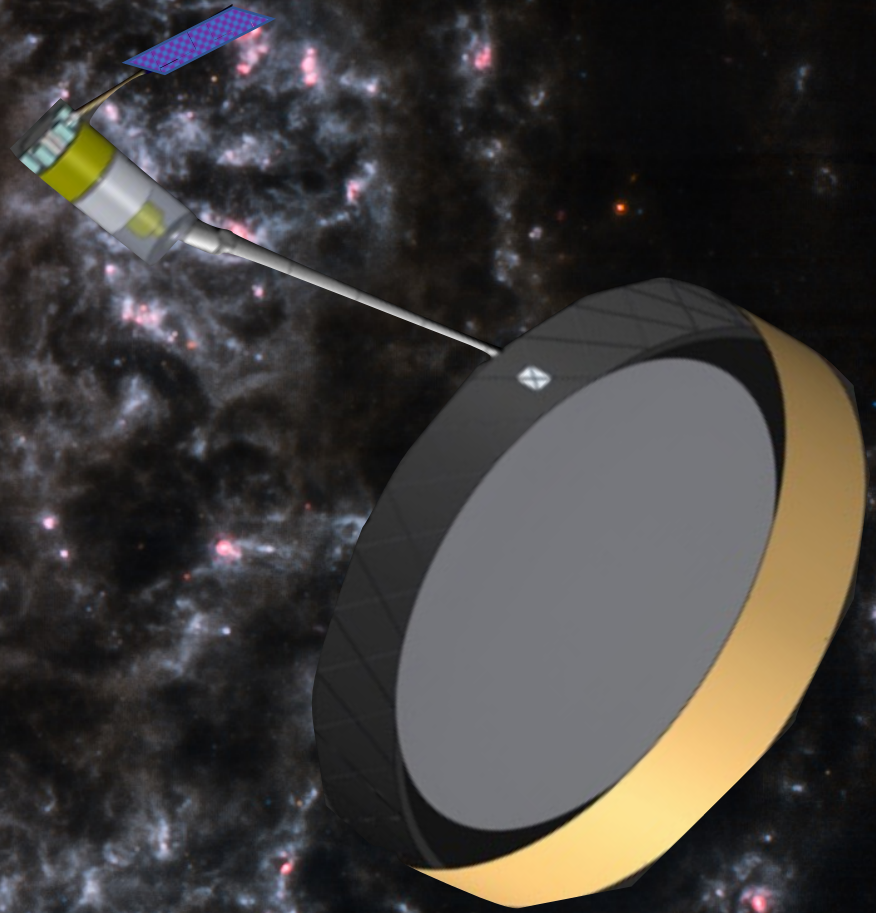


Extragalactic Science with SALTUS



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Dan Marrone, Desika Narayanan, Brant Robertson, Alice Shapley,
Renske Smit, Dan Stark, Tony Stark, Joaquin Vieira, Guang Yang

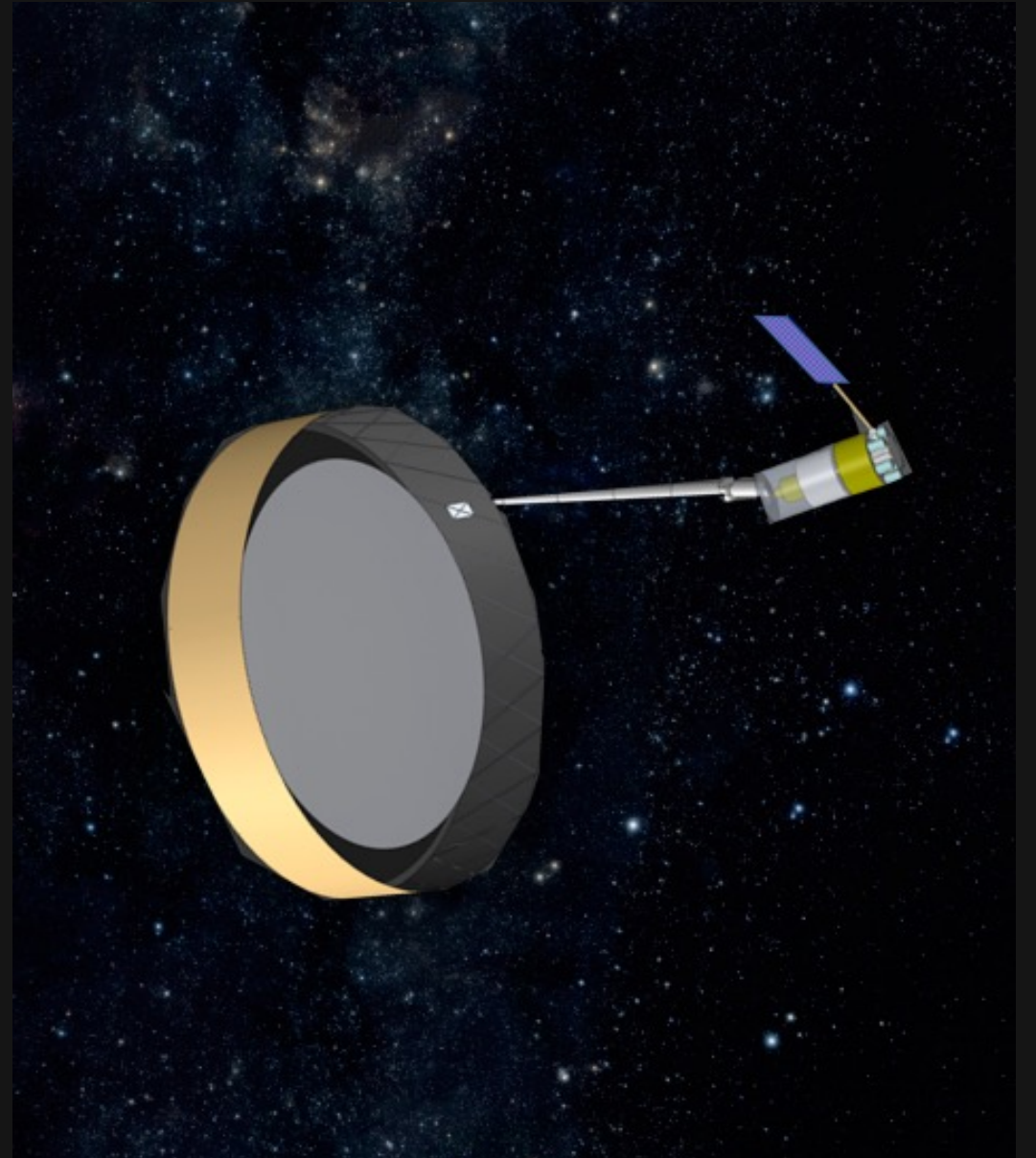
SALTUS Exgal

The Bottom Line

- SALTUS will be an extraordinarily powerful and versatile observatory for extragalactic science
- Orders of magnitude more sensitive than previous far-IR telescopes

