FIR Mission:
Unique Tools for Studying the Nearby and Distant Universe

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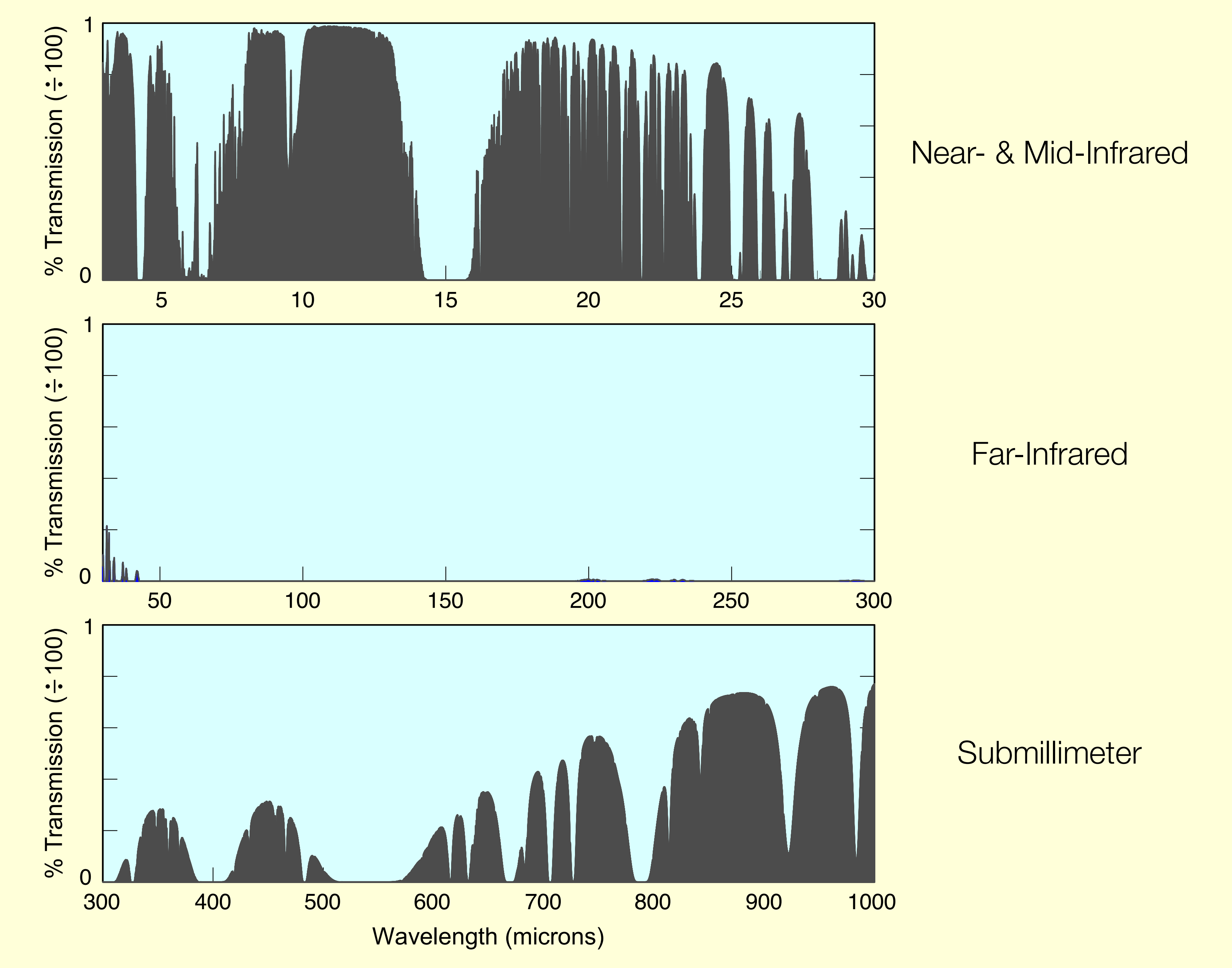
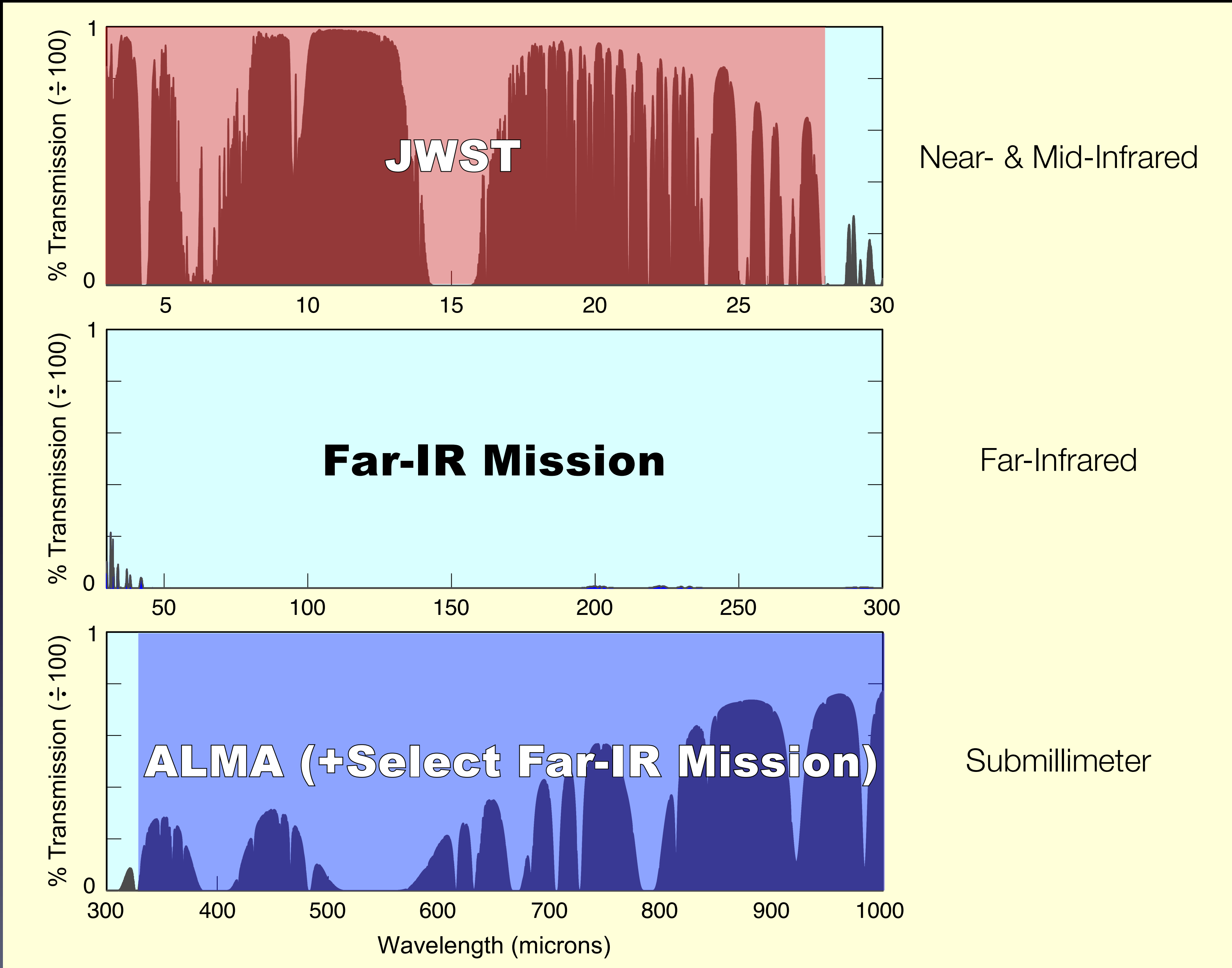


