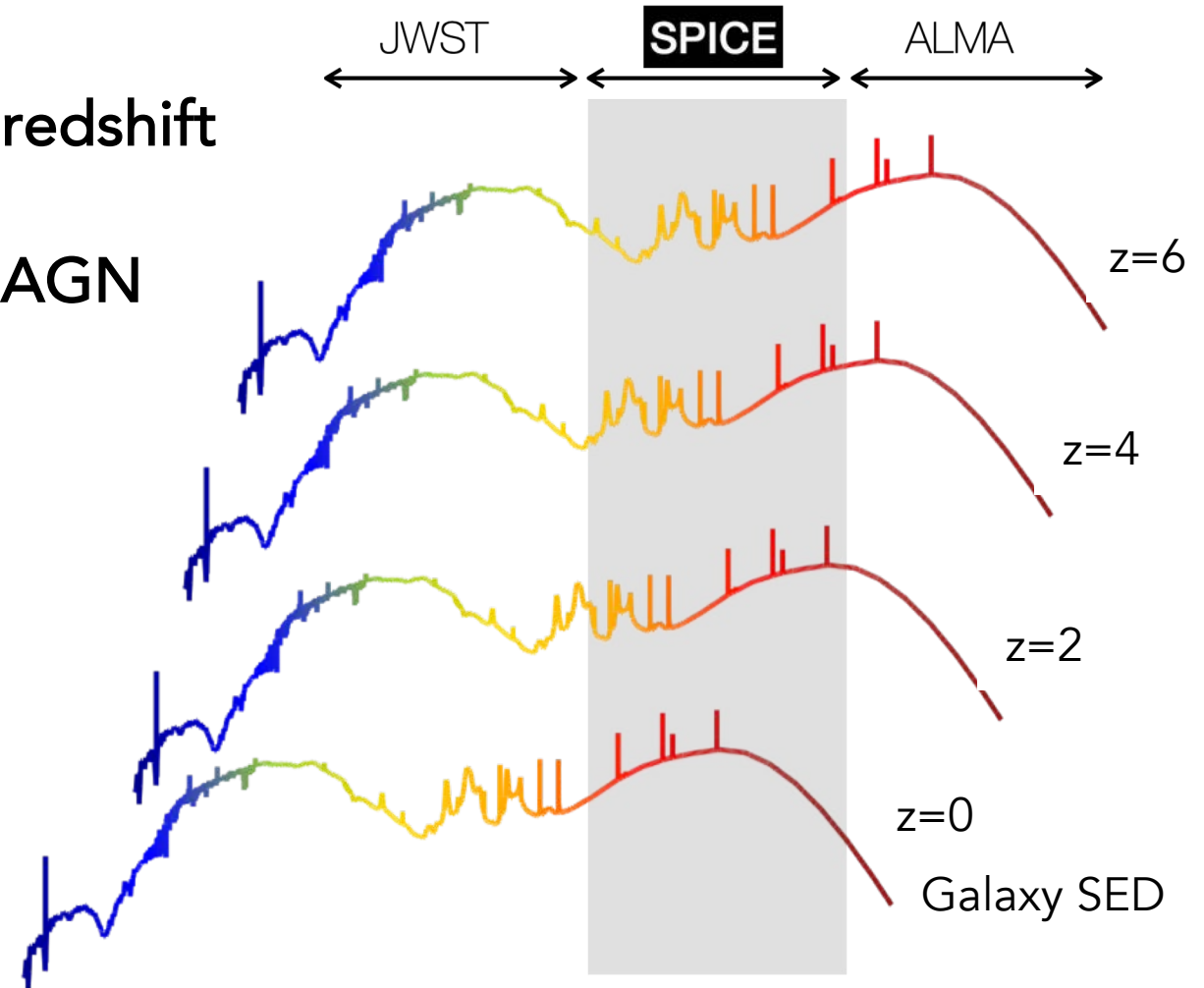




SPICE Far-IR Probe Extragalactic Science

1. Co-evolution of galaxies + BH to high redshift
2. Resolved studies of nearby galaxies + AGN





SPICE Far-IR Probe Extragalactic Science

1. Co-evolution of galaxies + BH to high redshift

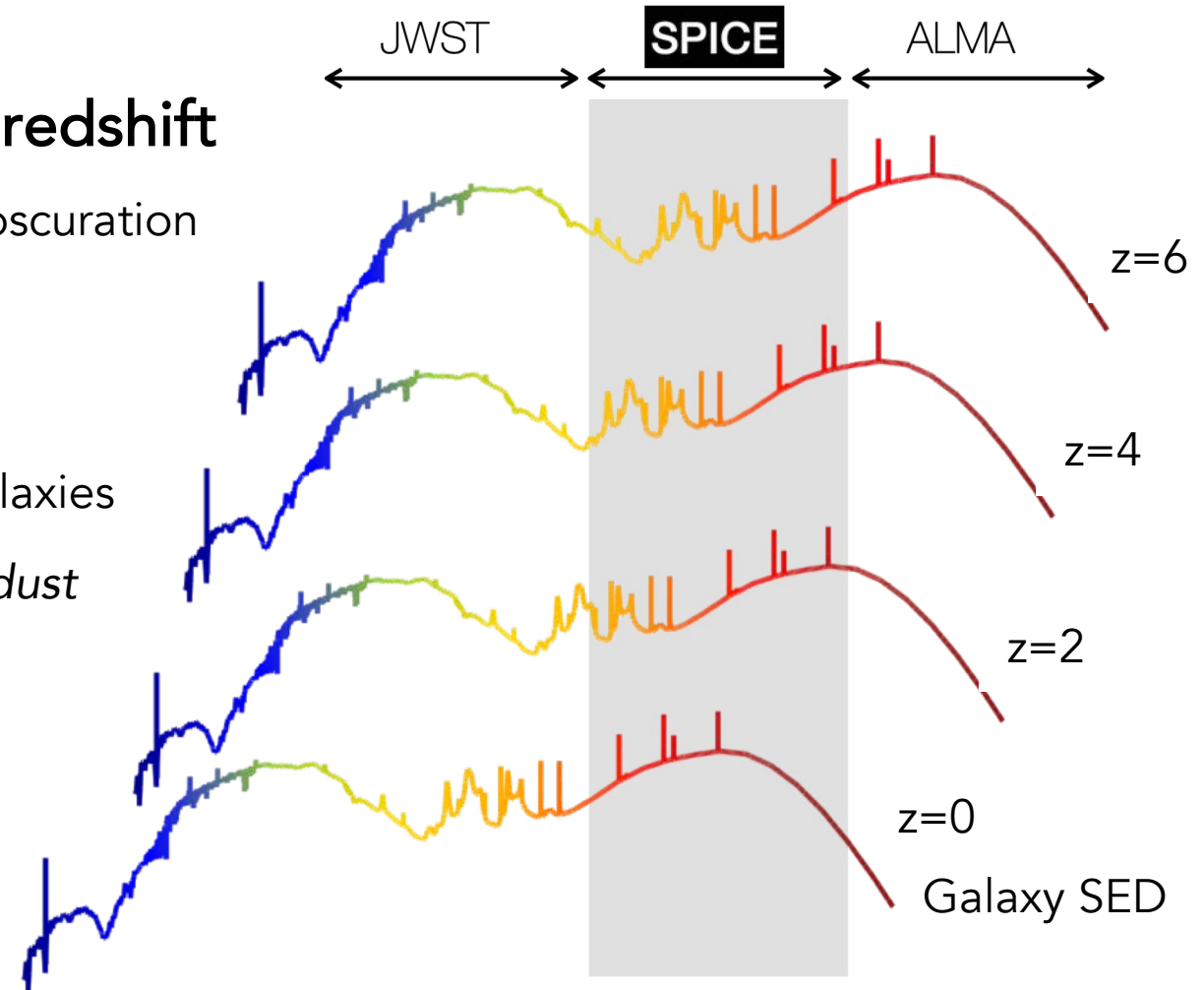
Demographics of AGN and galaxies unbiased by obscuration

