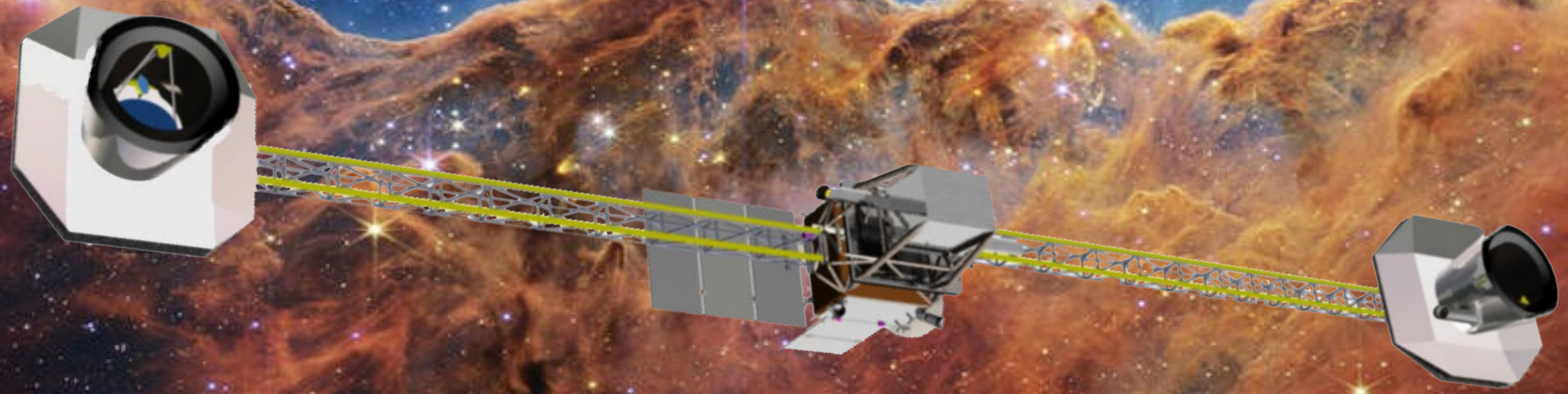
Space Interferometer for Cosmic Evolution

SPICE



PI: Lee Mundy, University of Maryland

and the SPICE team

SPICE is…

SPICE is a spatial-spectral interferometer

Simultaneous observations in 4 bands covering from 25-400 μm

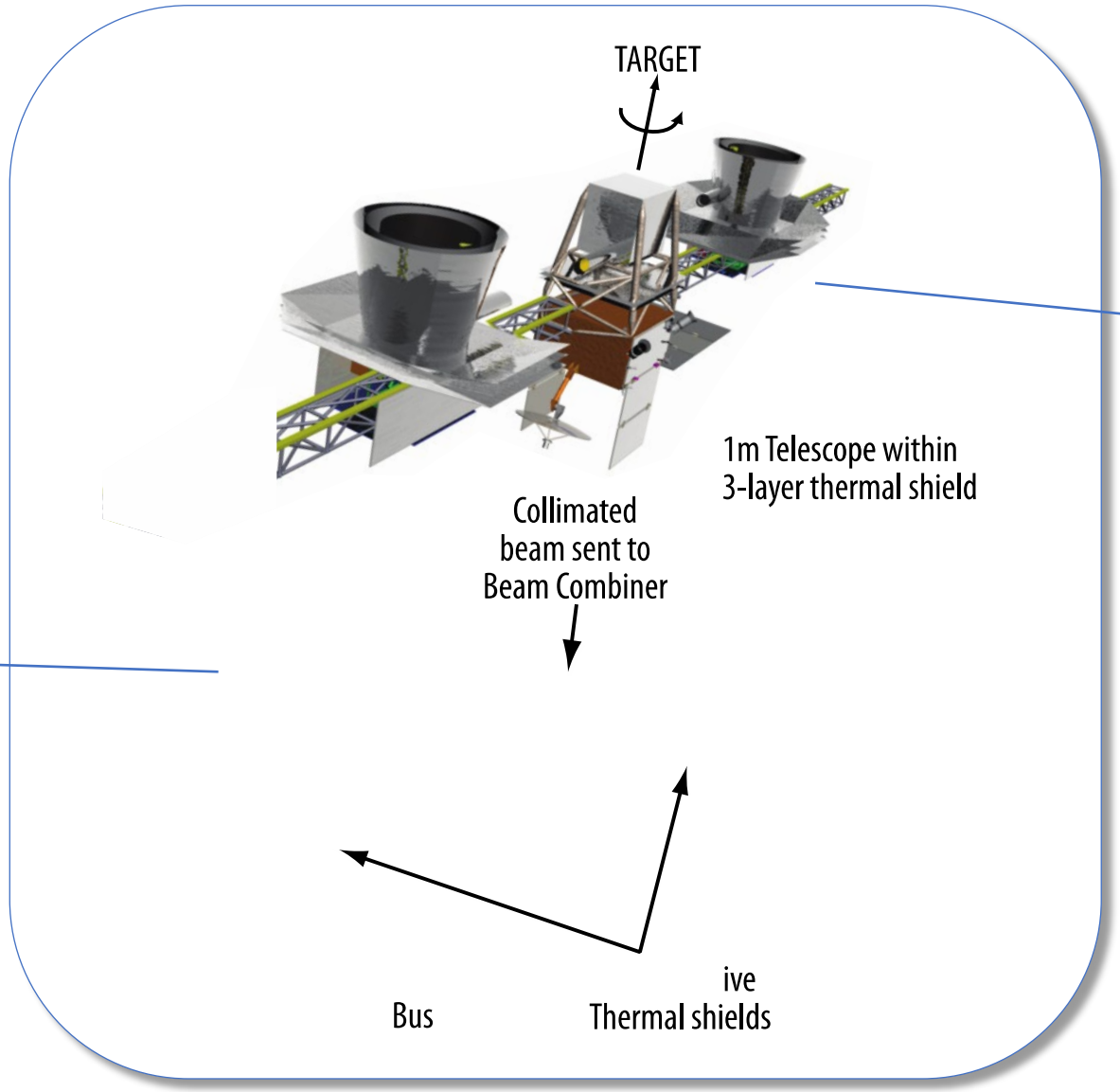
SPICE rotates around the line-of-sight vector and the telescope separation is adjustable.

