Airship Platform for Long-Wavelength Astrophysics

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BENEFITS OF HIGH ALTITUDE (≥ 60,000 ft) AIRSHIP PLATFORM FOR SUBMILLIMETER ASTRONOMY

REDUCED ATMOSPHERIC ABSORPTION

- Improved transmission in so-called airplane windows
- Access to frequencies that are largely opaque at aircraft altitudes
- Significant reduction in atmospheric noise
- Major reduction in system temperatures for heterodyne systems

INCREASED OBSERVING TIME

- Large-scale surveys are enabled

FLEXIBLE LOCATION

- Possible access to ALL of the Galactic Plane (and all of the sky!)

LINE OF SIGHT COMMUNICATION

- Data rate for balllons drifting around the Earth is a real problem: 60 kbps via TDRSS; also expensive

GUSSTO: Proposed ULDB Mission with 16-pixel Focal Plane Arrays for [NII],[CII], and [OI]; 1' Angular Resolution; Observing 23 hr/day

Even with such arrays, LARGE-SCALE GALACTIC PLANE SURVEYS ARE VERY TIME-CONSUMING

Galactic Plane Survey (GPS) Survey $-25^o < l < 25^o$ $-1^o < b < 1^o$ extended to $-2.2^o < b < +2.2^o$ for $|l| < 2^o$ [> 2 million Nyquist-sampled spectra; **39 days**]

[CII] Measure $N(H)=10^{21}$ cm^{-2} in the Galaxy and $2x10^{21}$ cm^{-2} in the LMC, equiv. to a 3σ detectability of $1x10^{-5}$ erg/s/cm2/sr in the Galaxy and half this in LMC for δv = 4 km/s

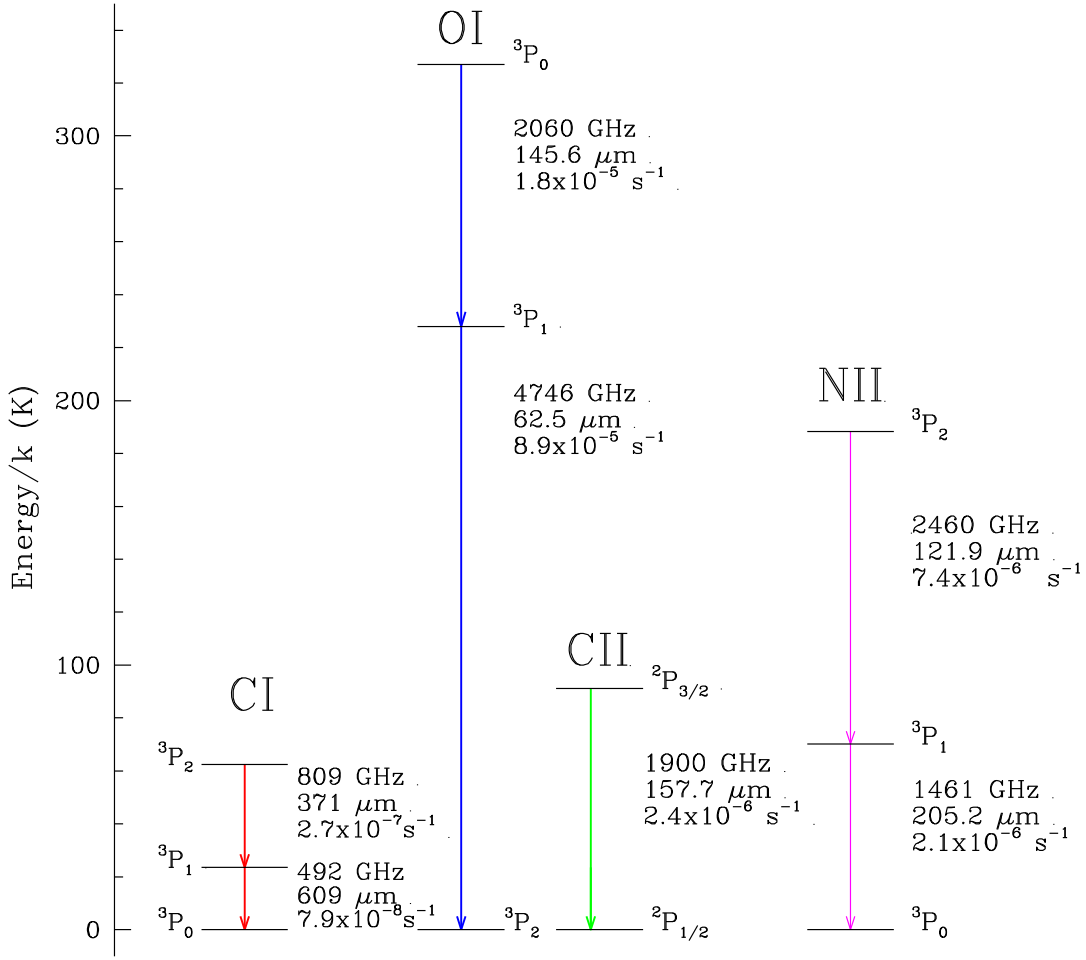
[NII] Measure ionized gas emission measures of >50 pc cm^{-6}, corresponding to a 3σ detectability of $8x10^{-6}$ erg/s/cm2/sr for δv =8 km/s

[OI] Measure column densities in dense gas of N_H=2x1021 cm^{-2}, corresponding to a 3σ detectability of $1x10^{-4}$ erg/s/cm2/sr for δv = 4 km/s

Large Magellanic Cloud Survey (LMCS) Survey 7^o x 7.5^o region covering all of the LMC [> 700,000 Nyquist-sampled spectra; **27 days**]

Targeted Deep Surveys (TDS) Survey selected 1^o x 1^o regions of MW and LMC Measure [OI] at full sptial resolution and [^{13}CII] [5 x 14000 Nyq.-sampled spectra; **20 days**]

Key FIR Fine Structure Lines for Probing the Life Cycle of the ISM & Star Formation



