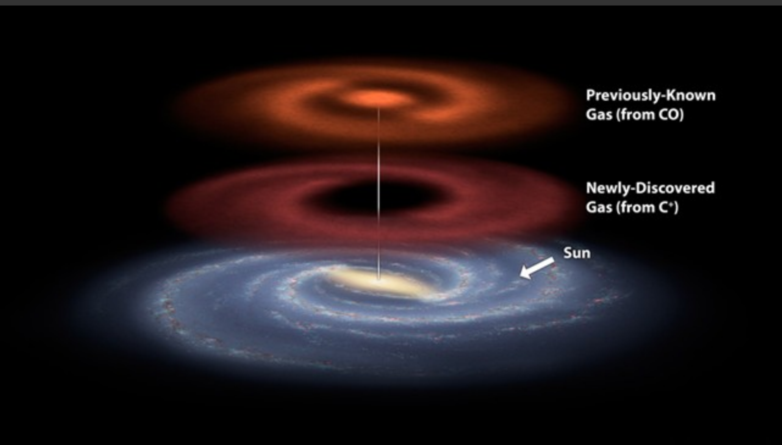
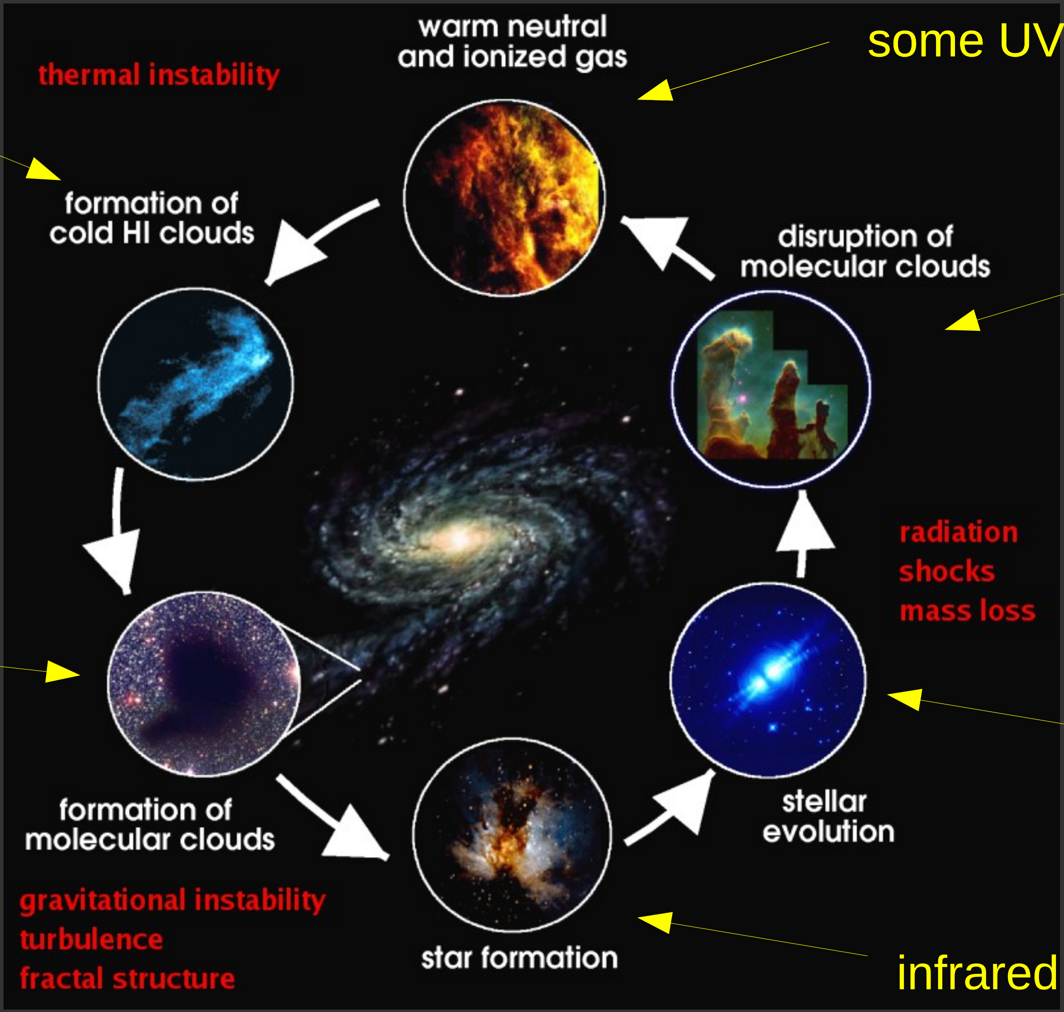


Terahertz (THz) Astronomy from Antarctica

New opportunities for groundbreaking science

The Life Cycle of matter in the Galaxy remains poorly understood.



21 cm radio

some UV, X-rays

??

??

visible light

infrared and mm waves

We need to see how material cycles between gas and stars to understand the origin of stars & planets and the evolution of entire galaxies!

Questions we want to answer

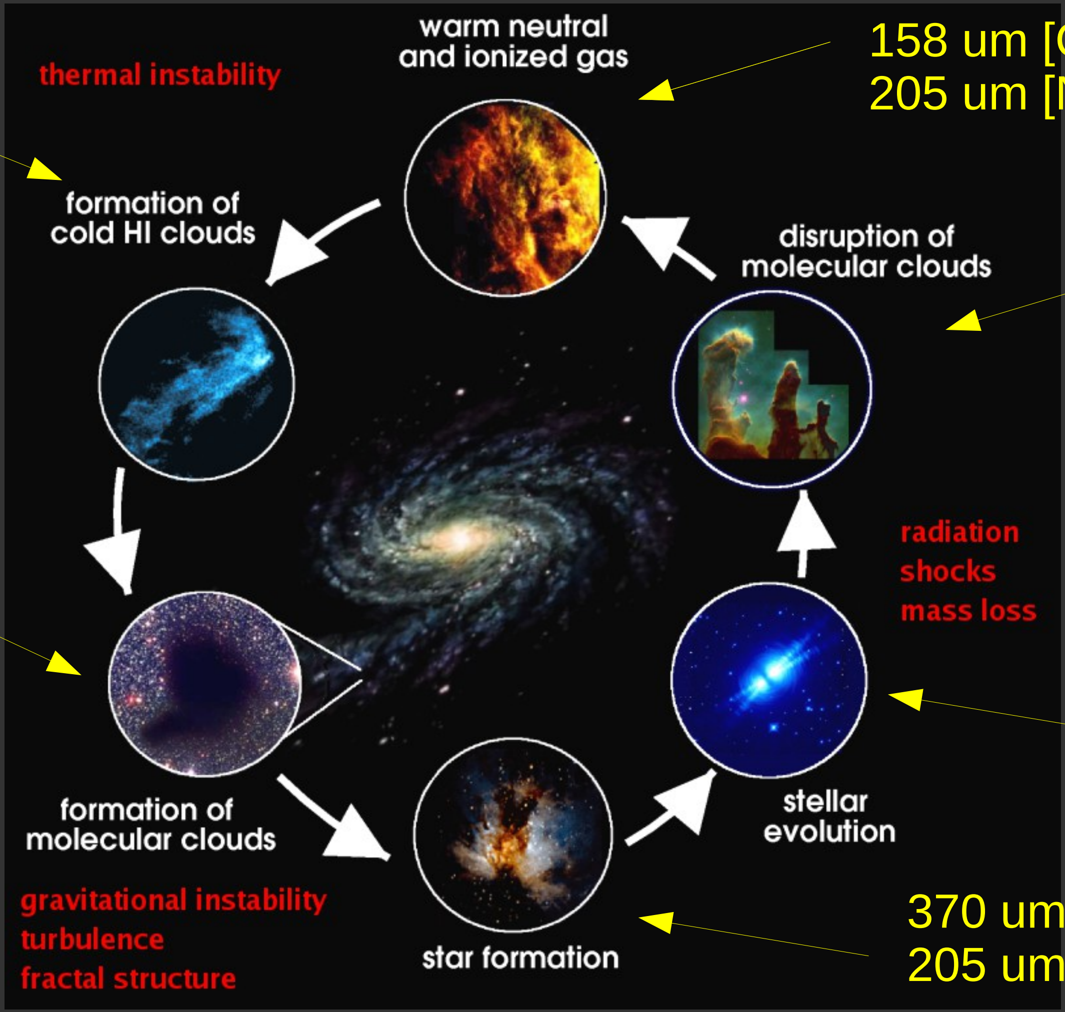
- How and where are interstellar clouds made, and how long do they live?
- Under what conditions do clouds form stars?
- How do stars return enriched material back to the Galaxy?
- How do these processes sculpt the evolution of galaxies, near and far?

