Solar and Exo- Zodiacal Light Signals:
Current Knowledge, Limitations and Impact on HWO Exoplanet Science

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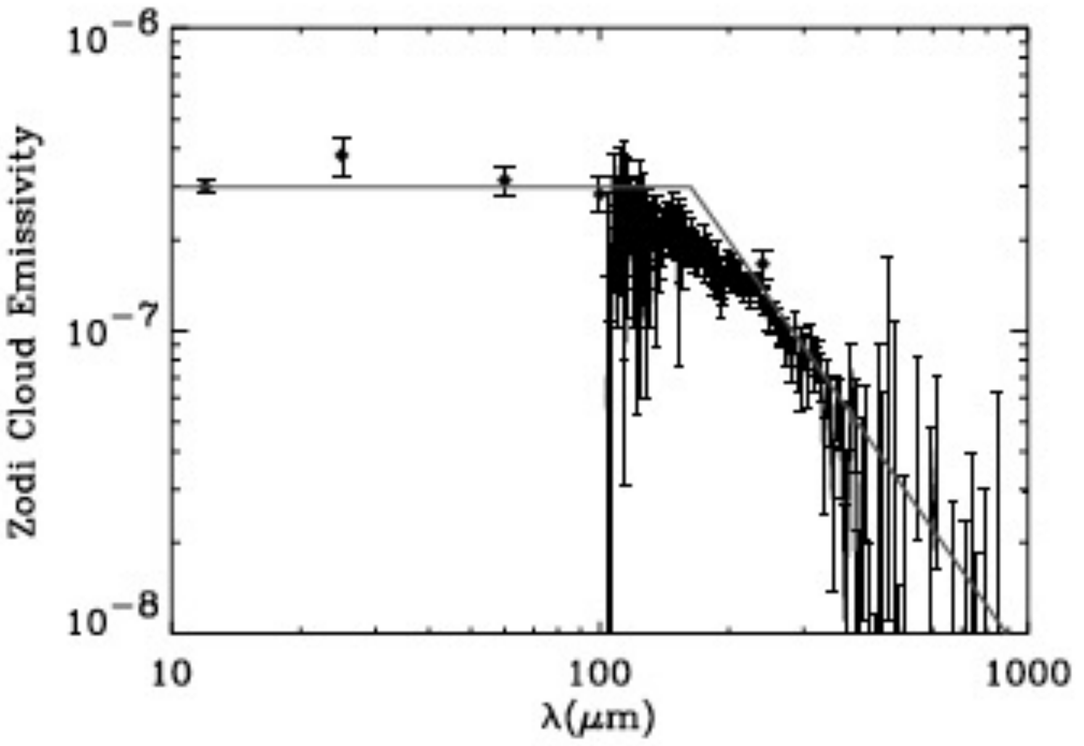
Solar Zodiacal Light

