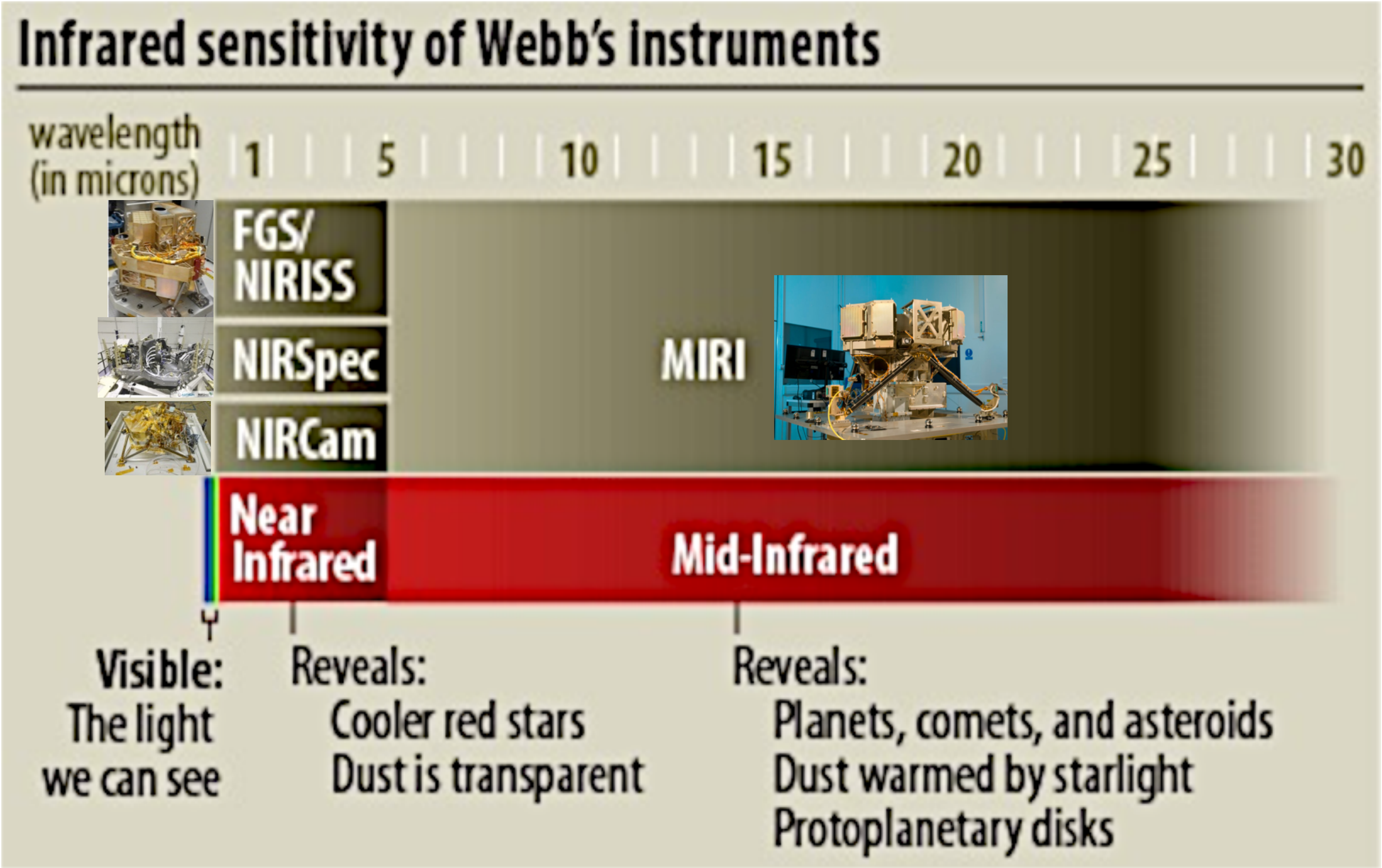
JWST Background
Components and Mitigation Strategies

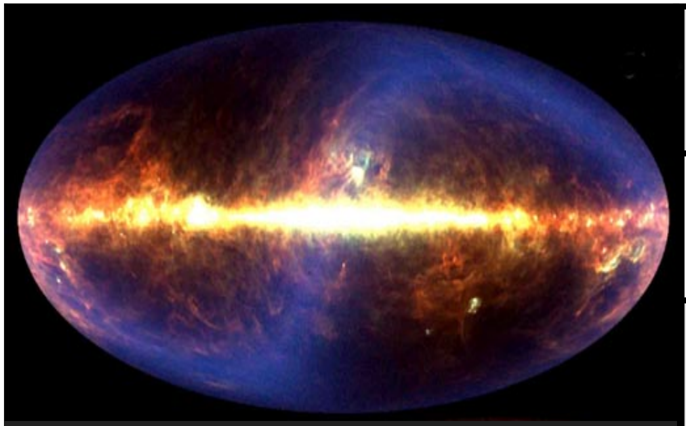
Macarena Garcia Marin

Introduction: JWST Instrumentation

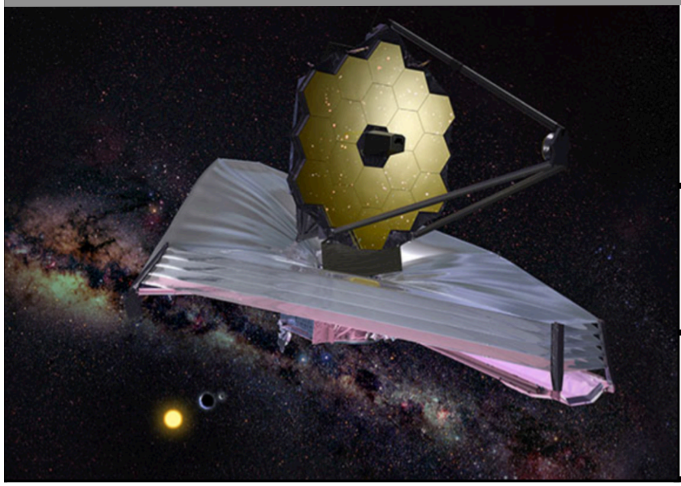


Background image credit: NASA

Introduction: JWST background components



- Zodiacal background
- Diffuse Galactic radiation
- Diffuse radiation from extragalactic sources



- Straylight which reaches the science path via the telescope structure
- Self Emission from the Observatory: Optical Telescope Element, sunshield, and instruments
- Detectors Noise

Sky background components

- Diffuse Galactic radiation: mostly starlight reprocessed by ISM material
- Diffuse radiation from extragalactic sources
- Zodiacal background: It has two main components
  - Sunlight scattered by interplanetary dust ($\lambda < \sim 4\ \mu m$)
  - Sunlight absorbed by interplanetary dust and re-radiated as thermal IR emission ($\lambda > \sim 4\ \mu m$)

Primary sources of diffuse light.