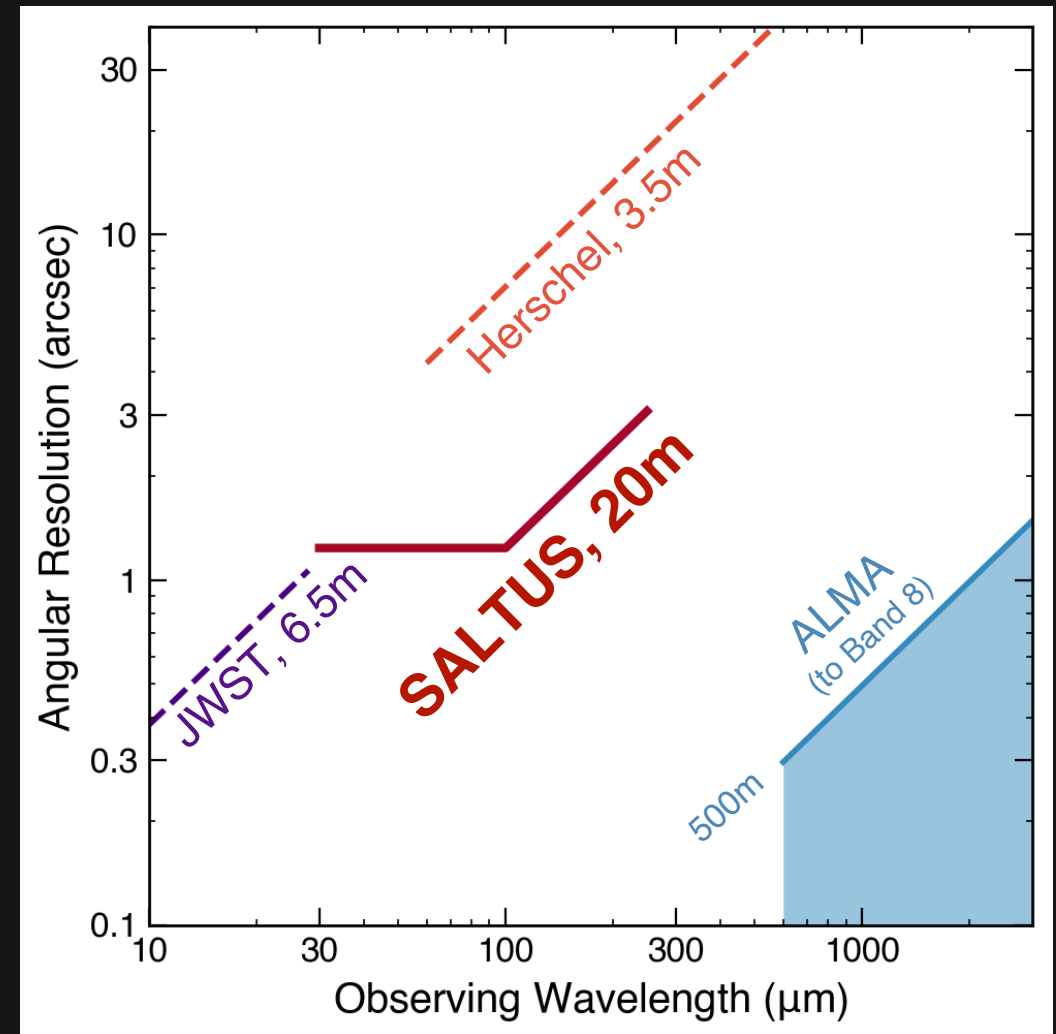
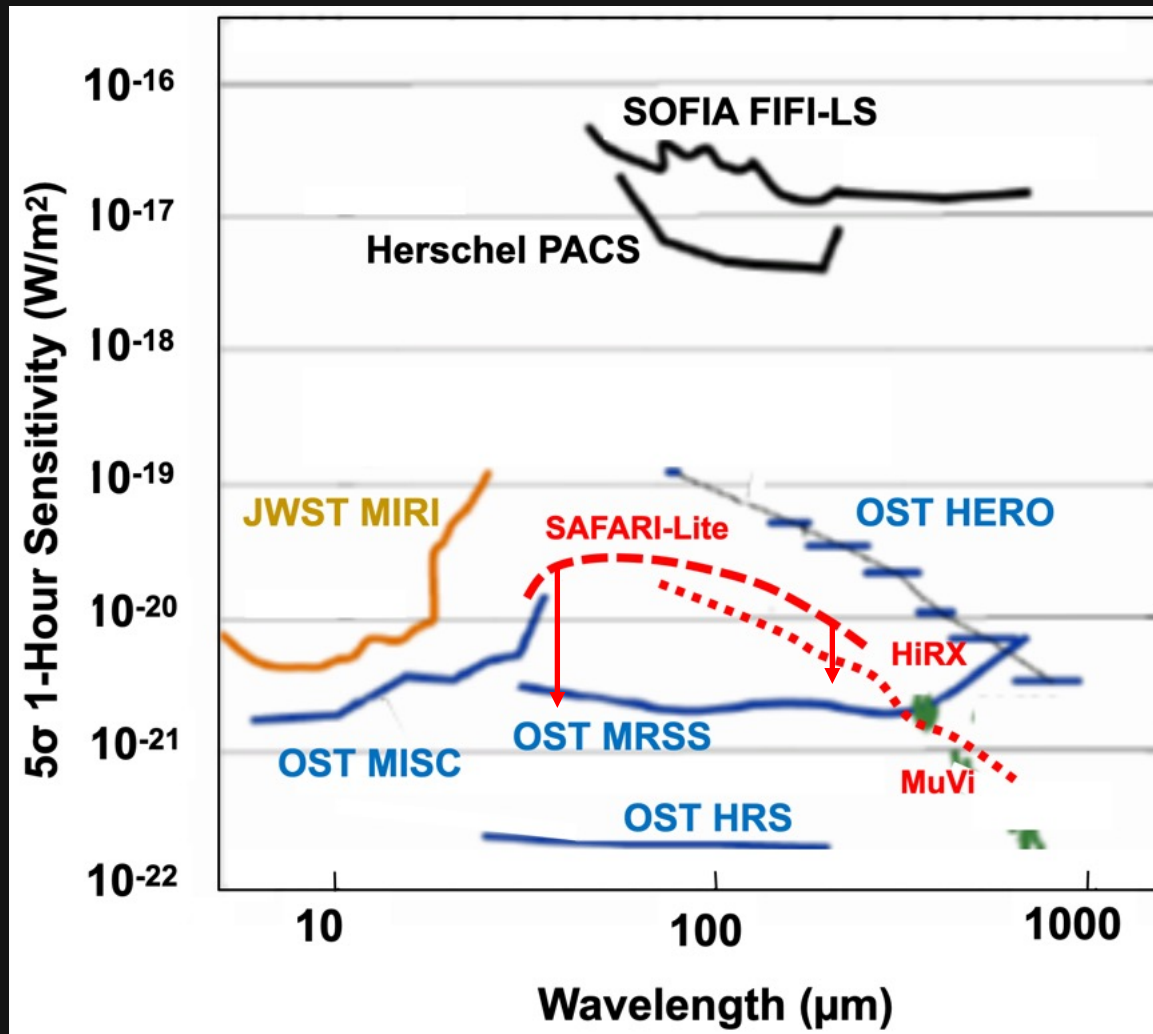
AND

- Arcsecond spatial resolution

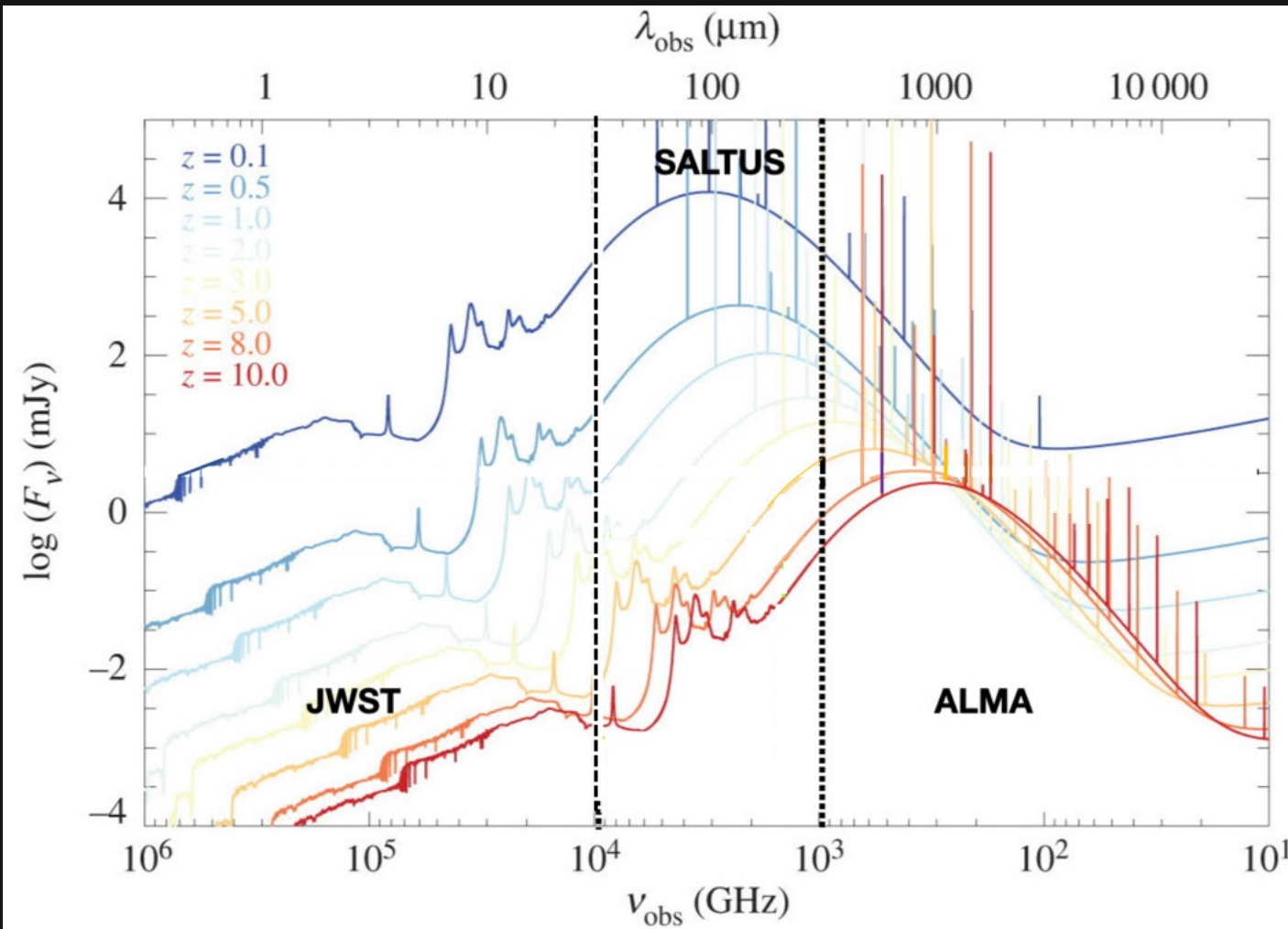


The Landscape for SALTUS

We don't have to choose between high sensitivity and high resolution!



