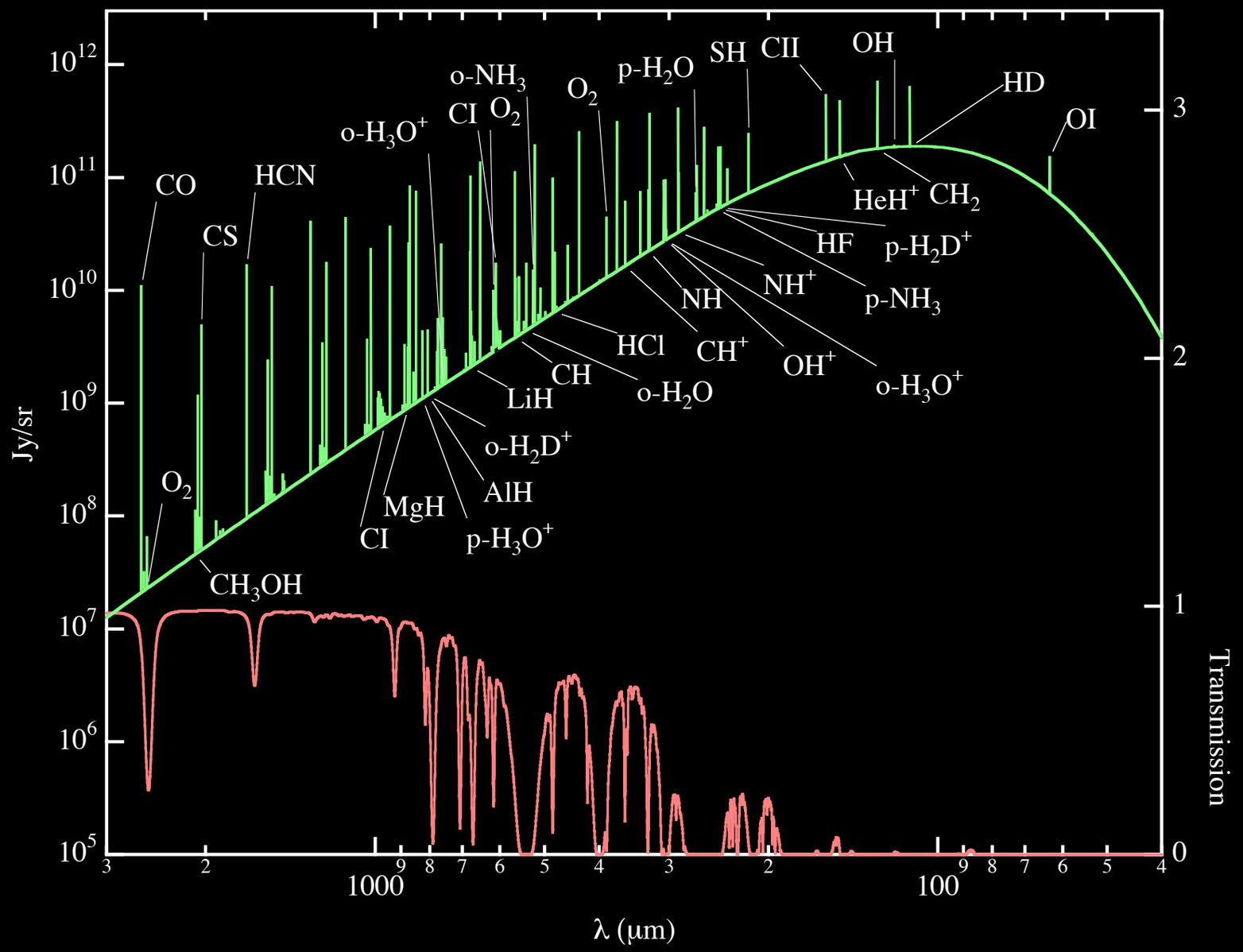
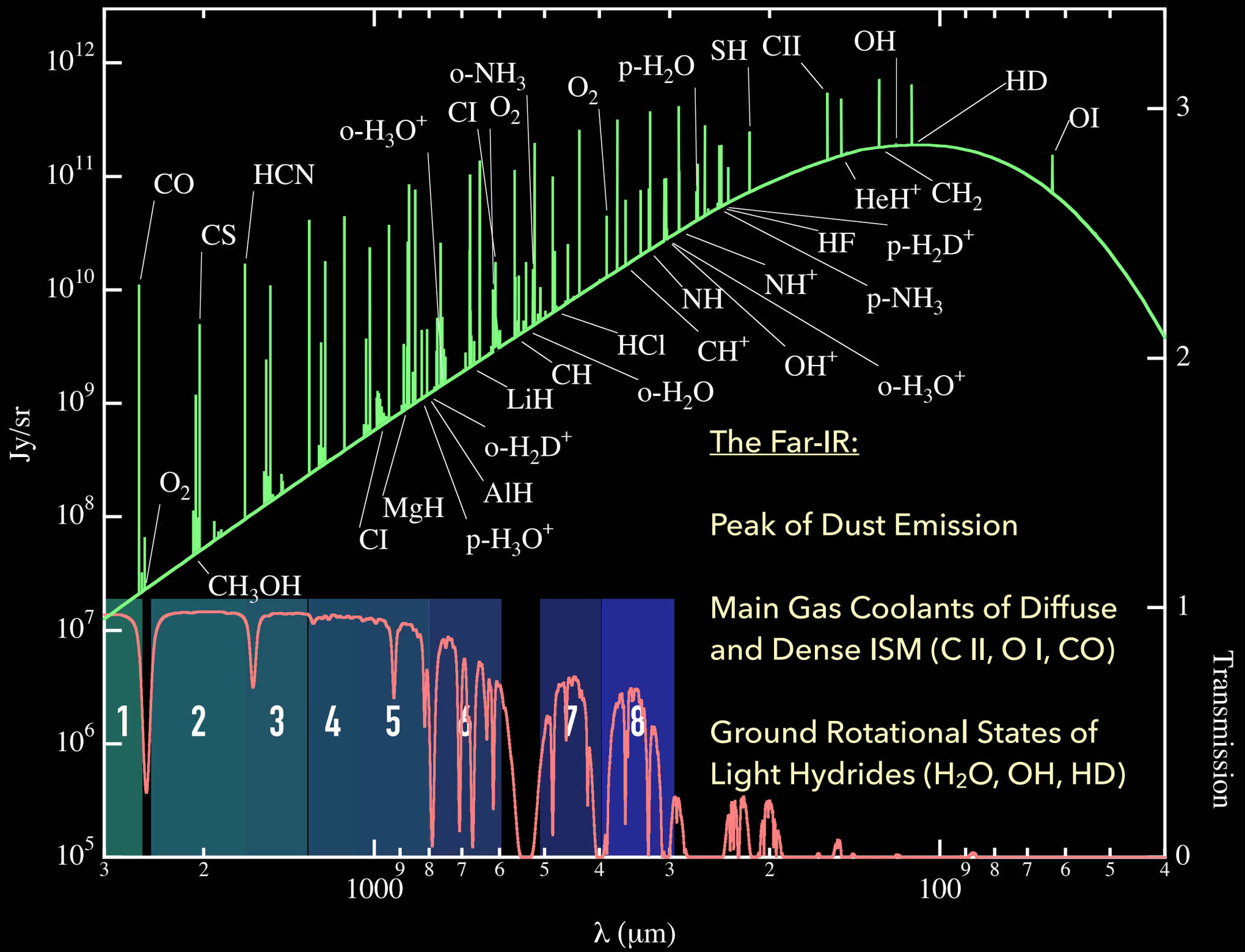
A LANDSCAPE FOR FAR-INFRARED GALACTIC ASTRONOMY OVER THE NEXT DECADE

