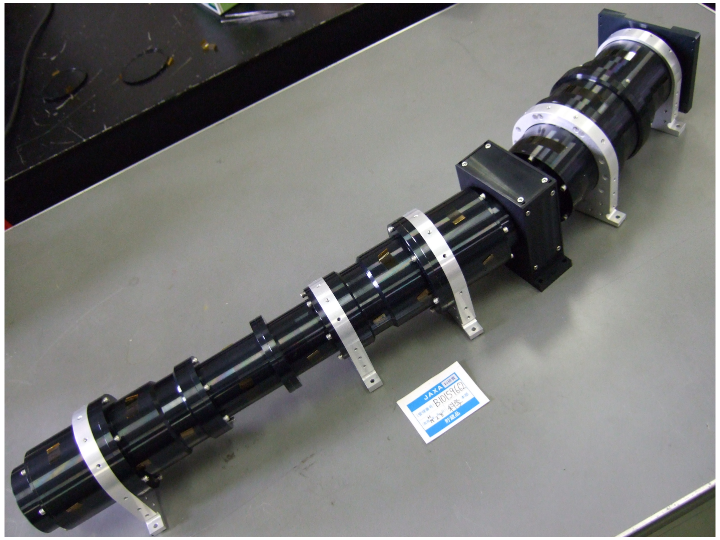


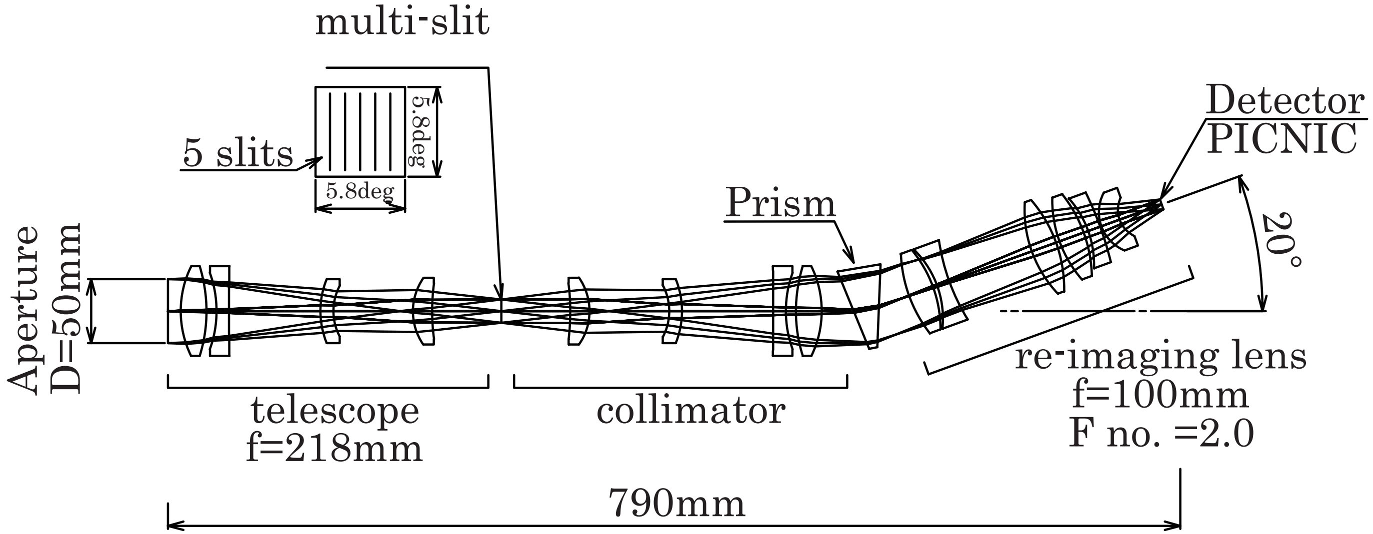
Low Resolution Spectrometer on CIBER

Low Resolution Spectrometer (LRS)

Wavelength: λ = 0.76-2.0μm

Spectral resolution: $R = (\lambda/\Delta\lambda) \sim 20$

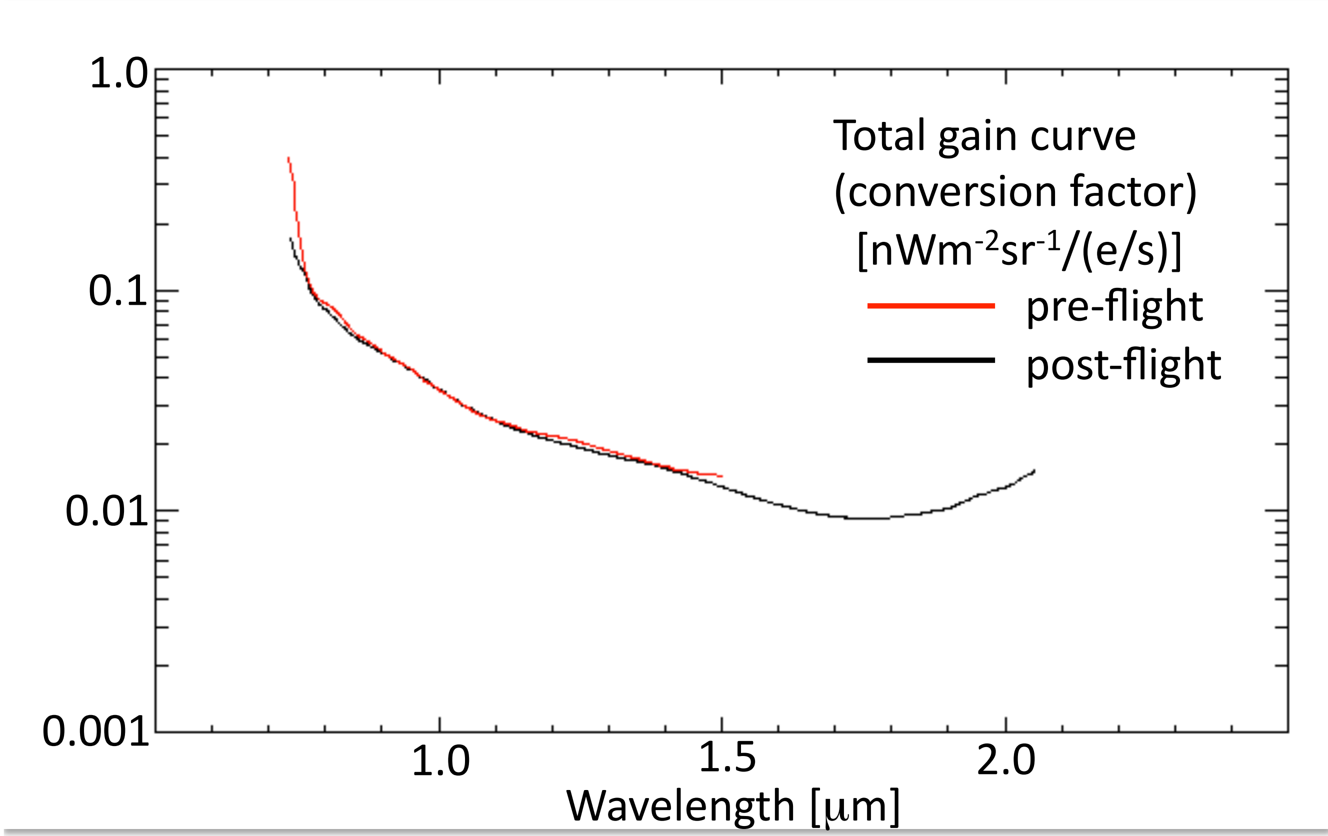


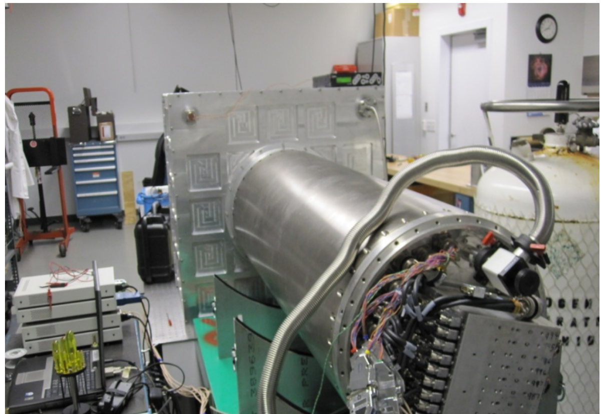


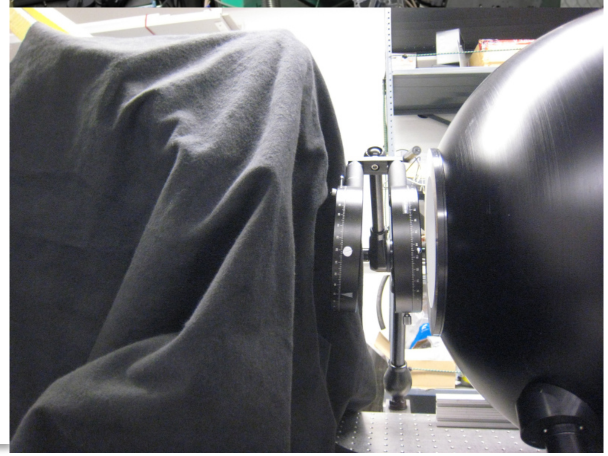
Wavelength dispersion

Calibration

- Calibration with diffuse light sources and detectors calibrated by NIST
- Pre-flight & post-flight calibrations agreed well with each other
- Absolute calibration accuracy ±2%

