SKYSURF: Unveiling the Cosmic Optical Background with Hubble and a new 3D Zodiacal Light Model Optimized for Optical Wavelengths

Rosalia O’Brien

Outline

Published:

1. **Sky-SB Measurements**
2. **COB Measurements**

Not yet published:

3. **A New Model of Zodiacal Light**
4. **Refined Diffuse Galactic Light Measurements**

Outline

My focus:
The diffuse components of SKYSURF

Published:

1. **Sky-SB Measurements**
2. **COB Measurements**

Not yet published:

3. **A New Model of Zodiacal Light**
4. **Refined Diffuse Galactic Light Measurements**

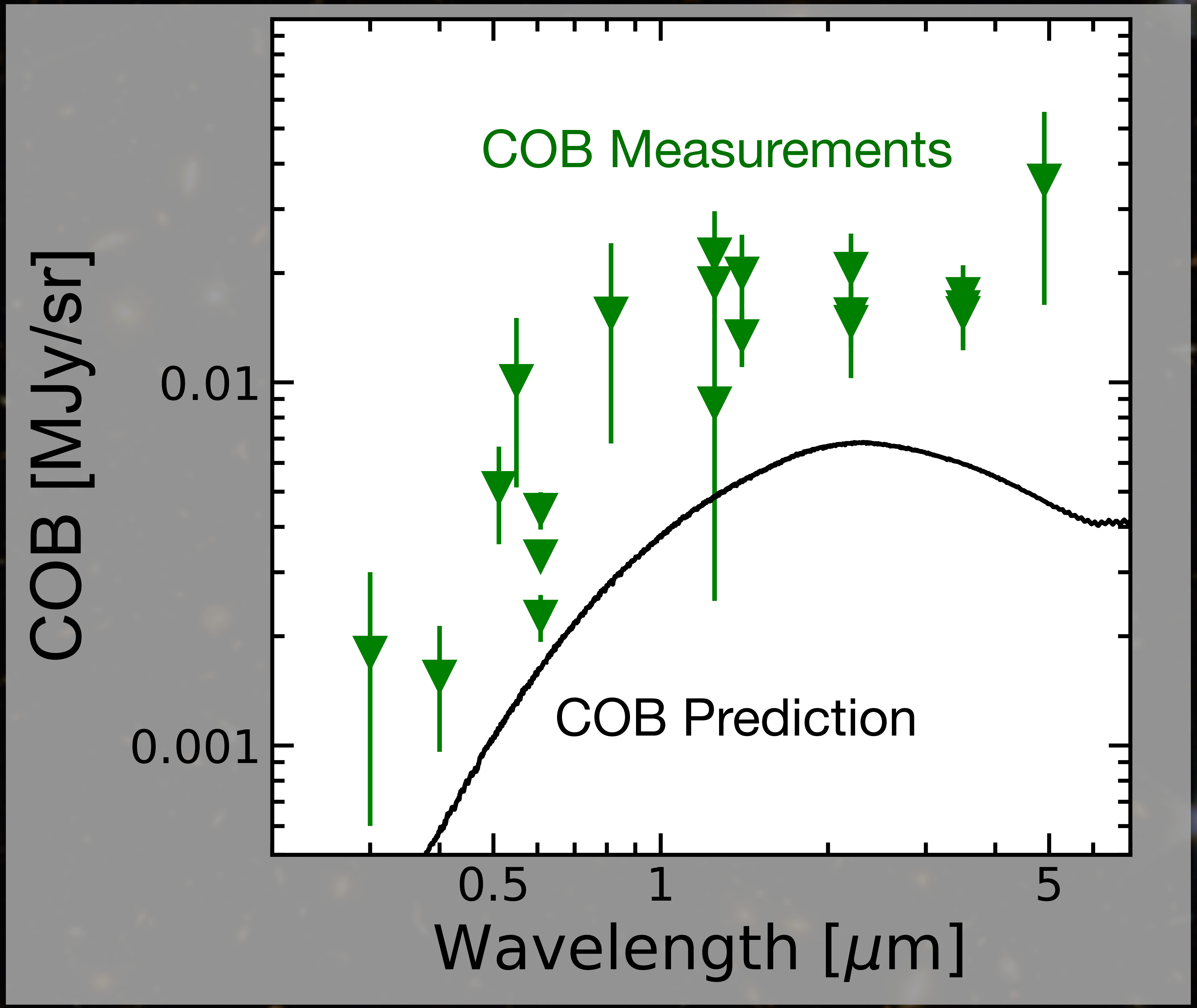
SKYSURF

skysurf.asu.edu

Project SKYSURF

- SKYSURF-1 (Windhorst+2022) - Survey Overview
- SKYSURF-2 (Carleton+2022) - First COB Measurements
- SKYSURF-3 (Kramer+2022) - Testing Crowded Fields for COB Measurements
- **SKYSURF-4 (O'Brien+2023) - Sky Measurements**
- SKYSURF-5 (Bhatia+2024) - Cross matching with SDSS
- **SKYSURF-6 (McIntyre+2024) - Thermal Variations of Hubble**
- **SKYSURF-10? (O'Brien+2025) - Refined Zodiacal Light Model**

The Cosmic Optical Background - Today



Current COB measurements face limitations due to

- small number of fields,
- narrow wavelength coverage,
- bright foregrounds,
- low sensitivity, and
- telescope systematics.

Project SKYSURF

PI: Prof. Rogier Windhorst (ASU)

Over 200,000 images

Wavelengths: 0.2 to 1.6 μm

The Hubble Space Telescope

Benefits:

- Extremely well calibrated instrument
- Thousands of independent areas of sky
- Broad wavelength coverage
- High resolution & sensitivity

Project SKYSURF

PI: Prof. Rogier Windhorst (ASU)

Over 200,000 images

Wavelengths: 0.2 to 1.6 μm

The Hubble Space Telescope

Goals:

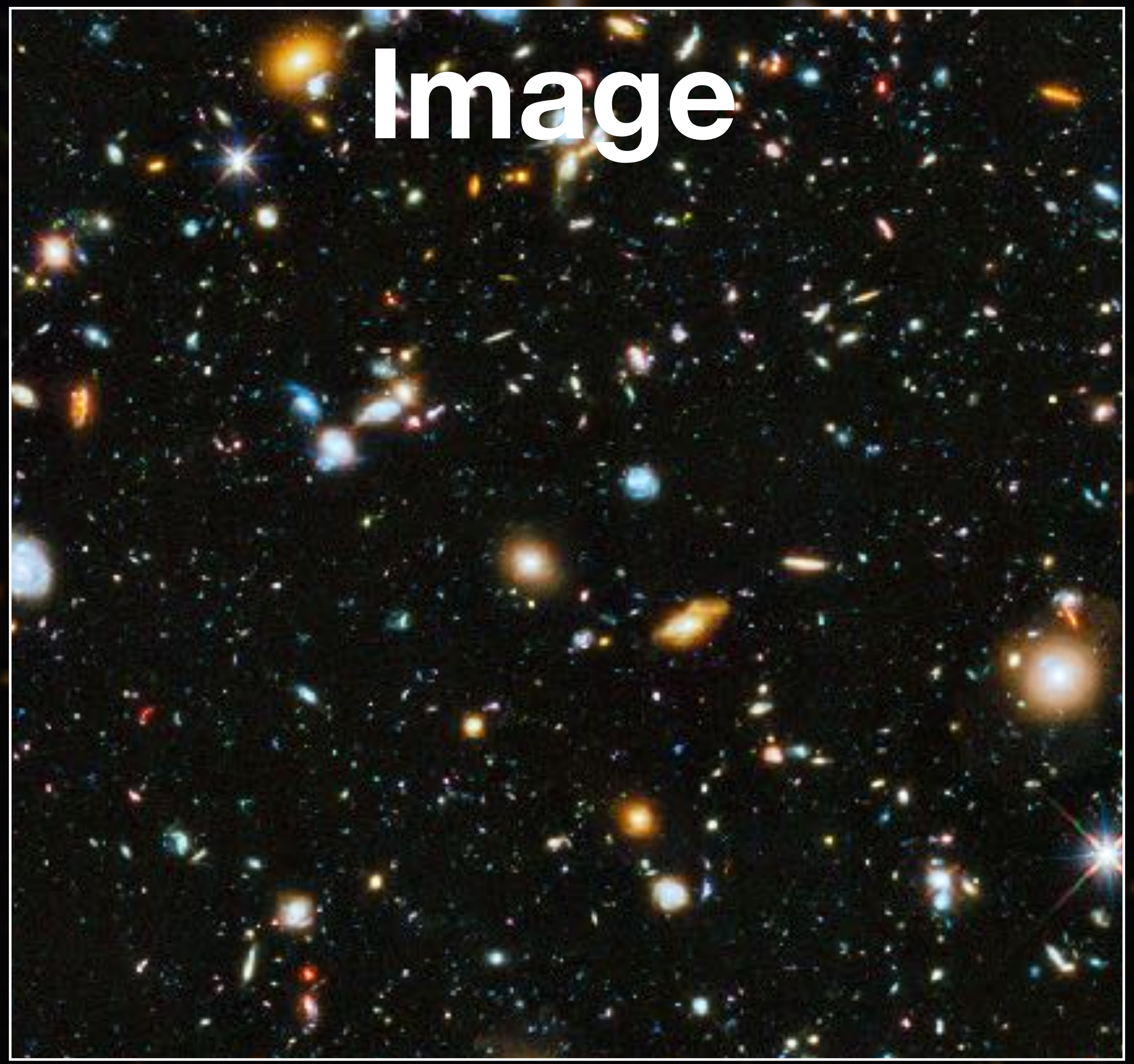
1. Measure the sky in all Hubble images
2. Retrieve COB signal by subtracting foregrounds

Over 200,000 images

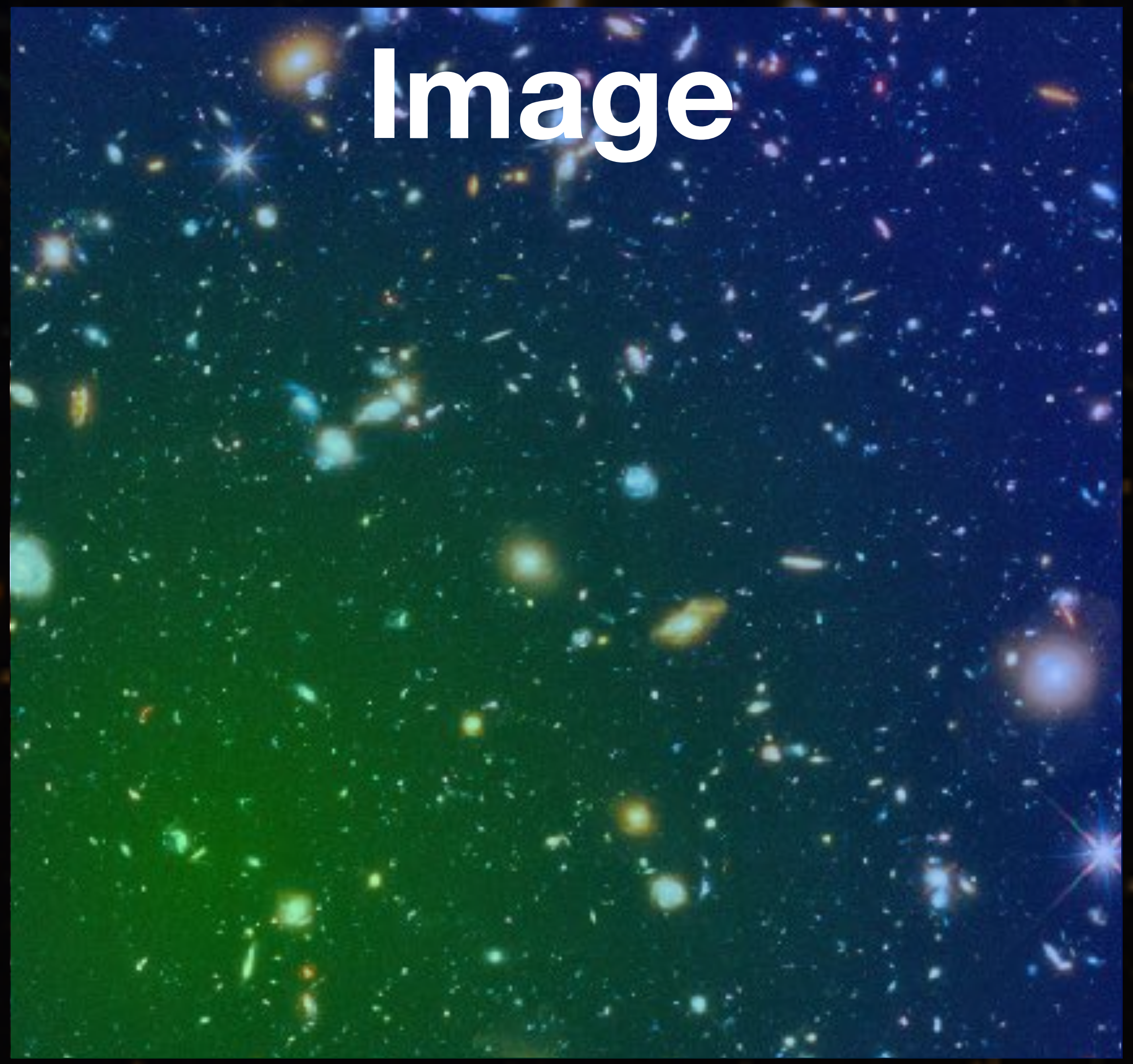
Wavelengths: 0.2 to 1.6 μm

1. Measure the sky surface brightness (sky-SB)

What is the sky surface brightness (sky-SB)?

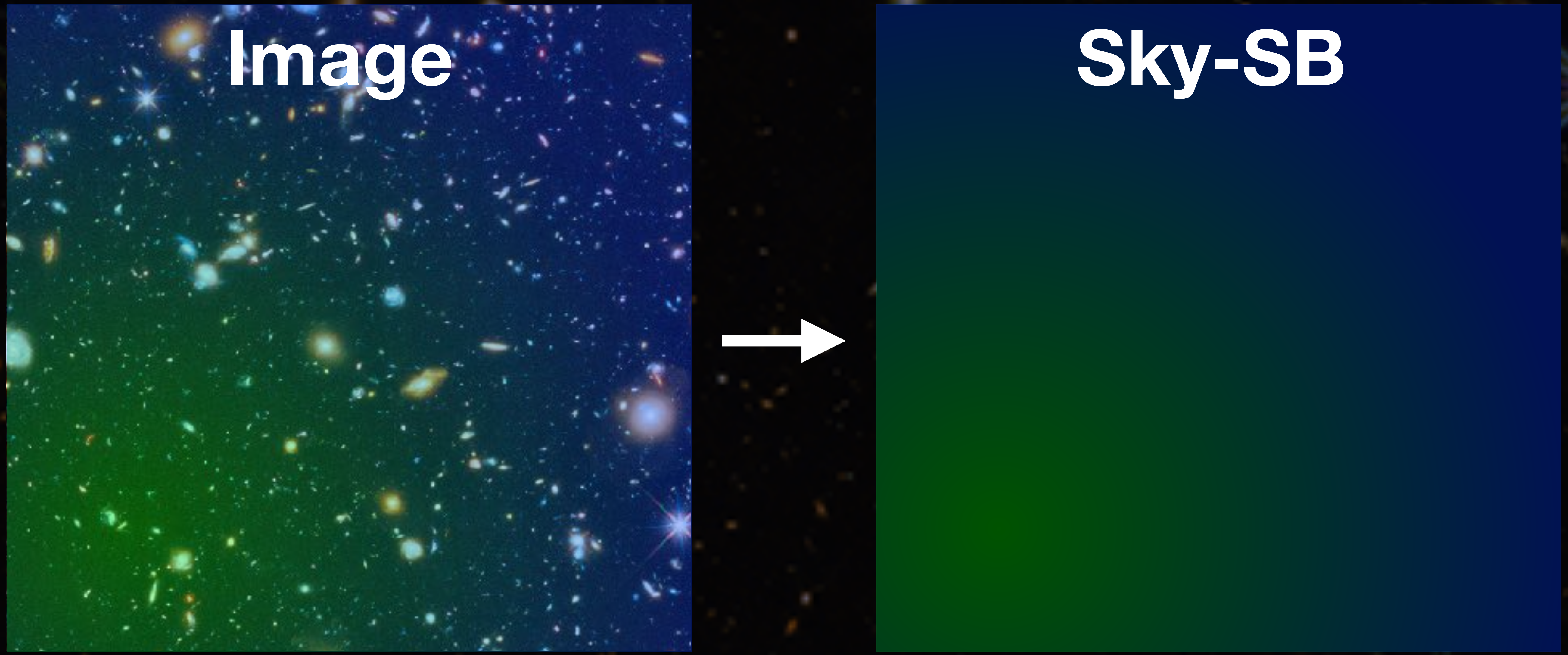


What is the sky surface brightness (sky-SB)?



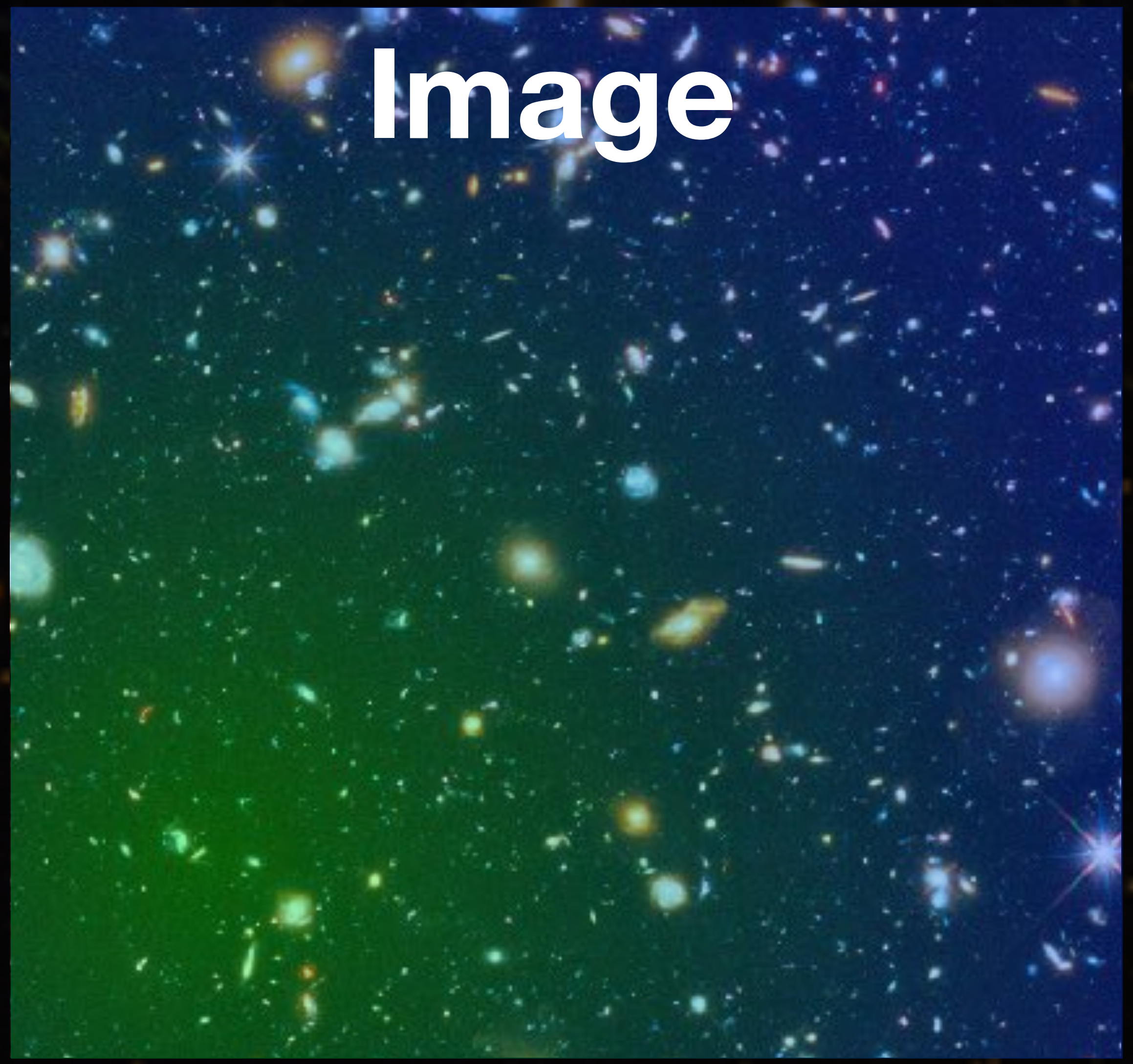
What is the sky surface brightness (sky-SB)?

Sky-Surface Brightness (sky-SB)



What is the sky surface brightness (sky-SB)?

Sky-Surface Brightness (sky-SB)



→

Zodiacal Light - Light scattered by dust in our Solar System

Diffuse Galactic Light - Light scattered by Milky Way ISM

COB/ EBL

Other

Sky-SB Measurements

THE ASTRONOMICAL JOURNAL, 165:237 (25pp), 2023 June
https://doi.org/10.3847/1538-3881/acccee

CrossMark

SKYSURF-4: Panchromatic Hubble Space Telescope All-Sky Surface-brightness Measurement Methods and Results

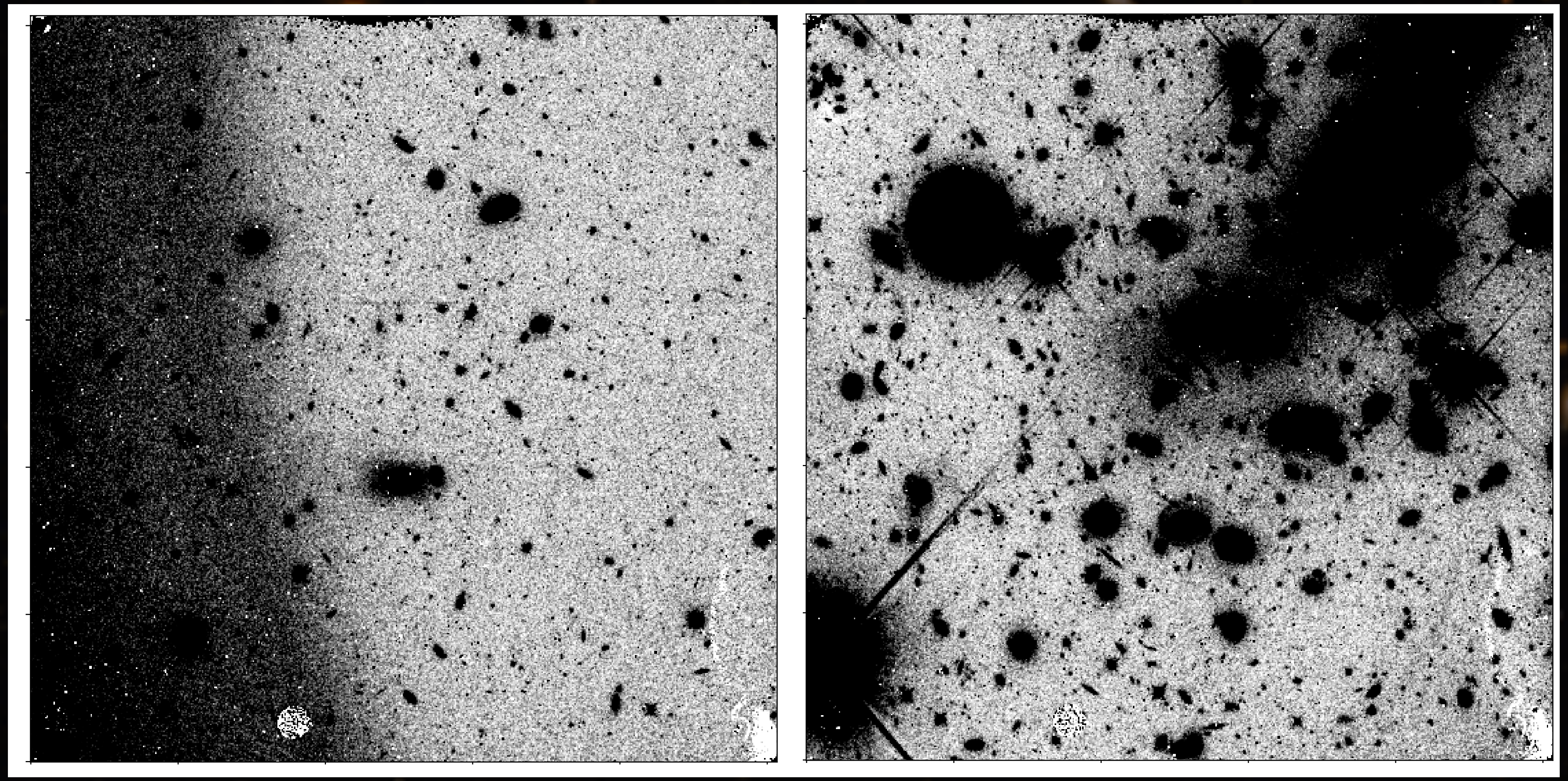
Rosalia O'Brien[1], Timothy Carleton[1], Rogier A. Windhorst[1], Rolf A. Jansen[1], Delondrae Carter[1], Scott Tompkins[2], Sarah Caddy[3], Seth H. Cohen[1], Haley Abate[1], Richard G. Arendt[4], Jessica Berkheimer[1], Annalisa Calamida[5], Stefano Casertano[5], Simon P. Driver[6], Connor Gelb[1], Zak Goisman[1], Norman Grogin[5], Daniel Henningsen[1], Isabela Huckabee[1], Scott J. Kenyon[7], Anton M. Koekemoer[5], Darby Kramer[1], John Mackenty[5], Aaron Robotham[6], and Steven Sherman[1]

+150,000 Public Sky-SB Measurements
<3% Uncertainties
Preliminary COB Measurements

Sky-SB Measurements

O'Brien et al. 2023

Real Hubble Images:

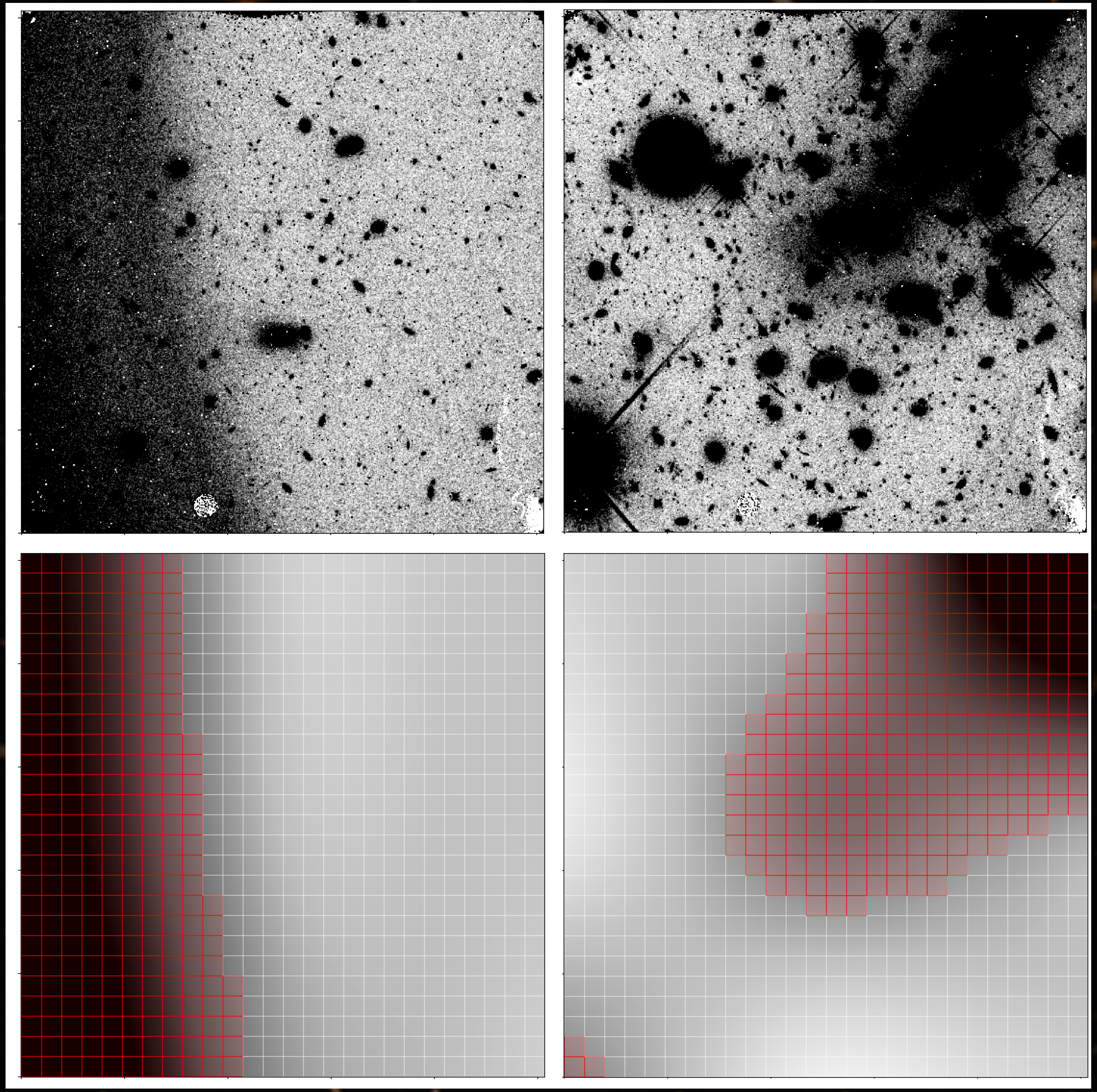


Sky-SB Measurements

O'Brien et al. 2023

Real Hubble Images:

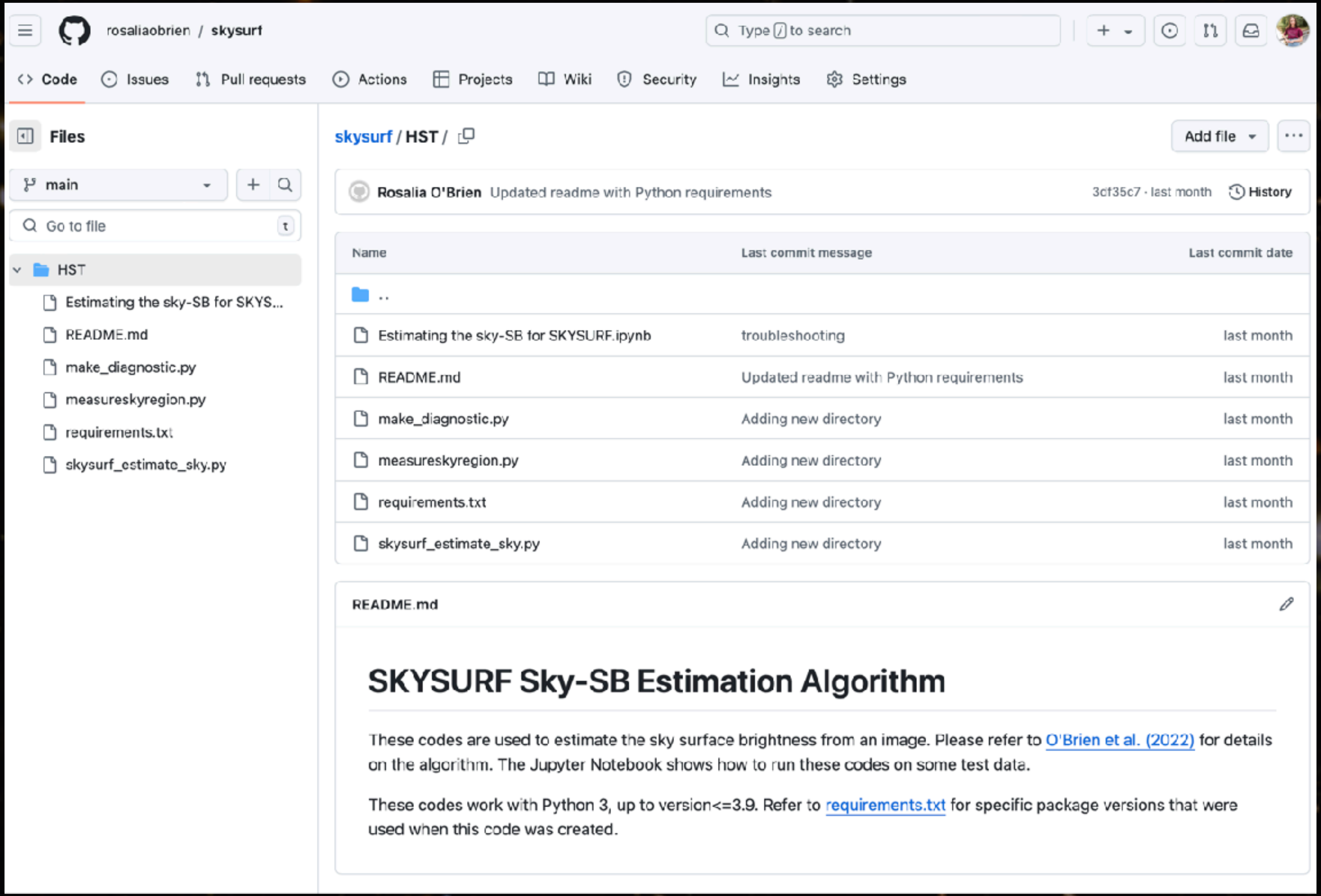
SKYSURF Sky Maps:



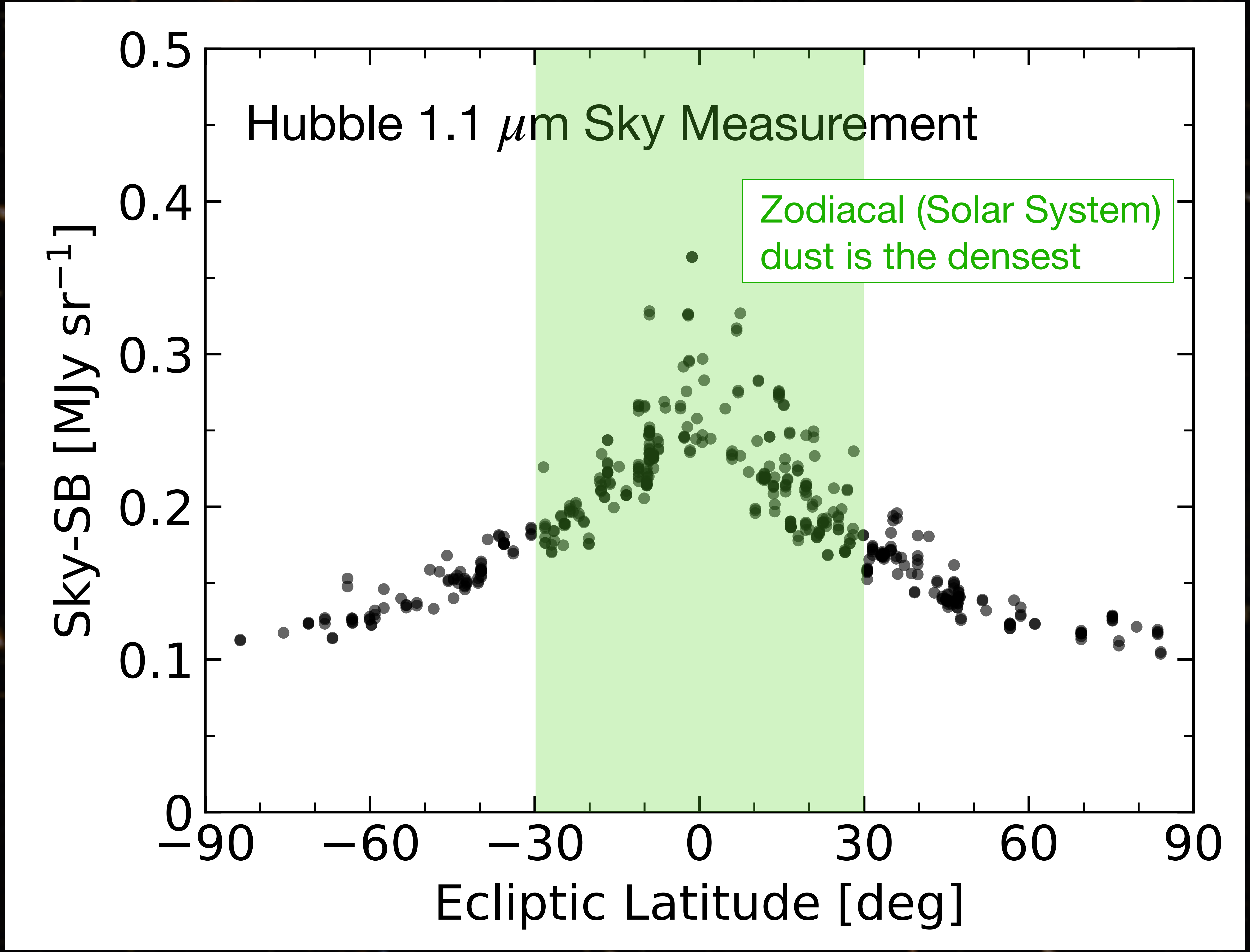
Used ProFound (Robotham et al. 2018) to create Sky maps

Our algorithm isolates most reliable part of the sky

Sky-SB Measurements



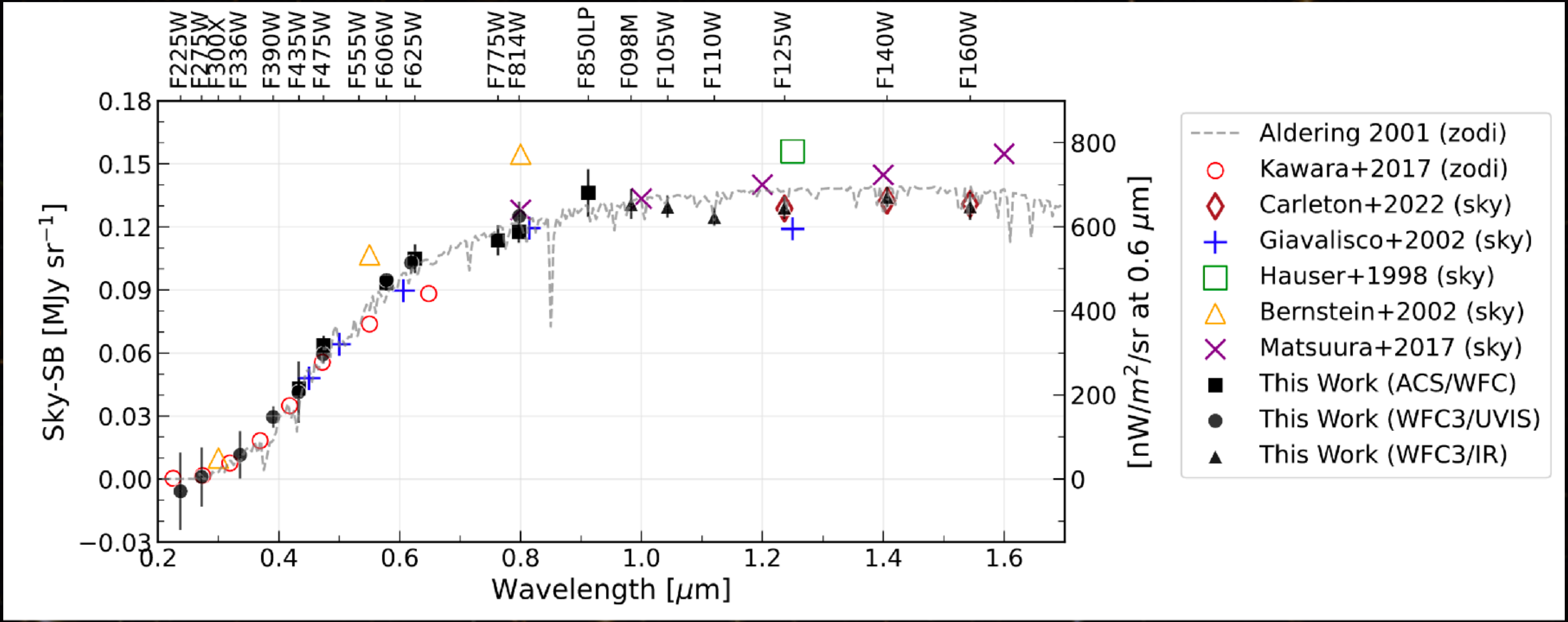
Sky-SB Measurements



O'Brien et al. 2023

Sky-SB Measurements

O'Brien et al. 2023



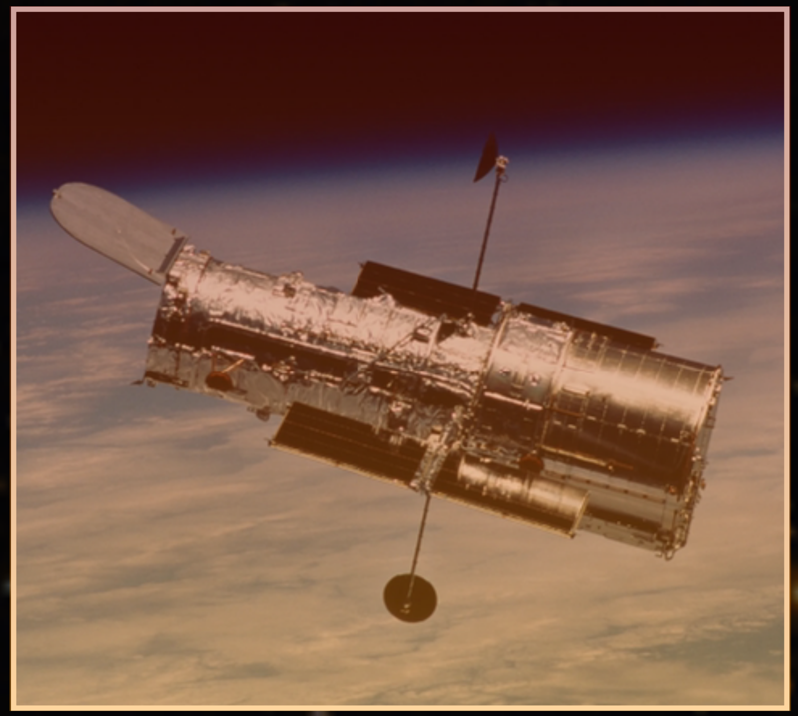
Thermal Emission Corrections

Thermal Emission Corrections

SKYSURF VI: The Impact of Thermal Variations of HST on Background Light Estimates

Isabel A. McIntyre,[1] Timothy Carleton,[1] Rosalia O'Brien,[1] Rogier A. Windhorst,[1] Sarah Caddy,[2] Seth H. Cohen,[1] Rolf A. Jansen,[1] John MacKenty,[3] and Scott J. Kenyon[4]

Thermal Dark Signal is instrument glow due to Hubble being > 0 Kelvin

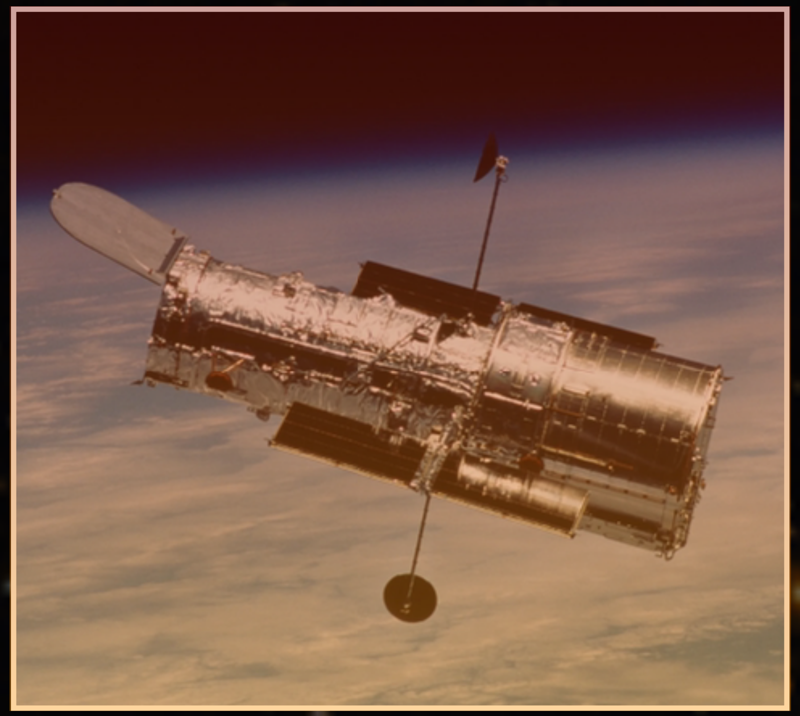


Thermal Emission Corrections

SKYSURF VI: The Impact of Thermal Variations of HST on Background Light Estimates

Isabel A. McIntyre,[1] Timothy Carleton,[1] Rosalia O'Brien,[1] Rogier A. Windhorst,[1] Sarah Caddy,[2] Seth H. Cohen,[1] Rolf A. Jansen,[1] John MacKenty,[3] and Scott J. Kenyon[4]

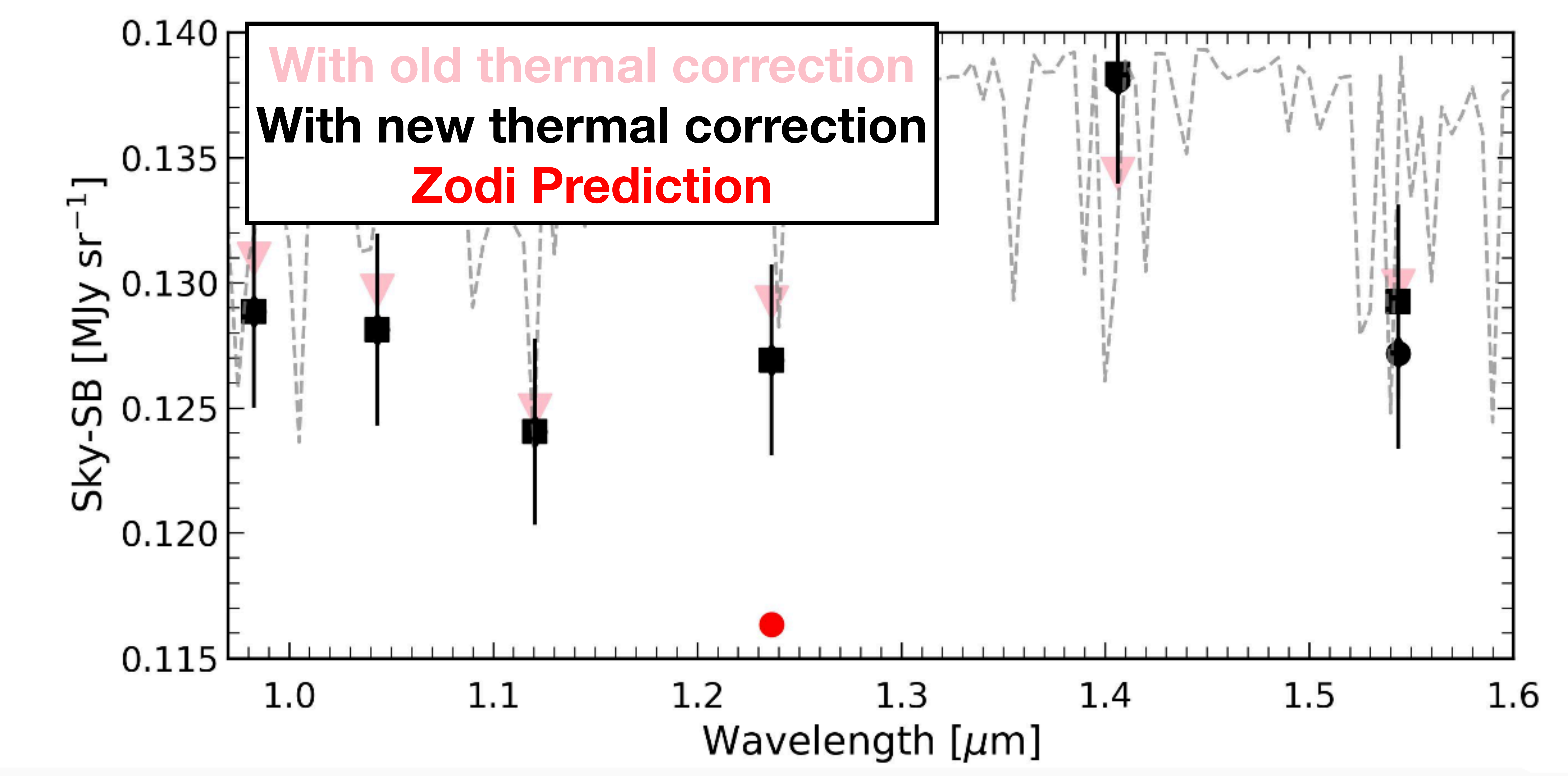
Thermal Dark Signal is instrument glow due to Hubble being > 0 Kelvin



Thermal dark corrections (in electrons/pix/s)
McIntyre et al. 2024

Filter	T_{POM} Thermal Dark	
	Min	Max
F098M	0.00454	0.00454
F105W	0.00455	0.00455
F110W	0.00480	0.00480
F125W	0.00479	0.00480
F140W	0.0213	0.0216
F160W	0.0807	0.0819

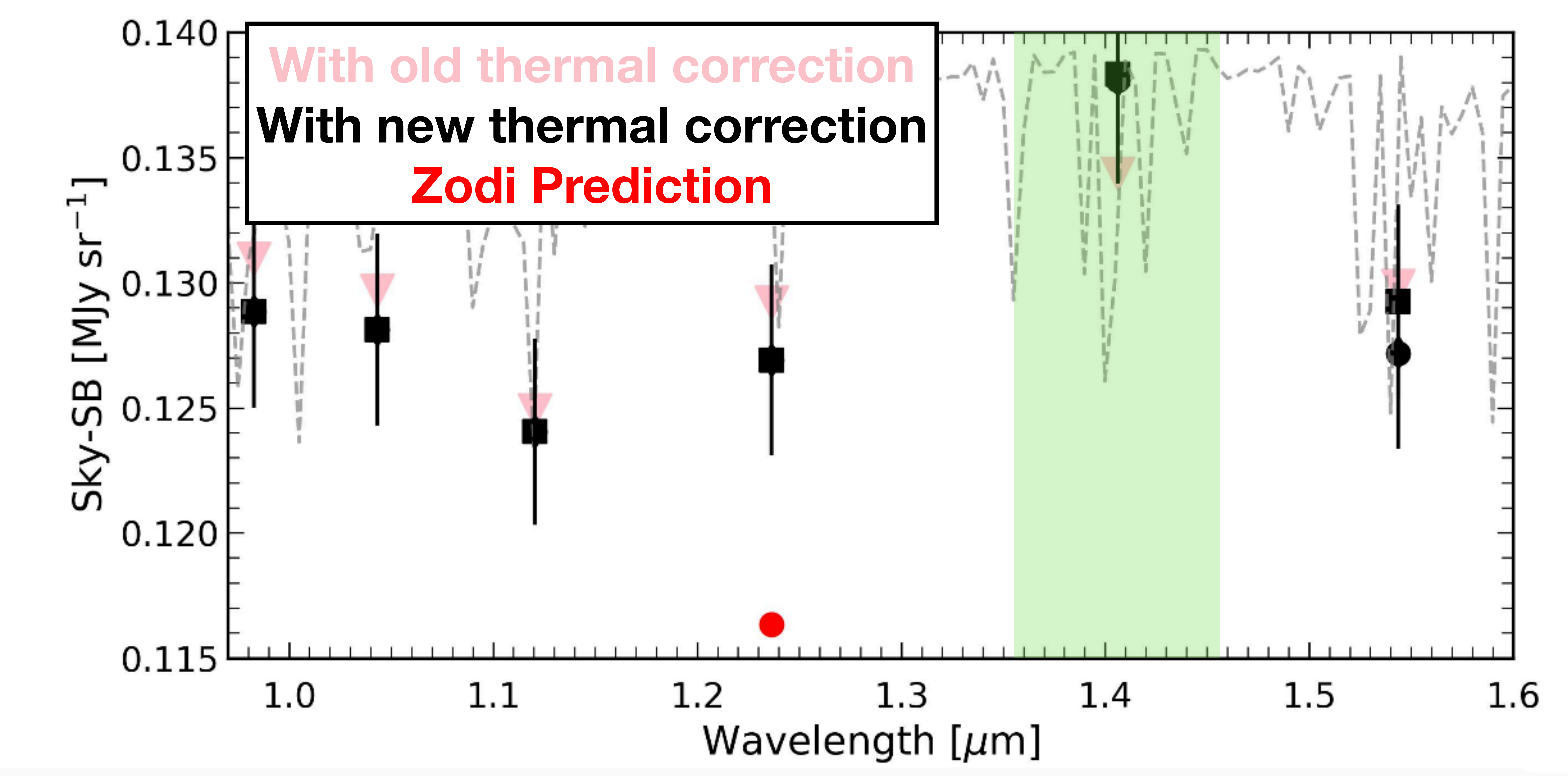
Thermal Emission Corrections



McIntyre et al. 2024

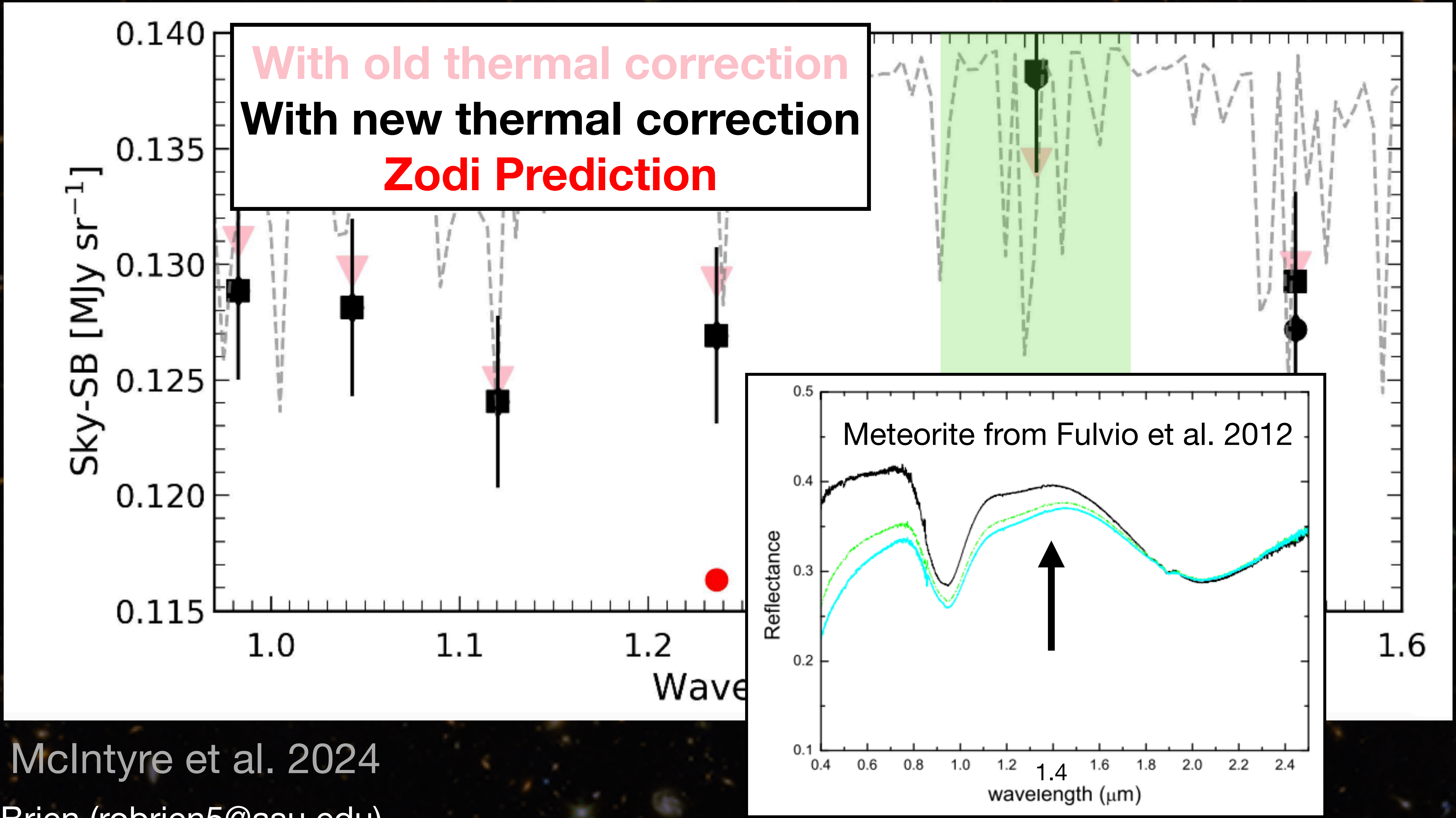
Rosalia O'Brien (robrien5@asu.edu)

Thermal Emission Corrections



McIntyre et al. 2024

Thermal Emission Corrections



McIntyre et al. 2024

2. Retrieve COB Signal

Measurement of COB

COB =
???

Measurement of COB

COB =

Sky-SB

Sky-SB - Image brightness ignoring discernible stars and galaxies

Measurement of COB

COB =

Sky-SB - Zodiacal Light

Sky-SB - Image brightness ignoring discernible stars and galaxies

Zodiacal Light - Light scattered off Solar System dust

>90% of total Sky brightness!