EDWIN BERGIN
UNIVERSITY OF MICHIGAN



THE FAR-IR FUTURE: GALACTIC ASTRONOMY



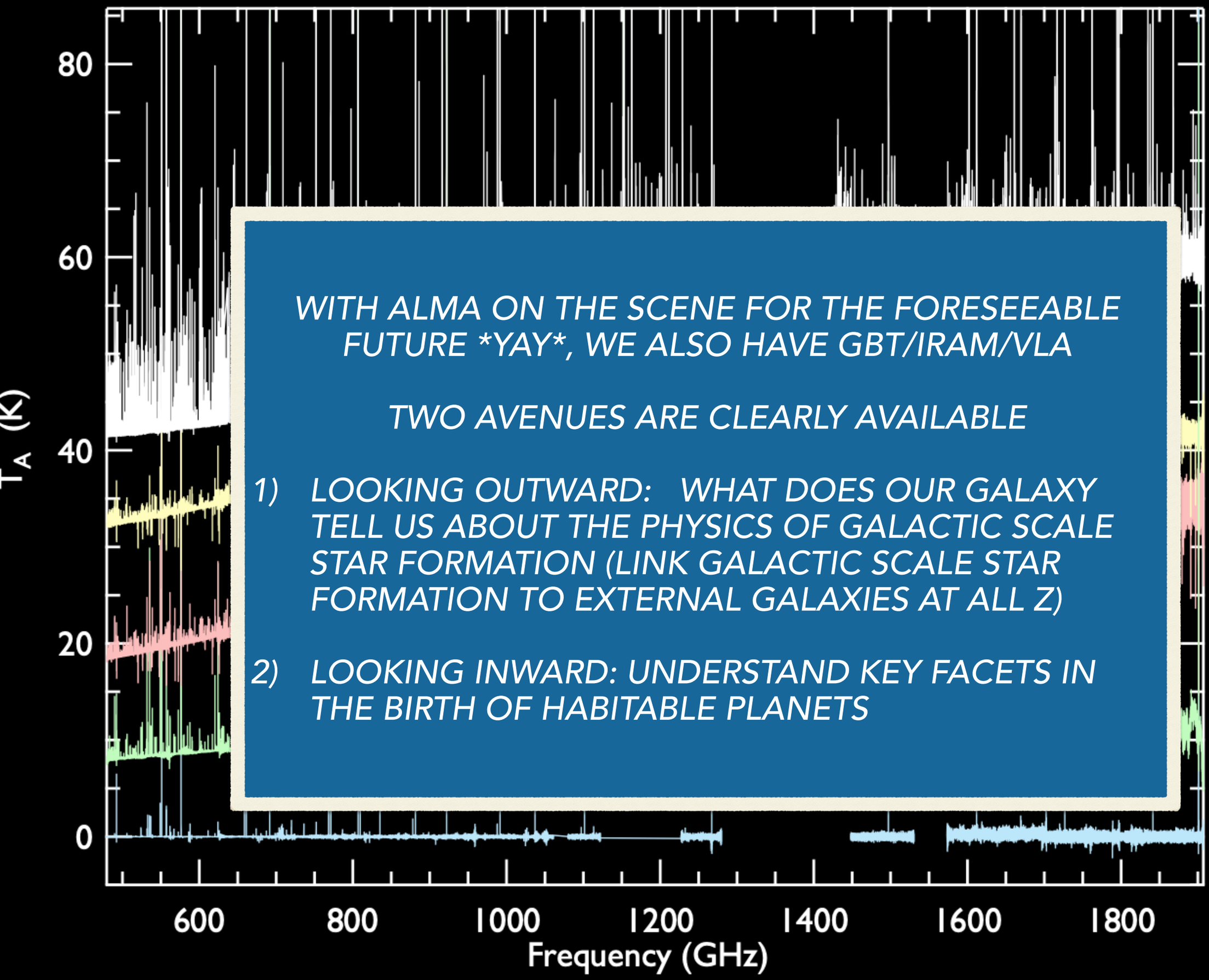
The Far-IR:

Peak of Dust Emission

Main Gas Coolants of Diffuse and Dense ISM (C II, O I, CO)

Ground Rotational States of Light Hydrides (H_2O, OH, HD)

FIR Spectrum of Ambient Gas



*WITH ALMA ON THE SCENE FOR THE FORESEEABLE FUTURE *YAY*, WE ALSO HAVE GBT/IRAM/VLA*

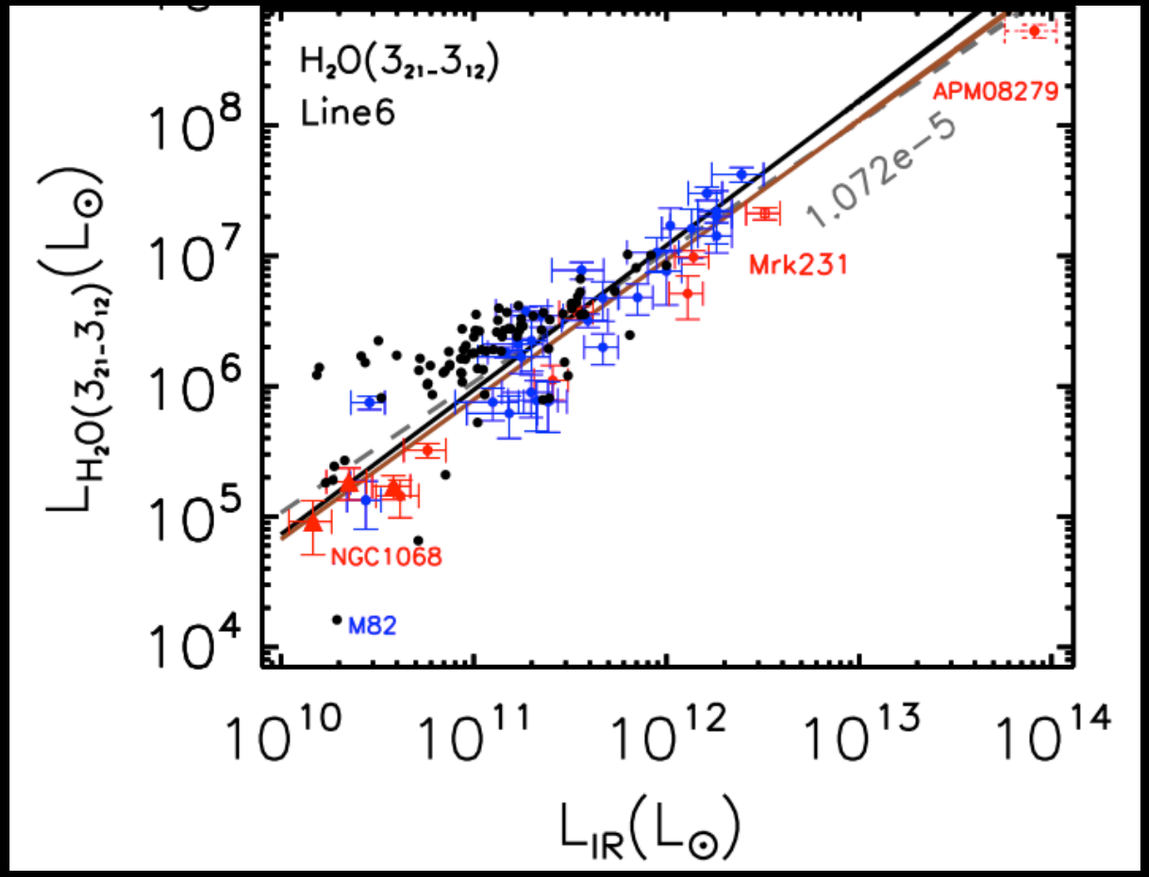
TWO AVENUES ARE CLEARLY AVAILABLE

1) *LOOKING OUTWARD: WHAT DOES OUR GALAXY TELL US ABOUT THE PHYSICS OF GALACTIC SCALE STAR FORMATION (LINK GALACTIC SCALE STAR FORMATION TO EXTERNAL GALAXIES AT ALL Z)*

