Warm gas in planet-forming circumstellar disks

(and protostellar envelopes)

viewed with submillimeter spectroscopy

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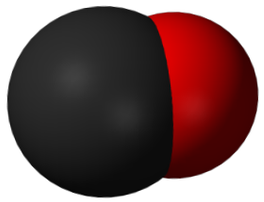
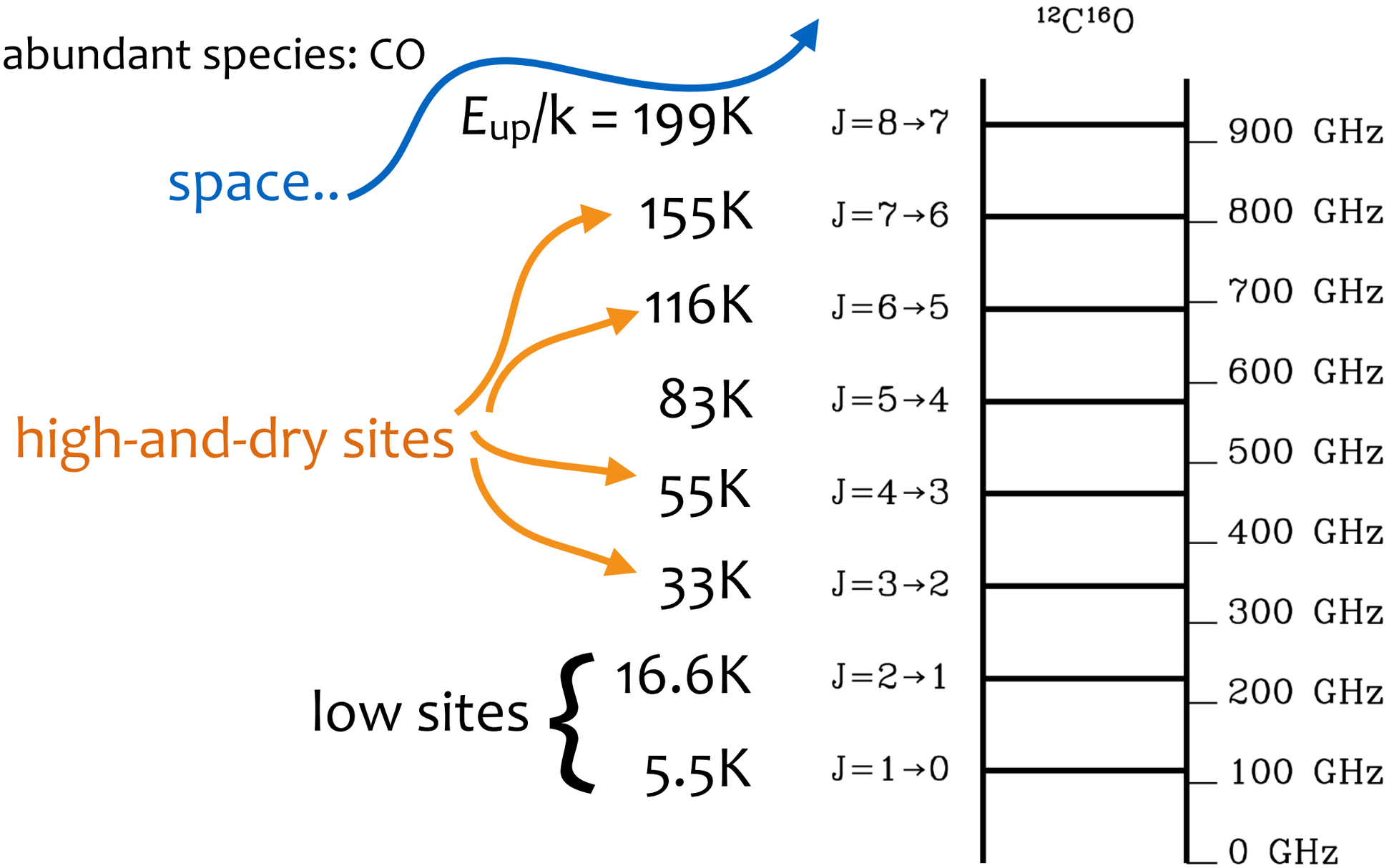
STARPLAN