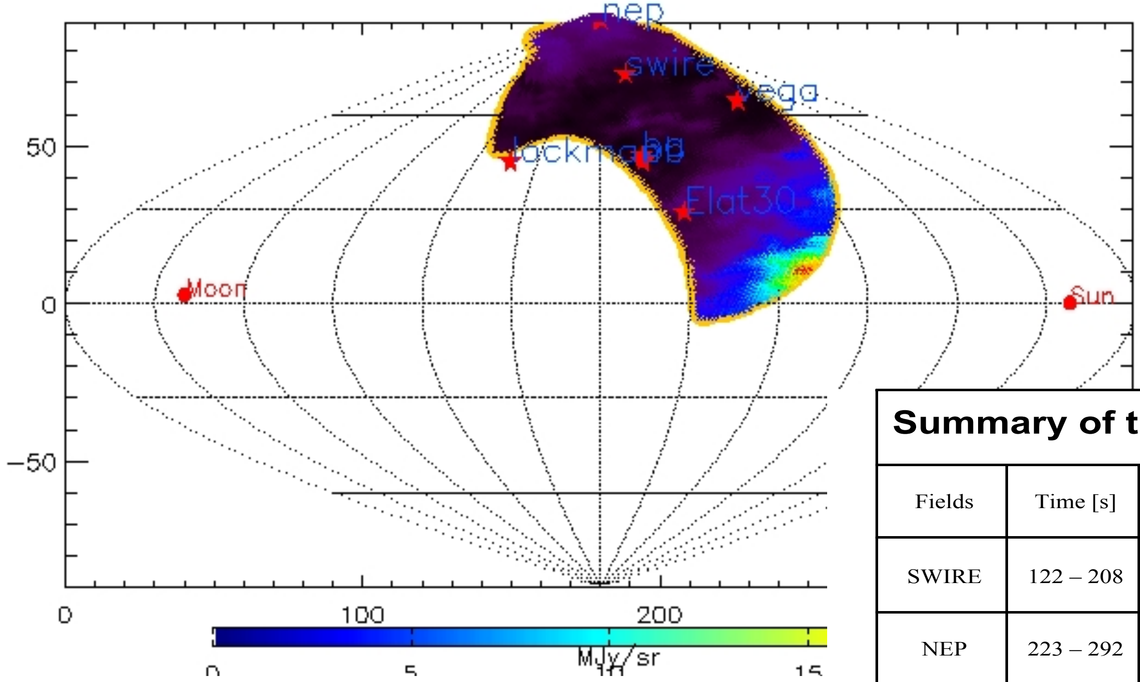






Science fields

- Various Ecliptic latitudes to estimate ZL
- Spitzer & AKARI survey fields, where point sources are well studied



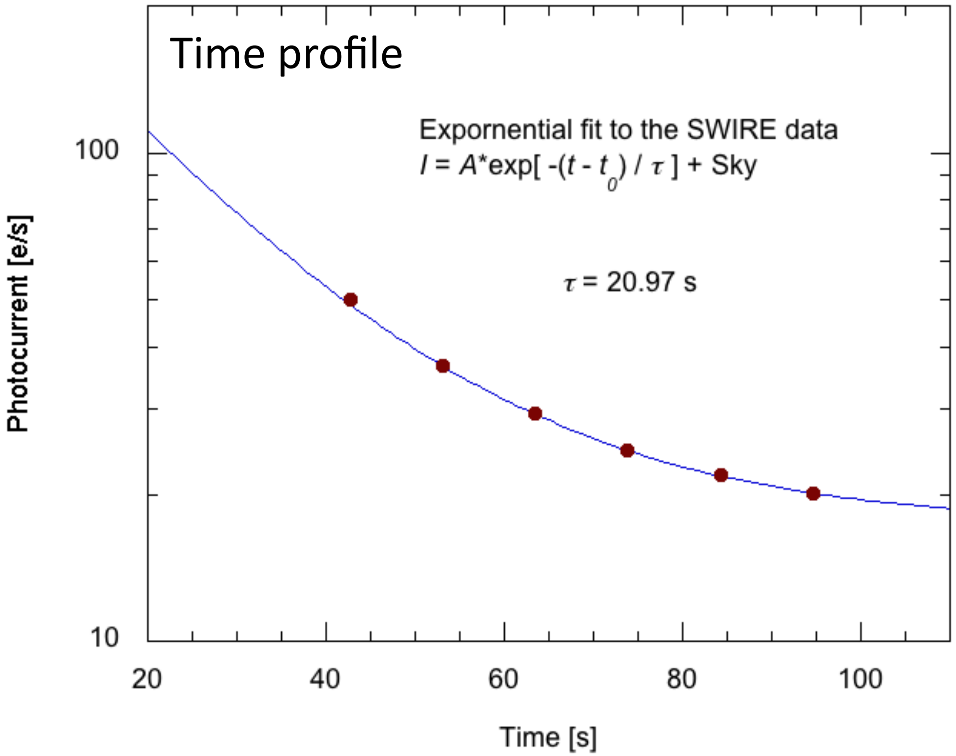
Ecliptic coordinate

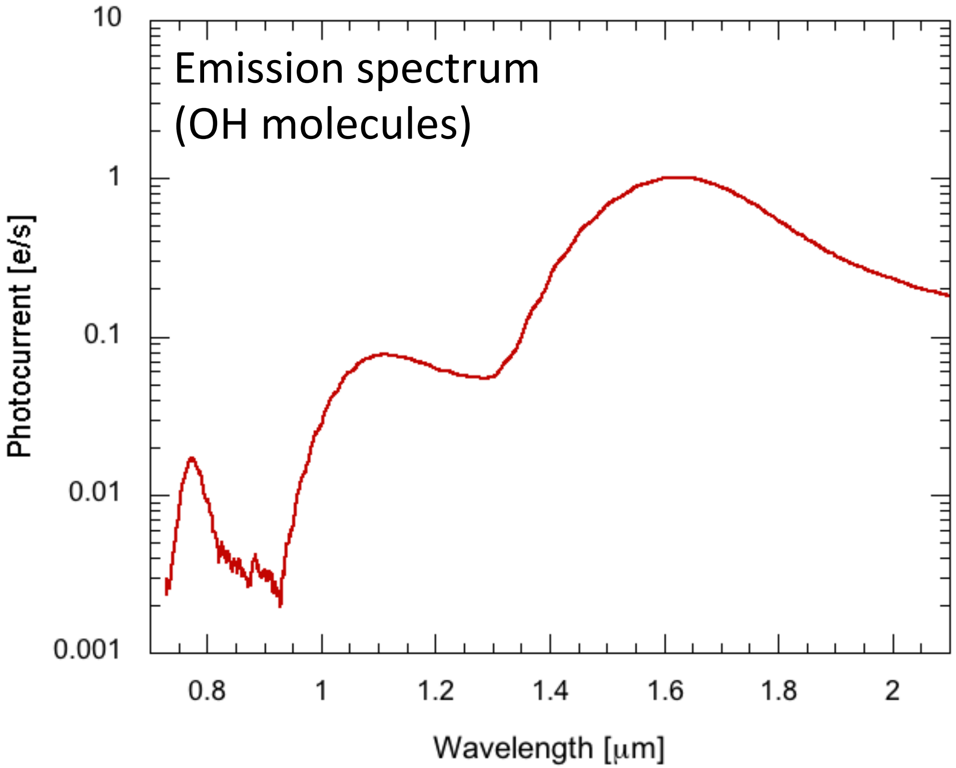
Summary of the CIBER observation targets

Fields	Time [s]	Altitude[km]	(RA, Dec)	(λ, β)	(l, b)
SWIRE	122 – 208	204 – 298	(242.75, 55.00)	(207.68, 72.73)	(84.89, 44.62)
NEP	223 – 292	308 – 329	(270.00, 66.34)	(279.88, 89.31)	(96.13, 29.81)
Elat-10	319 - 326	326 - 324	(227.00, -2.00)	(233.76, 10.71)	(356.88, 46.08)
Elat-30	340 - 357	319 - 310	(221.00, 20.00)	(212.82, 35.10)	(23.52, 63.31)
Bootes-A	372 - 442	301 - 231	(218.48, 34.88)	(200.75, 46.72)	(58.76, 66.79)
Bootes-B	456 - 523	211 - 99	(217.32, 33.39)	(200.30, 44.94)	(55.44, 68.02)

