

JWST Reveals the Early Universe in Our Backyard

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The Milky Way's Backyard Can Help Us Understand The Early Universe

- **Cosmic Noon**: the peak of star formation occurred in the early Universe (~2.5 billion years old, $z \sim 2-3$).
- **Metallicity** was significantly lower; heavy elements were rarer than today.
 - Does formation occur on different timescales?
 - Can planets begin to form?
- When directly observed, **early galaxies are small**, and individual stars cannot be distinguished.



NASA, ESA, CSA, STScI

NGC 346:

Where The Stars Are Born

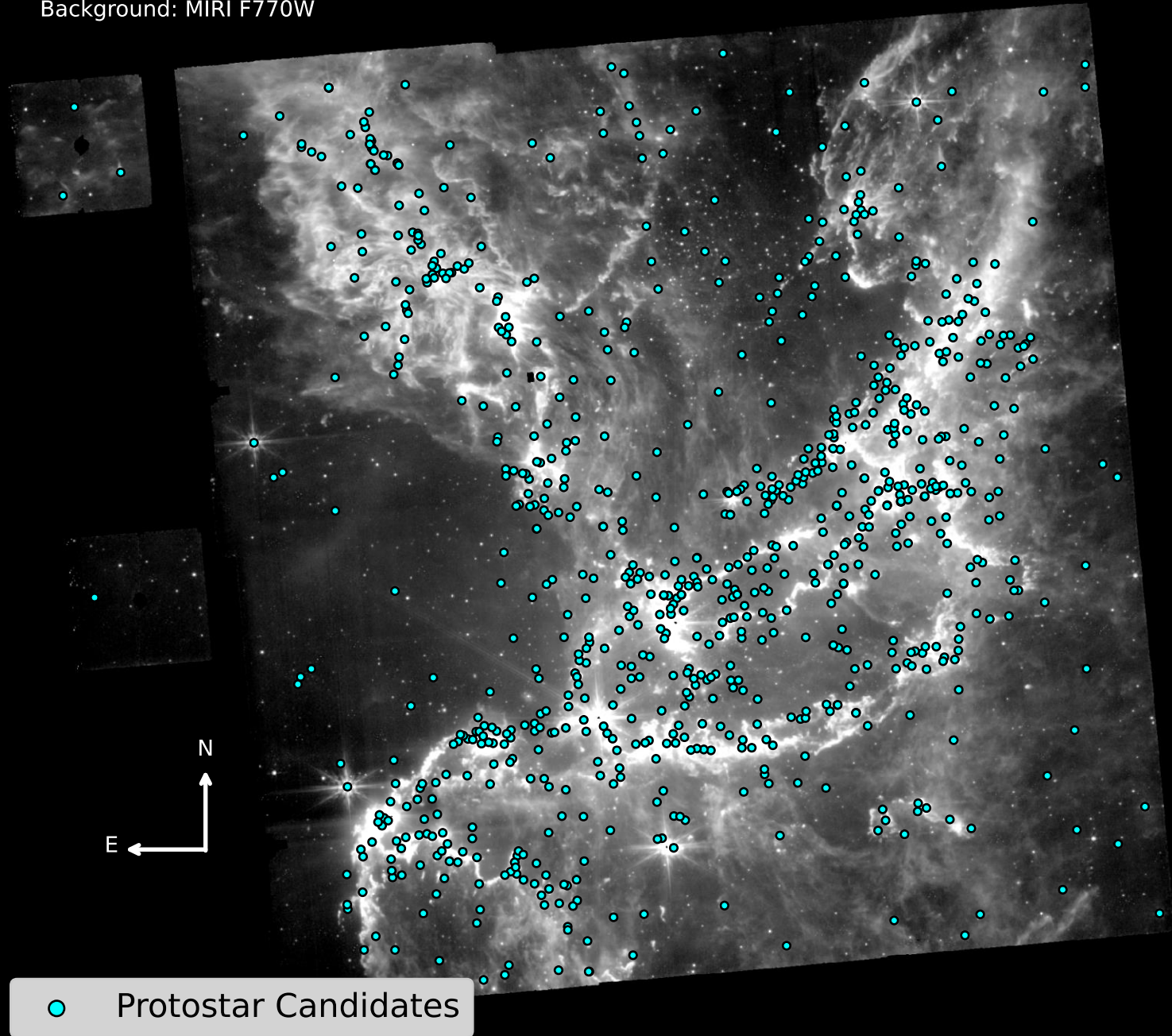
- Massive star formation region located in the Small Magellanic Cloud **200,000 light years away**
- Has a metallicity similar to that of Cosmic Noon (0.2 that of the Sun)
- Just near enough to distinguish thousands of individual forming stars called **protostars**



The youngest protostars are still enshrouded in dust and gas and **dim in visible light**.

But the heat in the dust and gas glows brightly in the **mid-infrared** ($\sim 5\text{-}27\ \mu\text{m}$).

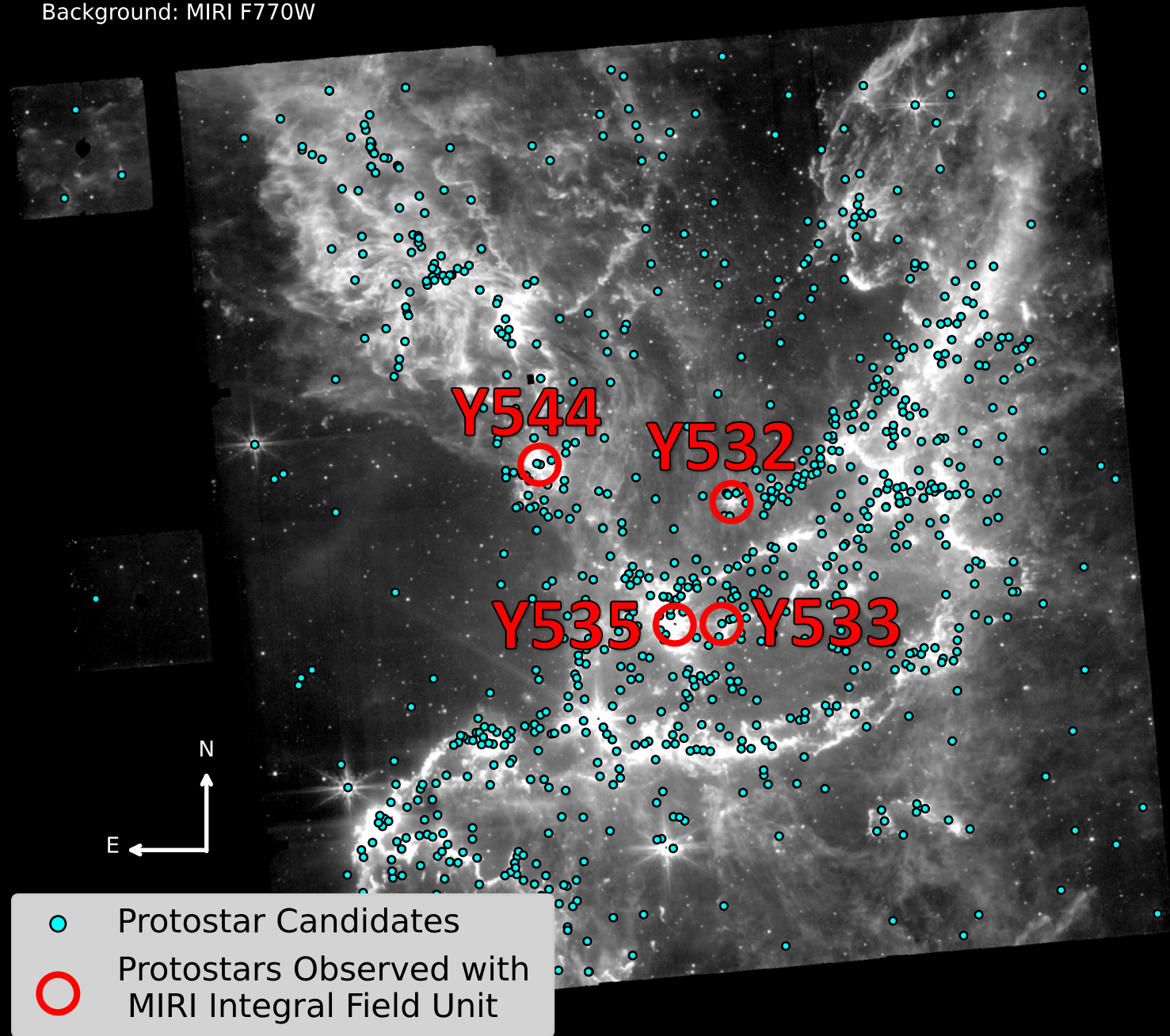
By searching images for the **reddest** objects, MIRI can find hundreds of protostars in NGC 346.



