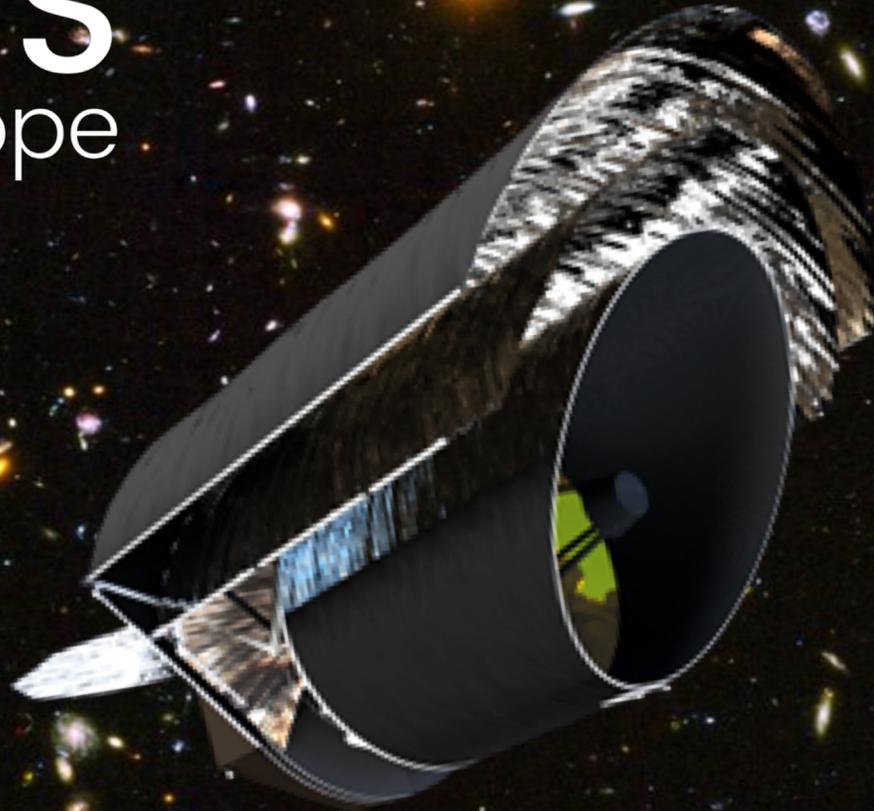




ORIGINS

Space Telescope

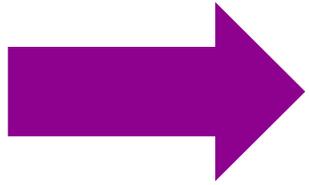


Extragalactic Science with Origins

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@NASAOriginsTele



HOW DOES THE UNIVERSE WORK?

How do galaxies form stars, make metals, and grow their central supermassive black holes from reionization to today?

Using sensitive spectroscopic capabilities of a cold telescope in the infrared, Origins will measure properties of star-formation and growing black holes in galaxies across all epochs in the Universe.



HOW DID WE GET HERE?

How do the conditions for habitability develop during the process of planet formation?

With sensitive and high-resolution far-IR spectroscopy Origins will illuminate the path of water and its abundance to determine the availability of water for habitable planets.



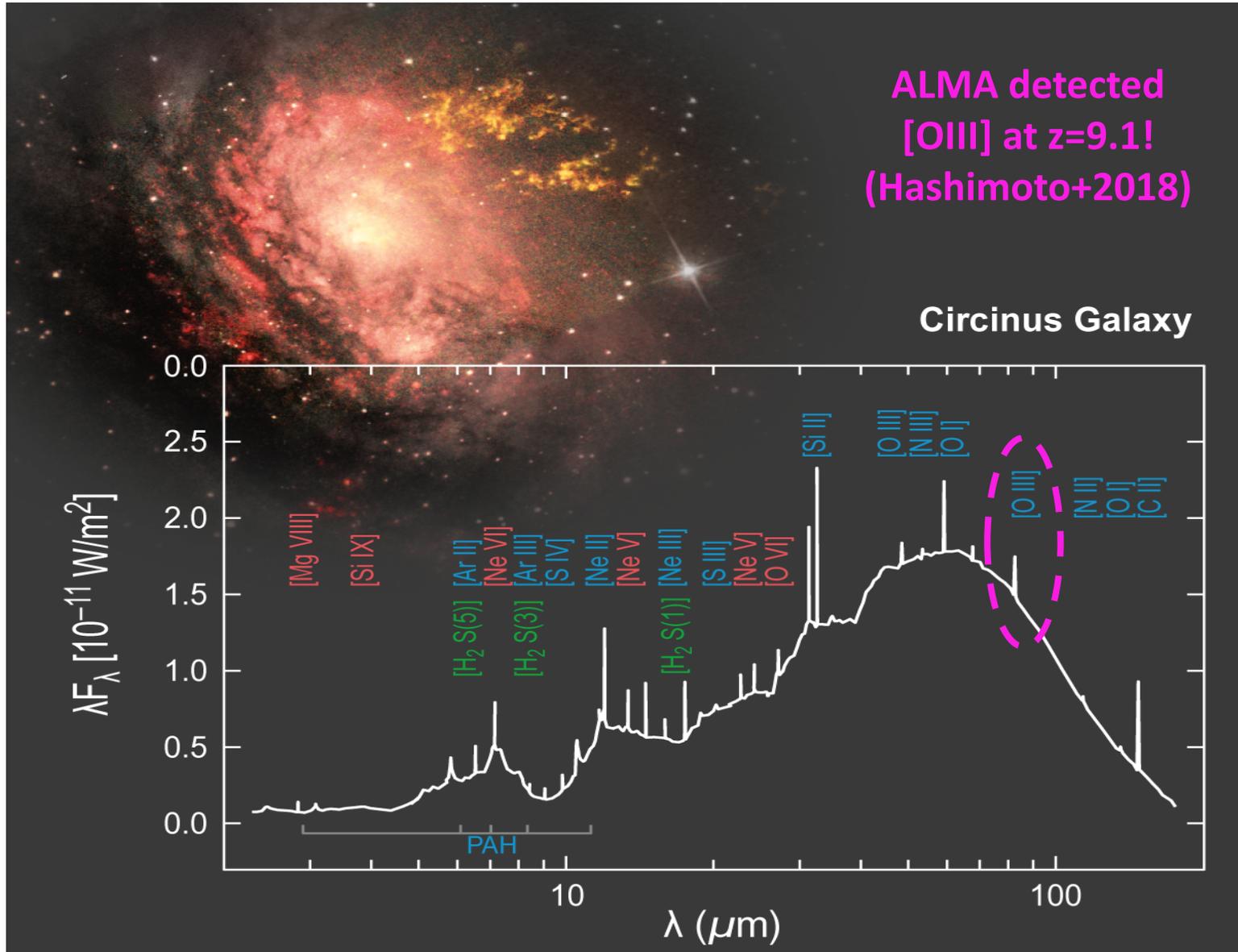
ARE WE ALONE?