Data reduction

- Dark current subtraction & responsivity correction
- Time-dependent component (atmospheric airglow, outgas)
  - Exponential fitting and subtraction
- Unit conversion to the brightness → raw spectra



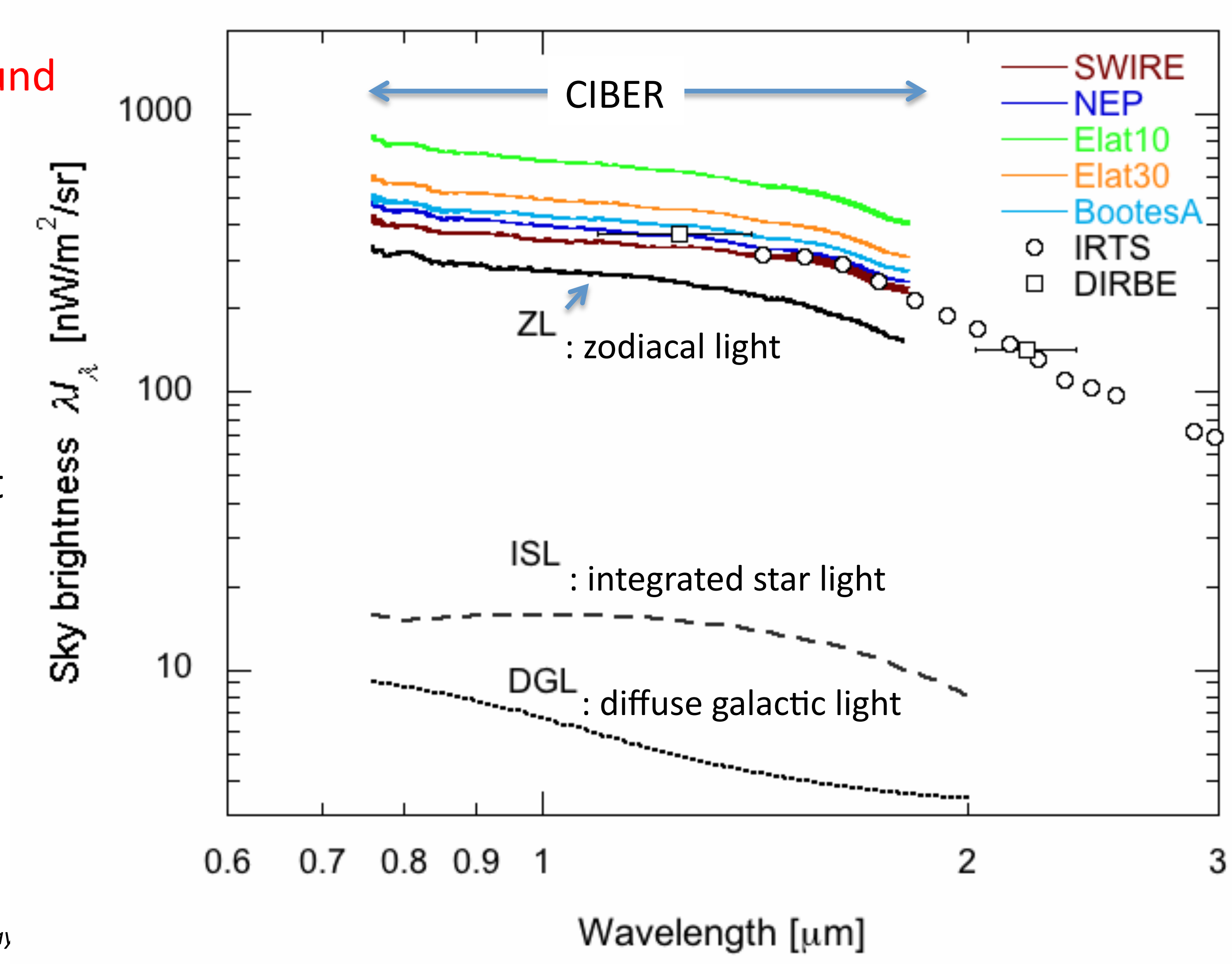


Observed sky brightness

Sky brightness levels are similar to previous observations

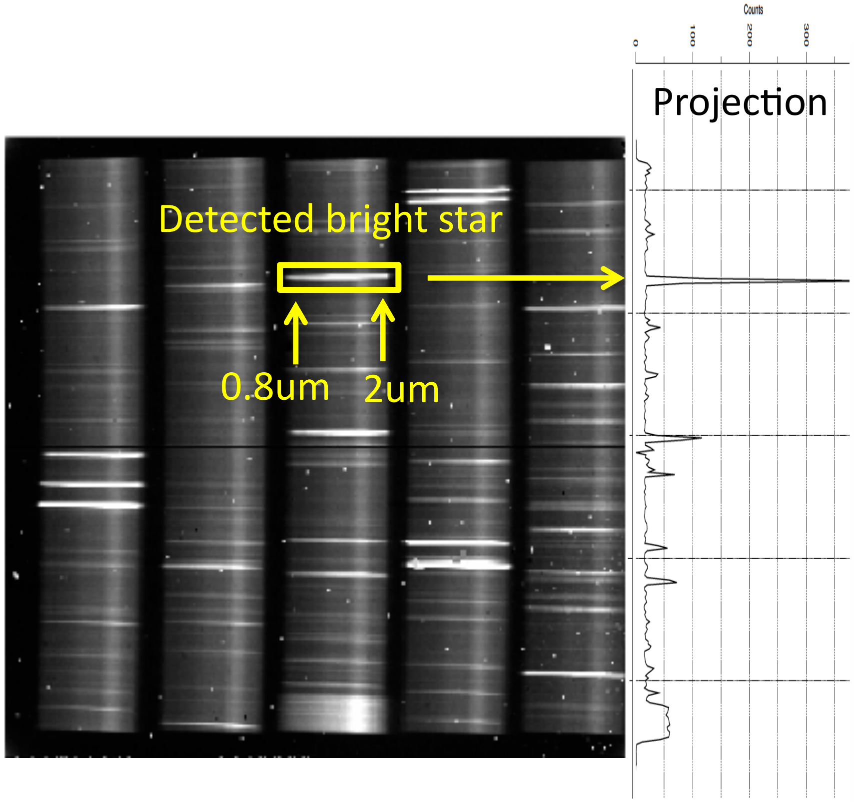
Extragalactic background
= Sky - foregrounds

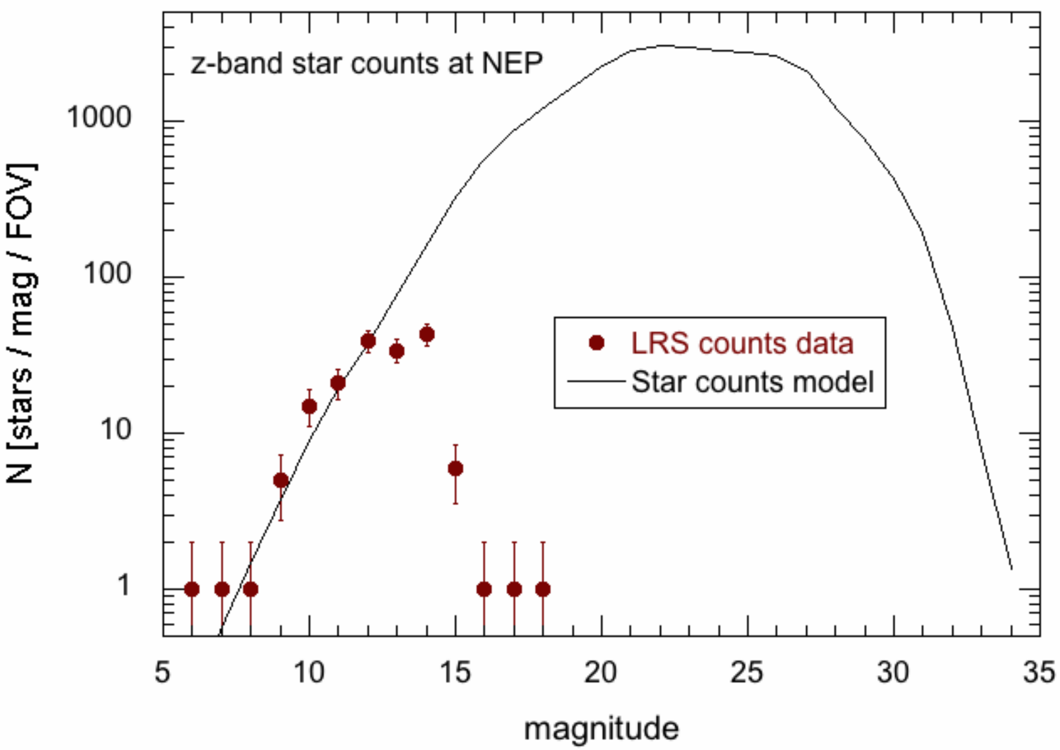
Foregrounds
- zodiacal light
- integrated star light
- diffuse galactic light