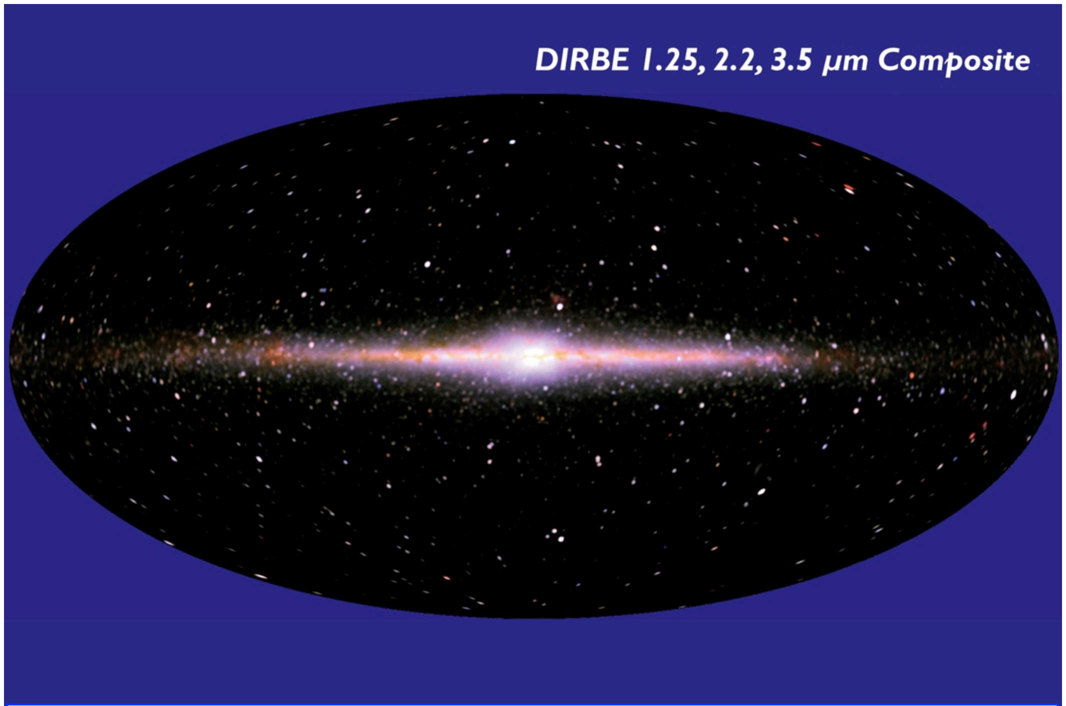


Image Credit: NASA. Emission dominated by stars in the Galactic plane

Sky background components

- Diffuse Galactic radiation: mostly starlight reprocessed by ISM material
- Diffuse radiation from extragalactic sources
- Zodiacal background: It has two main components
  - Sunlight scattered by interplanetary dust (l < ~ 4 μm)
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Primary sources of diffuse light.

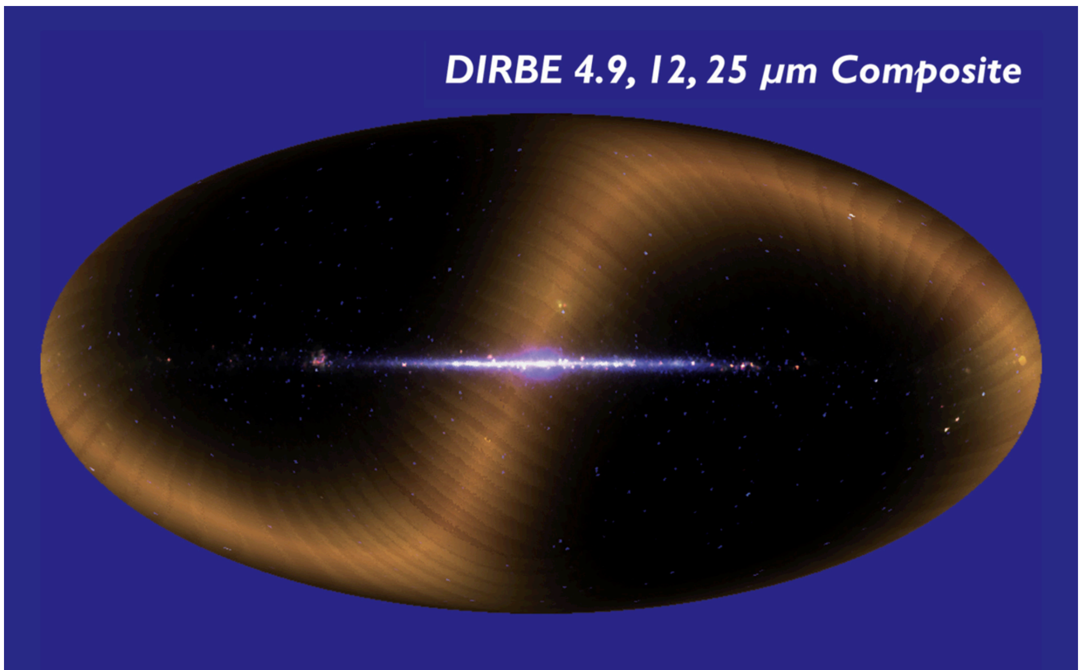
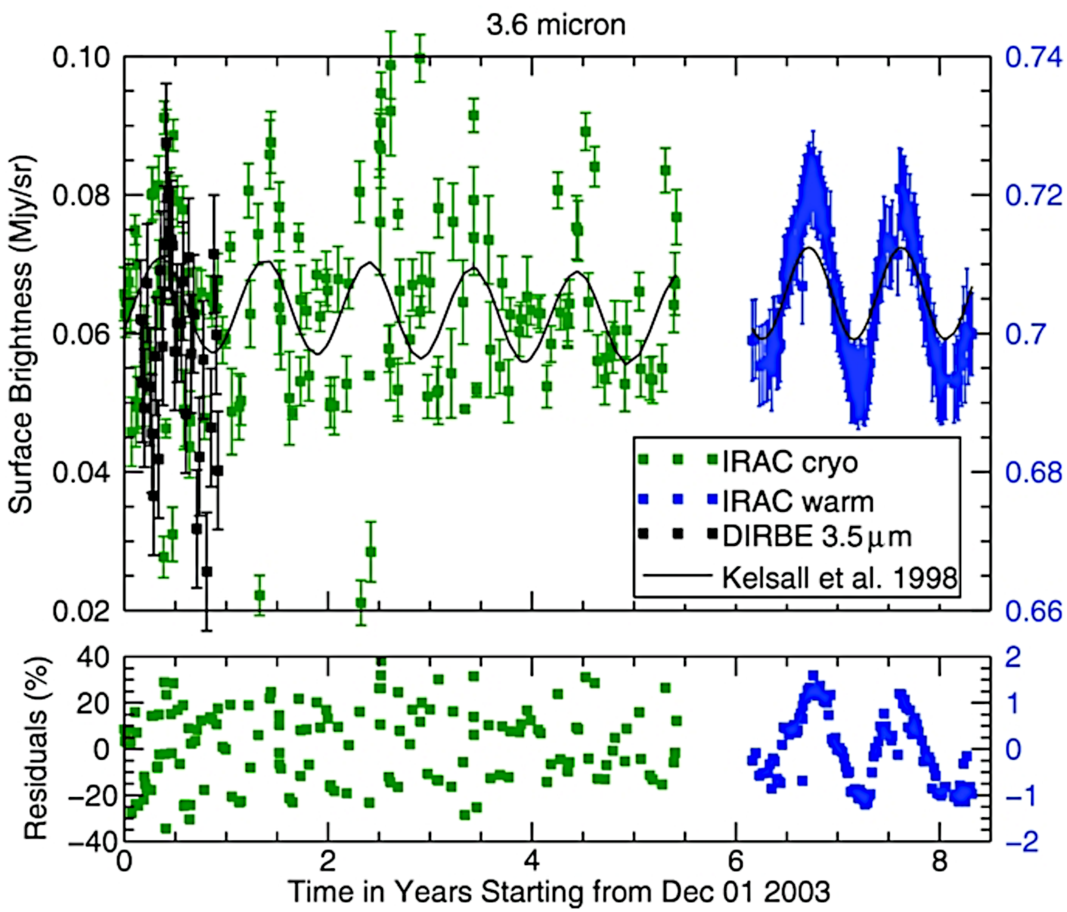