(image credit: NASA JPL)

introduction: rotational lines trace temperature

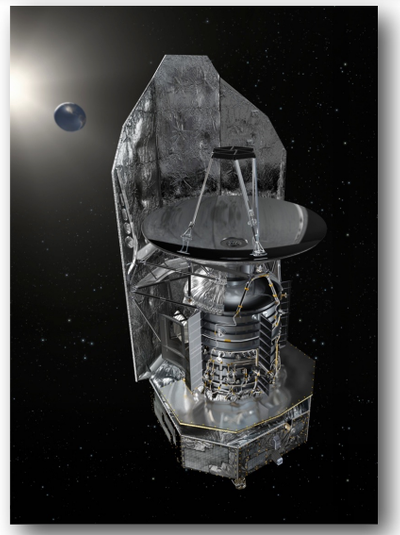
- carbon monoxide (CO) often used as tracer for cold gas
  - H_2 has no dipole moment, rovibrational levels only populated at temperatures above ~10^3 K
  - next most abundant species: CO



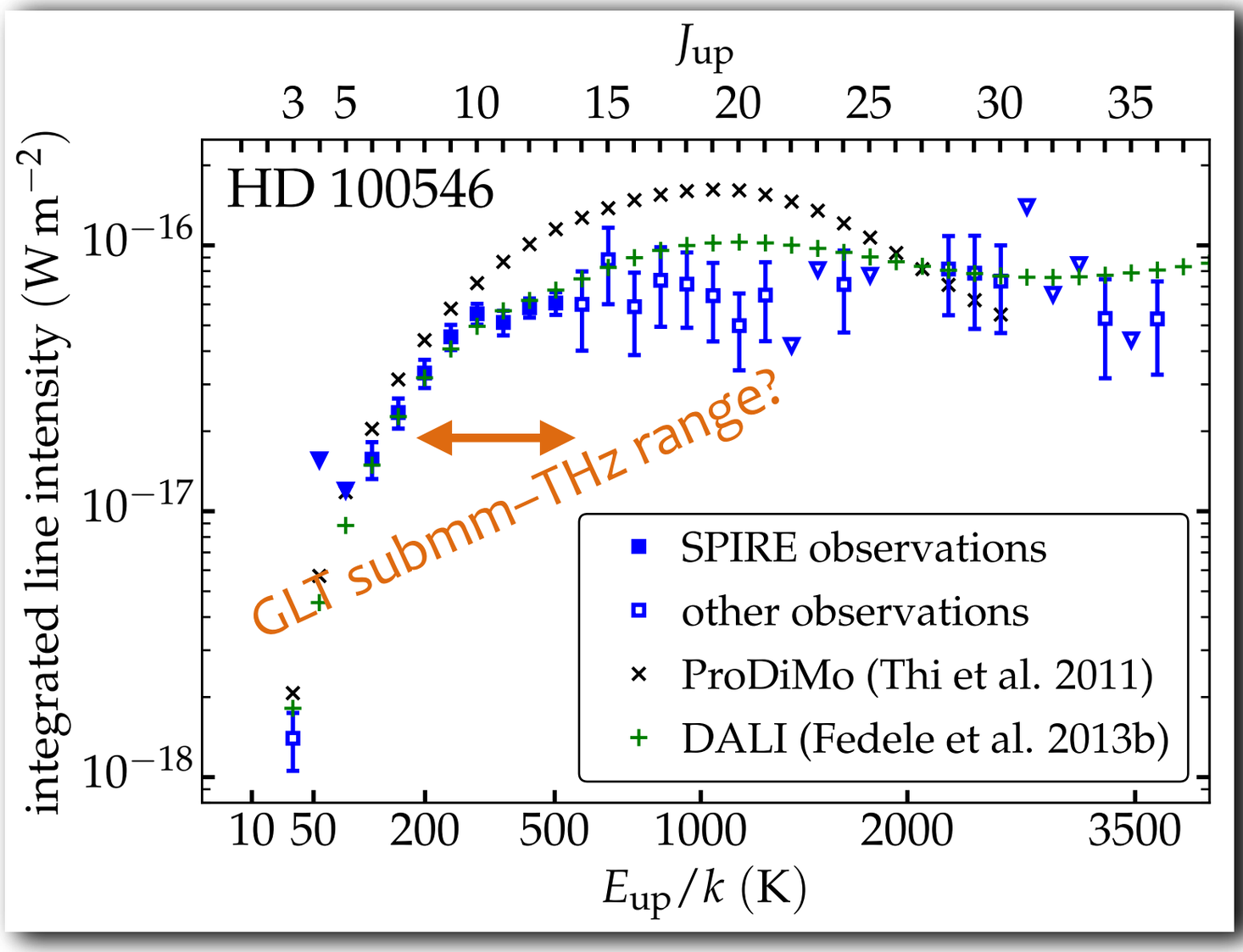


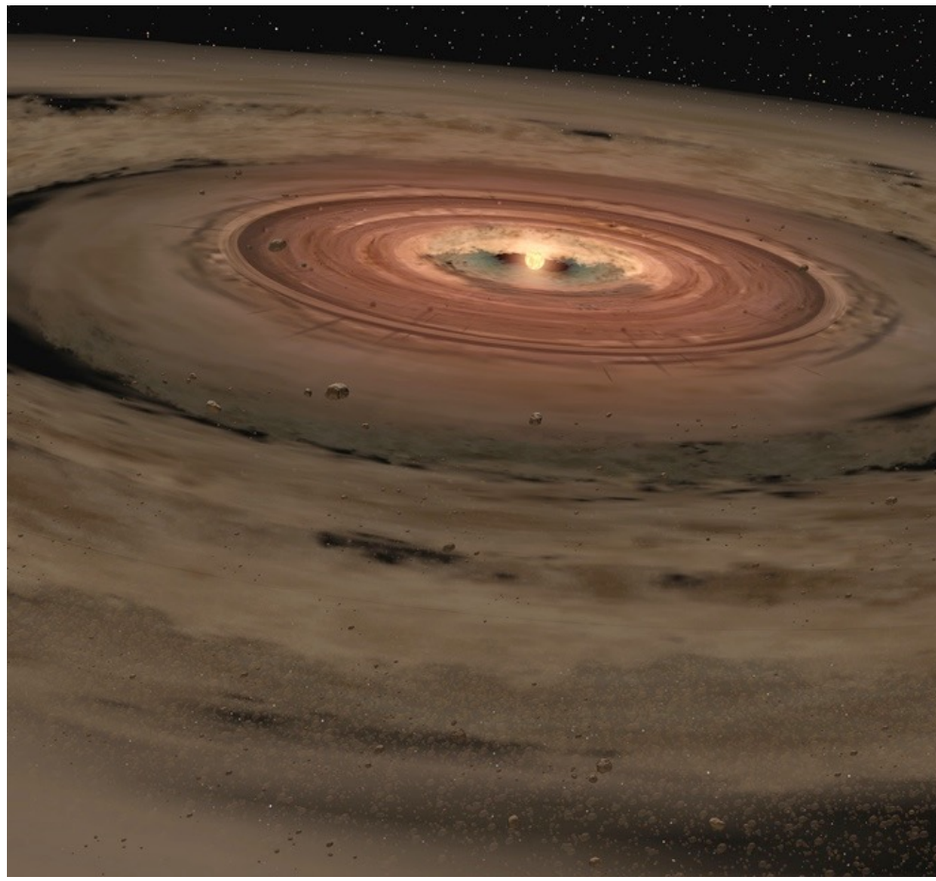
warm gas in planet-forming disks

- protoplanetary disks have a radial temperature gradient
- low-energy CO lines trace outer disk, ~100 au from star
- need higher-energy CO to trace intermediate radii where (massive) planets may form
- a 'sample' of disks was studied at low spectral res. PACS and SPIRE spectrometers on *Herschel* Space Observatory (e.g., Meeus+ 2012, 2013; Van der Wiel+ 2014)
- very few disks studied with high spectral resolution HIFI (Podio+ 2013; Fedele+ 2013b) —> confirmation that line emission is kinematically consistent with disk origin