Galactic foregrounds: Stars

- Detected stars（z < 13mag）　→　2-sigma clipping, pixel masking
- Below the limiting magnitude →　integrated model star counts (ISL)
  - Galaxy model : spectral type distribution, number density, extinction
    (Wainscoat et al. 1992, Bahcall&Soneila 1980, Cohen 2001)





Calculation of the ISL brightness

Total ISL brightness : F = *integral* [*Flux(m)* x *N*(*m*) x { 1 - *f*(*m*) }]

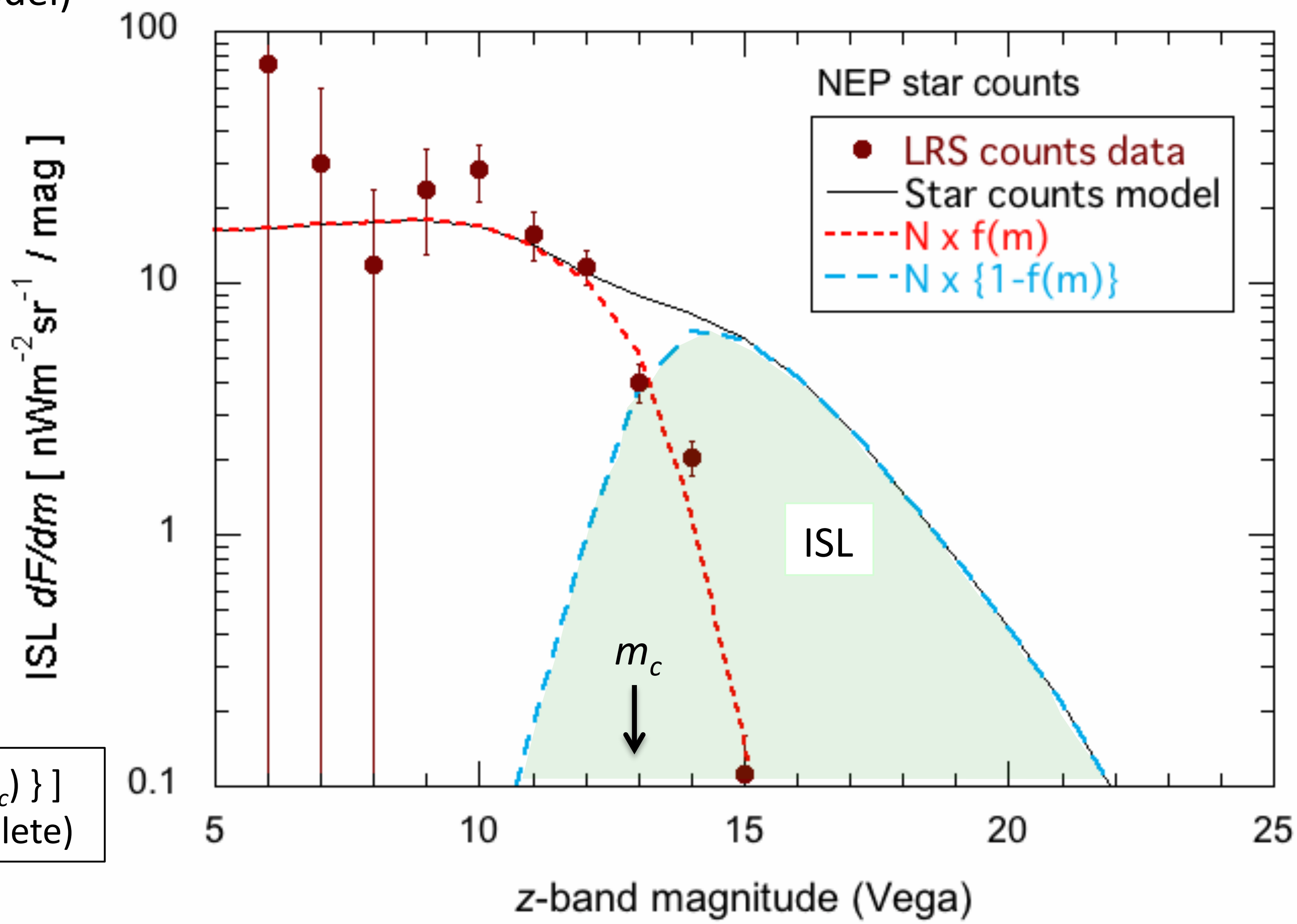
Flux(*m*) : flux of magnitude *m*

N(*m*) : star counts (model)

f(*m*) : completeness

dF/dm :

ISL brightness per magnitude



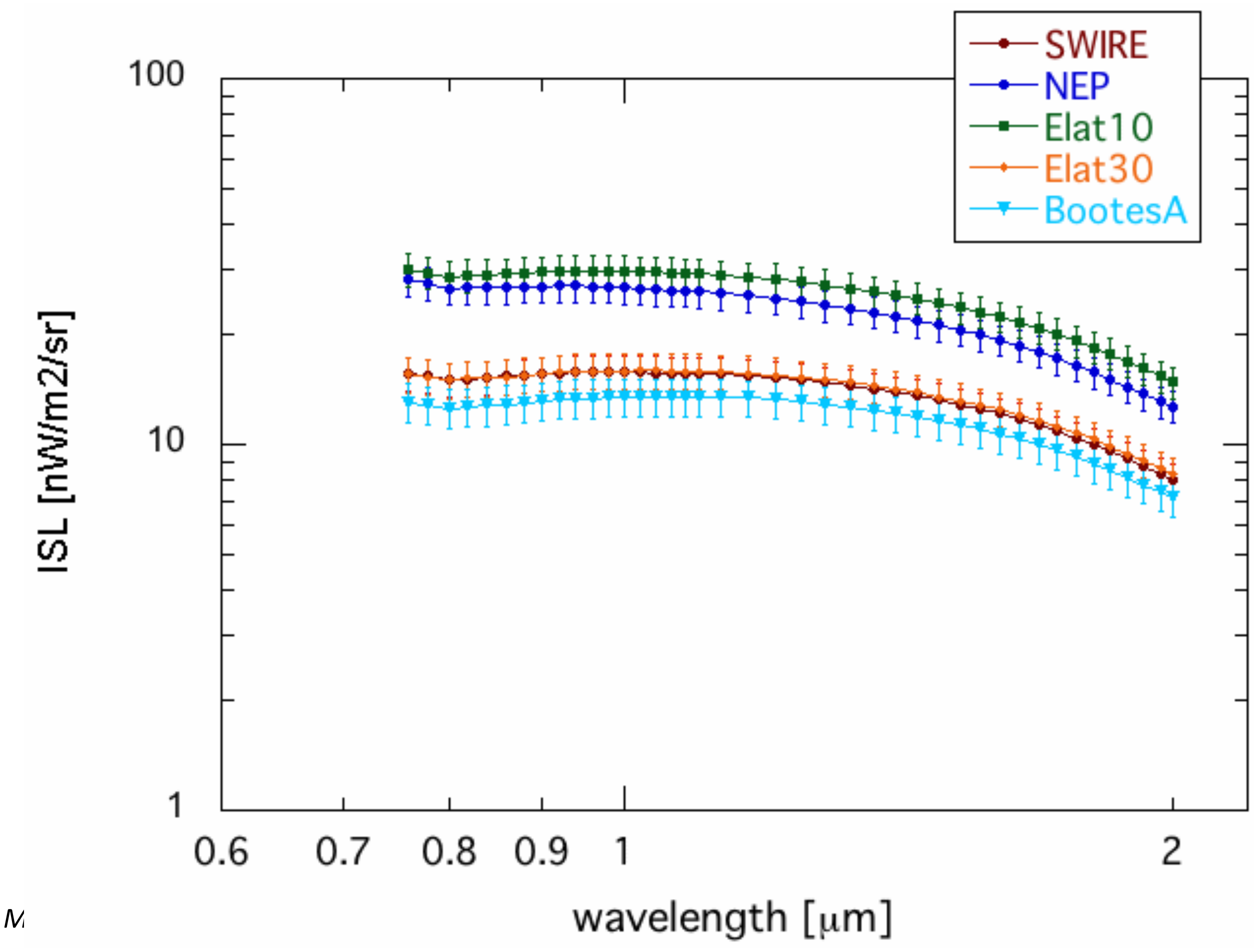
$f(m) = 1 / [1 + exp\{ a (m-m_c) \}]$

m_c : cut-off mag (50% complete)

ISL spectra in the observed fields

ISL spectra: < 30nW/m2/sr (< 10% of sky brightness)

Uncertainty: model uncertainty +/-9% (Cohen 2001, Wainscoat et al. 1992)
completeness fitting error



Galactic foregrounds: DGL

- Diffuse Galactic light（DGL）
  - Dust scattering of ISRF in Vis-NIR
- DGL spectrum
  - ISRF, scattering function & albedo
  - Observations of reflection nebulae
- Intensity
  - From linear correlation with NHI and 100um emission in low density regime