No source confusion at long wavelengths

Detections at redshifts $0 < z < 5$

Separate AGN from stellar emission in individual galaxies

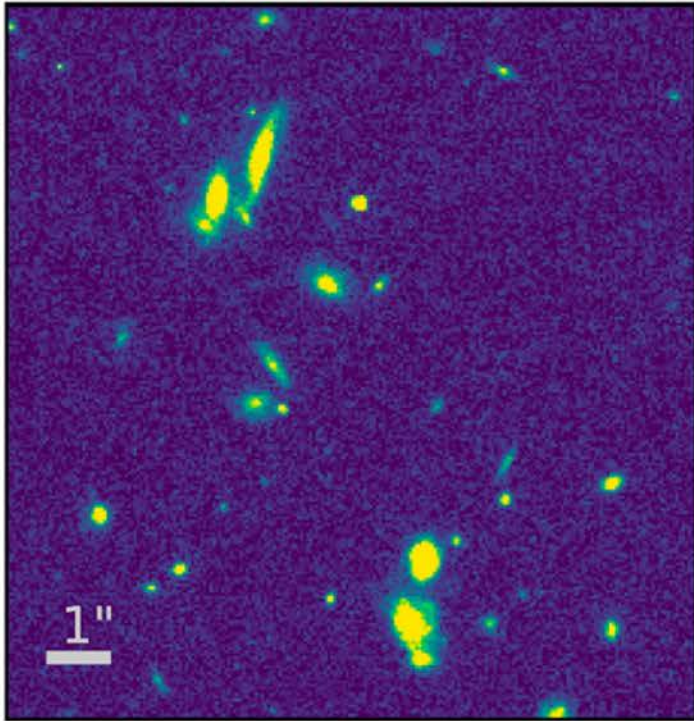
Star formation and BH accretion rates *unbiased by dust*