Beam-combining instrument (Fourier Transform type Spectrometer)

Sun-Earth L2 orbit

Operational modes:

- Full, deep imaging
- Sparse imaging
- Snapshot spectra
- Science driven configurations



Adjustable Baselines from ~6 to 36 m

4.5 K optical surfaces

State of the art detector sensitivity

Scientifically: What makes SPICE powerful?

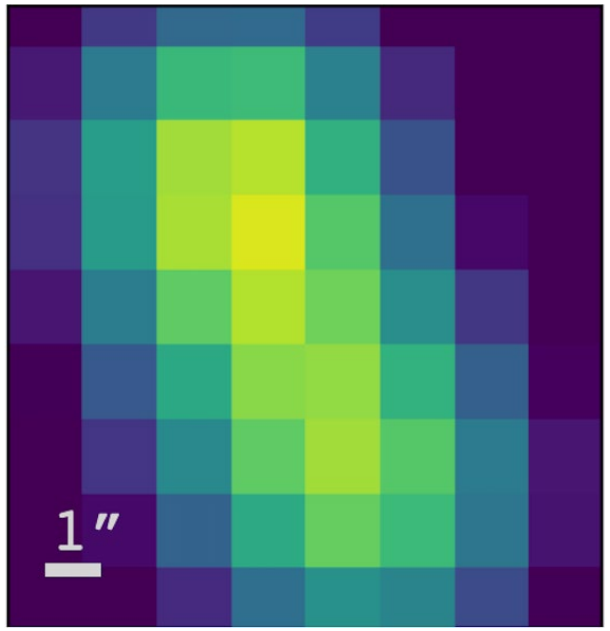
SPICE addresses the ASTRO 2020 Decadal goals for a Far-IR Probe as no other mission can with:

- **Unprecedented image resolution at Far-IR wavelengths**
- **Order of magnitude improved sensitivity over Herschel Space Telescope**
- **Spatial-spectral imaging with R up to 3,000**