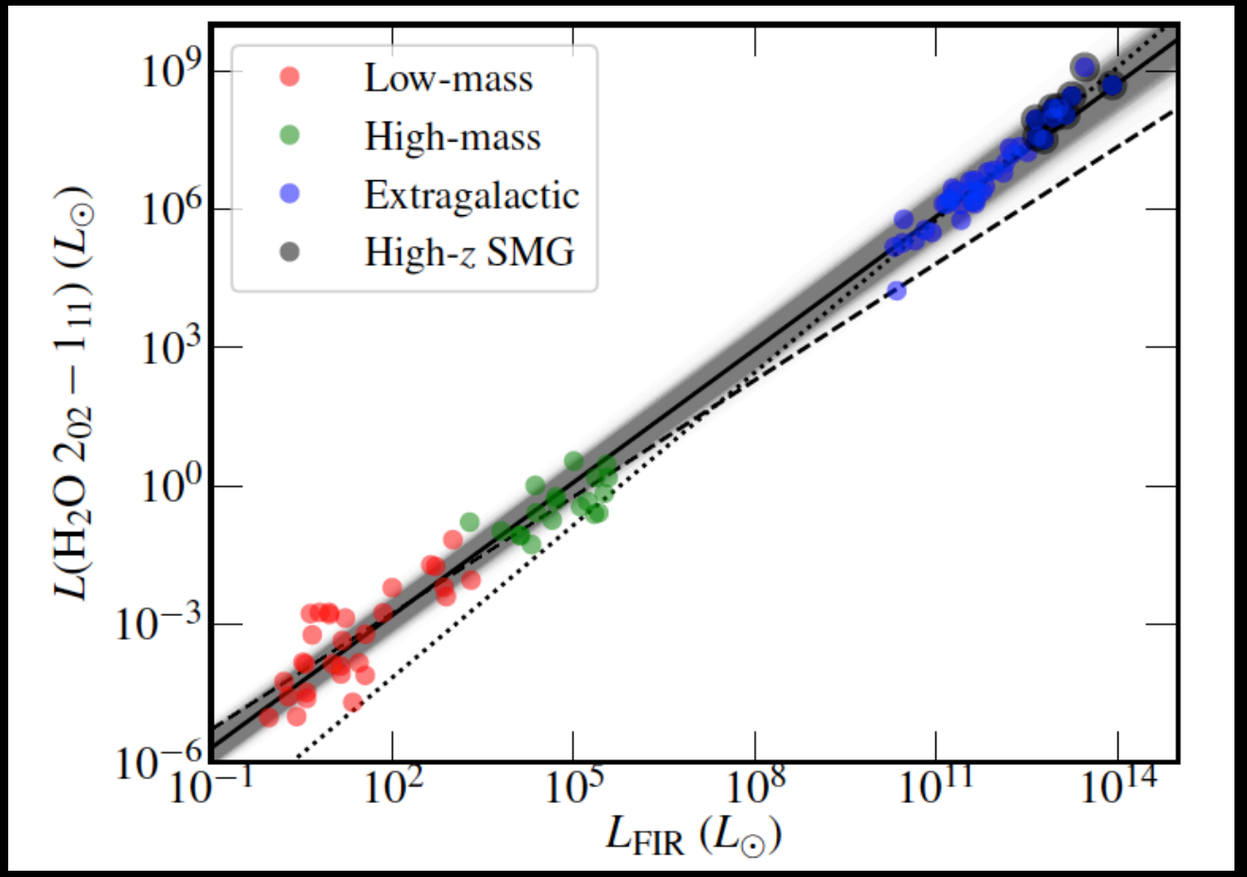
2) *LOOKING INWARD: UNDERSTAND KEY FACETS IN THE BIRTH OF HABITABLE PLANETS*

LOOKING OUTWARD

- Extragalactic water assumed to trace star formation via far-IR pumping of emission lines (Gonzalez-Alfonso 2008, 2010, 2012).
- Galaxy tells us that water emission is tracing shocked gas from outflows which relates to accretion and its luminosity (Kristensen & Bergin 2020).
- Water vapor lines are complex (emission/absorption) - require high spectral resolution.