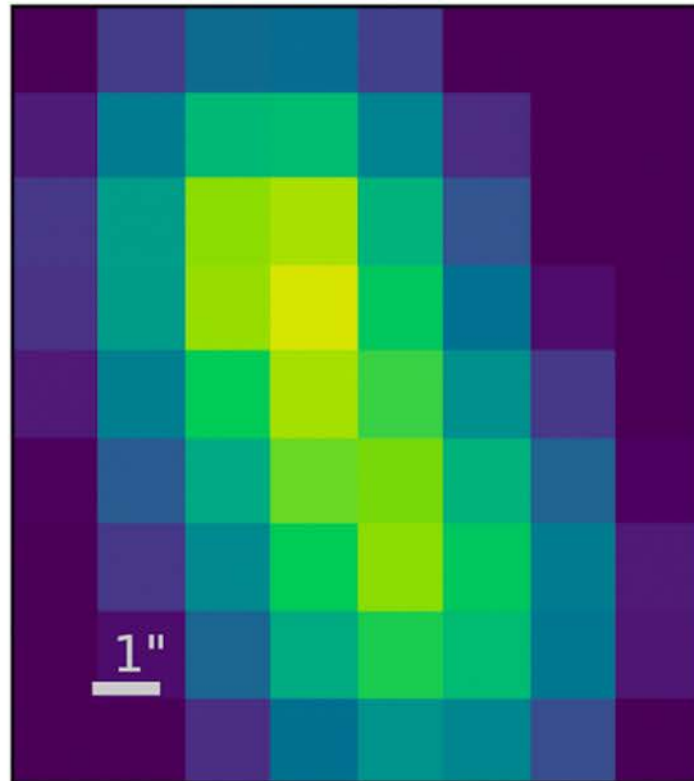


SPICE Far-IR Probe Extragalactic Science

JWST 0.06" at 1.6 μ m



Herschel 6.8" at 100 μ m

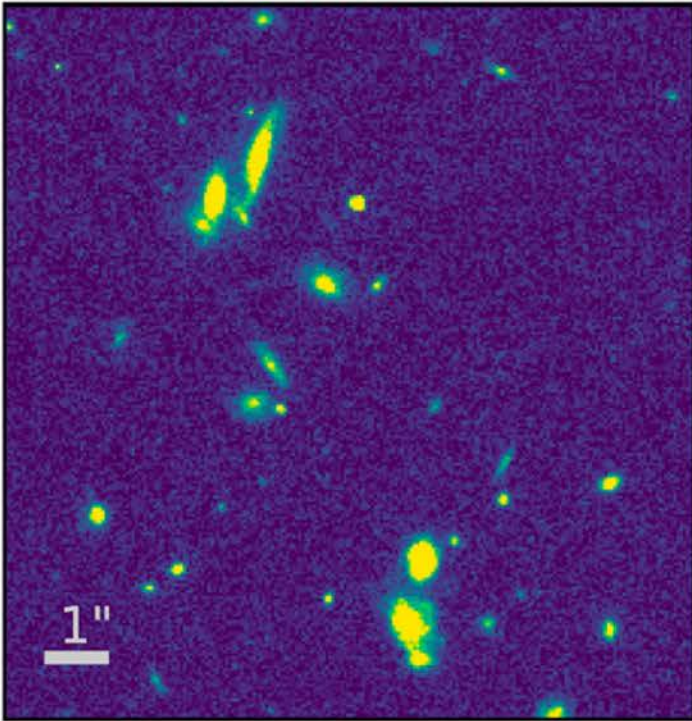




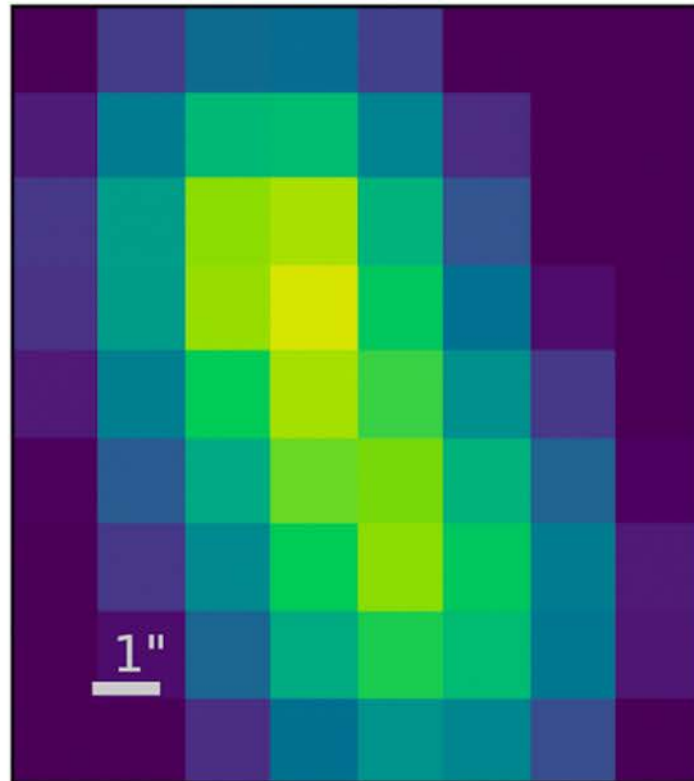
SPICE Far-IR Probe Extragalactic Science