Do planets orbiting M-dwarf stars support life?

By obtaining precise mid-infrared transmission and emission spectra, Origins will assess the habitability of nearby exoplanets and search for signs of life.

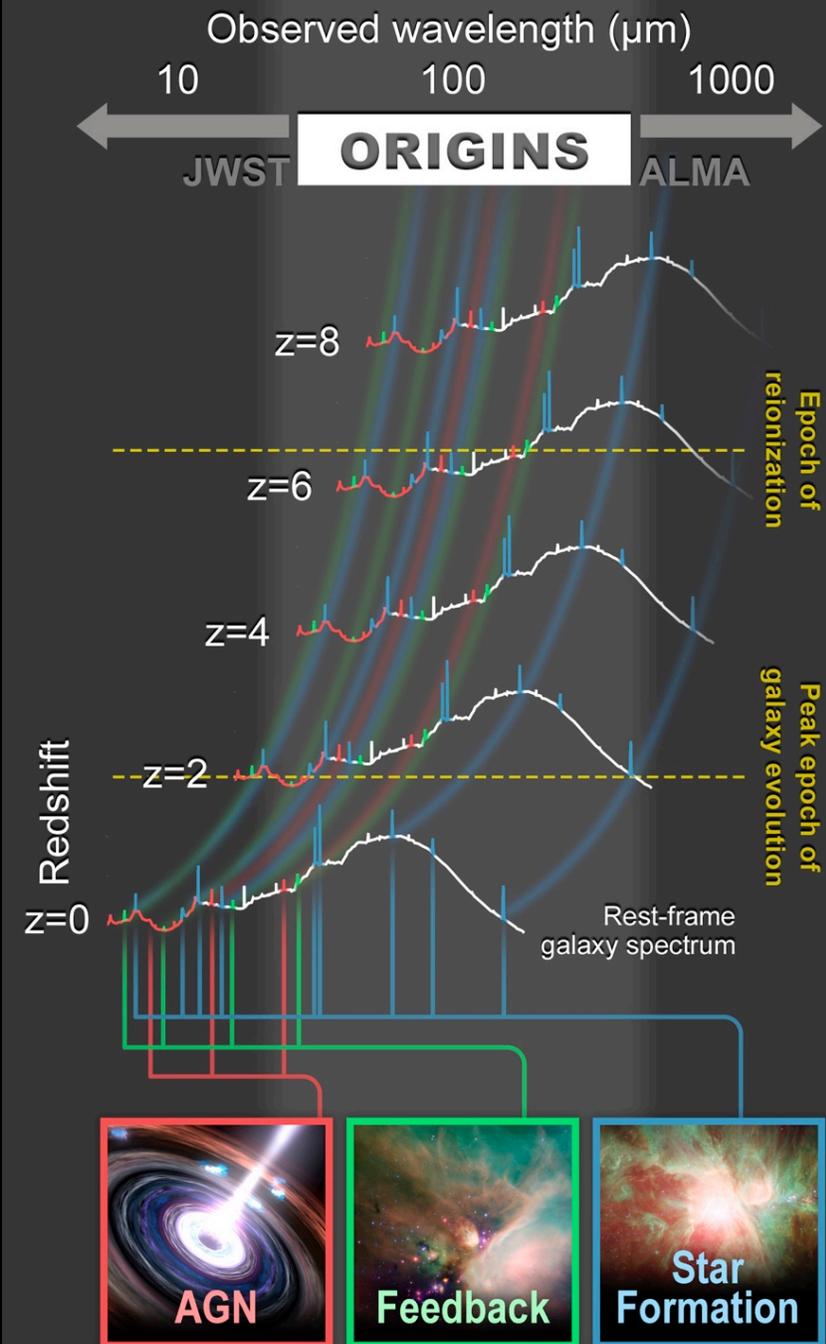


- The [OIII] 88 line will become a workhorse for SF detections with ALMA at $z > 7$
- We are currently blind to studying key MIR+FIR diagnostic lines like [OIII] 88 over much of cosmic time



Filling the IR Wavelength Gap

- Origins fills in the wavelength gap between JWST and ALMA in the next decade.
- Origins provides un-interrupted access to the key IR diagnostic features of star formation, SMBH growth and feedback from Cosmic Noon to EoR.





How do galaxies form stars, make metals, and grow their central supermassive black holes from reionization to today?