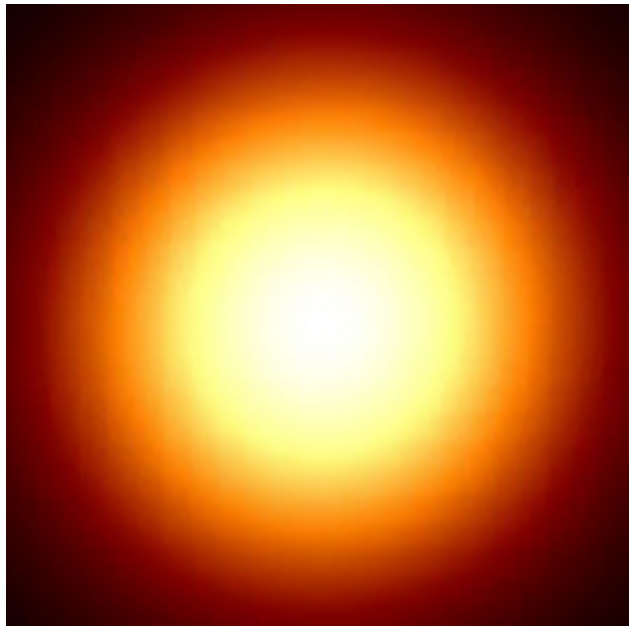
The past with *Herschel*

3.5 meter telescope

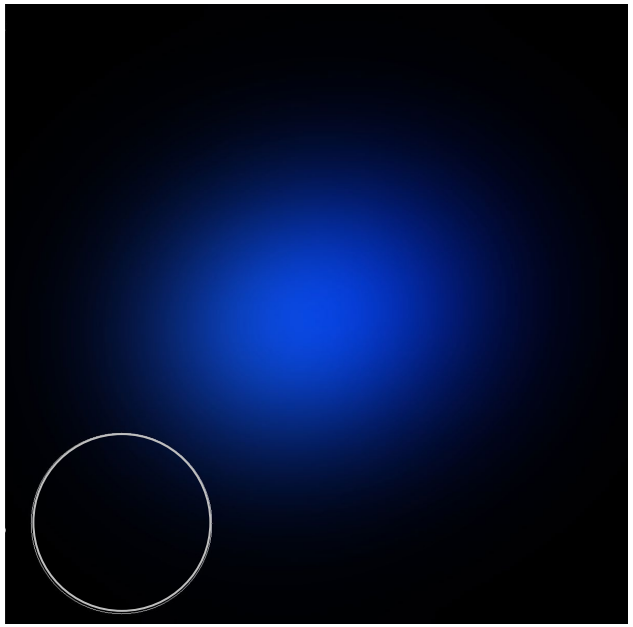
Extragalactic deep field



Protoplanetary disk



Debris disk



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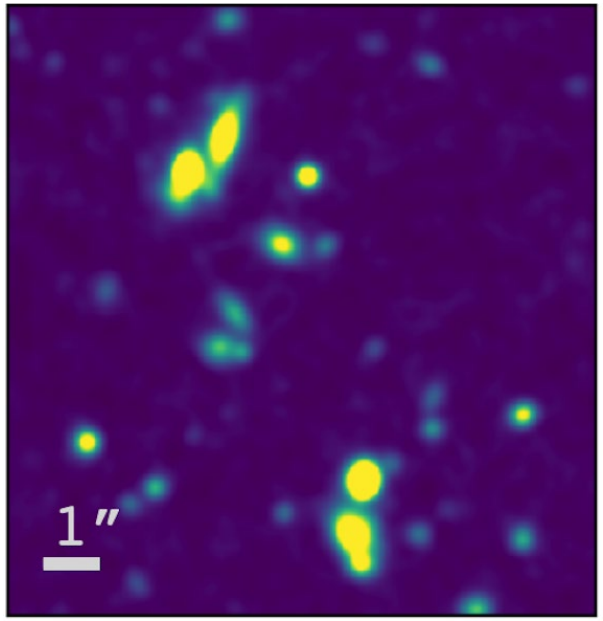
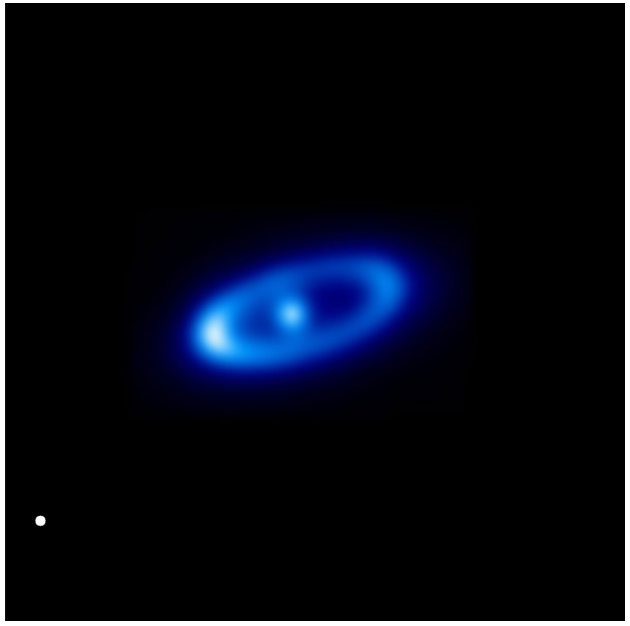
The future with *SPICE*

Extragalactic deep field



Protoplanetary disk

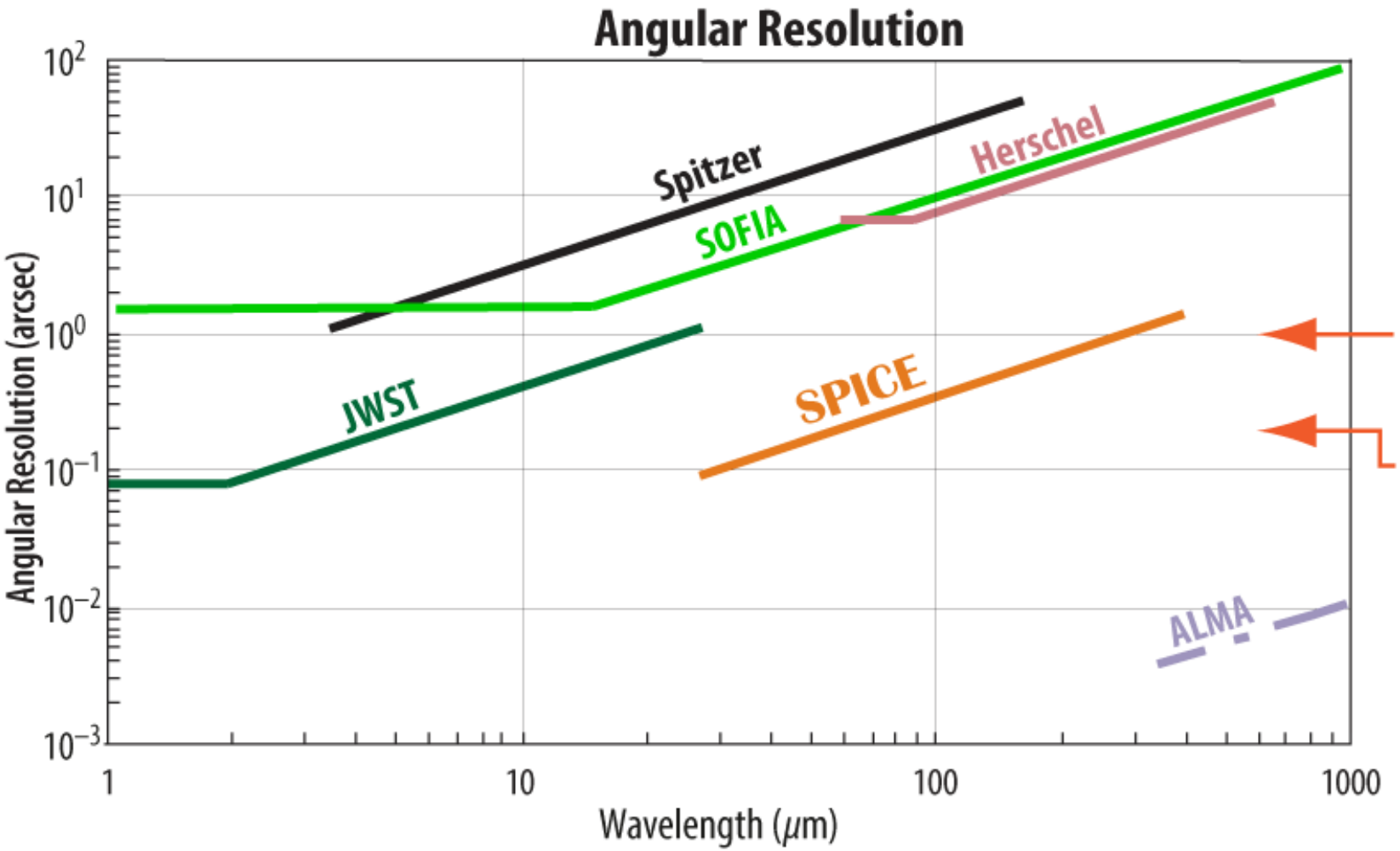
Debris disk



SPICE: Angular Resolution

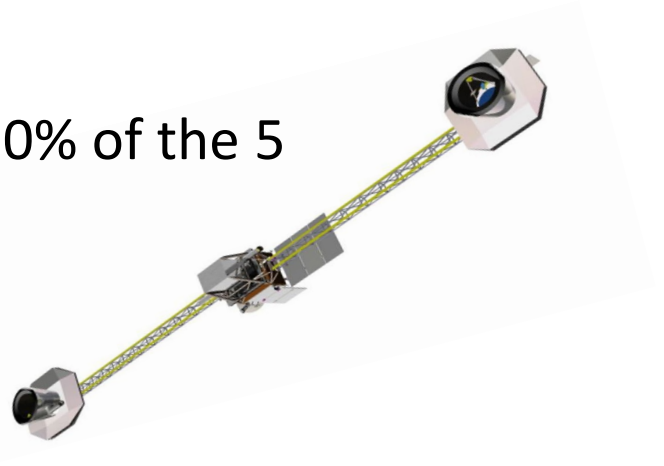
SPICE provides sub-arcsecond resolution out to 200 microns wavelength.