% Transmission (÷ 100)
1
0
5
10
15
20
25
30
Near- & Mid-Infrared
Far-Infrared
50
100
150
200
250
300
Submillimeter
400
500
600
700
800
900
1000
Wavelength (microns)



JWST
Far-IR Mission
ALMA (+Select Far-IR Mission)
Near- & Mid-Infrared
Far-Infrared
Submillimeter
% Transmission (÷ 100)
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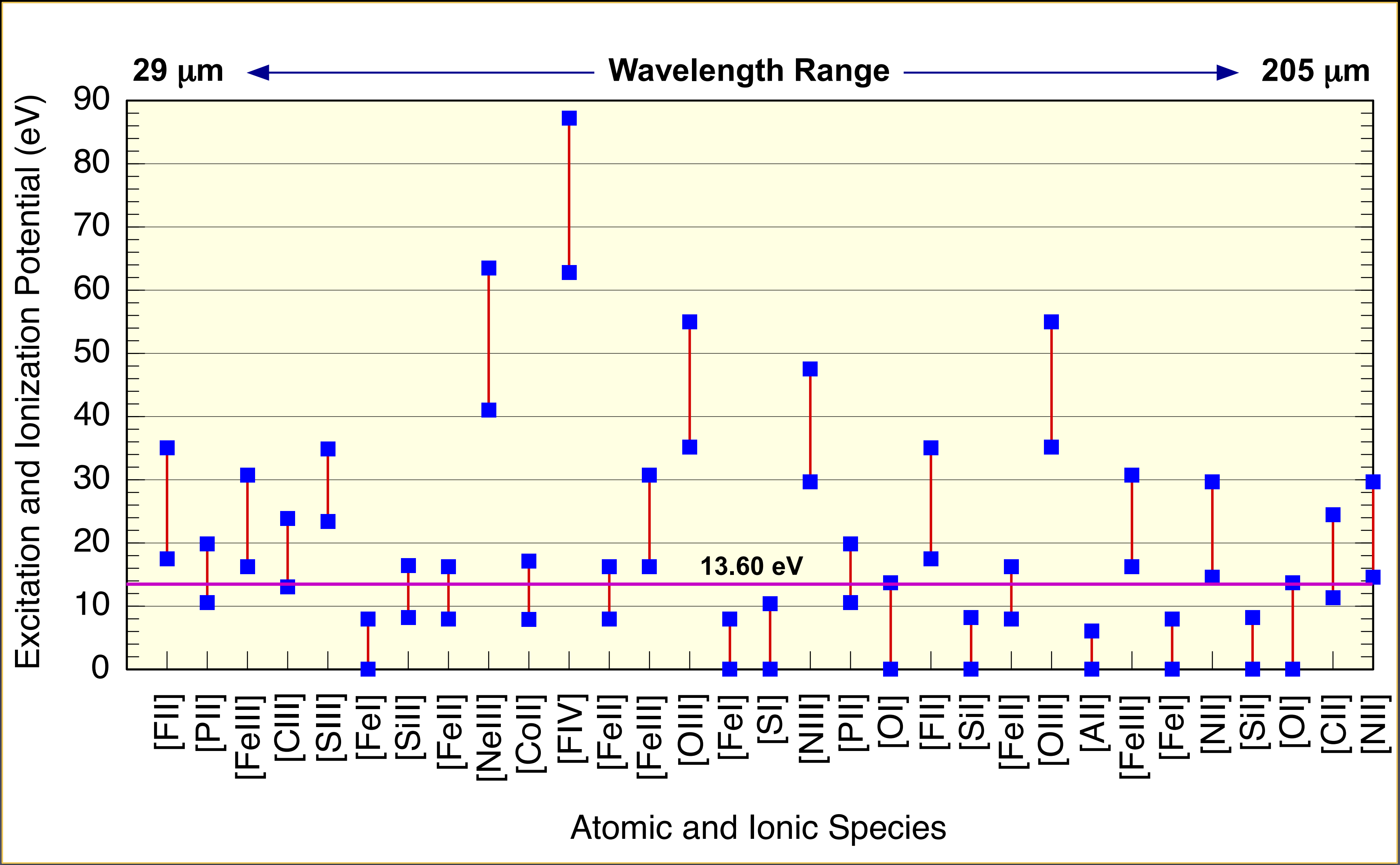
Wavelength (microns)