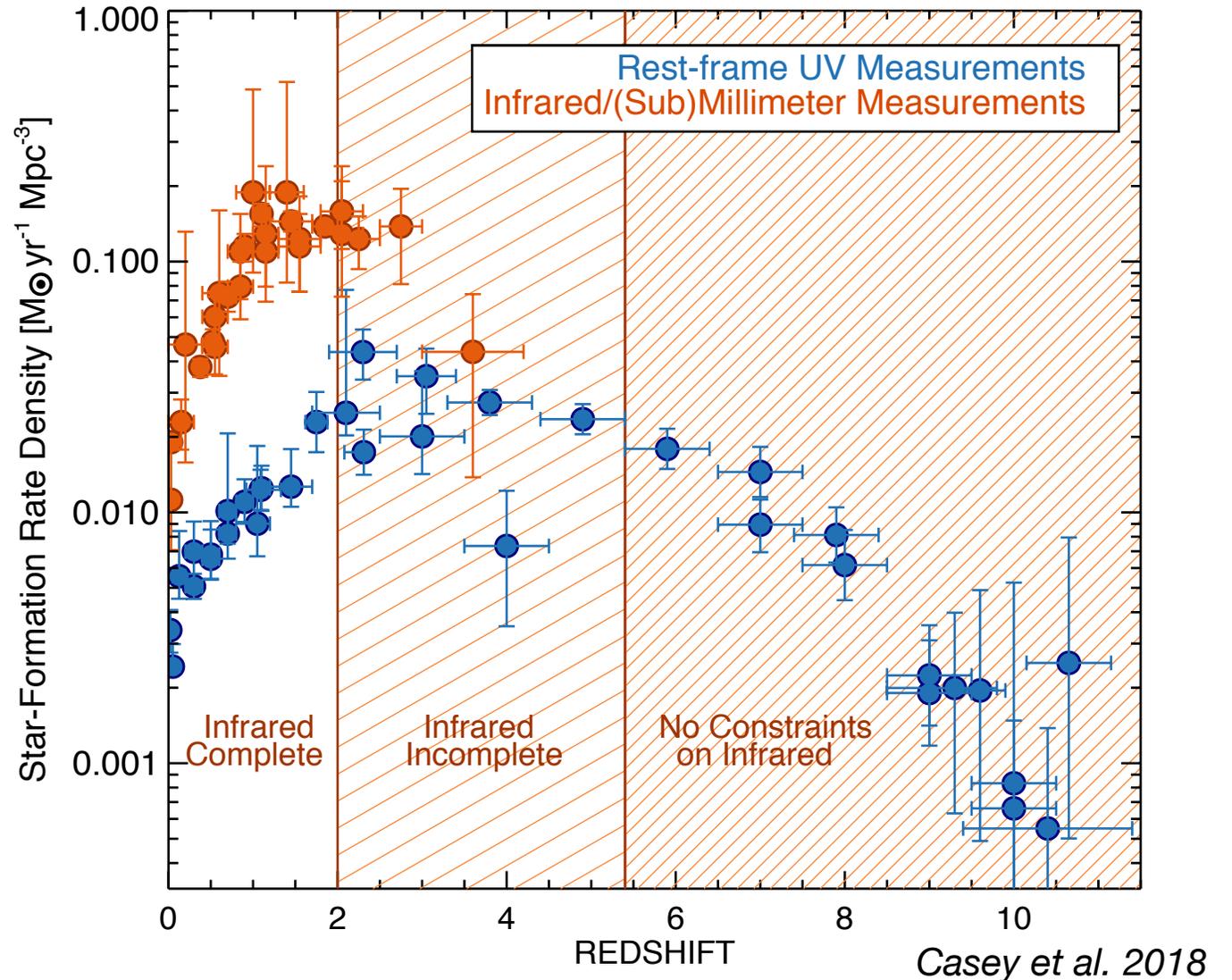
- Conduct the first unbiased survey of the co-evolution of stars and supermassive black holes by measuring redshifts, black-hole-accretion rates, and star-formation rates in $\geq 10^6$ galaxies since reionization to $1 M_{\odot}/\text{yr}$ at cosmic noon ($z=2$), and $10 M_{\odot}/\text{yr}$ at cosmic dawn ($z=6$).
- Measure the metal and dust content of $\geq 10^5$ galaxies out to $z=6$ as a function of cosmic time, morphology and environment, tracing the rise of heavy elements, dust and organic molecules.
- Establish an accurate model of galaxy growth and evolution, measuring galactic outflows in $\geq 10^3$ galaxies as a function of luminosity over the past 10 Gyr to determine the relative role of supernovae and AGN feedback.

SF/BH co-evolution

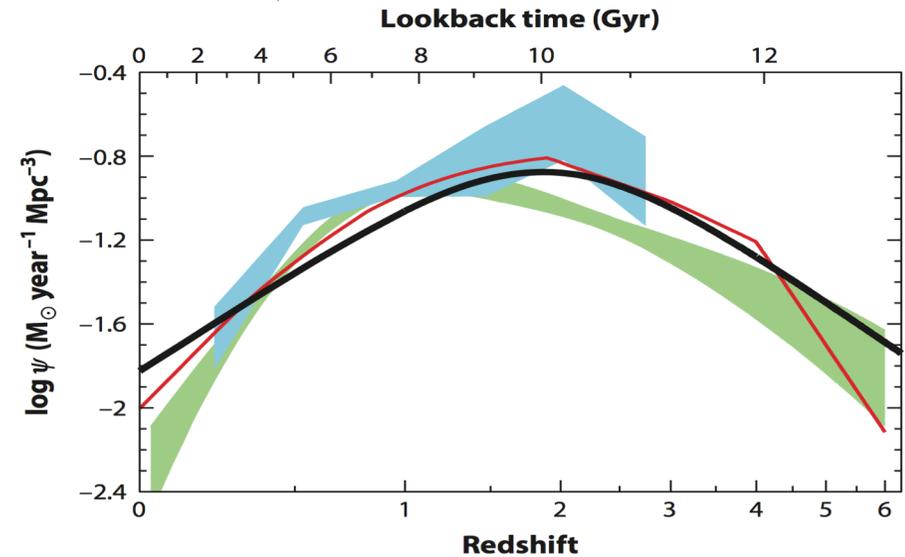
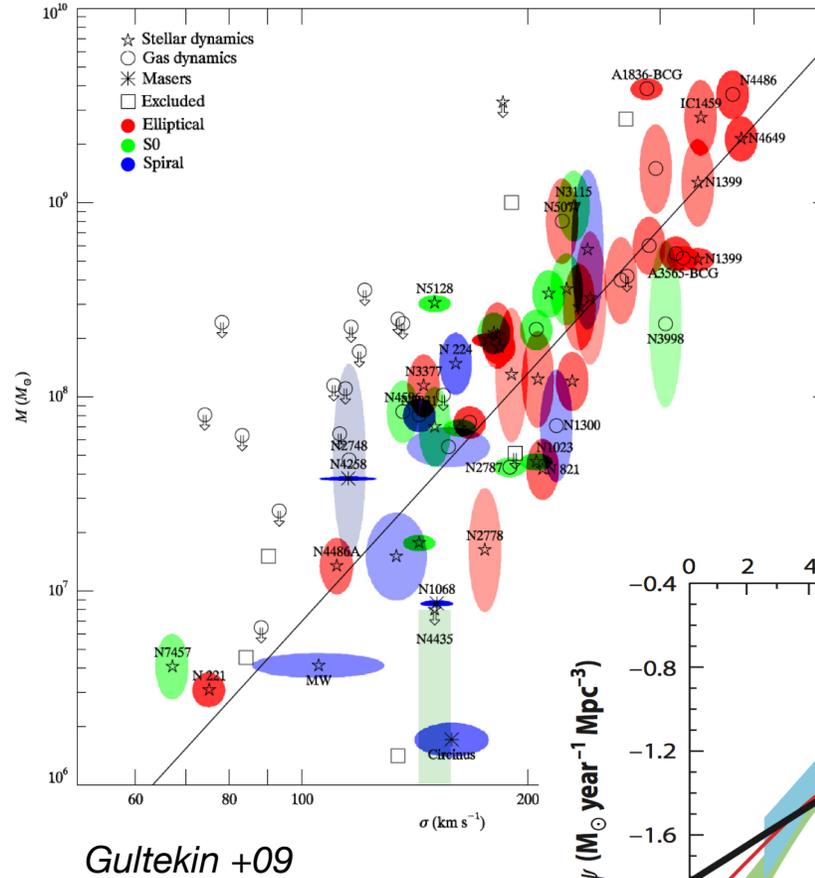
Rise of Metals and dust