We need a new tool to explore the cosmos – to see the universe in a different (far infrared) light

These questions can be well studied in the far-infrared...

158 um [CII]

158 um [CII]
205 um [NII]



158 um [CII]
370 um [CI]

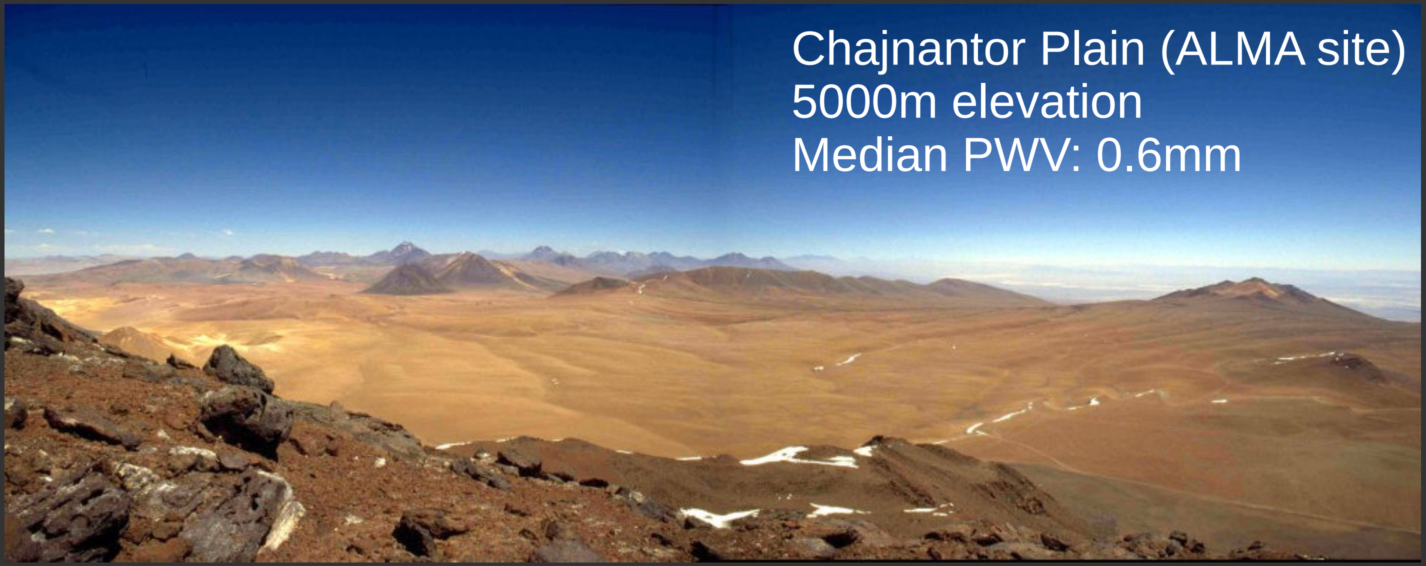
158 um [CII]
370 um [CI]

visible light

370 um [CI] and CO
205 um [NII]

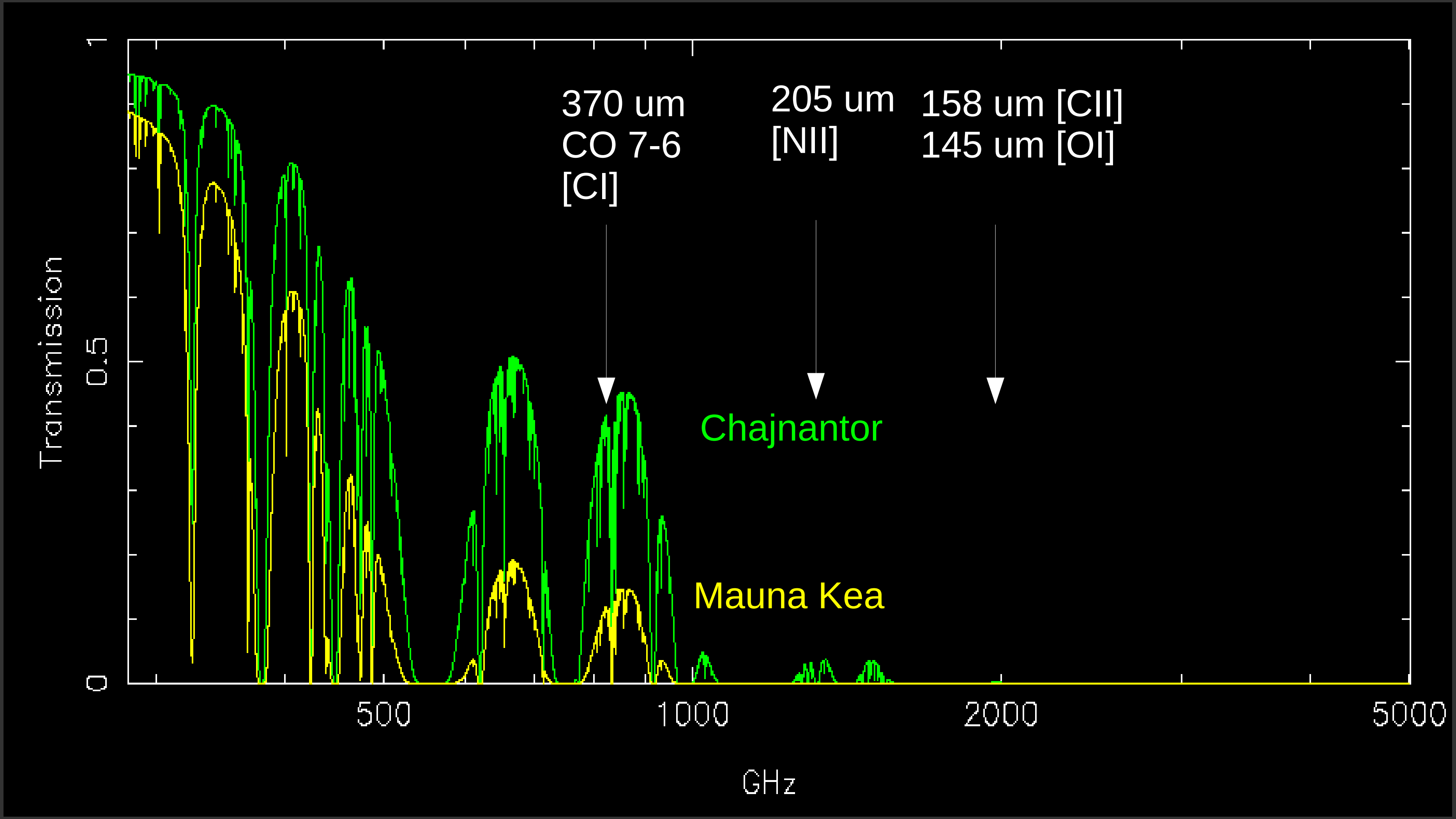
Large-scale THz imaging and spectroscopy of carbon, nitrogen & oxygen is needed to observe the **full life cycle**!

Established THz Observing Sites...