Image Credit: NASA. Sky dominated by Zodiacal and Galactic emission

Sky Background Variations

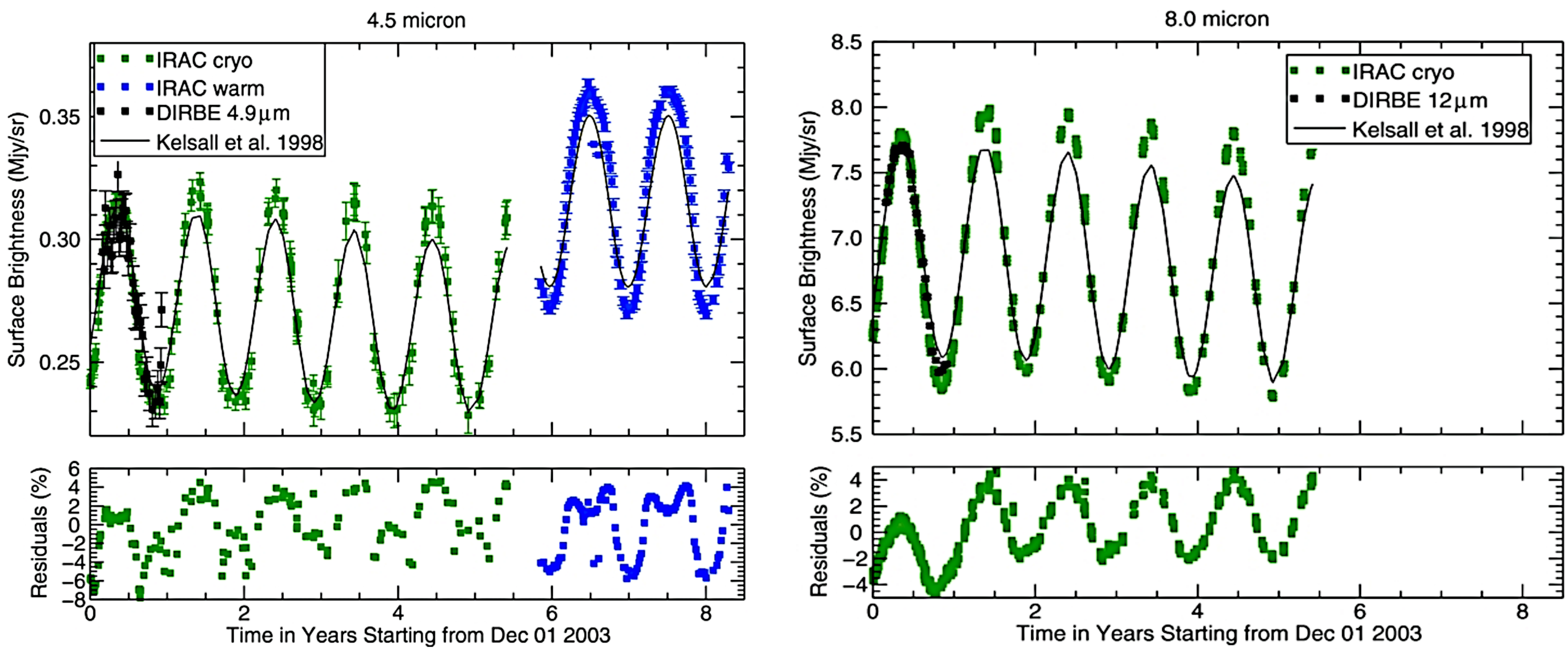
❖ Temporal: Temporal changes in the zodiacal emission while observing a fixed direction in the sky. Existing models assume that galactic foreground and extragalactic background are constant.