SNe and AGN feedback

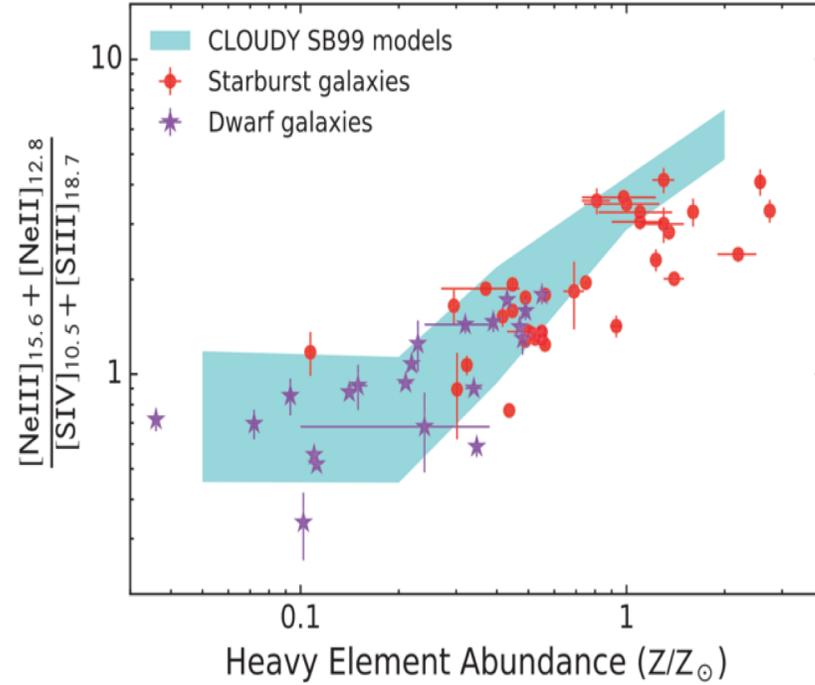
- We have very little information about the dust-enshrouded SF at $z > 3$.
- *Origins* will survey SF at $z > 3$ as a function of environment, mass, merger stage.
- *Origins* will use multiple diagnostic lines and the IR continuum to measure the **SF rate** and the **AGN luminosity (BHAR)** in every source measured in the multi-tier surveys



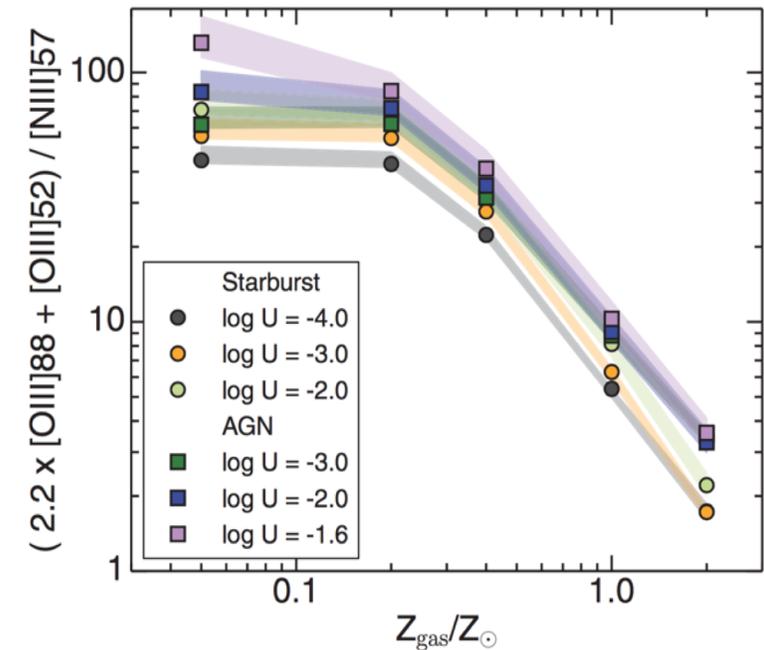
- Both $M_{\text{BH-bulge}}$ and **SFRD/BHARD vs. redshift** suggest that SMBH and galaxies co-evolve over cosmic time.
- But these are based on different samples of galaxies
- Next generation surveys need to be able to **simultaneously** measure SFR and BHAR in every source in large, **blind** surveys.