Measurement of COB

COB =

Sky-SB - Zodiacal Light - DGL

Sky-SB - Image brightness ignoring discernible stars and galaxies

Zodiacal Light - Light scattered off Solar System dust

Diffuse Galactic Light (DGL) - Light scattered off interstellar medium in Milky Way

Measurement of COB

COB =
Sky-SB - Zodiacal Light - DGL - Thermal Dark Signal

Sky-SB - Image brightness ignoring discernible stars and galaxies

Zodiacal Light - Light scattered off Solar System dust

Diffuse Galactic Light (DGL) - Light scattered off interstellar medium in Milky Way

Thermal Dark Signal - Instrument glow due to Hubble being > 0 Kelvin

Measurement of COB

COB =

Sky-SB - Zodiacal Light - DGL - Thermal Dark Signal + Galaxy Light

Sky-SB - Image brightness ignoring discernible stars and galaxies

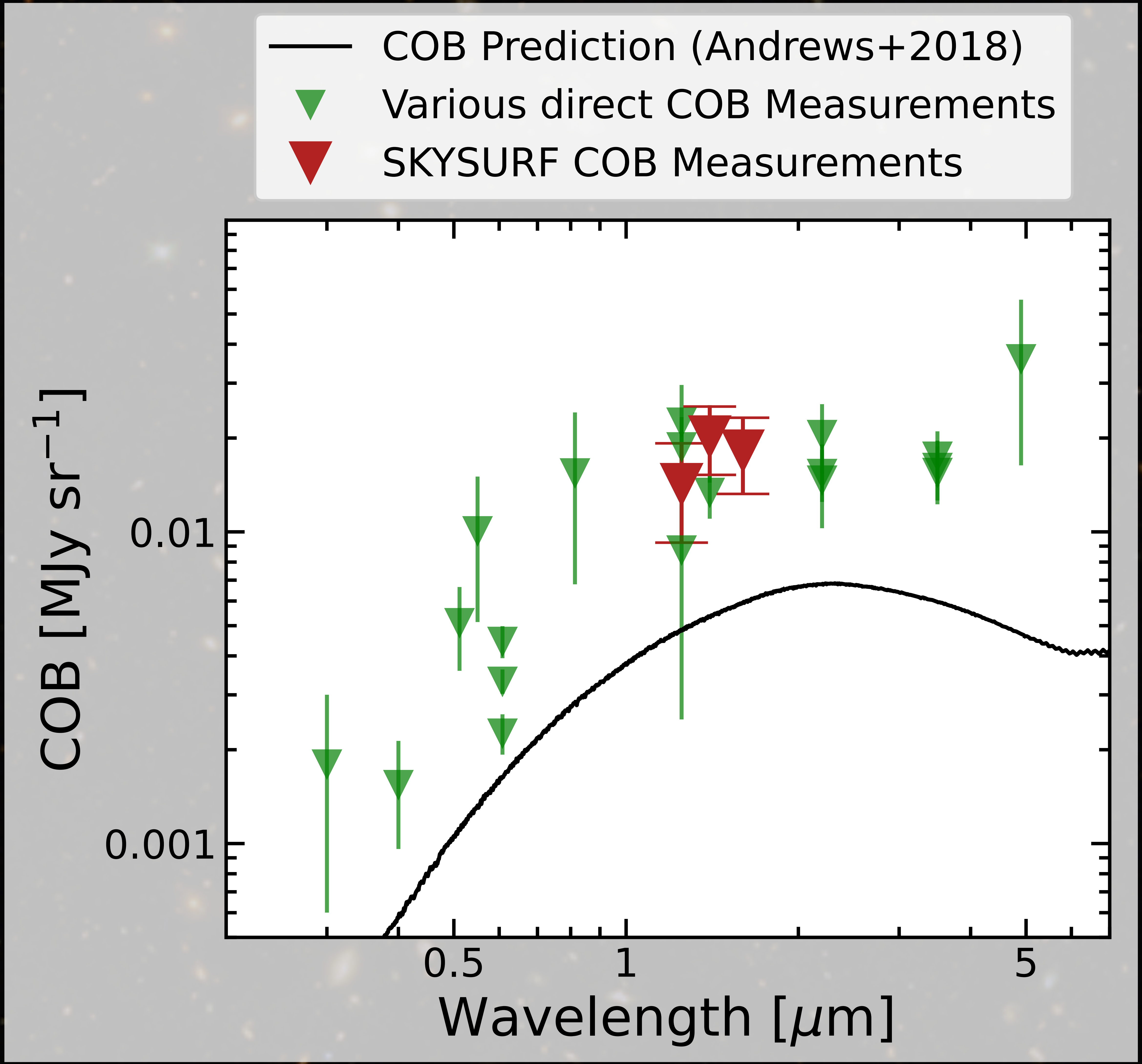
Zodiacal Light - Light scattered off Solar System dust

Diffuse Galactic Light (DGL) - Light scattered off interstellar medium in Milky Way

Thermal Dark Signal - Instrument glow due to Hubble being > 0 Kelvin

Galaxy Light - Light from all galaxies

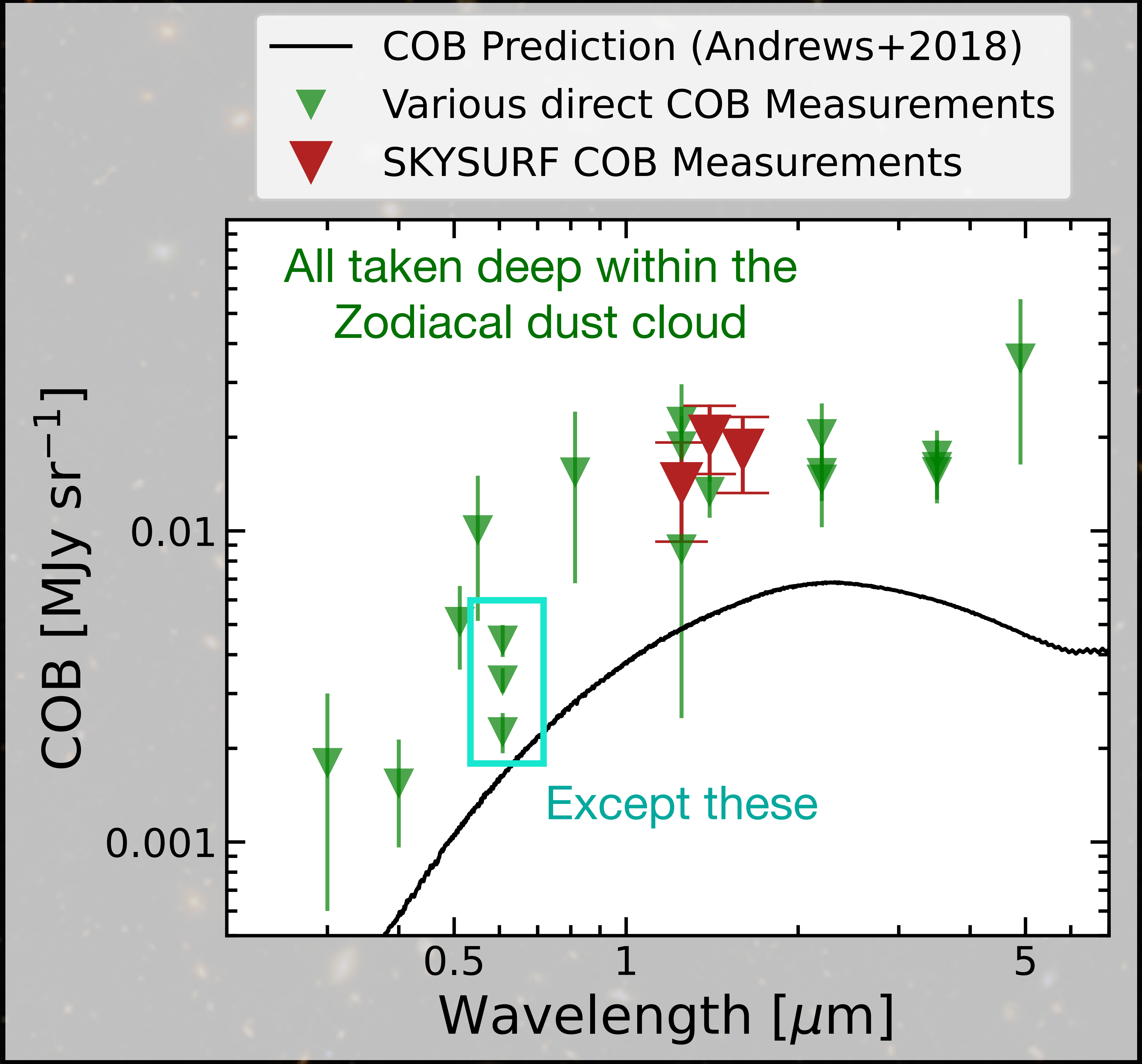
Measurement of COB



For SKYSURF COB Measurements, see

Windhorst et al. 2022
Carleton et al. 2022
O'Brien et al. 2023
McIntyre et al. 2024

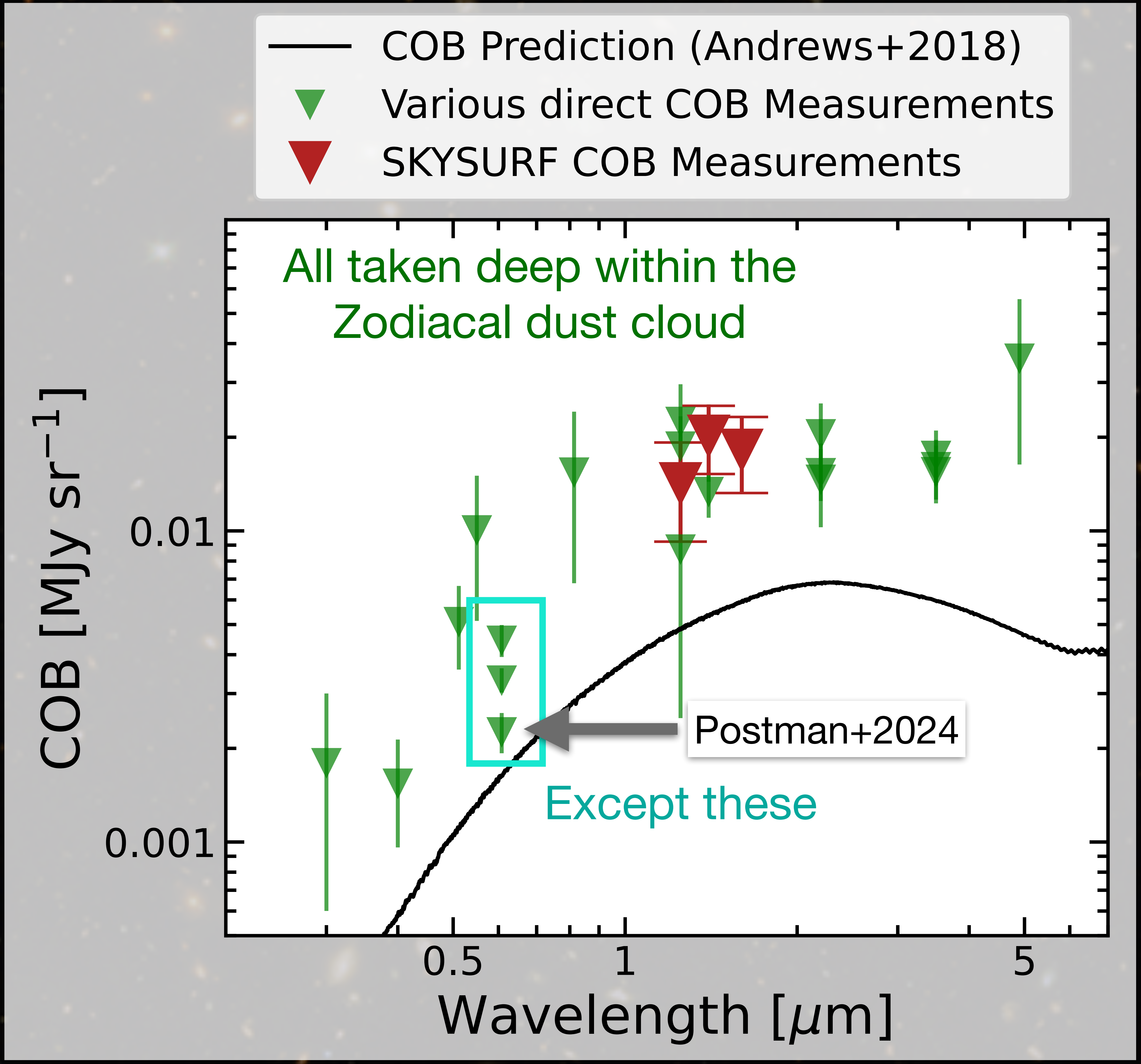
Measurement of COB



For SKYSURF COB Measurements, see

Windhorst et al. 2022
Carleton et al. 2022
O'Brien et al. 2023
McIntyre et al. 2024

Measurement of COB



For SKYSURF COB Measurements, see

Windhorst et al. 2022
Carleton et al. 2022
O'Brien et al. 2023
McIntyre et al. 2024

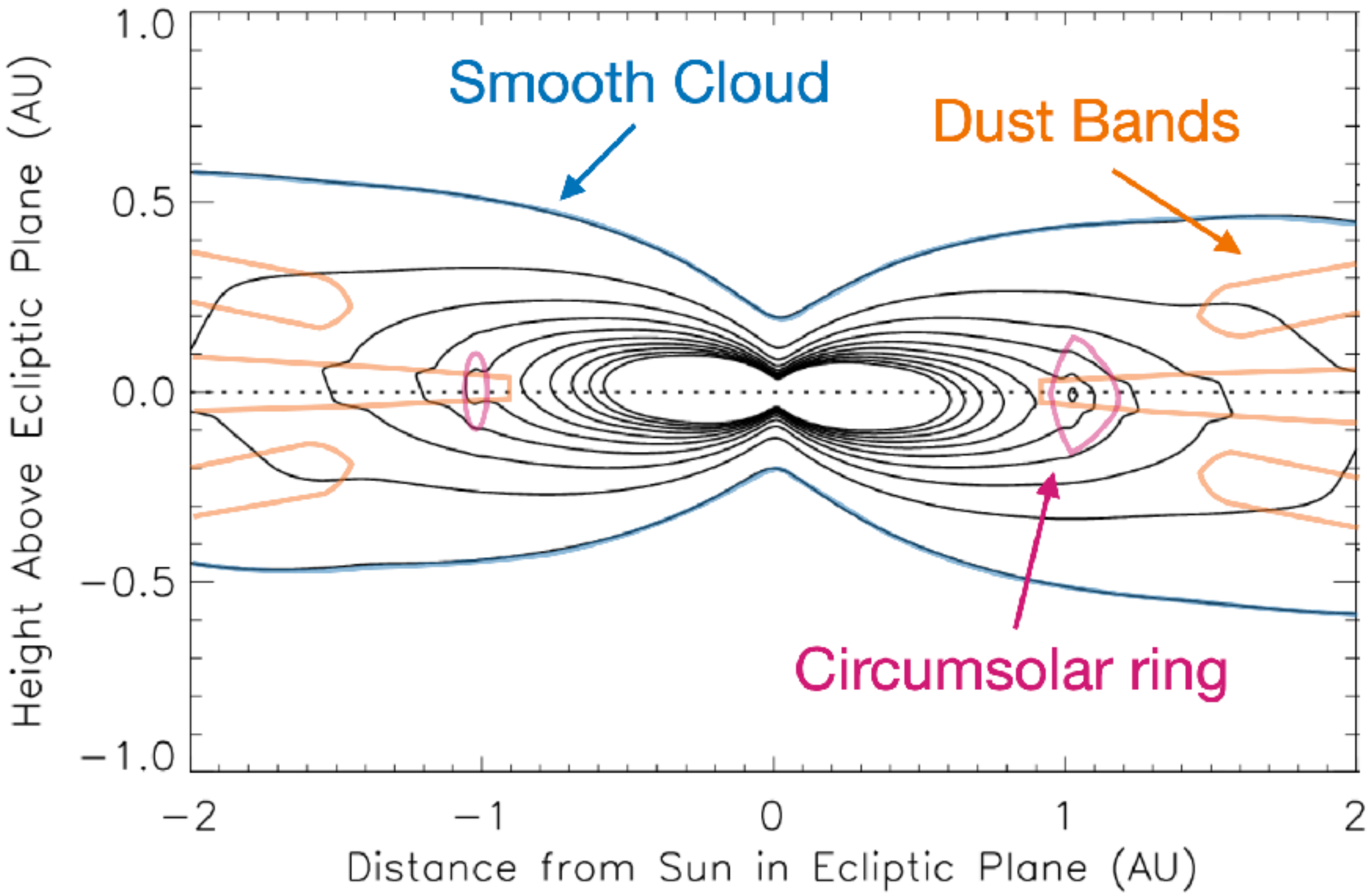
Creating a 3D Zodiacal Light Model Optimized for Optical Wavelengths

Rosalia O’Brien (robrien5@asu.edu)

THE *COBE* DIFFUSE INFRARED BACKGROUND EXPERIMENT SEARCH FOR THE COSMIC INFRARED BACKGROUND. II. MODEL OF THE INTERPLANETARY DUST CLOUD

T. Kelsall,[1,2] J. L. Weiland,[3] B. A. Franz,[4] W. T. Reach,[5] R. G. Arendt,[3] E. Dwek,[1] H. T. Freudenreich,[3] M. G. Hauser,[6] S. H. Moseley,[1] N. P. Odegard,[3] R. F. Silverberg,[1] and E. L. Wright[7]

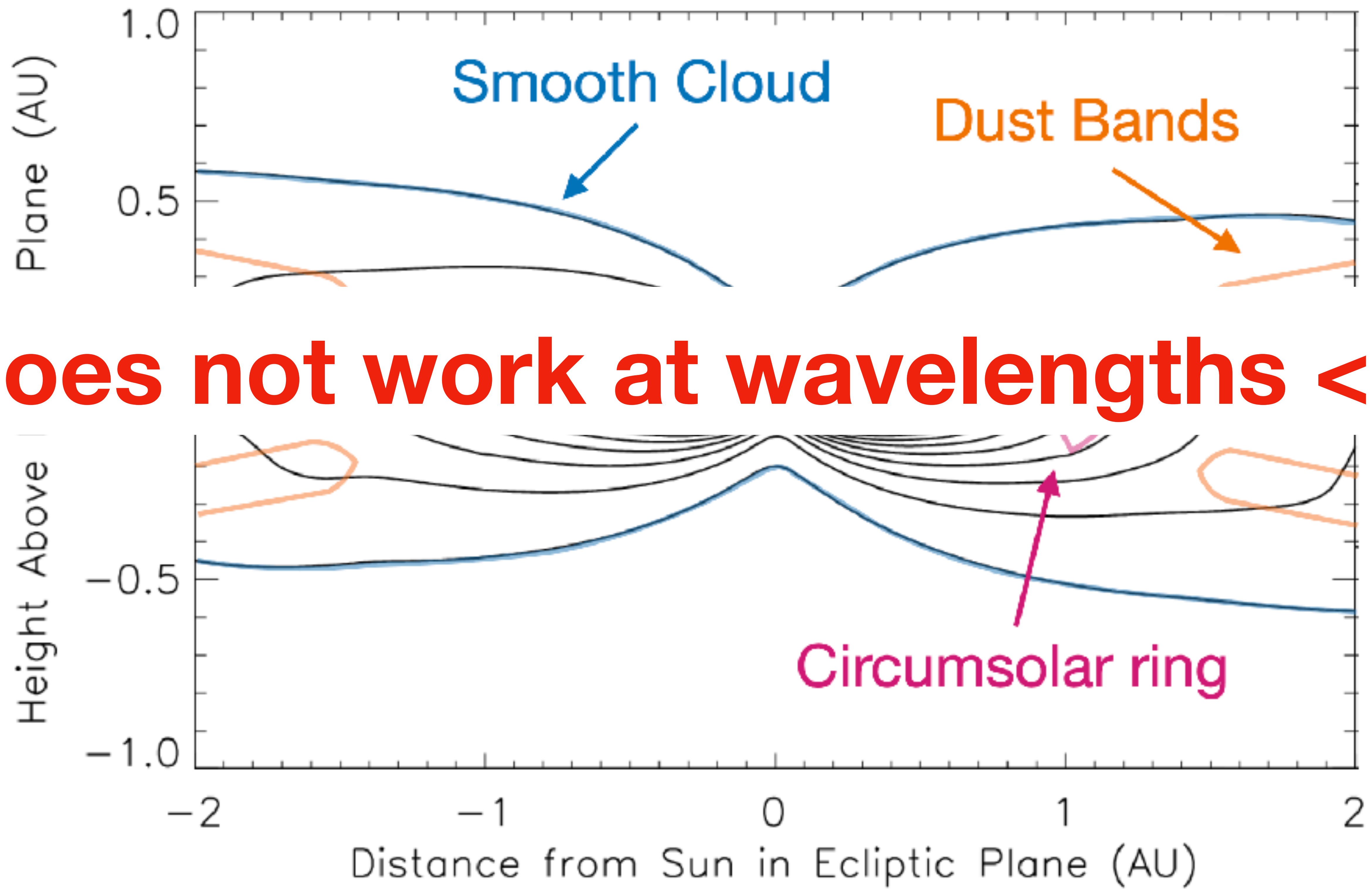
Received 1998 January 7; accepted 1998 June 22



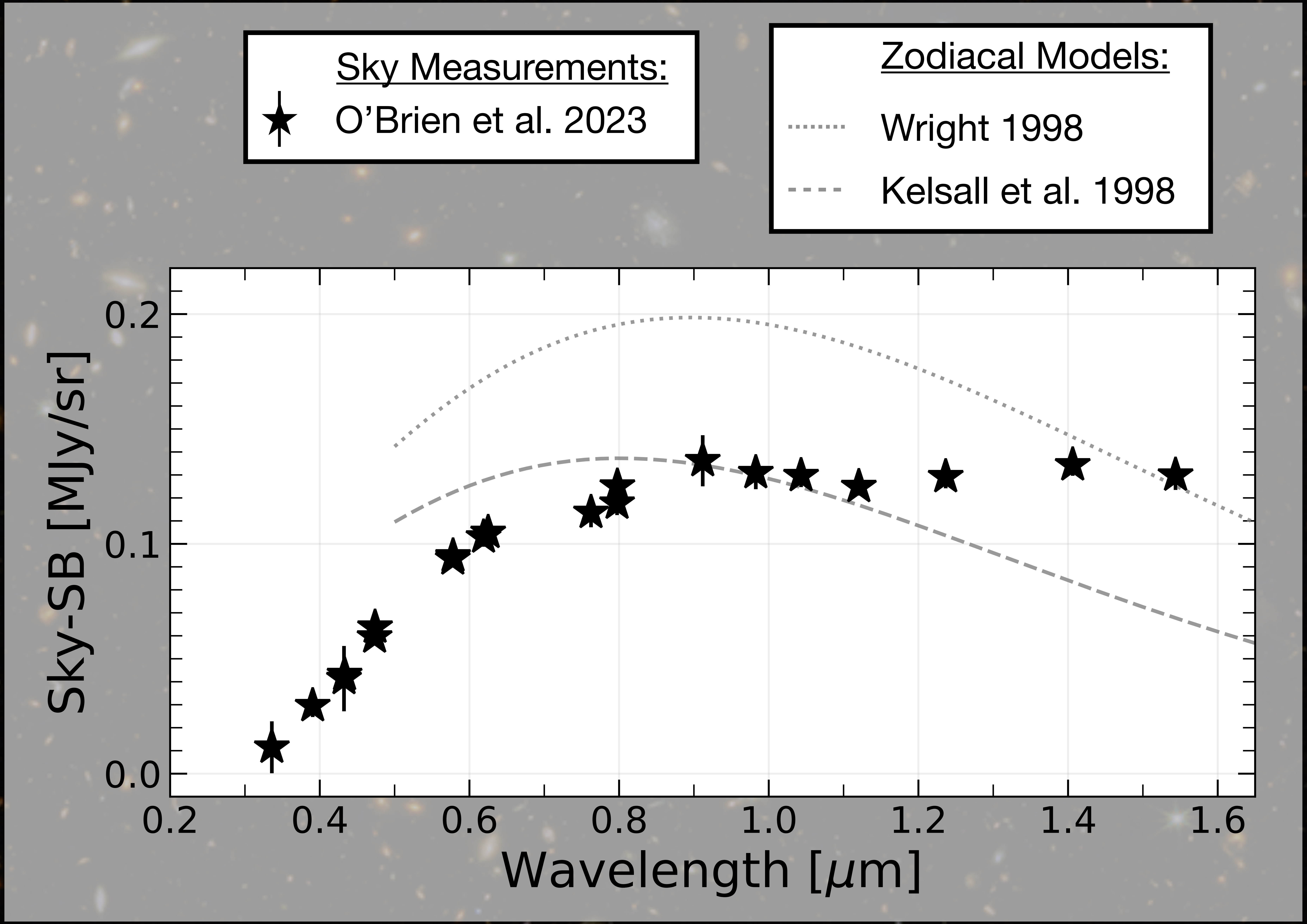
THE *COBE* DIFFUSE INFRARED BACKGROUND EXPERIMENT SEARCH FOR THE COSMIC INFRARED BACKGROUND. II. MODEL OF THE INTERPLANETARY DUST CLOUD

T. Kelsall,[1,2] J. L. Weiland,[3] B. A. Franz,[4] W. T. Reach,[5] R. G. Arendt,[3] E. Dwek,[1] H. T. Freudenreich,[3] M. G. Hauser,[6] S. H. Moseley,[1] N. P. Odegard,[3] R. F. Silverberg,[1] and E. L. Wright[7]

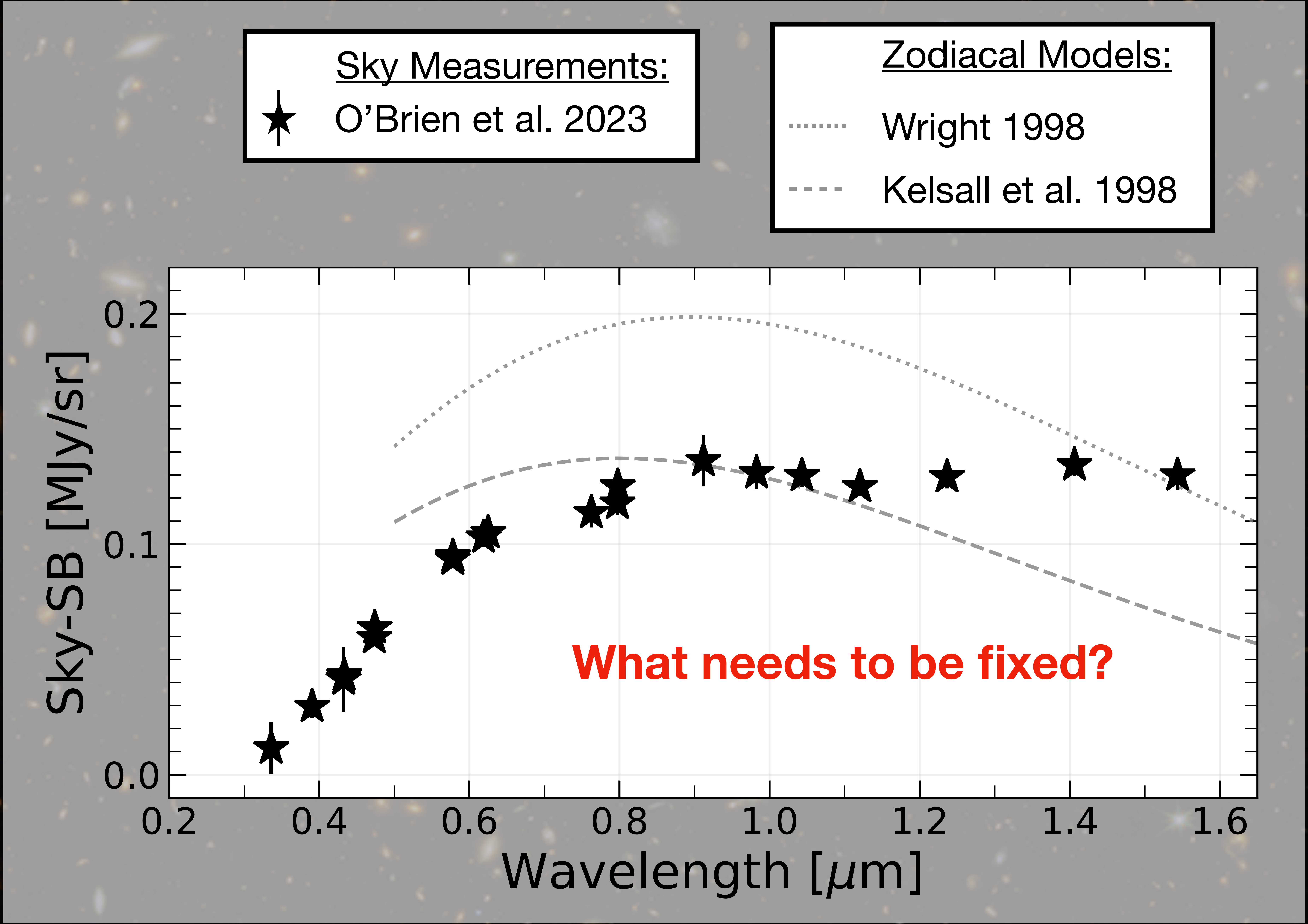
Received 1998 January 7; accepted 1998 June 22



Does not work at wavelengths <1.25 μm



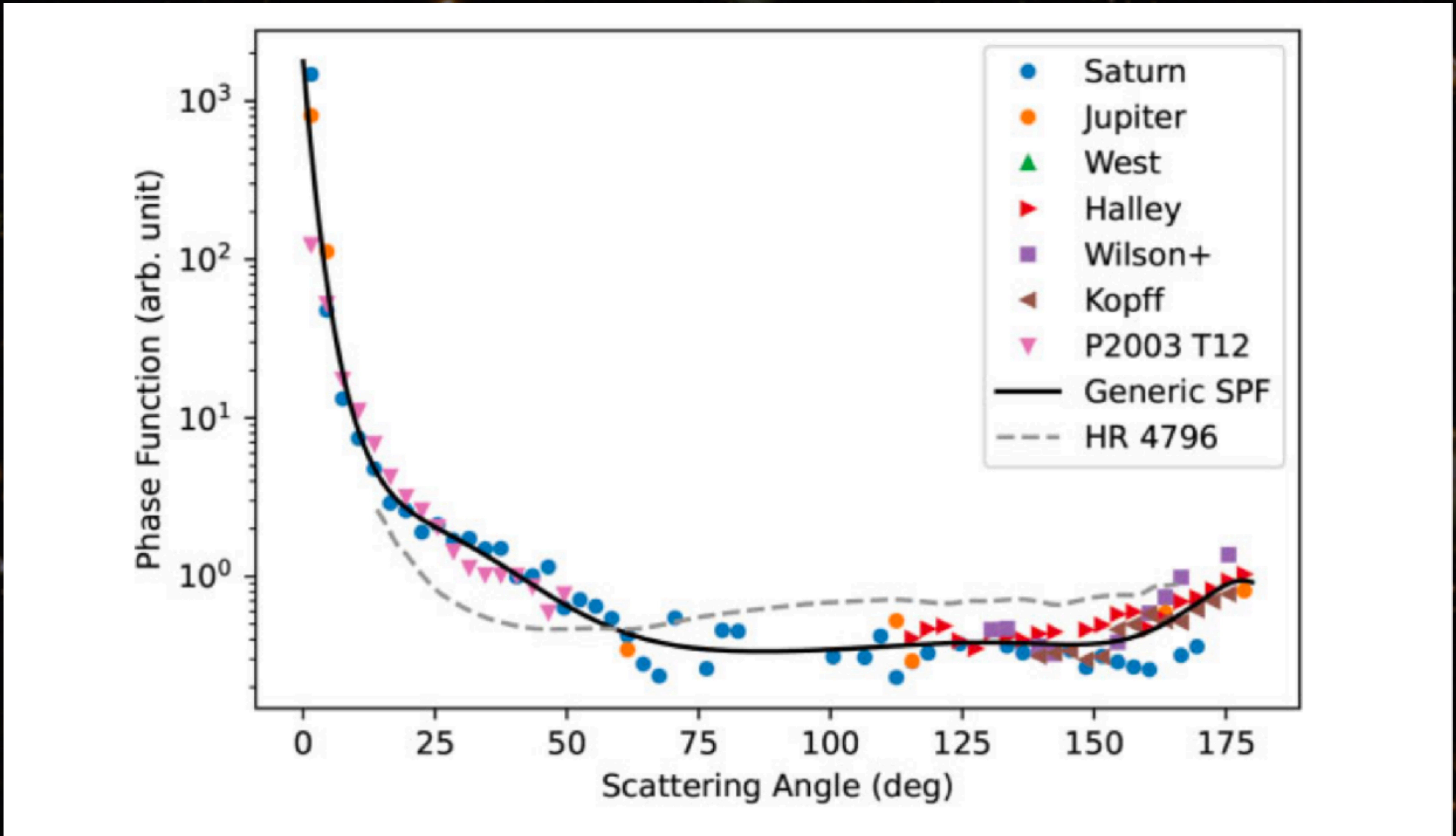
Sky Measurements:
O'Brien et al. 2023
Zodiacal Models:
Wright 1998
Kelsall et al. 1998
Sky-SB [MJy/sr]
0.0
0.1
0.2
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Wavelength [μm]


Sky Measurements:
O'Brien et al. 2023
Zodiacal Models:
Wright 1998
Kelsall et al. 1998
Sky-SB [MJy/sr]
0.0
0.1
0.2
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Wavelength [μm]
What needs to be fixed?