Effect of Atmosphere on Individual Spectral Line Observability

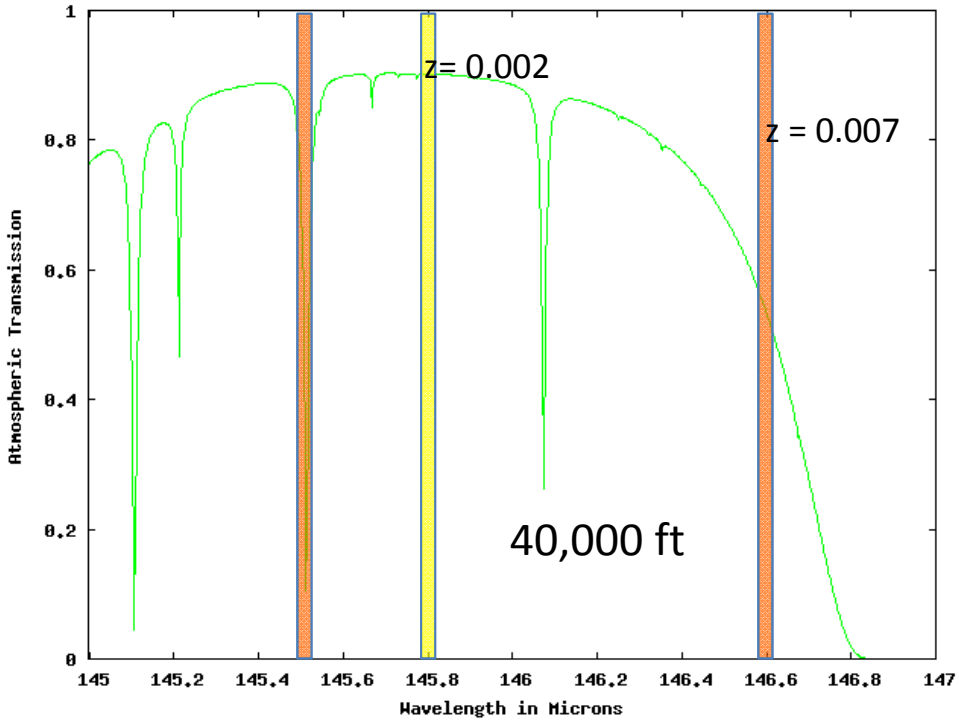
OI $^3P_0 - {}^3P_1$ Line

f = 2060.068 GHz
Λ = 145.53 µm

Not a major cooling line but a potentially valuable diagnostic of PDRs in conjunction with 63 µm $^3P_1 - {}^3P_2$ line

Located on O_3 line! But may be possible to observe albeit with significant penalty

M51 (z = 0.00154) is observable



Milky Way

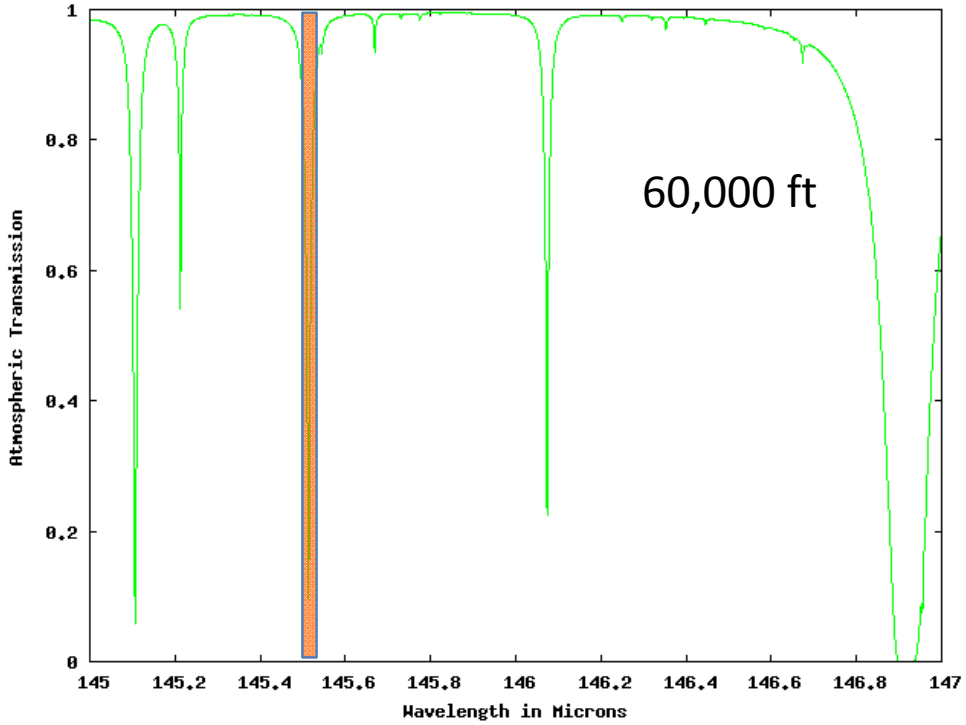
Effect of Atmosphere on Individual Spectral Line Observability