- Using local relations, and those extended with JWST, Origins will use bright MIR/FIR lines to measure gas-phase metallicities in every source.
- Covers a wide range of physical conditions, enrichment, obscuration. Much less sensitive to unknown temperatures than optical lines.



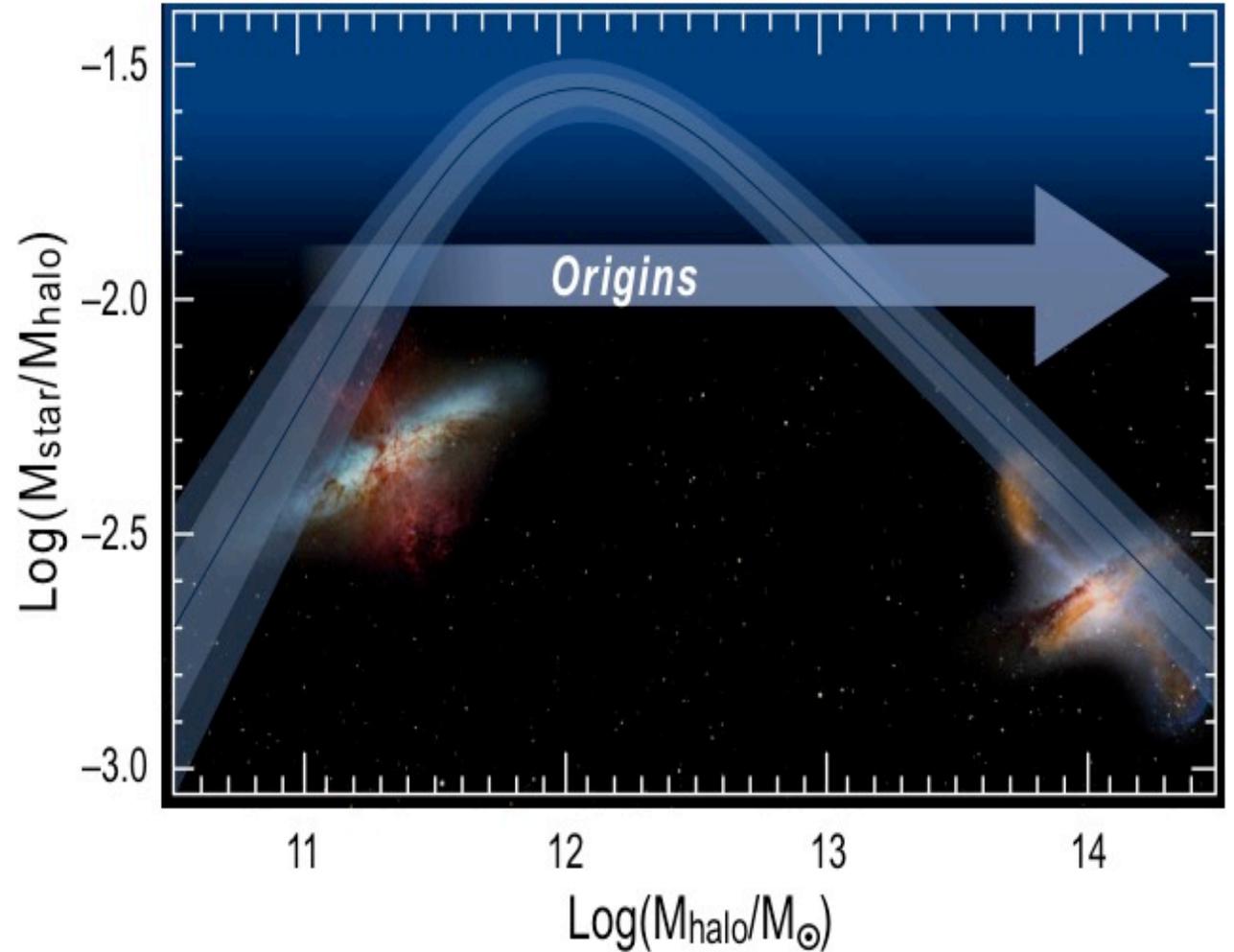
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Pereira-Santaella +17



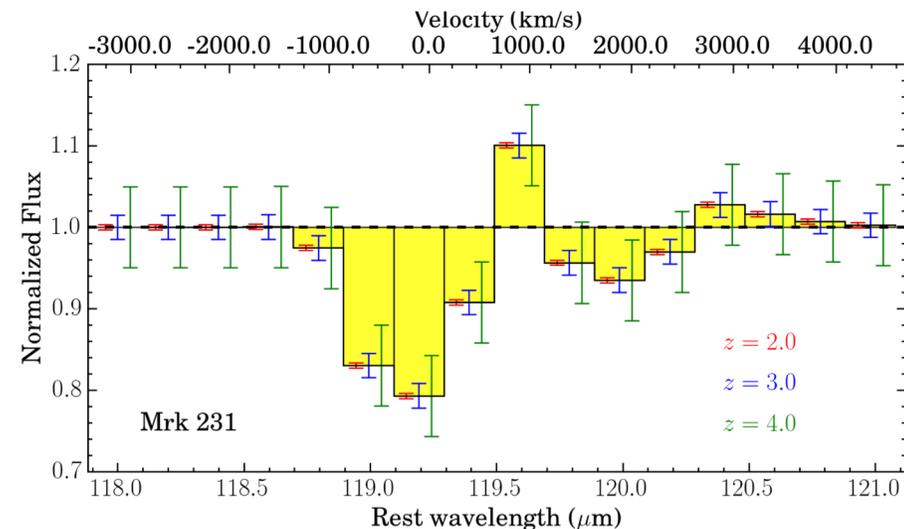
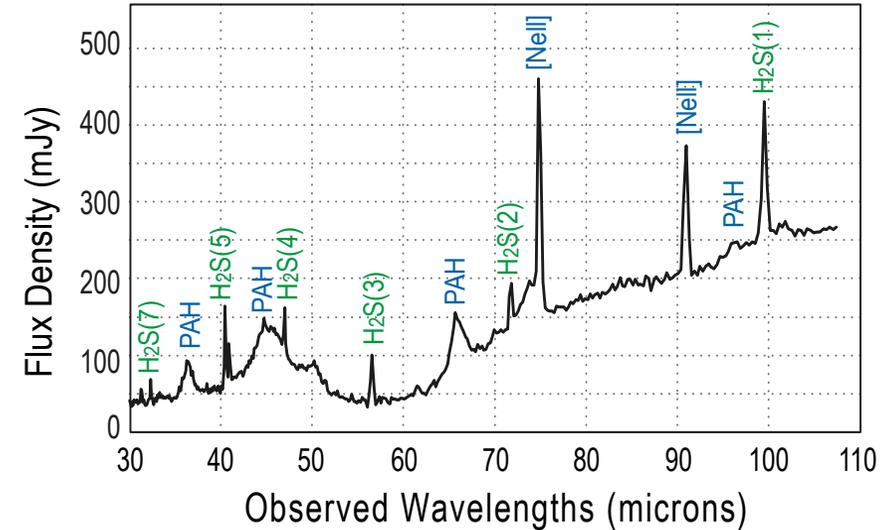