The Current Scattering Phase Function

The Current Scattering Phase Function

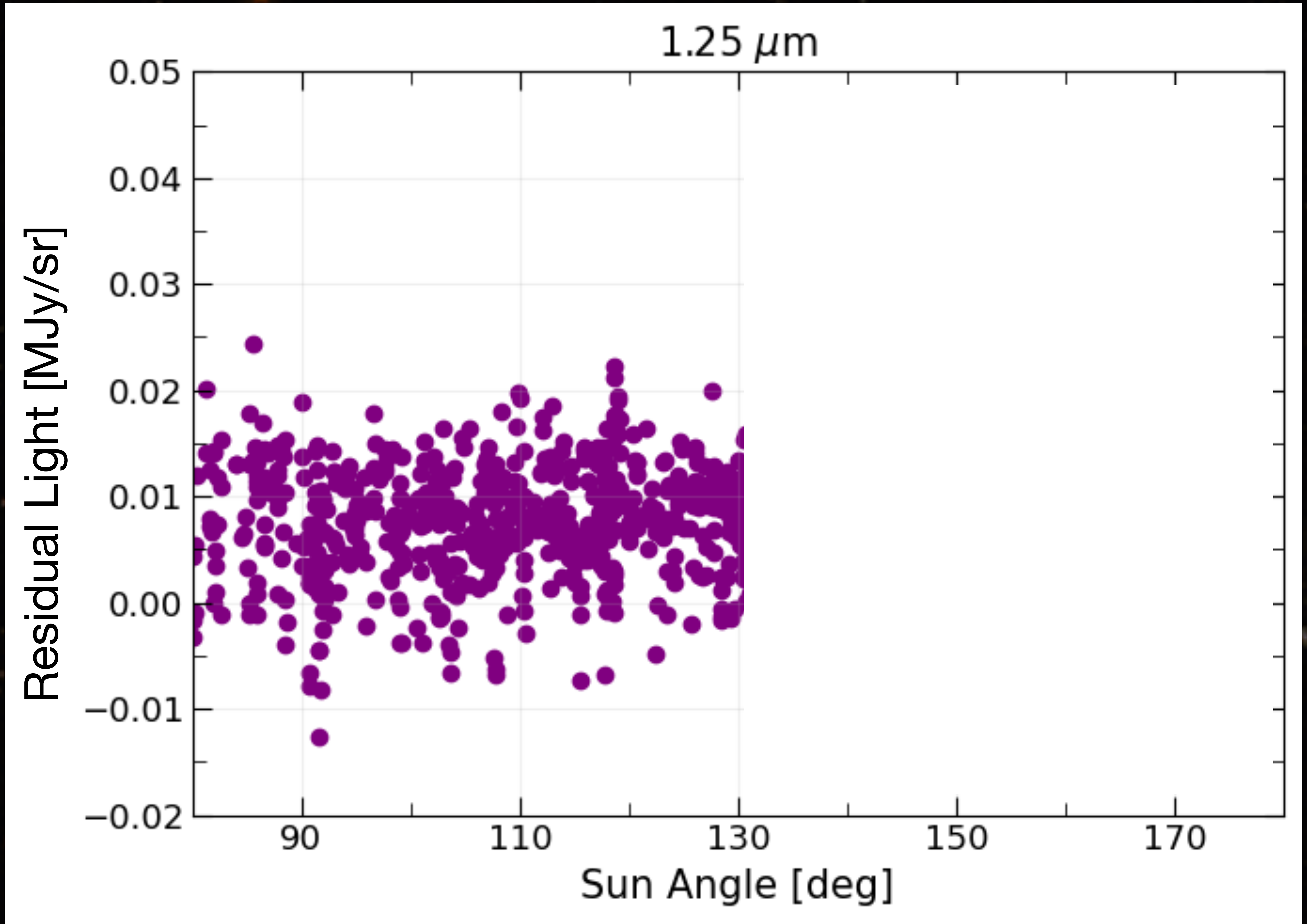
Forward Scattering ⟷ Backward Scattering



Hom et al. 2024

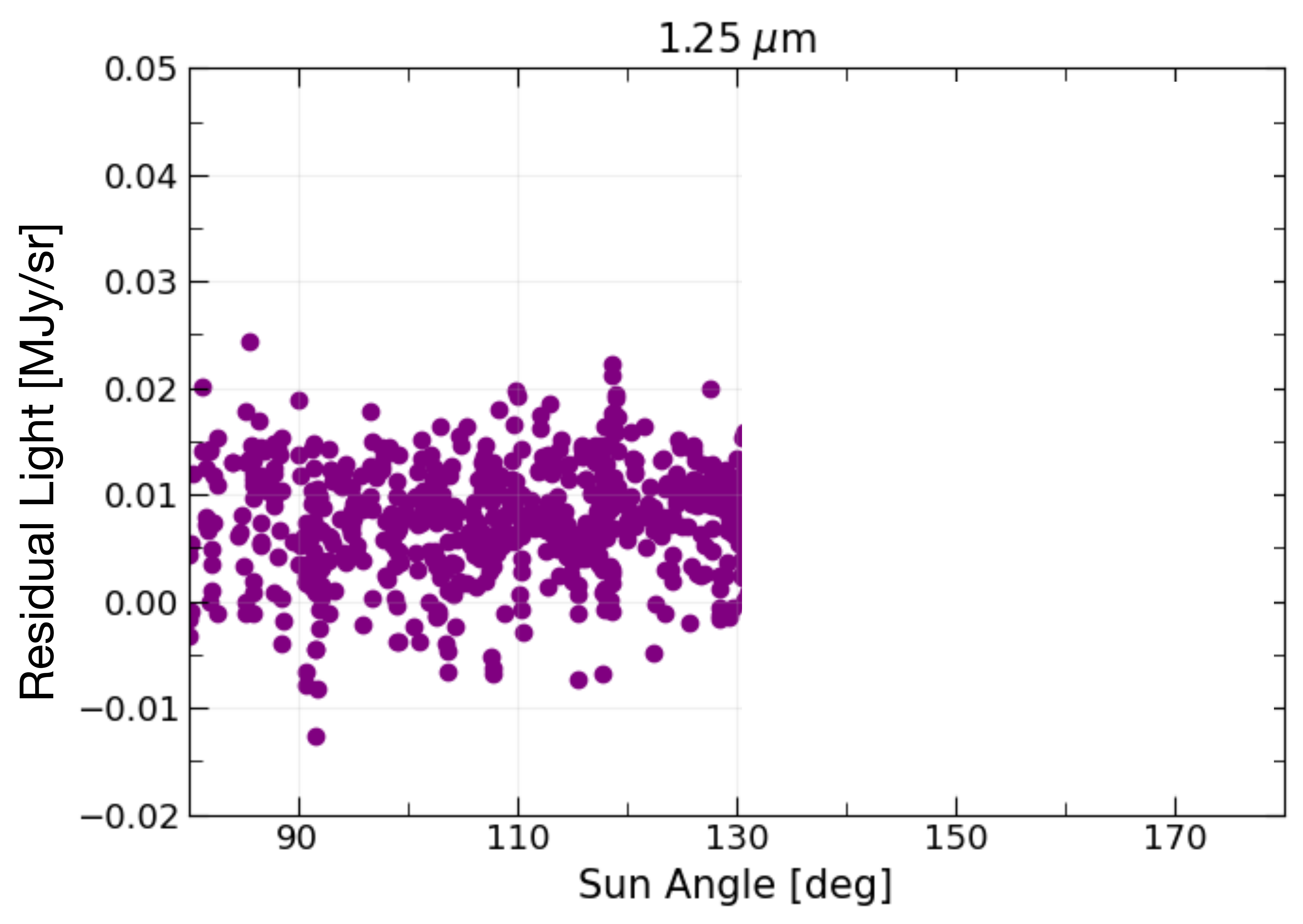
The Current Scattering Phase Function

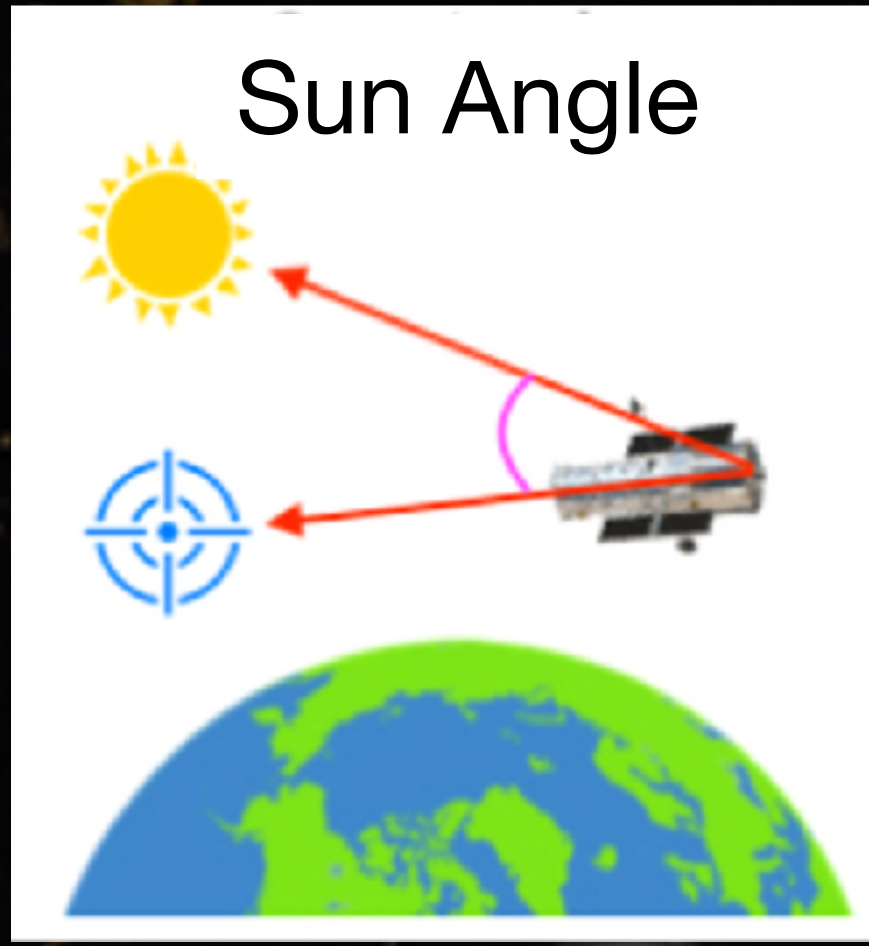
Residual Light =
Sky – Zodi –
Everything Else



The Current Scattering Phase Function

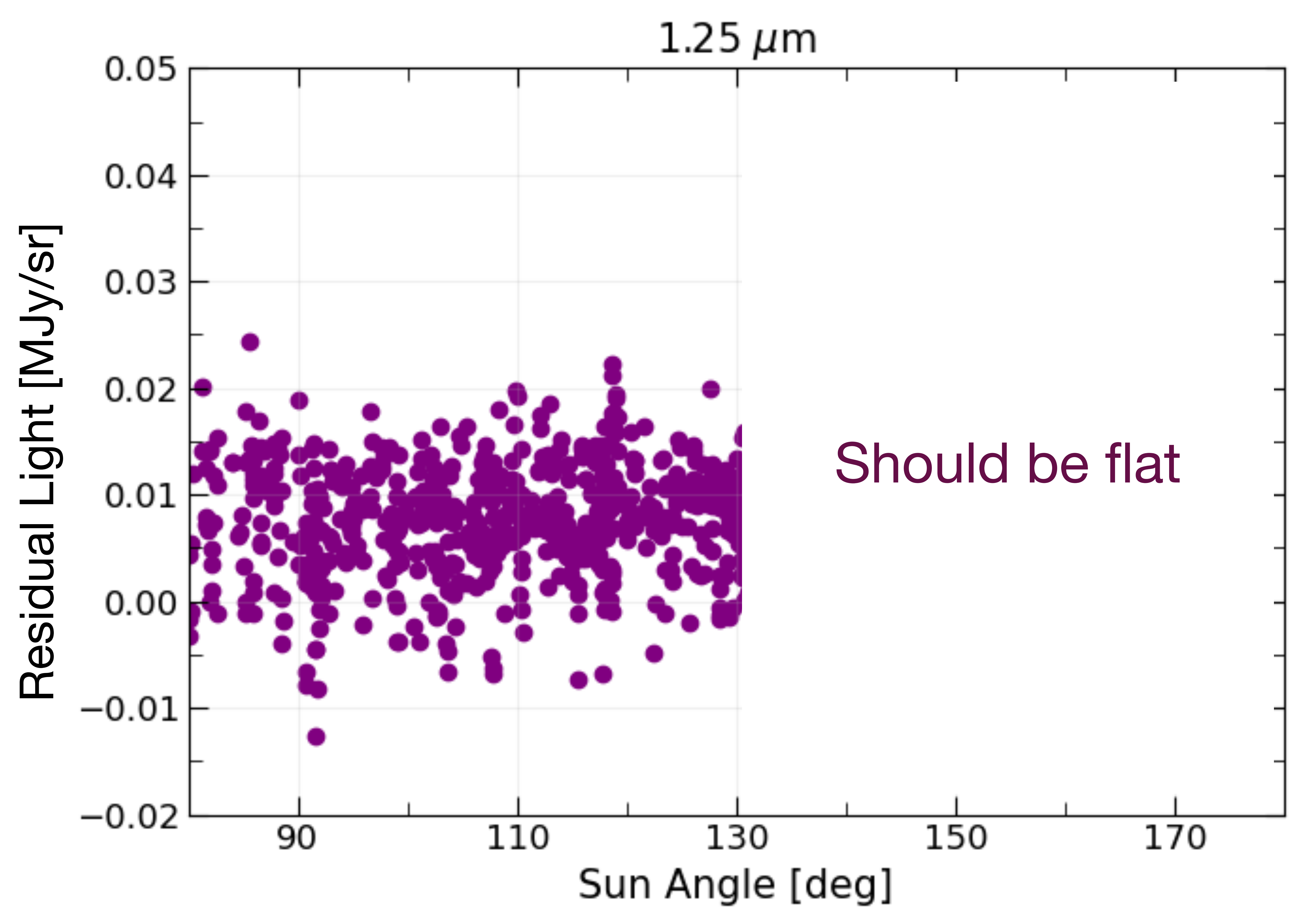
Residual Light =
Sky – Zodi –
Everything Else

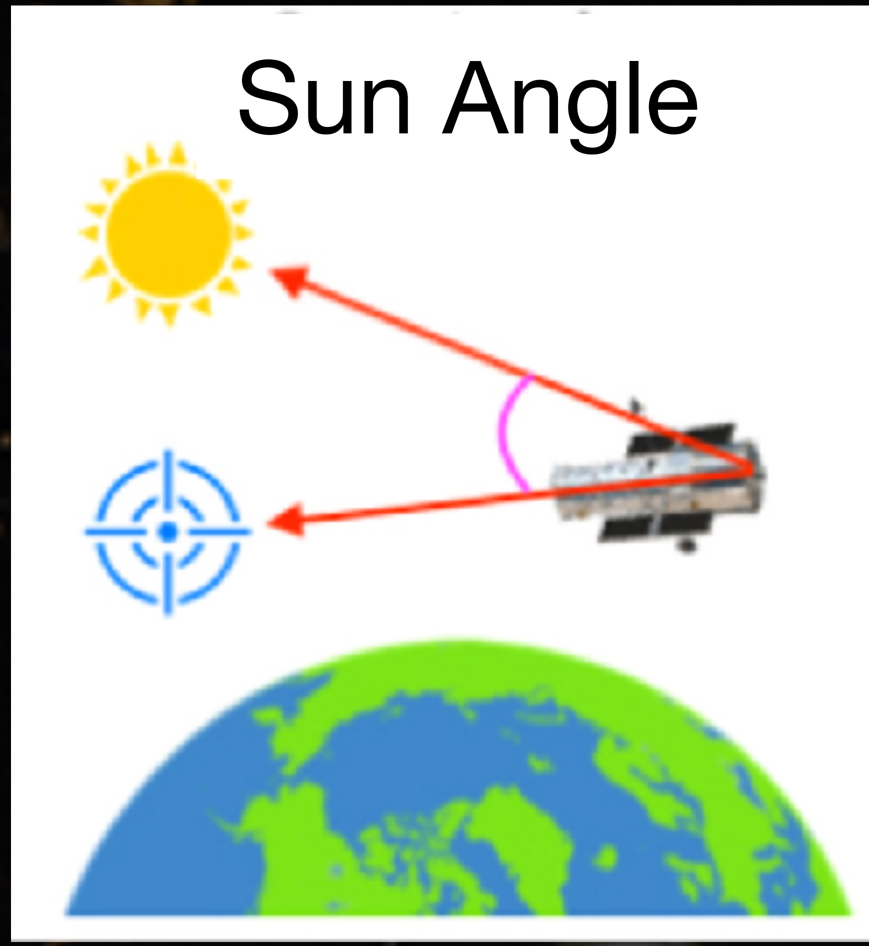




The Current Scattering Phase Function

Residual Light =
Sky – Zodi –
Everything Else

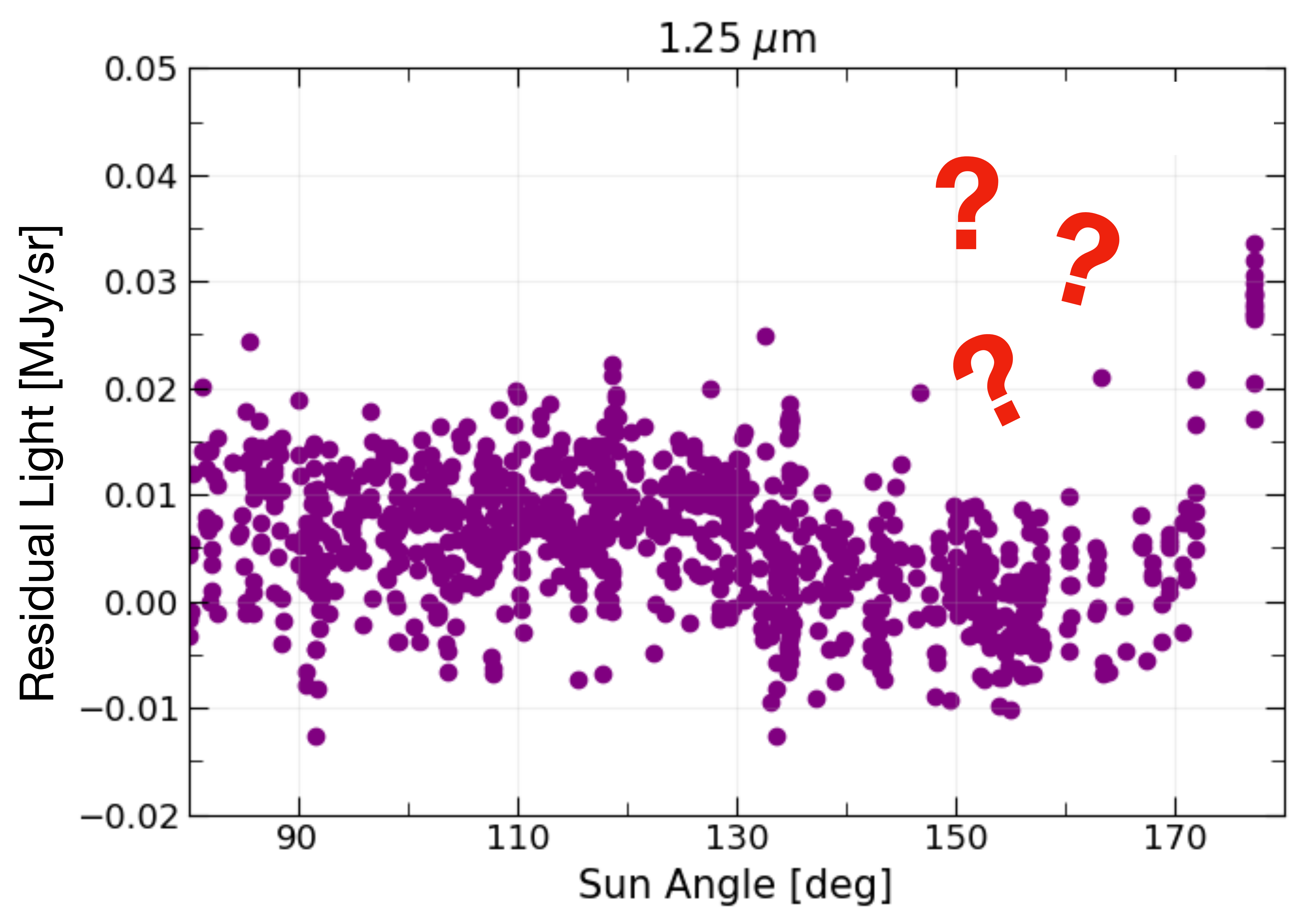


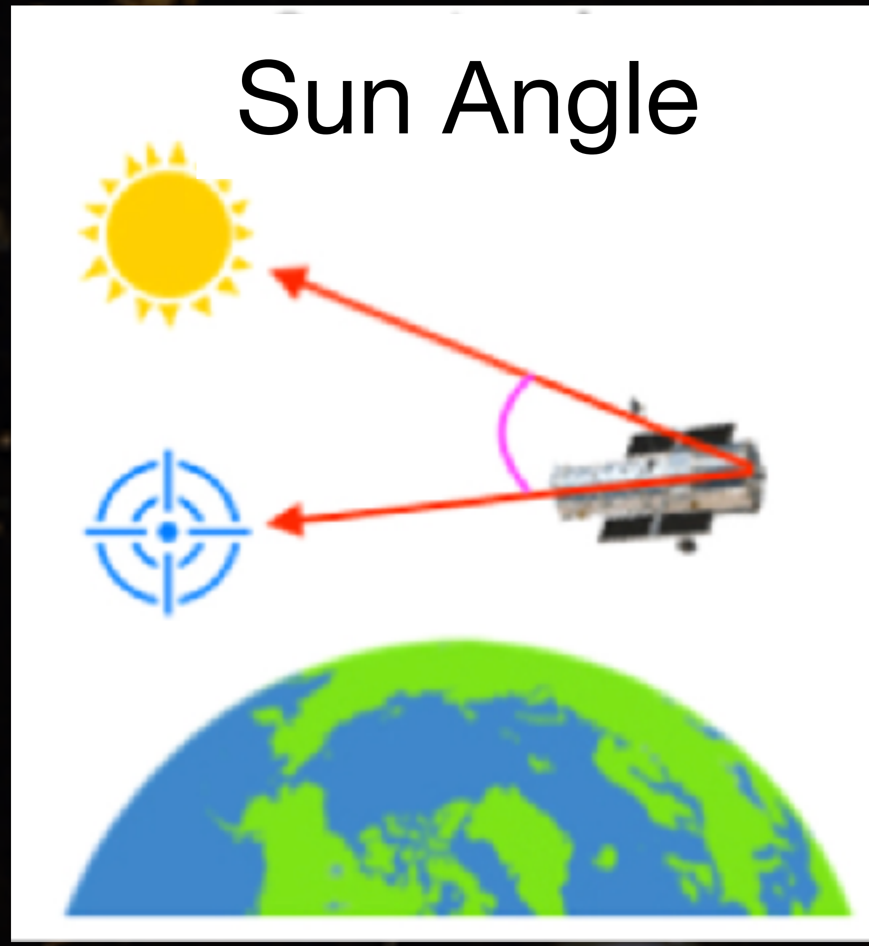


Rosalia O'Brien (robrien5@asu.edu)

The Current Scattering Phase Function

Residual Light = Sky – Zodi – Everything Else





Rosalia O’Brien (robrien5@asu.edu)

A New Scattering Phase Function

A New Scattering Phase Function

$$\Phi_\lambda(\theta) = \sum_{i=1}^{i=3} w_{i,\lambda} \frac{1 - g_{i,\lambda}^2}{[1 + g_{i,\lambda}^2 - 2g_{i,\lambda}\cos(\theta)]^{3/2}}$$

Weight

Relative contribution of forward/ backward scattering

g = 0 ⟶ Isotropic scattering
g > 0 ⟶ Forward scattering
g < 0 ⟶ Backward scattering

1985A&A...146...67H

Astron. Astrophys. 146, 67–75 (1985)

ASTRONOMY AND ASTROPHYSICS

Henyey-Greenstein representation of the mean volume scattering phase function for zodiacal dust

S. S. Hong*

Space Astronomy Laboratory, University of Florida, 1810 NW 6th Street, Gainesville, FL 32609, USA

Received July 9; accepted December 14, 1984

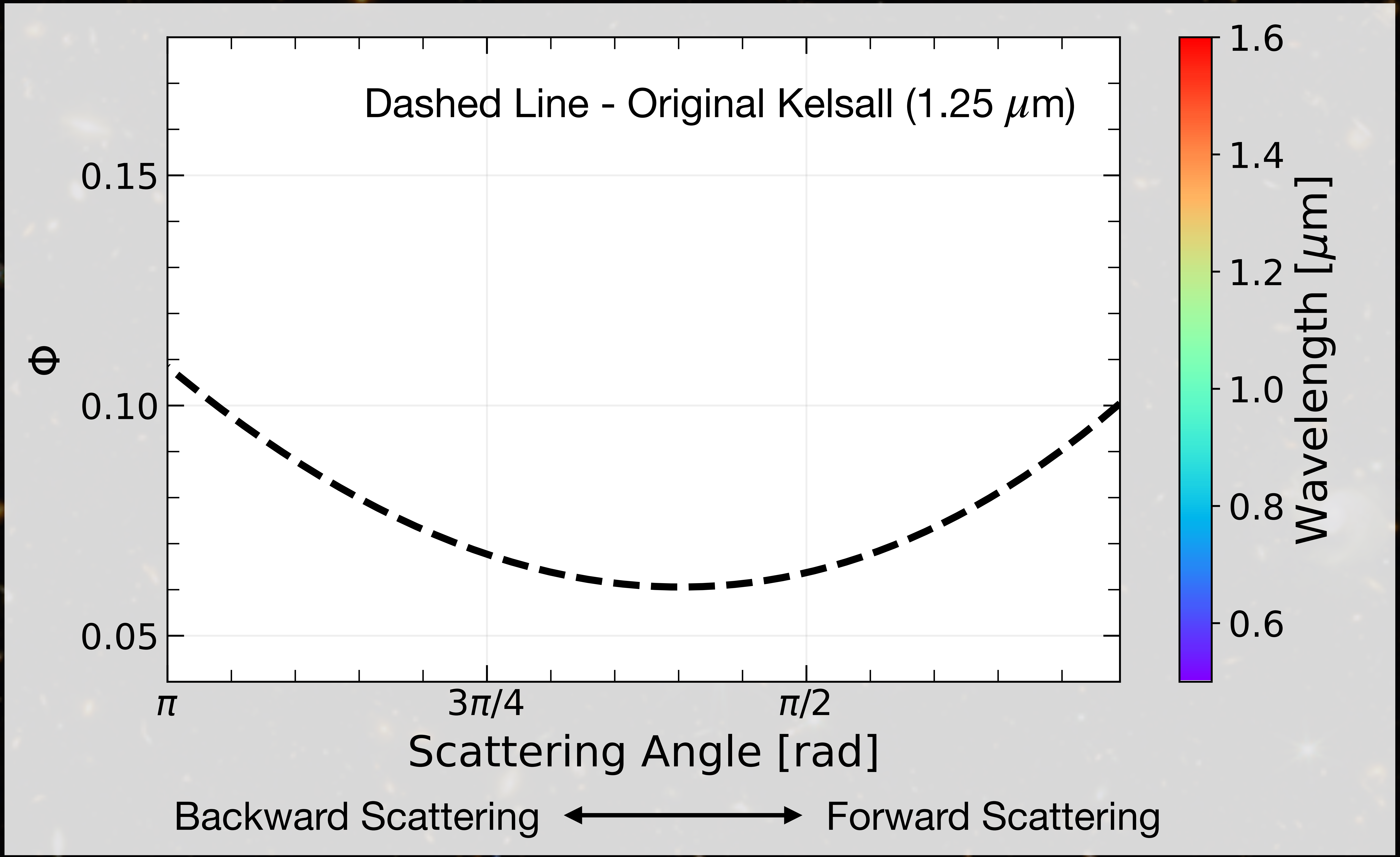
A New Scattering Phase Function

$$\Phi_\lambda(\theta) = \sum_{i=1}^{i=3} w_{i,\lambda} \frac{1 - g_{i,\lambda}^2}{[1 + g_{i,\lambda}^2 - 2g_{i,\lambda}\cos(\theta)]^{3/2}}$$