OI $^3P_0 - {}^3P_1$ Line

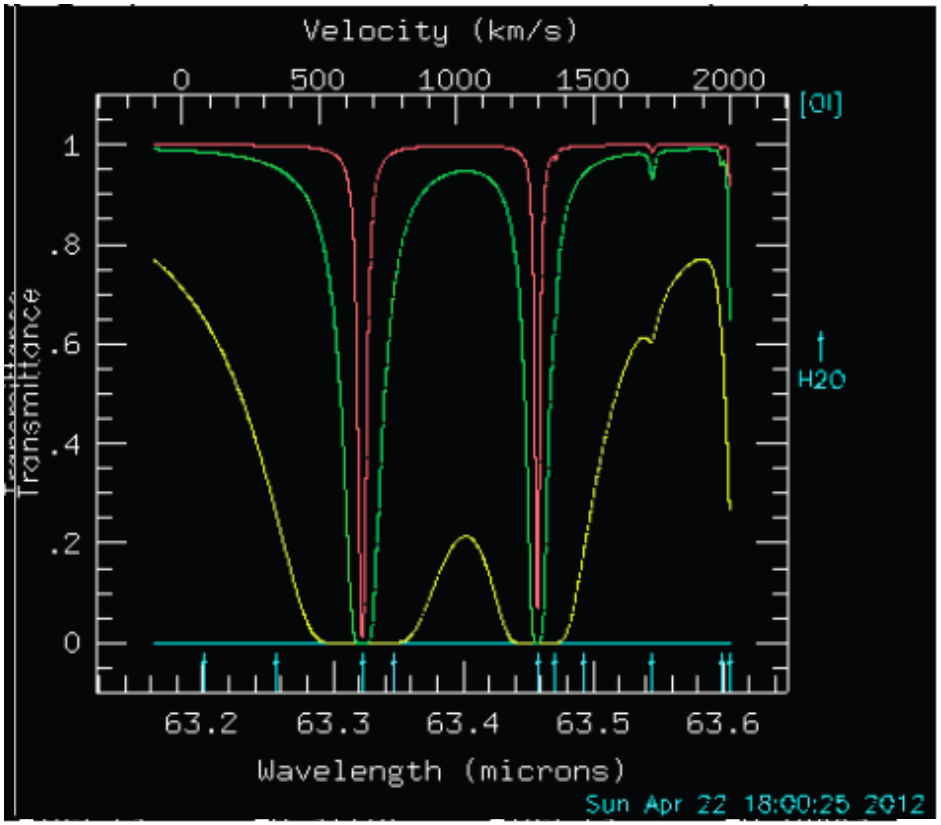
f = 2060.068 GHz
Λ = 145.53 µm

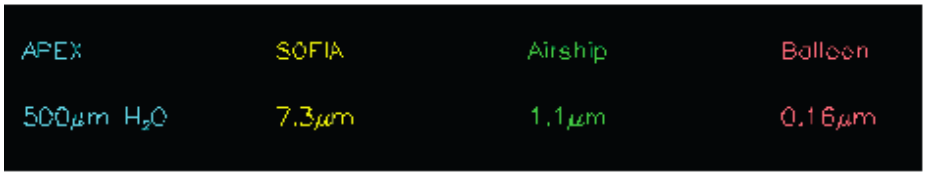
Not a major cooling line but a potentially valuable diagnostic of PDRs in conjunction with 63 µm $^3P_1 - {}^3P_2$ line

Airship altitude is not going to help this much for Millky Way but required redshift to become observable is slightly reduced and redshift range is enlarged



Observability of [OI] 63 µm Line is Severely Limited by the Atmosphere

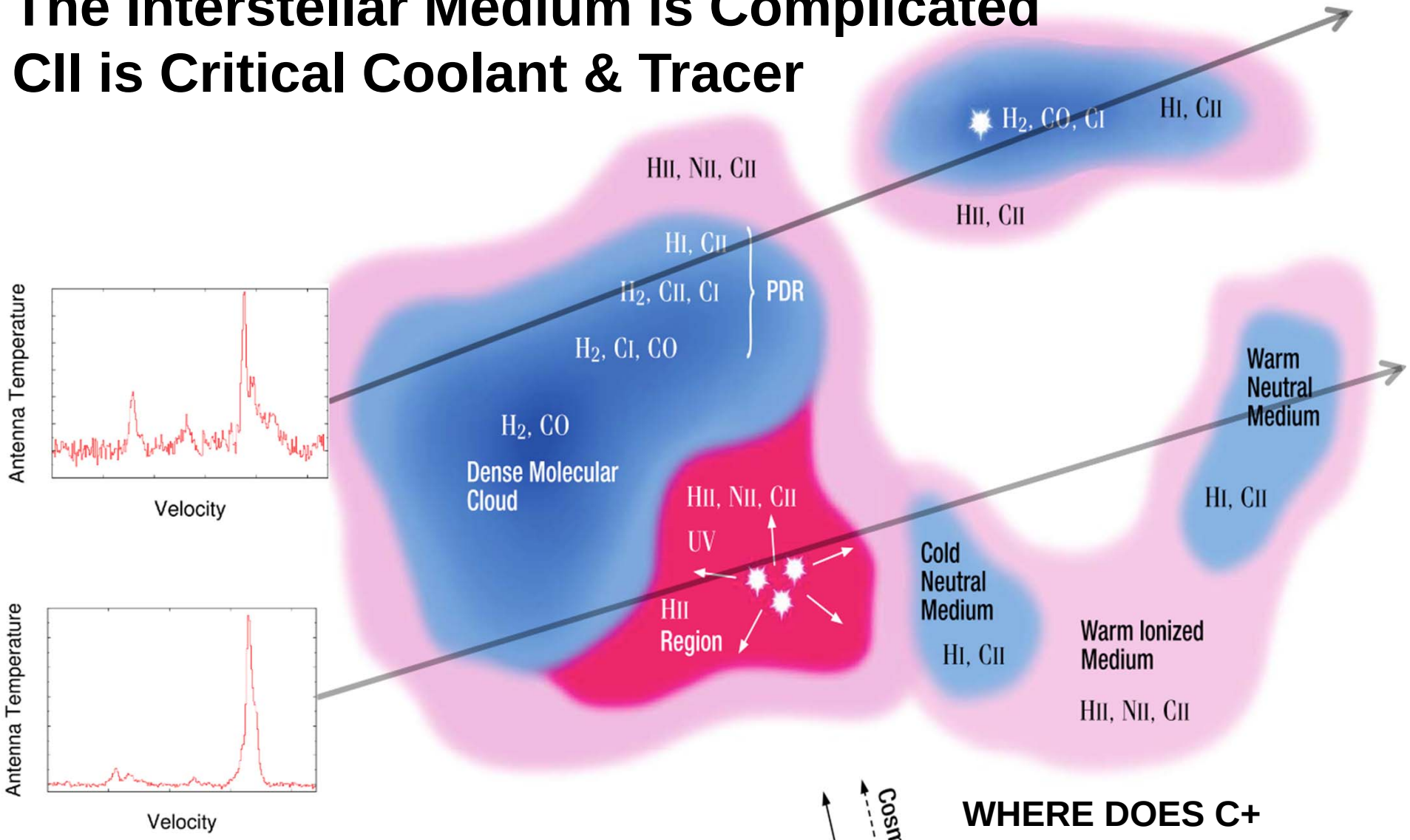




- This is second most important cooling line for ISM and its importance relative to [CII] is of great interest currently
- Observations of Milky Way are hampered by significant attenuation
- This plot is for ZA = 0 deg which is not typical (especially for SOFIA)
- The atmosphere gets much worse at even modestly redshifted velocities
- No observability at all up to several thousand km/s