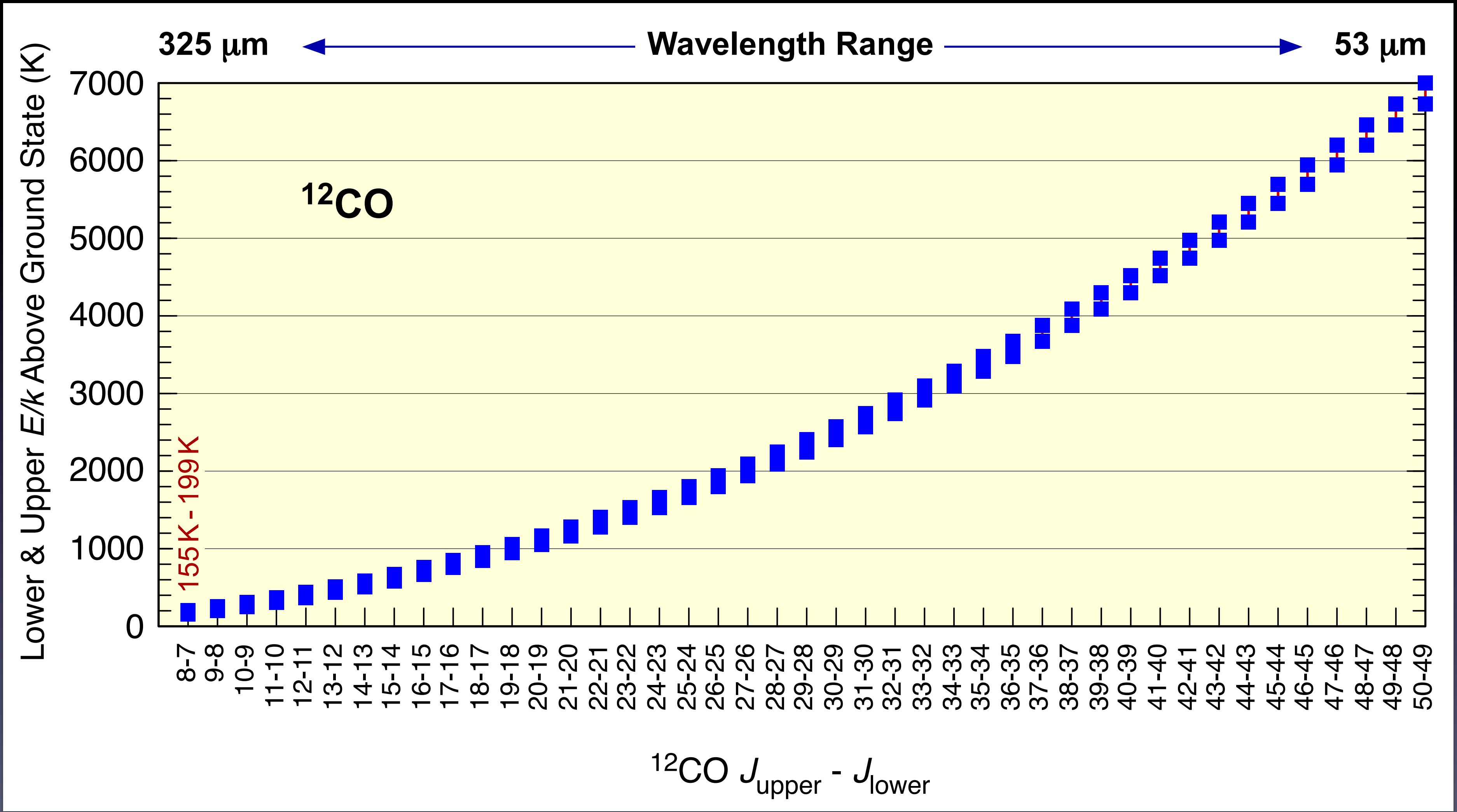
Atomic and Ionic Lines Unique to the Far-Infrared

[F II]	29.33 μm	[N III]	57.32 μm
[P II]	32.87	[P II]	60.64
[Fe III]	33.04	[O I]	63.18
[Cl II]	33.28	[F II]	67.20
[S III]	33.48	[Si I]	68.47
[Fe I]	34.71	[Fe II]	87.38
[Si II]	34.81	[O III]	88.35
[Fe II]	35.35	[Al I]	89.24
[Ne III]	36.01	[Fe III]	105.37
[Co II]	39.27	[Fe I]	111.18
[F IV]	44.07	[N II]	121.90
[Fe II]	51.30	[Si I]	129.68
[Fe III]	51.68	[O I]	145.53
[O III]	51.81	[C II]	157.74
[Fe I]	54.31	[N II]	205.18
[S I]	56.31		

Far-IR Atomic & Ionic Lines Sample a Broad Range of Excitations



Far-IR ^{12}CO Rotational Transitions Sample a Broad Range of Densities & Temperatures in Warm and Hot Gas