SPICE is not confusion limited in observations.



SPICE Science

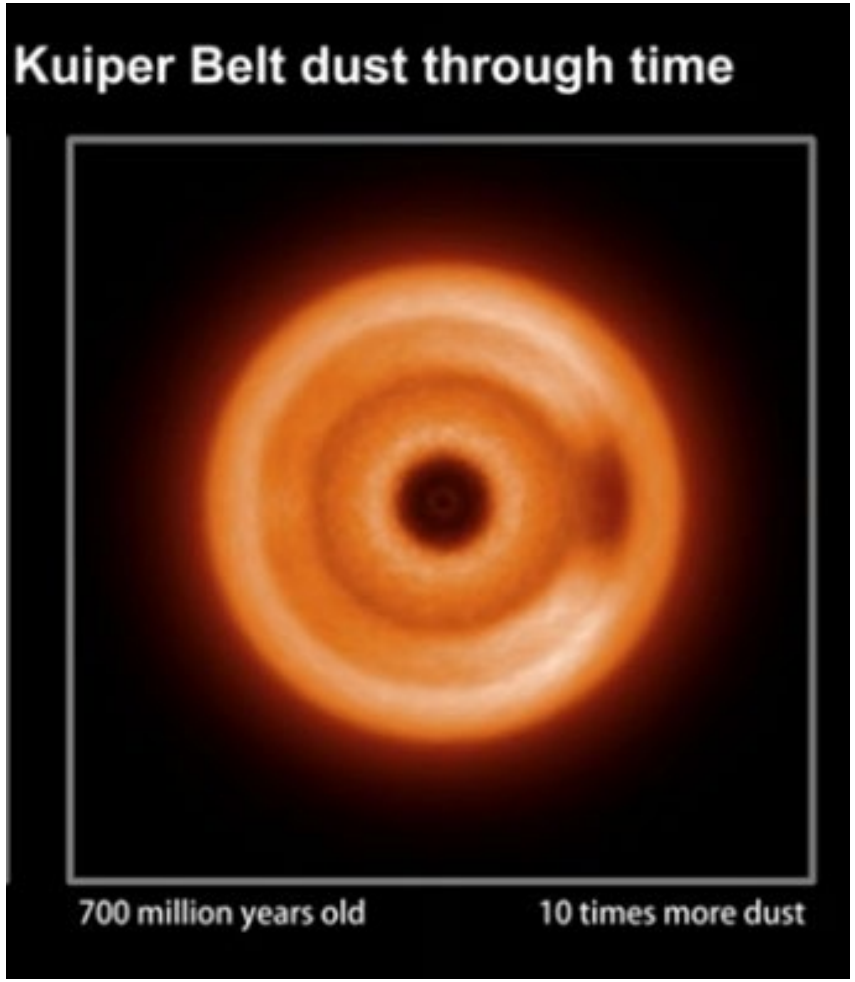
SPICE can address a wide range of science questions with at least 70% of the 5 year mission available to general observer science programs.



Three areas to be highlighted here are:

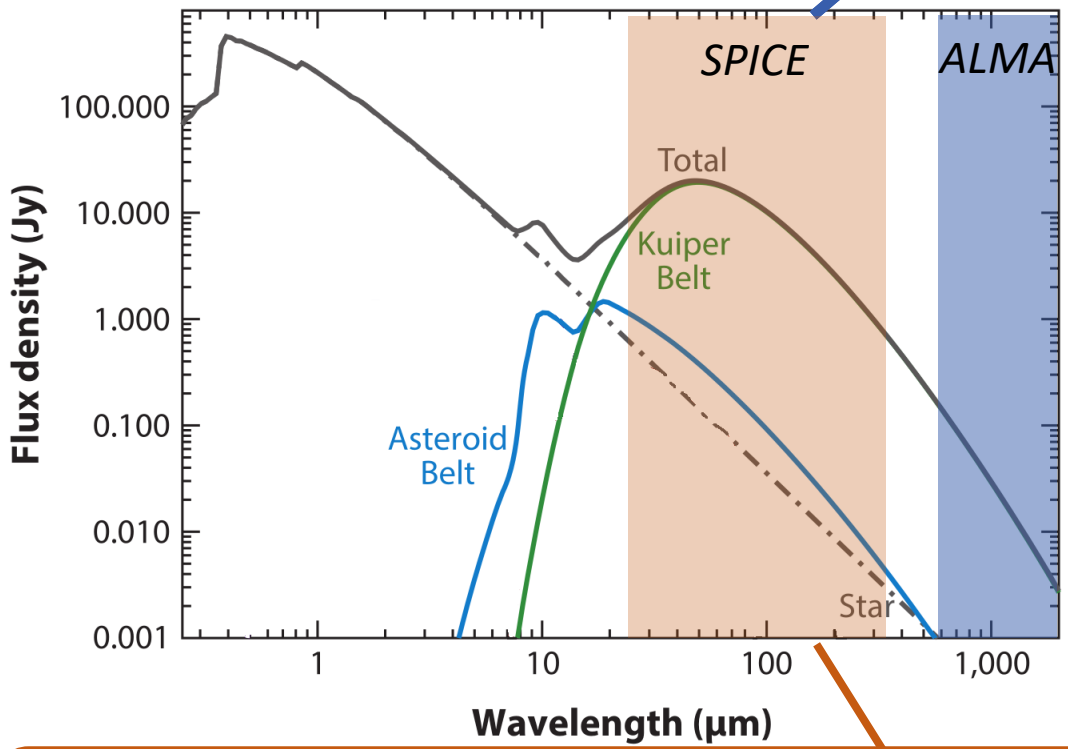
- The evolution of forming exo-planetary systems for protoplanetary disks to debris disks
- The evolution of volatiles and gas mass through the protoplanetary and planet forming period
- The evolution of galaxies, black holes, and star formation over cosmic time

How do planetary system architectures form and evolve through time?



Dynamical evolution history in the Solar System(DeMeo+ 2014).