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What is an “Integral Field Unit?”

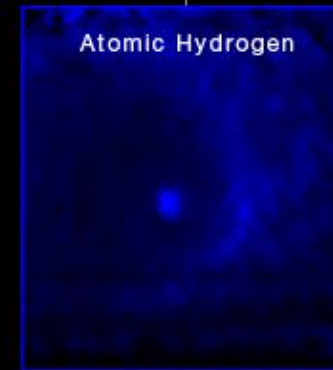
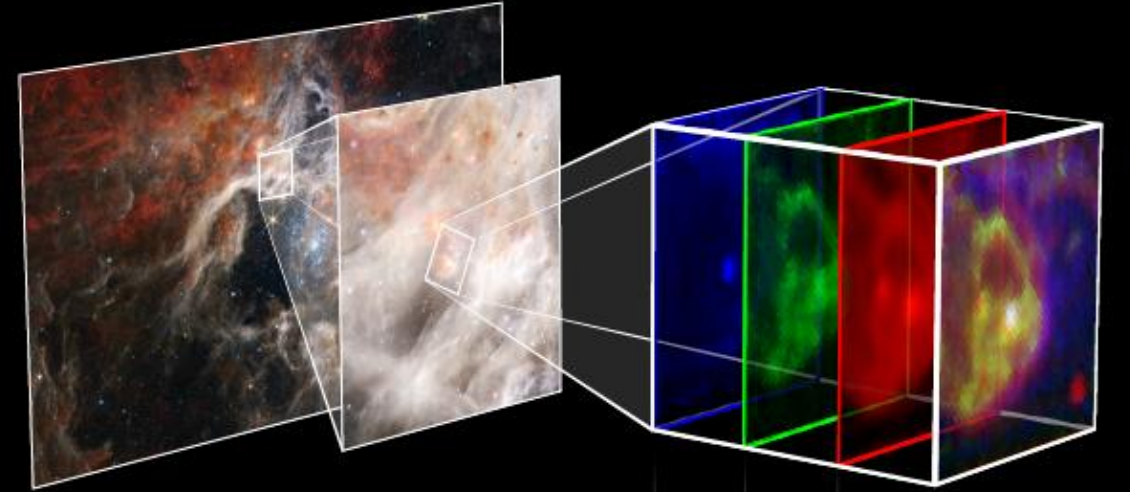


INTEGRAL FIELD UNIT

TARANTULA NEBULA STAR FORMATION REVEALED

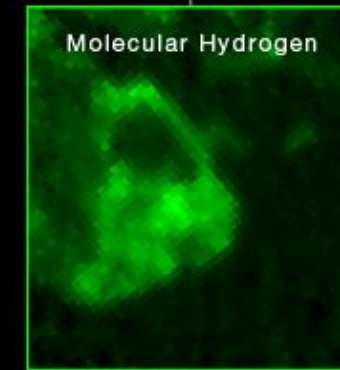
NIRCam Imaging

NIRSpec IFU Spectroscopy



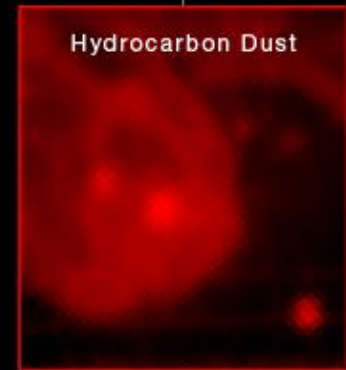
Atomic Hydrogen

1.87 microns
Wavelength of Light



Molecular Hydrogen

2.12 microns
Wavelength of Light



Hydrocarbon Dust

3.3 microns
Wavelength of Light

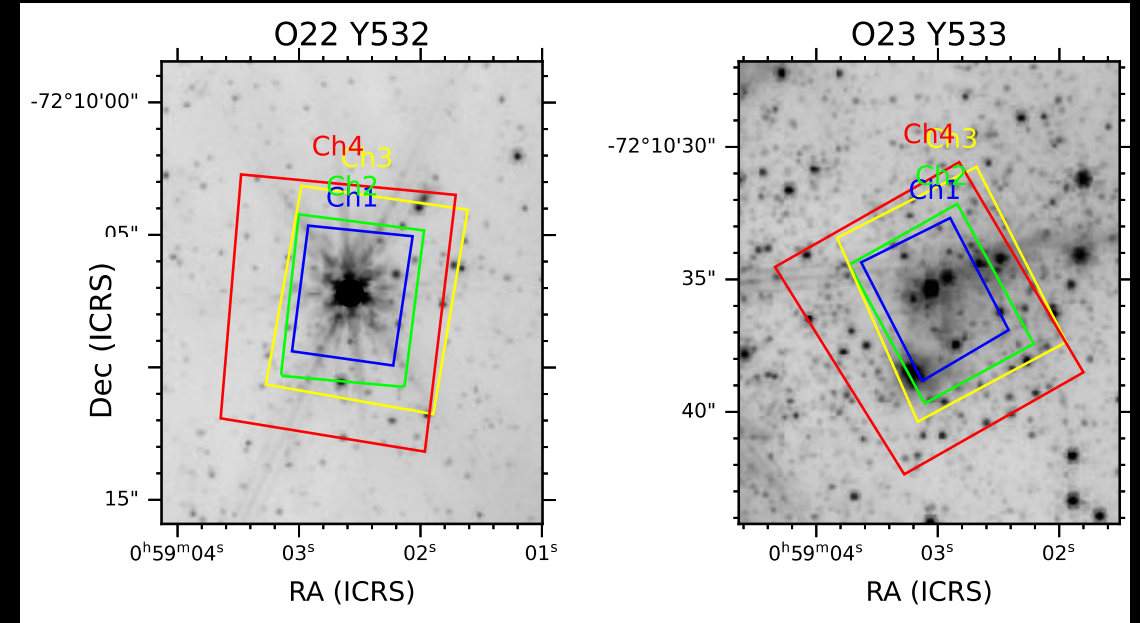
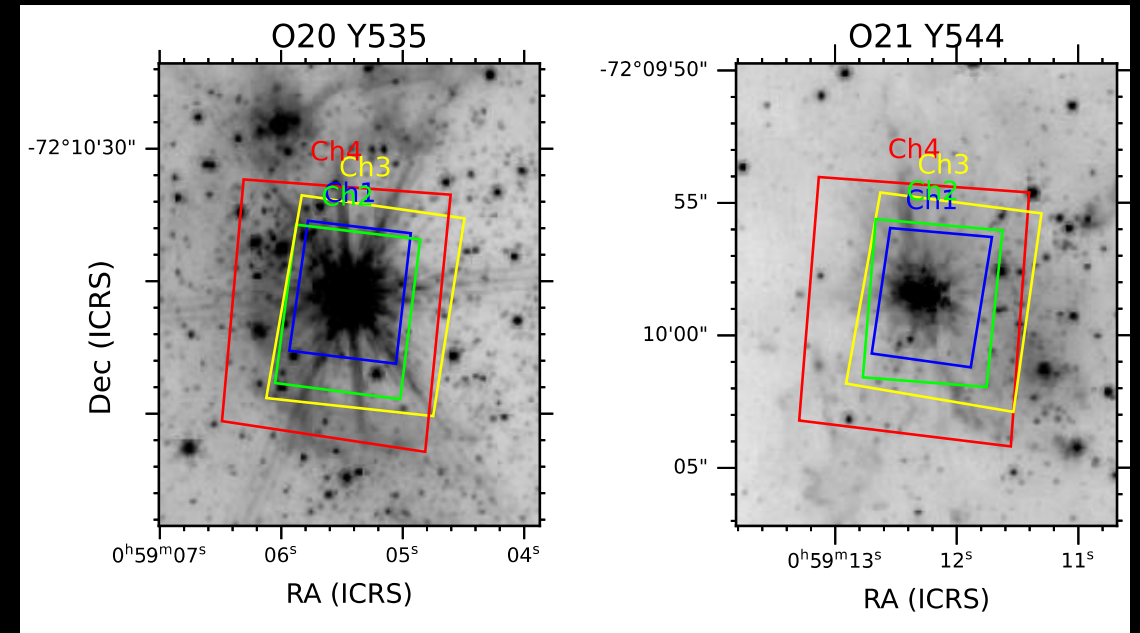
WEBB
SPACE TELESCOPE

