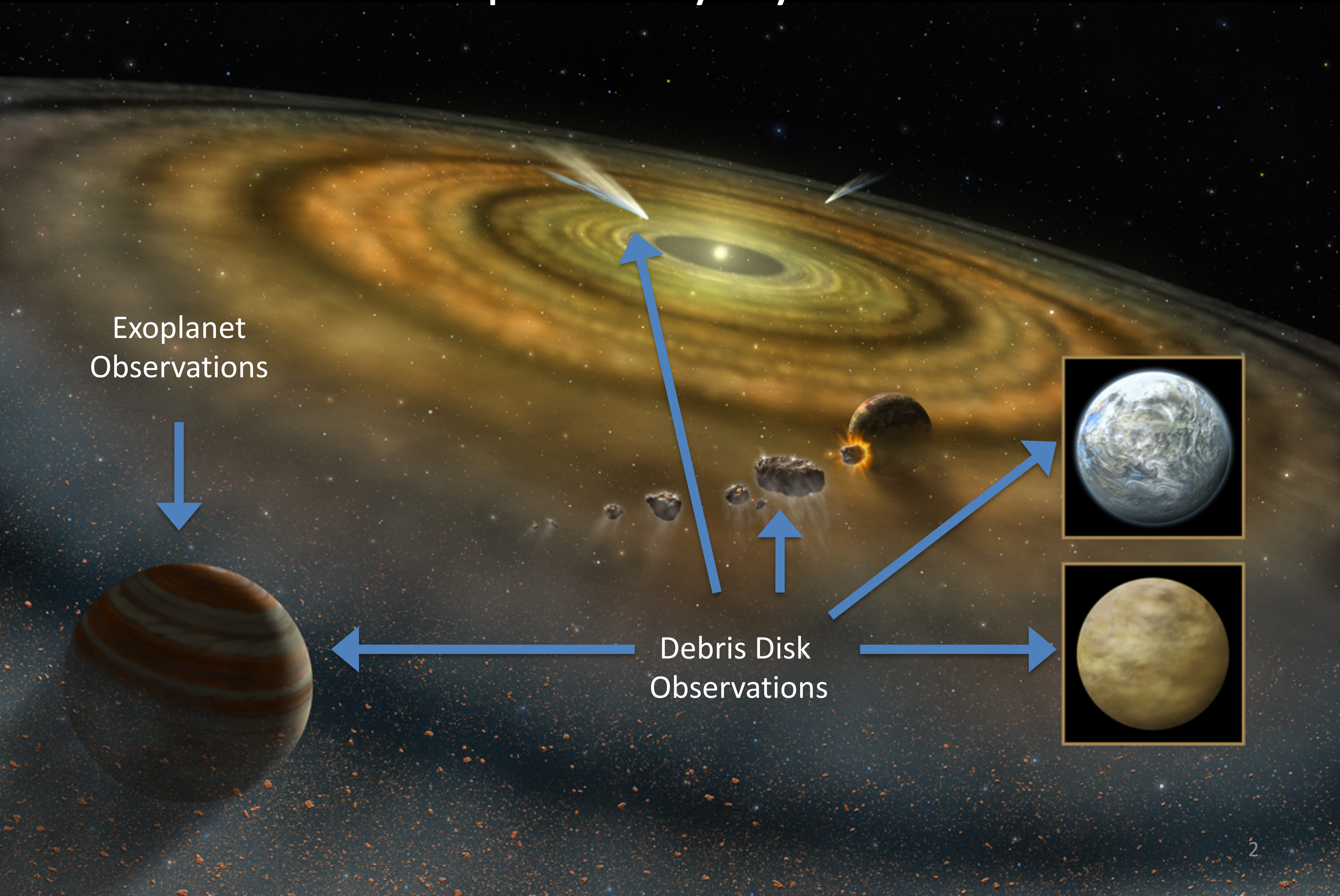
Characterizing Debris Dust and Gas in Exoplanetary Systems