Yang et al. 2013

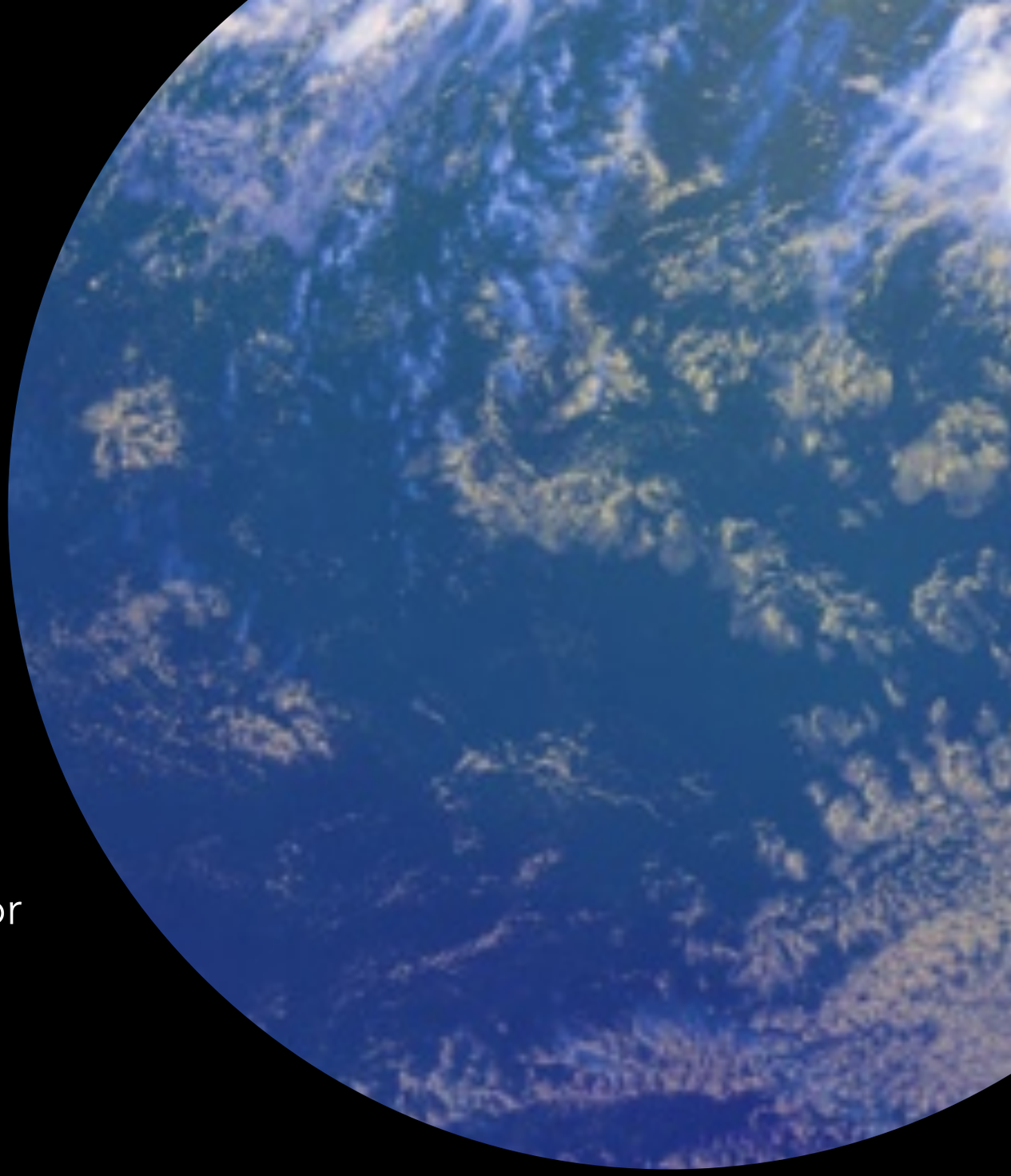


Kristensen & Bergin 2020, sub.

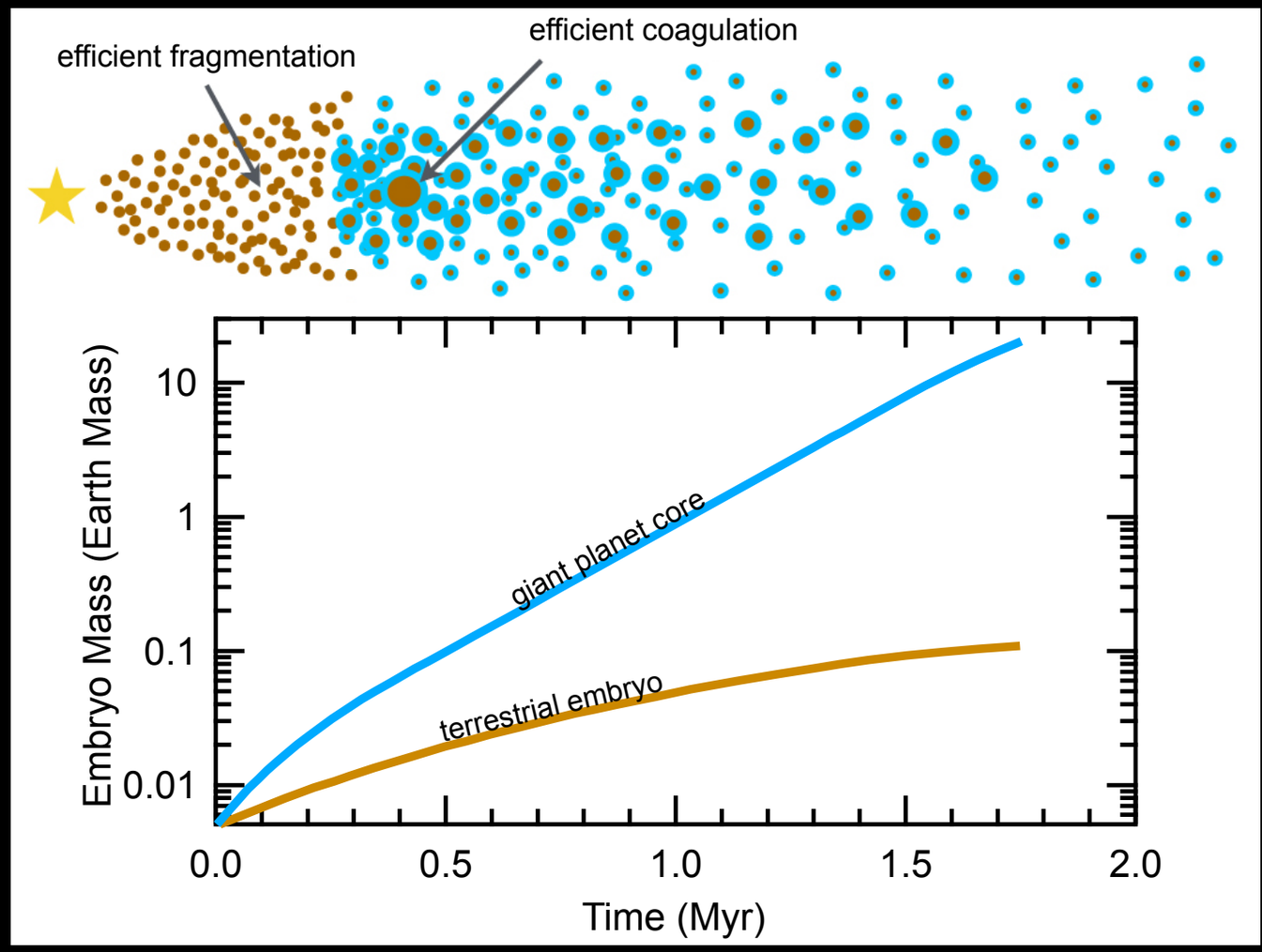
LOOKING INWARD

- Water is the KEY volatile in planet-formation.
  - ➡ The water content and its trail is the central link in understanding the formation of a habitable world.
  - ➡ *Cannot be readily done from the ground.*

- The total disk gas mass is the central quantity for planet formation.
  - ➡ Provides the grounding information needed to trace content and link to exoplanets.
  - ➡ Traditional probes (dust and CO) differ by over 1-2 orders of magnitude based on > 100 disks via ALMA surveys.
  - ➡ *We don’t know the disk gas mass.*



LOOKING INWARD



From:

Öberg & Bergin 2020

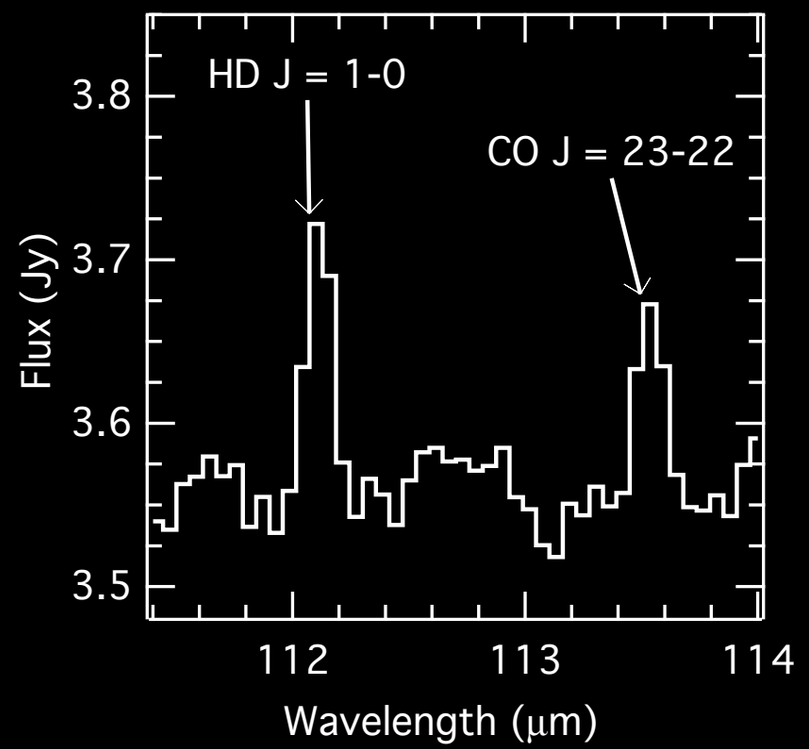
Sourced from:

Morbidelli et al. 2015

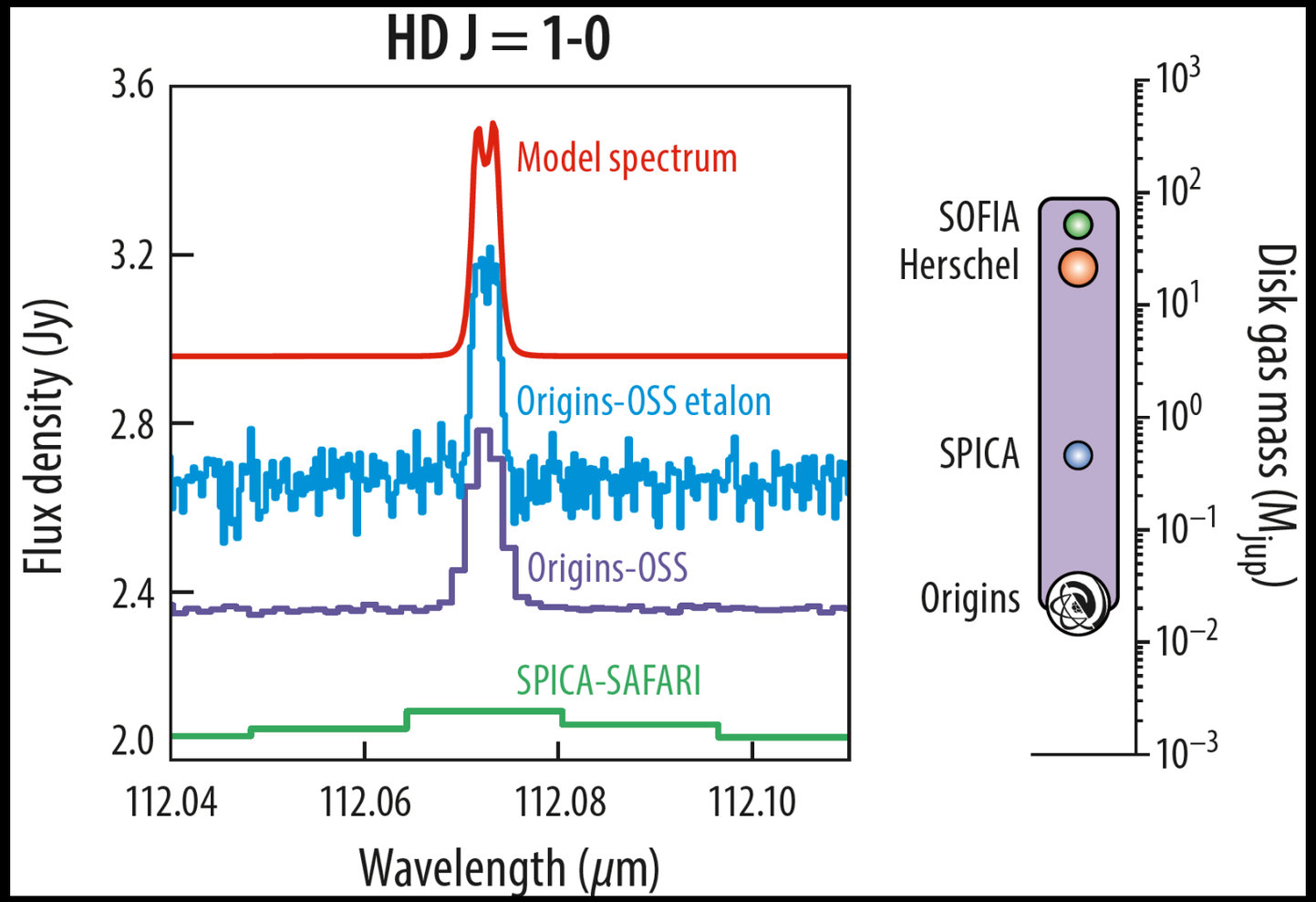
Banzatti et al. 2015

- JWST will survey hot (> 300 K) water vapor emission from inner few au in numerous systems.
- What is missing is the cold (tens of K) to warm (200 K) water vapor that is probed by far-IR - this can provide information on the snowline location
- Water ice has emission features in the far-IR at ~40 and 63 μm that uniquely trace bulk ice content.
- Herschel only provided a handful of detections of both vapor and ice.
- Critical information for understanding of water supply in planet formation.