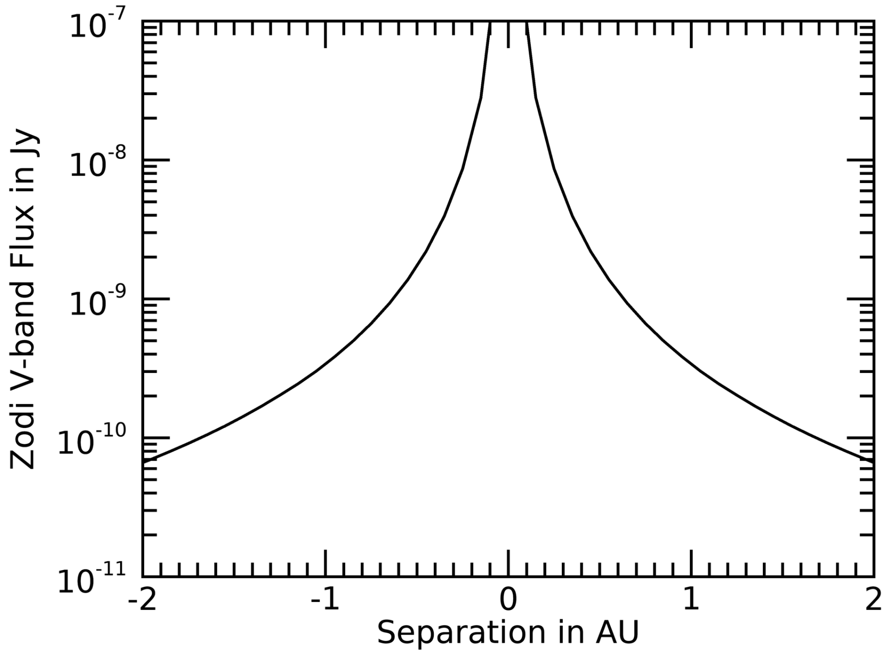
- Warm circum-solar dust located within the asteroid belt, from <0.1 AU to ~3.3 AU
- Optically thin cloud of small (1-100 μm) dust grains created from asteroid collisions, comets evaporation and disruption
- Temperature and density profiles measured by COBE/DIRBE (Kelsall et al. 1998):
  - Tdust ~ 286 K $(r/1AU)^{-0.467}$
  - Optical depth ~ 10^{-7} $(r/1AU)^{-1.34}$
- Total mass equivalent to asteroid of 15km radius or a few 10^{-9} Earth mass
- But *total* flux > 100 times the Earth at both visible and mid-infrared wavelengths
- Solar zodi surface brightness at 1 AU is ~ 23 mag/arcsec^2 at V band
  - Varying with ecliptic latitude (23.4 looking at poles, 22.5 in the plane)



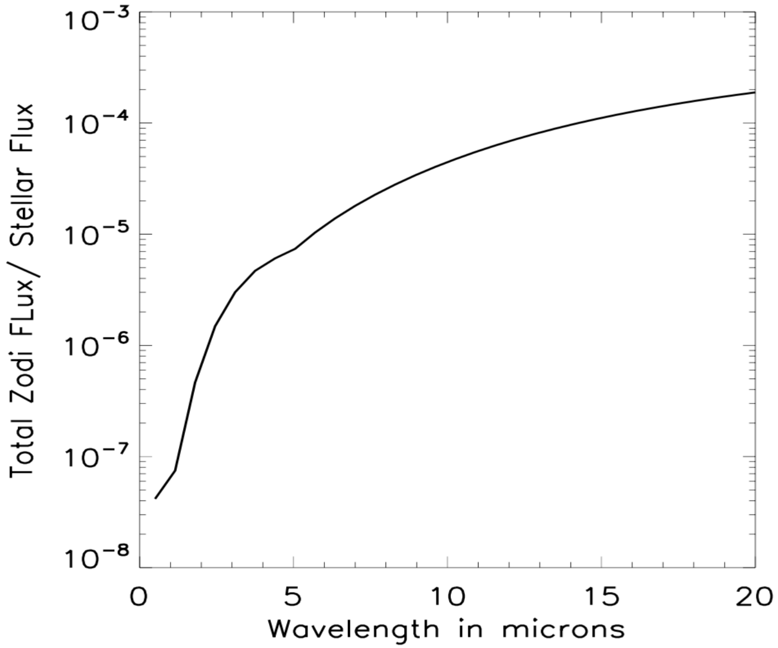
COBE/DIRBE NIR to FIR data
Fixsen & Dwek 2002

"1 zodi" worth of Exo-zodiacal dust

- Stars will have the equivalent of the solar zodi → exo-zodiacal dust
- Exo-zodi level of "1 zodi" means the exozodi dust density spatial profile, size distribution and albedo are strictly identical to solar system
  - With density profile rescaled by sqrt(L*/Lsun) to preserve dust density at EEID
  - V band apparent surface brightness is ~22 mag/arcsec^2 (e.g., Stark et al. 2014)