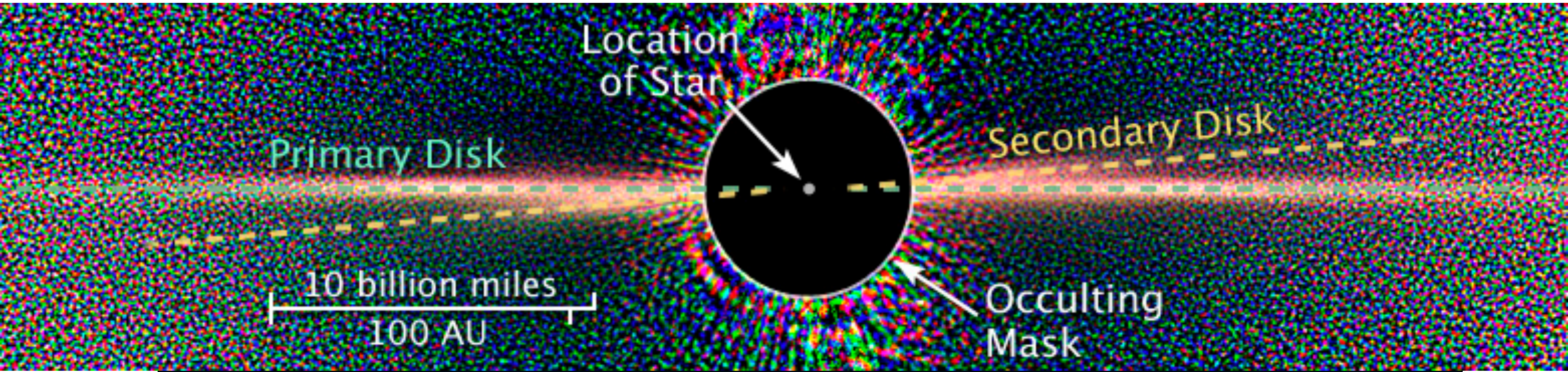
Christine Chen (MIRI GTO)