LOOKING INWARD



Bergin+ 2013; McClure+ 2016; Kama+ 2019



Origins report

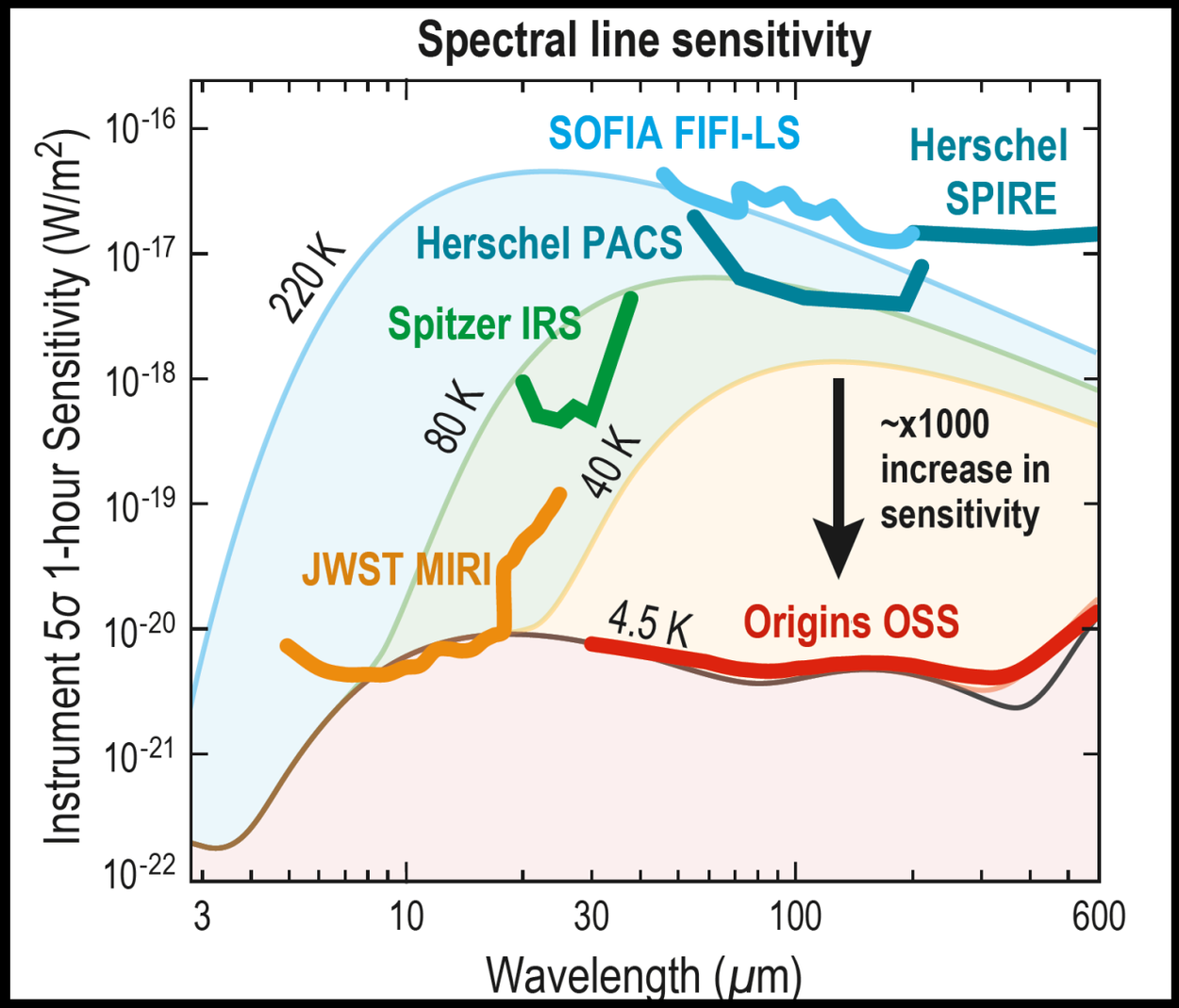
- HD 1-0 emission provides an independent tracer of the H_2 gas mass.
- Only 3 existing Herschel detections that are spatially and spectrally unresolved.
- Sensitive Far-IR instrument could survey hundreds to thousand of disk systems and provide needed information to interpret all JWST/ALMA observations of disk systems.

WE NEED A FUTURE

- At the baseline level we want to survey (large areas of the galaxy or a wide number of sources):

  ➡ What is needed is a large aperture cooled space telescope with large spectral grasp, multiple pixels, and high spectral resolution.

➡ Some aspects of this science case can be captured at reduced levels by SOFIA (CII, OI) or probe class missions with targeted lines and science cases. (e.g. cold water lines).