CO is an especially powerful probe because…

- CO is relatively abundant ($[^{12}CO]/[H_2] \sim 10^{-4}$)
- Strong line flux (resulting from large Einstein A coefficients)
- Large number of rotational transitions that are sensitive to temperatures from ~ 5 K to > 7000 K
- High critical densities ($\geq 10^6$ cm^{-3}) make CO sensitive to density
- Regions probed by Far-IR Mission are sufficiently warm that CO is undepleted (and, thus, traces H_2)
- The ratio of CO line intensities from different available transitions provide the gas temperature and density independent of the CO abundance and, to first-order, varying beam size (for transitions close in wavelength)
- This is a unique Far-IR Mission strength – ALMA cannot use CO to study gas much warmer than 150 K and JWST operates at too short a wavelength range to use CO

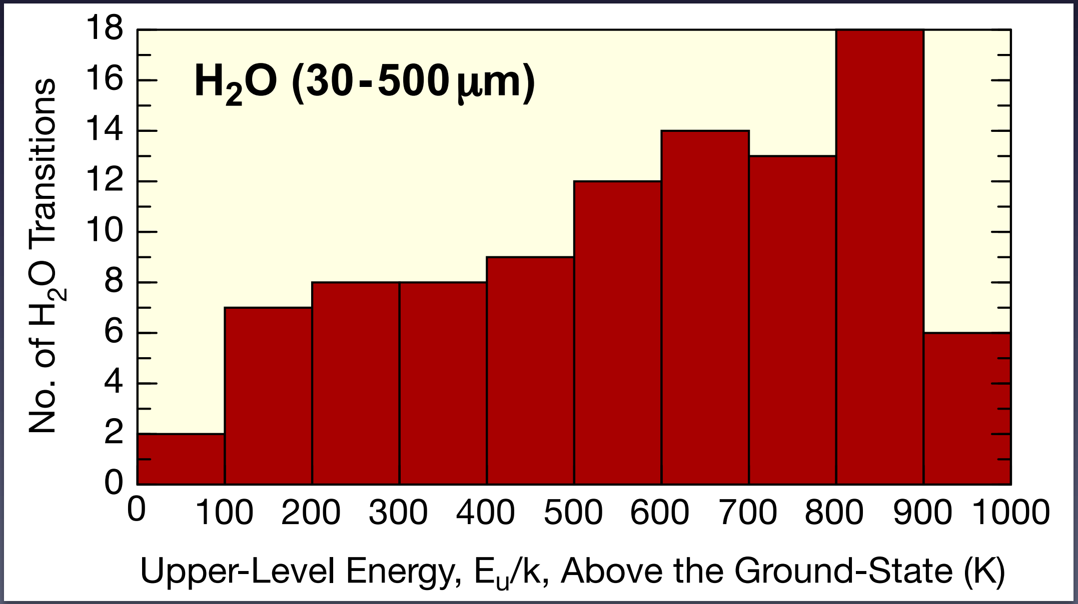
H_2O

The Far-IR Mission has superior access to Galactic (i.e., low Doppler shift) thermal water emission.

JWST: The 1 – 28 μm range contains only 1 H_2O ground-state transition with an upper level ≤ 1000 K above the ground state!