ALMA is powerful but can see only the brightest debris disks because of the spectral energy distribution.



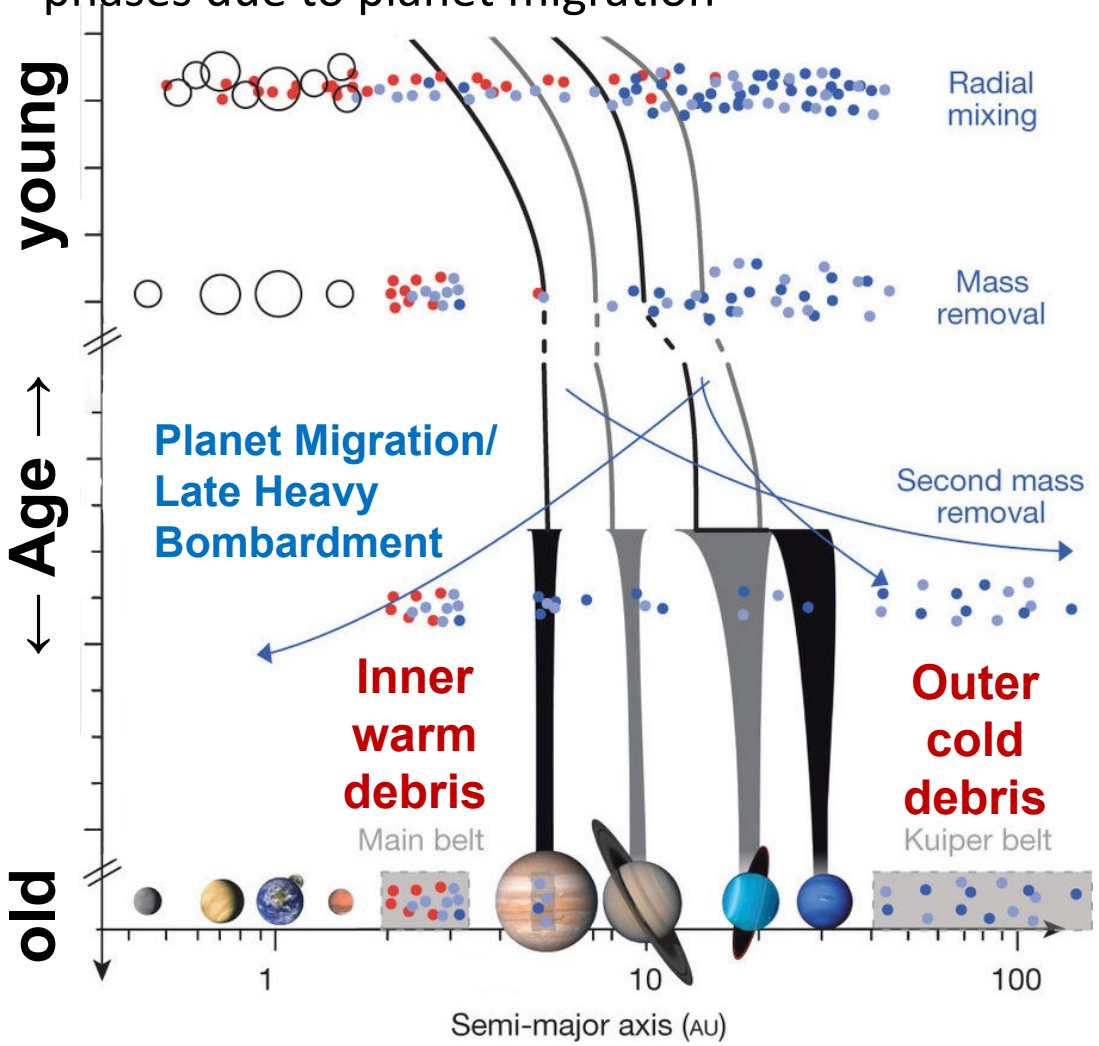
SPICE observes debris disks where they are 3 orders of magnitude brighter than at ALMA's wavelengths.

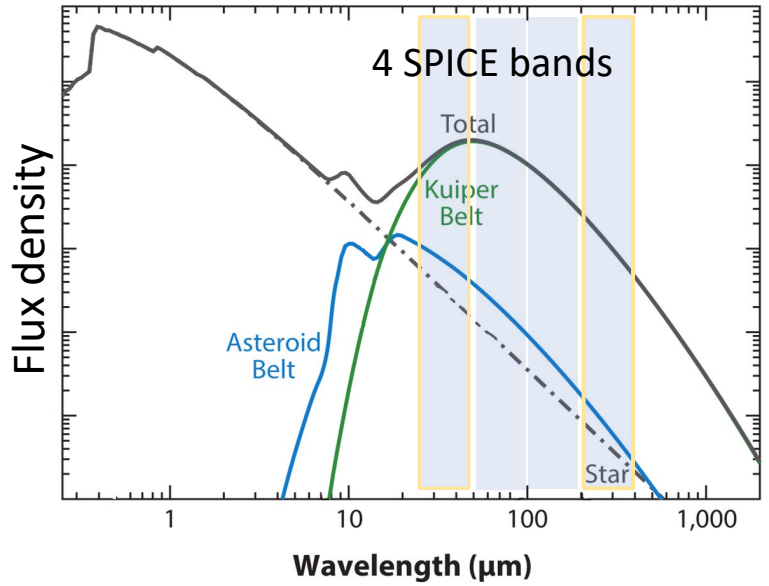
We need *SPICE* to make resolved images hundreds of transition and debris disks at various stages of their evolution and configuration.