Exoplanetary Systems

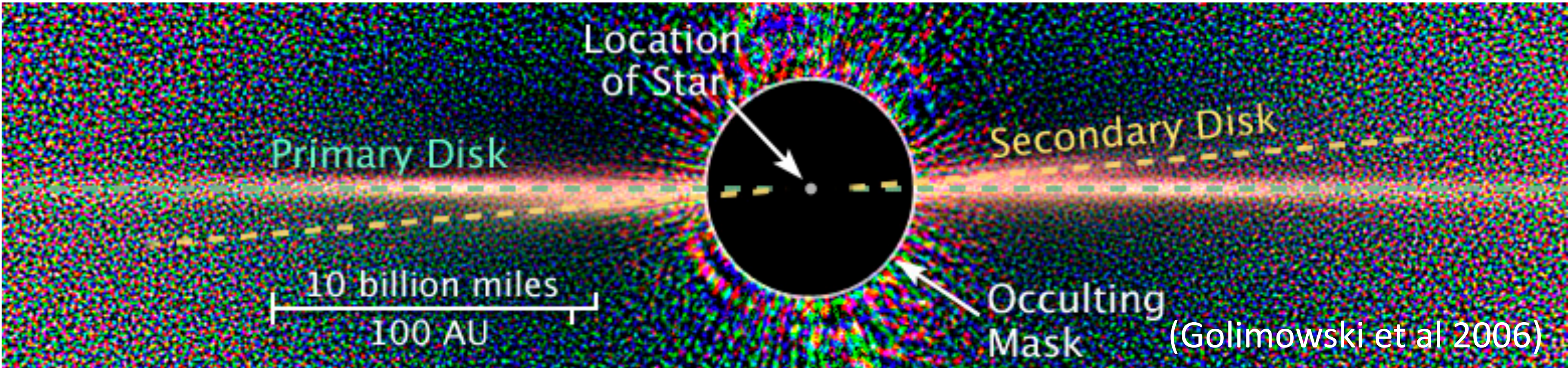


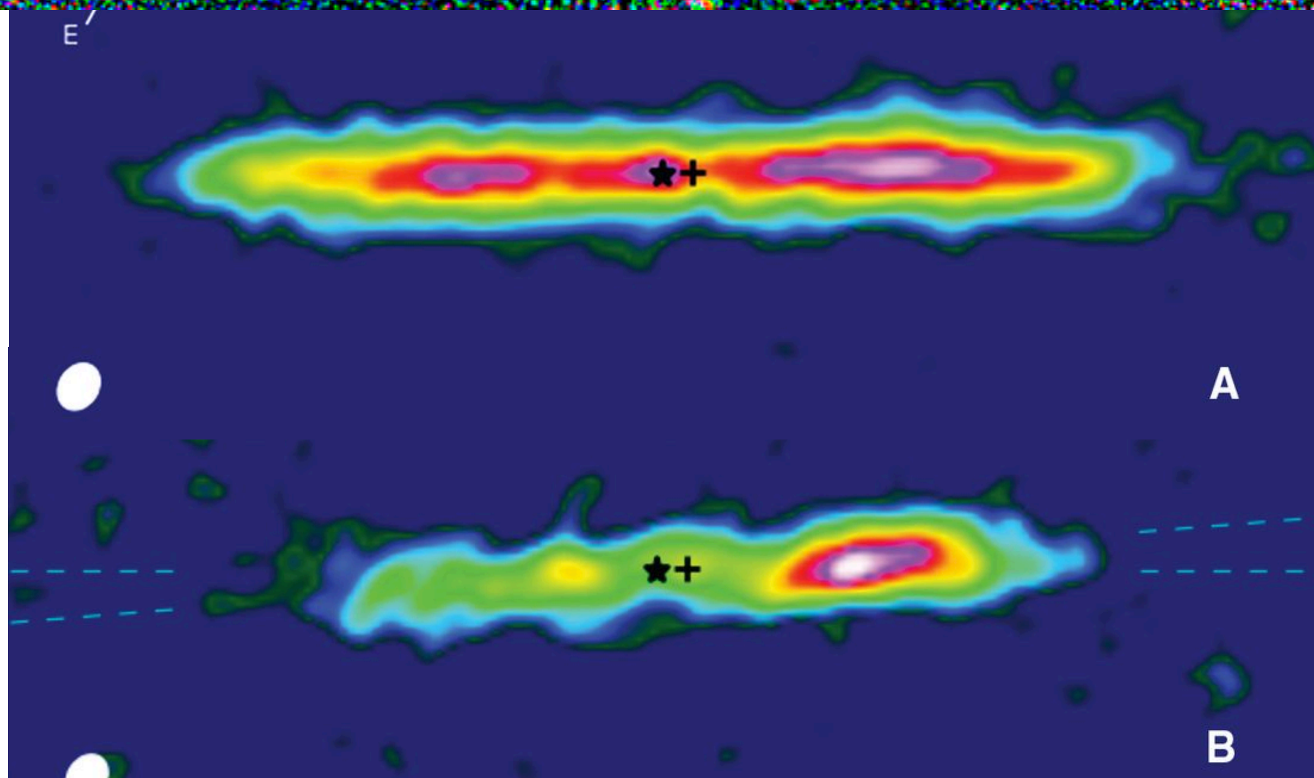
Reconstructing the β Pictoris Planetary System

Extended disk of small grains up to ~1400 AU from the star (Golimowski et al. 2006)



Reconstructing the β Pictoris Planetary System





Ring of large grains at 95 AU (Dent et al. 2014)

Clump of comets at 50 -60 AU (Dent et al. 2014)

Science Goals

Outstanding Science Questions:

- What is the origin of gas in debris disks? Is it primarily produced in collisions?
- What is the composition of the gas and the underlying parent bodies?

Landscape:

- ALMA has spatially resolved 'planetesimals birth rings' and discovered CO toward more than a dozen young systems and C I toward a handful of systems
- SOFIA/HIRMES will enable searches for solid-state ice features and kinematic studies of the gas

Infrared Spectral Features

λ (μm)	Species	Diagnostic	λ (μm)	Species	Diagnostic
1-5	H_2O gas		13.7	C_2H_2 gas	Organics
3.8-4.2	SiO v=2-0	Giant Collision	14.0	HCN gas	Organics
4.5-5.3	CO v=1-0	Mass and Temp	15-30	H_2O gas	Rotation water lines
5-7	H_2O gas	Water bend	15.2	CO_2 ice	Thermal history
6.2	PAH	Carbon-rich material	17.0	H_2 S(1)	Mass and Temp
7.7	CH_4 ice	Organics	18.5	$(Mg,Fe)SiO_3$	Crystalline pyroxene
7.7	PAH	Carbon-rich material	23.0	FeO	Oxides
8	SiO v=1-0	Giant Collision	25.2	[S I]	
8.6	PAH	Carbon-rich material	27.0	$H_2{}^{18}O$ gas	Isotope ratio
11.3	Mg_2SiO_4	Crystalline silicates	27.5	Mg_2SiO_4	Crystalline silicates
11.3	PAH	Carbon-rich material	27.7	OH gas	Photodissociation
12.8	[Ne II]		28.2	H_2 S(0)	Mass and Temp