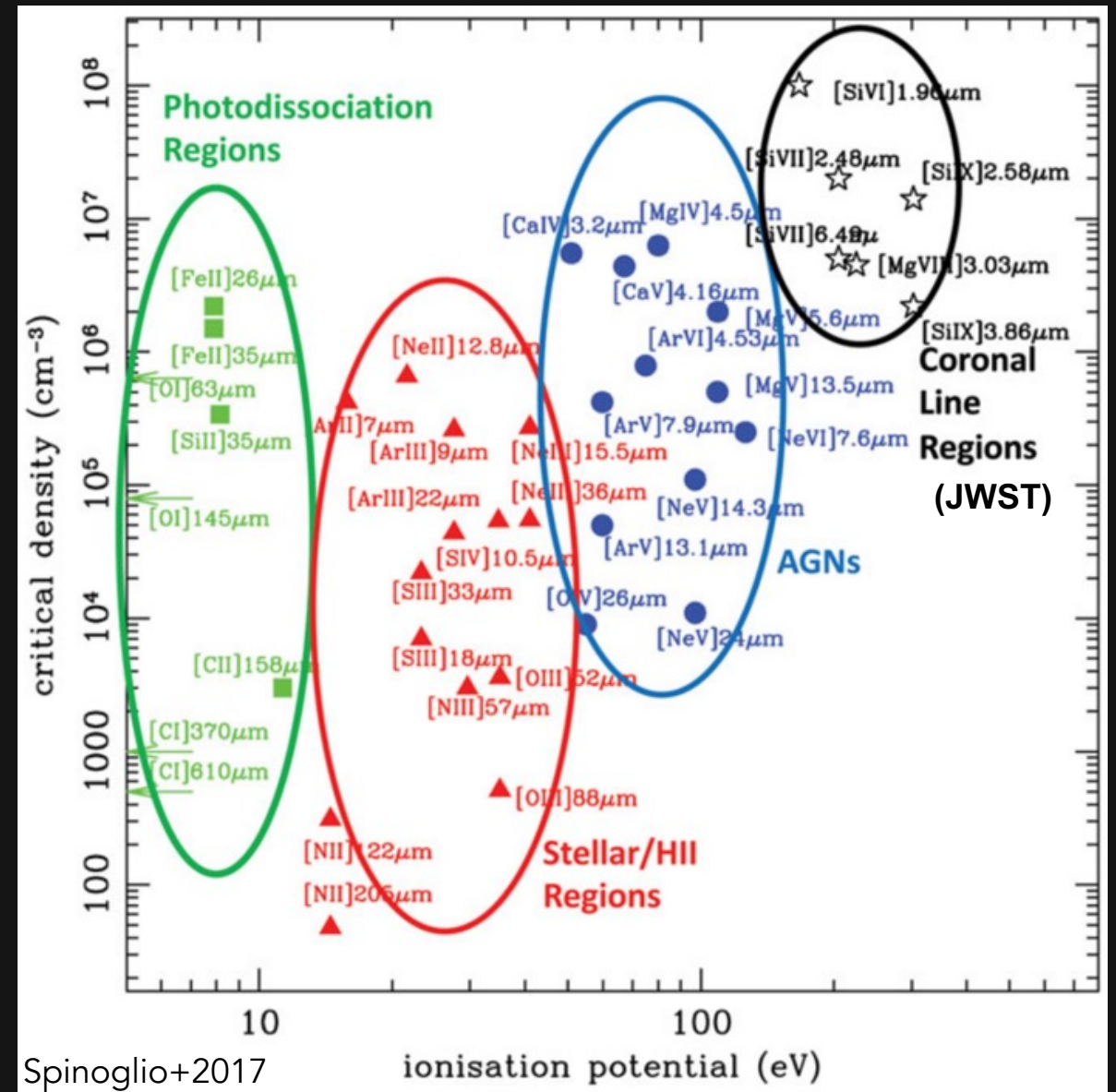
The Landscape for SALTUS



- SALTUS accesses key far-IR spectral diagnostics from the present day to $z > 4$
- Will measure the underlying continuum as well!
- Bridges the gap between JWST and ALMA without sacrificing angular resolution or sensitivity

A wealth of IR diagnostics

- SALTUS accesses key diagnostics of PDRs, HII regions, and AGN accretion to $z > 1$
- Key complement to JWST and X-ray diagnostics of very hot gas, ALMA access to coldest molecular phase



What can SALTUS do for you?

- Sensitive far-IR mapping on ~ 5 arcmin scales at ~ 1 arcsec resolution
- No confusion! No de-blending! No cross-matching!
- Blank-field surveys over ~ 30 arcmin² without long slew times
- Deep targeted followup of individual interesting galaxies - mid/far-IR lines, PAH features, deep confusion-free continuum limits
- High spectral resolution of water, HD, far-IR lines to $z \sim 1$ in bright targets
- Imaging capabilities

SALTUS Exgal Science Themes

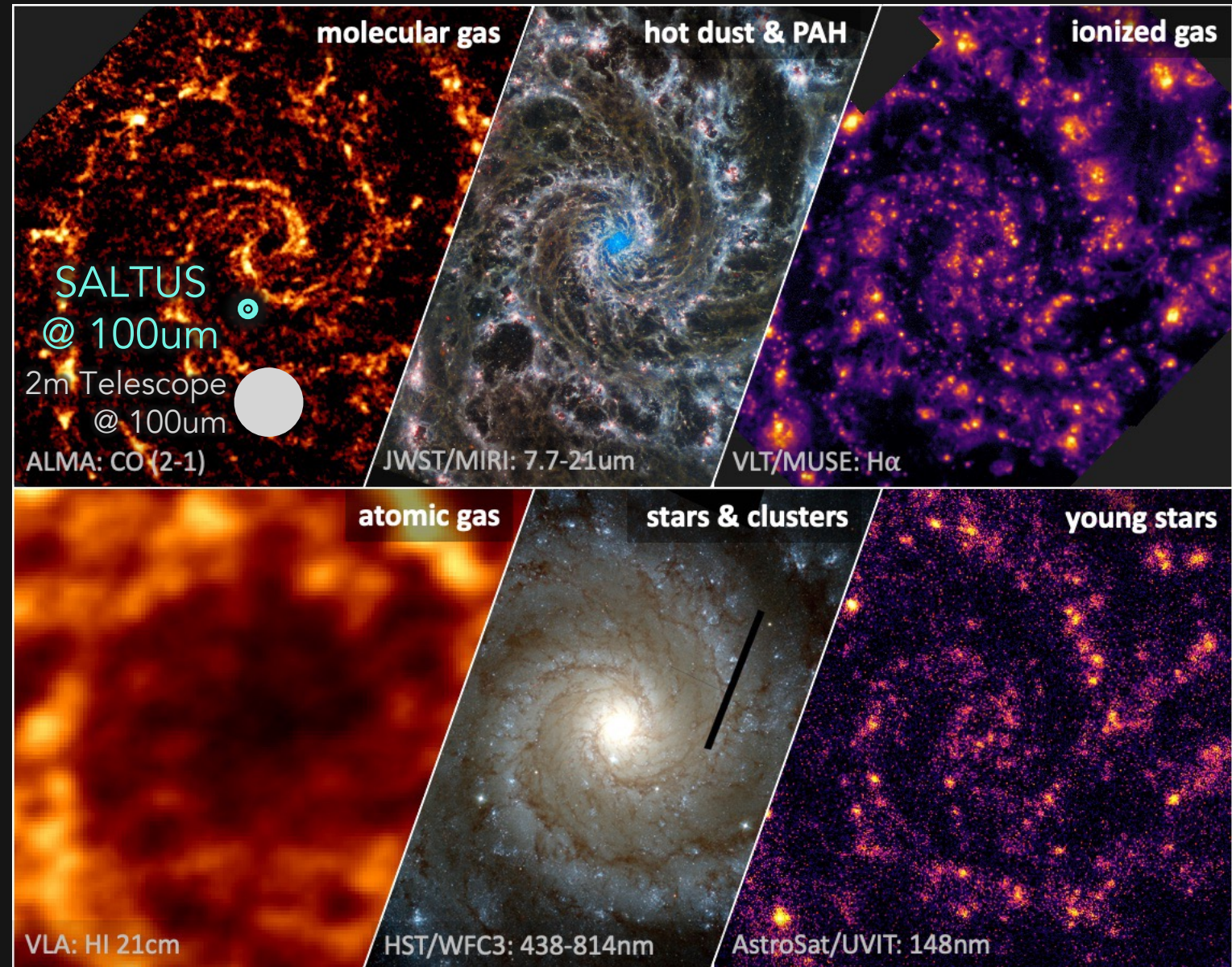
1. Small-scale feedback in the local universe
2. Black hole – galaxy co-evolution over cosmic time
3. Connecting feeding black holes to cosmic ecosystems
4. First production and growth of small dust grains
5. Guest observing – your ideas here!