SPICE will answer: *When are gas giant planets forming? How is the inner and outer disk evolving through time? How do debris disks evolve with time and how broad is the range of their behavior?*

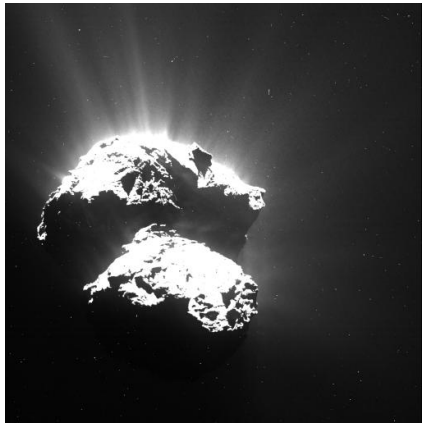
SPICE will Probe Inner and Outer Debris Zones

- Multi-wavelength resolved images of systems at different evolutional stages can probe chaotic phases due to planet migration





- Search for volatiles (H2O, CO, CO2) released by planetesimals



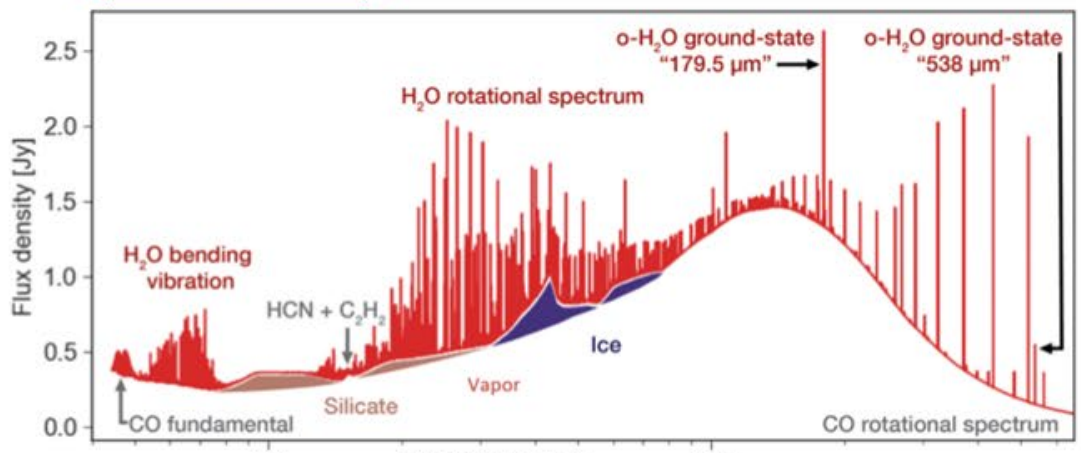
- Solid-state ice and crystalline silicate features
- Volatiles photodissociated in optically thin disks
  → [OI] & [CII] (main cooling lines)

SPICE will enable measurement of the volatiles available for delivery to inner solar systems across different evolutionary stages.

How do nascent planets obtain water, the most basic ingredient for life?

A protoplanetary disk, where planets are born

JWST will access hot gas-phase water very close to the star, which is a tiny fraction of the total water reservoir available to forming planets



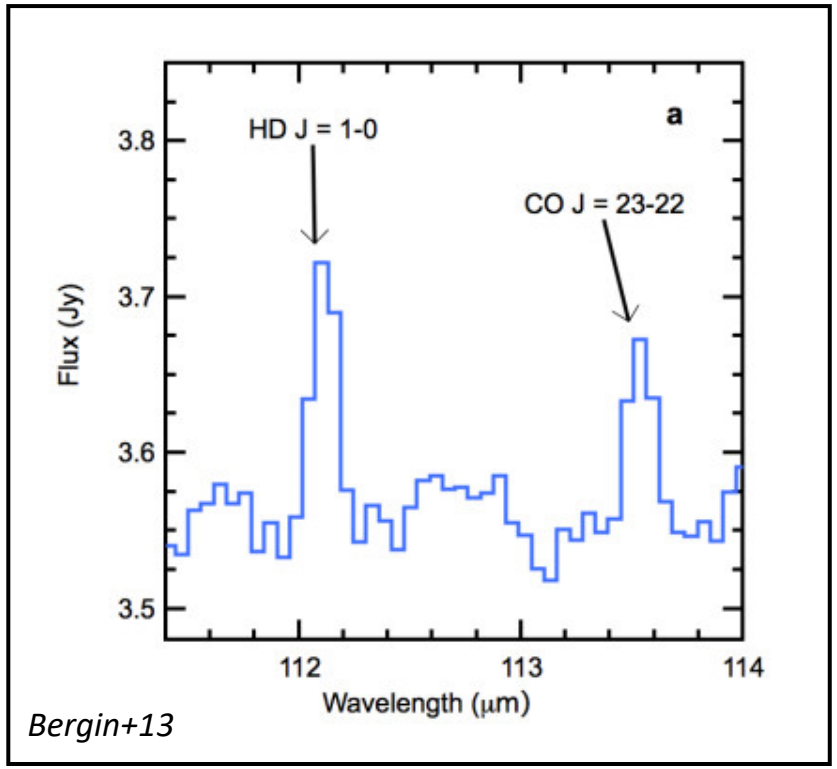
The mid- to far-IR view of a protoplanetary disk

We need ***SPICE*** to probe the bulk water inventory in disks: cool gas-phase water and cold ice-phase water

SPICE will answer: *How much water is available to forming planets and icy bodies? How is the water distributed across different planet-forming zones? How is water connected to rocky planetary building blocks?*

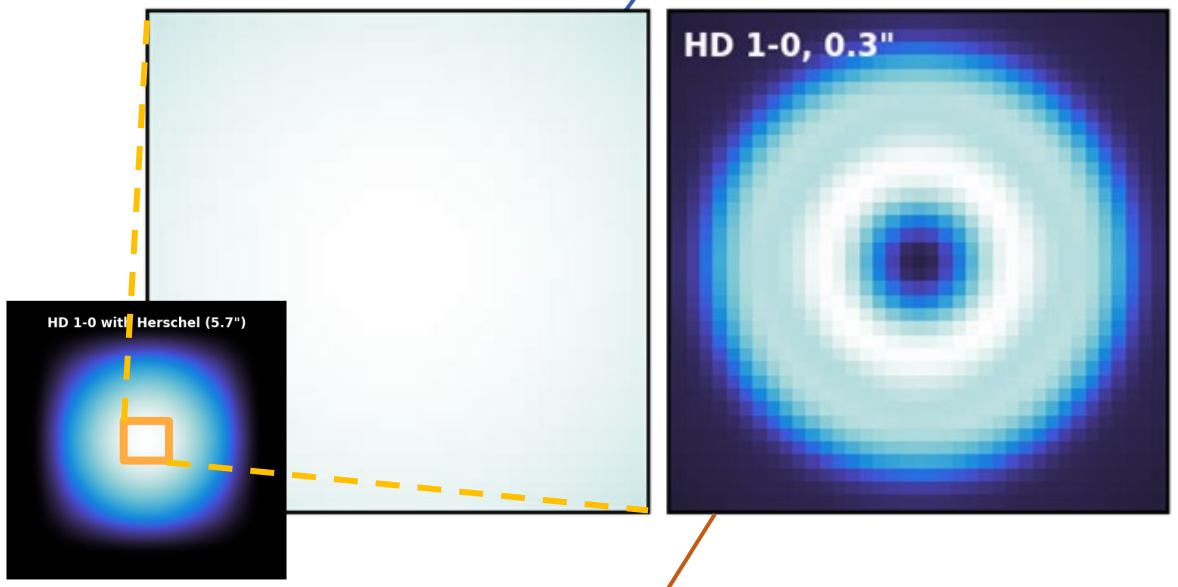
What is the mass budget available for planet formation?