Observations

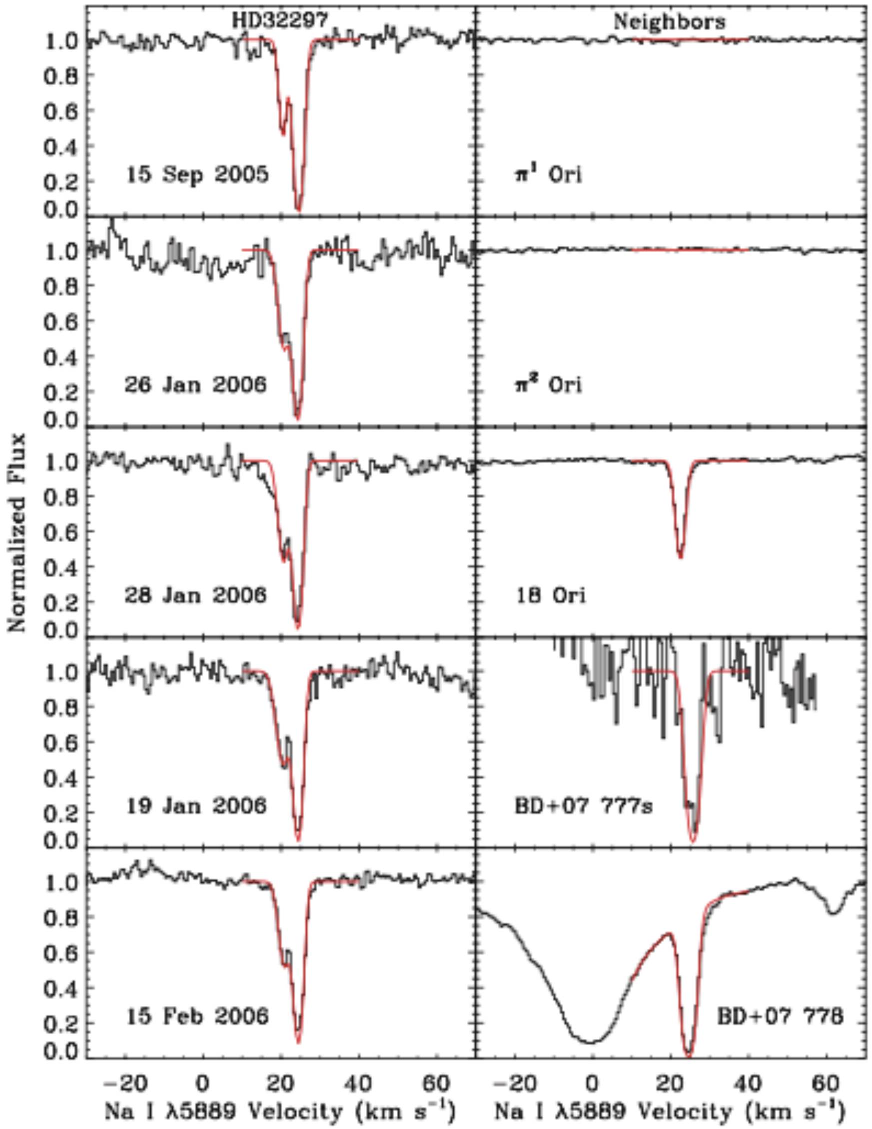
NIRSpec:

- Fixed Slit (S1600A) spectroscopy
- G140H/F100LP G235H/F170LP, G395/F290LP grism/filter combination (provide R~2700 spectroscopy at 0.977 – 4.123 μm)
- SUB1024A and SUB1024B subarrays (needed to avoid saturation)

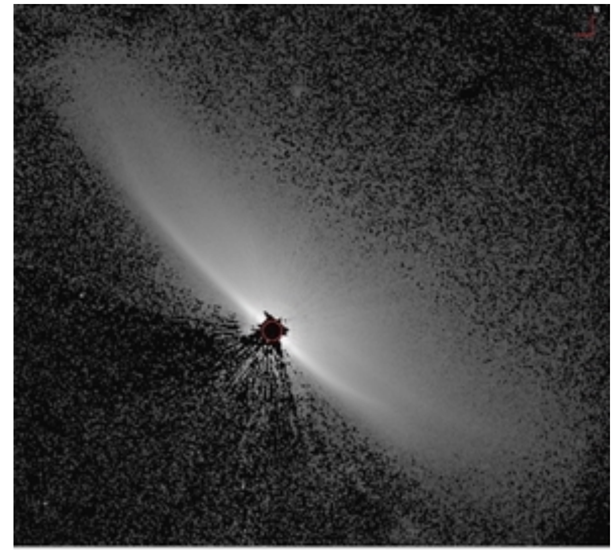
MIRI:

- Medium Resolution Spectrograph
- Channels 1-4 observed simultaneously (provides R~3000 spectroscopy)
- Grating Settings A-Short, B-Medium, and C-Long are needed to cover the full wavelength range (4.88-28.34 μm)

NIRSpec Target: HD 32297



Redfield et al. (2007)



Schneider et al. (2014)

Spectral Type: A0V

Distance: 112 pc

T_{dust}: 190 K

L_{IR}/L_*: 2.7×10^{-3}

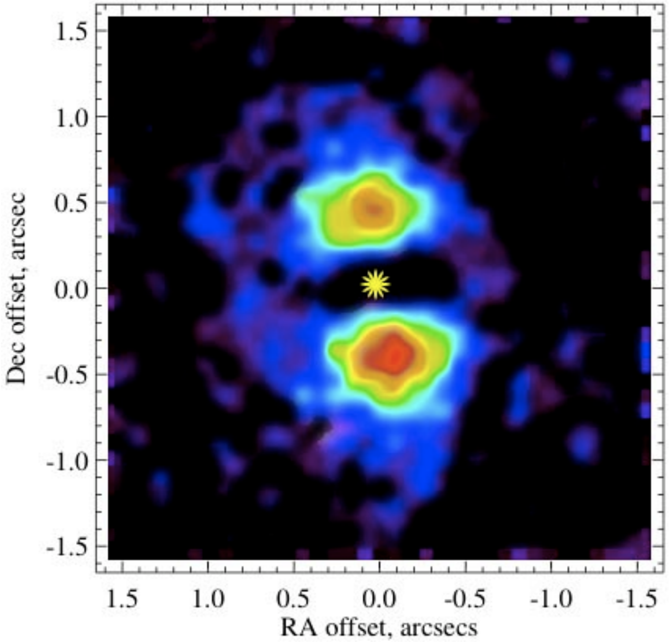
M_{dust}: $0.56\pm0.07\ M_\oplus$

R_{dust}: 50 – 1680 AU

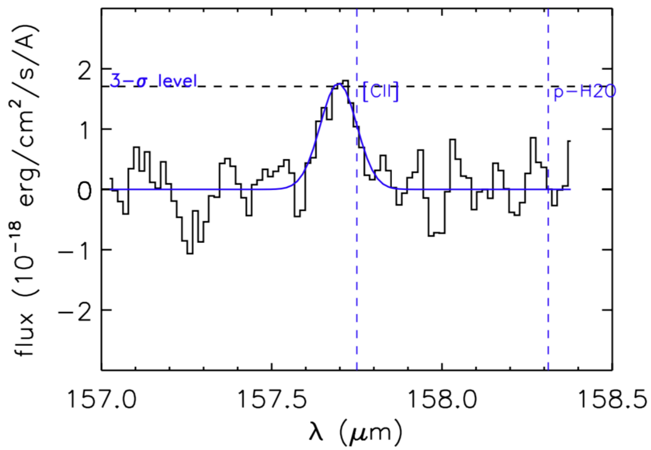
Inclination: 90° (edge-on)