Thanks to Steve Lord and ATRAN pgm

The Interstellar Medium is Complicated
CII is Critical Coolant & Tracer

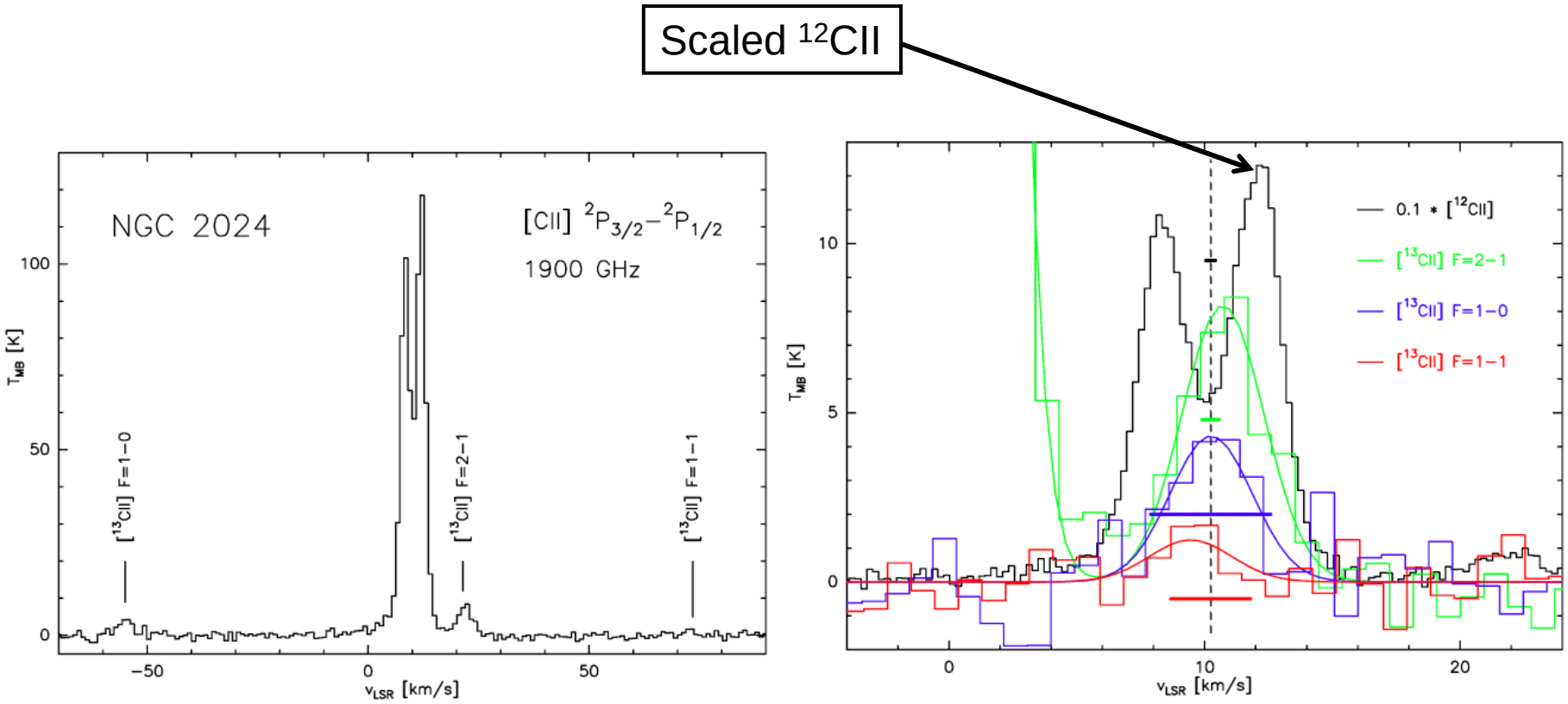


Different Phases Often all Closely Associated with Massive Star Formation

WHERE DOES C+ EMISSION ORIGINATE?

Need velocity-resolved spectroscopy

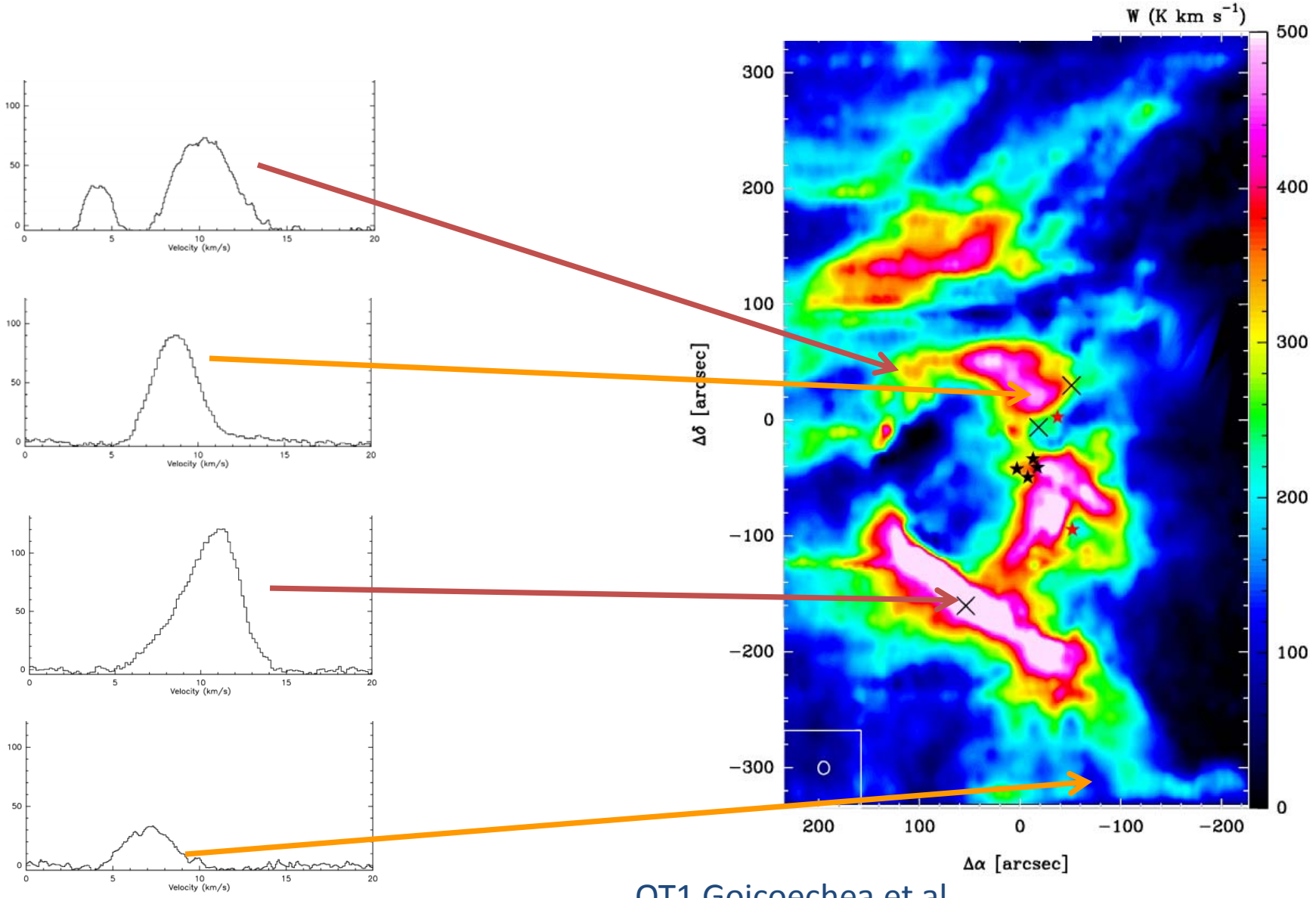
High Spectral Resolution Enables Observation of [^{13}CII] and Correction for Saturation