Krick et al. 2012

Sky Background Variations

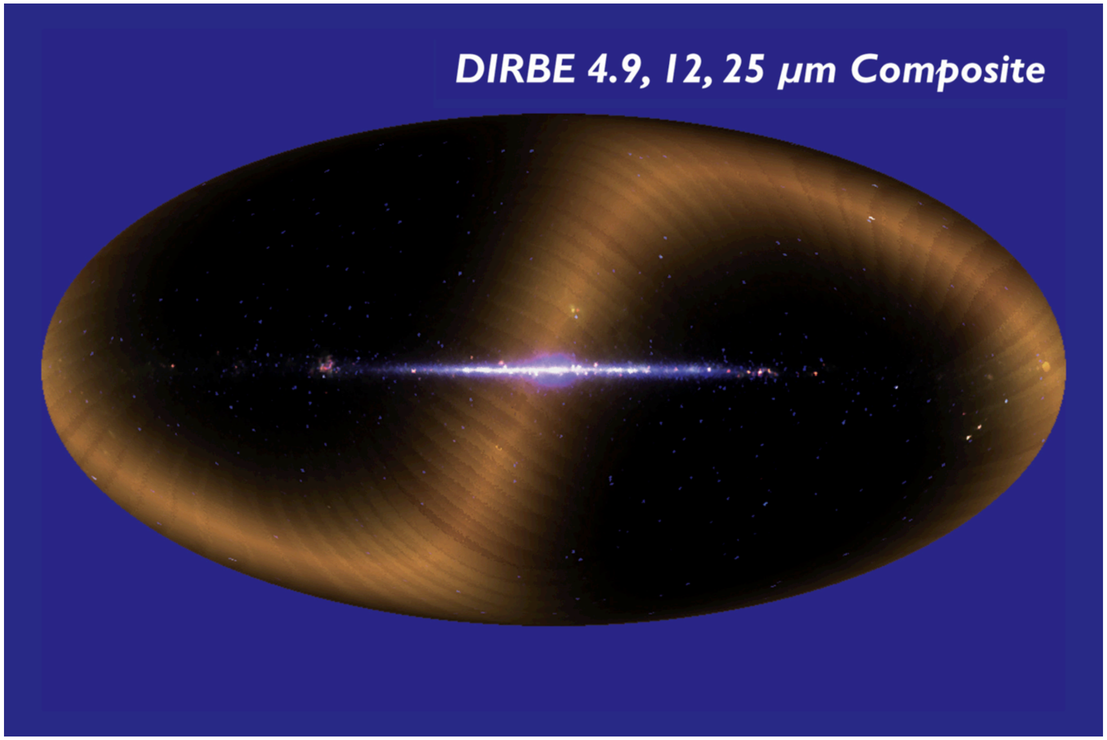
- Temporal: Temporal changes in the zodiacal emission while observing a fixed direction in the sky. Existing models assume that galactic foreground and extragalactic background are constant. Temporal variations are primary model constraints



Krick et al. 2012

Sky Background Variations

- Spatial: Obvious background variations when changing direction



- But there are also evidences of small scales spatial fluctuations:
  - ISO observations at 25μm: <0.2% at scales ~3′-30′ (Ábrahám et al. 1997).
  - Spitzer observations at 8μm: <0.1 nW m^{-2} sr^{-1} at ~200″ (Kashlinsky et al. 2005)

Telescope-Related Background: JWST orbit and temperatures

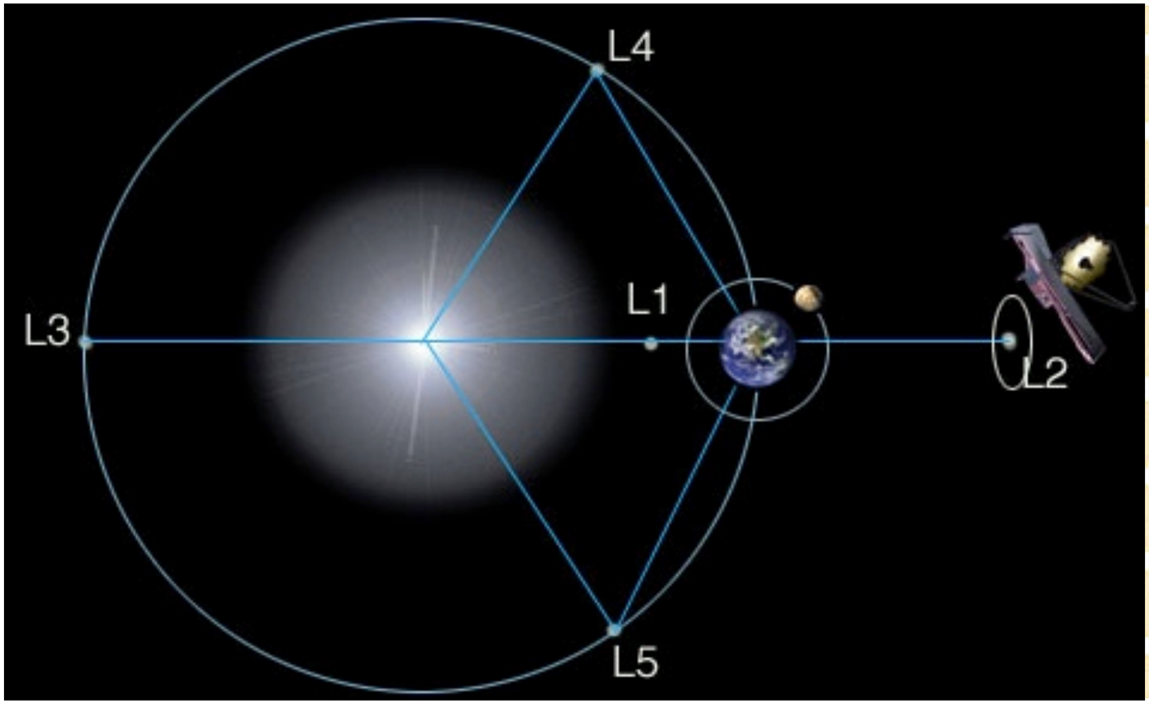


Image Credit: NASA

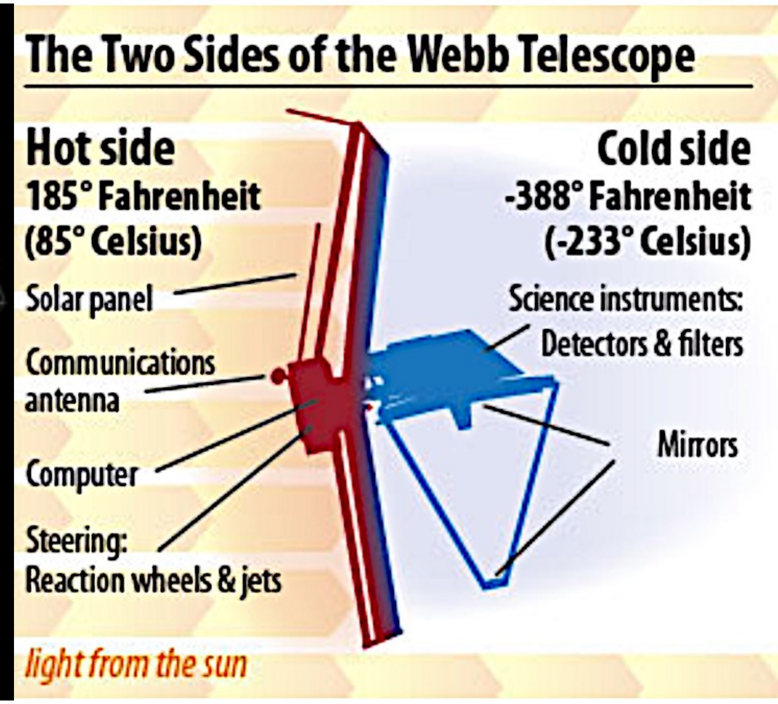


Image Credit: NASA

The sunshield protects the telescope from Sun radiation/heat. Passive cooling to about 40 K (as opposed to 200-300 K EARTH/HST)