Age: ~10 Myr

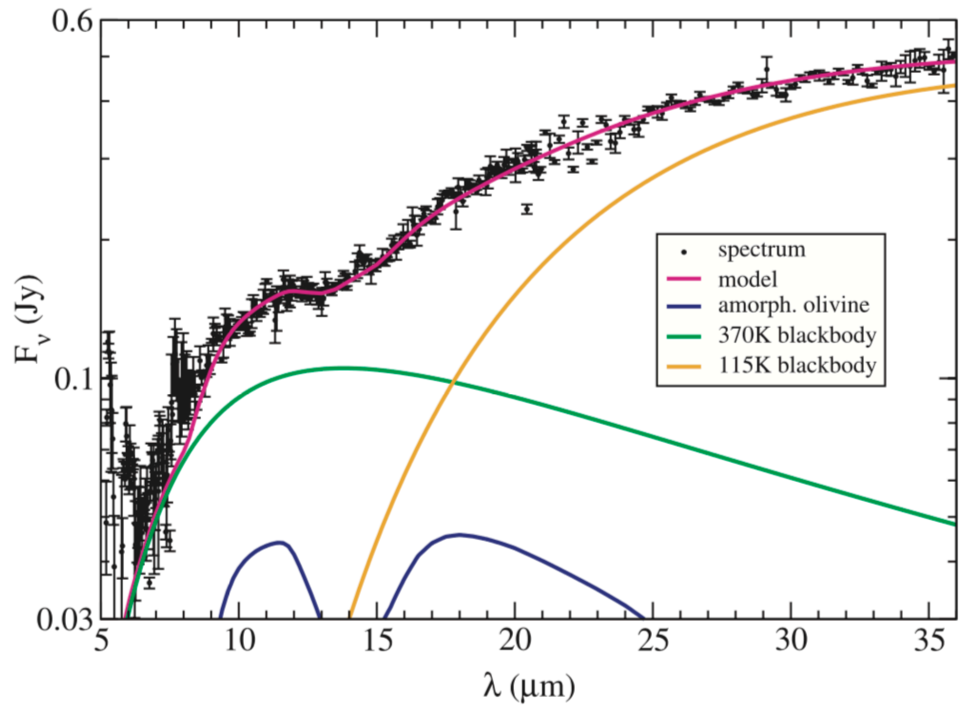
MIRI Target: η Tel



Smith et al. (2019)



Riviere-Marichalar et al. (2014)



Chen et al. (2006)

Spectral Type: A0V

Distance: 48 pc

T_{dust}: 140 K

L_{IR}/L_*: 2.4×10^{-4}

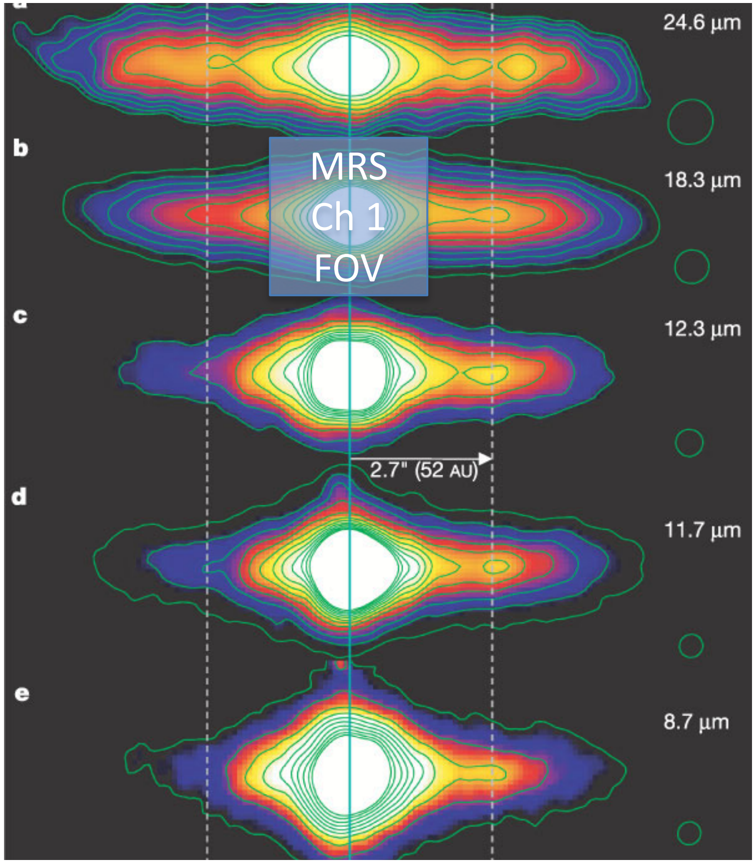
M_{dust}: 0.0.13 $M_\oplus$

R_{dust}: 4 – 24 AU

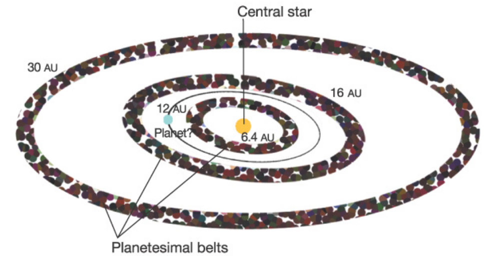
Inclination: 90° (edge-on)