HD emission accurately traces the bulk component of planet forming disks, H_2, has been detected, but never been physically resolved to measure its distribution



Bergin+13

ALMA and *JWST* cannot access HD, and 2-3-meter class far-infrared telescopes cannot resolve HD emission in planet forming disks



Simulations of the HD emission of the AS209 planet forming disk. Left: 3-m class telescope, Right: SPICE

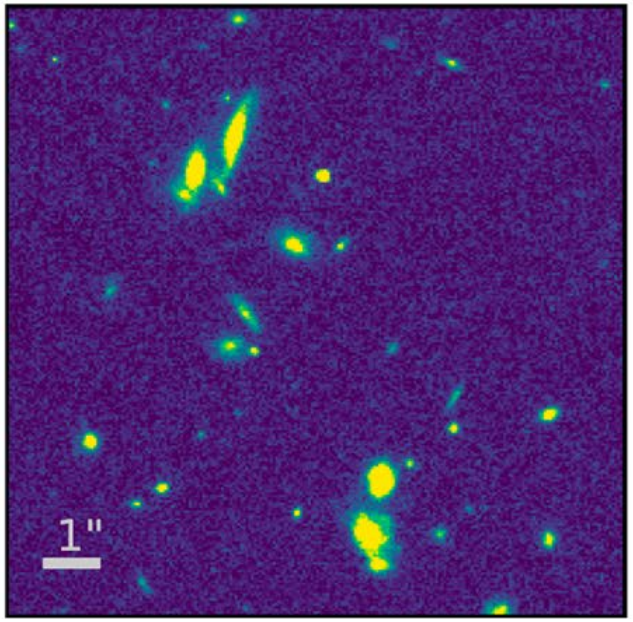
We need ***SPICE*** to ***physically resolve*** *HD emission* and chart the evolution of the bulk component of planet building material

SPICE will answer: *How much mass is available to form planets as disks evolve? What mechanisms regulate the evolution of disk mass? How is mass distributed across different planet-forming zones?*

The only way to observe *individual* distant galaxies in FIR is with ***high resolution***:

Current status of optical/near-IR

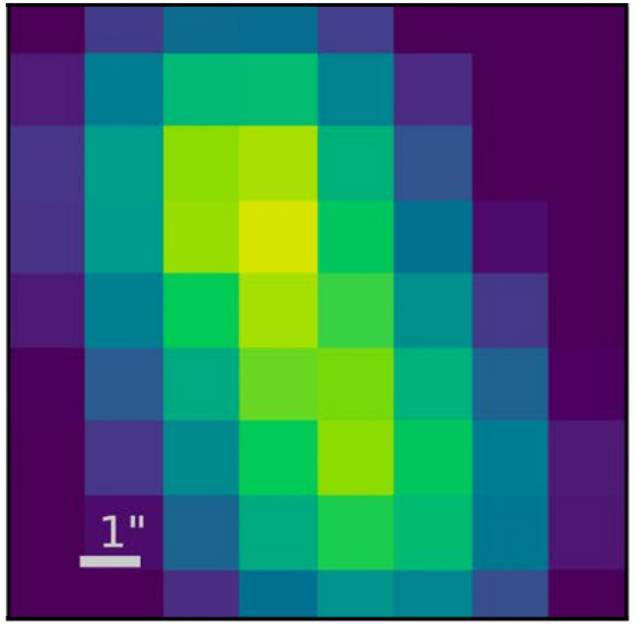
JWST 0.06'' at 1.6μm



The sky as it will be seen by <u>JWST/NIRCam at 1.6µm</u>

Single dish (3.5m) FIR

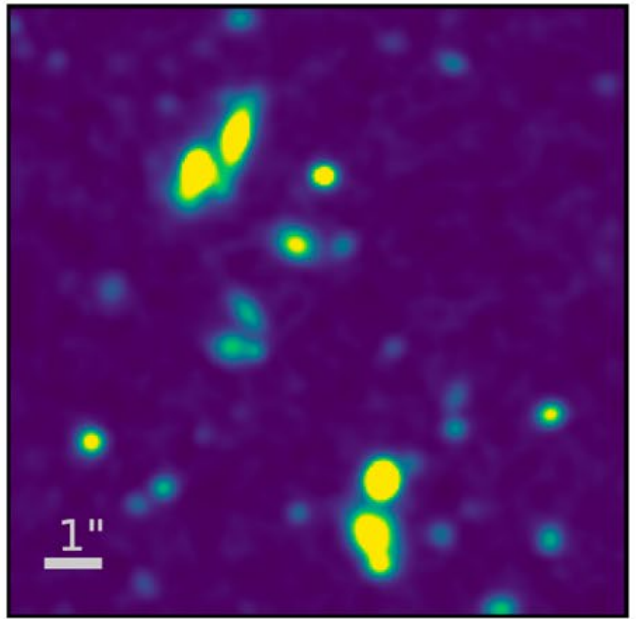
Herschel 6.8'' at 100μm



Same field simulated for the <u>3.5m single dish Herschel</u>

High resolution FIR

SPICE 0.3'' at 100μm



Same field simulated for the <u>SPICE interferometer</u>

Galaxy Evolution Science with SPICE

1. Co-evolution of galaxies and their supermassive blackholes

Astro2020

How do supermassive black holes form and how is their growth coupled to the evolution of their host galaxies?