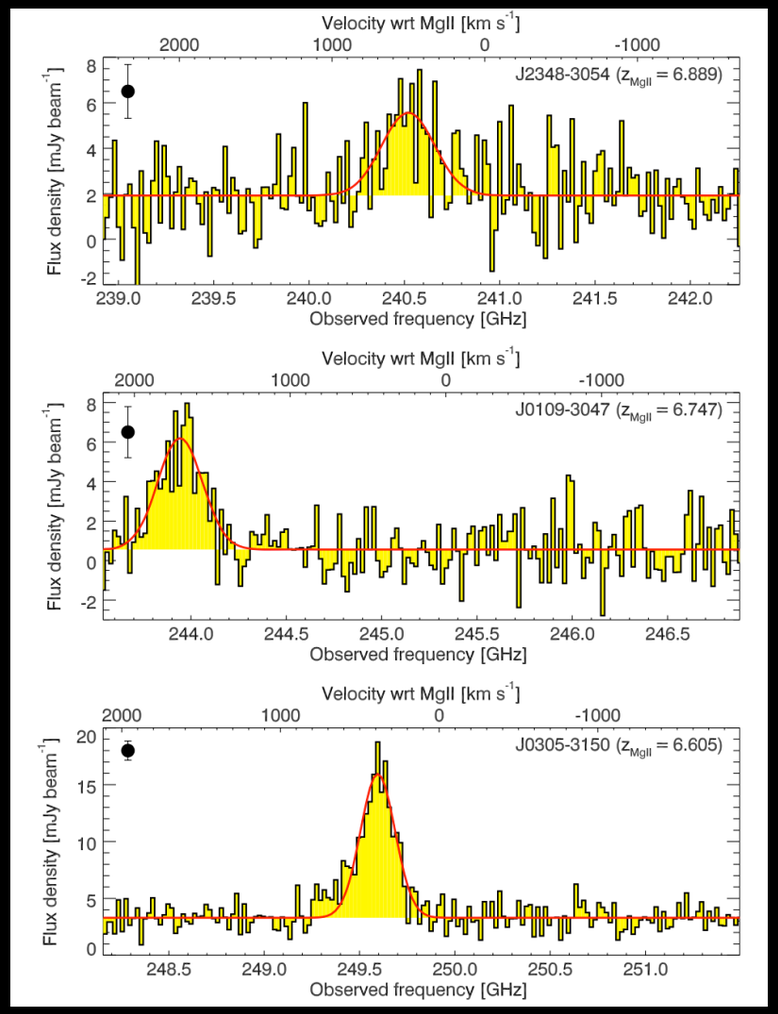


Origins report

LOOKING OUTWARD

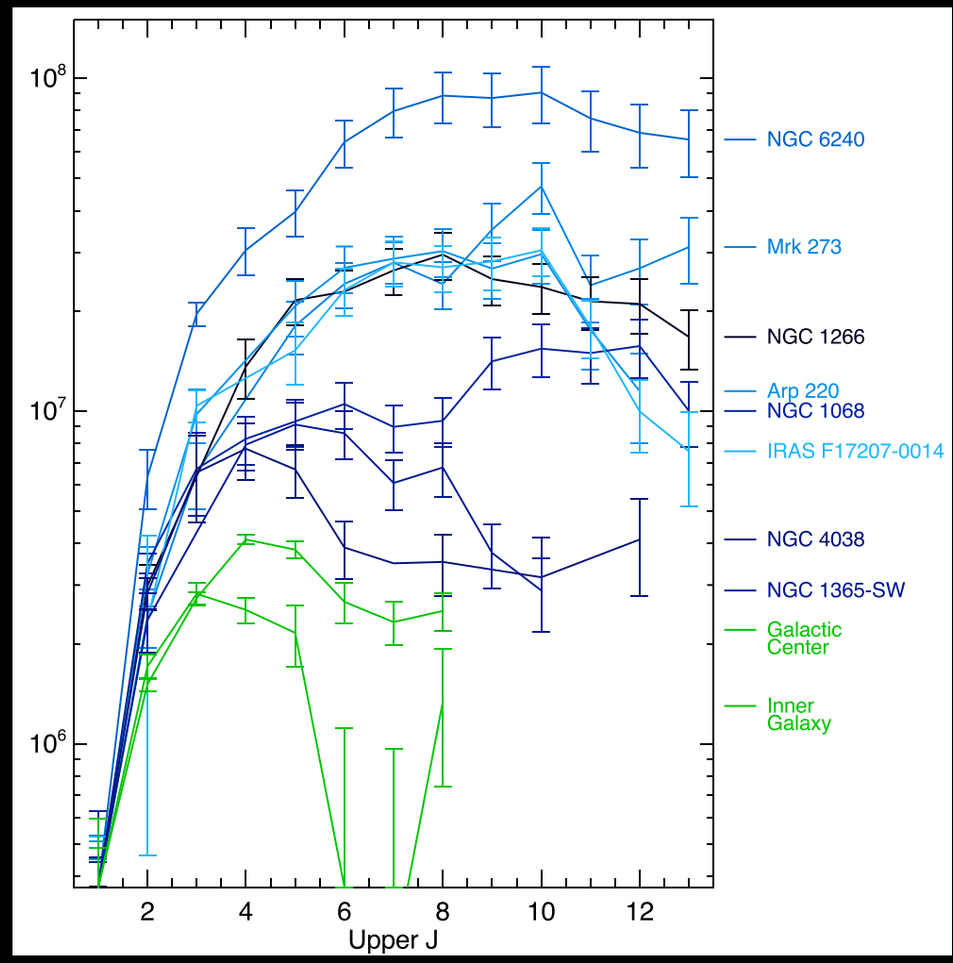
2 examples -> (can give many more)

CII @z > 6.6



Venemans et al. 2016

CO SLEDS



Kamenetzky et al. 2012
see also Indriolo et al. 2017

➡ Need to obtain spectral maps and understand physics!

➡ Requires high sensitivity, large spectral grasp, multiple pixels, high spectral resolution