1. Map GMC-scale feedback in galaxies at <math><100\text{pc}</math> resolution

- SALTUS / SAFARI-Lite resolution well-matched to star clusters and GMCs to $D \sim 20\text{Mpc}$
- Measure impacts of feedback locally, where energy and momentum are injected into ISM
- Resolve feedback on scales of individual star-forming regions and BH spheres of influence
- Highly complementary to multiwavelength local galaxy surveys

NGC 628

Figure by Jiayi Sun (PHANGS)

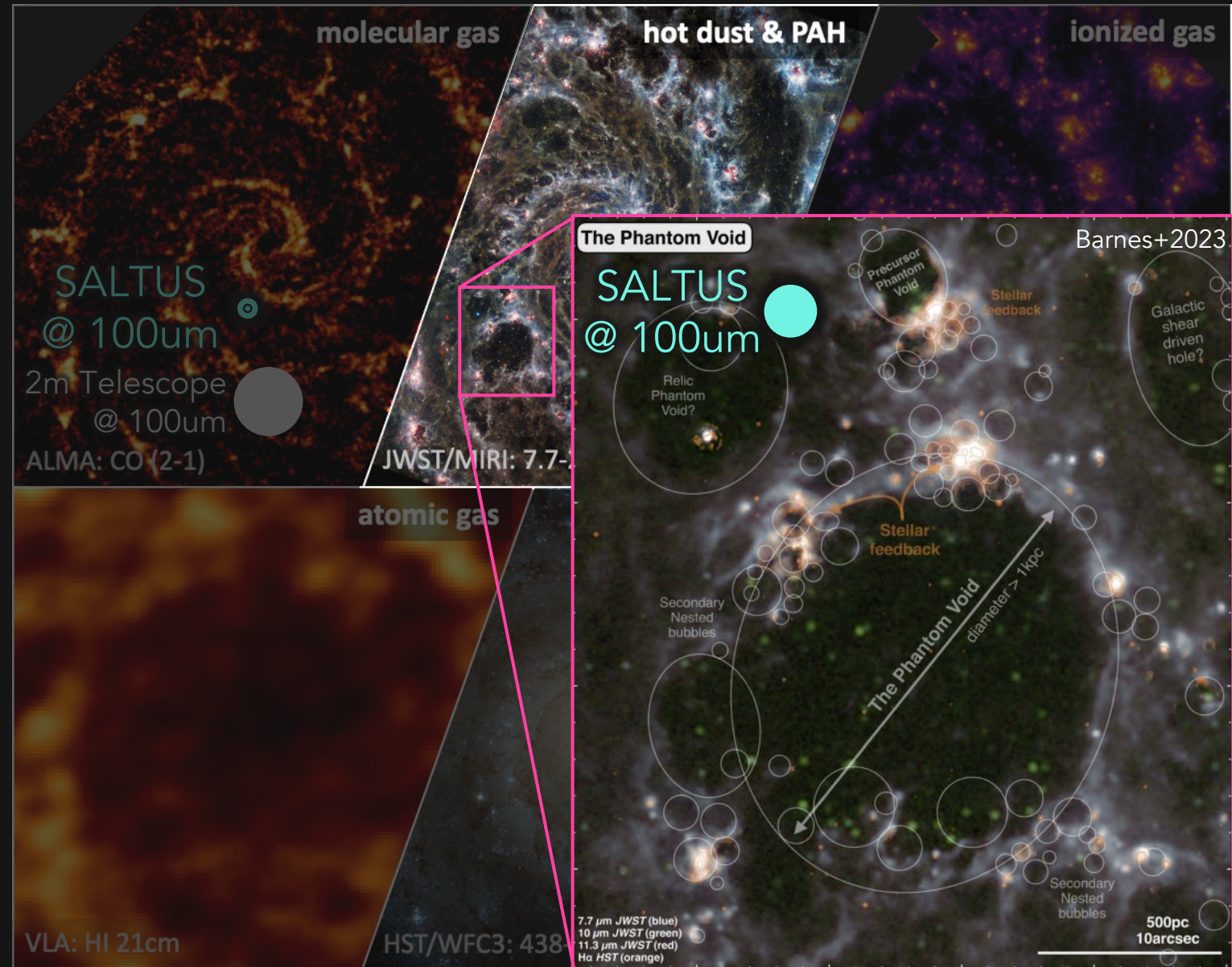


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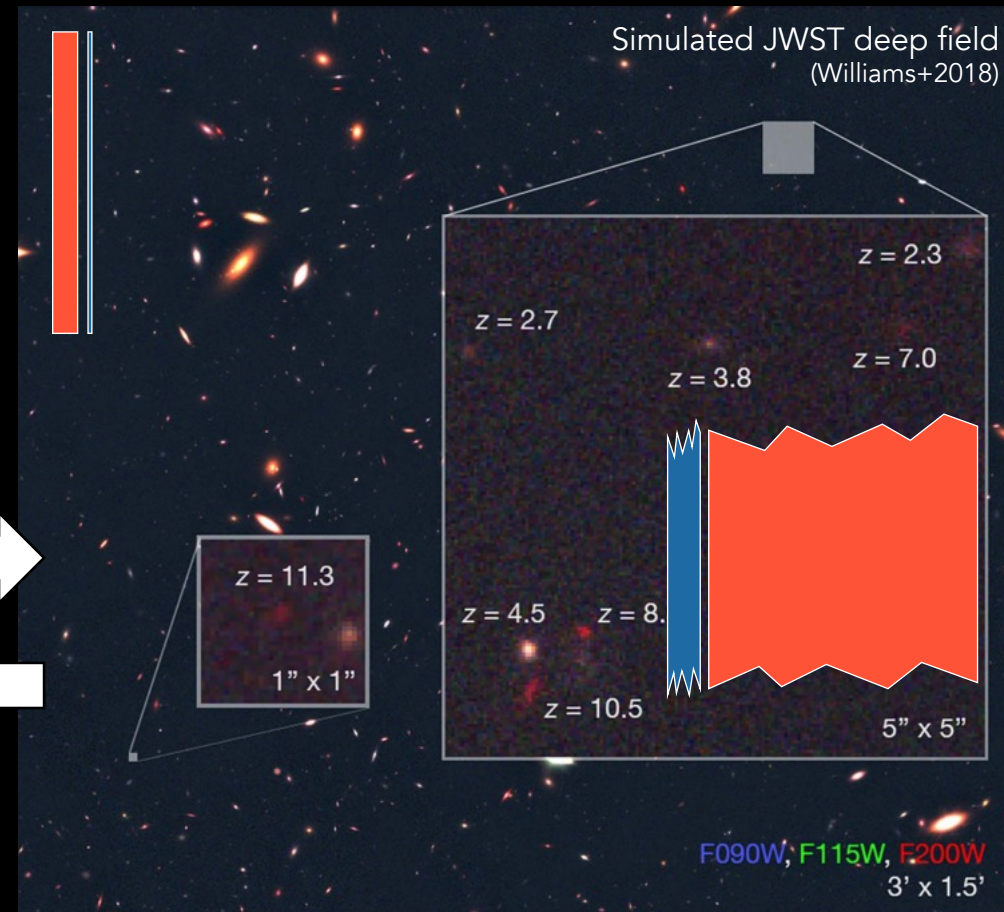
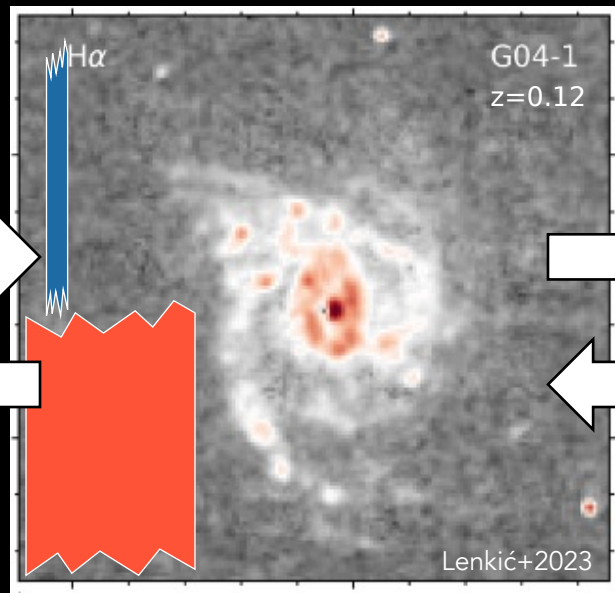
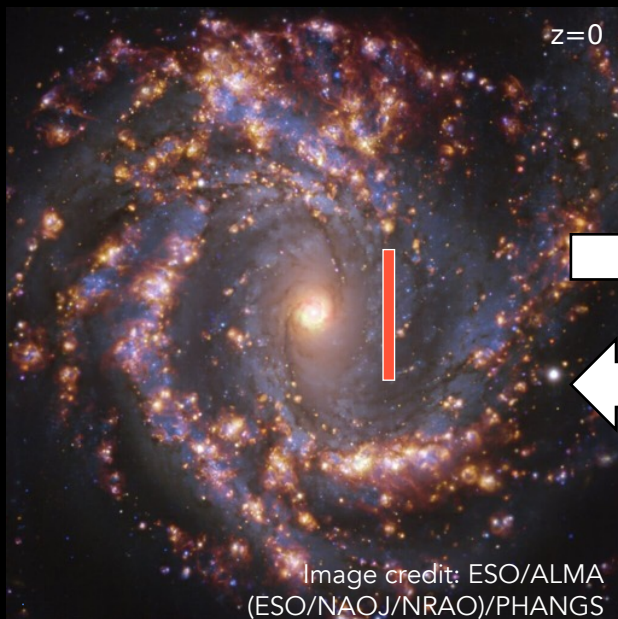
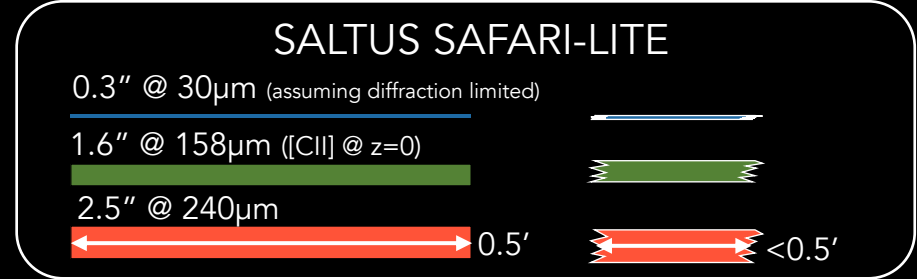
NGC 628