- An **integral field unit** combines the power of imaging with spectroscopy.
- With an integral field unit, we can “image” an object with nearly any wavelength of light.
- Because atoms and molecules have signatures at known wavelengths, we can detect them and see their impact.

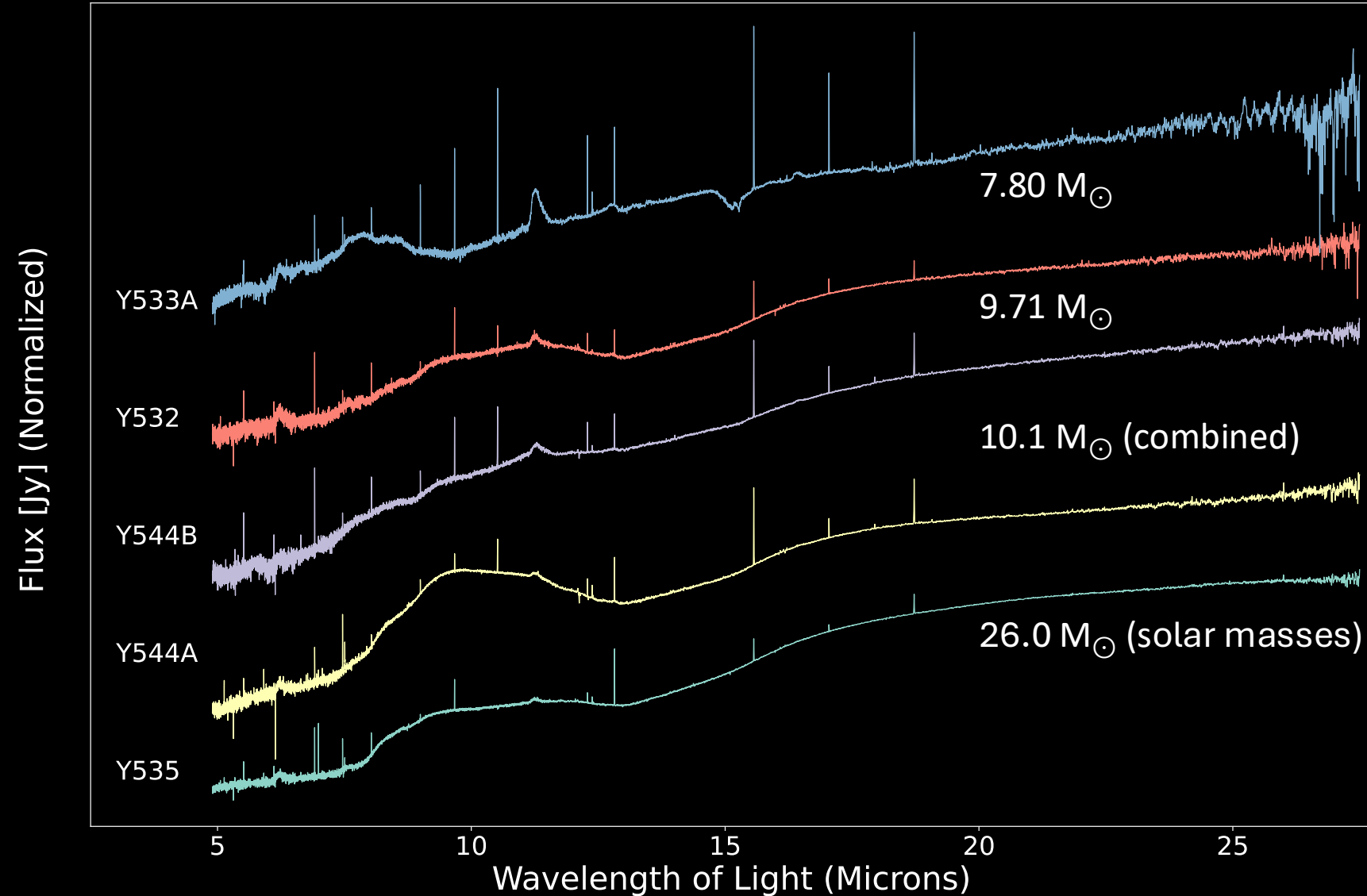
We acquired spectroscopy of 5 medium- to high-mass protostars with JWST's MIRI instrument.

- Range from ~8 – 26 Solar Masses
- At an early stage of evolution (stage I)
- Likely formed ~ 1–5 Million years ago