2. Star formation across cosmic time

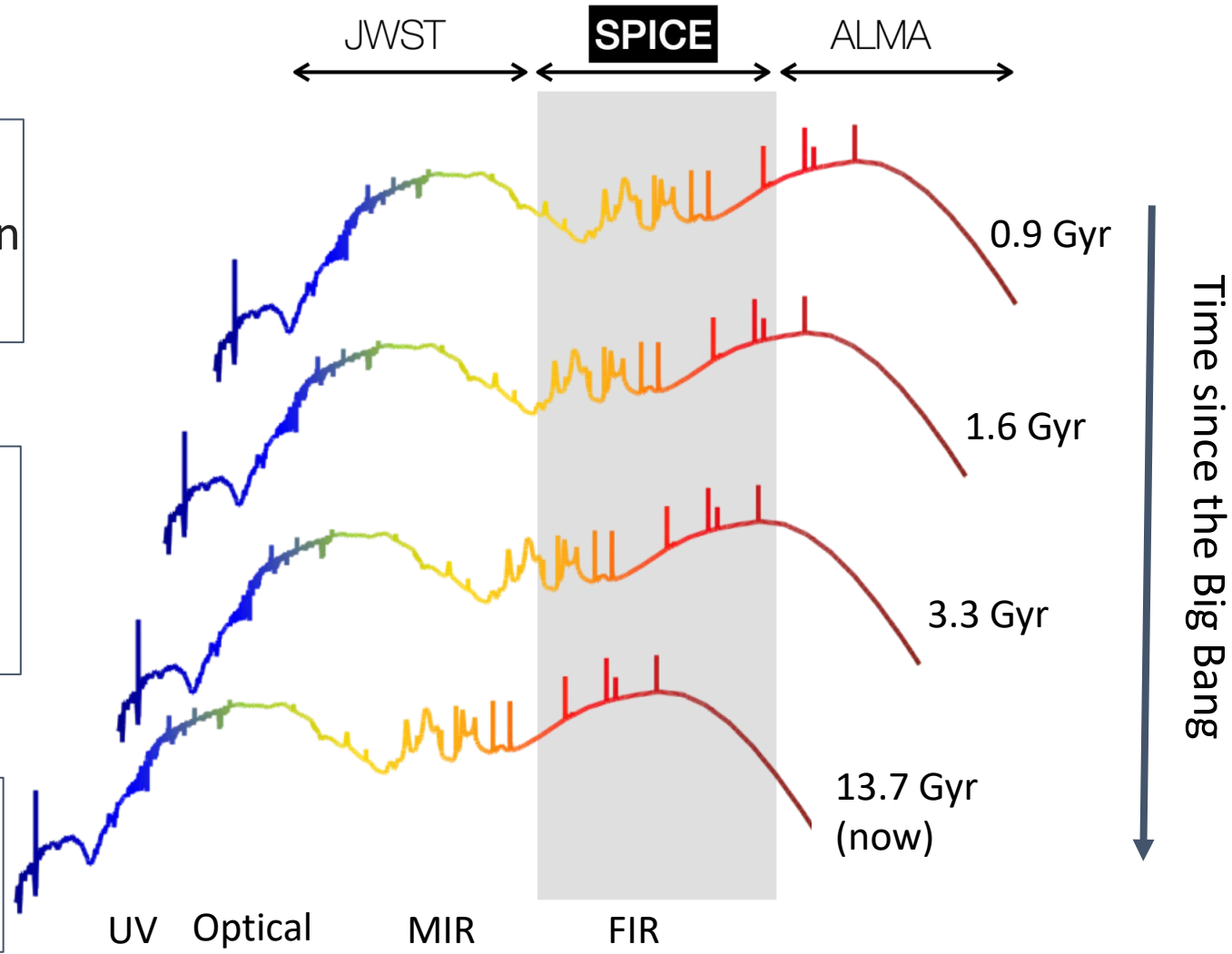
Astro2020

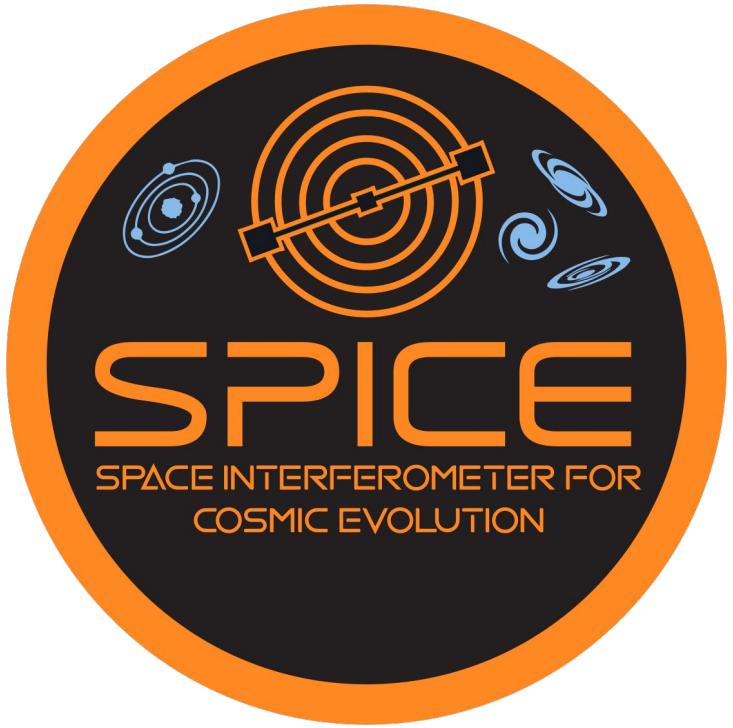
How do the histories of galaxies and their dark matter halos shape their observable properties?

3. Structure of interstellar medium

Astro2020

How do gas, metals, and dust flow into, through, and out of galaxies?





Enabling transformational science at Far Infrared Wavelengths with Sub-arcsecond Resolution