FIRE simulation (Phil Hopkins et al.)

Star formation is inefficient on all scales

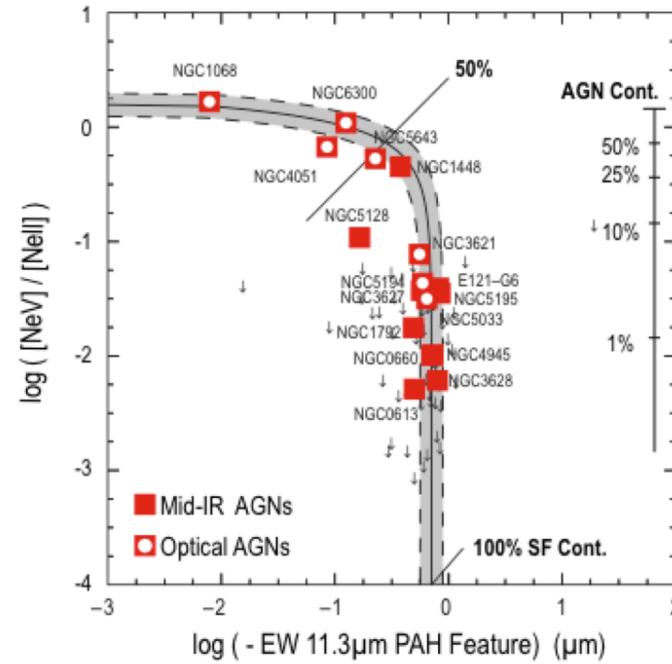


- Galaxies experiencing powerful feedback on their ISM will be visible to high- z via **strong H₂ emission** and **blueshifted OH absorption**
- Origins* will provide a **census of feedback** to $z > 5$ and beyond and **directly link feedback to SB/AGN power**, merger state, environment helping to constrain models at both the low and high mass end

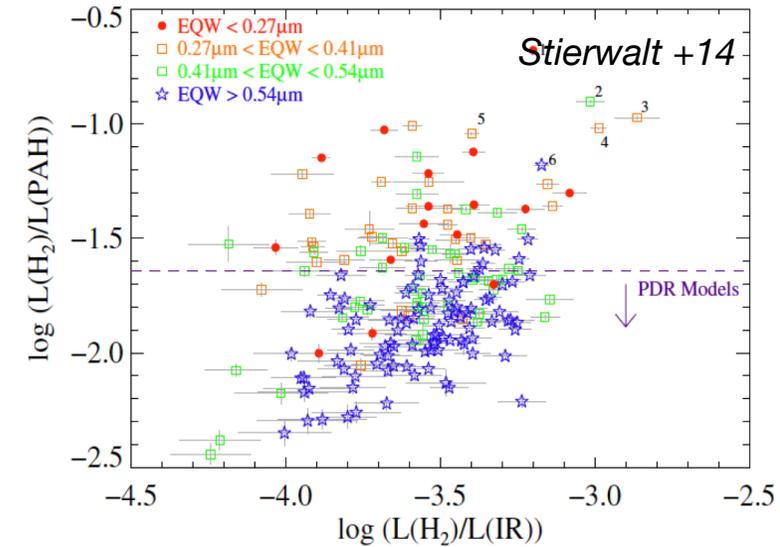


PAHs and warm dust are extremely valuable as:

- Direct measures of star formation
- Diagnostics (with large grains) of the presence of AGN
- Complimentary probes of enrichment and metals in the ISM
- Signposts of shocks on the gas and dust in galaxies experiencing feedback

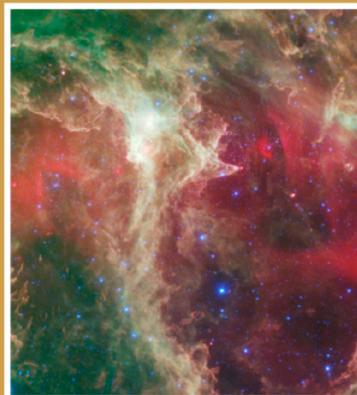


Goulding & Alexander 2009



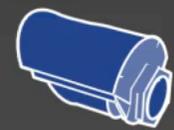
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DISCOVERY SPACE OF ORIGINS



Origins is not only capable of addressing known questions, but has a vast discovery space that will enable astronomers in the 2030s to find new phenomena and address currently unknown questions. All science programs on Origins will be selected by the community via peer review.