Figure by Jiayi Sun (PHANGS)



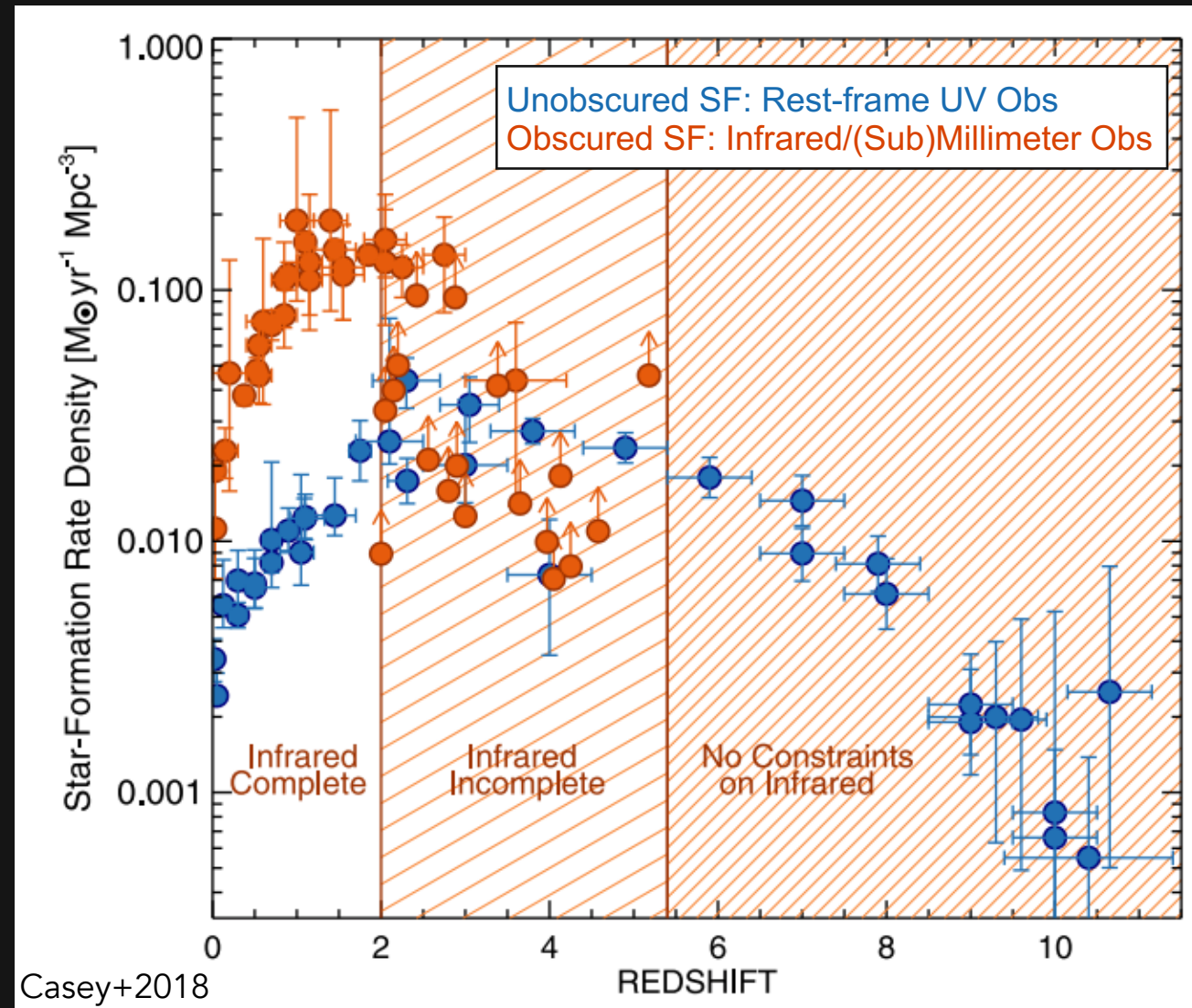
Other low-z science goals

- Anchor high-z measurements
 - Appropriate comparison samples, analogs, and case studies
- Leverage spatial resolution to understand detailed physics (SAFARI-LITE & HiRX)
- Samples of galaxies to understand how diagnostics change as a function of environment and physical conditions
- Synergies with other surveys and facilities



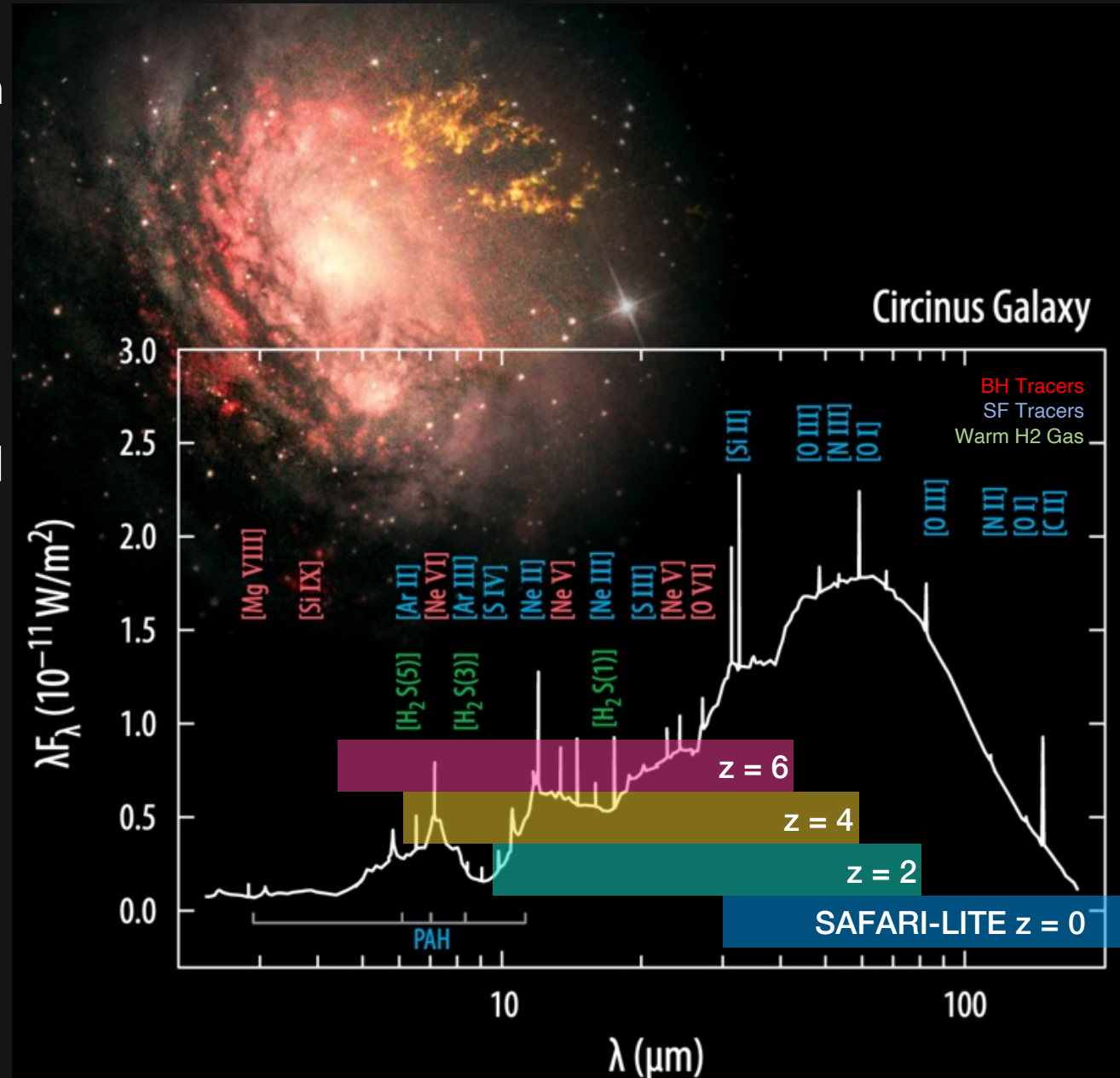
2. Track Dust-Immune Galaxy and Black Hole Growth