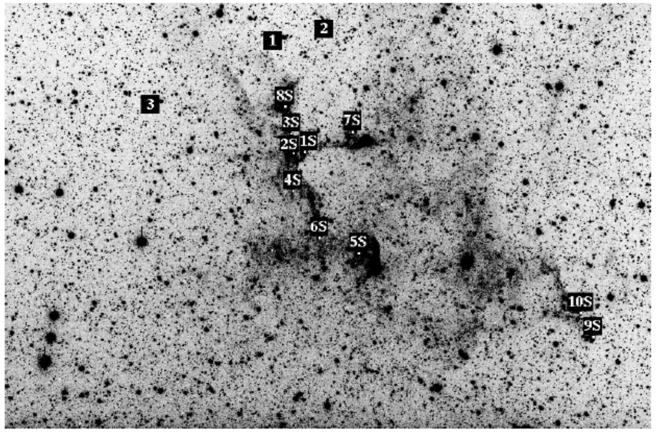
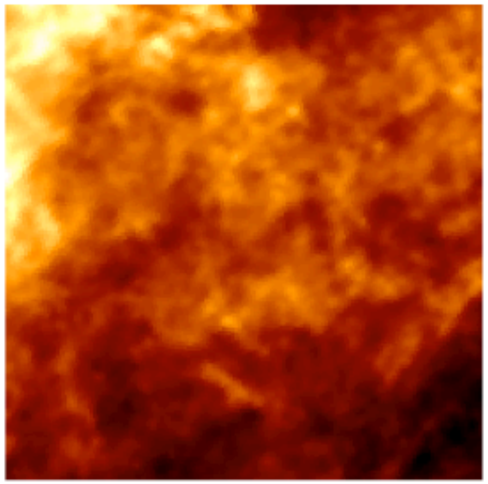


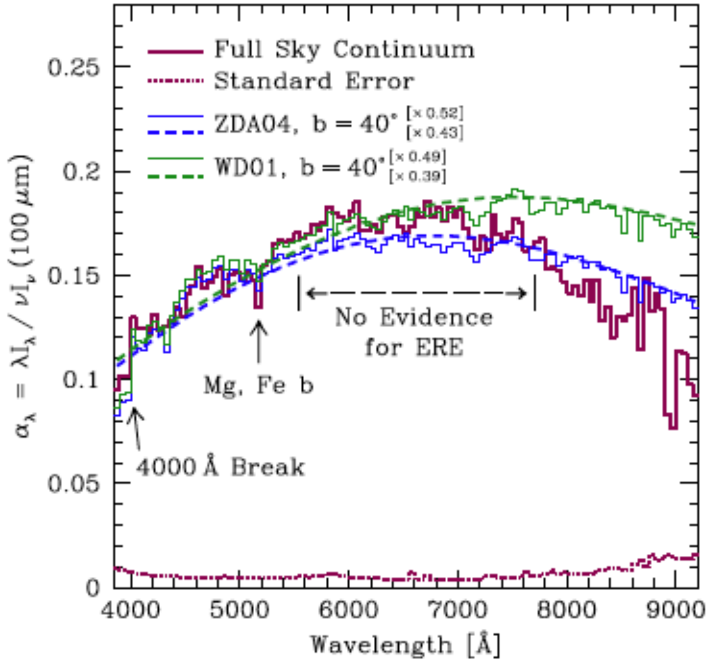
FIG. 2a

FIG. 2.— We display the R-band images of (a) MBM 25, (b) MBM 30, (c) MBM 32, (d) MBM 41A, and (e) MBM 41D. The image sizes are 2° × 3°, with north up and east to the left. Reference sky positions are indicated by labels 1, 2, and 3, while the cloud positions at which surface brightness measurements were conducted are labeled 1S–10S in each case.

Witt et al., ApJ, 679, 497 (2008)



SFD 100um map at the NEP field



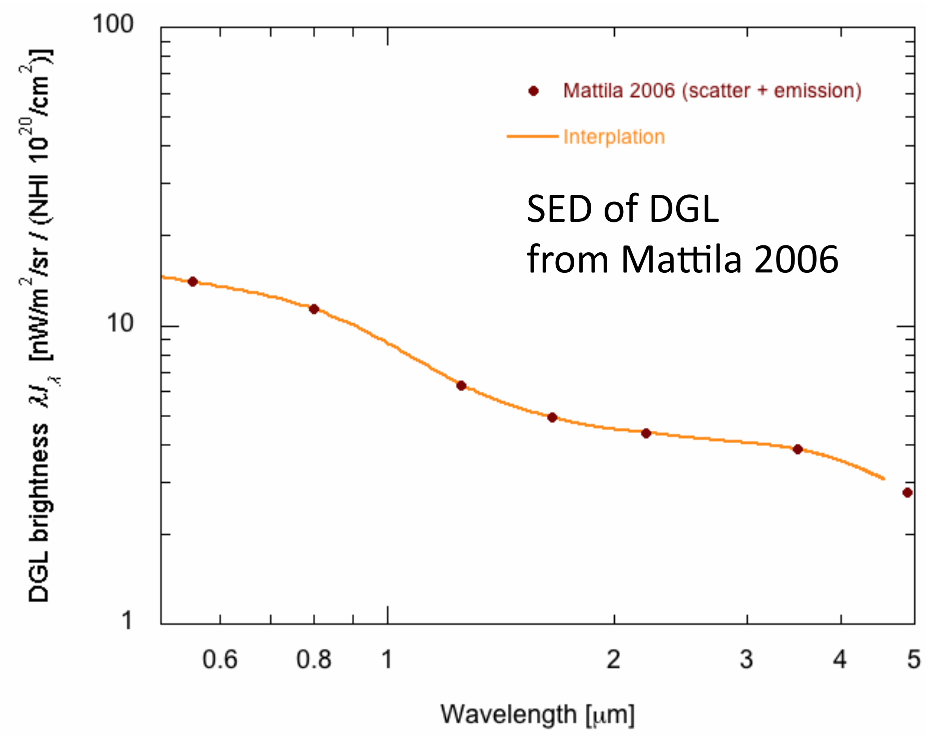
Brandt & Draine., ApJ, 744, 129 (2012)

Uncertainty of the DGL intensity

- DGL estimate from 100um flux is very uncertain
- Factor of ~2 difference among previous works in the visible

- Our estimate here : mid point (Mattila 2006) with 50% error

Reference	Conv. Factor (nW/m²/sr) / (I_{100}MJy/sr)	Wavelength (um)
Mattila 2006	15 (1.5)	0.65 (interpolated)
Witt et al. 2008	7 (0.3)	0.63
Matsuoka et al. 2011	22 (0.6)	0.65
Brandt & Draine 2011	12 (2.2)	0.66



DGL spectra in the observed fields

DGL spectra:

negligibly small at low cirrus region such as SWIRE and Bootes

large comparable to ISL at NEP and Elat fields

Uncertainty:

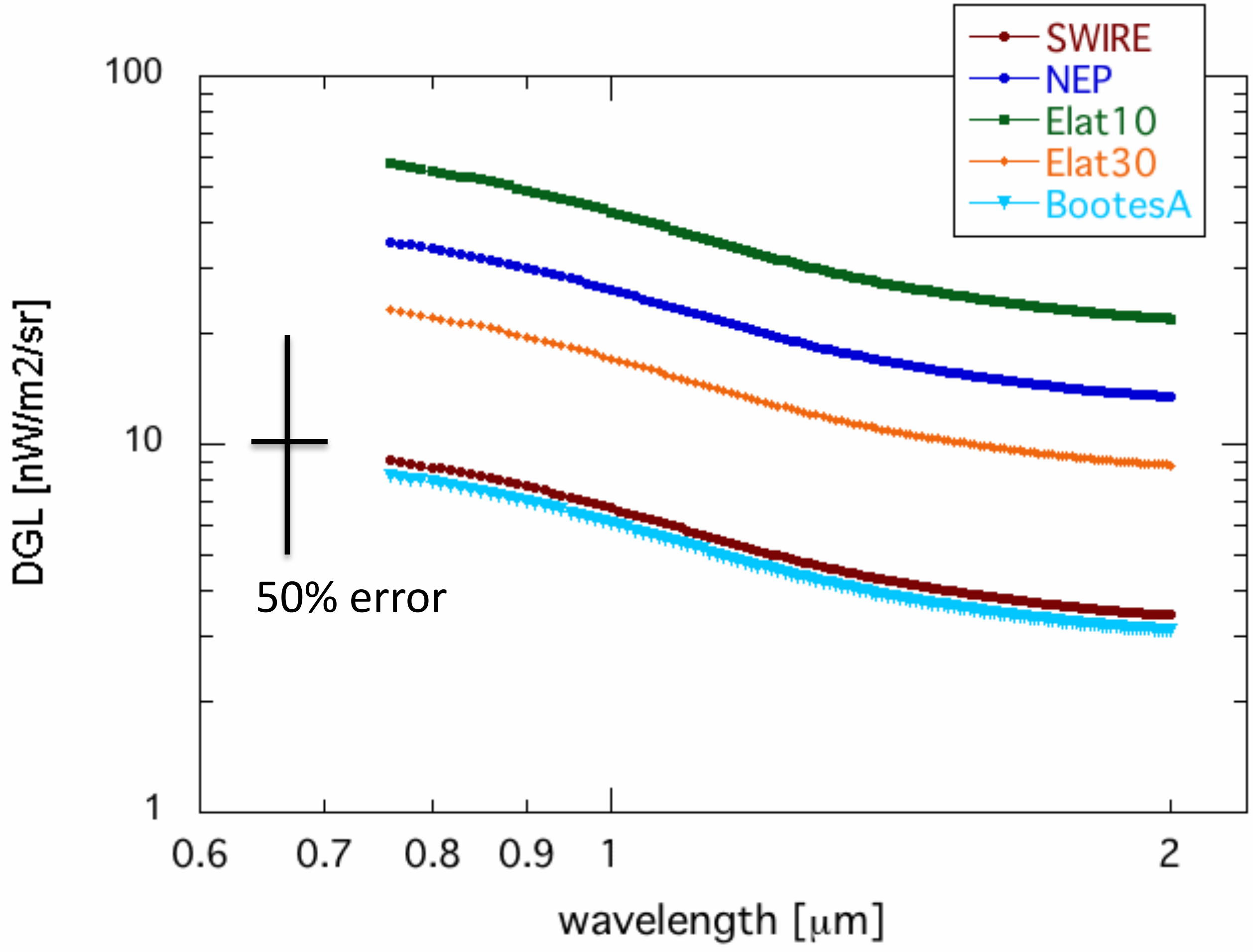
conversion factor : 50%

(to be improved)

100um zero-point error

(Schlegel et al. 1998)

LRS position accuracy



Zodiacal light spectrum

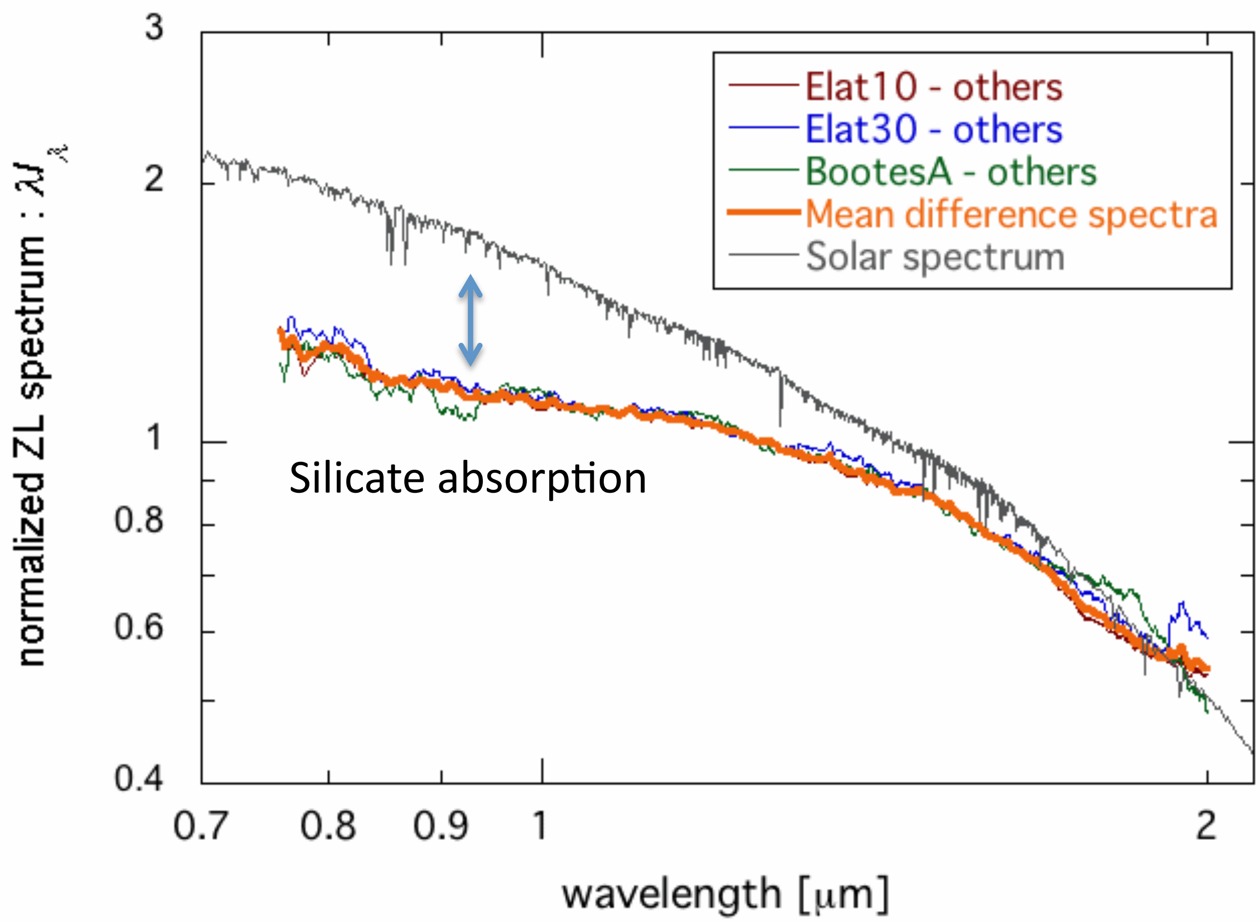
- Zodiacal light (ZL): scattered sun light by interplanetary dust
- ZL spectrum – difference of sky spectra (Sky-ISL-DGL) at different ecliptic latitudes, to extract pure ZL removing isotropic background
- <u>Model-independent</u>

Result :

- Spectral shape is isotropic

→ This spectral template is usable to predict ZL in any places only by scaling

- Silicate absorption
  1st flight result
  Tsumura et al., ApJ, 2010

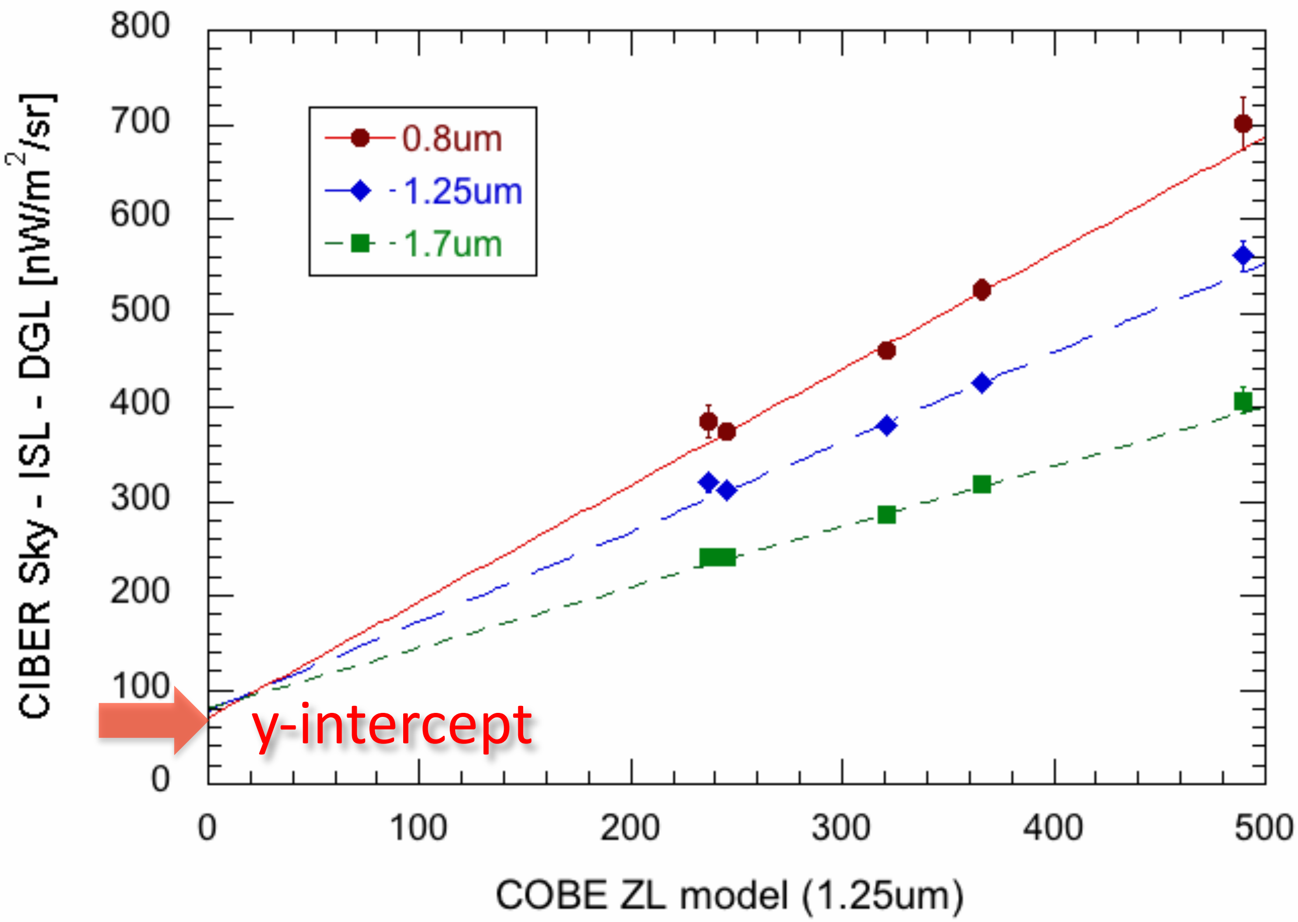


ZL subtraction w/ DIRBE model

- COBE/DIRBE ZL model (Kelsall et al. 1998)
- Correlation method: Sky-ISL-DGL (CIBER) vs. ZL model (1.25um)

  y-intercept = isotropic background

- Good correlation in all CIBER bands
  - Positive intercepts
- Large error bars at Elat10 and NEP are due to DGL