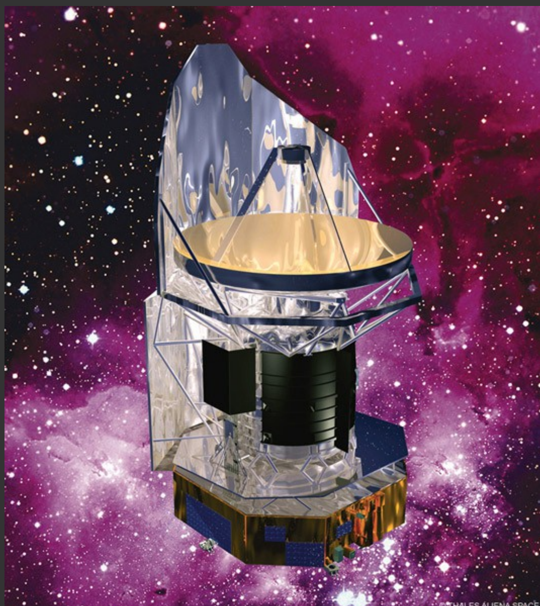
… are simply not good enough.

We need to go higher, drier, and colder...



(Sub)orbital Platforms for THz Astronomy

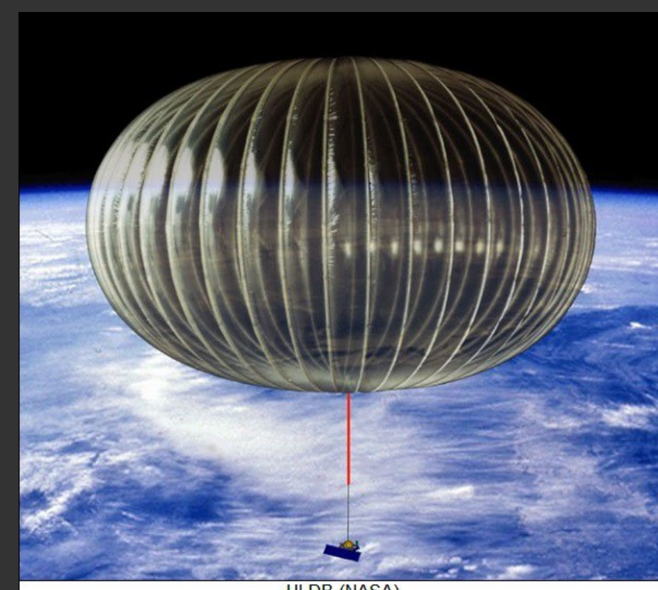
Expensive, w/ limited access and observing time



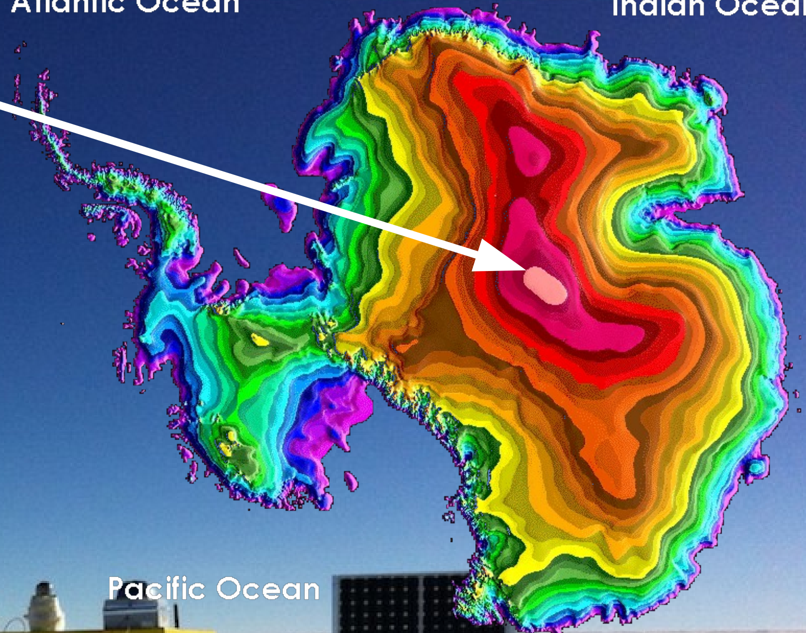
Herschel (2009-2013)
3.5m aperture at L2
$120,000 / hr

SOFIA (2010-2020+)
2.5m aperture at 12 km
$100,000 / hr...
...if it can fly 1000 hr/yr

Long duration balloons
1m aperture at 35 km
$15-25,000 / hr
14-30 day missions


ULDB (NASA)

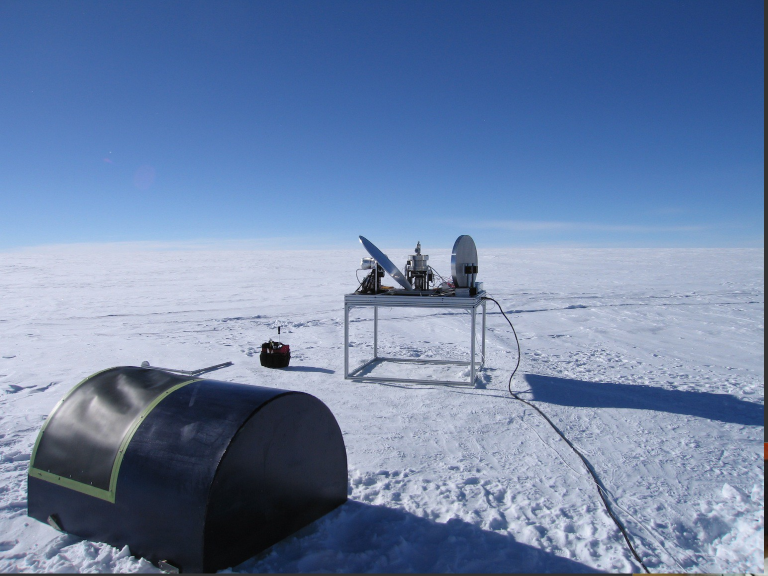
Antarctica's role as a pivotal THz platform



- 1 meter-class robotic telescope at 4.7 km pressure altitude
- Submillimeter (< 1 THz) observing conditions all of the time
- Super-THz (>1.5 THz) observing conditions 25% of the time
- By far the best THz transmission and stability on Earth
- You can land a Twin Otter aircraft at Ridge A
- **~$100 / hr observing time!**

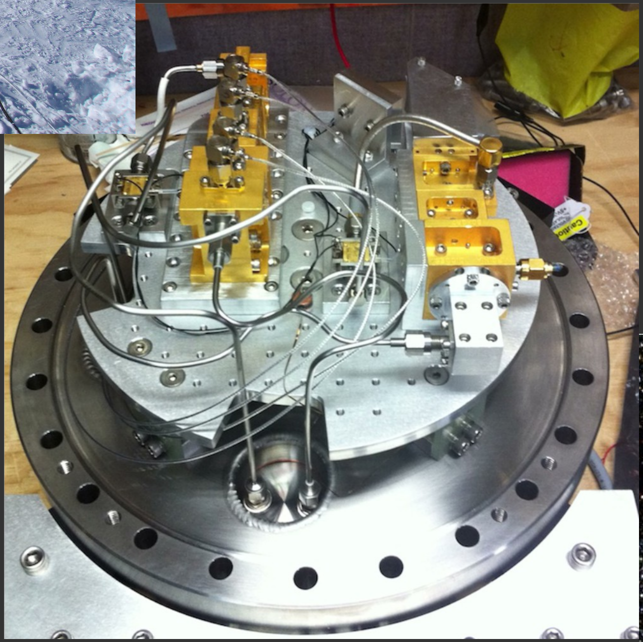
High Elevation Antarctic Terahertz (HEAT) telescope

prototype telescope deployed in 2012 to Ridge A with PLATO-R

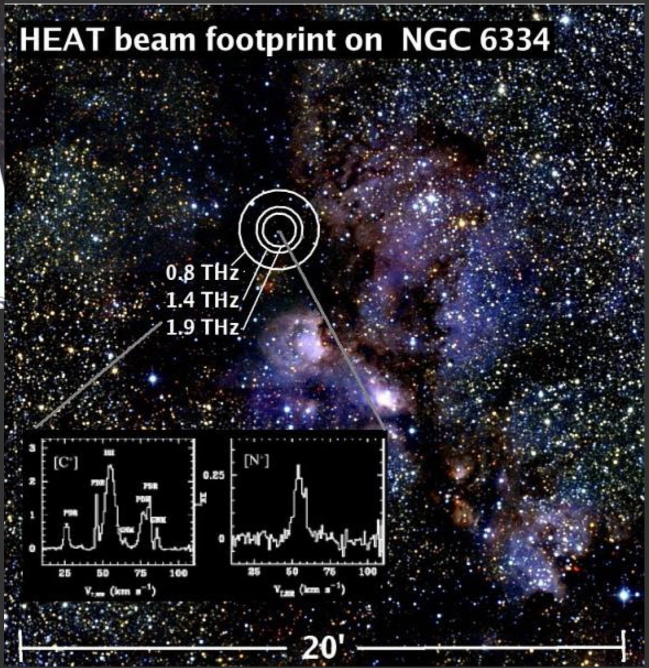


HEAT is...