SPICE sees **individual galaxies** beyond the local universe

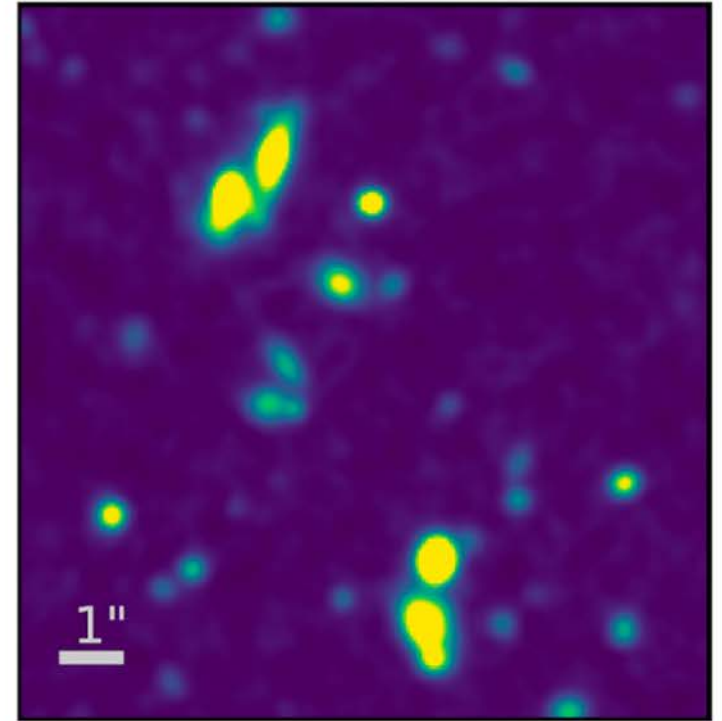
JWST 0.06" at 1.6 μ m



Herschel 6.8" at 100 μ m



SPICE 0.3" at 100 μ m

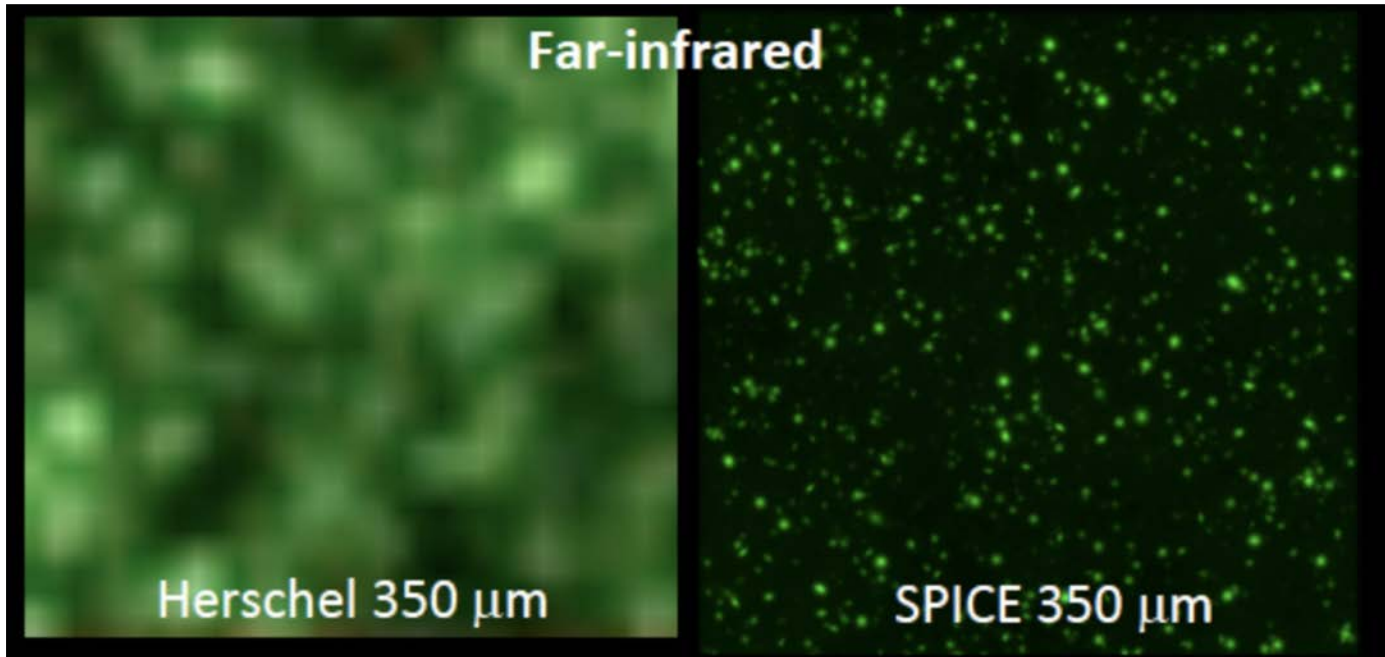




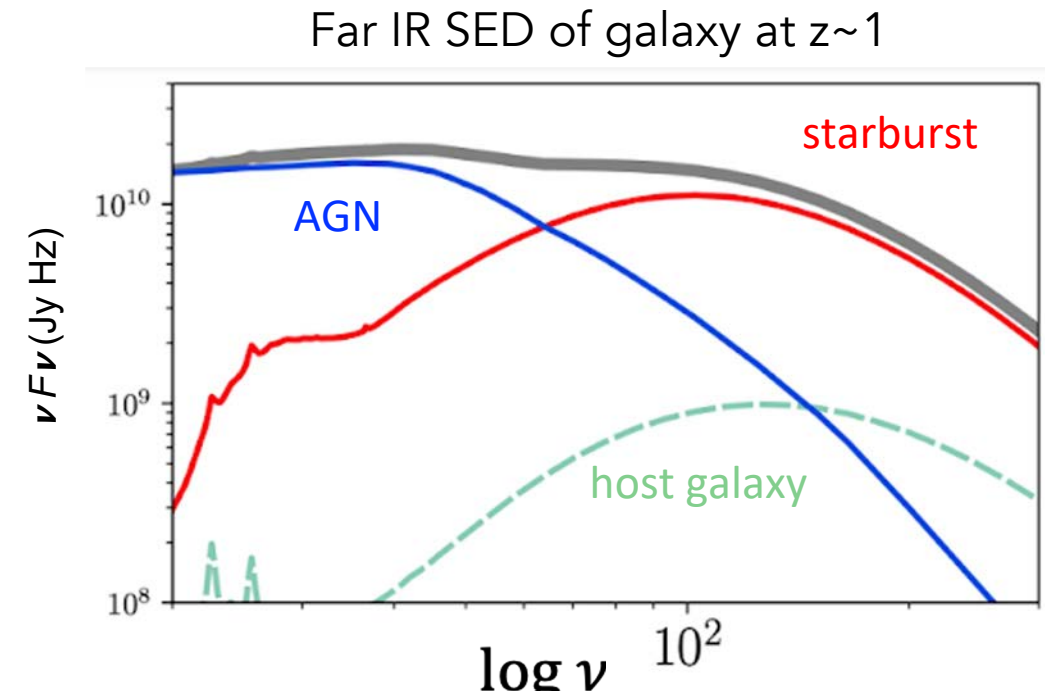
SPICE Far-IR Probe Extragalactic Science

Extragalactic survey

1000 h, $\sim 1 \text{ deg}^2$, $F_{\text{lim}} \sim 0.3 \text{ mJy}$, 50,000 gal+AGN



4.7 x 4.7 arcmin cutout from Herschel GOODS deep field and simulated SPICE observation of an area the same size.