- Most star formation and black hole growth over cosmic history has been obscured behind dust
- The rest-frame mid-/far-IR are mostly immune to dust obscuration



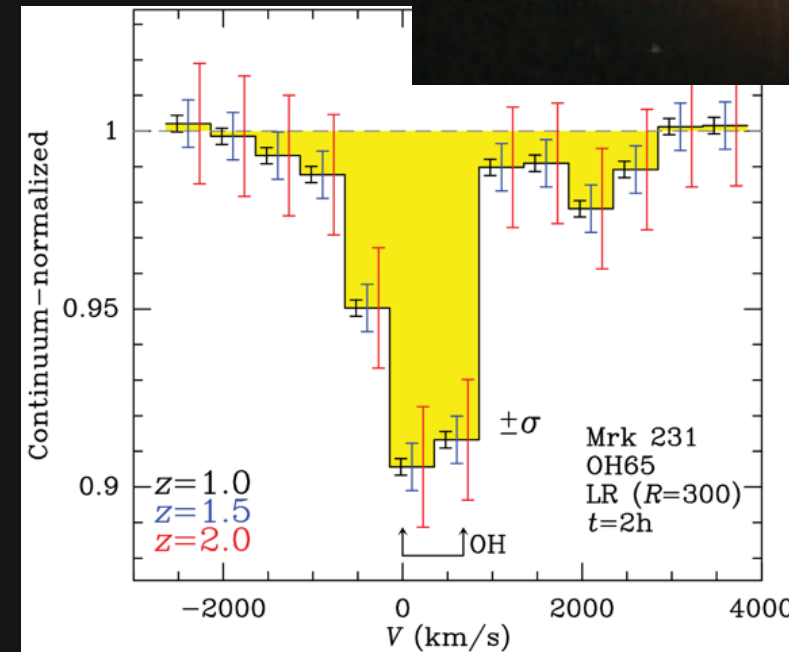
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- The rest-frame mid-/far-IR are mostly immune to dust obscuration
- SALTUS accesses key tracers of SF and BH accretion
 - detectable to $z \sim 1-4$ simultaneously in the same galaxies
 - $z > 5$ in the most luminous systems
- Key lines:
 - **Black hole accretion rates:** [OIV] 25.9 μm , [NeV] 7.65/14.3 μm
 - **Star formation rates:** [NeII] 12.8 μm , [NeIII] 15.6 μm , [OIII] 88 μm , [CII] 158 μm



3. Directly constrain AGN Feedback to Cosmic Noon

- SALTUS/SAFARI-Lite accesses tracers of multi-phase gas inflows and outflows within galactic ecosystems to $z \sim 2$
 - Molecular phase: OH absorption
119/84/79/65 μm , H_2O
 - Neutral phase: [CII] 158 μm , [SIII] 35 μm , [SII] 18 μm
 - Ionized phase: [OIII] 52/88 μm , [OIV] 26 μm
- AGN drive fast $>1000\text{km/s}$ outflows with $T = 10 - 10^7 \text{ K}$ and $n = 10^{-3} - 10^2 \text{ cm}^{-3}$, detectable even at $R \sim 300$
- Links Athena measurements of ultra-fast X-ray winds at the nuclear launch sites to the Mpc-scale gas reservoirs

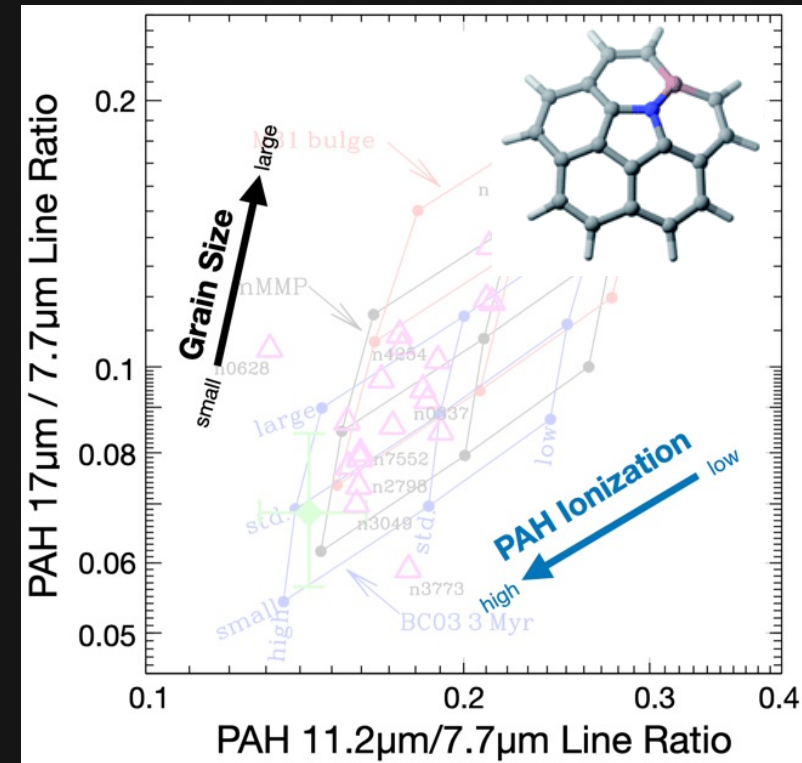
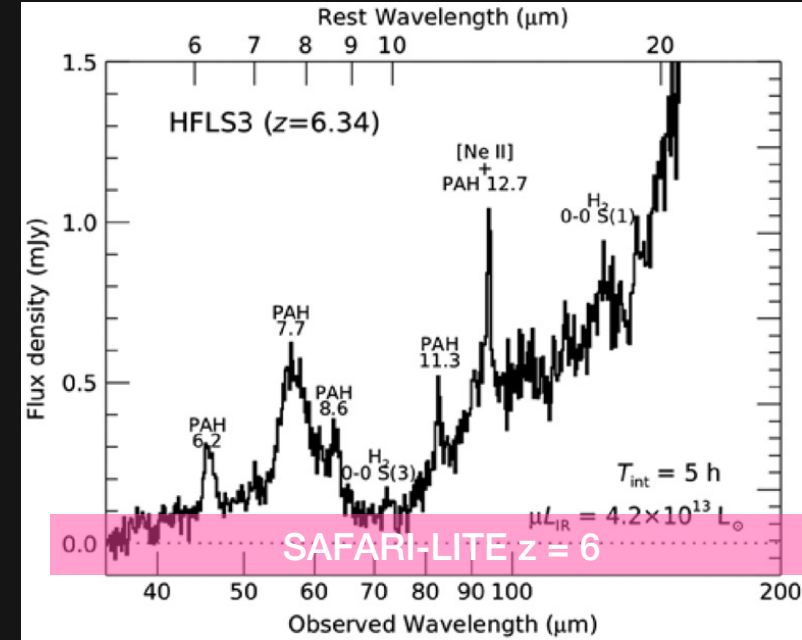