ZL subtraction w/ DIRBE model

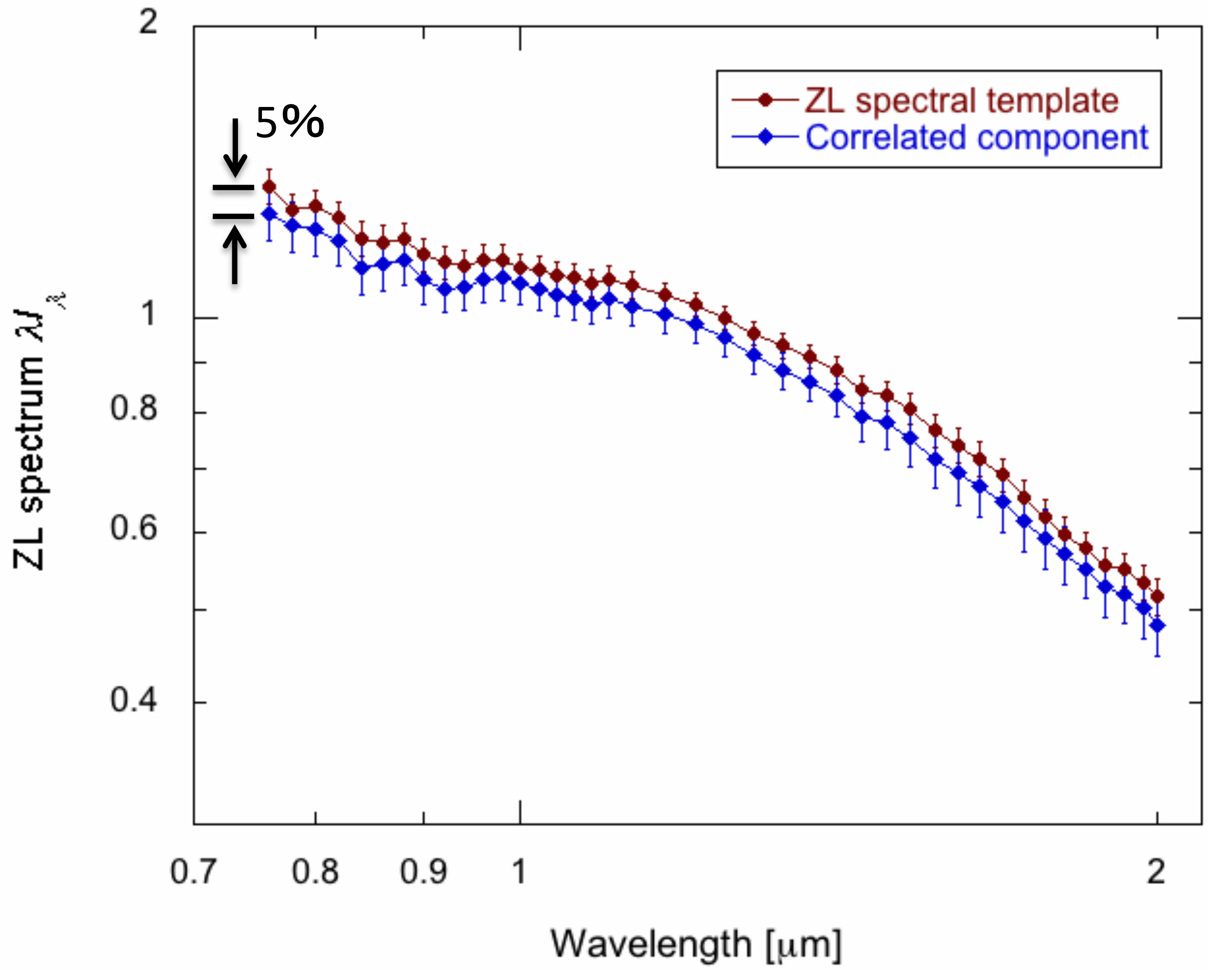
- ZL-model correlated component
  - Spectral shape agrees with the ZL spectral template
  - Intensity is systematically 5% lower due to some gain difference

    Calibration errors:

    CIBER 2%, DIRBE 1.5%

Direct use of the ZL model may cause over-subtraction

→ Correlation method is not affected by this type of systematics

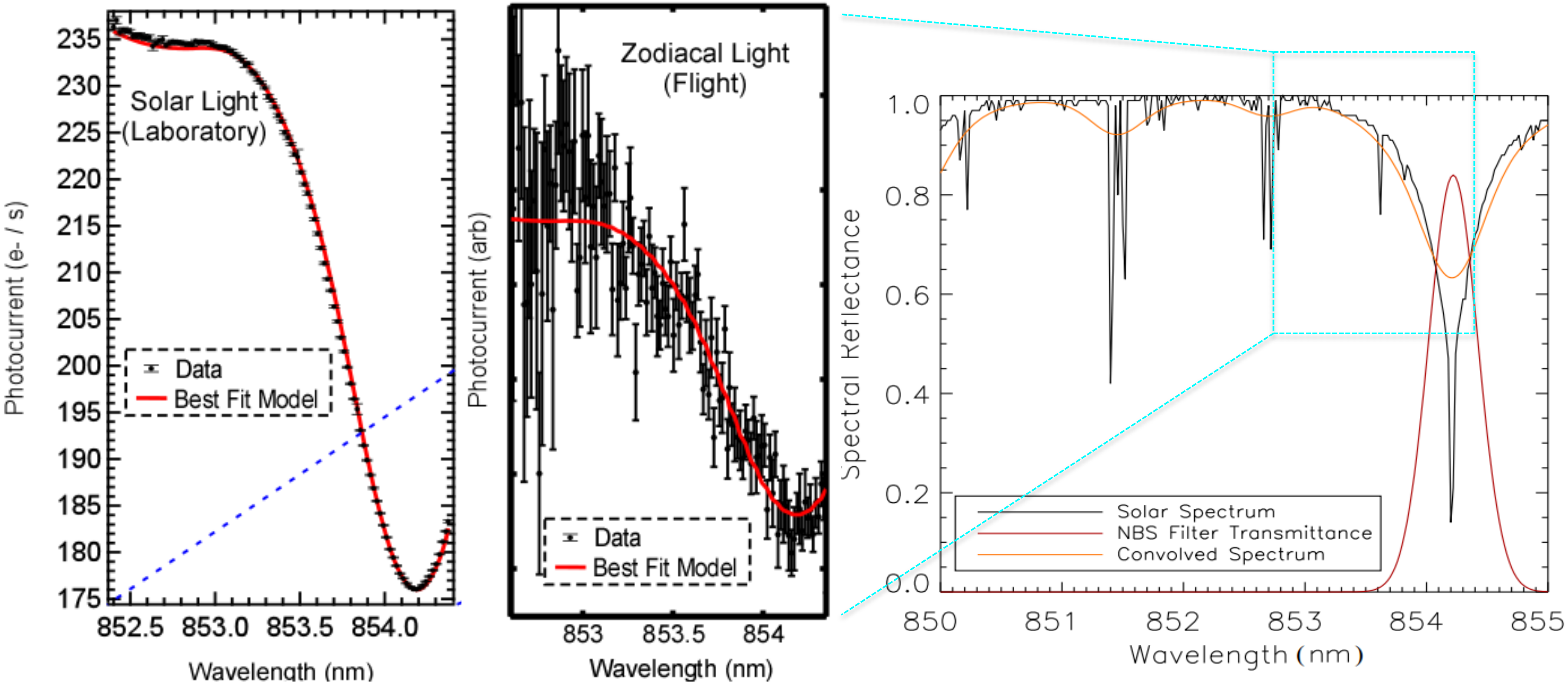


Model independent ZL subtraction

- SED (Silicate absorption) → on-going work with CIBER/LRS
- Fraunhofer line → preliminary result with CIBER/NBS

Korngut et al. (poster presentation at this WS)