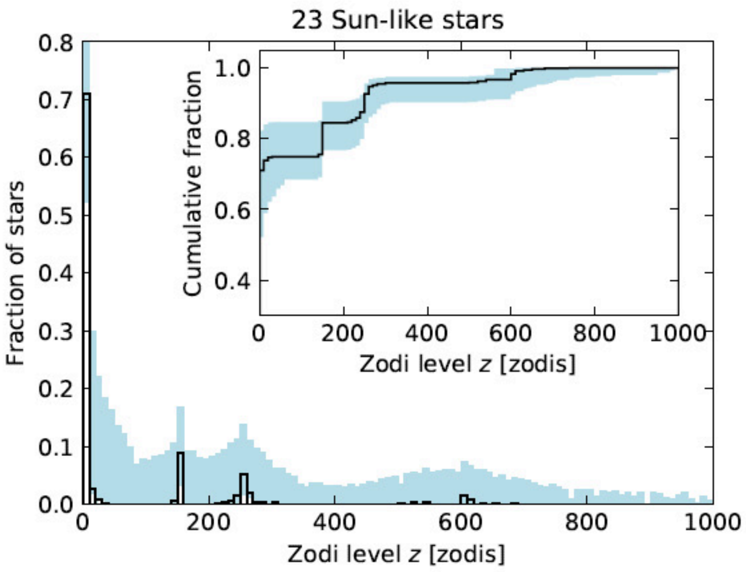
1 Zodi worth of exozodi flux as seen from 10 pc



Total exozodi flux vs wavelength, assuming "1 Zodi"

Current Knowledge of Exozodi Levels and Representation in Yield Estimates

- Best measurements to date come from LBTI Exozodi Survey around 11 μm
- 23 sunlike stars observed, typical 1σ uncertainty per star ~ 50 zodis
- Statistical analysis suggest stars come in 2 flavors: < 30 zodis (most) and > 100 zodis
- Median Exozodi Level = 3^{+6}_{-2} zodis, with 95% confidence upper limit of 27 zodis



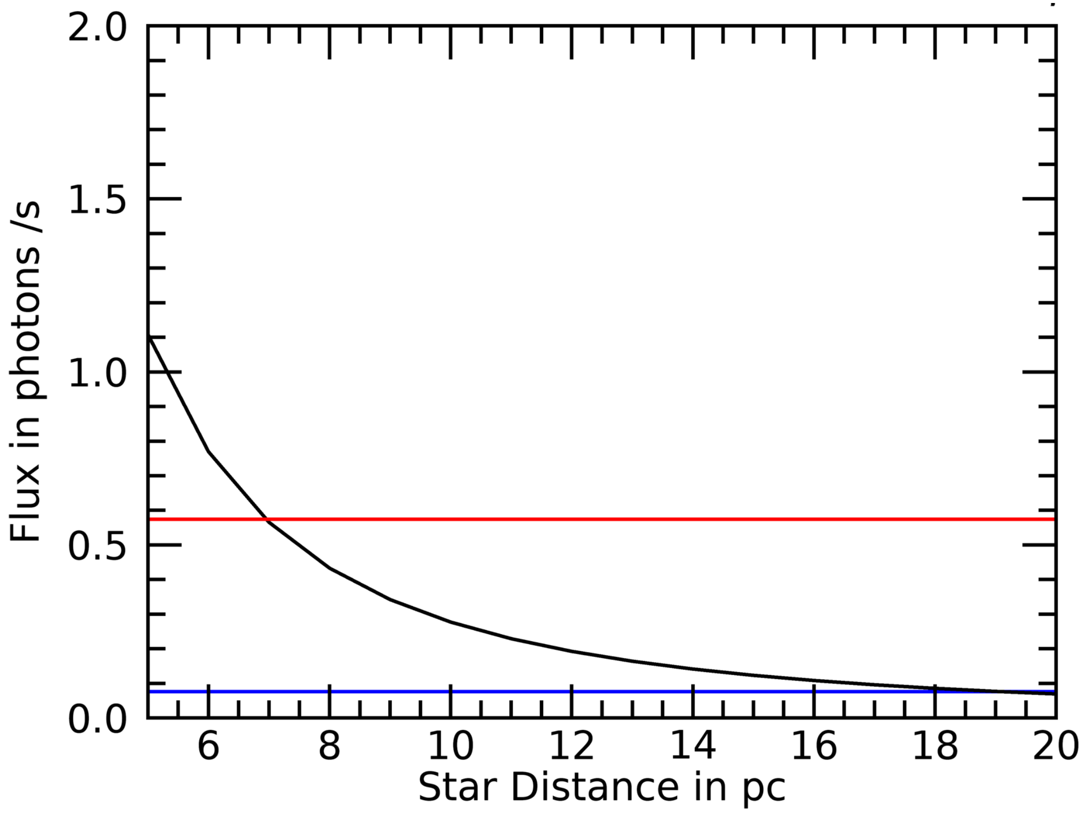
LBTI survey results
Ertel et al. 2020

Current Exozodi representation in Yield Simulations:

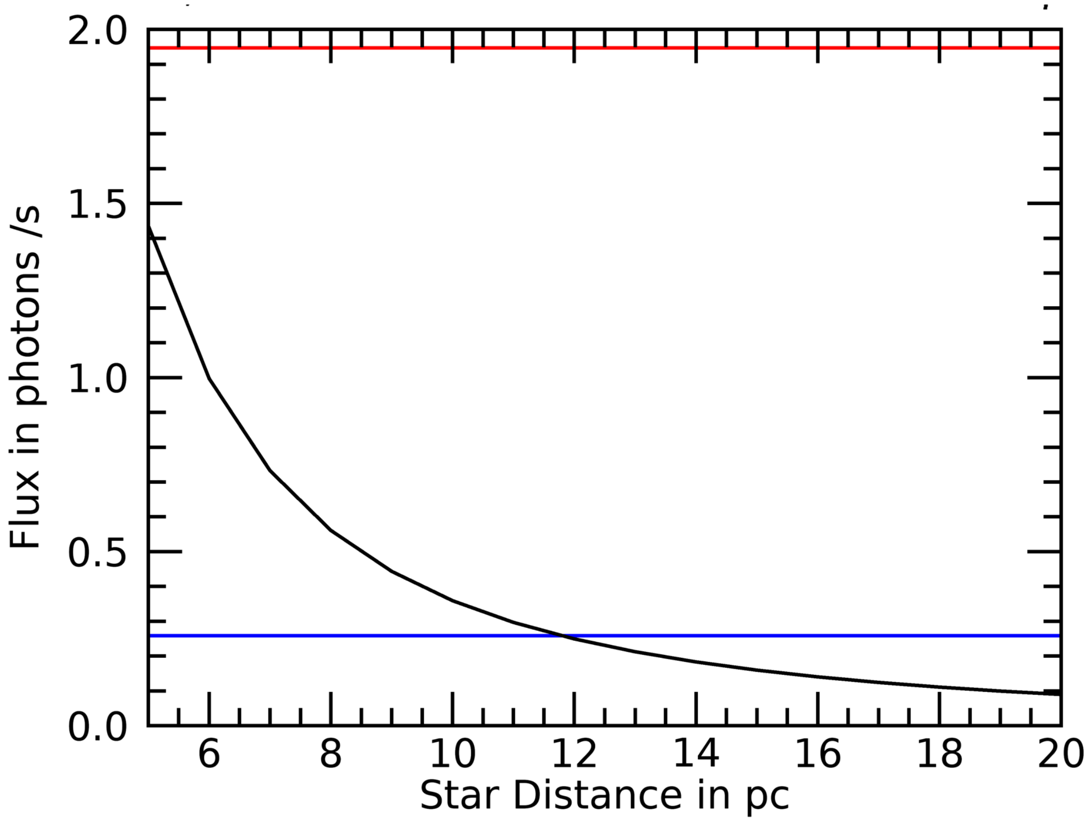
- Randomly draws exozodi values for each individual HWO target star using:
  - LBTI Optimistic Distribution (-1σ median exozodi level = 1 zodi)
  - Nominal: LBTI max likelihood distribution (median exozodi level = 3 zodis)
  - LBTI Pessimistic Distribution (+1σ median exozodi level = 9 zodis)
- Assumes that exozodi signal at exoplanet location can be perfectly estimated and removed, except for shot noise

Impact as a function of stellar distance (G2V star)