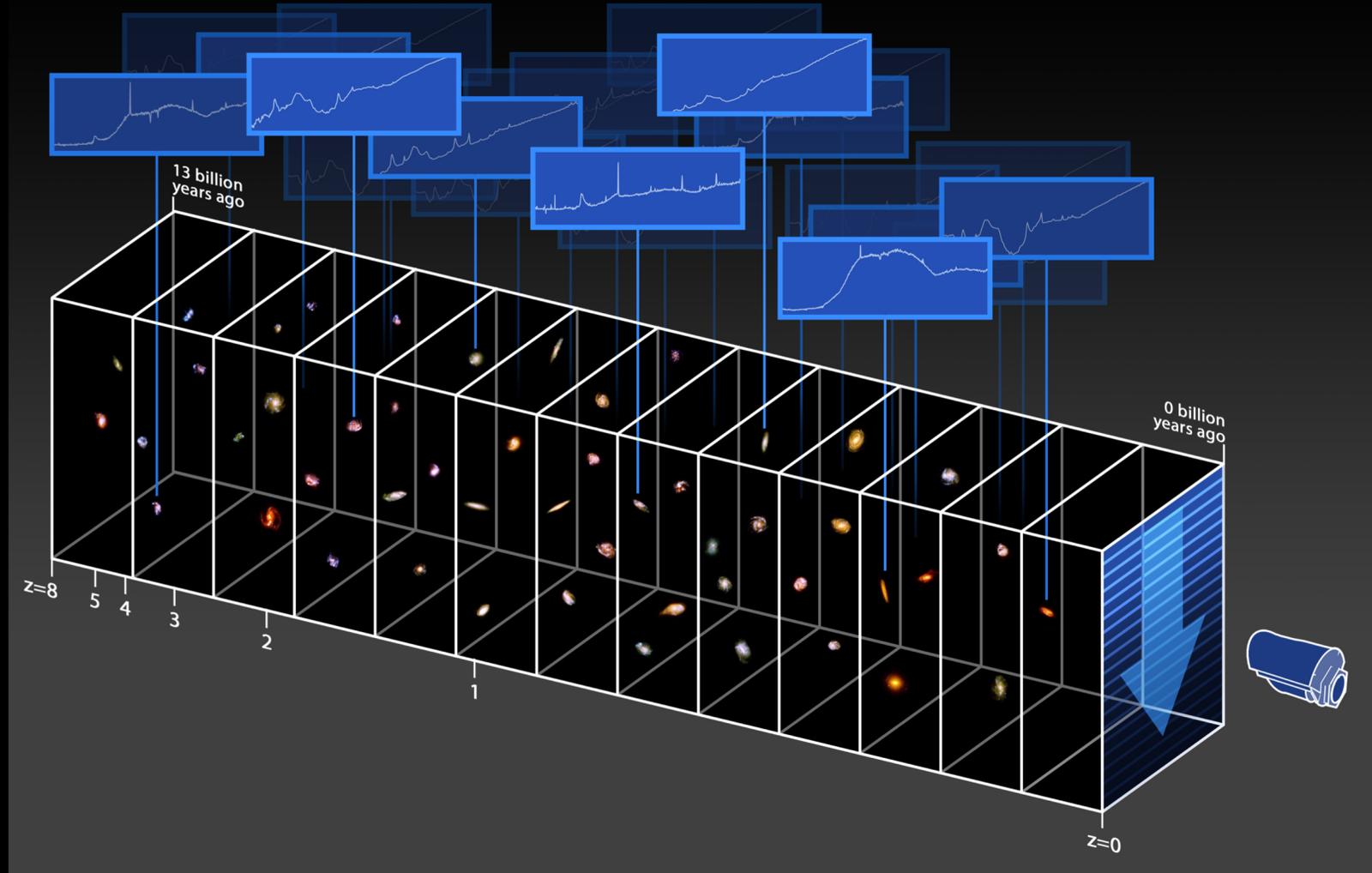




3D Infrared Spectroscopic Surveys

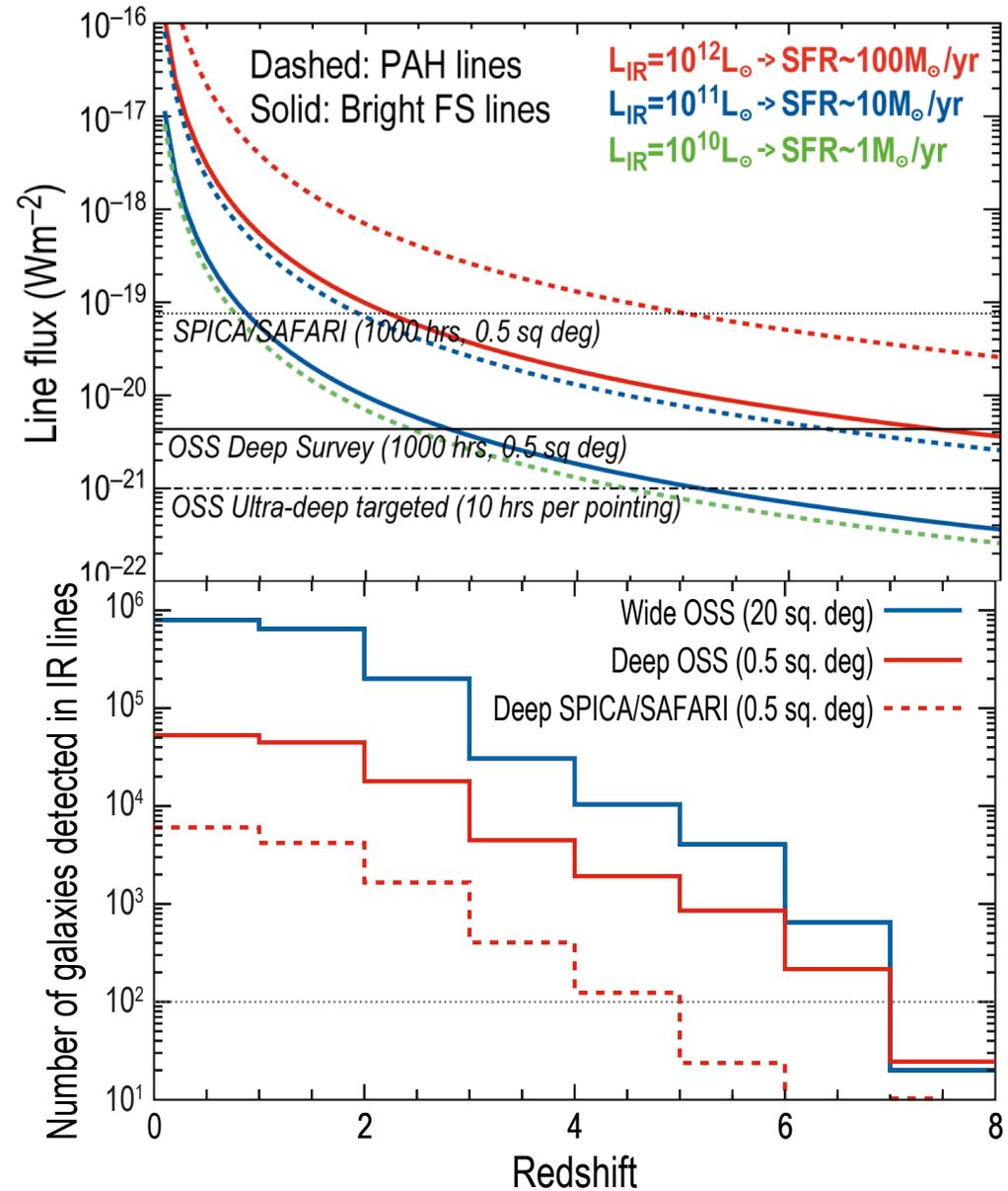
With unbiased deep and wide surveys, Origins can:

- Generate millions of MIR/FIR spectra across cosmic time - **SDSS for the infrared!**
- Chart the luminosity function, star formation and AGN history through EoR
- Create tomographic maps of neutral gas, HII regions, warm molecular gas and AGN/coronal gas as a function of redshift

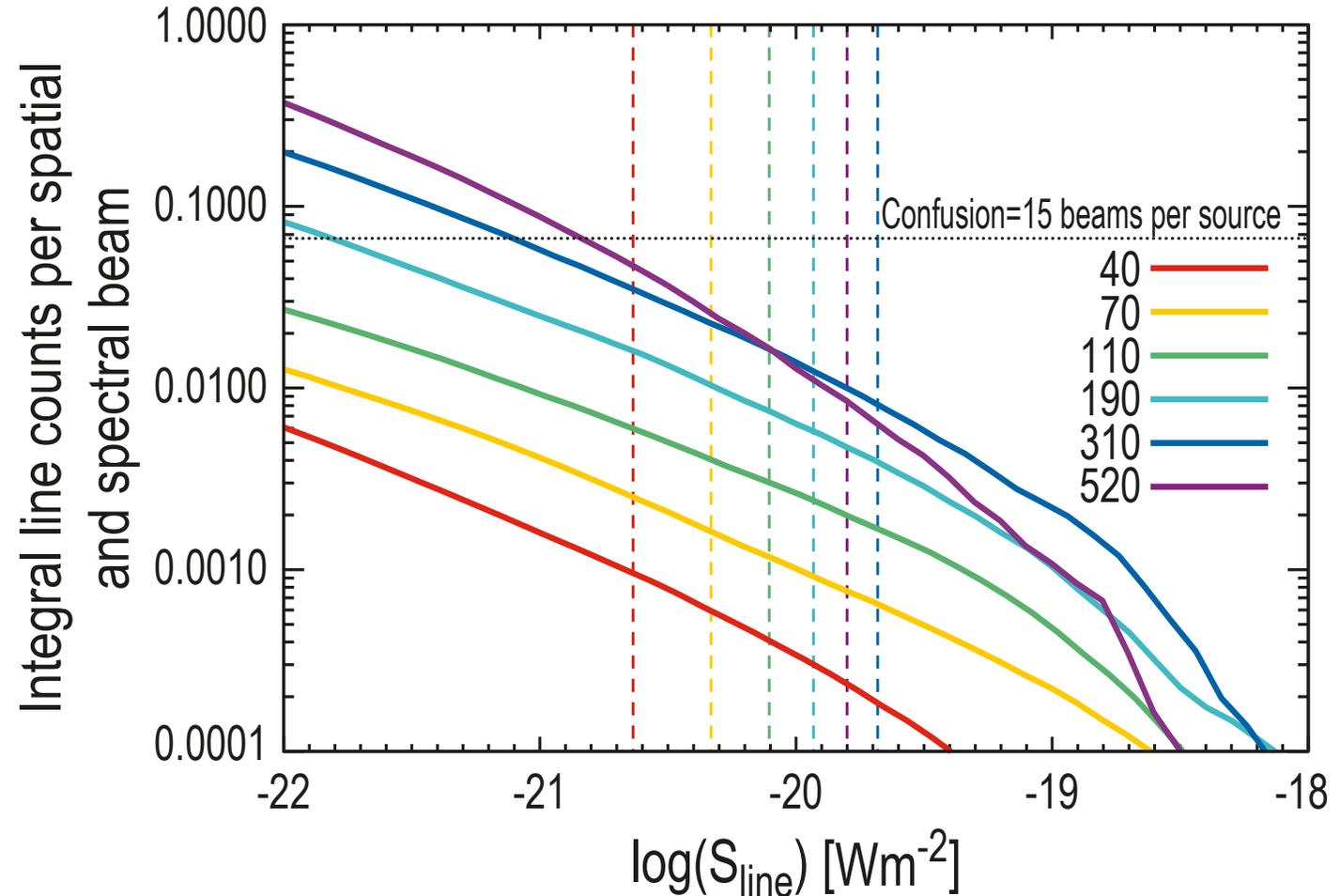


Using **deep (0.5 sq. deg)** and **wide (20 sq deg.)** surveys with OSS, Origins can:

- Measure SFR and BHAR in MS galaxies since EoR down to 5 Msun/yr at $z=5$, 1 Msun/yr at $z=2$
- Measure AGN luminosities of 10^{11} Lsun and BHAR = 0.1 Msun/yr at $z=3$
- Measure a million galaxies to $z\sim 8$, with >100 per redshift bin to $z\sim 7$



- Confusion has been a fundamental limit for deep surveys in the FIR.
- Planned deep 3D spectroscopic surveys with *Origins* can effectively “beat” confusion
- Integral line counts per spatial/spectral beam are well below the confusion limit in all OSS bands



The Galactic Ecosystem

- Galaxies growth is intimately connected to the CGM, IGM and the cosmic web
- Origins* will directly probe many of the processes that drive the galactic ecosystem on a wide variety of physical scales