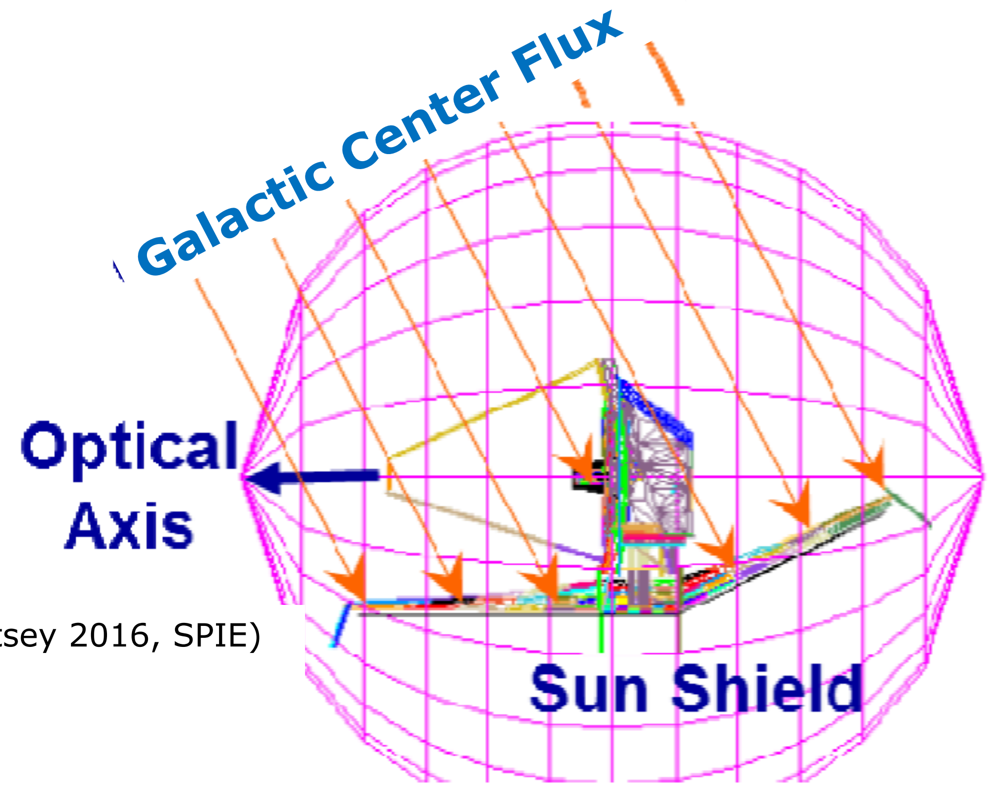
NIRSpec
NIRCam
FGS/NIRISS

~39 K

MIRI ~ 6.7 K (dedicated cooler)

Stray Light

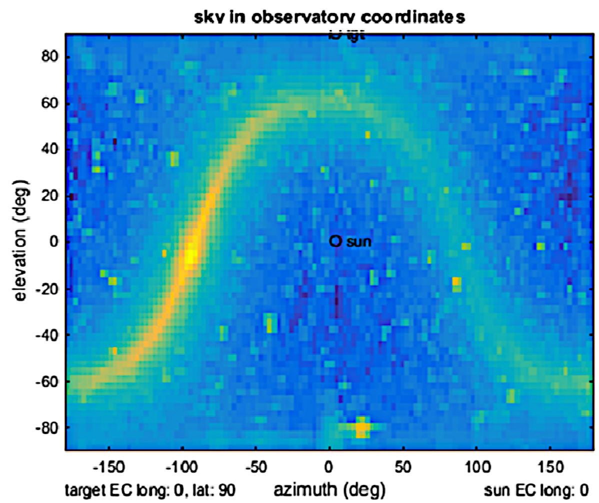
❖ Straylight reaching the science path via the telescope structure. It dominates at wavelengths shorter than ~ 15 microns.



(Lightsey 2016, SPIE)

Stray Light

- Straylight reaching the science path via the telescope structure. It dominates at wavelengths shorter than ~ 15 microns. The stray light model is calculated by overlaying the radiance maps of the celestial sky background (both galactic and zodiacal background) onto the Radiative Transfer Function map. (Lightsey, 2016)



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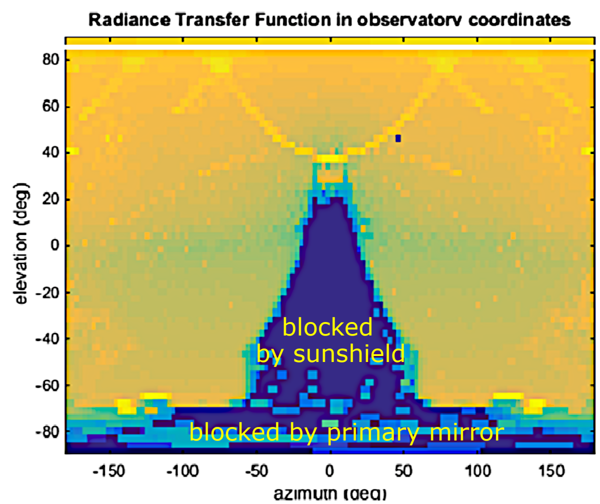
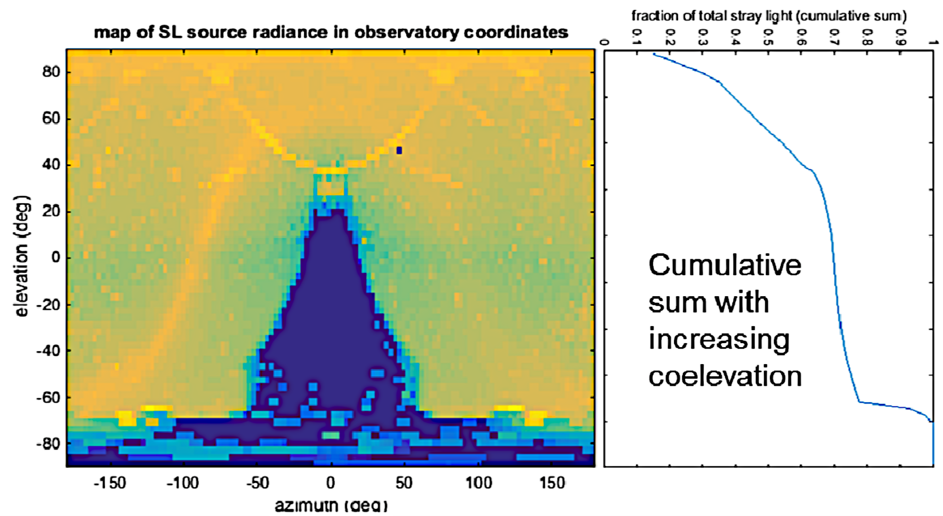