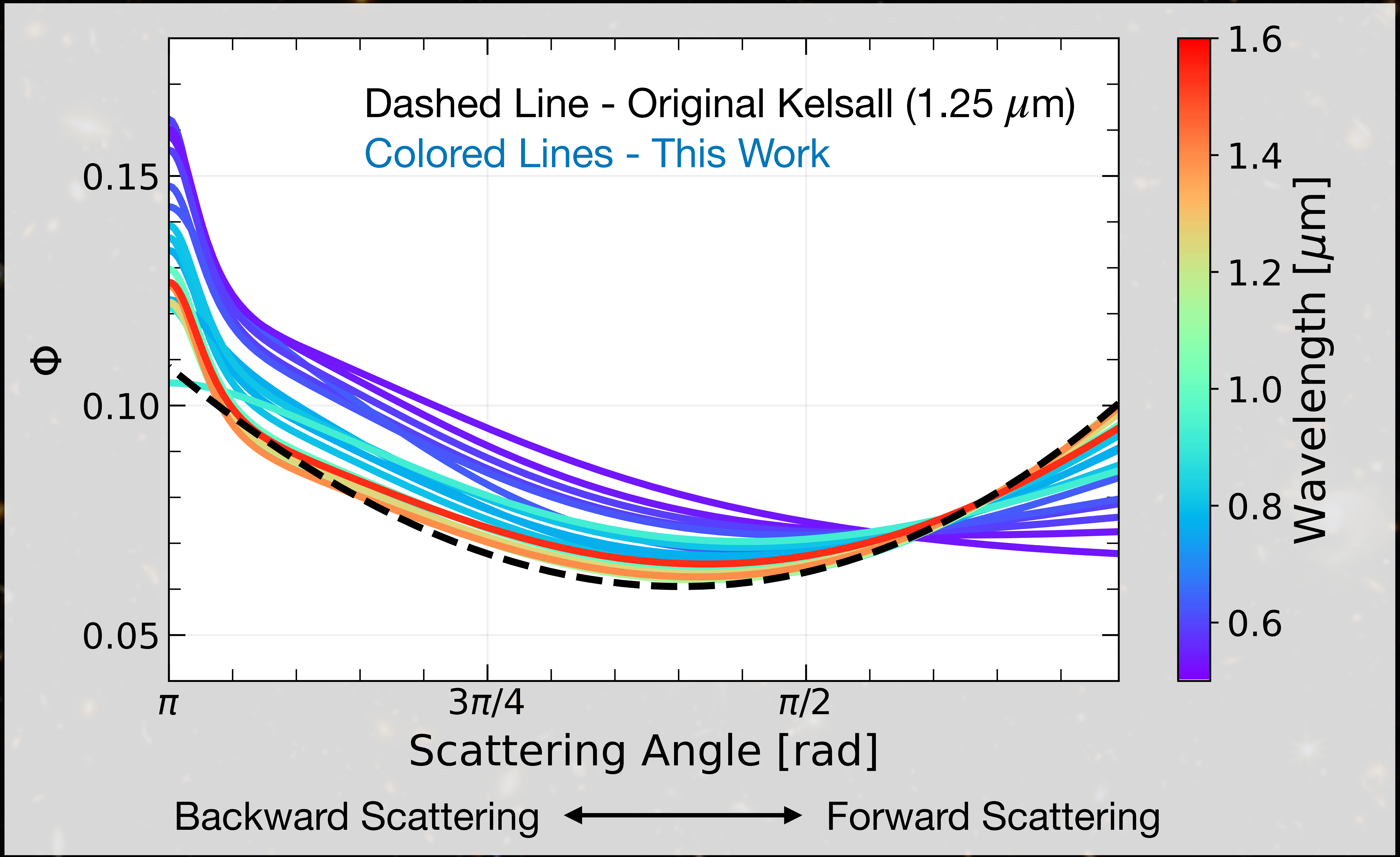
My Methods:

1. Feed sky-SB measurements into model
2. Adjust new phase function parameters (chi-squared or bayesian MCMC)
3. Get best-fit phase function

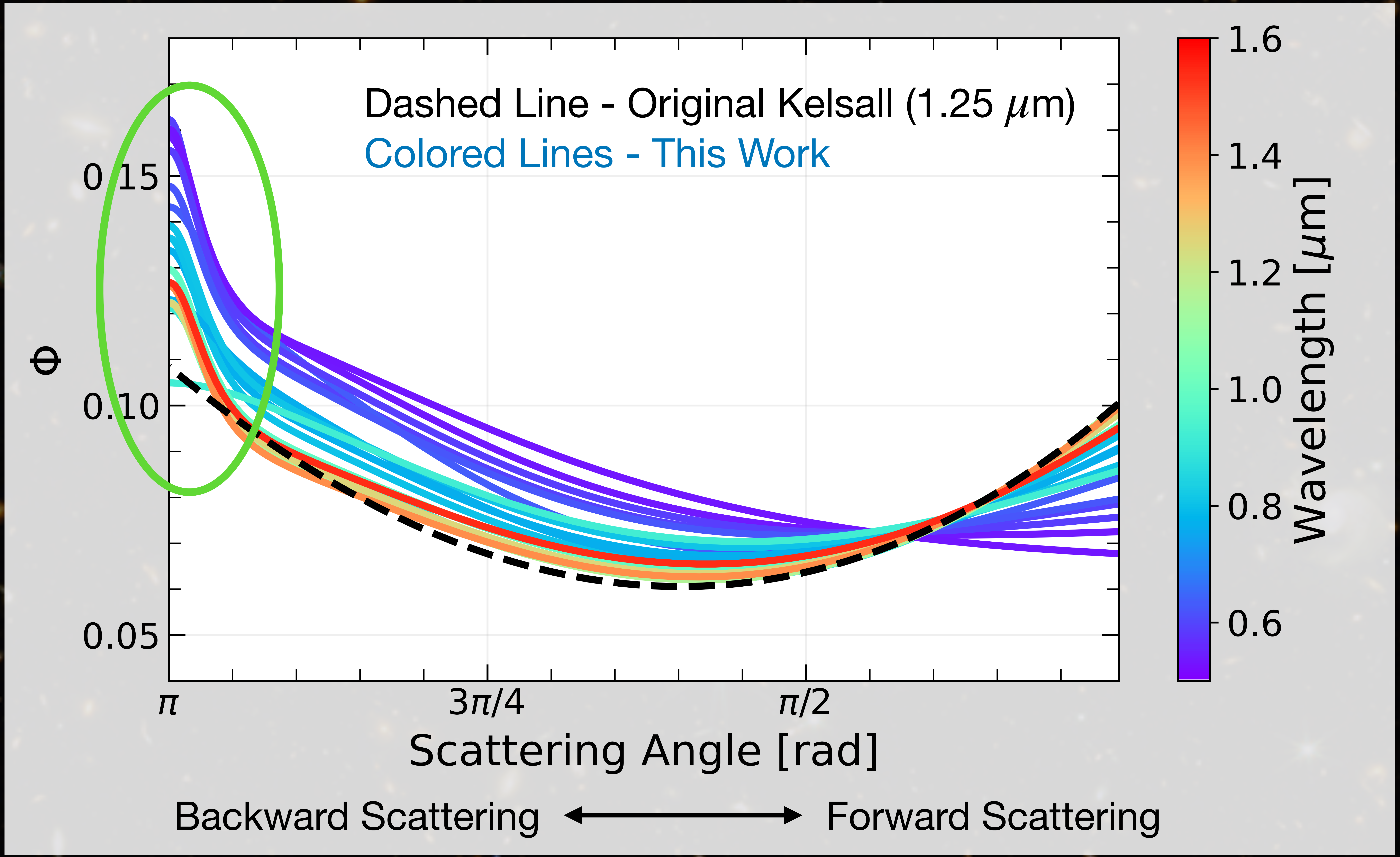
A New Scattering Phase Function



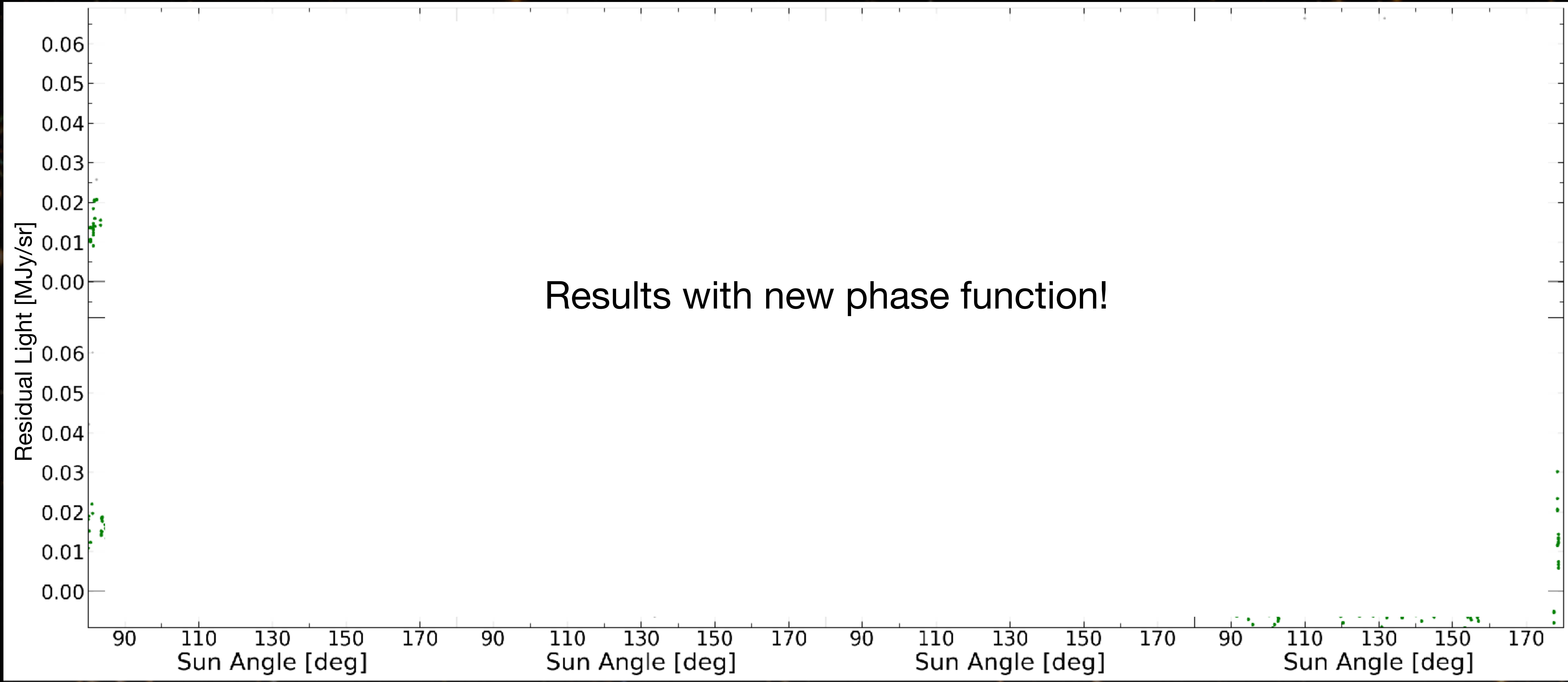
A New Scattering Phase Function



A New Scattering Phase Function

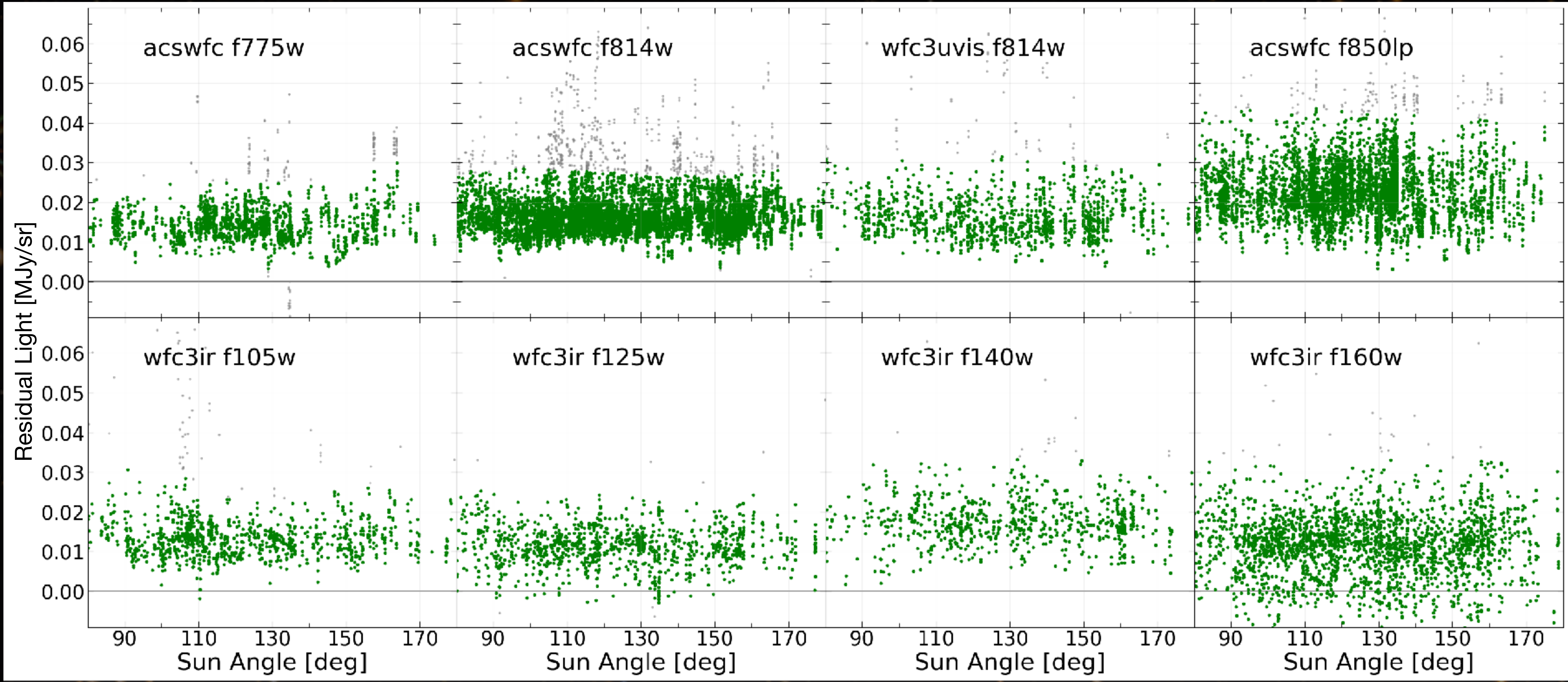


A New Scattering Phase Function



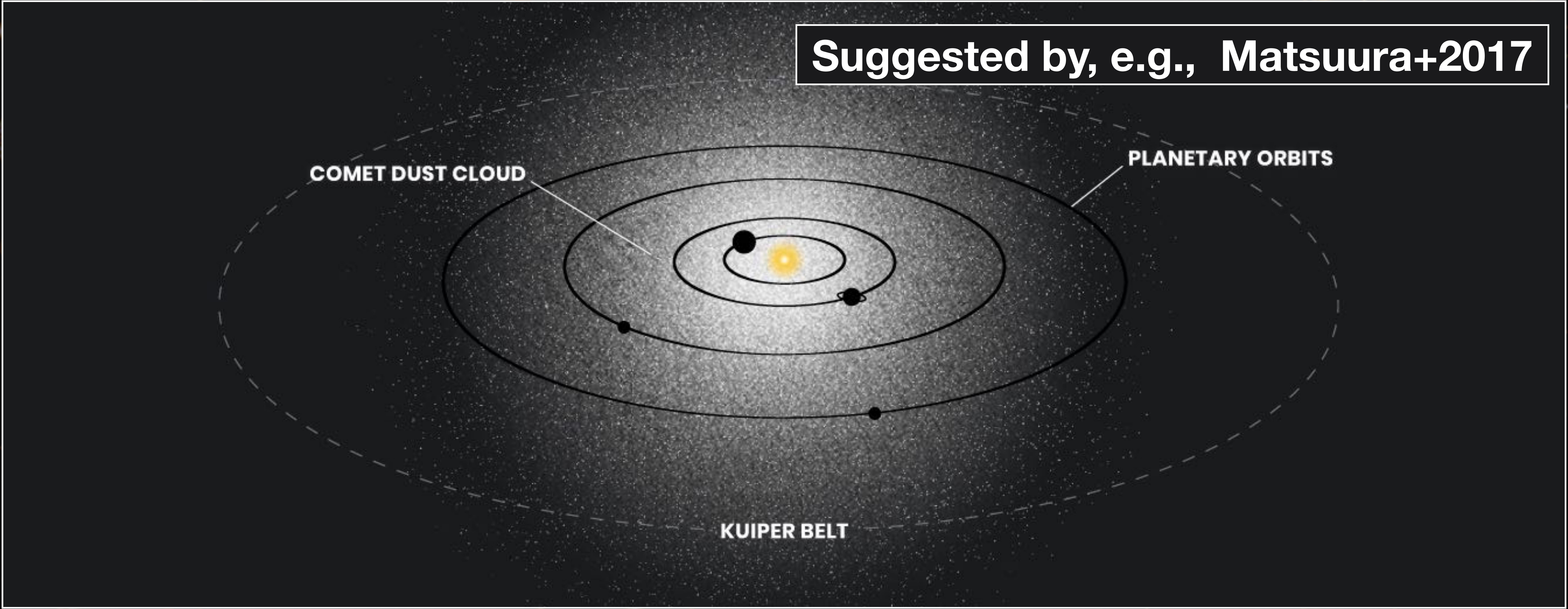
Results with new phase function!

A New Scattering Phase Function



Rosalia O'Brien (robrien5@asu.edu)

Need a New Spherical Cloud Component?



NASA, ESA, Andi James (STScI)

New Diffuse Galactic Light Measurements

THE ASTROPHYSICAL JOURNAL, 972:95 (23pp), 2024 September 1 https://doi.org/10.3847/1538-4357/ad5ffc

CrossMark

New Synoptic Observations of the Cosmic Optical Background with New Horizons

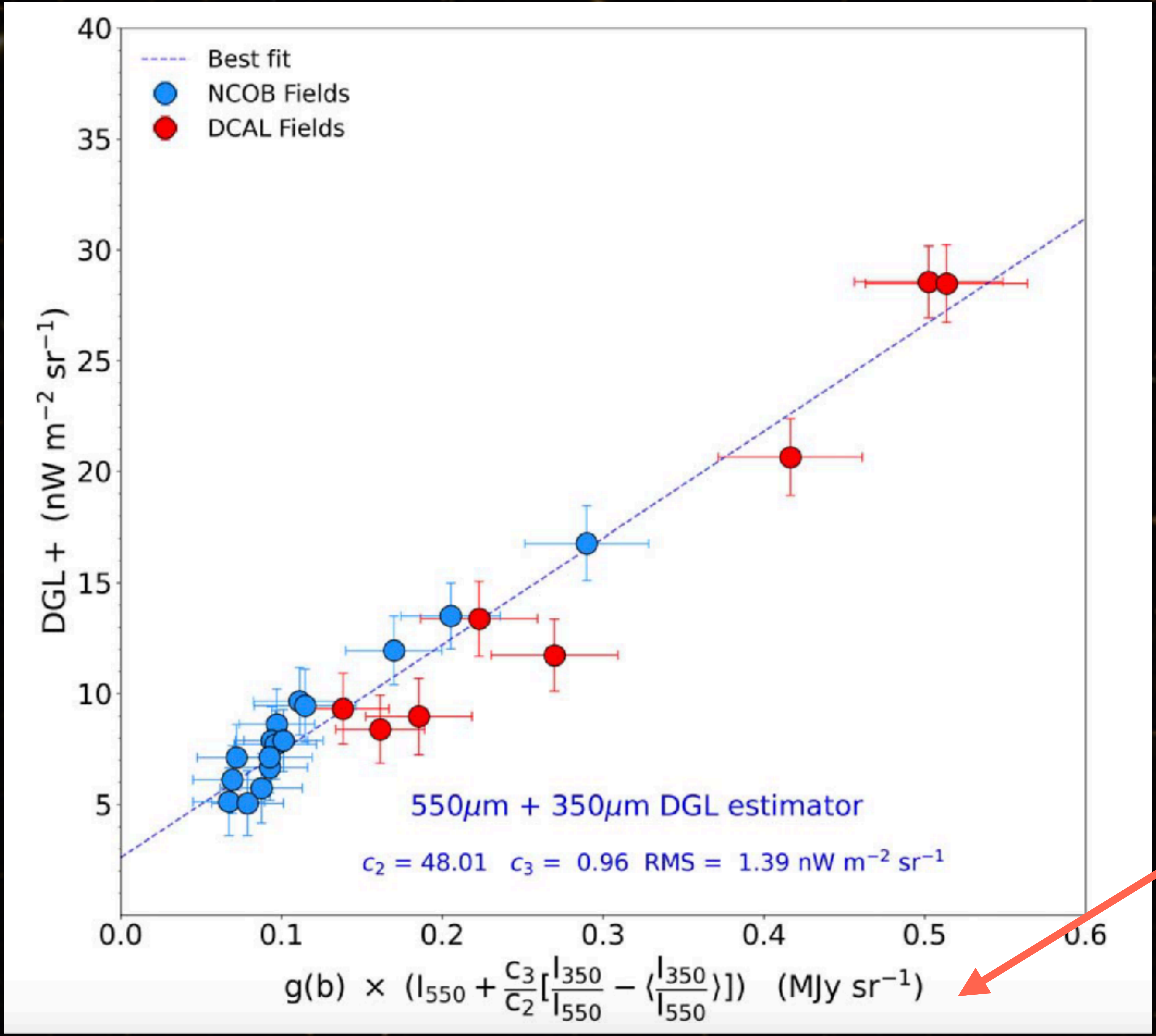
Marc Postman[1], Tod R. Lauer[2], Joel W. Parker[3], John R. Spencer[3], Harold A. Weaver[4], J. Michael Shull[5,6], S. Alan Stern[7], Pontus Brandt[4], Steven J. Conard[4], G. Randall Gladstone[8,9], Carey M. Lisse[4], Simon B. Porter[3], Kelsi N. Singer[3], and Anne. J. Verbiscer[10]

[1] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA[11]; postman@stsci.edu
[2] U.S. National Science Foundation National Optical Infrared Astronomy Research Laboratory, P.O. Box 26732, Tucson, AZ 85726, USA[12]
[3] Department of Space Studies, Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302, USA
[4] The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723-6099, USA
[5] Department of Astrophysical & Planetary Sciences, CASA, University of Colorado, Boulder, CO 80309, USA
[6] Department of Physics & Astronomy, University of North Carolina, Chapel Hill, NC 27599, USA
[7] Space Science and Engineering Division, Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302, USA
[8] Southwest Research Institute, San Antonio, TX 78238, USA
[9] University of Texas at San Antonio, San Antonio, TX 78249, USA
[10] University of Virginia, Charlottesville, VA 22904, USA

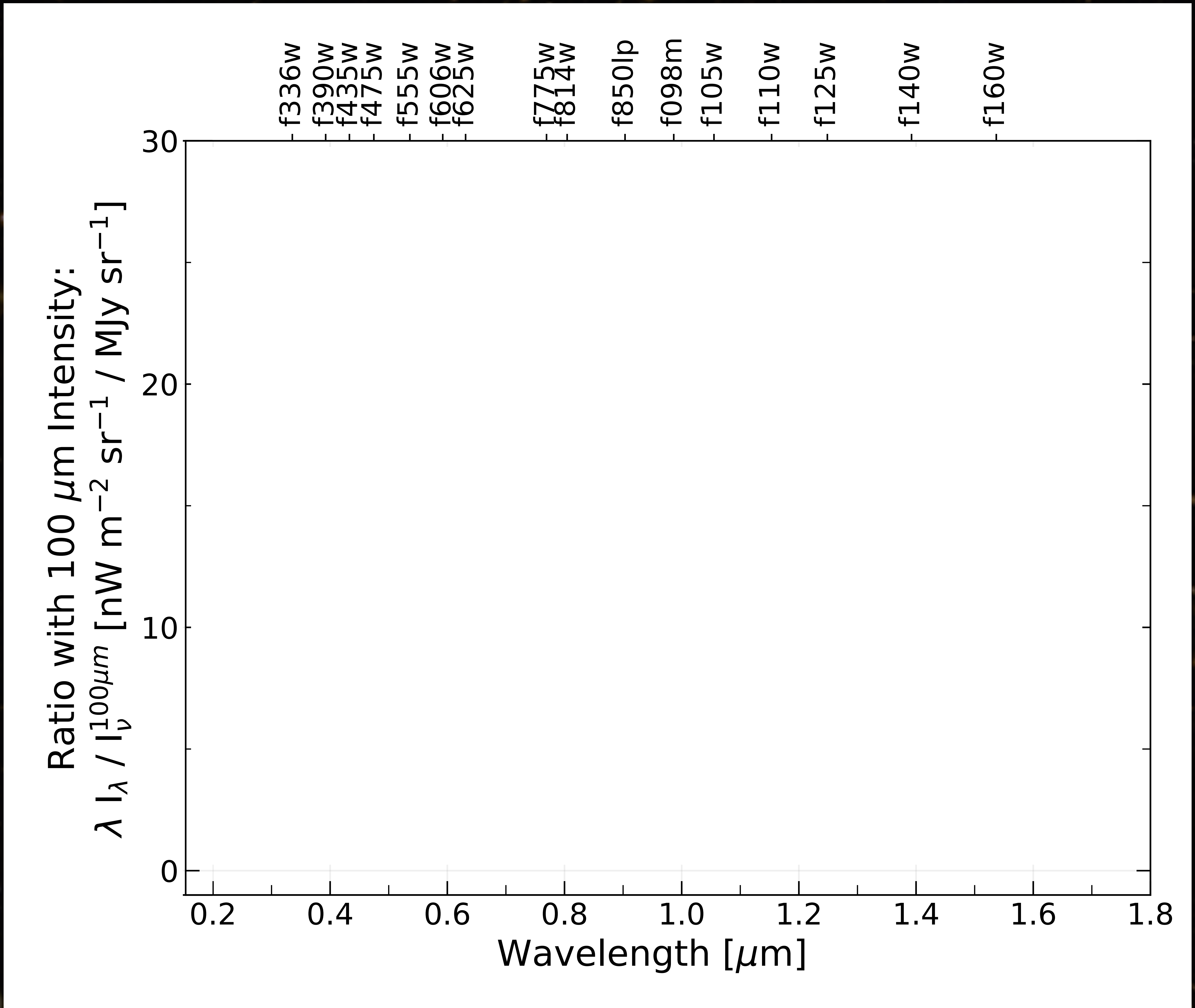
Received 2024 April 4; revised 2024 July 3; accepted 2024 July 6; published 2024 August 28