Star (x 10^{-10}), Solar Zodi and Exo-Zodi Fluxes around **0.55 μm**



Star (x 10^{-10}), Solar Zodi and Exo-Zodi Fluxes around **0.9 μm**



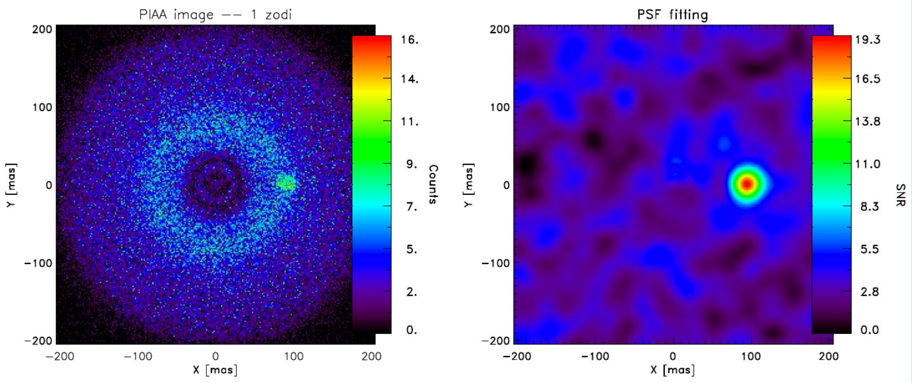
Fluxes detected per solid angle $(\lambda/D)^2$ over a 20% spectral bandwidth assuming a 6m telescope with unit optical transmission and QE. Exozodi level assumed to be “3 zodis", flux computed at 1AU from the star. Starlight assumed to be rejected by 10^{10} at that location.

- At the current best estimate of typical exozodi level (3 zodis), exozodi signal dominates over residual starlight level
  - Even more so at longer wavelengths

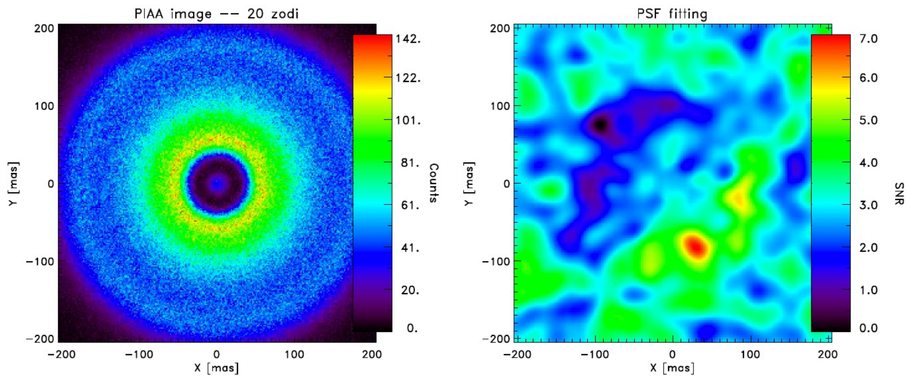
Limitations and Future Work

- LBTI measures is a total mid-infrared (~11 um) excess integrated over a few 100 mas
- A solar zodi like model is assumed to convert excess to exozodi brightness, scaling up from “1 zodi” density at 1 AU (or EEID)
- Converting to exozodi level at visible wavelengths also depends on exozodi dust model (albedo, grain size and spatial distributions)
- There is evidence, from joint MIR and NIR interferometric measurements that some stars have exozodi dust very different from solar (hot dust phenomenon, Absil et al. 2006 & 2009, Ertel et al. 2014, Mennesson et al. 2011)
- Yield simulations assume smooth exozodi signals and only a shot noise impact
    - Need to include the effect of any bright resonant dust clumps that may mimic planets and hamper their detection
- Roman Coronagraph could conduct a visible coronagraphic survey of HZ exozodi dust around 70 HWO targets down to 10-100 zodis sensitivity (5σ), depending on in-flight performance

Simulations of V-band coronagraphic observations of a Sun/Earth twin at 10 pc with a 4m telescope (Defrere et al. 2012)



1 “zodi” case: exo-Earth is retrieved



20 “zodis” case : bright dust clump is retrieved instead of planet