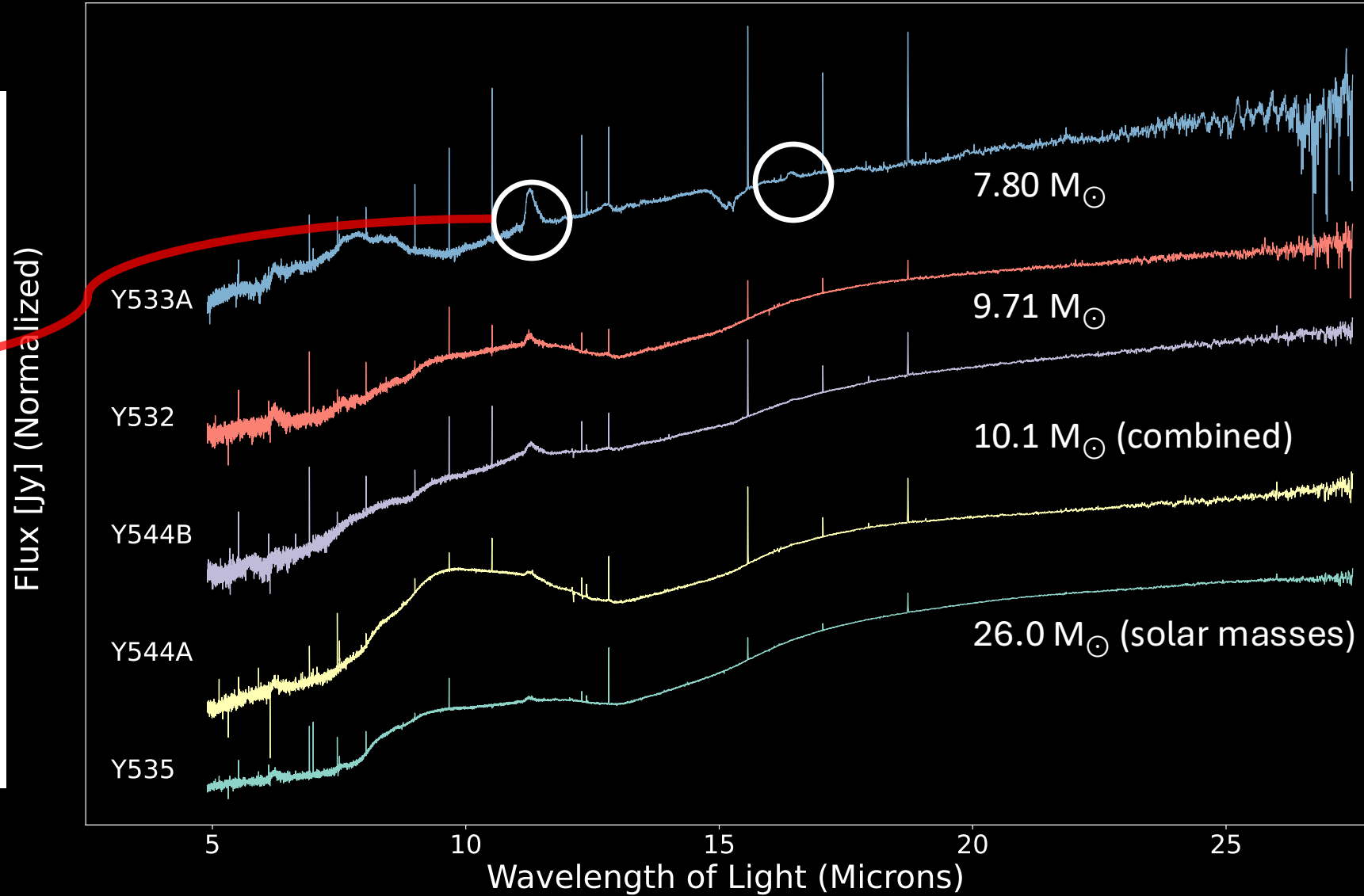
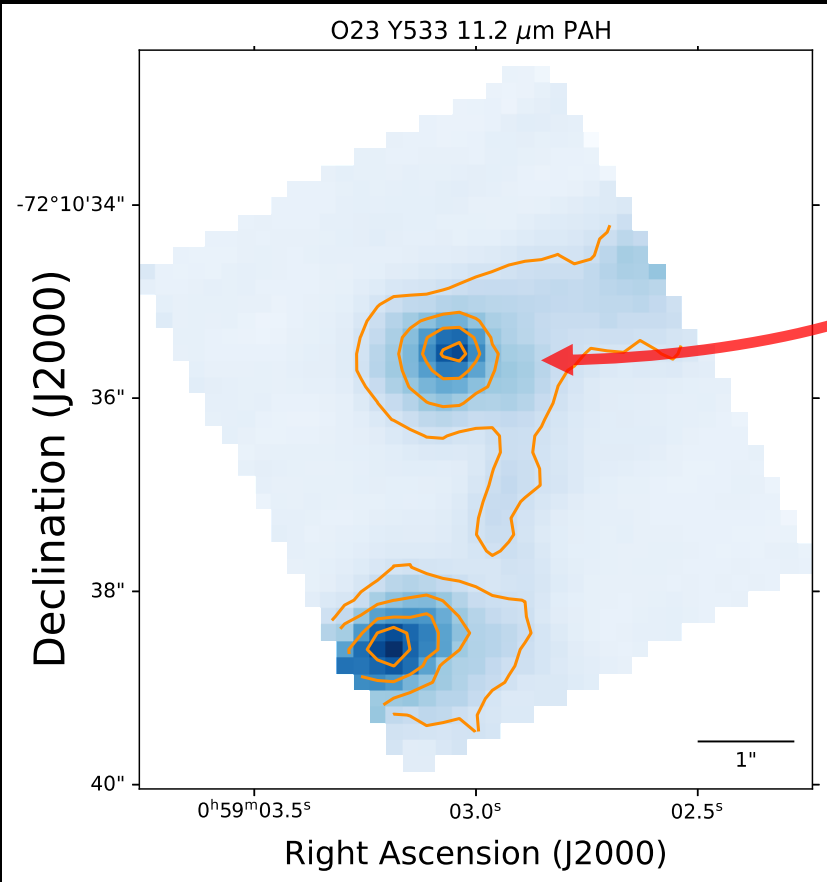
	Y535	Y544	Y532	Y533A
Known YSO Properties				
RA ¹	14.7726	14.8010	14.7606	14.7624
Dec ¹	-72.176	-72.166	-72.168	-72.176
Luminosity (L_{\odot})	27200	3240	5180	4940
Stellar Temp. (K)	31622	7100	12700	—
Stellar Mass (M_{\odot})	26.0	10.10	9.71	7.80
Evolution Stage	I	I	I	—
K-band ¹ (mag)	12.13	13.63	14.24	—



