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 balloons drifting around the Earth is a real problem: 60 kbps via TDRSS; also expensive
Even with such arrays, LARGE-SCALE GALACTIC PLANE SURVEYS ARE VERY TIME-CONSUMING

**Galactic Plane Survey (GPS)** Survey -25° < l < 25° -1° < b < 1° extended to -2.2° < b < +2.2° for |l| < 2° [> 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}=2x10^{21} 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° x 7.5° region covering all of the LMC [> 700,000 Nyquist-sampled spectra; **27 days**]

**Targeted Deep Surveys (TDS)** Survey selected 1° x 1° regions of MW and LMC Measure [OI] at full spatial resolution and [^{13}CII] [5 x 14000 Nyq.-sampled spectra; **20 days**]
Key FIR Fine Structure Lines for Probing the Life Cycle of ISM & Star Formation

- **OI**
  - $^3P_0$ to $^3P_1$
  - Energy: 2060 GHz
  - Wavelength: 145.6 $\mu$m
  - Rate: $1.8 \times 10^{-8}$ s$^{-1}$

- **NII**
  - $^3P_2$ to $^3P_1$
  - Energy: 2460 GHz
  - Wavelength: 121.9 $\mu$m
  - Rate: $7.4 \times 10^{-8}$ s$^{-1}$

- **CI**
  - $^3P_2$ to $^3P_1$
  - Energy: 809 GHz
  - Wavelength: 371 $\mu$m
  - Rate: $2.7 \times 10^{-7}$ s$^{-1}$

- **CII**
  - $^2P_{3/2}$ to $^2P_{1/2}$
  - Energy: 1900 GHz
  - Wavelength: 157.7 $\mu$m
  - Rate: $2.4 \times 10^{-8}$ s$^{-1}$

- **CII**
  - $^3P_1$ to $^3P_0$
  - Energy: 1461 GHz
  - Wavelength: 205.2 $\mu$m
  - Rate: $2.1 \times 10^{-8}$ s$^{-1}$
Effect of Atmosphere on Individual Spectral Line Observability

**OI $^{3}P_{0} - ^{3}P_{1}$ Line**

- $f = 2060.068 \text{ GHz}$
- $\Lambda = 145.53 \mu\text{m}$

Not a major cooling line but a potentially valuable diagnostic of PDRs in conjunction with 63 $\mu\text{m}$ $^{3}P_{1} - ^{3}P_{2}$ line

Located on O$_{3}$ line! But may be possible to observe albeit with significant penalty

M51 ($z = 0.00154$) is observable
Effect of Atmosphere on Individual Spectral Line Observability

OI $^3P_0 - ^3P_1$ Line

$f = 2060.068$ GHz  
$\Lambda = 145.53$ $\mu$m

Not a major cooling line but a potentially valuable diagnostic of PDRs in conjunction with 63 $\mu$m $^3P_1 - ^3P_2$ line

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

60,000 ft
Effect of Atmosphere on Individual Spectral Line Observability

**OI \( ^3P_0 - ^3P_1 \) Line**

\[ f = 2060.068 \text{ GHz} \]
\[ \Lambda = 145.53 \text{ \( \mu \)m} \]

Not a major cooling line but a potentially valuable diagnostic of PDRs in conjunction with 63 \( \mu \)m \( ^3P_1 - ^3P_2 \) line

Airship altitude is not going to help this much for Milky 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
Atmospheric Transmission near [CII]

$h = 40,000 \text{ ft} \quad \text{pwv} = 8.4 \mu \quad ZA = 0^\circ$

![Graph showing atmospheric transmission near CII with wavelengths in microns and transmission values ranging from 0 to 1. The graph includes markers for M31 and M83.](image)
Atmospheric Transmission near [CII]

$h = 60,000 \text{ ft} \quad \text{pwv} = 1.4 \mu \quad ZA = 0^\circ$
Another: HeH\(^+\) @2010.187 GHz (\(\lambda = 149.136\) 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.
An Important Molecular Ion: HeH$^+$ Lowest Rotational Transition at 2010.187 GHz ($\lambda = 149.136$ 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.
Long-Wavelength Astrophysics Benefitting 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-latitude surveys

• CMB Observations
  – Large sky coverage at high (?) resolution

• Polarimetry
  – Time-consuming from ground and could be significantly improved from airship