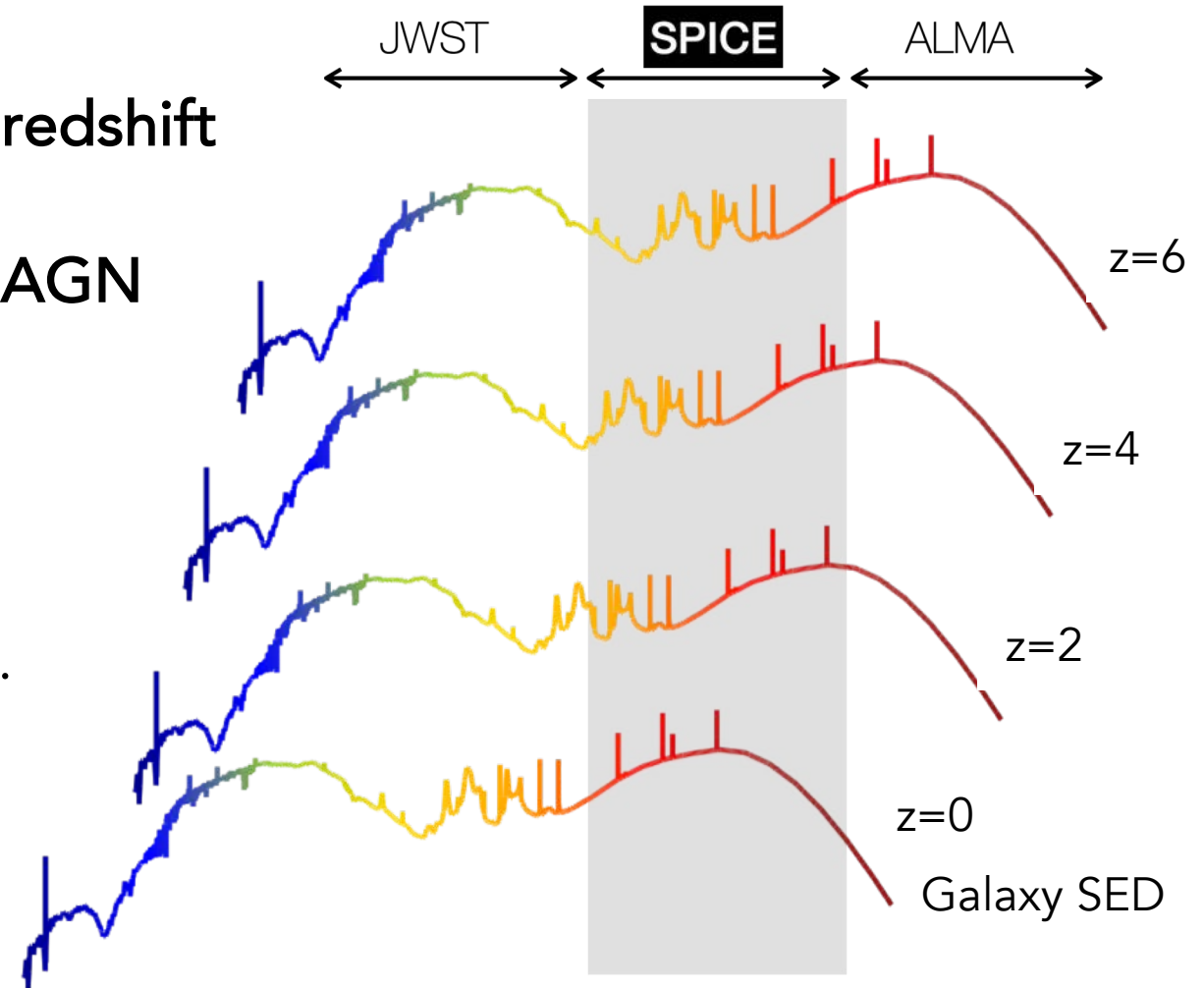


SPICE Far-IR Probe Extragalactic Science

1. Co-evolution of galaxies + BH to high redshift

2. Resolved studies of nearby galaxies + AGN

- Morphologies + feedback
- Sub-kpc structure of ISM mapped in important FIR tracers
- Match resolution of ALMA + JWST + ...





SPICE Far-IR Probe Extragalactic Science

Completing wavelength coverage for local galaxies

FIR lines provide important, unattenuated diagnostics of ISM

SPICE observations of local galaxies provide analogs for high-z galaxies seen with ALMA



HST



JWST

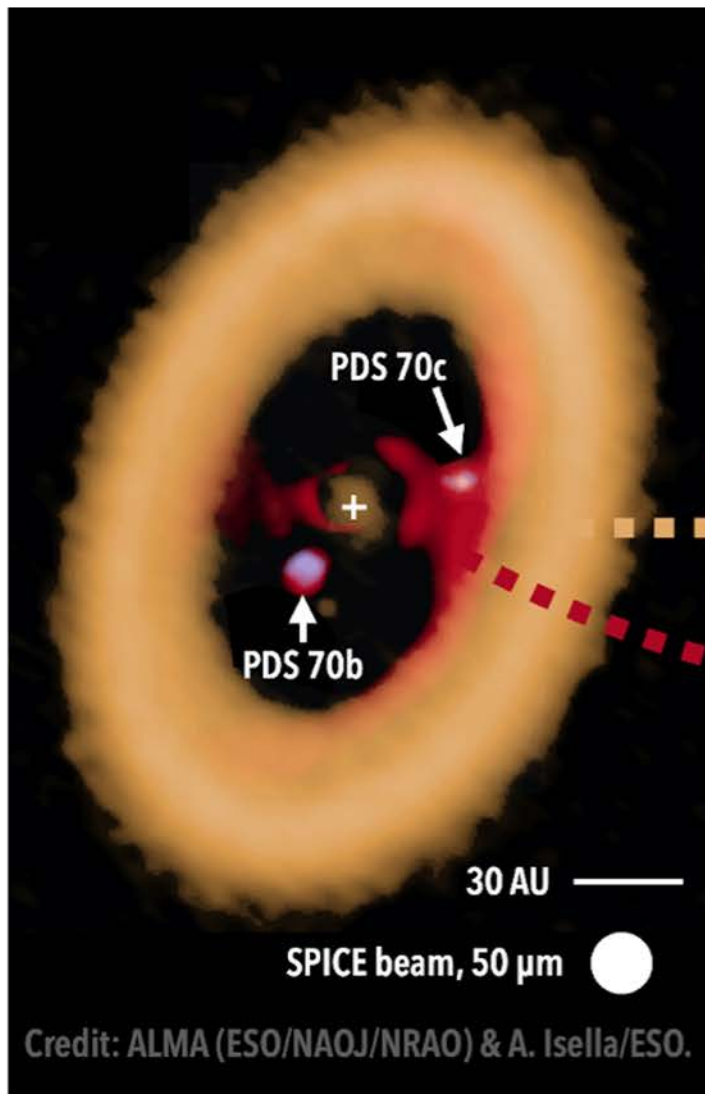
PHANGS collaboration

SPICE maps at similar resolution of:

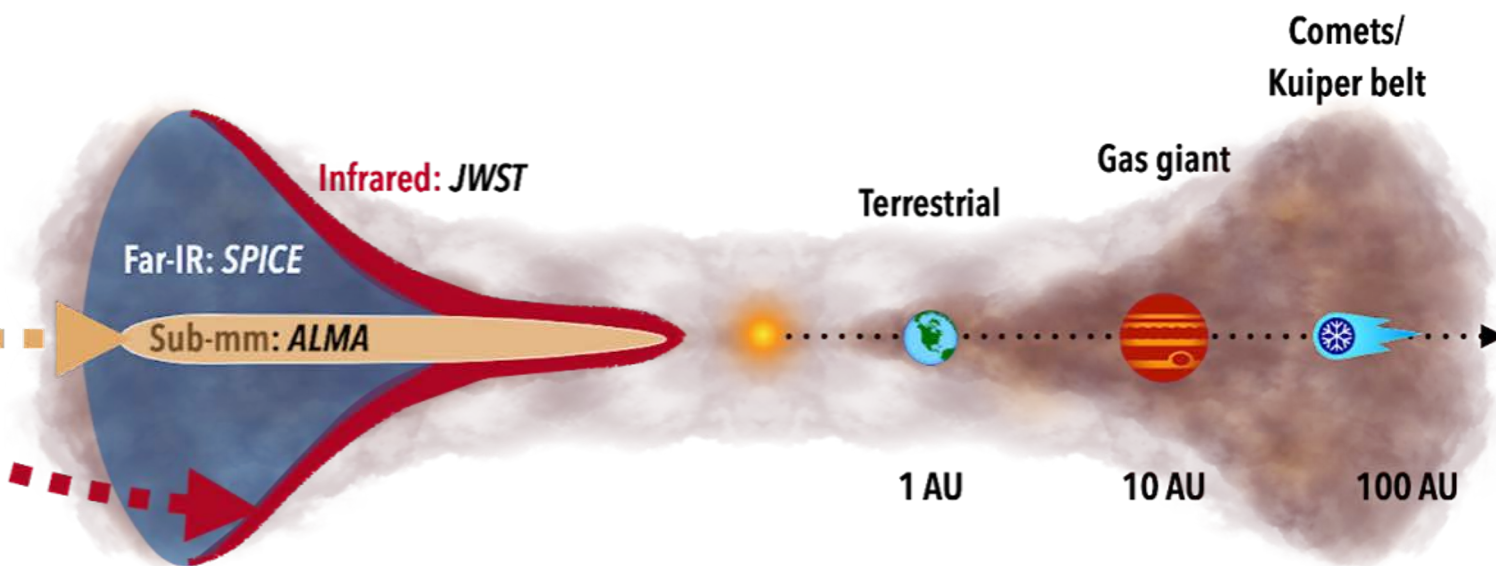
- [CII] 158 μm
- [OI] 63, 144 μm
- [NII] 122, 205 μm
- [OIII] 52, 88 μm
- Attenuation-free tracers of density, metallicity, heating/cooling rates, ionization parameter