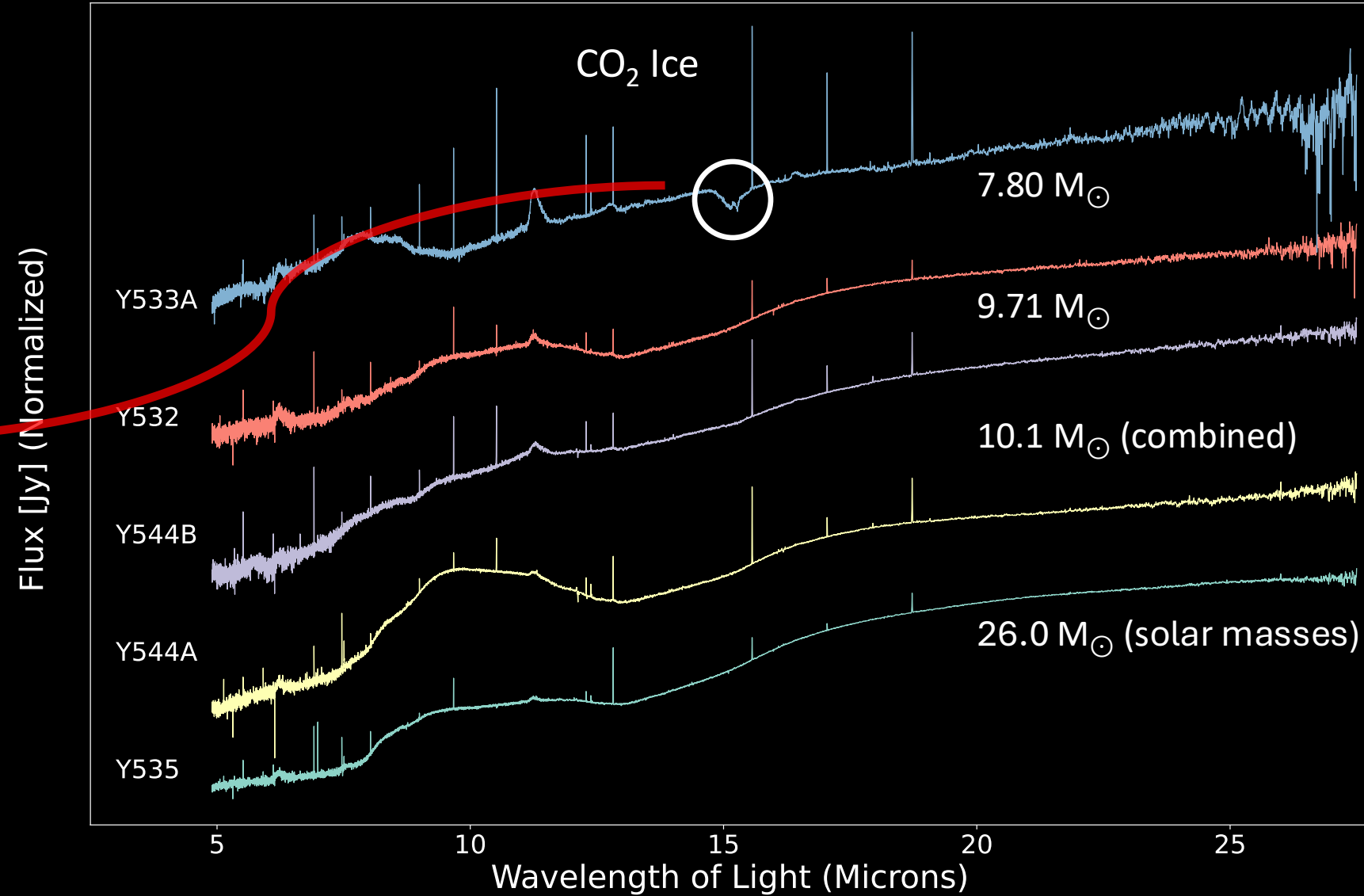
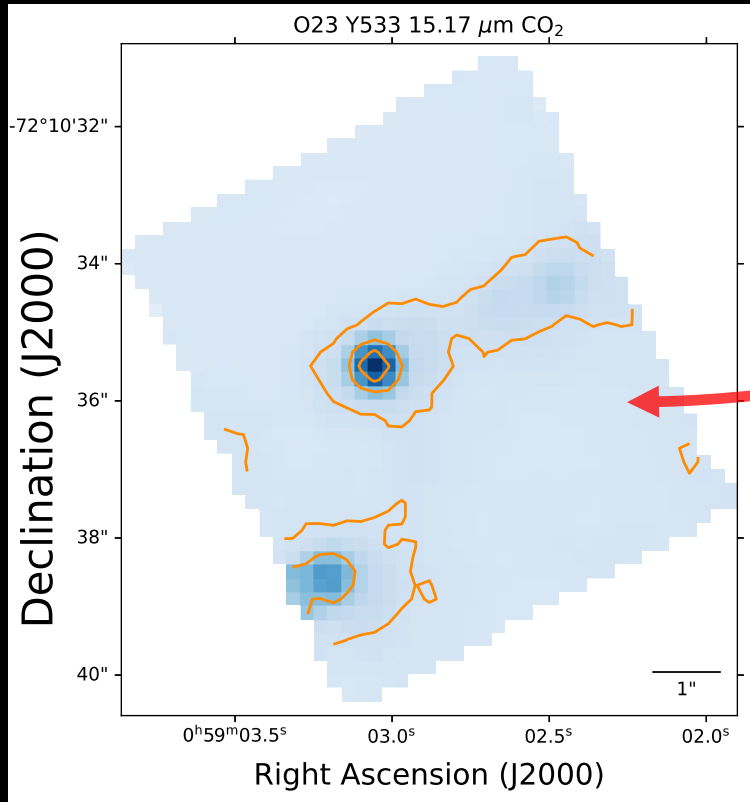
With **MIRI**, JWST
can probe the
environment and
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processes of
individual stars in
nearby galaxies.



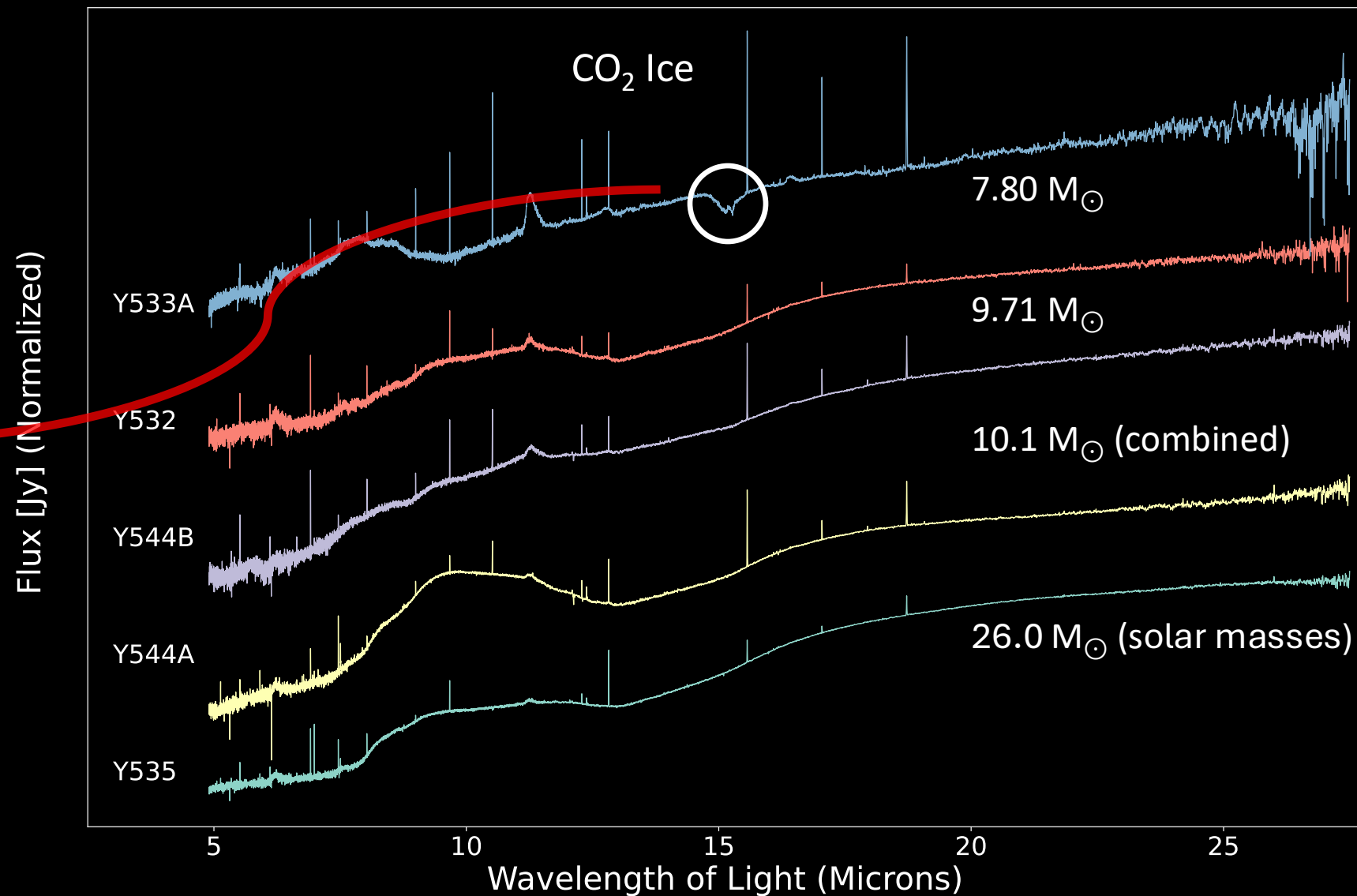
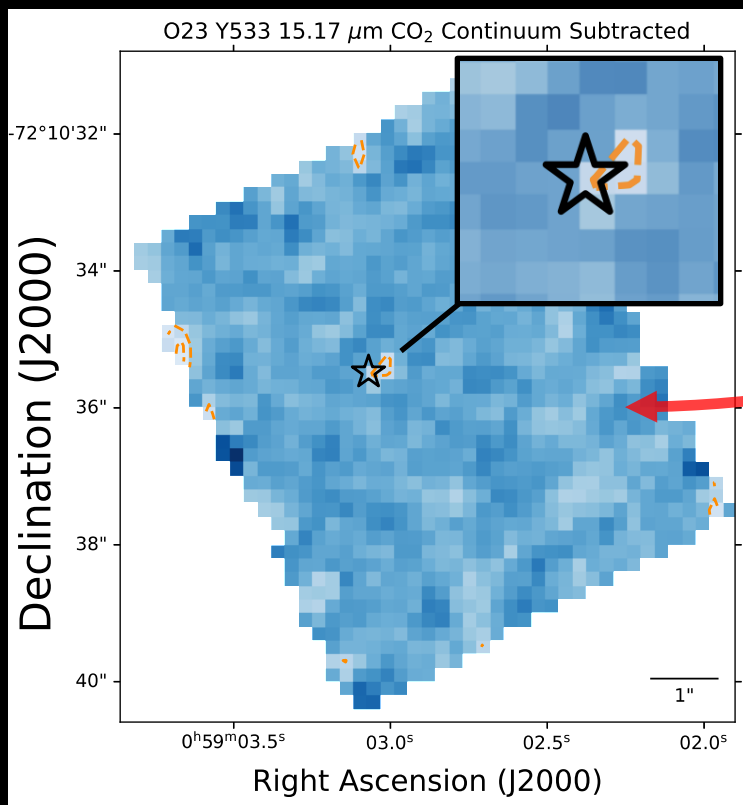
Polycyclic Aromatic Hydrocarbons (PAHs) reveal dust.