At 2 microns
0.078 MJy/sr
1.2xmin zodi= 0.091 MJy/sr

=



(Lightsey 2016, SPIE)

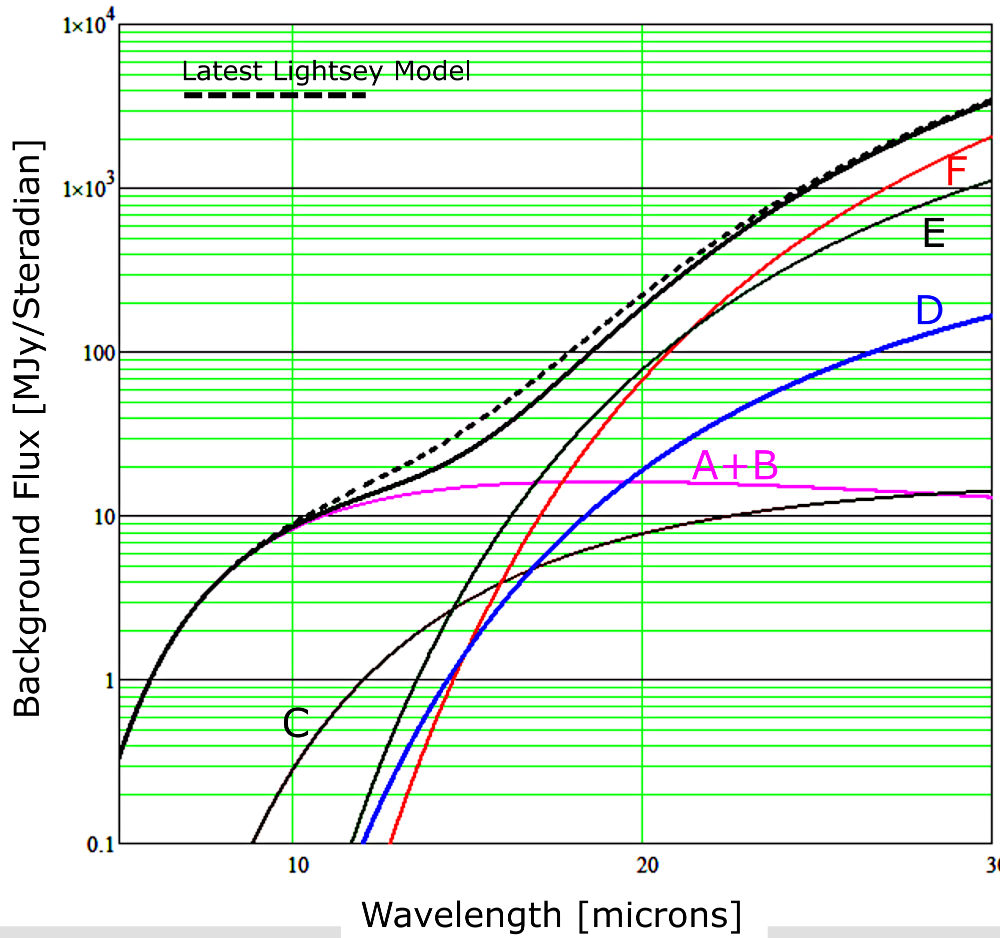
Telescope Thermal Self Emission

- Telescope thermal emission dominates at wavelength >~15 microns.
- J. Rigby and Bowers (GSFC) have provided a model consisting of 20 BB (consistent with Lightsey's description).
- Out of all model components, the sunshield dominates at wavelengths < ~22 um, and the primary mirror dominates at longer wavelengths.
- No expected variation with inclination /attitude. This will be tested during commissioning.

A and B: fits to the scattered and emissive components of the zodiacal dust spectrum towards the celestial north pole.

C to F are derived from a fit to a detailed straylight model of the observatory background (Lightsey and Wei, 2012)

Image courtesy of A. Glasse



Detectors noise

- MIRI observations are mostly background limited
- MIRI read noise: 14 electrons rms for Fowler 8 sampling
- NIR detectors are “detector noise limited”, for instance:
  - NIRSpec Total noise in 1000 seconds integrations 5-7 electrons
  - NIRCam 8.8 to 9.4 @ long wave, 5.3 to 7.8 @ short wave.

Instrument Specific Background

- NIRSpec MSA leakage: It affects the IFU observations. Most relevant when observing extended source. Also in long/deep exposures in the diffuse sky emission can leak through.
- Light comes through the MSA shutters (failed open) and through the material/ bars in between the shutters.

See N. Luetzgendorf presentation on the NIRSpec IFU on Wednesday.

Implications for observers:

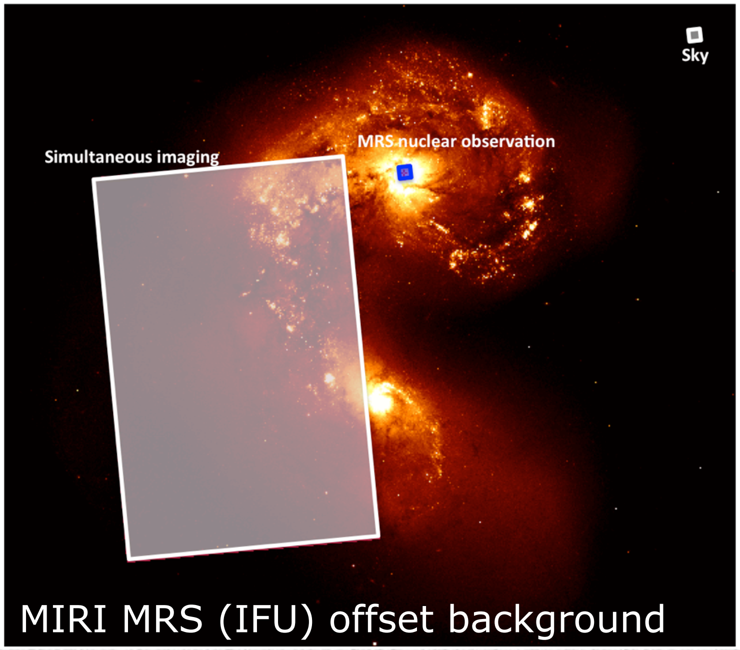
- Time Estimations: The ETC flight release (not yet available) includes:
  - Uses a background model generator (IPAC). Zodi and Galactic emission for a given RA and DEC (two methods: for a given RA and DEC and as a percentage of the background for those coordinates over the visibility, pre-computing).
  - Stray light calculated using a fine wavelength grid (0.7-15 microns).
  - Telescope thermal self-emission (20 BB components).
  - Detectors read noise…