Preliminary Fraunhofer Measurements

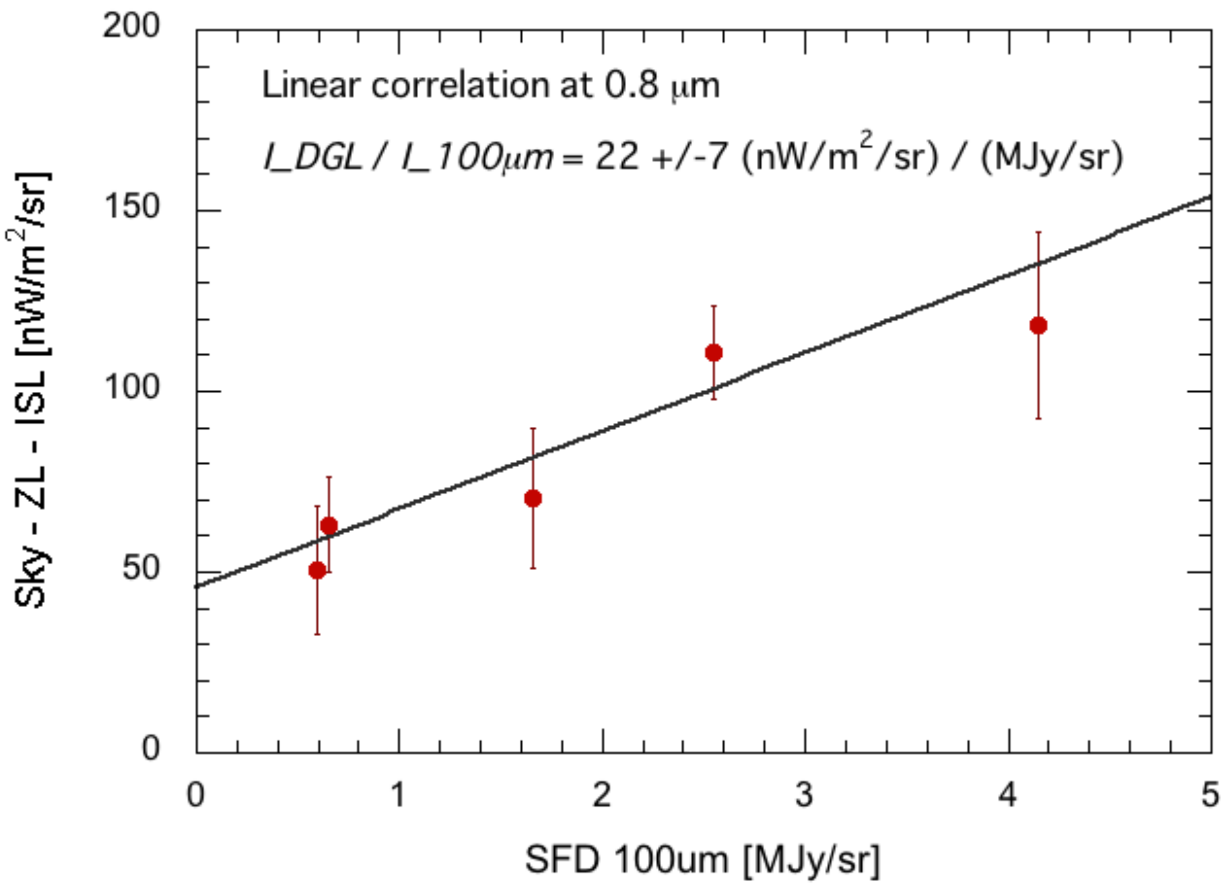


Total error budget

	Mean intensity [nW/m²/sr]	Error	Error contents (+/-error)
Sky (NEP at 1.25μm)	366	1	Airglow subtraction error Detector noise
ZL	236	11 (4) correlation method	ZL template error: 3% ZL model error: 1.5% DIRBE calibration: 1.5%
ISL	25	2	Star count model: 9% Completeness fit Slit aperture correction
DGL	19	10	Conversion factor: 50% 100um map accuracy LRS position error
Calibration	-	7	Absolute calibration: 2%
Uncertainty for EBL	DIRBE 20-60	17 (13)	Detectable

For better estimate of DGL

- Self-consistent scaling of the DGL intensity
  - Sky-ZL-ISL(=DGL+EBL) vs. 100μm
    - Conversion factor = 22+/-7 , inconsistent with primary used factor = 13
    - Similar to Matsuoka et al. 2011 and Mattila's scale for NHI
  - back to ZL correlation for Sky-ISL-DGL



Summary

Result:

- CIBER measured absolute sky spectrum in Vis-NIR
- Foreground subtraction is still on-going work
- Estimated uncertainty indicates detectability of EBL

Future:

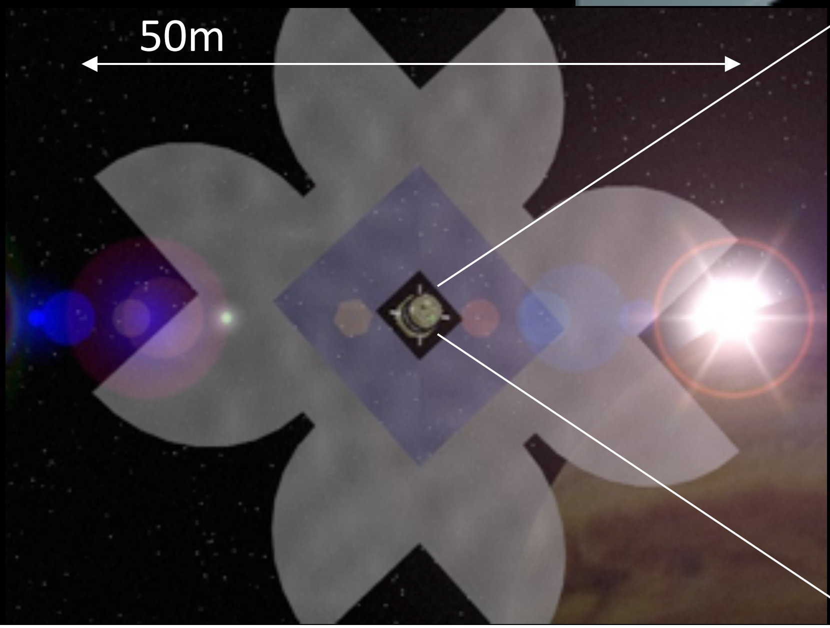
- More works on the foreground analysis
  - Model independent ZL subtraction
- Success of the 3rd CIBER flight on Mar 22, 2012
  - Confirmation of the 2nd flight result presented here
  - Polarization measurement for ZL estimate

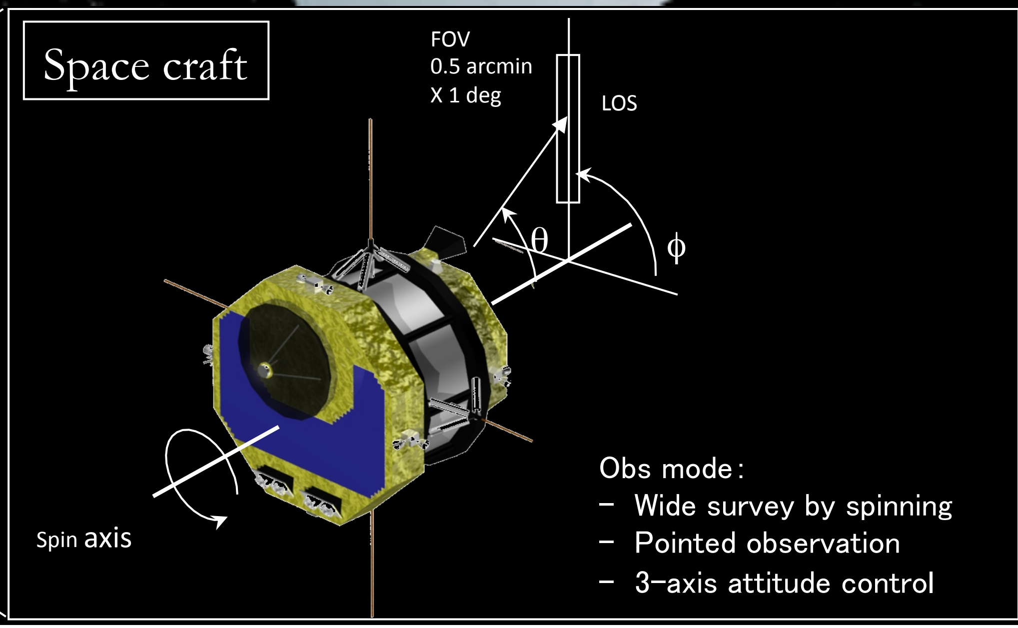
The END

EXZIT : Exo-Zodiacal Infrared Telescope

- Infrared instrument to be onboard Solar-sail spacecraft of JAXA
- Solar-sail mission is to explore Jupiter and Trojan asteroids
- Toward Jupiter orbit at 5AU, observation during the cruising phase
- Absolute spectrum of EBL in Vis-MIR range with no ZL
- Launch ~2020

See poster presentation (Matsuura et al.)





Sensitivity of this mission