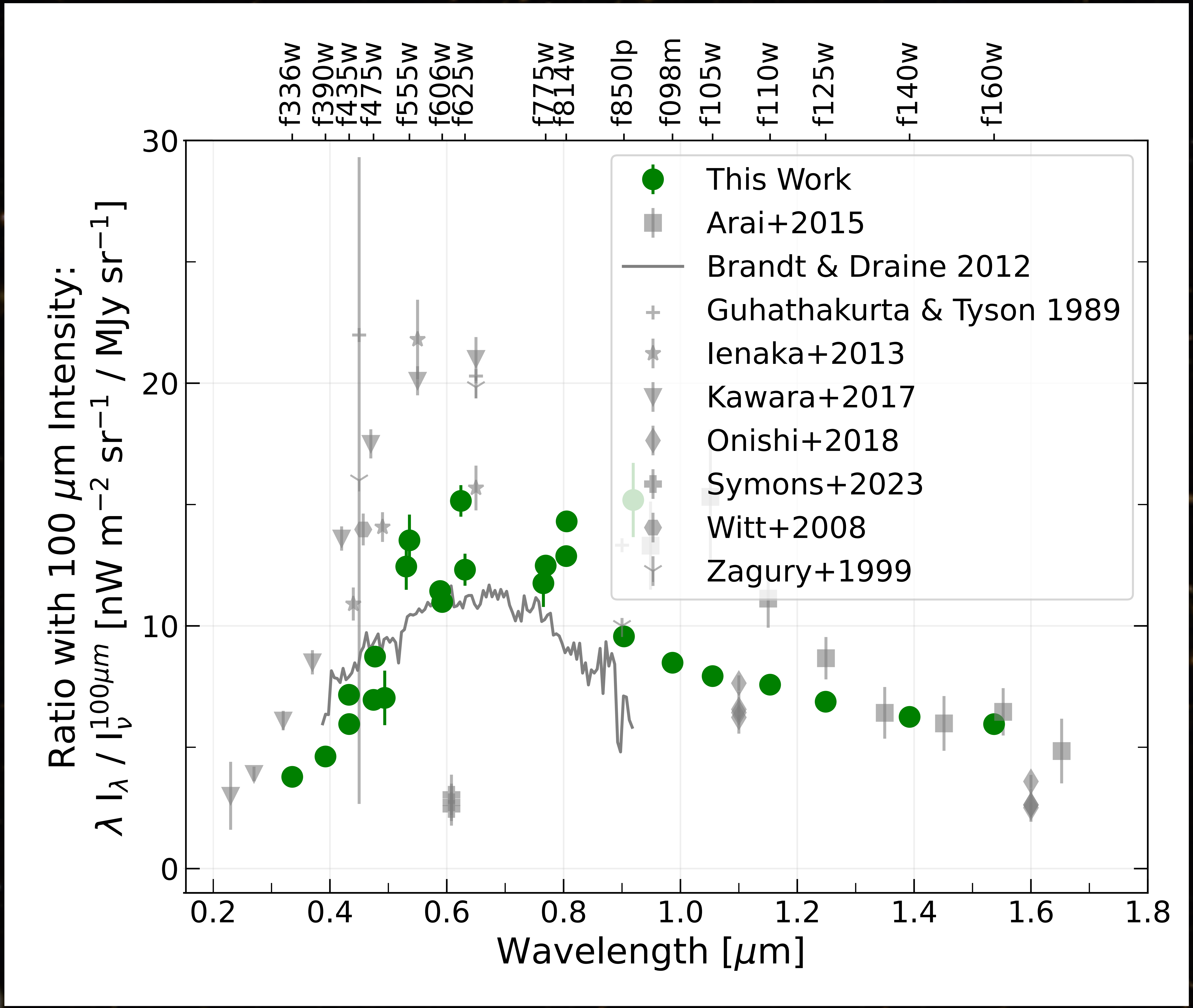
Postman+2024

DGL Measurement with New Horizons



DGL Estimate using Planck maps


f336w
f390w
f435w
f475w
f555w
f606w
f625w
f775w
f814w
f850lp
f098m
f105w
f110w
f125w
f140w
f160w
30
20
10
0
Ratio with 100 μm Intensity:
λ I_λ / I_ν^100μm [nW m^−2 sr^−1 / MJy sr^−1]
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Wavelength [μm]


f336w
f390w
f435w
f475w
f555w
f606w
f625w
f775w
f814w
f850lp
f098m
f105w
f110w
f125w
f140w
f160w
Ratio with 100 μm Intensity:
λ I_λ / I_ν^100μm [nW m^−2 sr^−1 / MJy sr^−1]
Wavelength [μm]
This Work
Arai+2015
Brandt & Draine 2012
Guhathakurta & Tyson 1989
Ienaka+2013
Kawara+2017
Onishi+2018
Symons+2023
Witt+2008
Zagury+1999

Ongoing SKYSURF Projects

- New Zodiacal Light Model (Rosalia O'Brien, Rick Arendt, Scott Kenyon, etc)
- Final SKYSURF COB Measurements (Rosalia O'Brien, Megan Miller)
- Galaxy counts (Delondrae Carter, Scott Tompkins)

See Tim's talk (up next)

Megan Miller

Ongoing SKYSURF Projects

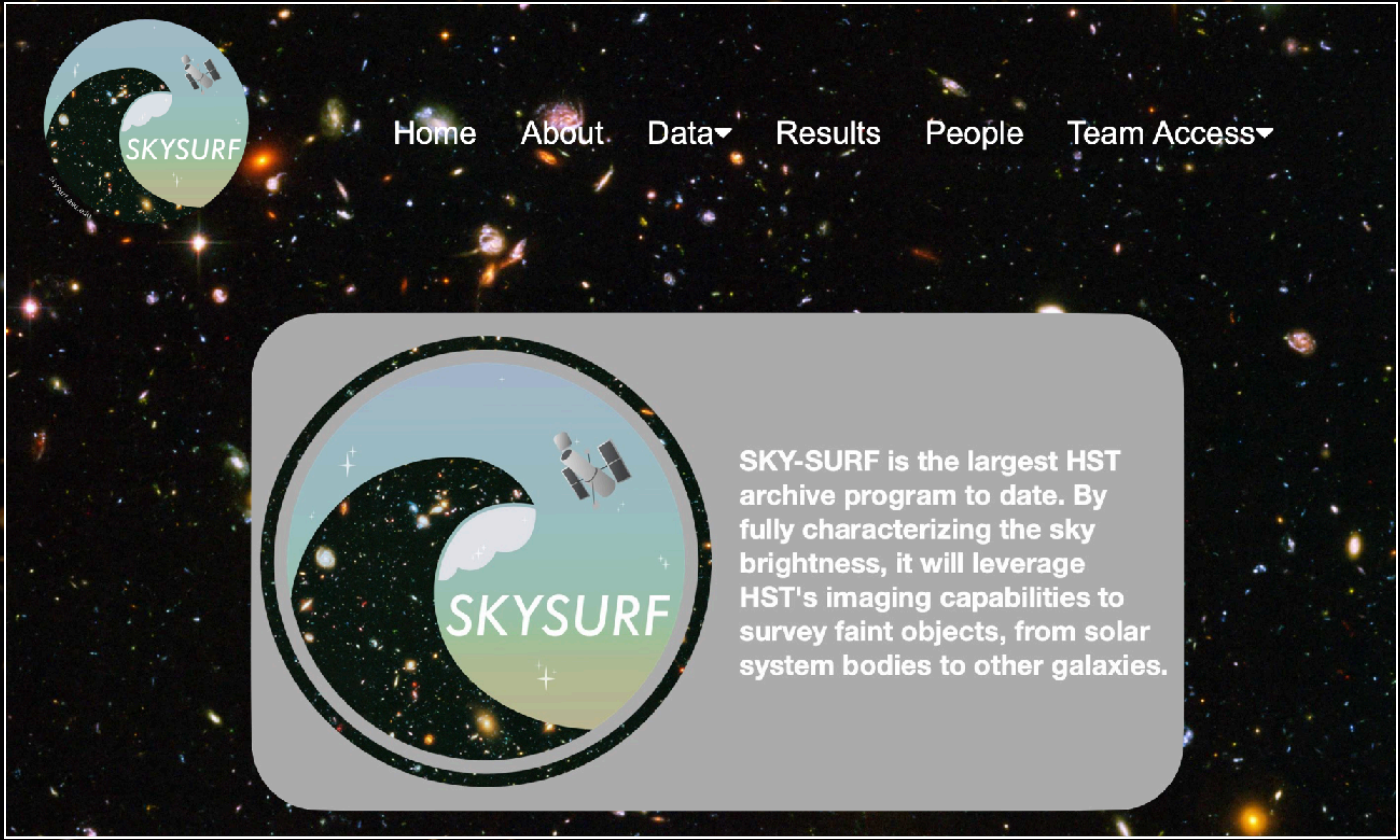
- Sky Measurements with older Hubble cameras (Hal Ingram)
- PSF Leakage into Sky Measurements (Logan Conrad)
- Implementation of new zodi model into ZodiPy (Tejovrash Acharya)

Hal Ingram

Logan Conrad

Tejovrash Acharya

skysurf.asu.edu



SKYSURF-IR

PIs: Prof. Rogier Windhorst &
Dr. Timothy Carleton

<u>Grad Students:</u>

Rafael Ortiz III

Jessica Berkheimer

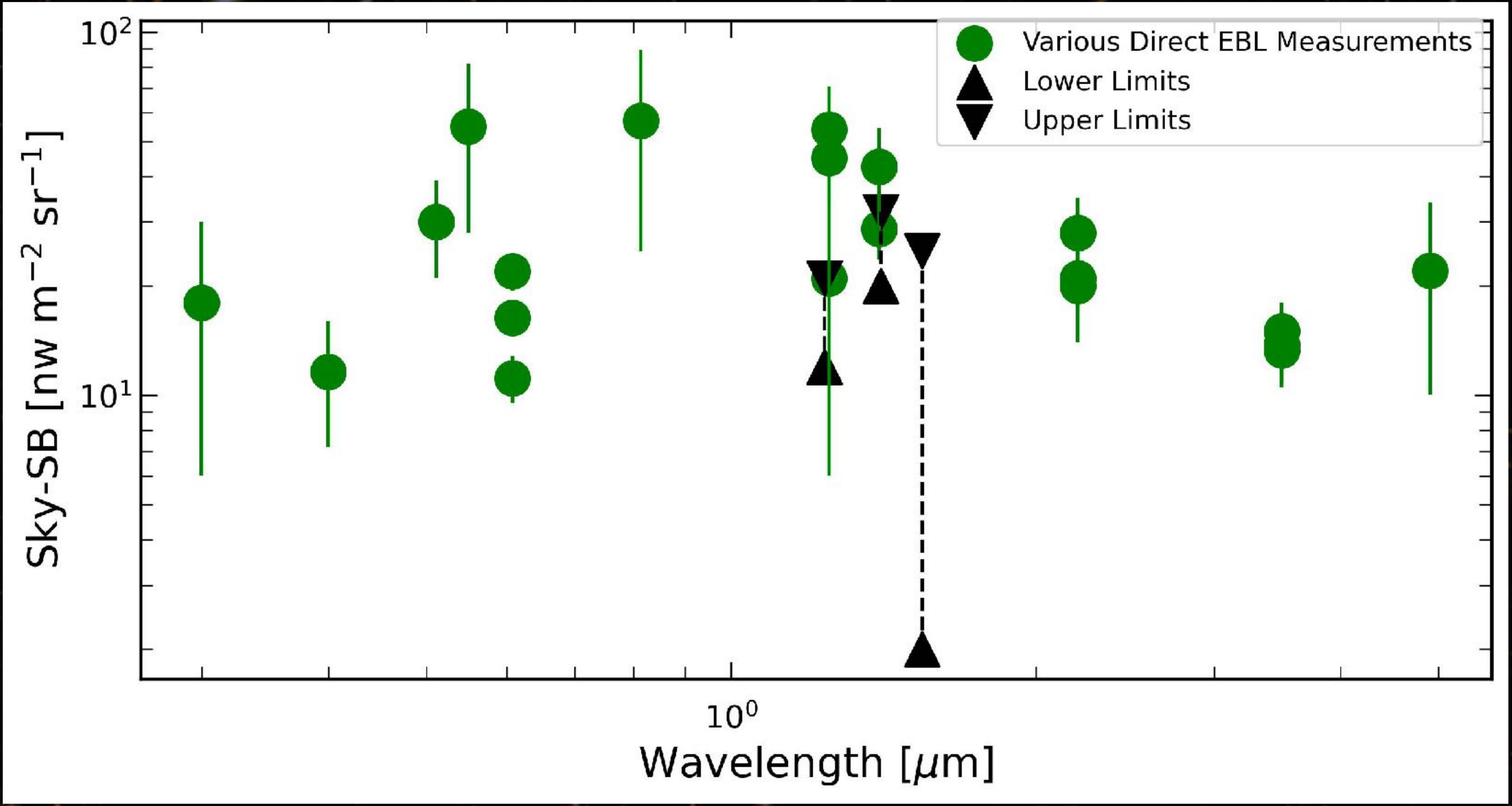
Conclusion

- SKYSURF published sky-SB measurements for +150,000 Hubble images.
- Measurements of the SKYSURF COB are difficult due to bright foregrounds. —> A new Zodiacal Light model is needed.
- Currently using Postman+2024 DGL estimates
- Project SKYSURF remains ongoing.
- SKYSURF-IR (with JWST)

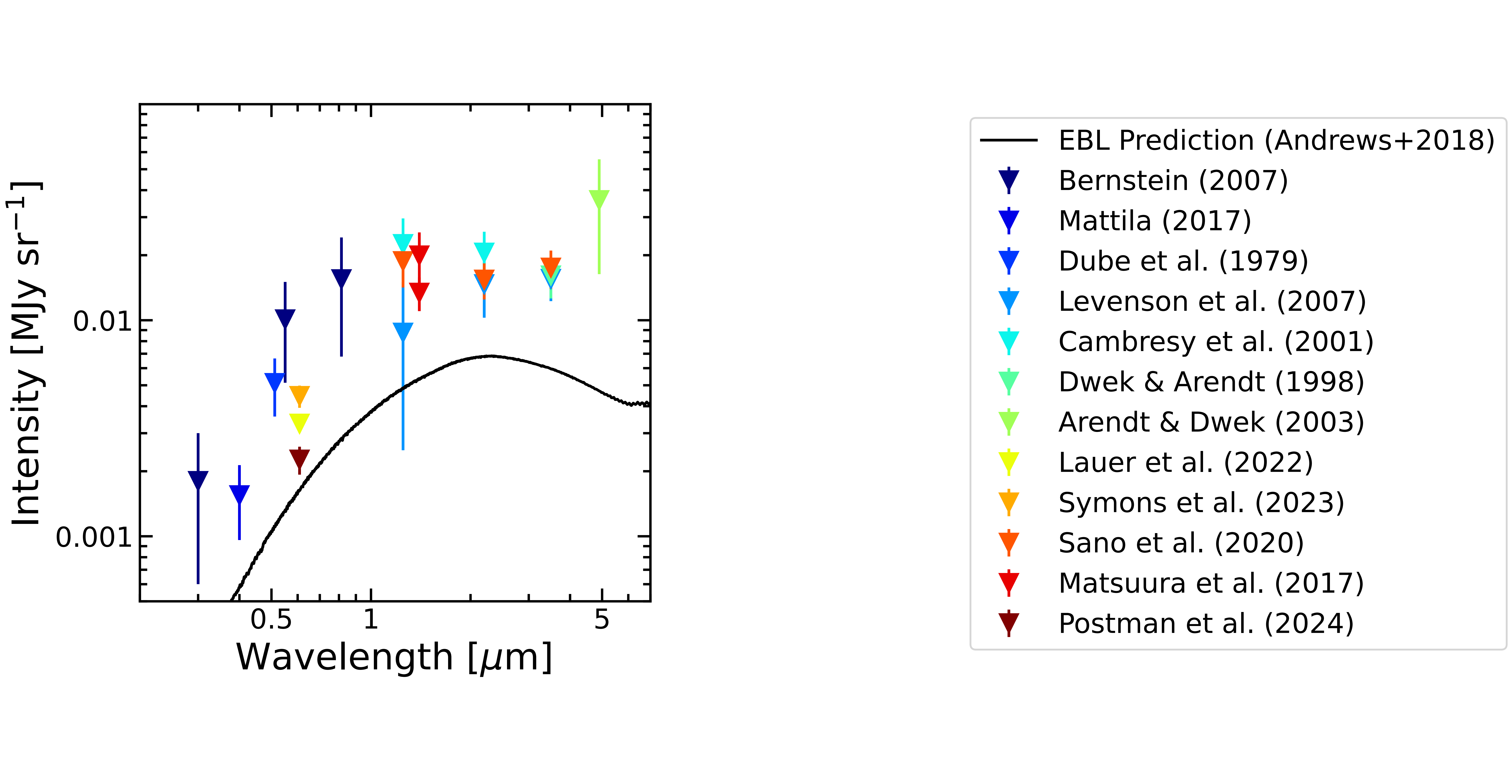
EXTRA SLIDES

Image Credits

- History of the Universe - NASA
- Big Bang Icon - Pablo Carlos Budassi; Unmismoobjetivo/Wikimedia Commons
- Galaxy Icons - NASA
- Thumbs up stick person - The Happiness Project (https://happinessproject.com/products/the-happiness-sticker-pack)
- Image of the night sky - NASA Night Sky Network
- Glasses icon - Warby Parker
- Hubble image - NASA
- Andromeda image - Westend61 via Getty Images
- Comet dust cloud image - NASA Hubblesite



McIntyre et al. 2024



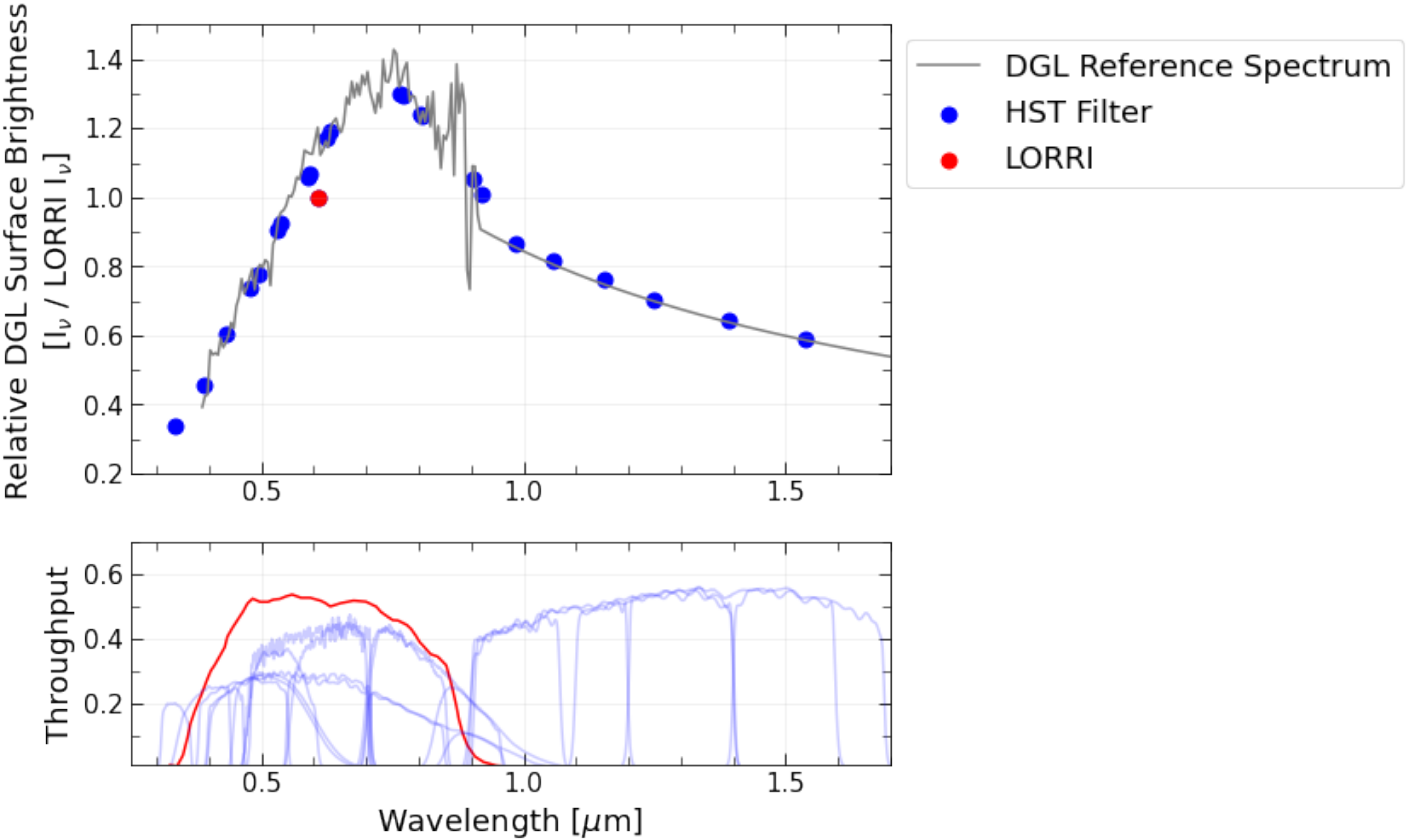
Intensity [MJy sr^{-1}]
0.01
0.001
0.5
1
5
Wavelength [μm]
EBL Prediction (Andrews+2018)
Bernstein (2007)
Mattila (2017)
Dube et al. (1979)
Levenson et al. (2007)
Cambresy et al. (2001)
Dwek & Arendt (1998)
Arendt & Dwek (2003)
Lauer et al. (2022)
Symons et al. (2023)
Sano et al. (2020)
Matsuura et al. (2017)
Postman et al. (2024)

Postman Equation 8

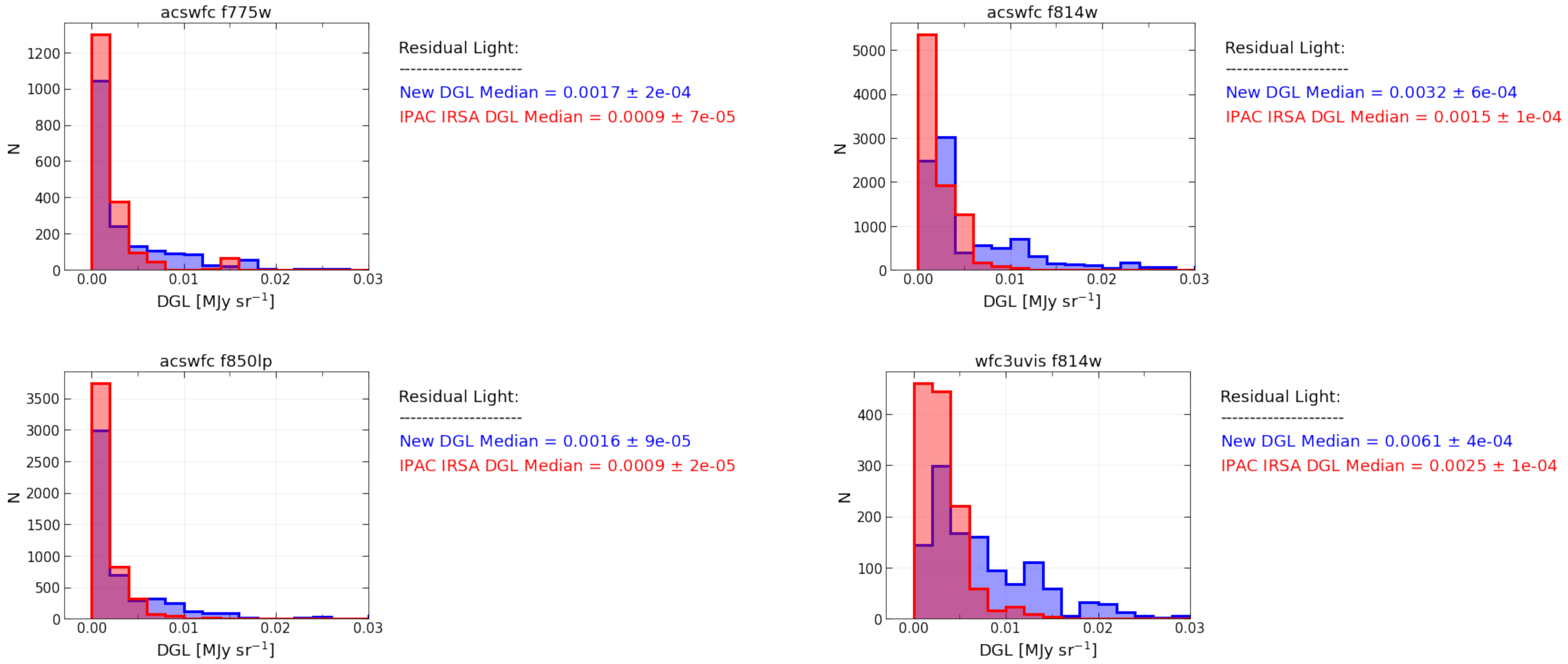
Planck maps with CIB subtracted manually

$$\mathrm{DGL(nW\ m^{-2}\ sr^{-1})} = \mathrm{g(b)}\left[48.01\ \mathrm{I_c(550\ \mu m)}\ +\ 0.96\left(\frac{\mathrm{I_c(350\ \mu m)}}{\mathrm{I_c(550\ \mu m)}} - 3.66\right)\right], \tag{8}$$

LORRI Instrument: 0.608 micron pivot wavelength
(Huge bandpass spanning 0.4 and 0.9 microns)



Relative DGL Surface Brightness
[I_ν / LORRI I_ν]
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.5
1.0
1.5
DGL Reference Spectrum
HST Filter
LORRI
Throughput
0.6
0.4
0.2
0.5
1.0
1.5
Wavelength [μm]


acswfc f775w
Residual Light:

New DGL Median = 0.0017 ± 2e-04
IPAC IRSA DGL Median = 0.0009 ± 7e-05
acswfc f814w
Residual Light:

New DGL Median = 0.0032 ± 6e-04
IPAC IRSA DGL Median = 0.0015 ± 1e-04
acswfc f850lp
Residual Light:

New DGL Median = 0.0016 ± 9e-05
IPAC IRSA DGL Median = 0.0009 ± 2e-05
wfc3uvis f814w
Residual Light:

New DGL Median = 0.0061 ± 4e-04
IPAC IRSA DGL Median = 0.0025 ± 1e-04
N
DGL [MJy sr^{-1}]


wfc3ir f125w
Residual Light:

New DGL Median = 0.0021 ± 2e-04
IPAC IRSA DGL Median = 0.0011 ± 4e-05
wfc3ir f105w
Residual Light:

New DGL Median = 0.0024 ± 3e-04
IPAC IRSA DGL Median = 0.0015 ± 1e-04
wfc3ir f140w
Residual Light:

New DGL Median = 0.0031 ± 3e-04
IPAC IRSA DGL Median = 0.0014 ± 8e-05
wfc3ir f160w
Residual Light:

New DGL Median = 0.0027 ± 1e-04
IPAC IRSA DGL Median = 0.0012 ± 4e-05
N
DGL [MJy sr^{-1}]

COB Prediction

- Phenomological model (forward modeling)
- Assumptions of star formation history, spectral evolution of stellar populations, IMF, SED of starlight, dust attenuation

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **474,** 898–916 (2018) doi:10.1093/mnras/stx2843
Advance Access publication 2017 November 6

Modelling the cosmic spectral energy distribution and extragalactic background light over all time

S. K. Andrews,[1,2★] S. P. Driver,[1,2★] L. J. M. Davies,[1] C. d. P. Lagos[1] and A. S. G. Robotham[1]

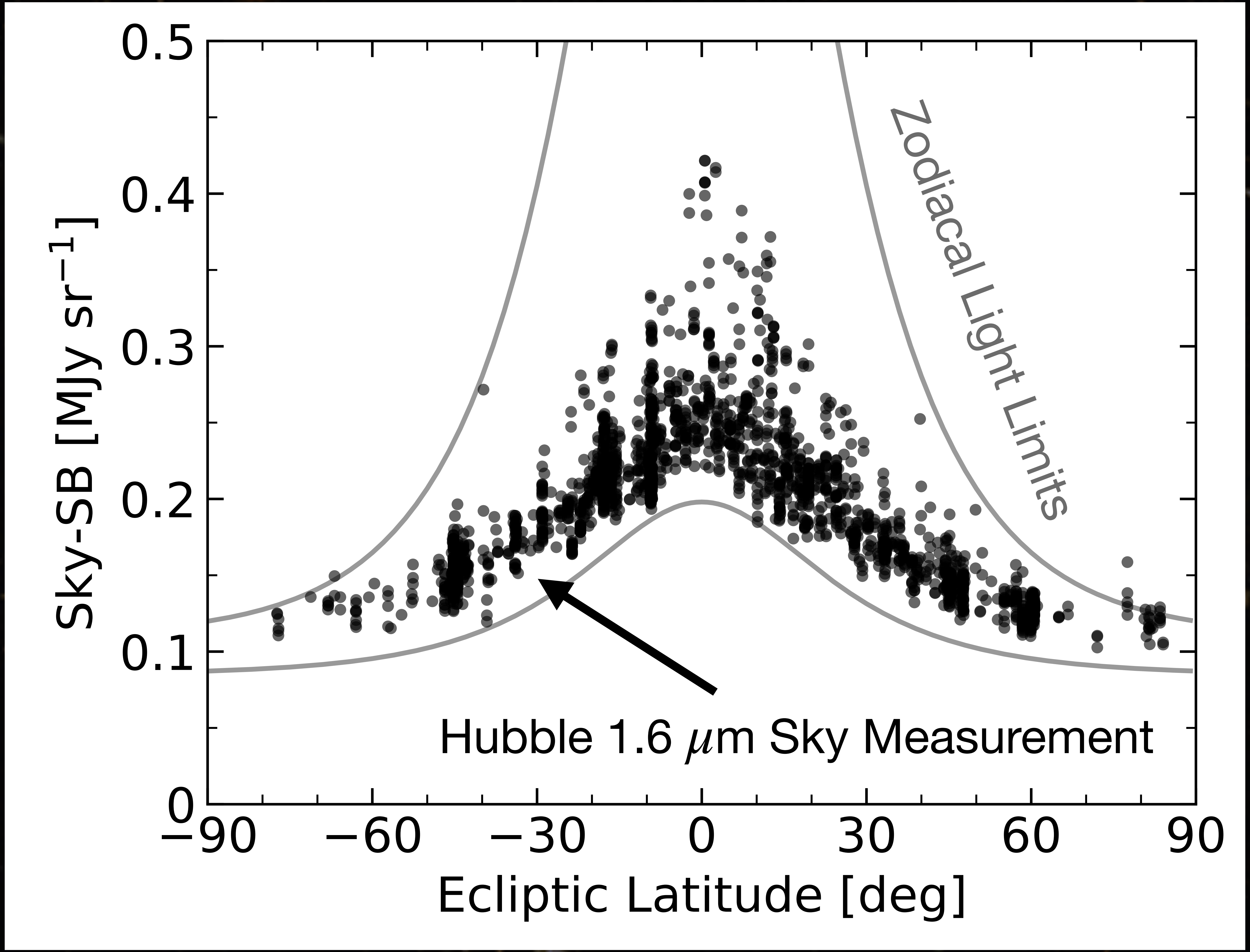
[1] *International Centre for Radio Astronomy Research, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia*
[2] *School of Physics & Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, UK*

Accepted 2017 October 31. Received 2017 October 31; in original form 2017 June 13

Zodi Origin?