Graf et al. (2012) using GREAT instrument on SOFIA

UV-irradiated neutral gas
Complex kinematics → line profiles.

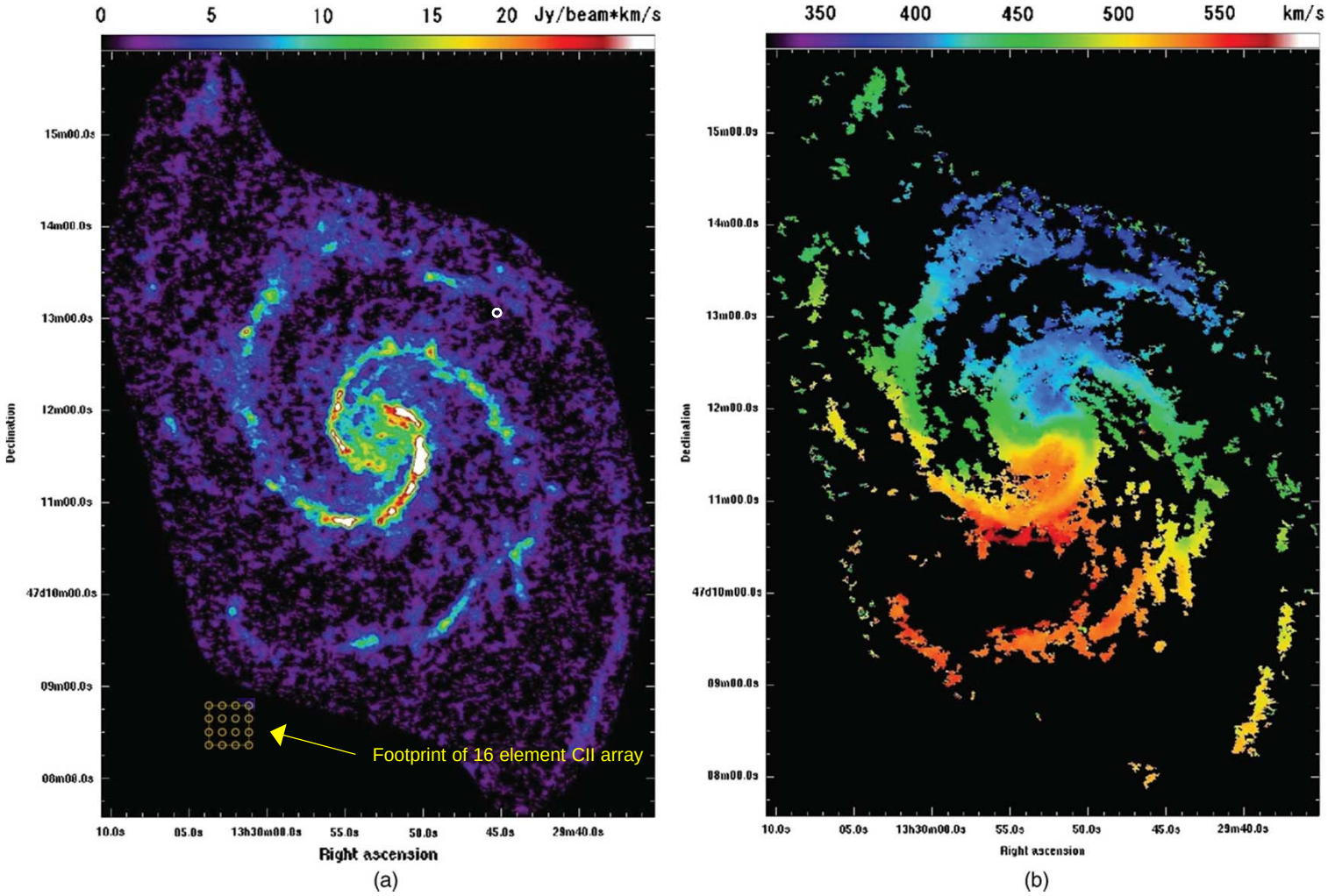
[CII] 1900 GHz
Herschel HIFI 9 hr beam=11.6”