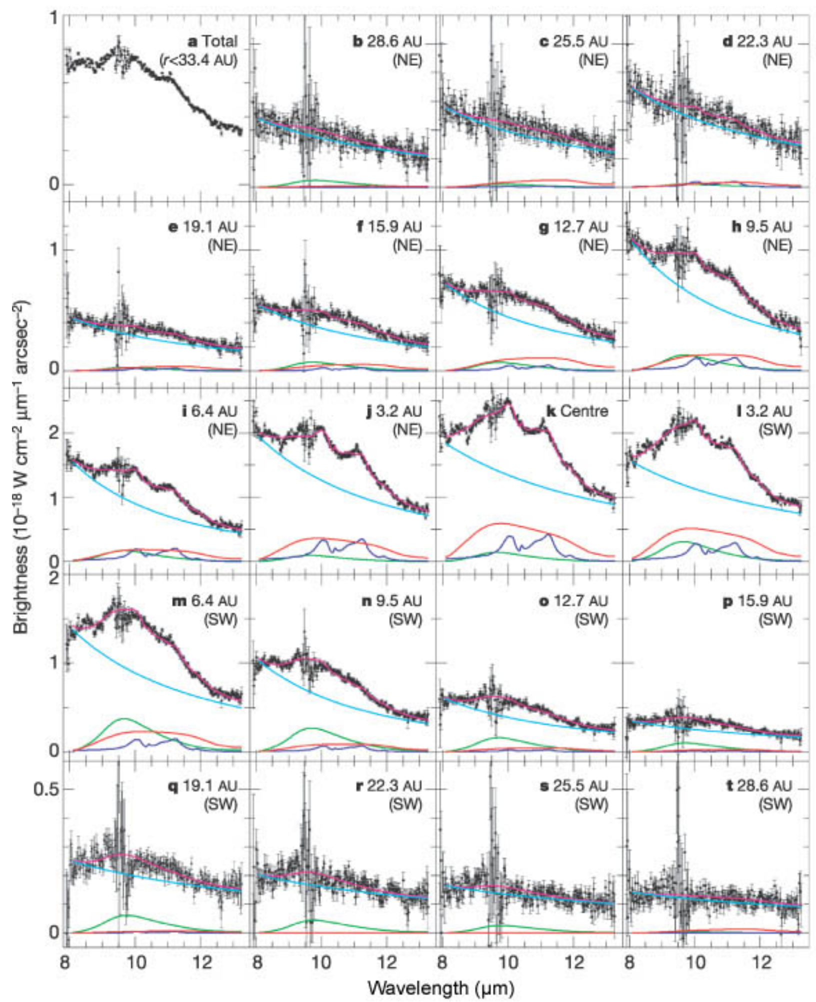
Age: ~20 Myr

MIRI Target: β Pic



Telesco et al. (2005)





Okamoto et al. (2004)