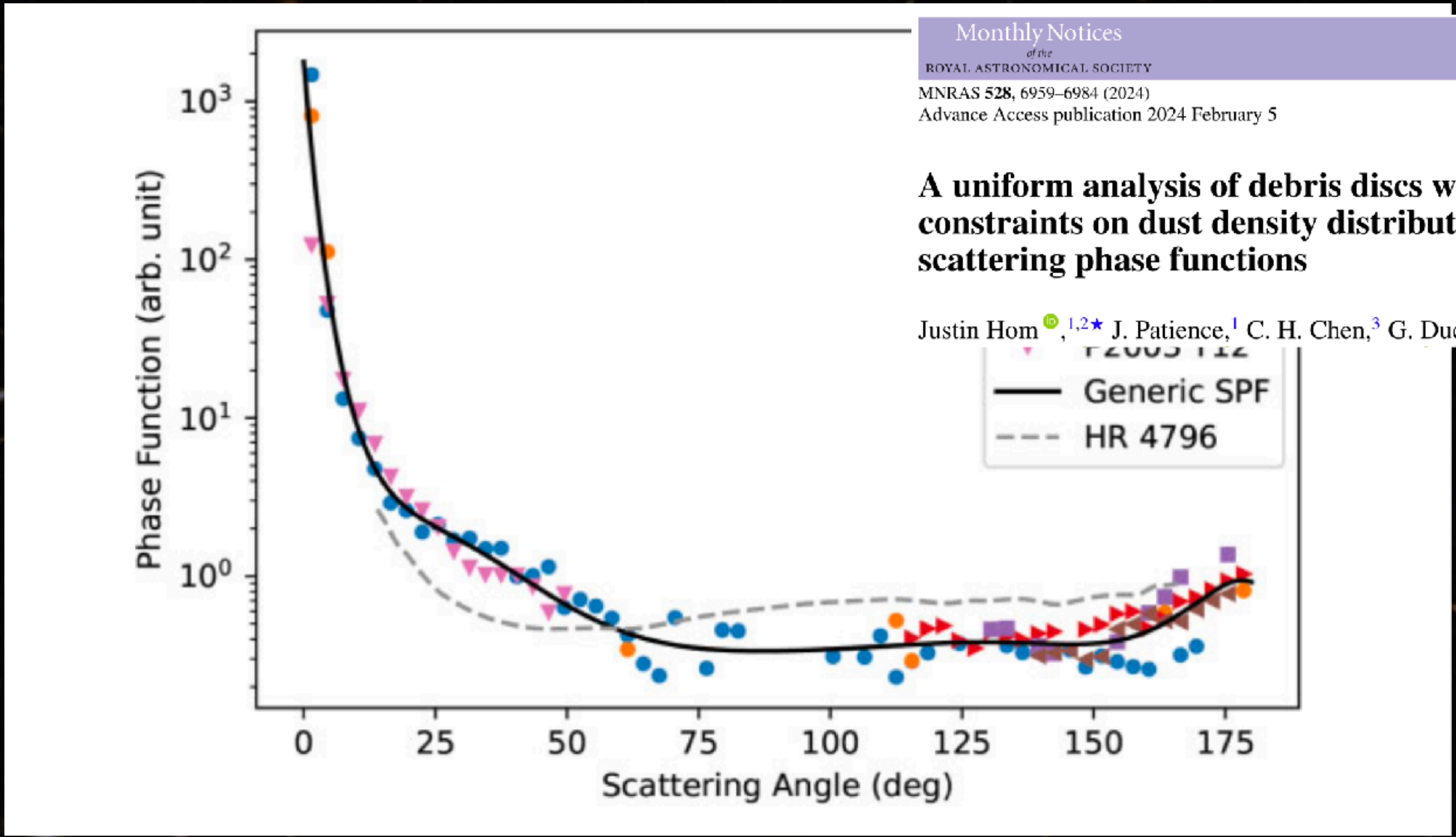
- Smooth Cloud: asteroid collisions (Dermott et al. 1984; Schramm et al. 1989; Tsumura et al. 2010); cometary ejections (Liou et al. 1995; Nesvorný et al. 2010; Yang and Ishiguro 2015)
- Dust Bands: Believed to be asteroidal collisional debris; The material producing them is likely to be debris spiraling into the Sun under Poynting-Robertson drag (effect that causes dust grains to lose angular momentum due to radiation pressure from the Sun).
- Circumsolar rings: The Earth temporarily traps migrating dust particles into resonant orbits near 1 AU if they are in low-eccentricity orbits, as is expected for asteroidal debris

Sky Measurements



O'Brien et al. 2023

A New Scattering Phase Function



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

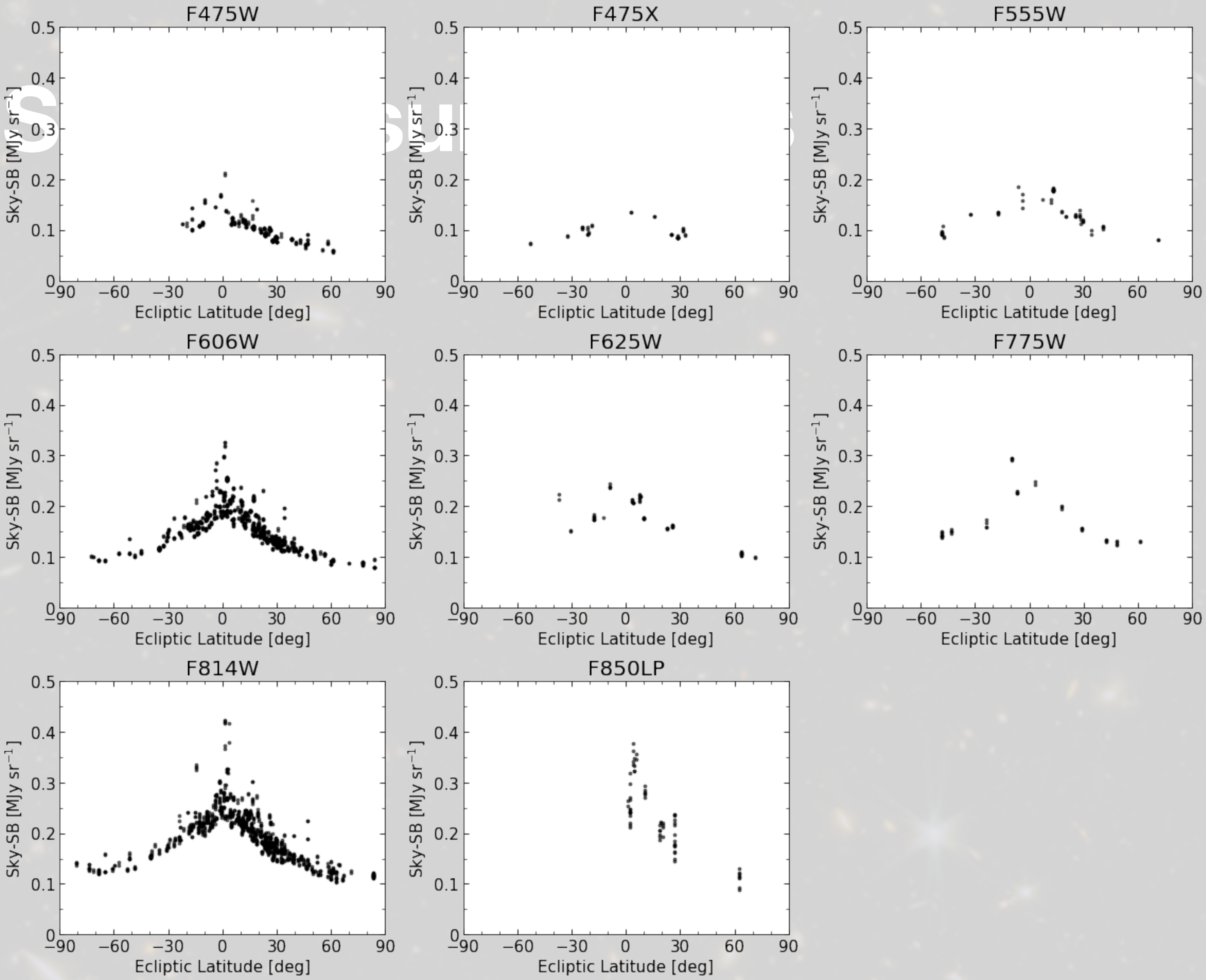
MNRAS 528, 6959–6984 (2024) https://doi.org/10.1093/mnras/stae368

Advance Access publication 2024 February 5

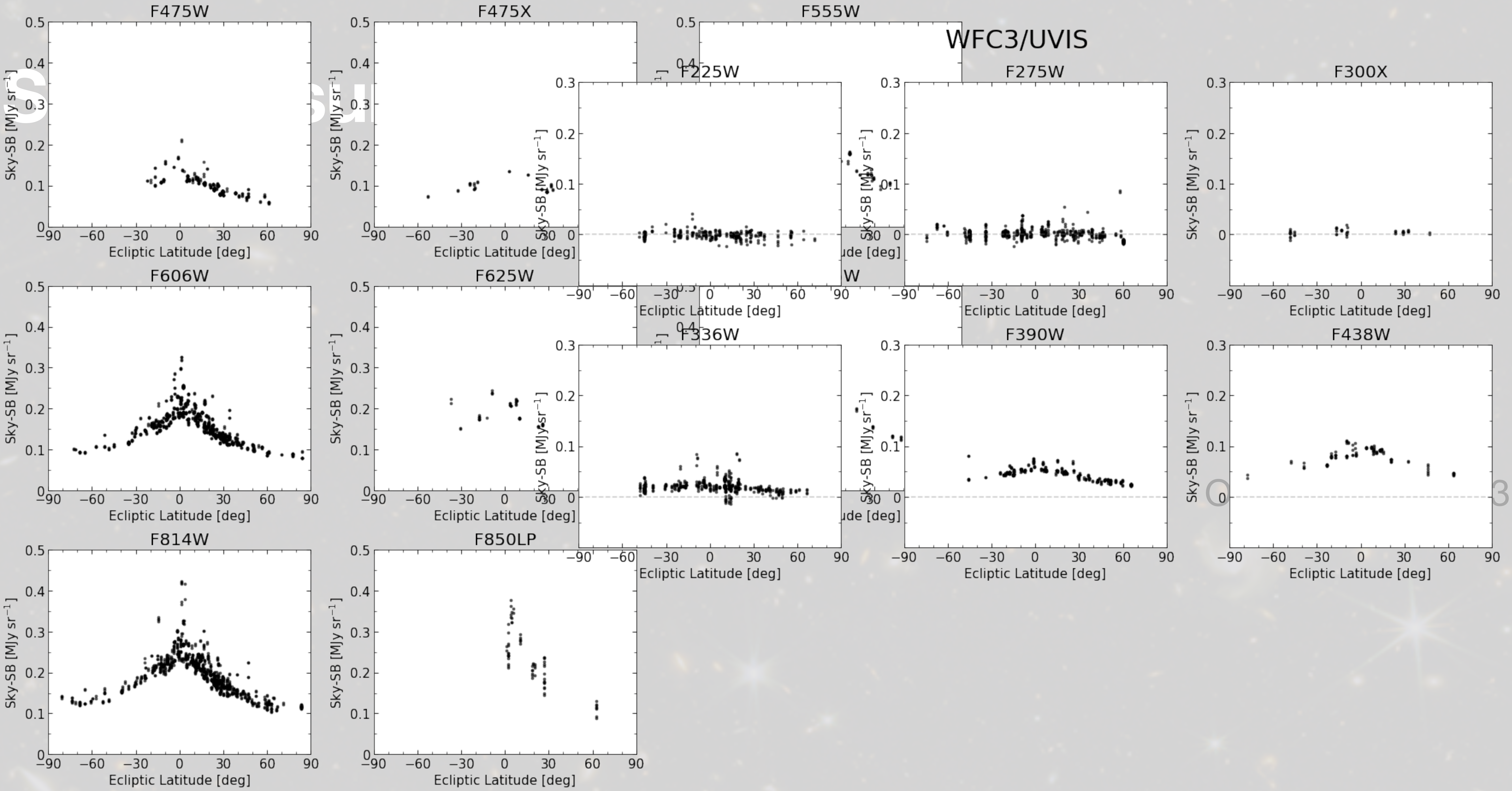
A uniform analysis of debris discs with the Gemini Planet Imager II: constraints on dust density distribution using empirically informed scattering phase functions

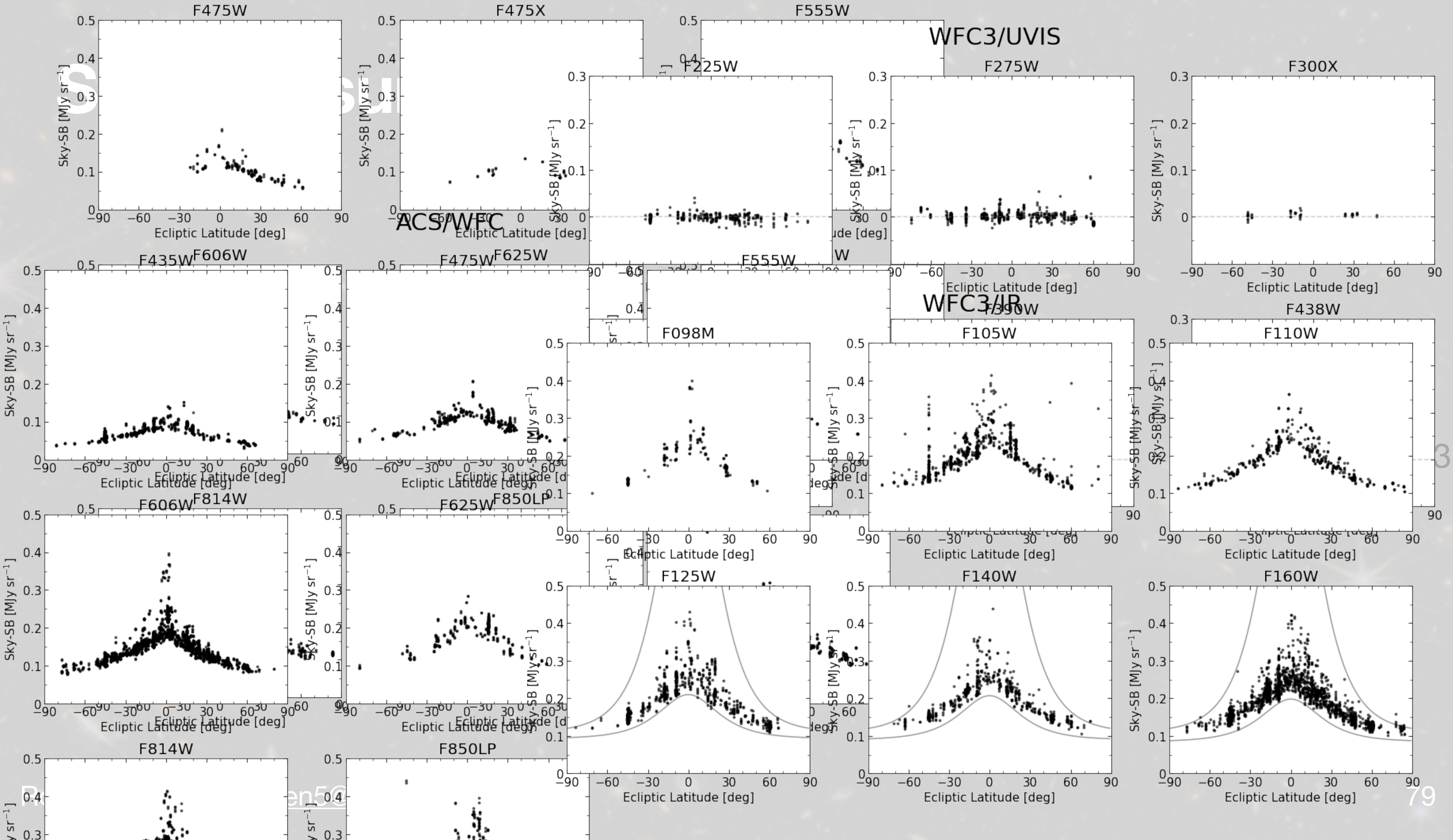
Justin Hom,[1,2★] J. Patience,[1] C. H. Chen,[3] G. Duchêne,[4,5] J. Mazoyer,[6] M. A. Millar-Blanchaer,[7]

Hom et al. 2024



O’Brien et al. 2023


WFC3/UVIS
F475W
F475X
F555W
F225W
F275W
F300X
F606W
F625W
F336W
F390W
F438W
F814W
F850LP
Sky-SB [MJy sr^{-1}]
Ecliptic Latitude [deg]


WFC3/UVIS
F225W
F275W
F300X
ACS/WFC
F435W
F475W
F555W
F606W
F625W
F814W
F850LP
WFC3/IR
F098M
F105W
F110W
F125W
F140W
F160W
Sky-SB [MJy sr^{-1}]
Ecliptic Latitude [deg]

Diffuse Light measurements

skysurf.asu.edu

Diffuse Light = Sky-SB – Zodiacal Light – DGL – IGL - Thermal Dark

IPAC/IRSA Background Model

Arendt+1998 and Schlegel+1998

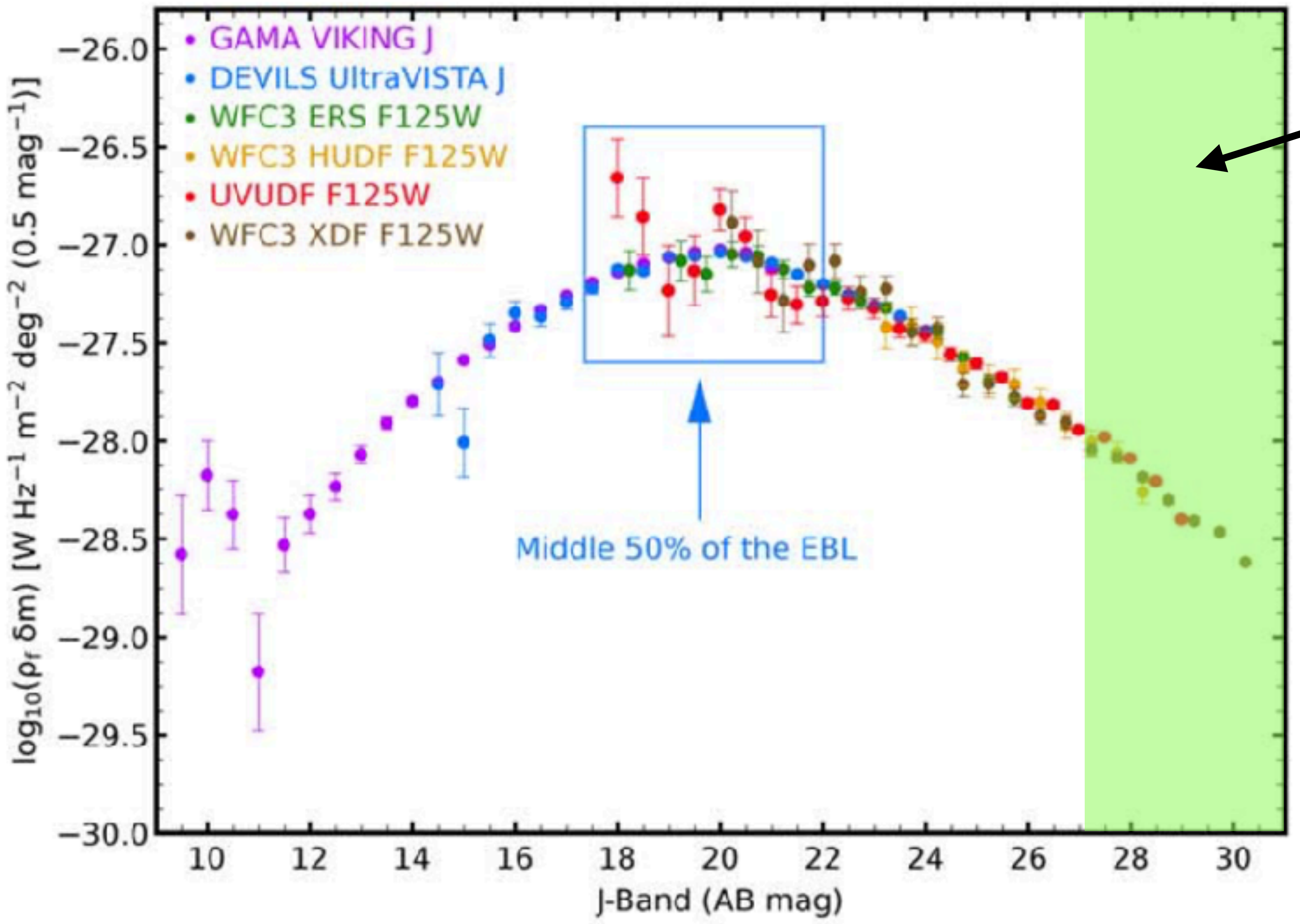
Rosalia O'Brien
robrien5@asu.edu

Diffuse Light measurements

skysurf.asu.edu

Diffuse Light = Sky-SB – Zodiacal Light – DGL – IGL - Thermal Dark

Windhorst+2022 (AJ)



For now: Integral of galaxy flux energy density for mag > 26.5

0.56 nW m^{-2} sr^{-1}

0.0003 MJy sr^{-1}

Rosalia O'Brier
robrien5@asu.edu

Diffuse Light measurements

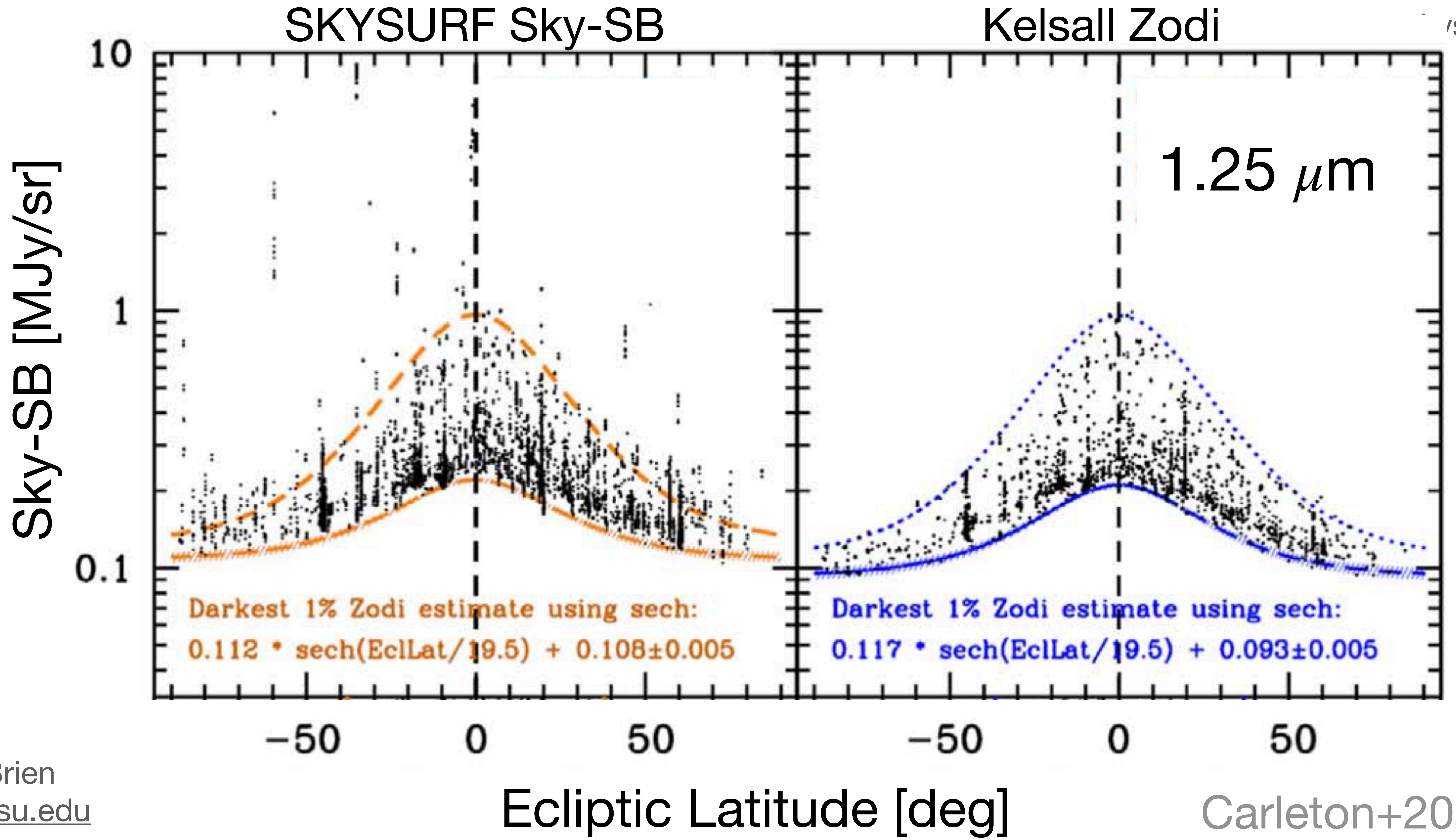
skysurf.asu.edu

Diffuse Light = Sky-SB – Zodiacal Light – DGL – IGL - Thermal Dark

Filter	Thermal Dark [e s^{-1}]	Thermal Dark [MJy sr^{-1}]
F098M	0.0044	0.0023
F105W	0.0044	0.0013
F125W	0.0040	0.0012
F140W	0.0201	0.0050
F160W	0.0772	0.0308