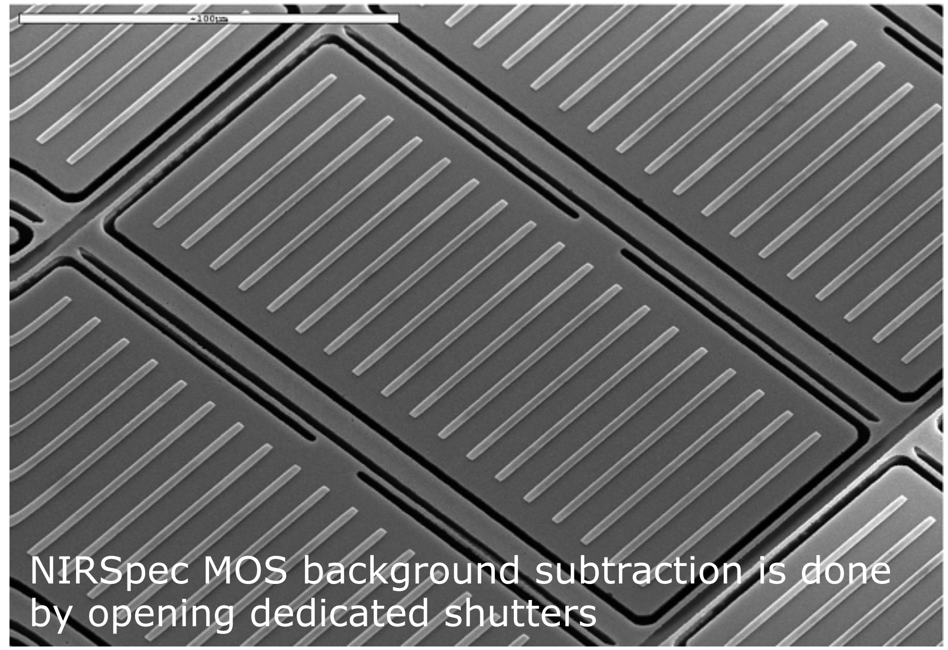
The ETC will provide the adequate exposure time to reach the desired source SNR on an individual case basis.

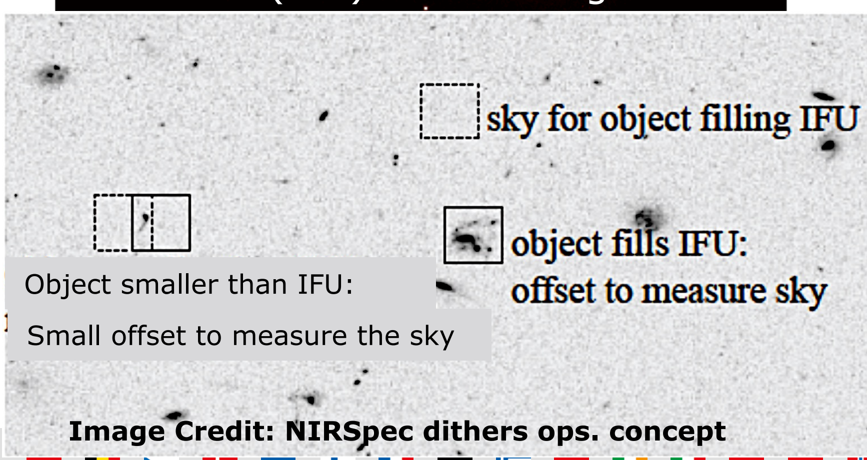
See an ETC demonstration (development version) by D. Karakla on Wednesday.

Background: Mitigation strategies

- A combination of dithers+background/sky observations will work best.







- Background data will allow removal of the contaminating signal

Background: Mitigation strategies

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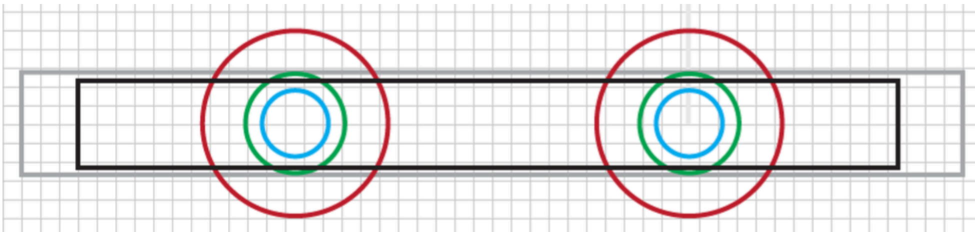
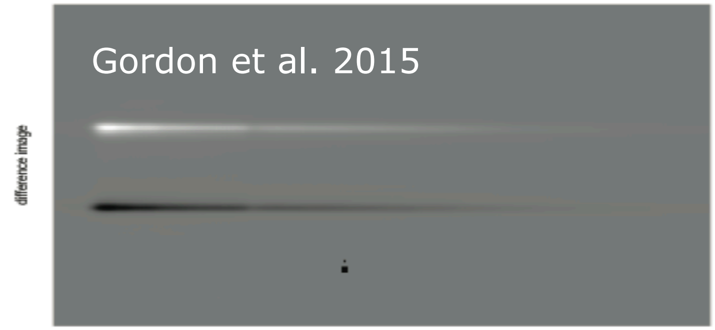
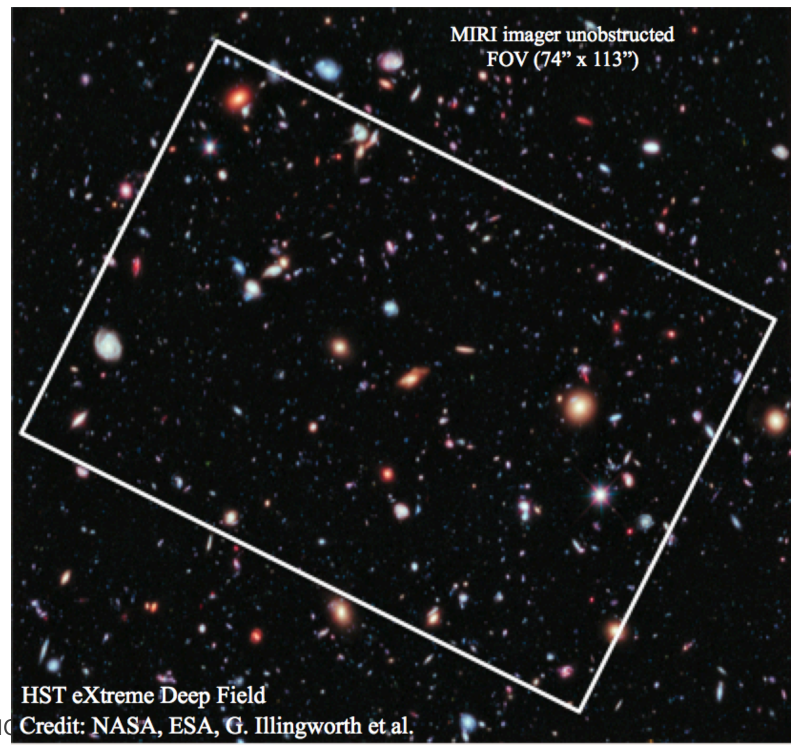
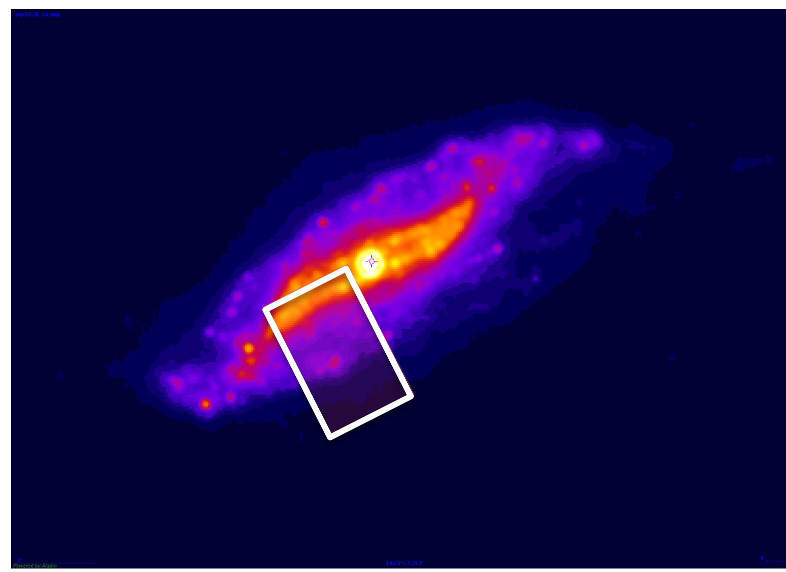