Spectral Type: A0V

Distance: 48 pc

T_{dust}: 140 K

L_{IR}/L_*: 2.4×10^{-4}

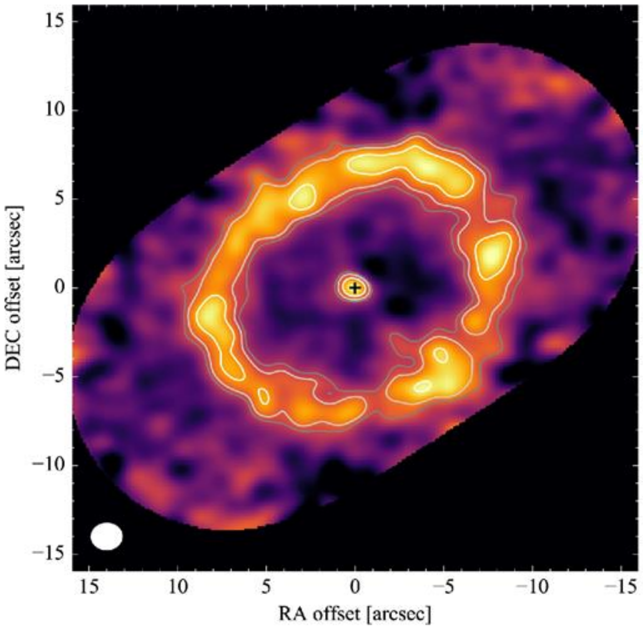
M_{dust}: 0.0.13 $M_\oplus$

R_{dust}: 4 – 24 AU

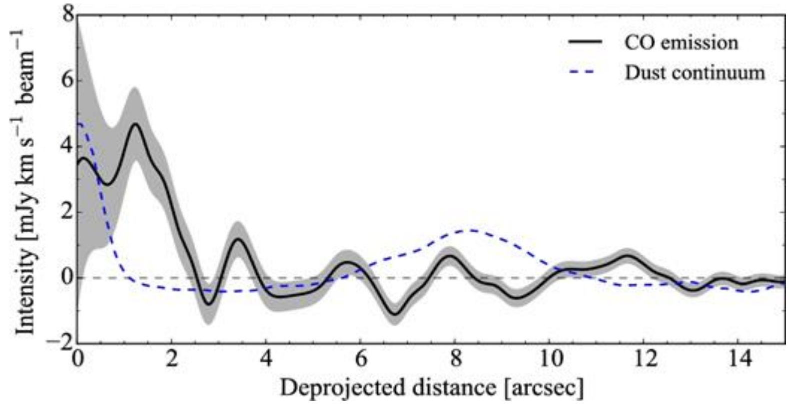
Inclination: 90° (edge-on)

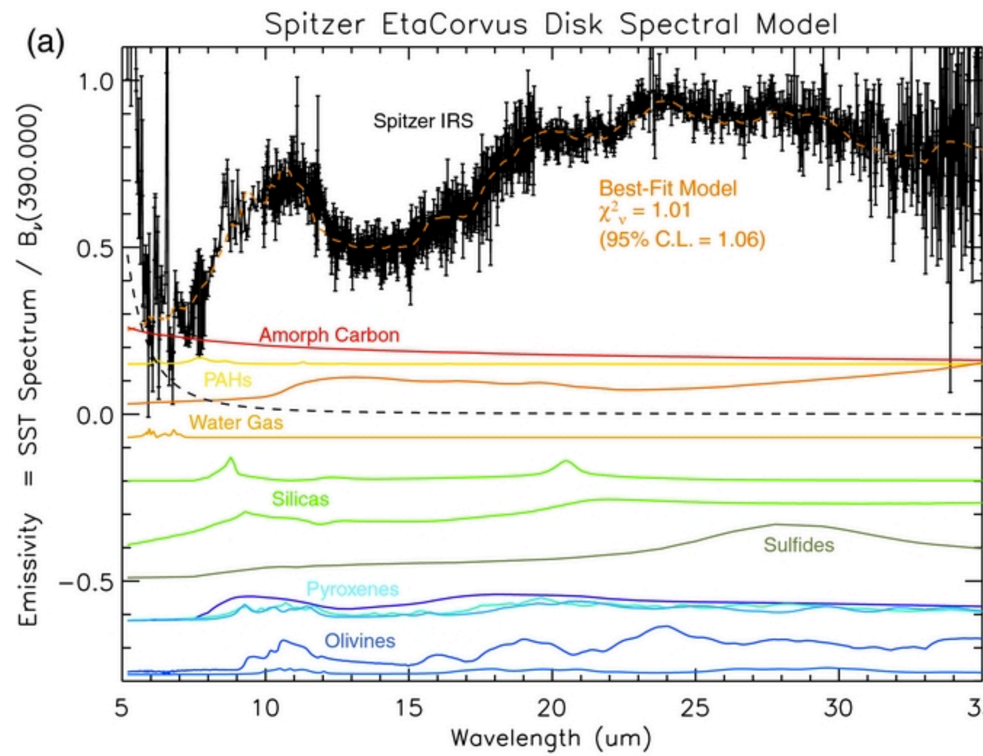
Age: ~20 Myr

MIRI Target: η Crv



Marino et al. (2017)





Lisse et al. (2012)

Spectral Type: F2V
Distance: 18.3 pc
T_{dust}: 390 K (inner)
40 K (outer)
M_{dust}: 0.014±0.001 $M_\oplus$
R_{dust}: 2-4 (inner)
100-200 AU (outer)
Inclination: 35°
Age: 1.4 Gyr

Summary

12 hours total

Debris Gas:

1. Search for and characterize atomic and molecular gas emission to measure elemental abundances and gas excitation temperatures
2. Infer whether the gas is primordial or second-generation and constrain the production mechanism

Debris Dust:

1. For objects with silicate emission features, map change in grain properties as a function of stello-centric distance
2. Search for changes in the silicate emission features, indicative of on-going collisional activity