Rosalia O’Brien
robrien5@asu.edu

Diffuse Light measurements

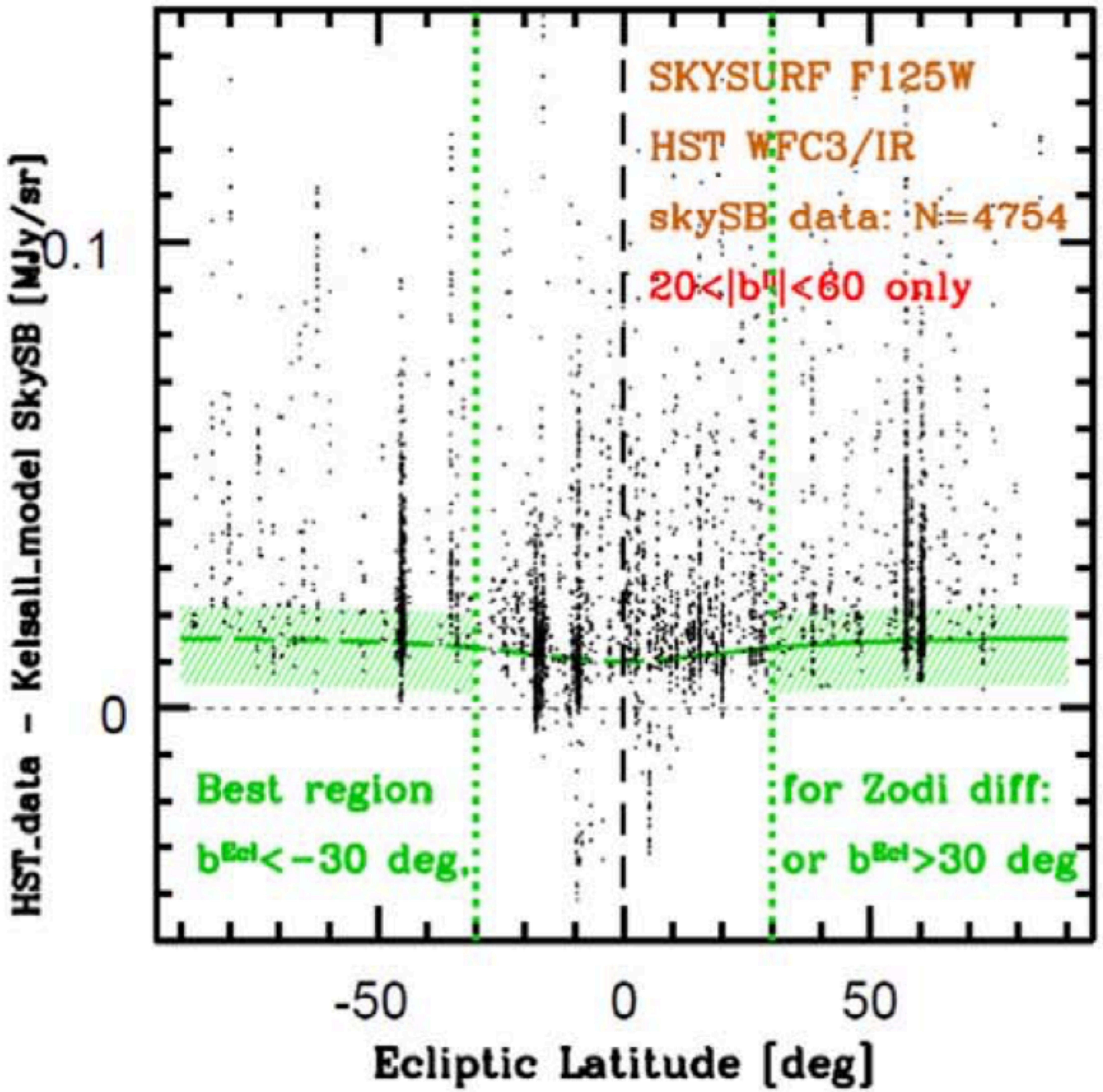


Carleton+2022

Rosalia O'Brien
robrien5@asu.edu

Diffuse Light measurements

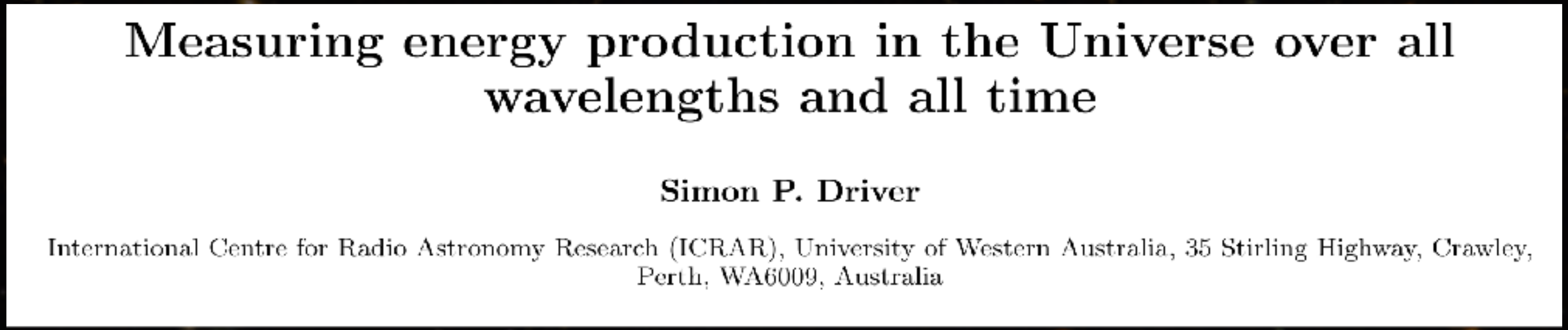
skysurf.asu.edu



Carleton+2022

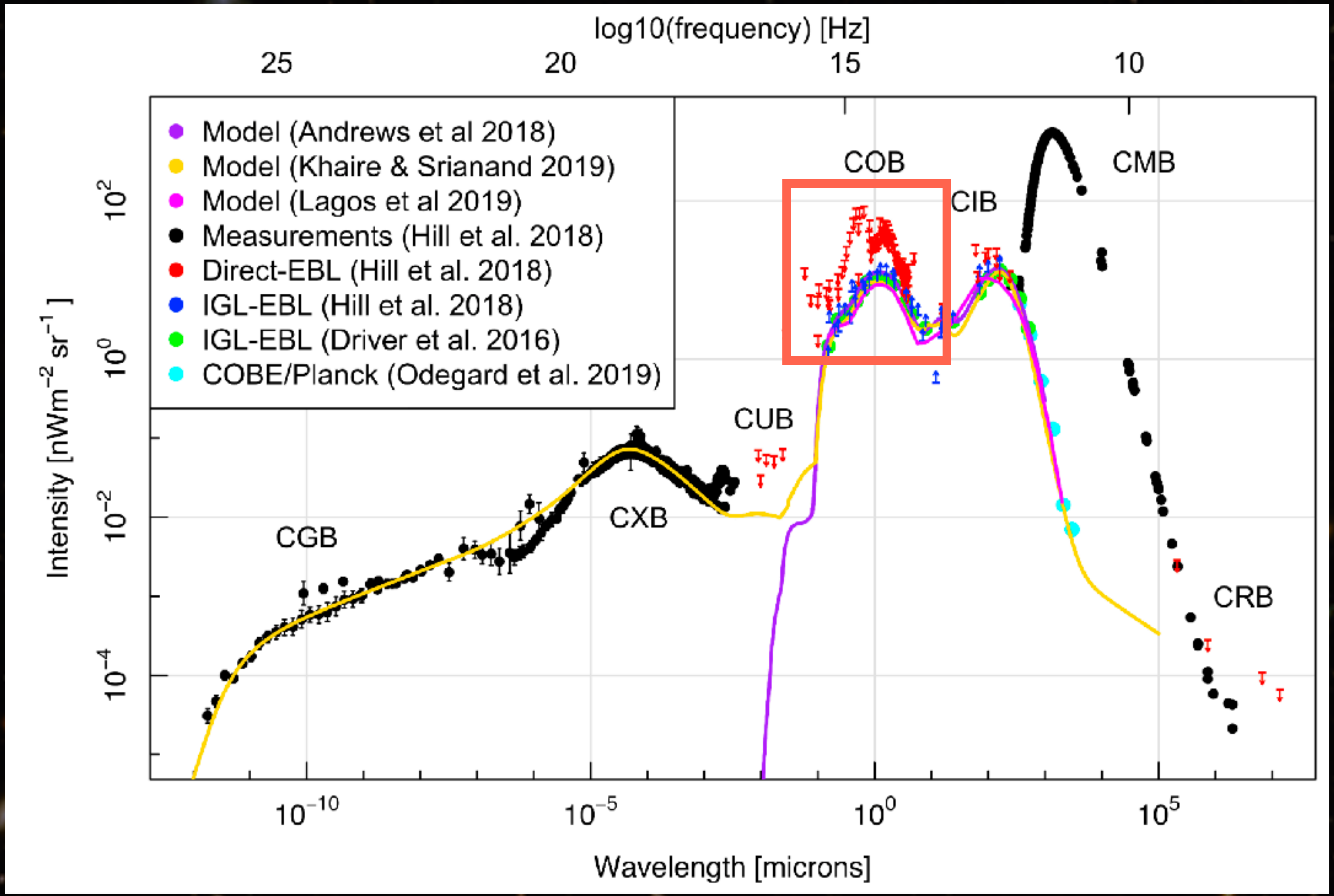
Rosalia O’Brien
robrien5@asu.edu

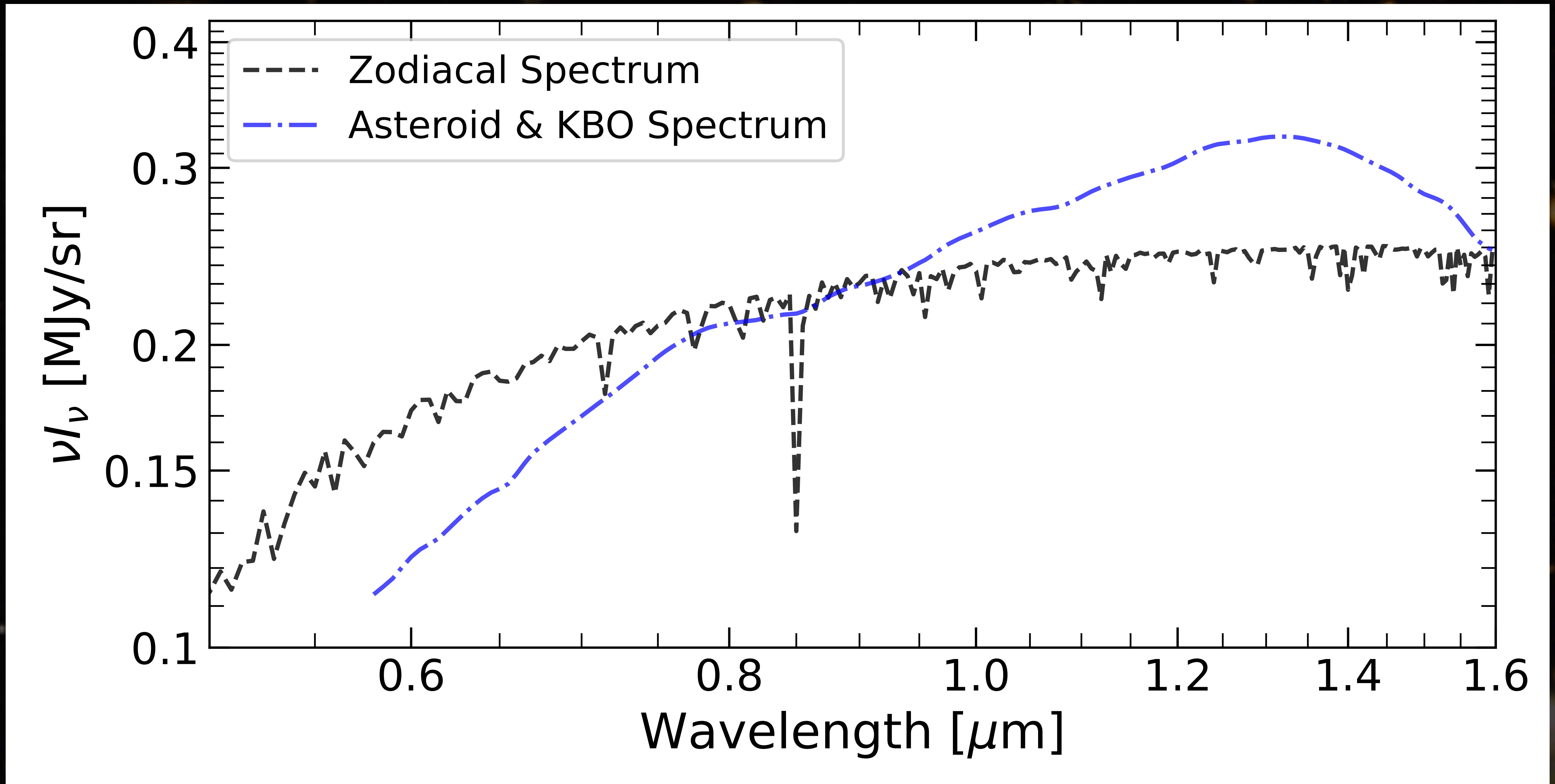
- Represents the light from all galaxies throughout cosmic history.
- Vital to understanding the history of the universe, as it probes star formation, black hole activity, and dust properties over cosmic time.


Measuring energy production in the Universe over all wavelengths and all time

Simon P. Driver

International Centre for Radio Astronomy Research (ICRAR), University of Western Australia, 35 Stirling Highway, Crawley, Perth, WA6009, Australia





Rosalia O’Brien (robrien5@asu.edu)

Space weathering of Vesta and V-type asteroids: new irradiation experiments on HED meteorites★

D. Fulvio[1,2], R. Brunetto[3], P. Vernazza[4], and G. Strazzulla[2]

[1] Laboratory for Atomic and Surface Physics, University of Virginia, Thornton Hall B-113, Charlottesville, VA 22904, USA
e-mail: df6vz@virginia.edu; dfu@oact.inaf.it
[2] INAF – Osservatorio Astrofisico di Catania, via S. Sofia 78, 95123 Catania, Italy
[3] Institut d'Astrophysique Spatiale, CNRS, UMR-8617, Université Paris-Sud, Bât. 121, 91405 Orsay Cedex, France
[4] European Southern Observatory, K. Schwarzschild-Str. 2, 85748 Garching, Germany

Received 18 November 2011 / Accepted 27 December 2011

ABSTRACT

Context. In the past few decades, several tens of main belt asteroids have been found to exhibit basaltic surface composition, similar to the one of Vesta and basaltic Howardite, Eucrite, and Diogenite achondrite meteorites (HEDs). Most of these objects (V-types) belong to the Vesta dynamical family. Several questions on the relationship between Vesta, V-types, and HEDs are still unresolved. In particular, Vesta is spectroscopically bluer than most V-types.
Aims. To date, it has not yet been understood whether these spectral differences are due to space weathering, similar to what has been observed for OC meteorites and S-type asteroids. To test this hypothesis, ion irradiation experiments were performed on different samples of eucrites to simulate the effects of space weathering on Vesta and V-types by solar wind ions.
Methods. Eucrite meteorites were analyzed before and after different stages of ion irradiation by VIS-NIR reflectance spectroscopy (0.4–2.5 μm). We used different ions (Ar^+, C^+) with different energies (from 60 to 200 keV) to weather the samples.
Results. Ion irradiation was observed to alter the spectral properties of eucrite meteorites, inducing progressive reddening and darkening of the irradiated samples. Different eucrite samples (Bereba and Dar Al Gani 684) show different reddening behaviors. Because they are patchy, reddening also varied between different parts of the same meteorite. Moreover, for both meteorites, irradiation effects are much faster (~100 times) for C^+ than for Ar^+ ions.
Conclusions. Comparing the laboratory spectra of eucrites before and after different stages of ion irradiation with those of V-types, it turns out that the slope spread shown by V-type asteroids can be explained by space weathering. These results provide new clues to the connection between Vesta, V-types, and HEDs, and are also useful in the context of the NASA Dawn mission to Vesta.

Key words. minor planets, asteroids: individual: Vesta – techniques: spectroscopic – methods: laboratory – infrared: general

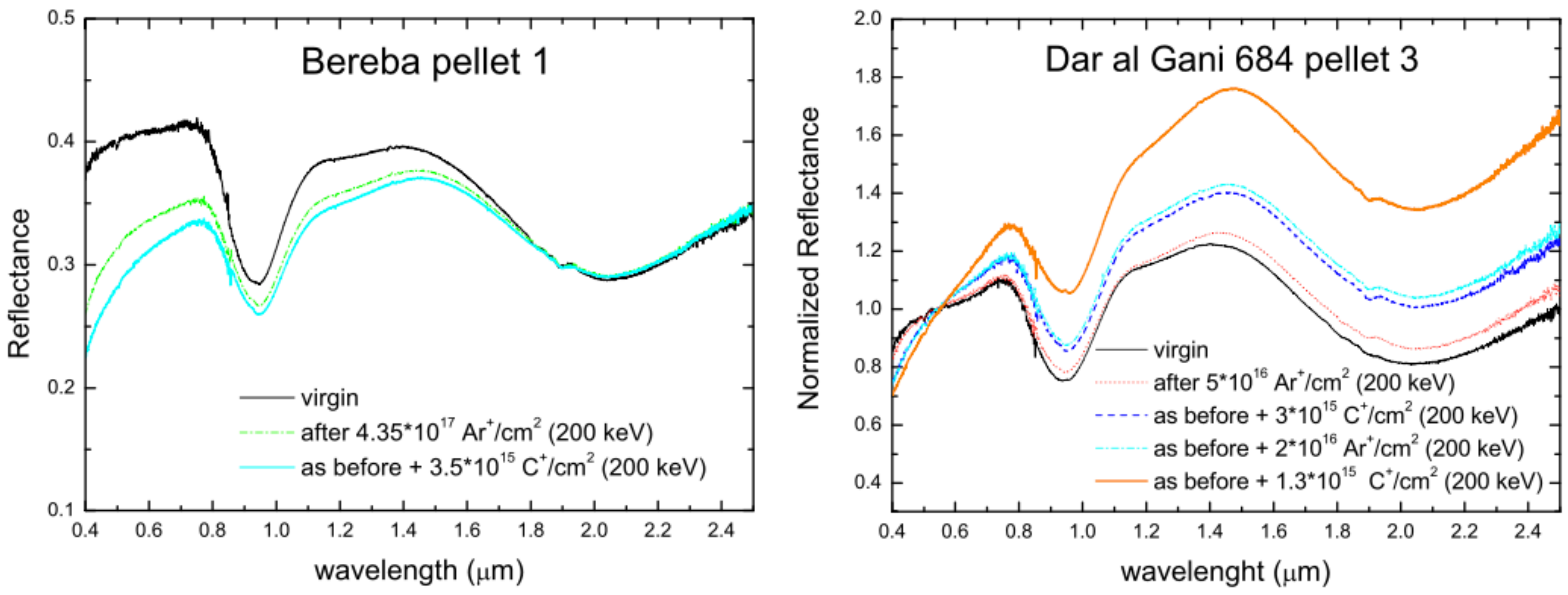
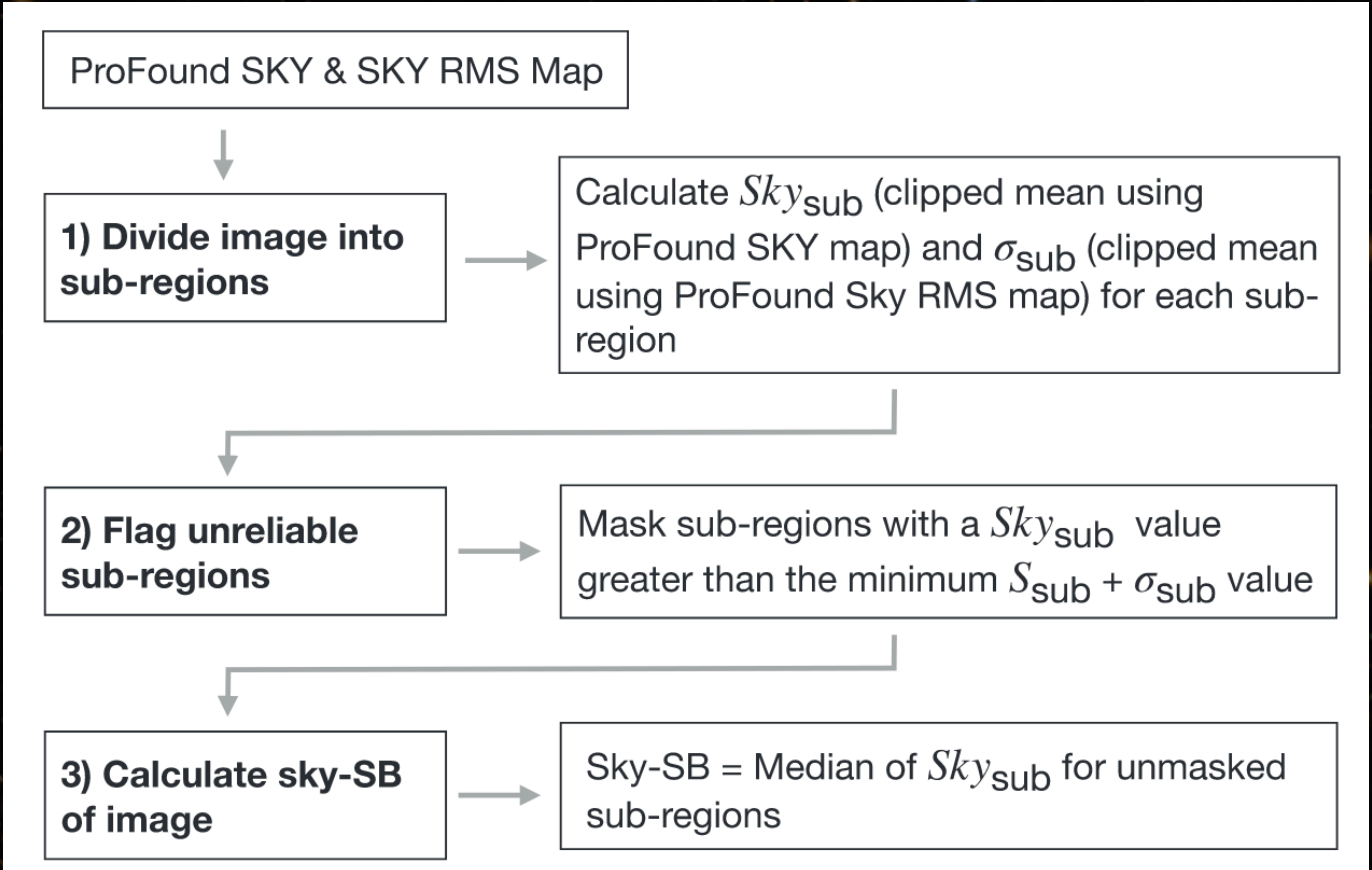
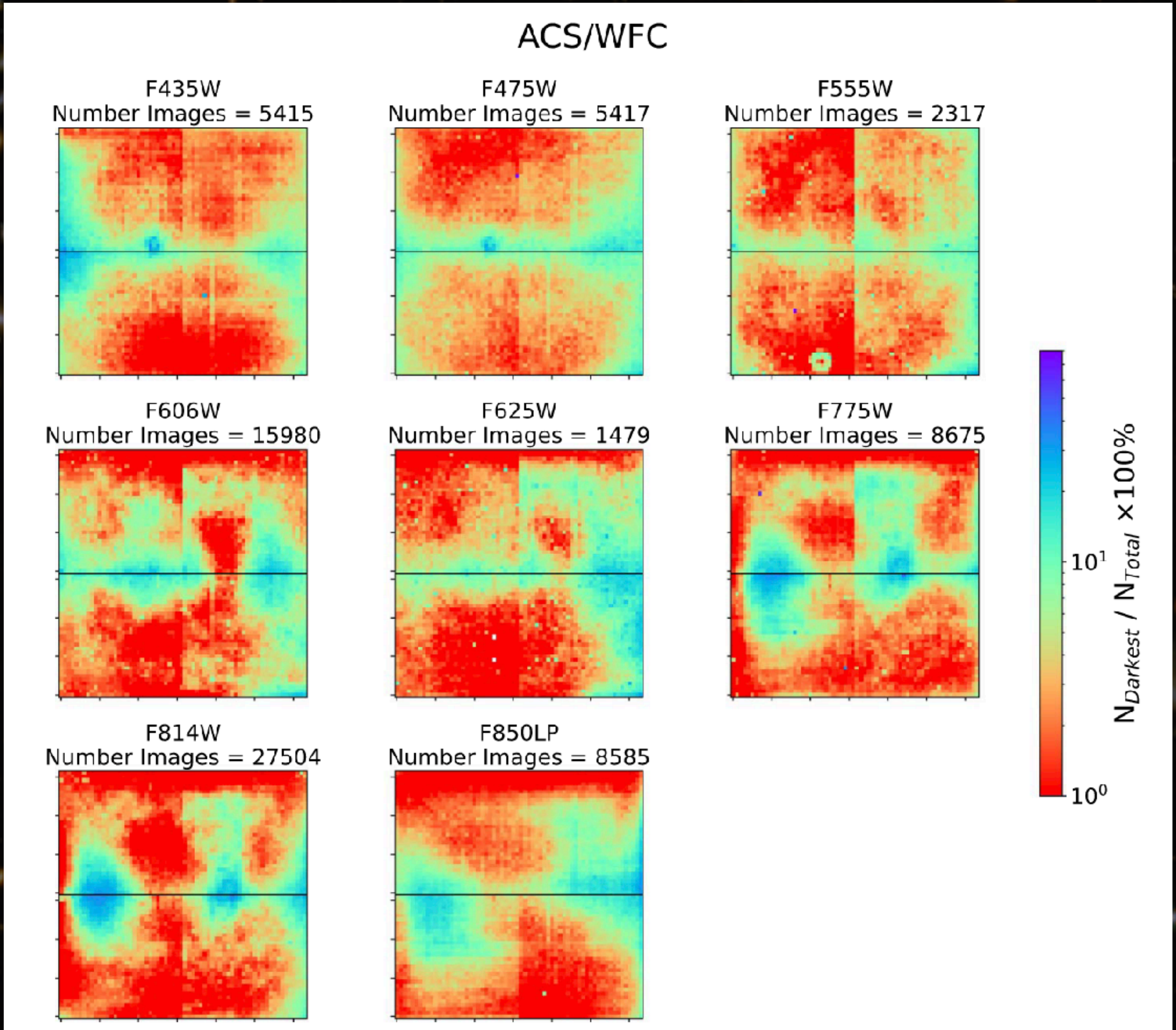


Fig. 1. VIS-NIR reflectance spectra of Bereba pellet 1 and Dar Al Gani 684 pellet 3 (normalized reflectance), before and after multiple irradiations.

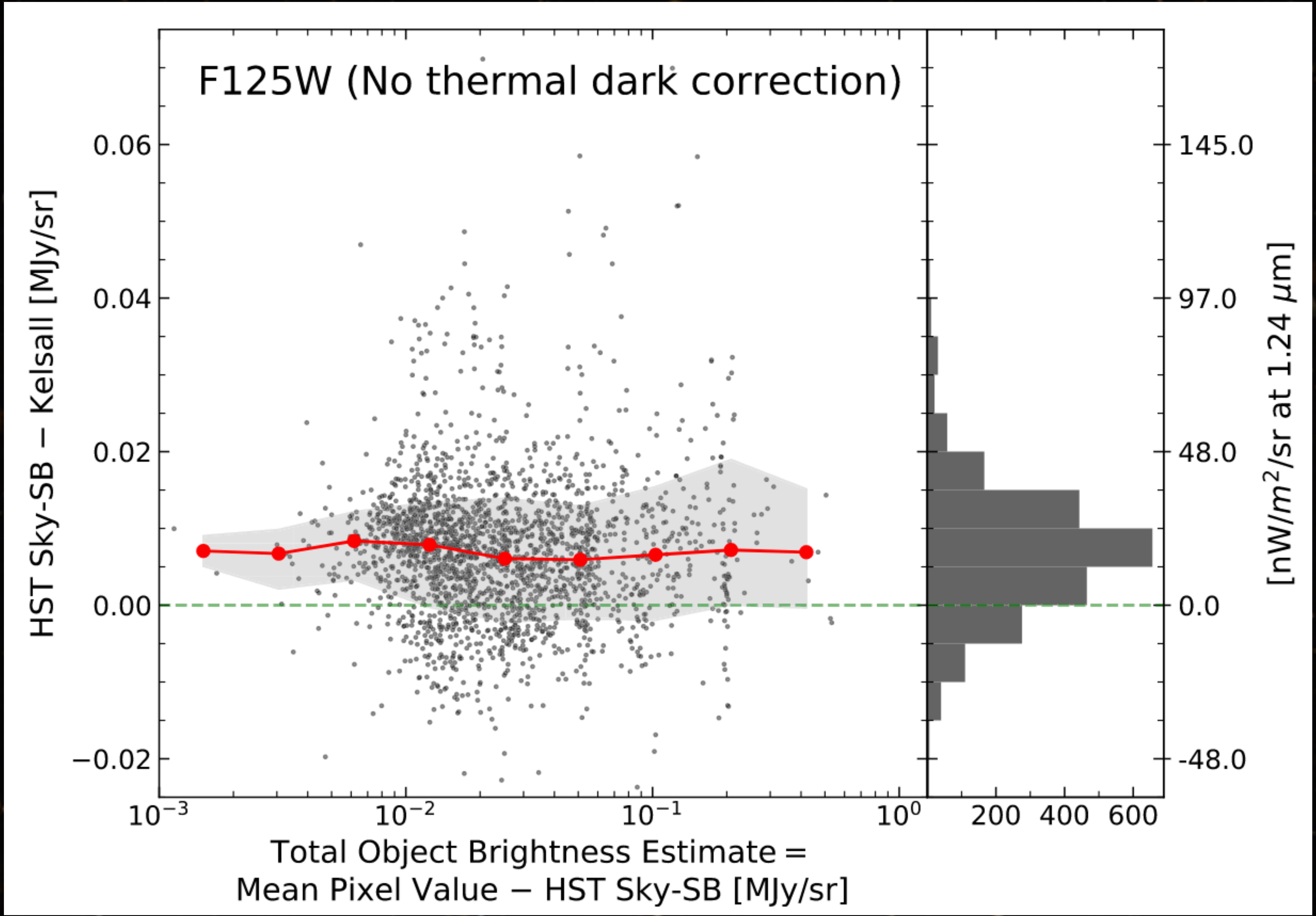
Table 2
SKYSURF sky-SB Uncertainties

Uncertainty	WFC3/UVIS	WFC3/IR	ACS/WFC
Sky Algorithm	0.4%	0.4%	0.4%
Flat field	1%	2%	2.2%
Zero-point	0.2%	1.5%	1%
Nonlinearity	N/A	0.5%	N/A
Bias	0.2 e^- (1.4%)	0.005 e^-/s (0.7%)	0.6 e^- (1.5%)
Dark	0.3 e^- (2.1%)	0.005 e^-/s (0.7%)	0.5 e^- (1.2%)
Thermal Dark	N/A	0.01 e^-/s (1.3%)	N/A
Post-flash	0.16 e^- (1.1%)	N/A	0.37 e^- (0.9%)
Total	3.0%	3.1%	3.2%


ProFound SKY & SKY RMS Map
1) Divide image into sub-regions
Calculate Sky_{sub} (clipped mean using ProFound SKY map) and σ_{sub} (clipped mean using ProFound Sky RMS map) for each sub-region
2) Flag unreliable sub-regions
Mask sub-regions with a Sky_{sub} value greater than the minimum $S_{sub} + \sigma_{sub}$ value
3) Calculate sky-SB of image
Sky-SB = Median of Sky_{sub} for unmasked sub-regions



Rosalia O’Brien (robrien5@asu.edu)


F125W (No thermal dark correction)
HST Sky-SB − Kelsall [MJy/sr]
0.06
0.04
0.02
0.00
−0.02
10^{-3}
10^{-2}
10^{-1}
10^{0}
Total Object Brightness Estimate =
Mean Pixel Value − HST Sky-SB [MJy/sr]
200 400 600
145.0
97.0
48.0
0.0
-48.0
[nW/m^2/sr at 1.24 μm]