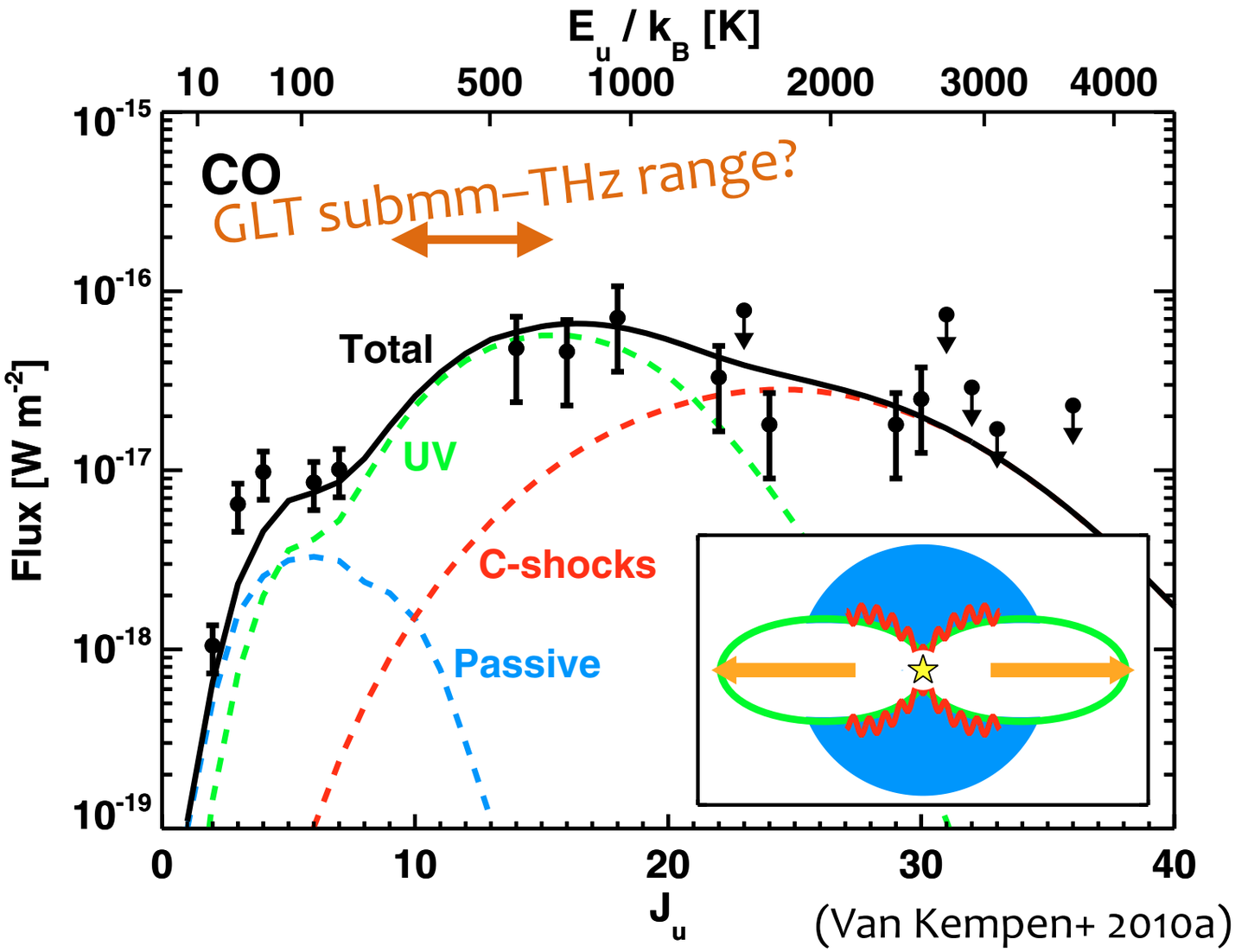
Herschel





Van der Wiel+ (2014)