SPICE resolves in situ planet formation around young stars, like PDS 70



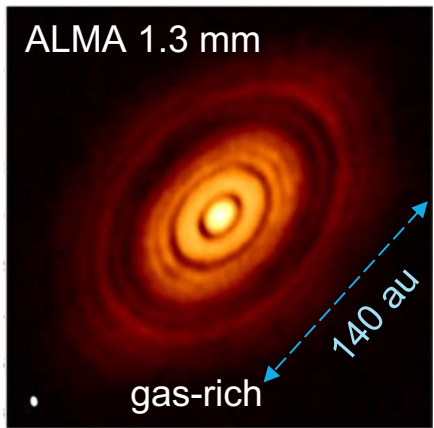
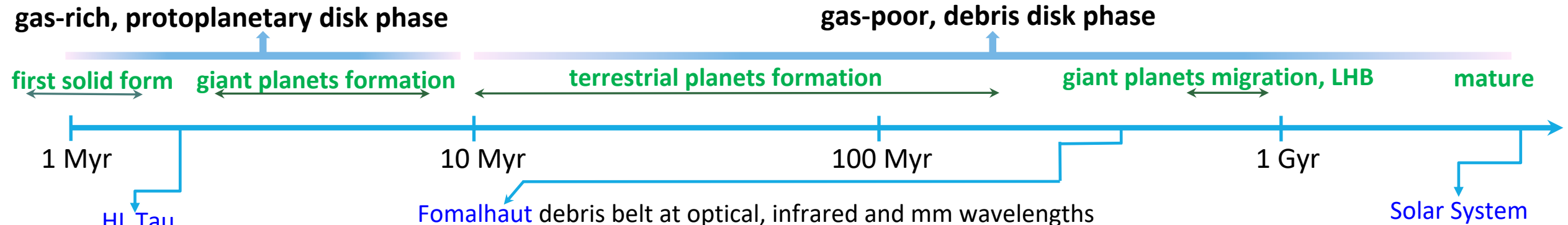
Spatially resolved far-IR observations probe outer disk, down to disk midplane...



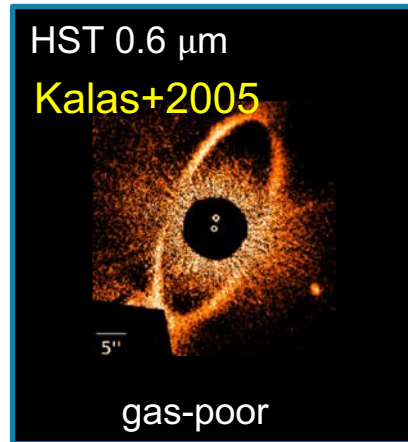
...which directly accesses the composition and structure of planet birth zones.

Credit: M.K. McClure

Formation & Evolution of a Planetary System

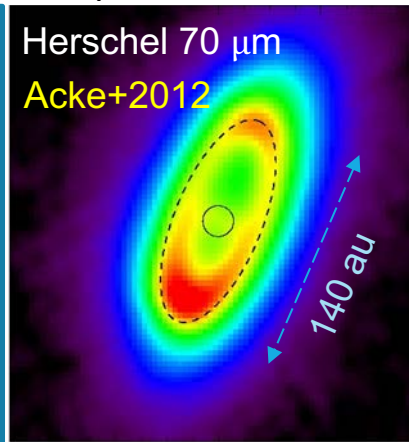


~1200 publications:
~ 500 since 2015
(ALMA image)



~ 1200 publications:

~ 700 since 2005 (HST/Spitzer images)
~ 400 since 2012 (Herschel/ALMA image)