… a 62 cm off-axis telescope

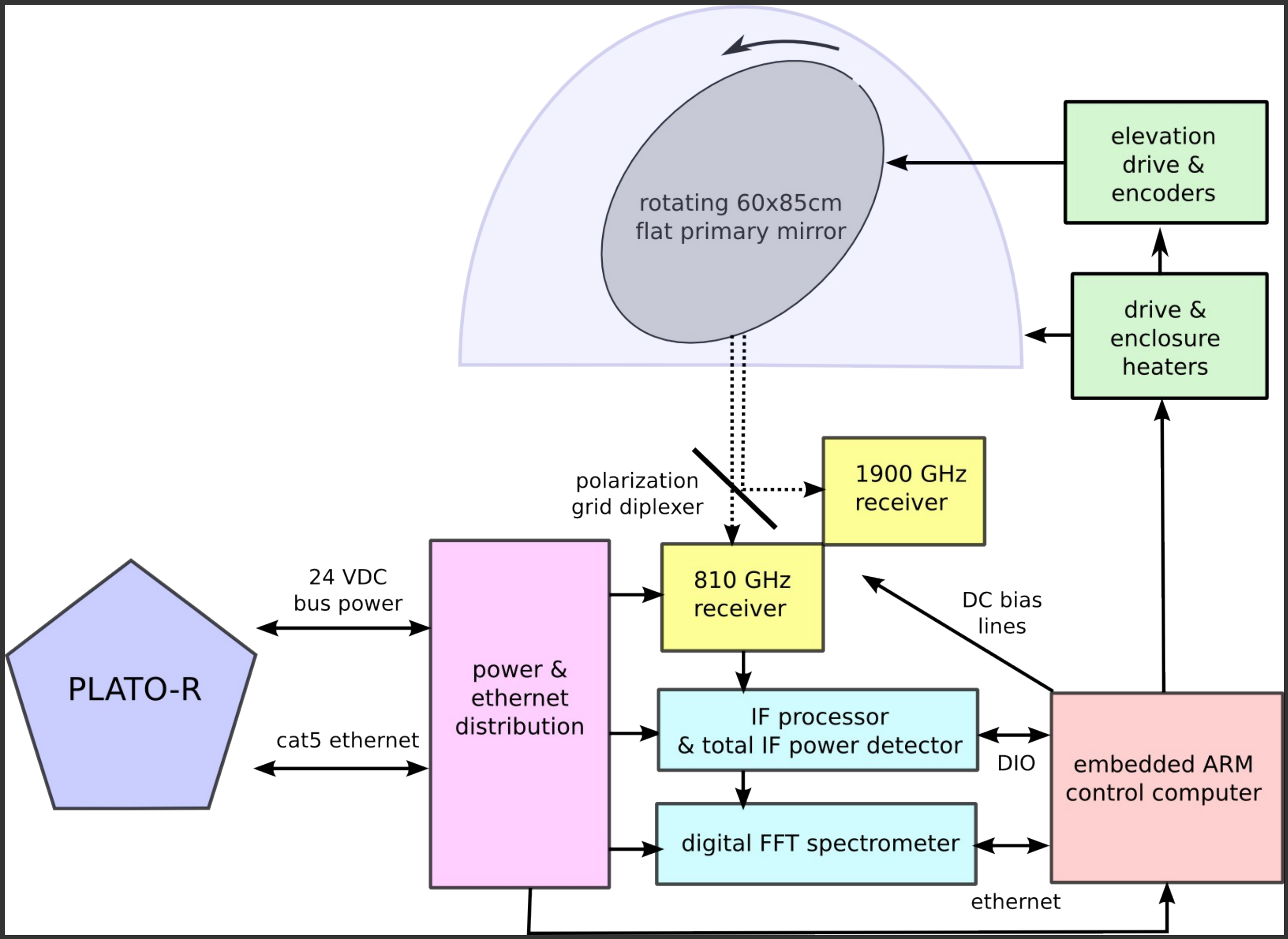


… with cryogenic heterodyne receivers in the far-infrared (150–600 um)



...performing a focused spectroscopic survey of the Milky Way in its most important THz lines of carbon, nitrogen and oxygen.

HEAT is a complete THz telescope… in a box



Crucial features...

First autonomous cryogenic (50K) receivers on the plateau, or anywhere! Receivers achieve good sensitivity with only 80W DC power

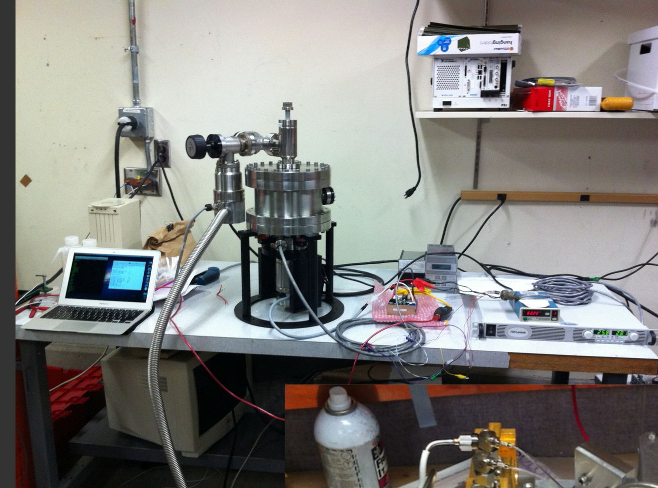
First digital wideband FFT spectrometers (up to 3 GHz, 30W typical). 5 GHz in design.

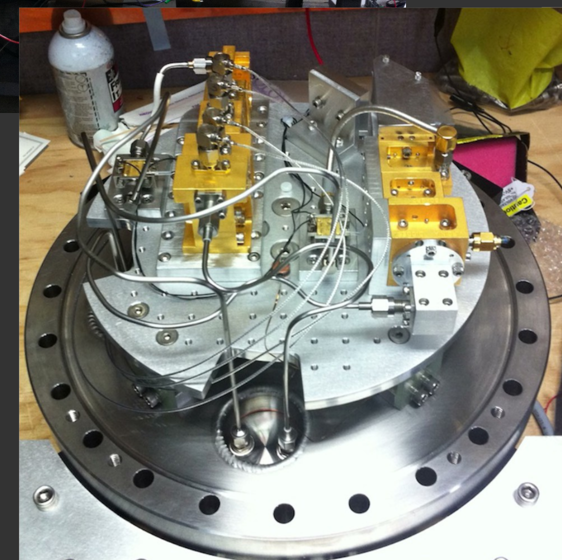
A complete THz observatory for <200 watts!

Autonomous data pipeline over Iridium.

Publicly available data with no proprietary period.