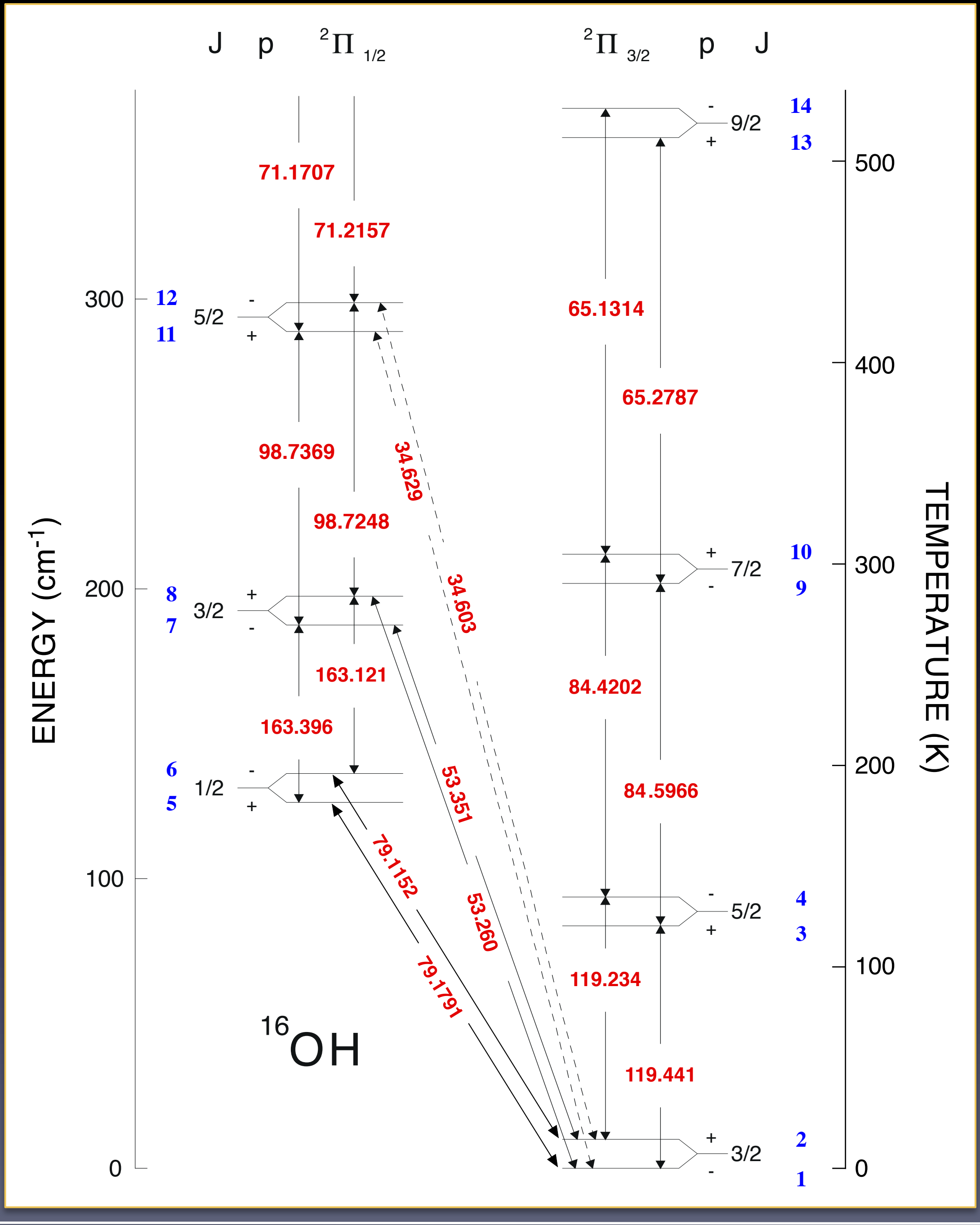
ALMA: The 325 μm – 1 mm range contains 9 H_2O ground-state transitions with an upper level ≤ 1000 K above the ground state, *but all are entirely blocked or suffer from very low atmospheric transmission.*

Far-IR: The 30 μm – 500 μm range contains 97 H_2O ground-state transitions with an upper level ≤ 1000 K above the ground state.



^{16}OH is a powerful diagnostic of dense gas and an important daughter product of H_2O.

ALL of the lowest-lying transitions lie in the far infrared (shown in red in microns).



Hydrogen Deuteride – HD

- HD is an important surrogate for H_2.
- Even though its abundance is ~10^{-5} of H_2, its dipole moment makes it detectable.
- Its lower energy transitions makes HD a better probe of warm (T < 500 K) gas than H_2.
- The lowest lying and most important transitions lie between 28 μm & 112 μm

HD:

Transition	λ (μm)	E_u/k (K)
1–0 R(0)	112.07	128.4
2–1 R(1)	56.23	384.3
3-2 R(2)	37.70	765.9
4–3 R(3)	28.50	1270.7

Redshifted H_2

To obtain the total gas content and cooling within young, high-redshift *(z > 7)* galaxies discovered by JWST (and ALMA) and which have low metallicity, it may be essential to measure redshifted emission from several H_2 transitions.

This will be the exclusive domain of a sufficiently sensitive Far-IR Mission.

Transition	Rest Wavelength (µm)	Redshift that Places H_2 Line Between 30 µm and 320 µm (z)
S(0)	28.2188	0.1 – 10
S(1)	17.0348	0.8 – 18
S(2)	12.2786	1.4 – 25
S(3)	9.6649	2.1 – 32