Markarian 231 Outflow
Gonzalez-Alfonso+2017



4. Chart the Growth of Dust from Reionization to Today

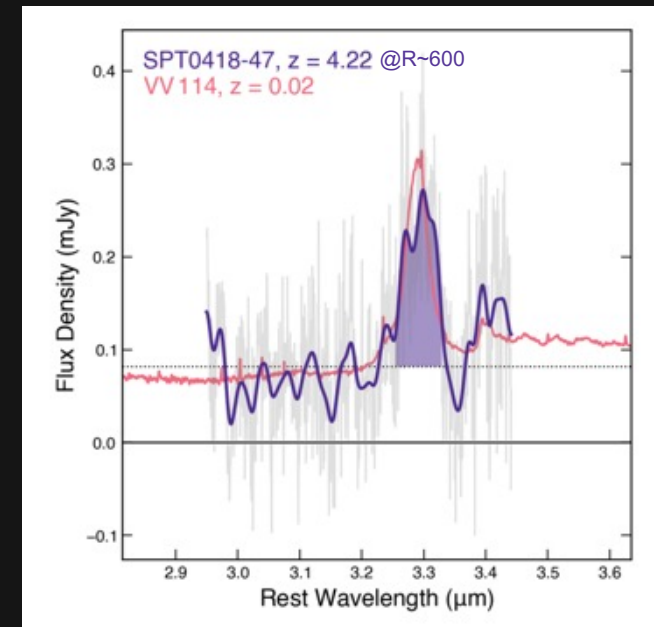
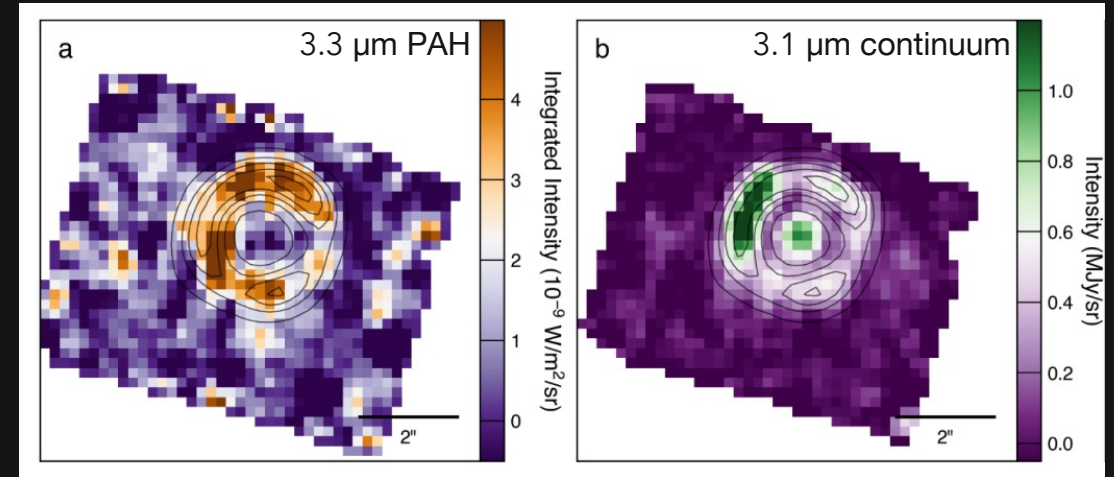
- ALMA now routinely detects dust-obscured galaxies to $z > 9$. Where does this dust come from, and how do small grains grow over time?
- SALTUS access rich suite of PAH features at $z > 1$, detectable in $\sim 1-10h$ to $z > 6$ in IR-luminous systems
- SALTUS will extend JWST observations at $z \sim 0.5$ out to $z > 6$, measuring grain size distributions in dusty starbursts and (lensed) normal galaxies



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SPT01418-47 ($z=4.22$) with JWST/MIRI

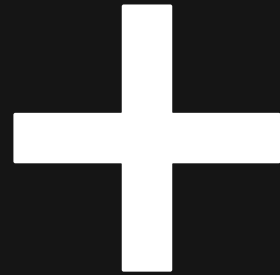


Spilker+2023

Tracing Galaxy Evolution with SALTUS

Map the feedback between galaxy growth and cosmic ecosystems

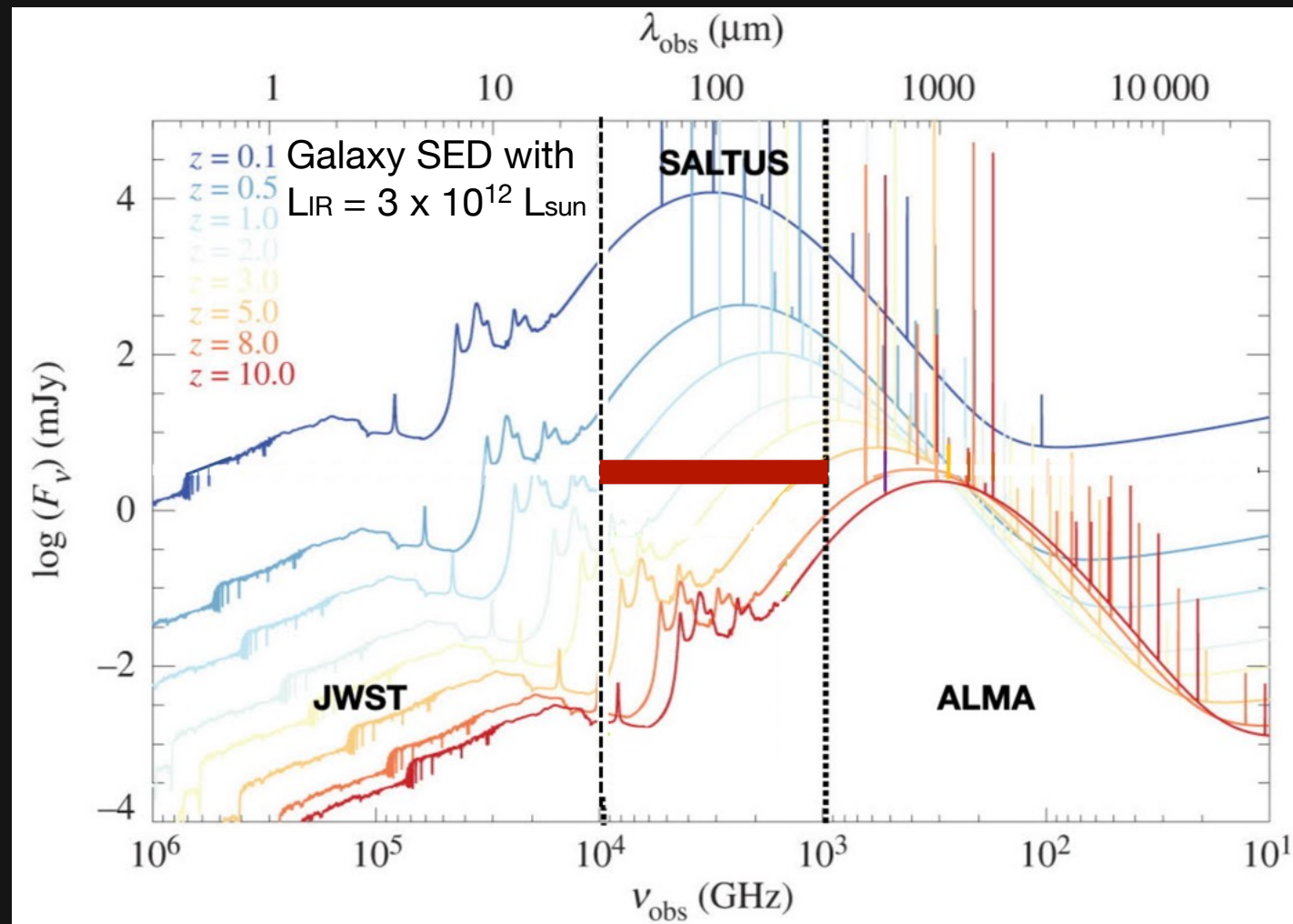
Chart the rise of metals and small dust grains from the early universe to today



Wide variety of other science programs!
Your ideas here!

Blank-Field Surveys with SAFARI-Lite

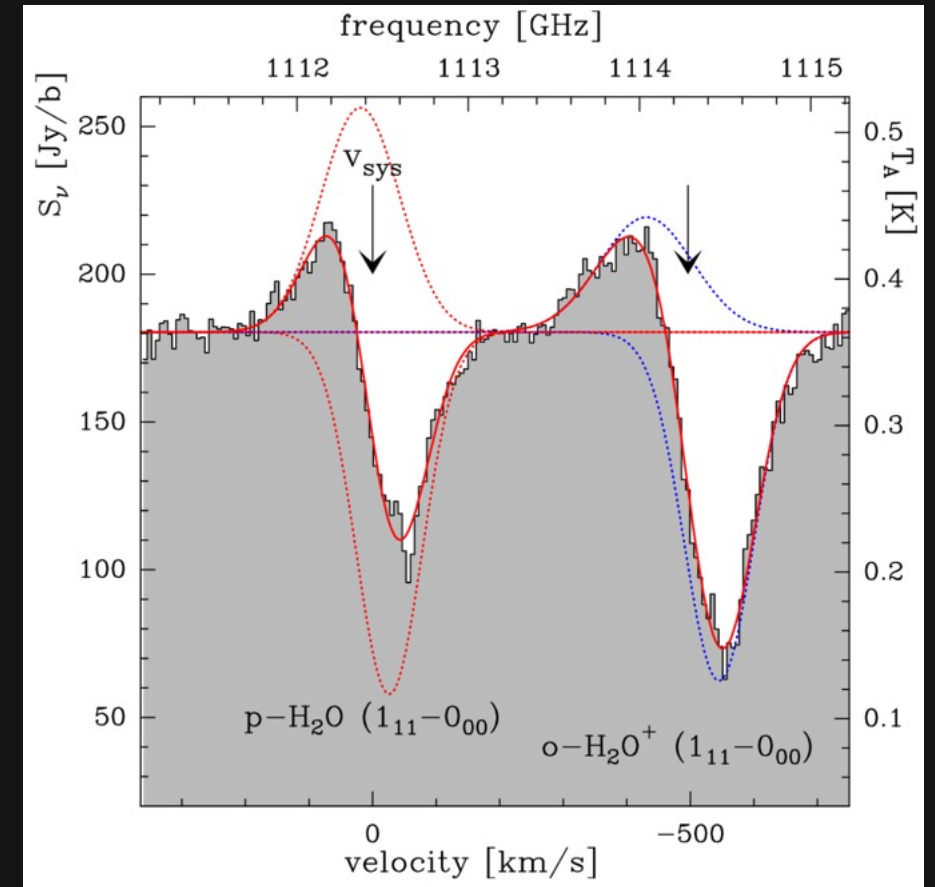
- High sensitivity and spatial resolution of SALTUS, plus ability to map within ~ 5 arcmin without repointing, allows deep unbiased surveys
- Wavelength coverage very well suited to peak epoch of star formation $z \sim 1-3$, earlier times possible with deeper 'wedding cake' tiers
- Example: map the entire Hubble deep field in ~ 100 hrs; detect galaxies spectrally or bin for pseudo-imaging