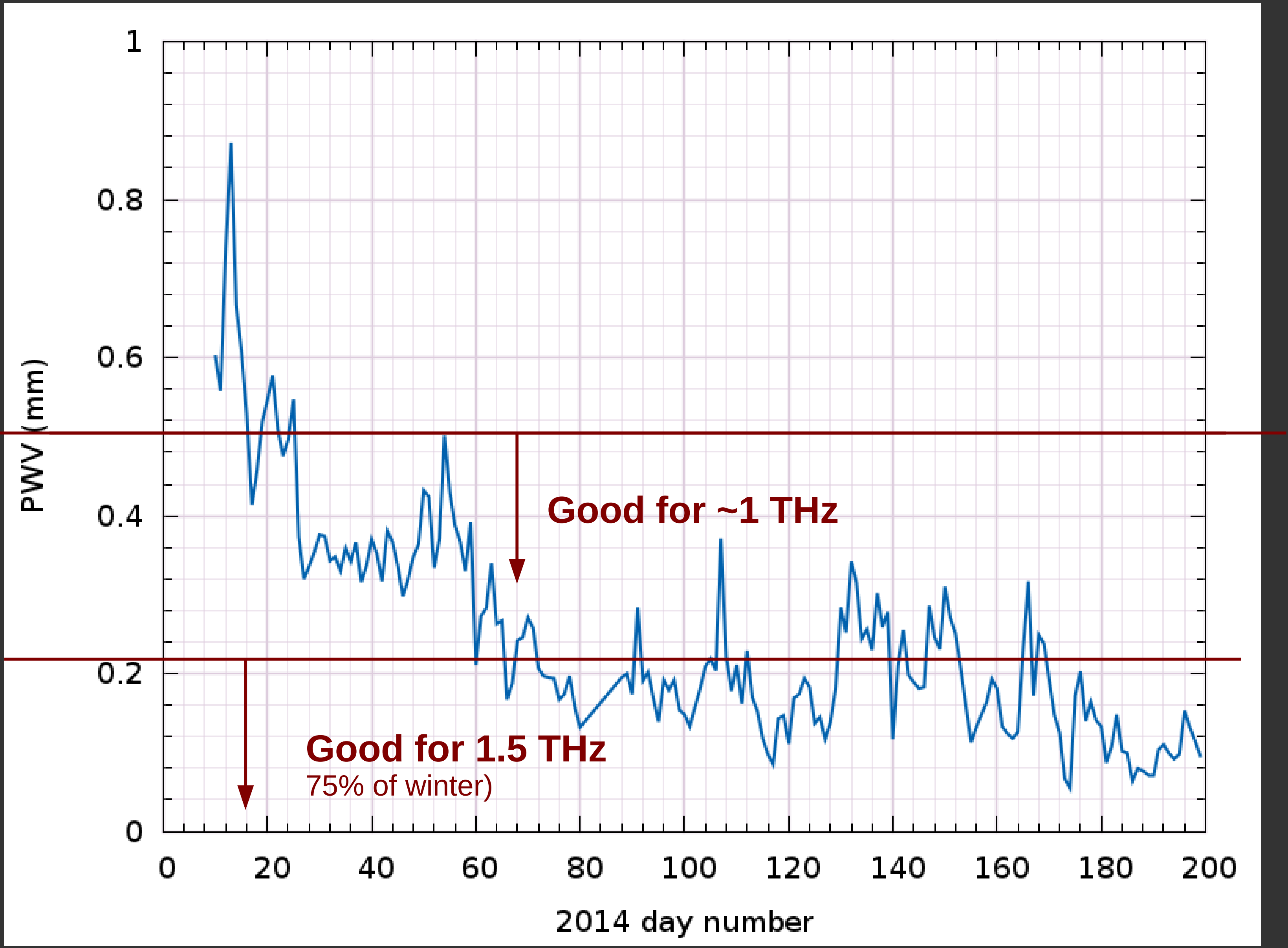
Builds technological readiness for future spaceflight hardware (cryocoolers, microwave synthesizers, amplifiers, detectors, optomechanics & control systems)



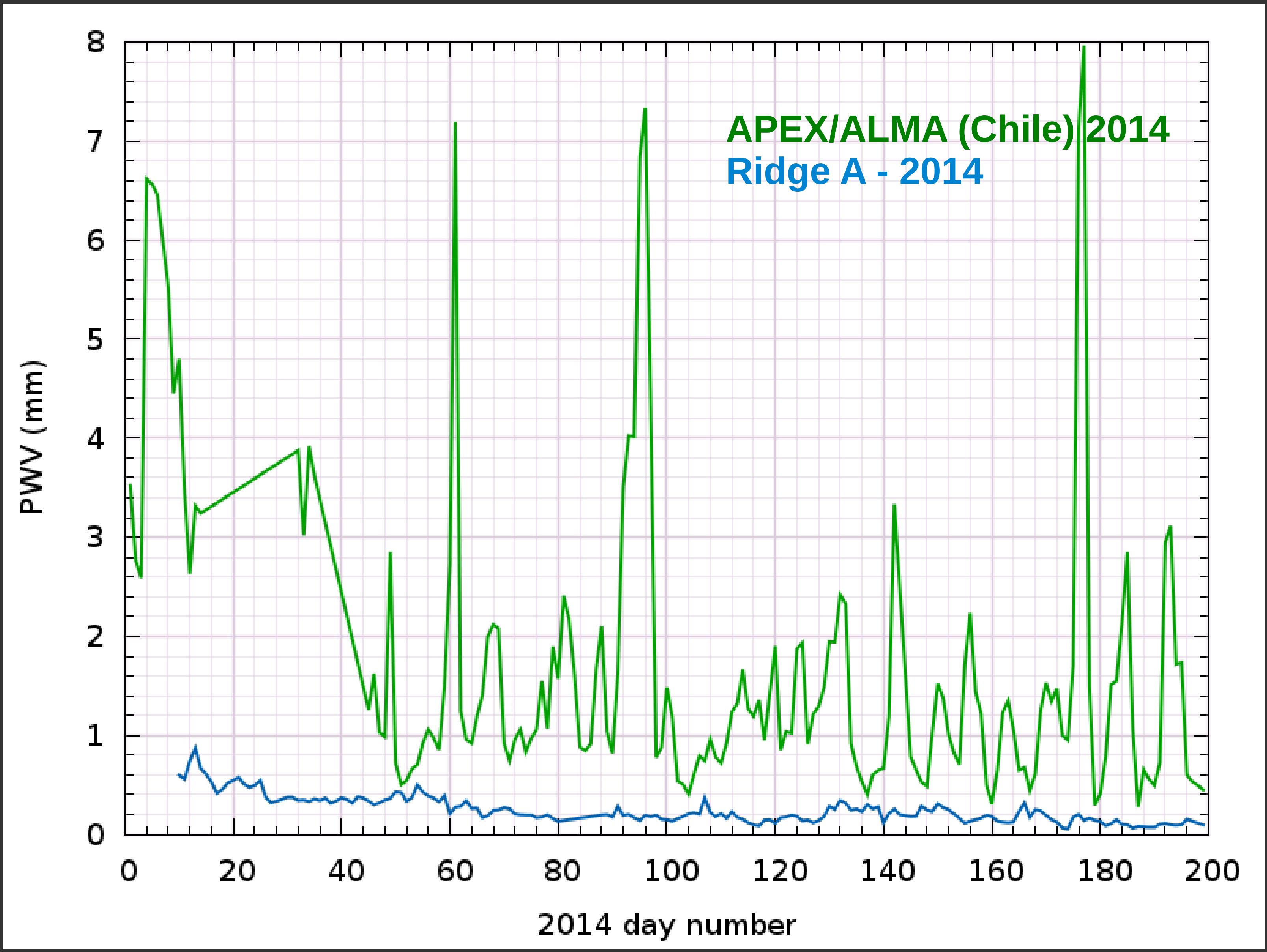


The Ridge A site is truly exceptional!