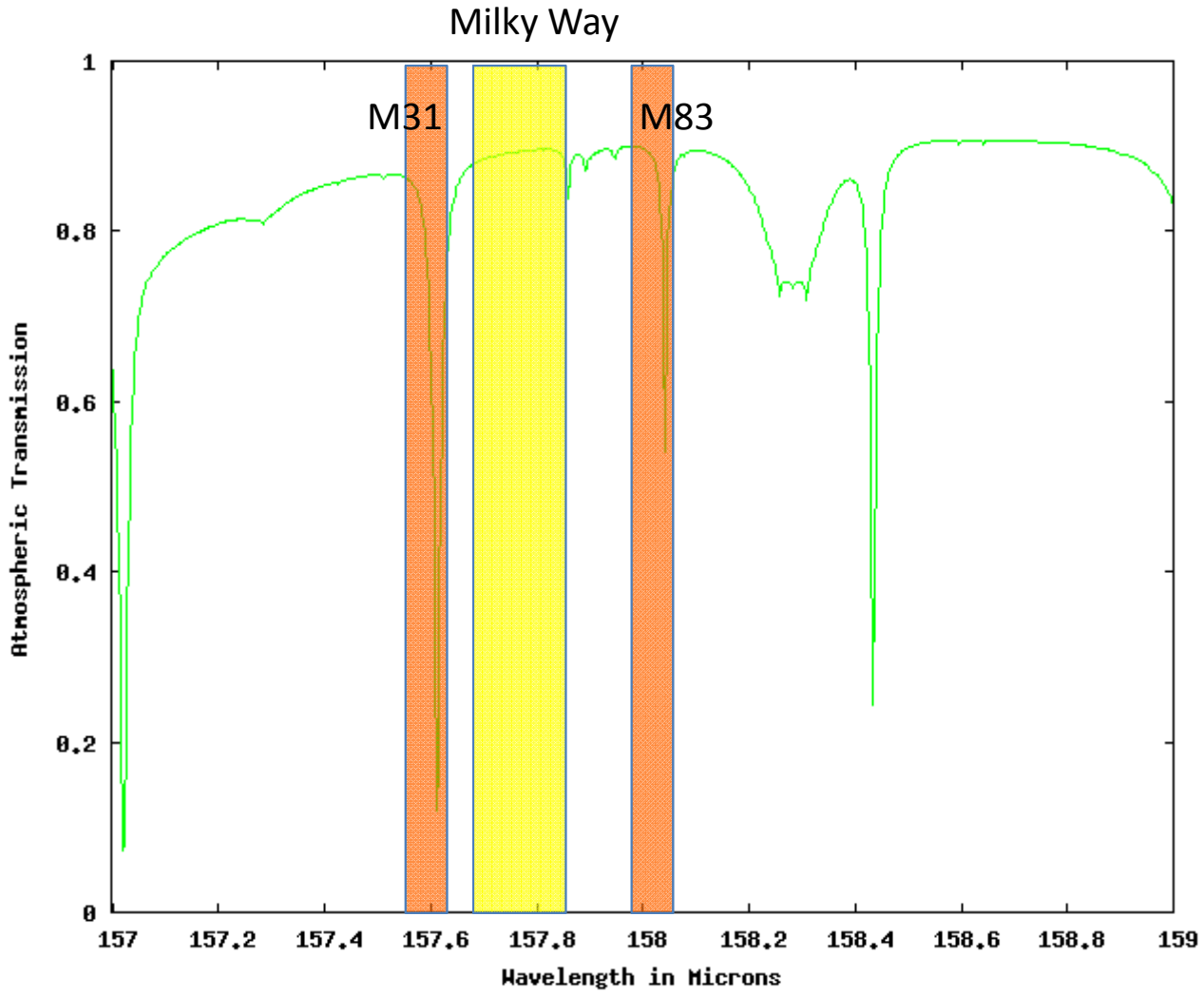
OT1 Goicoechea et al.

M51

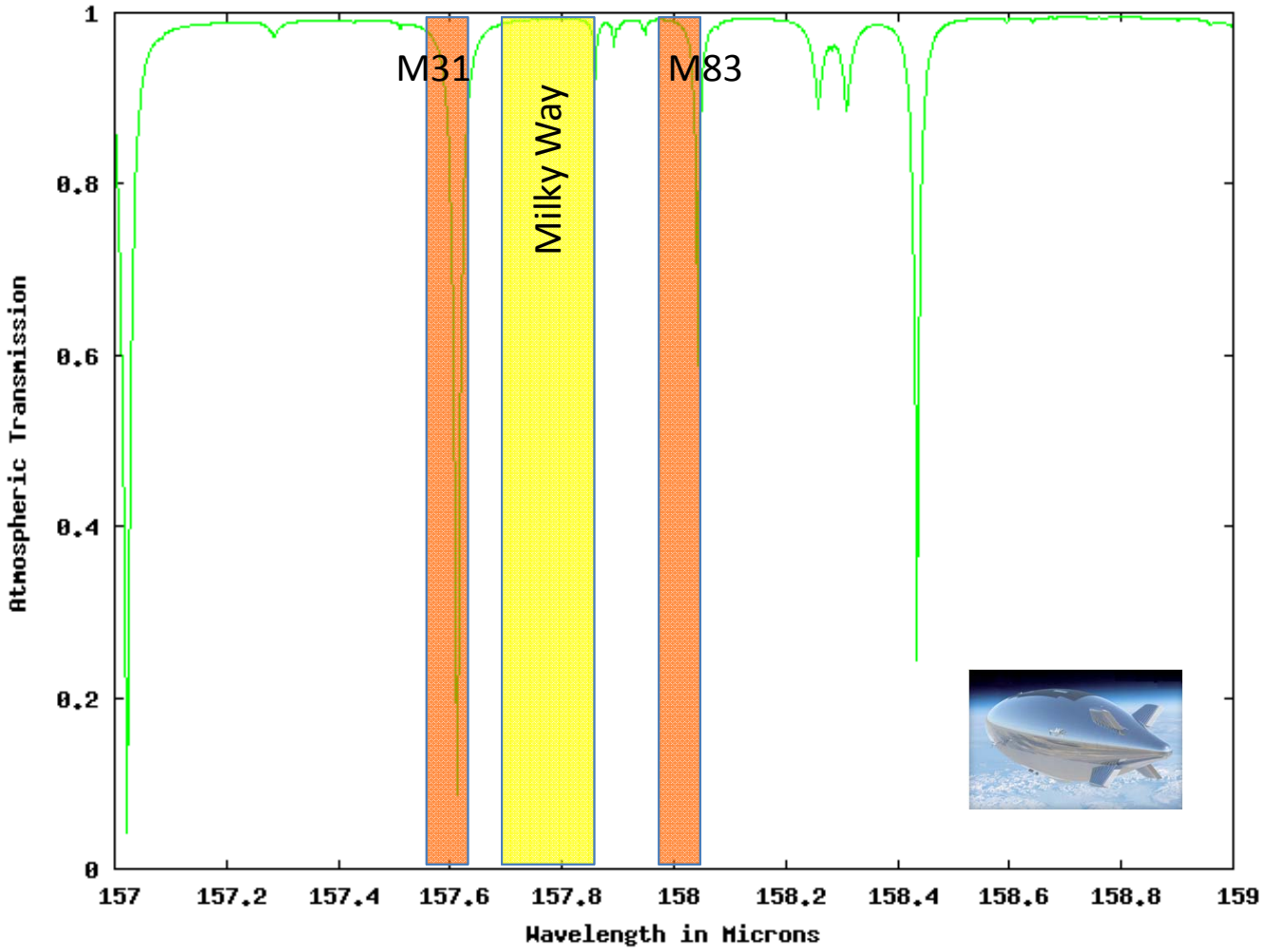
CO J =1-0 4” Resolution (Koda et al. 2009)