Effective SAFARI-Lite 10sigma / 1hr / 1arcmin² imaging depth = 3mJy

Feeding and Feedback in Dusty Nuclei

- SALTUS can measure local injection of feedback energy and momentum in dusty IR-luminous galaxies using HiRX observations of water
- Measure robust molecular masses using HD 112 μ m, cosmic ray impacts on ISM using OH⁺, H₂O⁺, H₃O⁺
- Large gain in sensitivity over Herschel HIFI allows less luminous, more distant targets

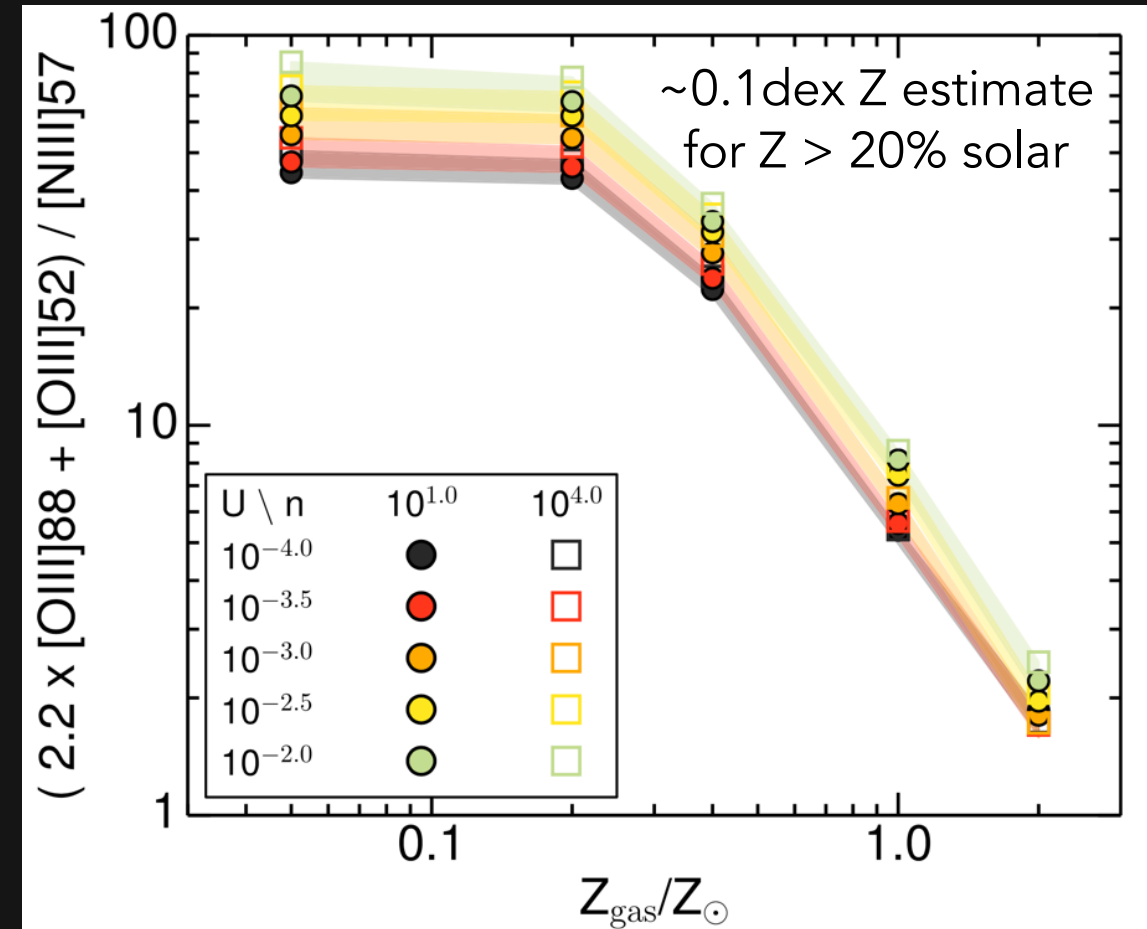
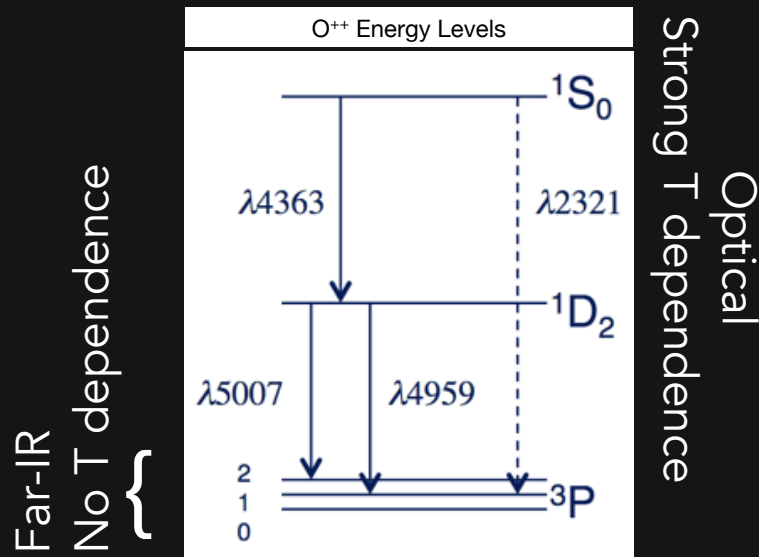


P-Cygni profile in Water 1.1THz line
= Nuclear Molecular Outflow

Herschel/HIFI; van der Tak 2016

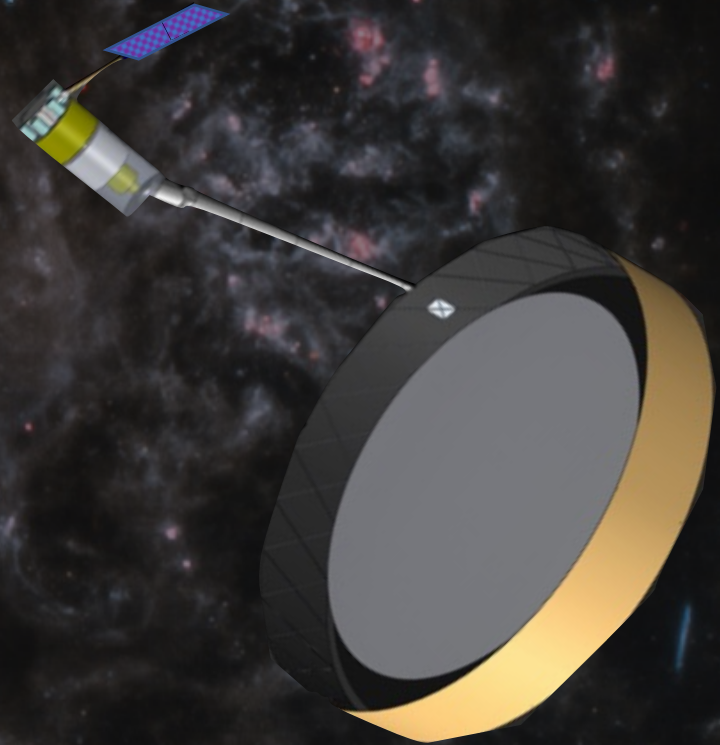
Measure Chemical Enrichment of the Universe to $z > 3$

- Optical estimates of metallicity are subject to ~ 1 dex uncertainties due to unknown HII region temperatures, dust extinction
- JWST will help, but only a little: crucial T-sensitive OIII 4363A line is very weak
- SALTUS far-IR abundances are insensitive to temperature, immune to extinction



How to get involved

- The SALTUS Exgal working group is always recruiting!
- Are you an expert in one of these brief science highlight areas?
Do you have other cool ideas that need a sensitive, high-resolution far-IR mission?
- Contact **Justin Spilker**, jspilker@tamu.edu, to get added to our science interest group



Questions and Comments?