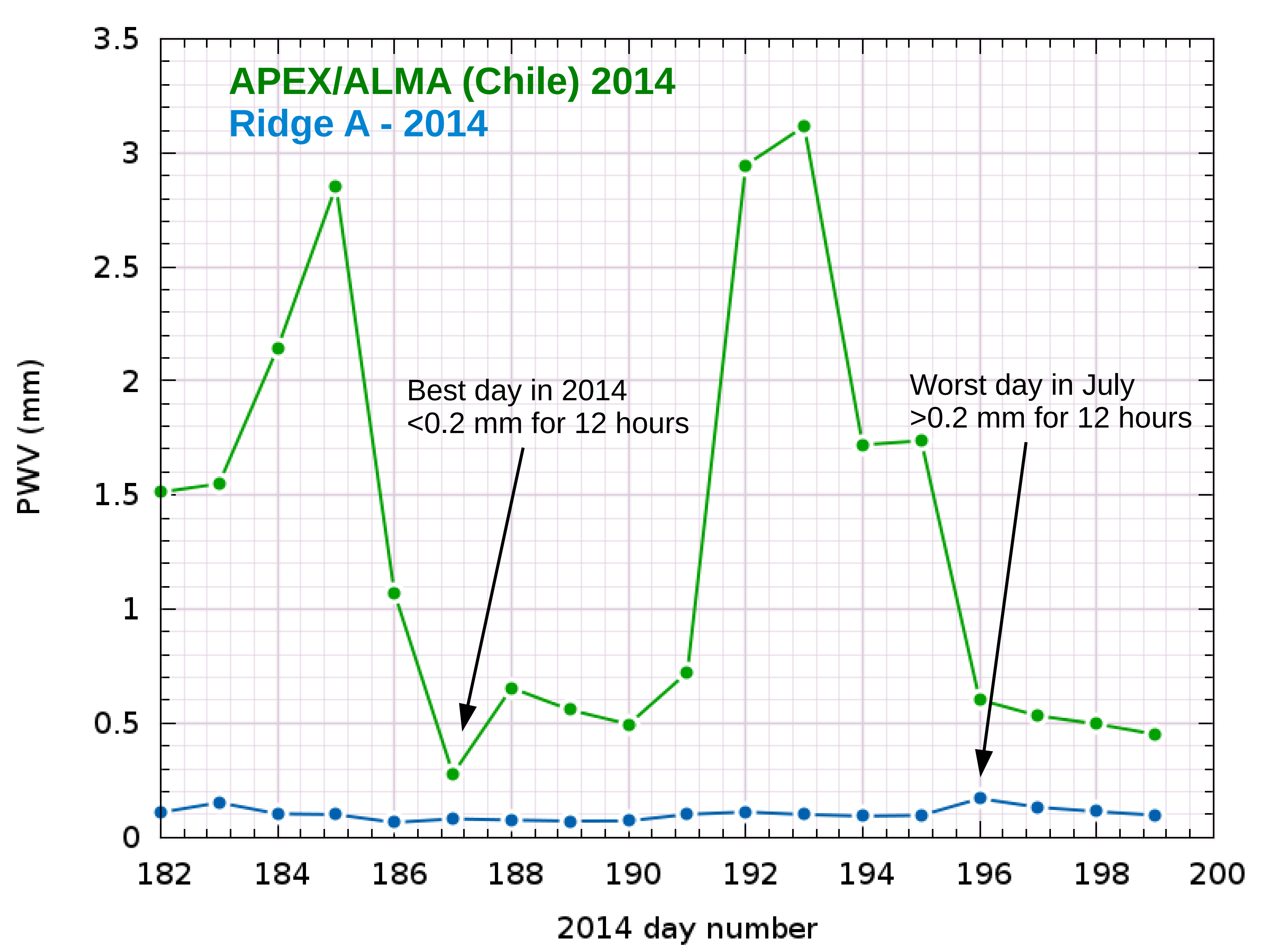
(daily averages so far in 2014)



And far better than Atacama...

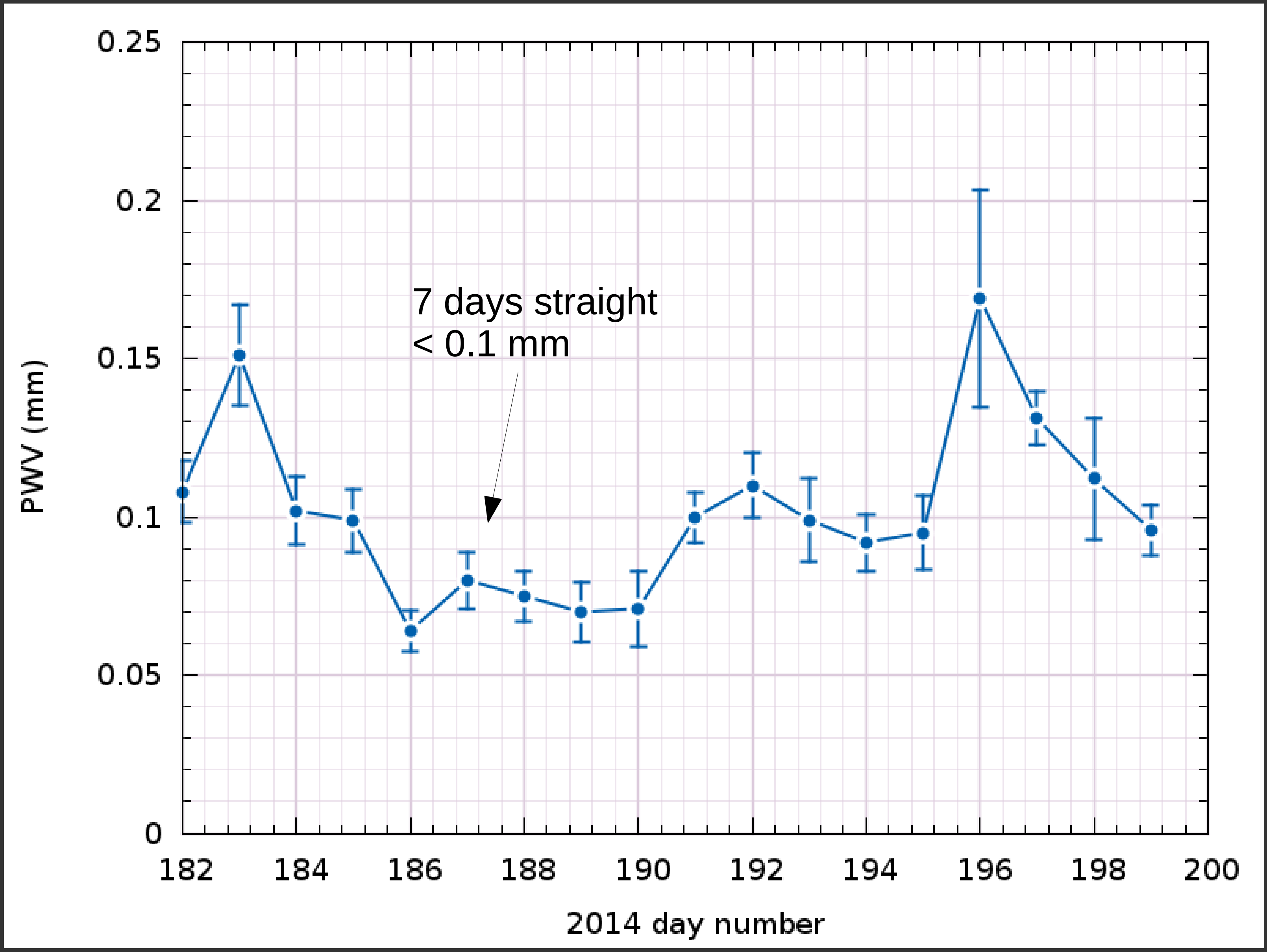


Zooming into July 2014, so far...