Atmospheric Transmission near [CII]
h = 40,000 ft pwv = 8.4 μ ZA = 0°

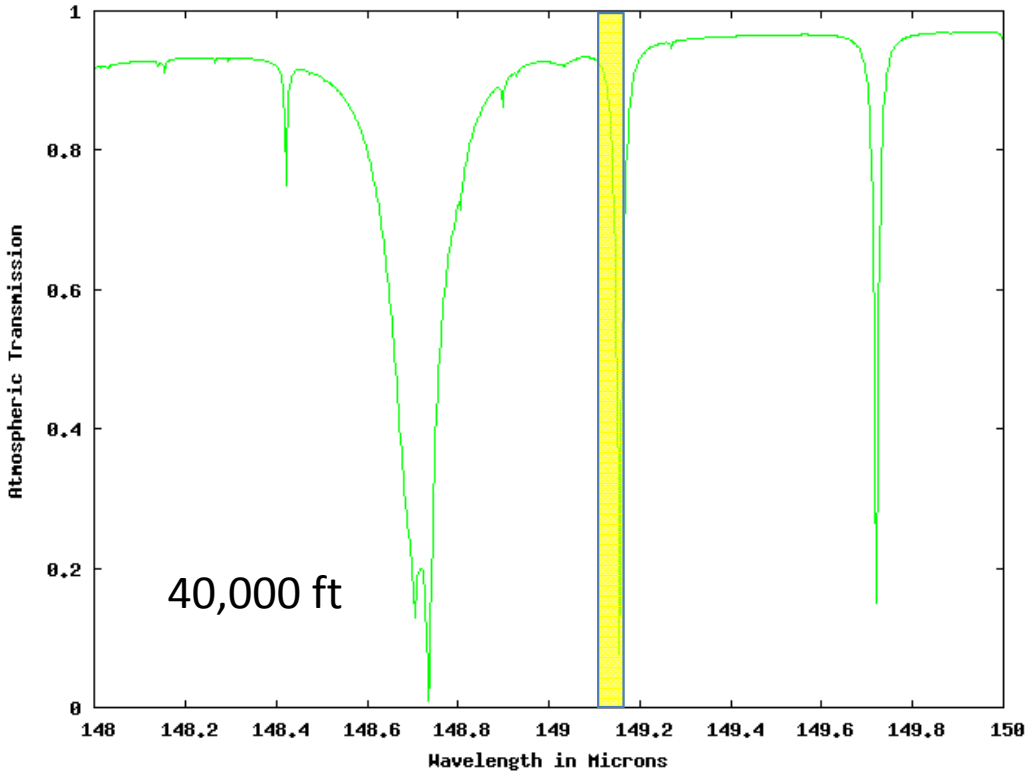


Atmospheric Transmission near [CII]
h = 60,000 ft pwv = 1.4 μ ZA = 0°



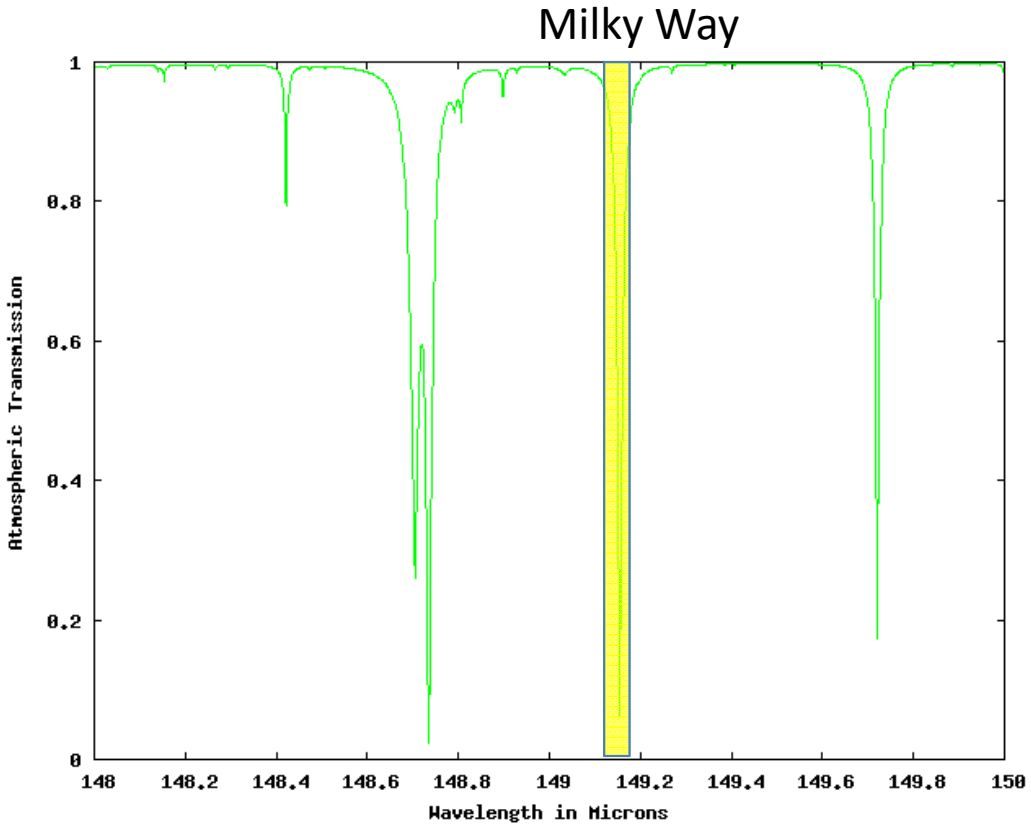
HeH^+ @2010.187 GHz (λ = 149.136 μm)