irradiated / shocked gas in protostellar envelopes

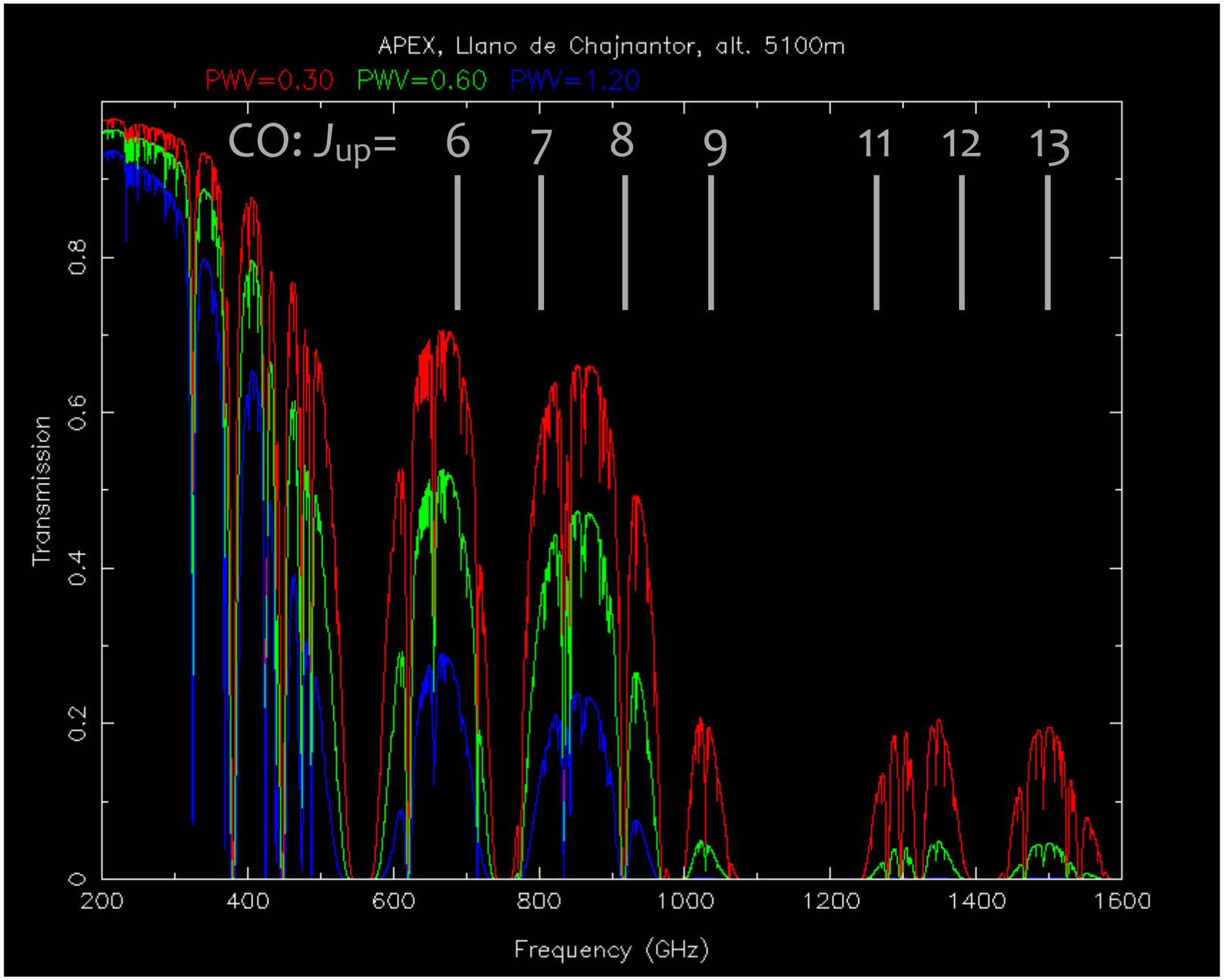


(Van Kempen+ 2010a)

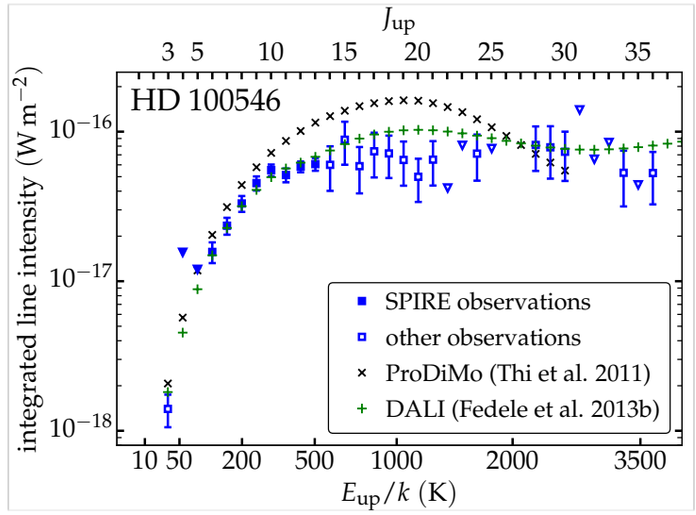
- outflow cavity walls are irradiated and shocked: sparks interesting chemistry
- need high-energy CO lines to study energy balance of such regions