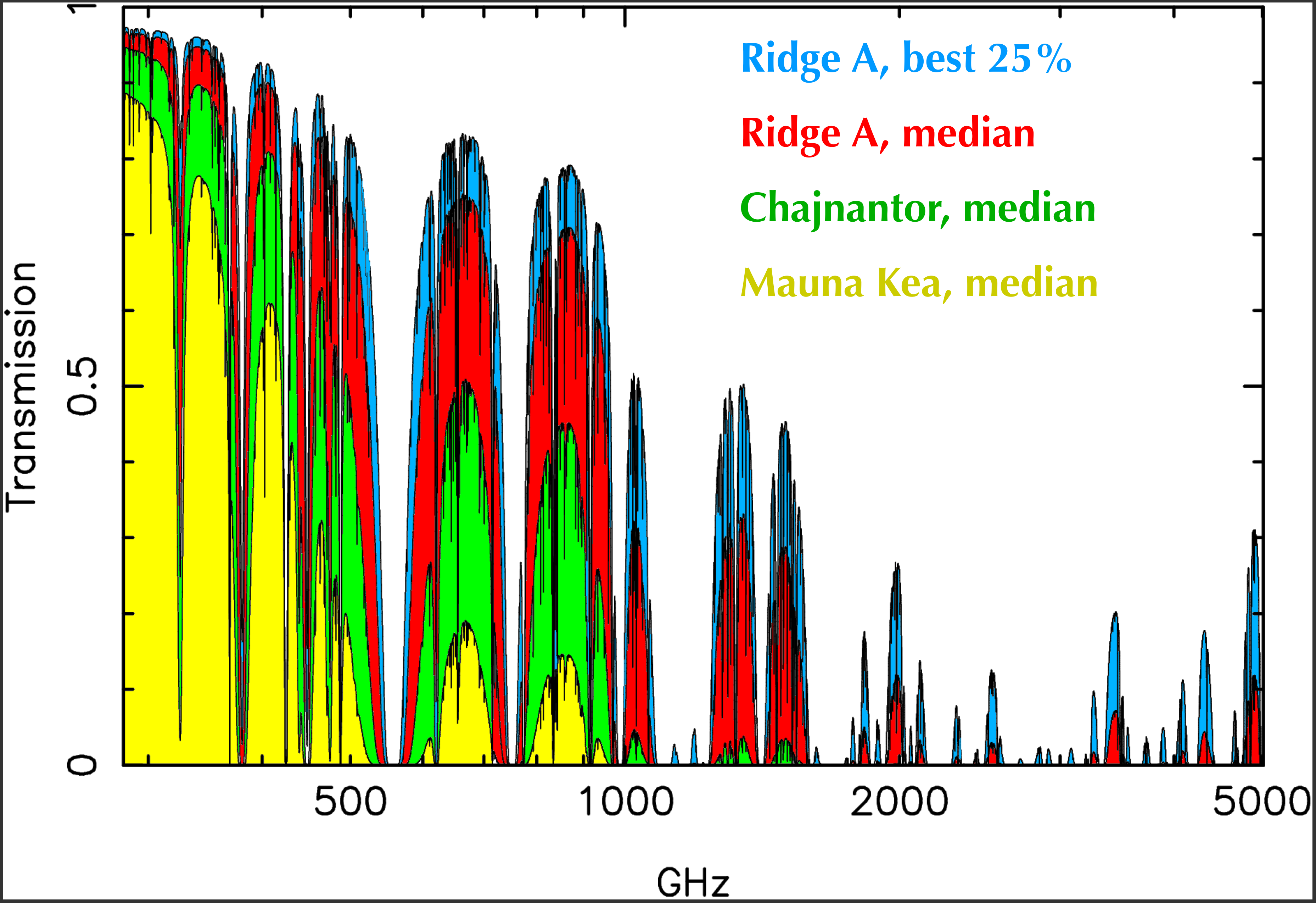


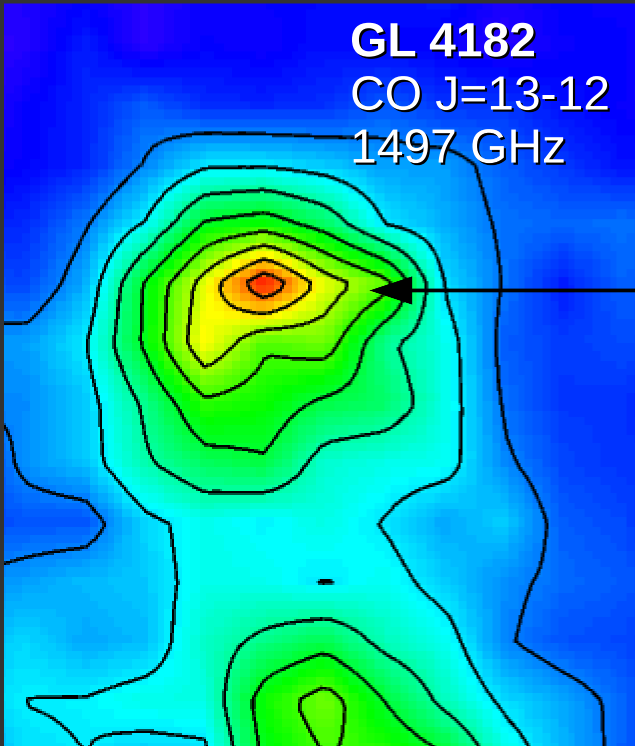
Rescaling to Ridge A: Clear, dry & stable!

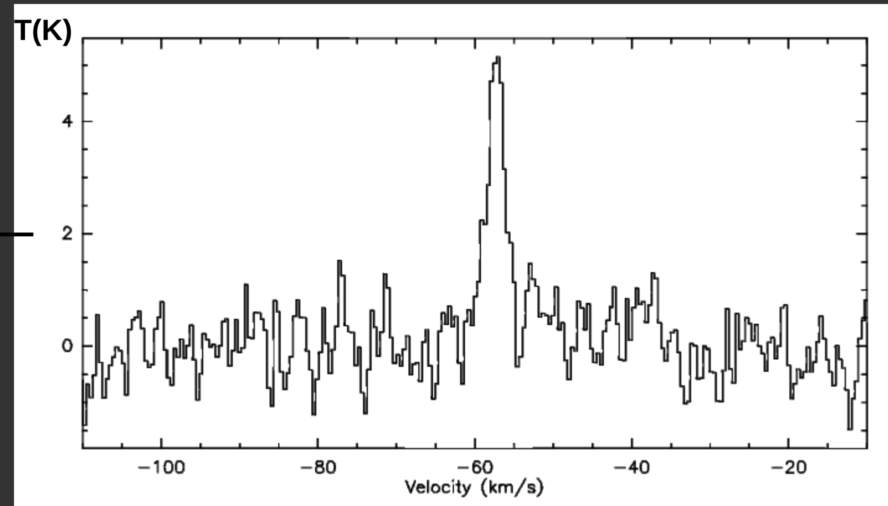
High transparency, low sky noise, ideal for mapping and interferometry



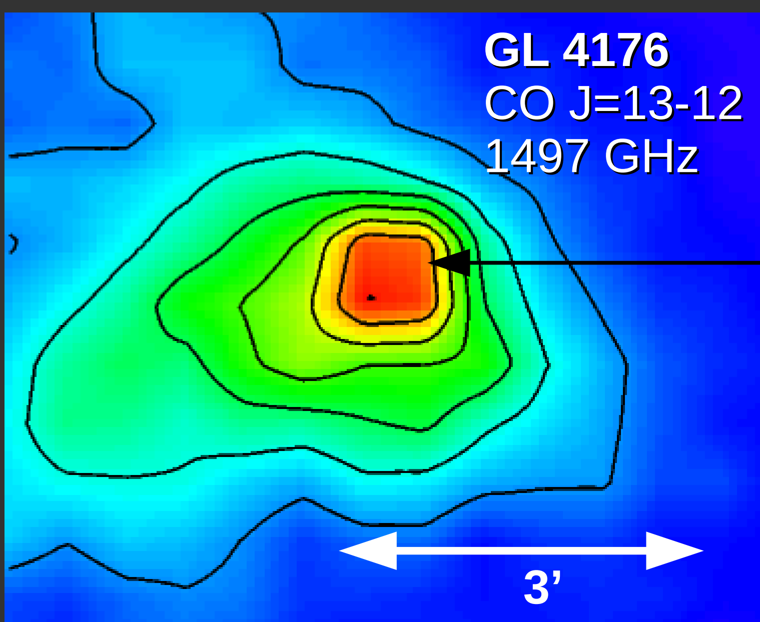
Yes! New atmospheric windows open over Ridge A