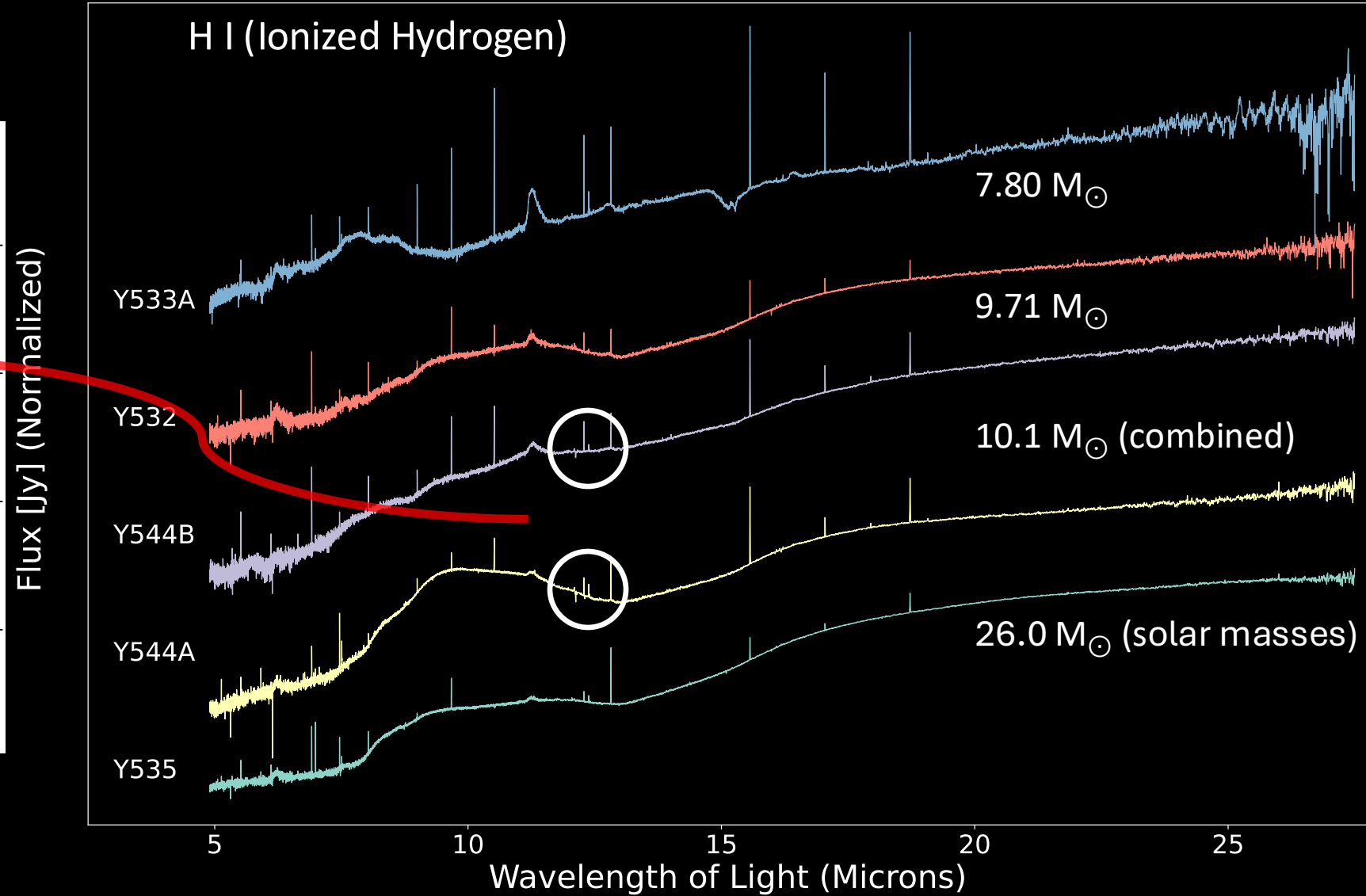
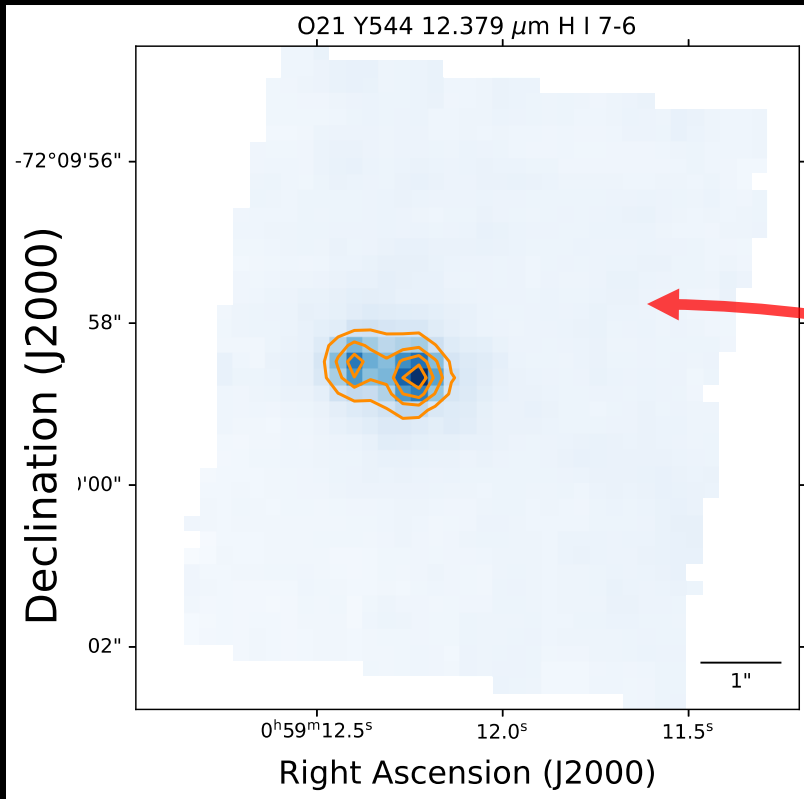
Absorption reveals CO₂ ice surrounding the protostars.