- This molecular ion is primarily of cosmological interest – it could be one of the first molecules in the universe
- Not yet convincingly detected in a Milky Way HII region, although attempts have been made (ISO)
- At SOFIA altitude an ozone line makes observations within the Milky Way very difficult if not impossible. M31, M33, M33 all doable



HeH^+ Lowest Rotational Transition at 2010.187 GHz (λ = 149.136 µm)

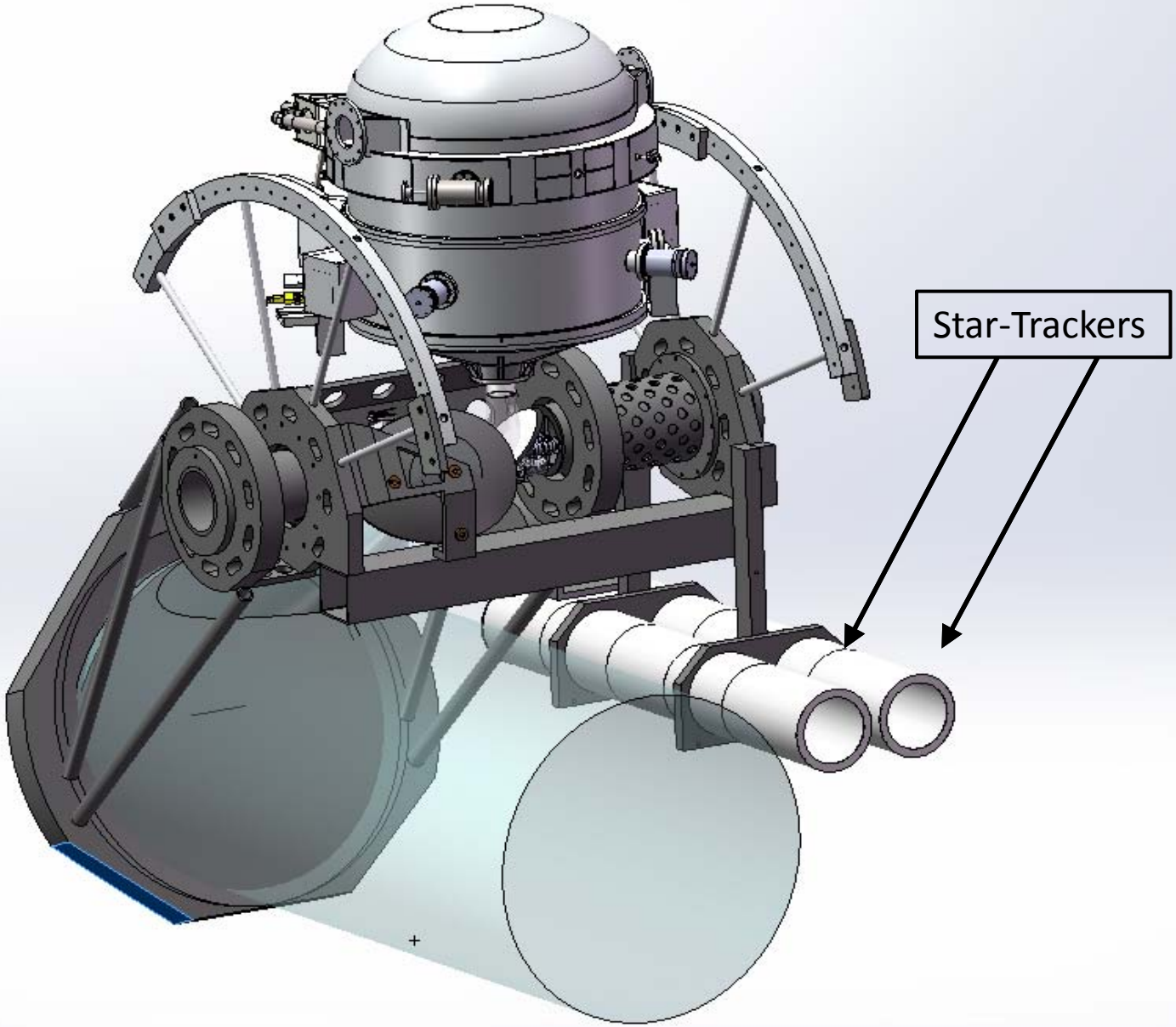
- This molecular ion is primarily of cosmological interest – it could be one of the first molecules in the universe
- Not yet convincingly detected in a Milky Way HII region, although attempts have been made (ISO)
- Airship altitude offers only small advantage: transmission for modest red- and blueshifts is nearly unity
- Requires space for relatively unhindered access



A Notional FIR Airship Observatory

- 10m diameter CFRP antenna
  - Minimum wavelength = 60 μm
  - Smallest beam size = 1”
  - Pointing will be a challenge: need star tracker
  - Equip with large heterodyne focal plane arrays for high resolution spectroscopy AND/OR
  - Equip with continuum cameras AND/OR
  - Equip with polarimeter
- Could obviously be reduced size
- Need serious study of capability of Airship in terms of lifting capacity, stability, pointing, power available

Off-Axis 1m CFRP Telescope (GUSSTO Balloon)



Long-Wavelength Astrophysics Benfiting from Airship Platform

- Spectral Line Surveys
  - Partially blocked lines observable and significantly higher sensitivity available
- Continuum Surveys
  - less dramatic improvement since wavelength relatively flexible; high-Galactic latitude surveys
- CMB Observations
  - Large sky coverage at high (?) resolution
- Polarimetry
  - Time-consuming from ground and could be significantly improved from airship