Image Credit: STScI. MIRI Ops. Concept.
MIRI slit point source observations. 2 points dither





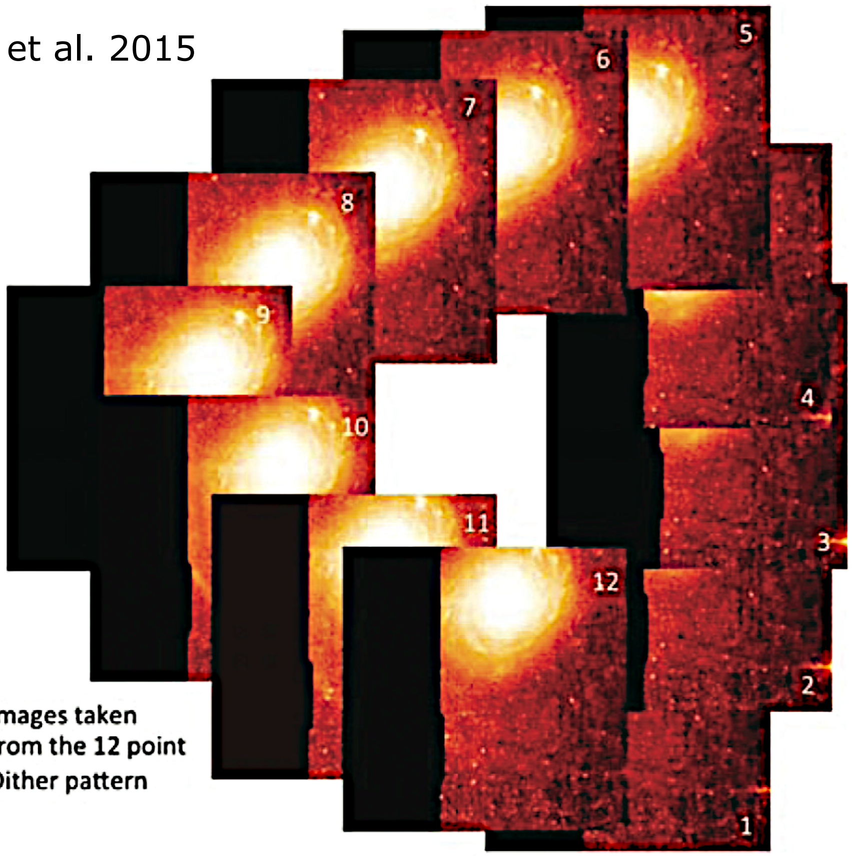
- Imaging background correction techniques will depend on the science case/object size..

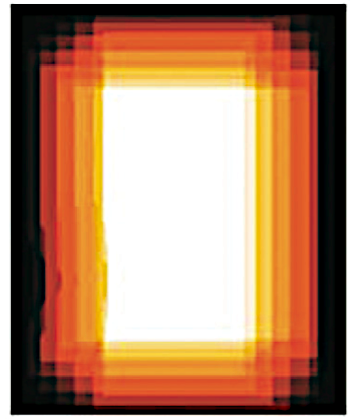


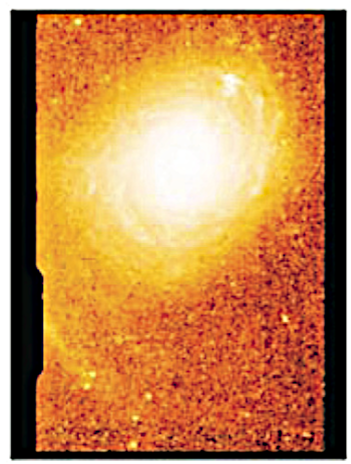
Background: Mitigation strategies

- The use of dithers will largely improve data quality. Not only for PSF and cosmetics reasons, but regions of the sky observed by different pixels will be used for carrying out background matching. See further details on dithers in the dedicated instrument modes presentations. The NIRSpec MSA leak will be corrected using a specific dither technique.
- More details in strategies will be give in each intrument/modes talks.

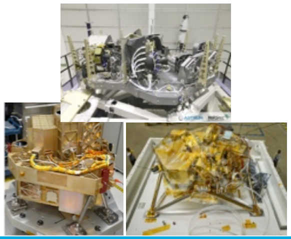
Gordon et al. 2015

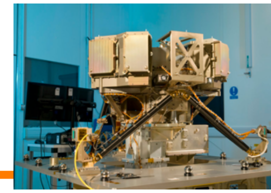



Mosaic coverage map


Resulting mosaicked image

Summary: JWST background





0.6µm | 5 µm | 10 µm | 15 µm | 20 µm | 25 µm | 28 µm

Zodiacal +Galactic

Straylight

Thermal emission

Detectors noise

Instrument-related

- These components have been modeled and will be included in the ETC flight release.
- Specific observing strategies (off-source observations, dithers) will help remove the background.