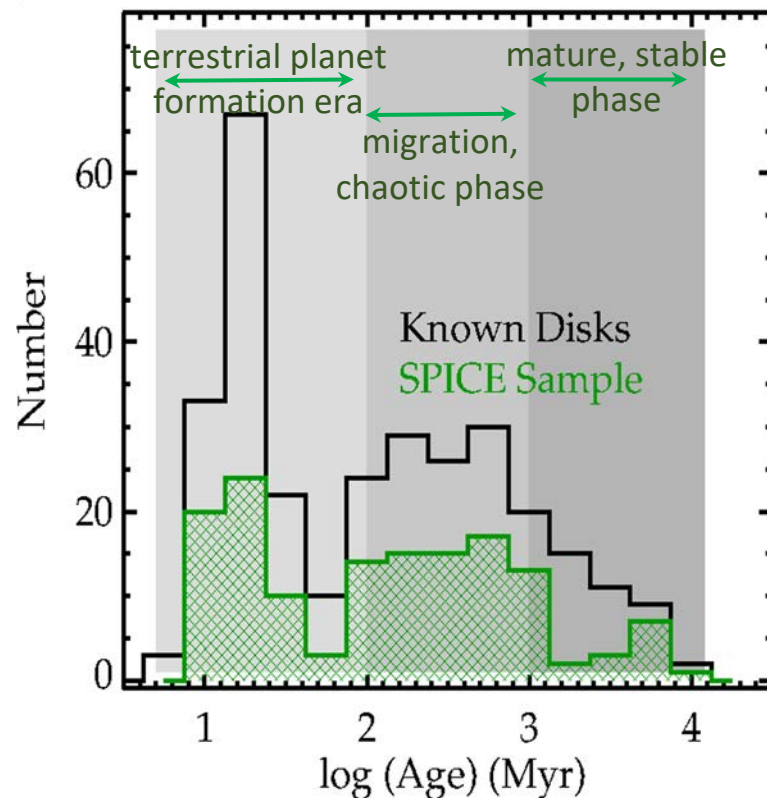
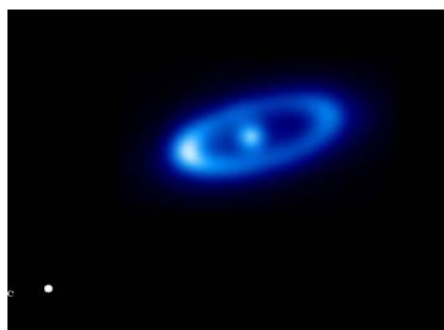


A well resolved image has a long lasting legacy value!

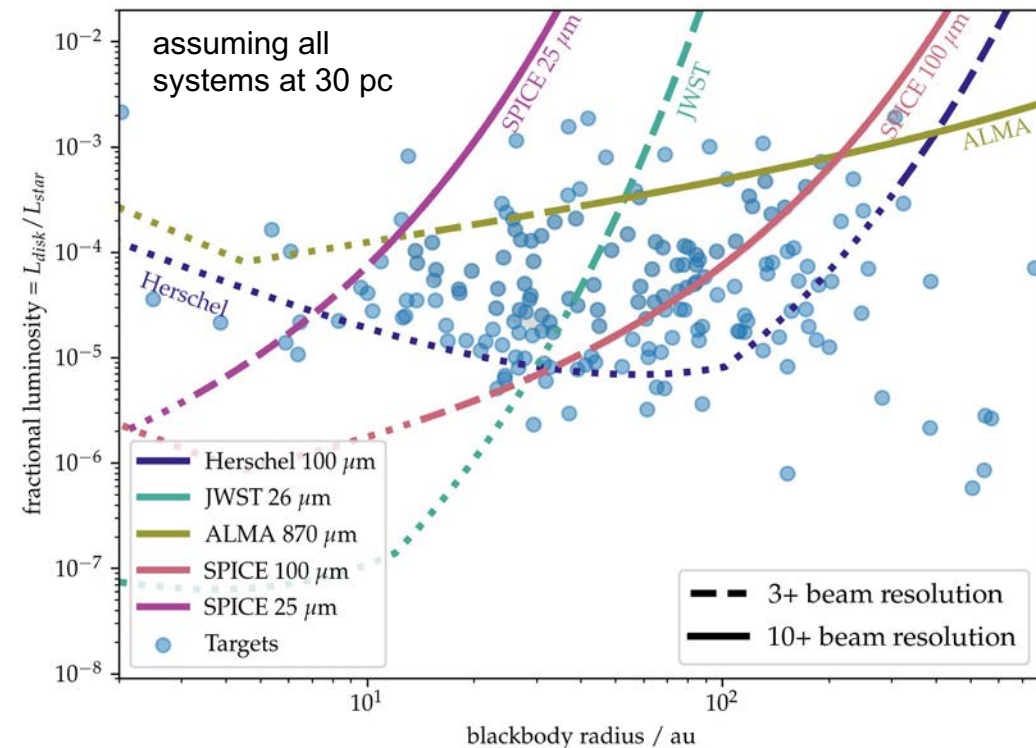


SPICE Debris Disk Legacy Survey

- SPICE will target **~100 known disks** identified by prior infrared surveys within ecliptic latitudes of $\pm 30^\circ$ around **different masses and ages** of stars to probe the **full duration of planetary system evolution**.



Terrestrial planet formation era: **~10 – 200 Myr**
 Planet migration, chaotic phase: **200 – 1000 Myr**
 Mature, stable phase: **> 1 Gyr**



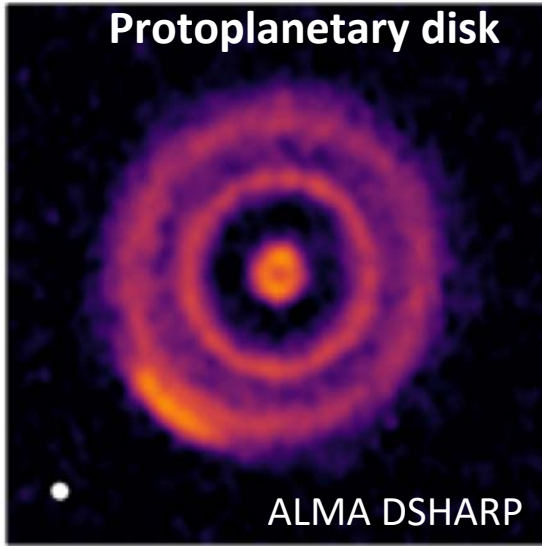
SPICE's **sensitivity** and **unprecedented resolution** will resolve and **explore a large sample of disks**, opening up parameter space beyond other facilities. 50% of disks will be resolvable with 10+ beams.



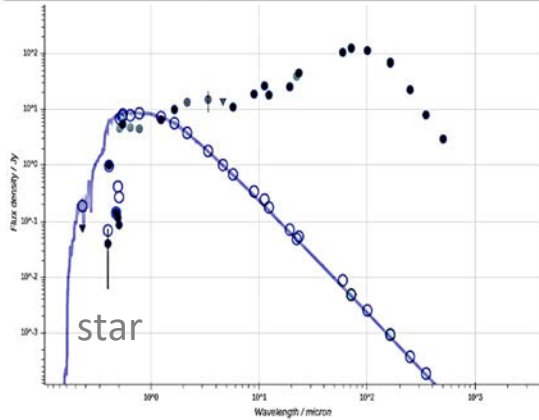
What are the typical architectures of planetary systems?