  (e.g., Van Kempen+ 2010a; Yıldız+ 2012, 2013a; Van der Wiel+ 2013)

.. a good THz site on Greenland ..

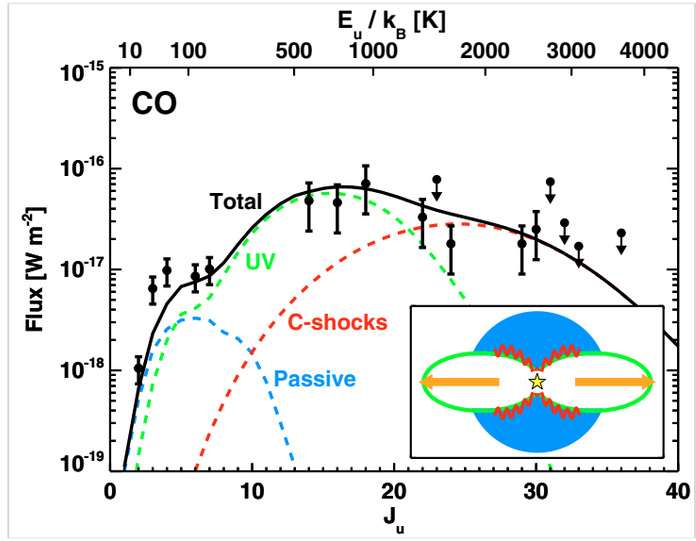
.. could cover a very interesting section of the CO spectral line energy distribution



(APEX site)



(Van der Wiel+ 2014)



(Van Kempen+ 2010a)