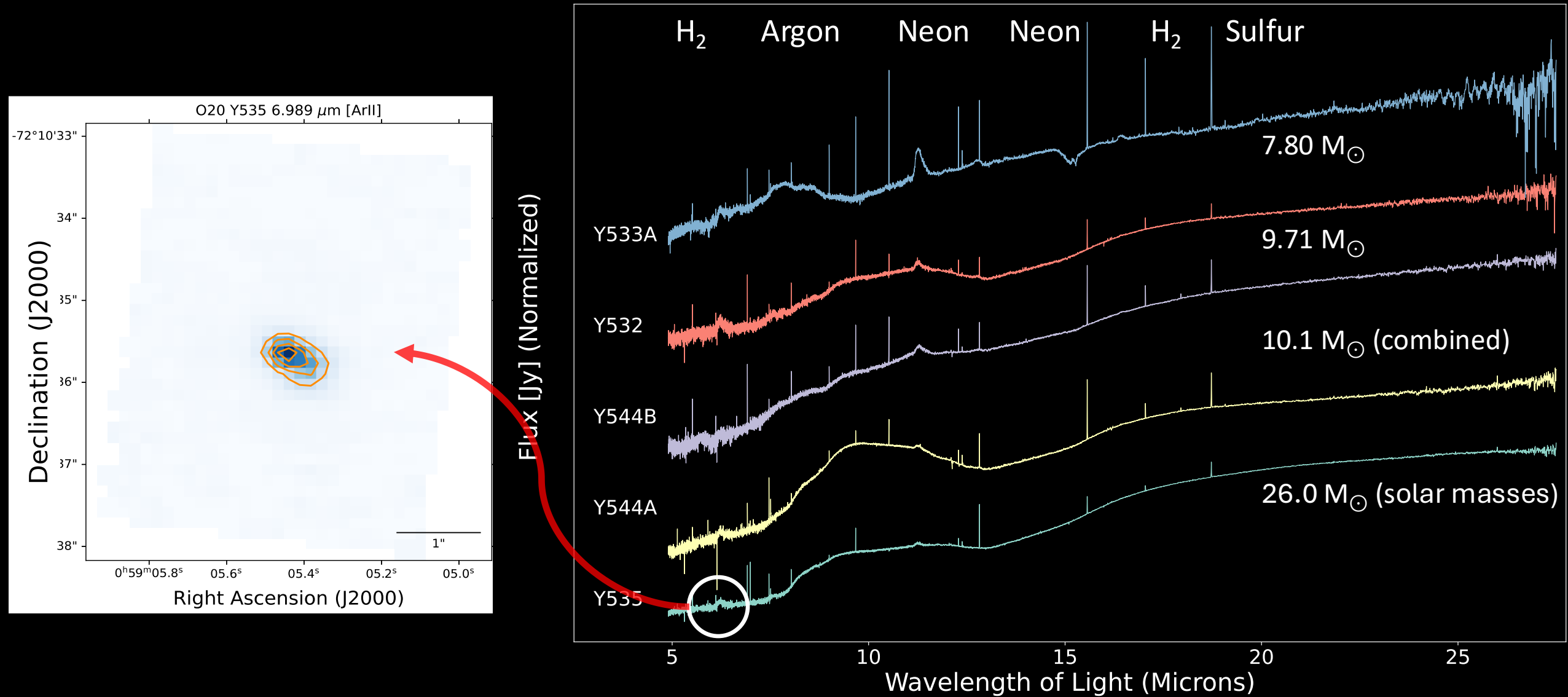
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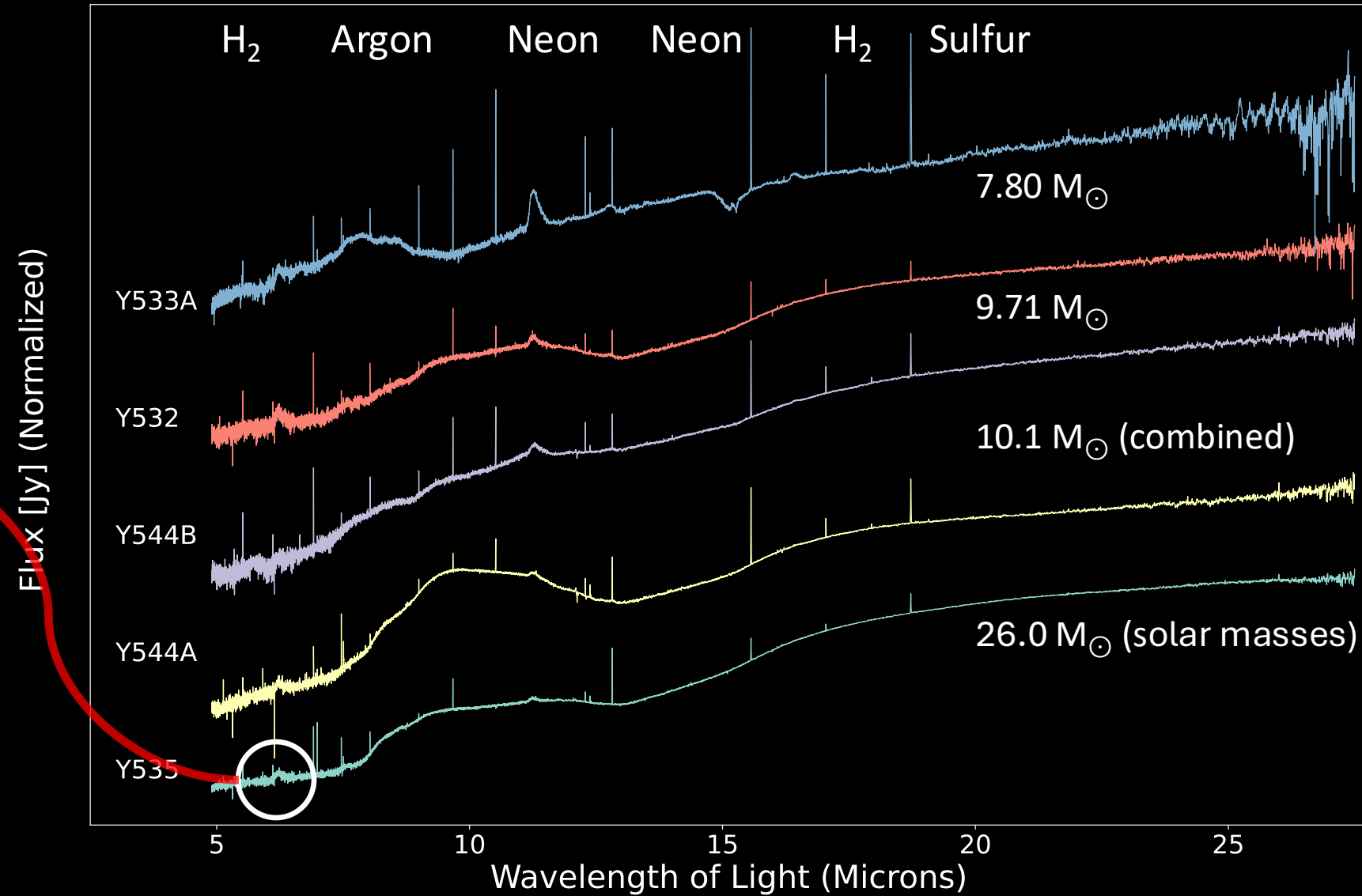
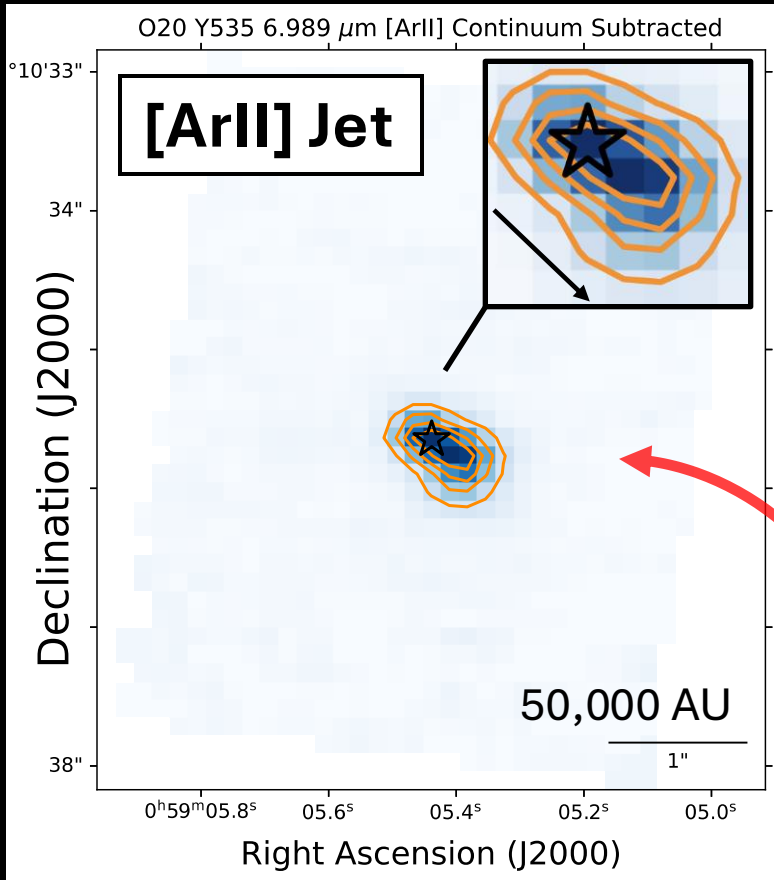
Ionized hydrogen reveals accretion (rate of formation).