HD 14300

Protoplanetary disk

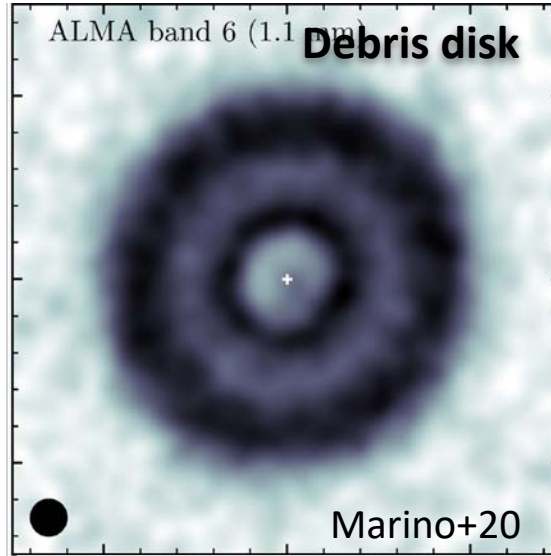


ALMA DSHARP

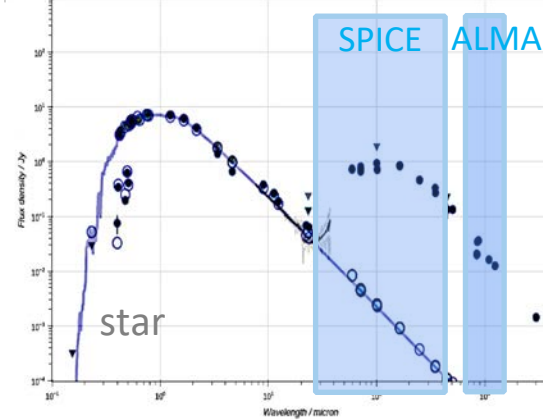


HD107146

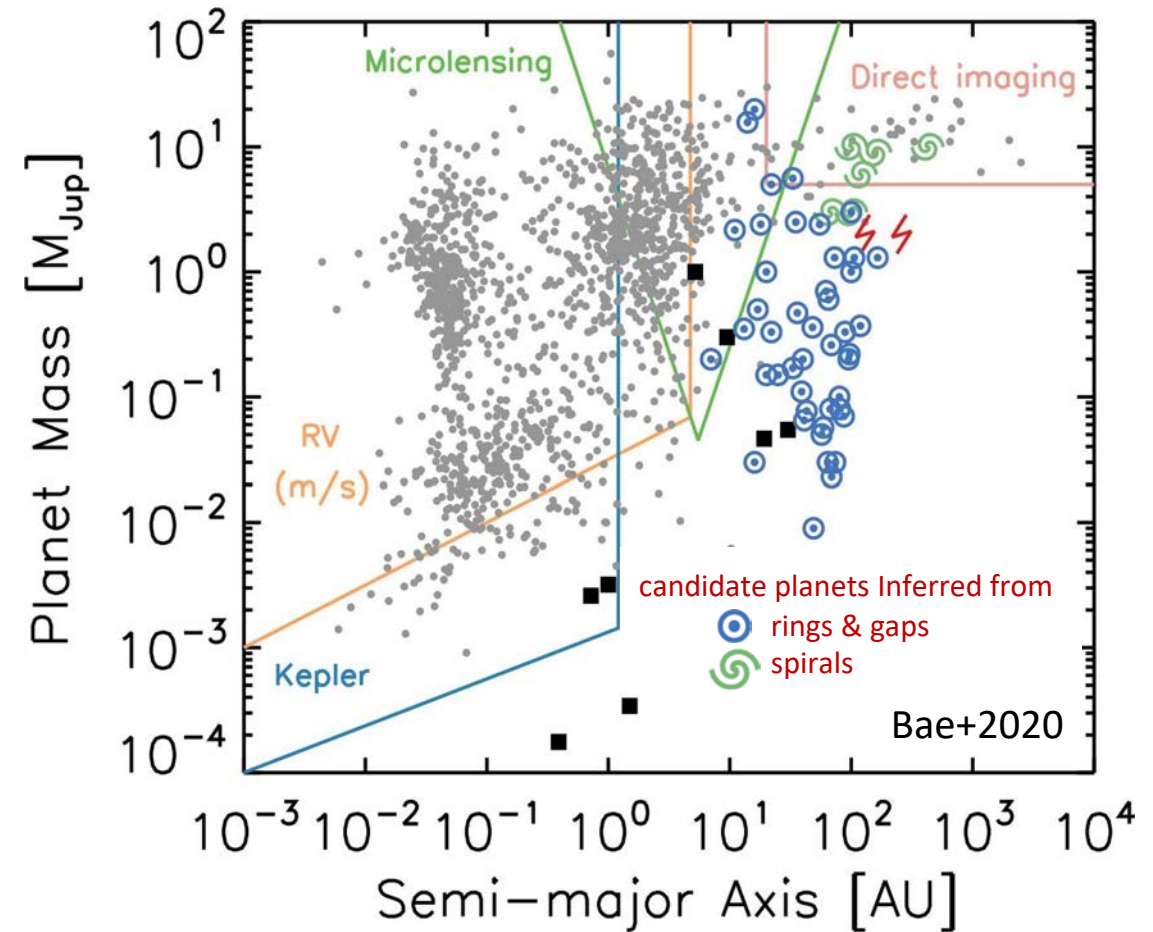
ALMA band 6 (1.1 mm) Debris disk



Marino+20



Debris disks are two orders of mag fainter than PPDs!
ALMA wavelengths are two orders of mag fainter than SPICE!





SPICE Provides Answers to Key Questions in Astro2020

E-Q1b. What Are the Typical Architectures of Planetary Systems?

E-Q1c. How Common Is Planetary Migration, How Does It Affect the Rest of the Planetary System, and What Are the Observable Signatures?

E-Q1d. How Does the Distribution of Dust and Small Bodies in Mature Systems Connect to the Current and Past Dynamical States Within Planetary Systems?

E-Q3d. What Are the Key Observable Characteristics of Habitable Planets?

F-Q4. Is Planet Formation Fast or Slow?

F-Q4a. What Are the Origins and Demographics of Disk Substructures?

SPICE's multiwavelength, well-resolved debris disk survey around ~ 100 exoplanetary systems across different mass and ages of stars will provide constraints on these questions!