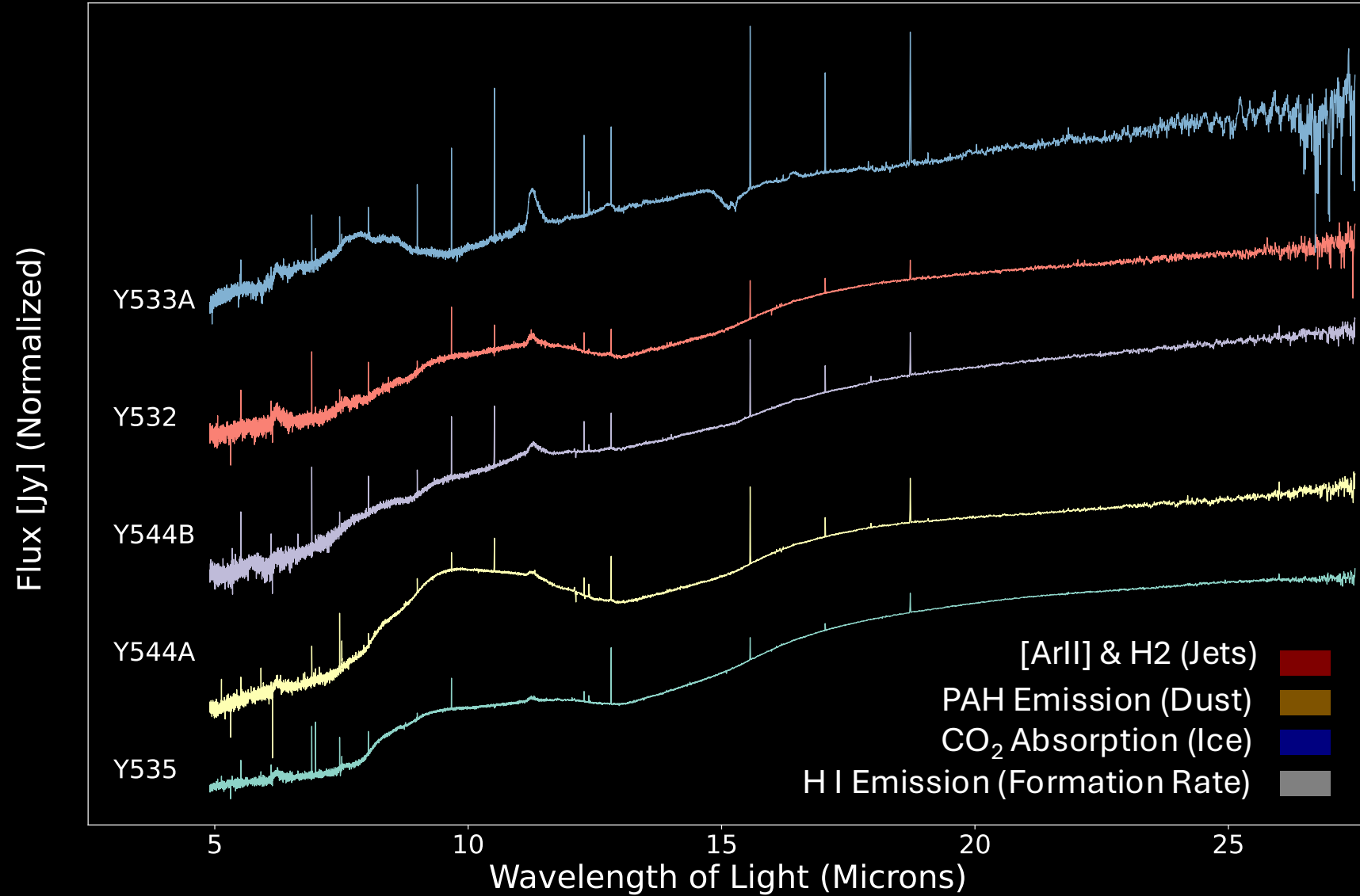
Atomic lines and molecular hydrogen lines reveal outflows.



Atomic lines and molecular hydrogen lines reveal outflows.



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SUMMARY: JWST Reveals the Early Universe in Our Backyard

- Protostars in the **Small Magellanic Cloud** are nearby analogs of those that formed in the distant, **early Universe**.
- We find **dusty molecules important for planet formation** and distinguish if they are near the star or in the surrounding environment.
- Molecules **of ice surrounding protostars** absorb light and mark a young stage in formation.
- Emission **from ionized hydrogen** tells us how fast a star is forming.
- JWST finds the first evidence of **extragalactic protostellar jets** in the Small Magellanic Cloud.