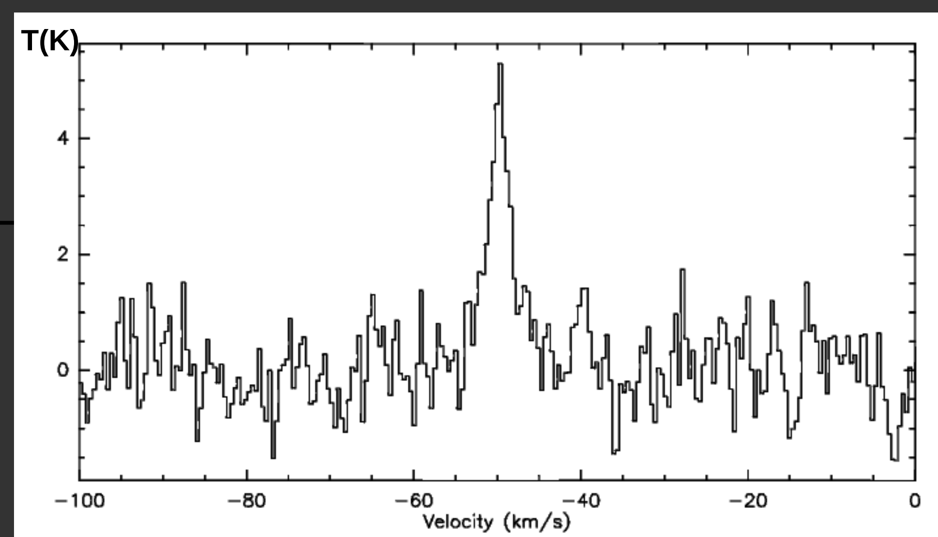




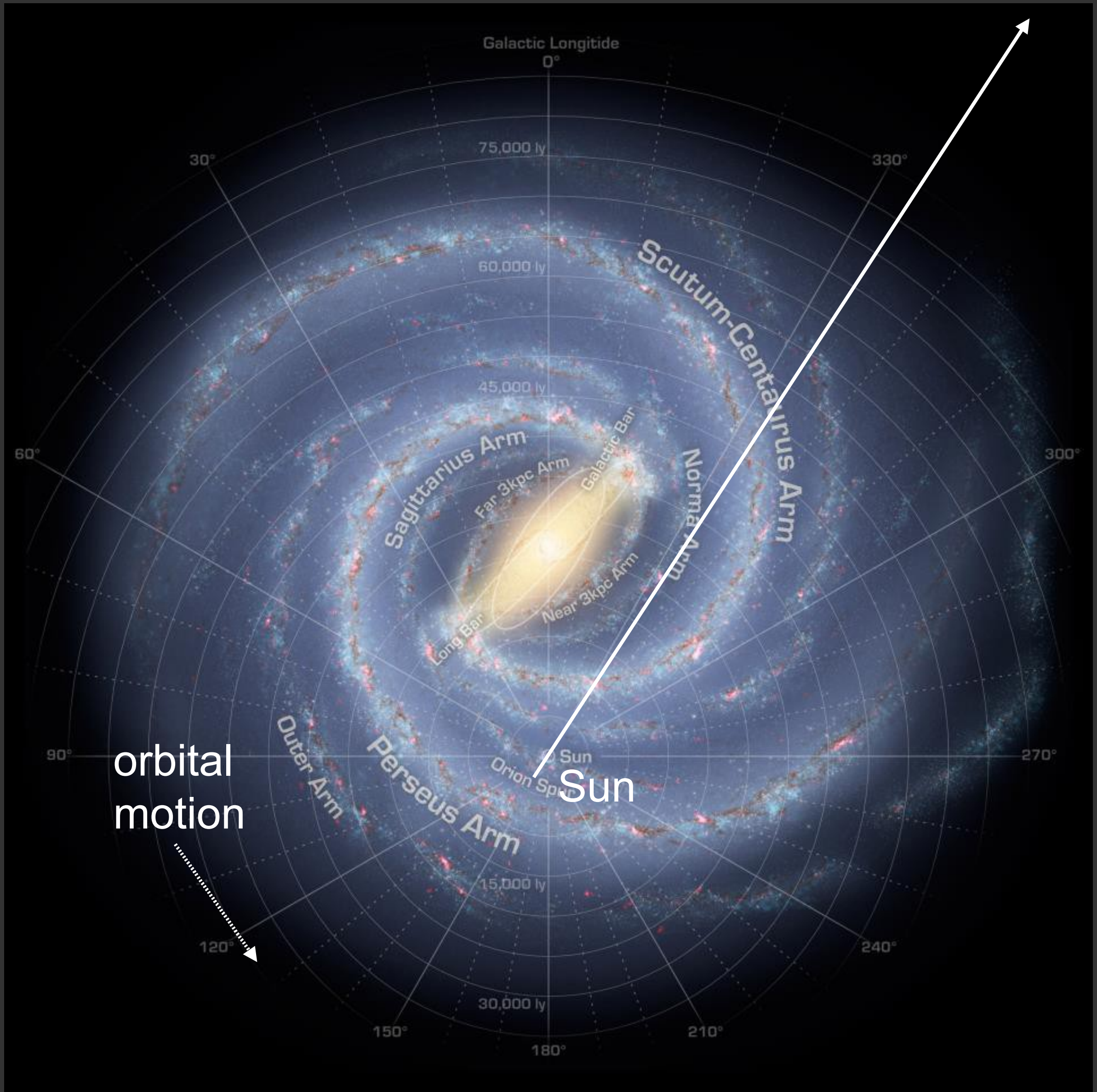


First HEAT Observations at 1.5 THz!





High resolution (heterodyne) spectroscopy turns ordinary 2D maps of the sky into a 3D map of the Galaxy...

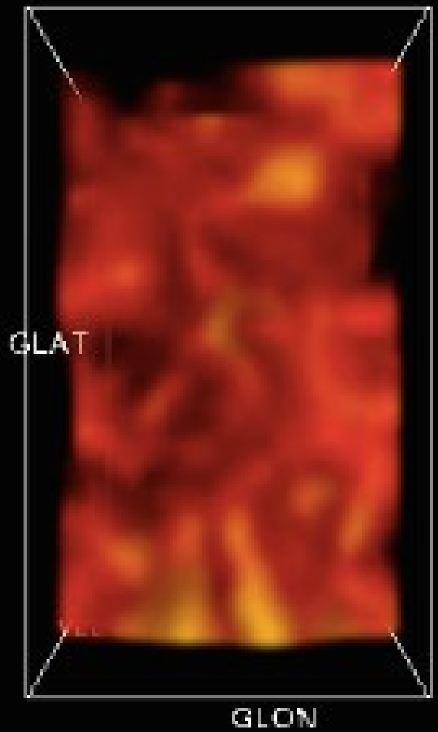


High resolution (heterodyne) spectroscopy turns ordinary 2D maps of the sky into a 3D map of the Galaxy...

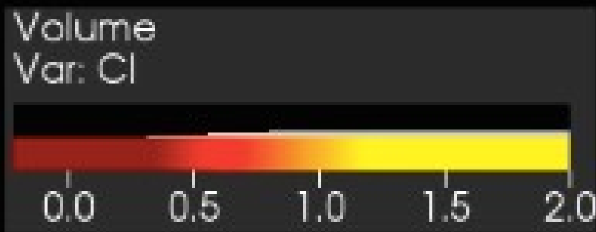
Integrated intensity of HEAT atomic carbon line emission at 809 GHz over ~1 square degree.

Analogous to numerous infrared continuum surveys (Spitzer MIPSGAL, Herschel HiGAL, 2MASS extinction mapping, etc.)

How to disentangle the many clouds along a line of sight?

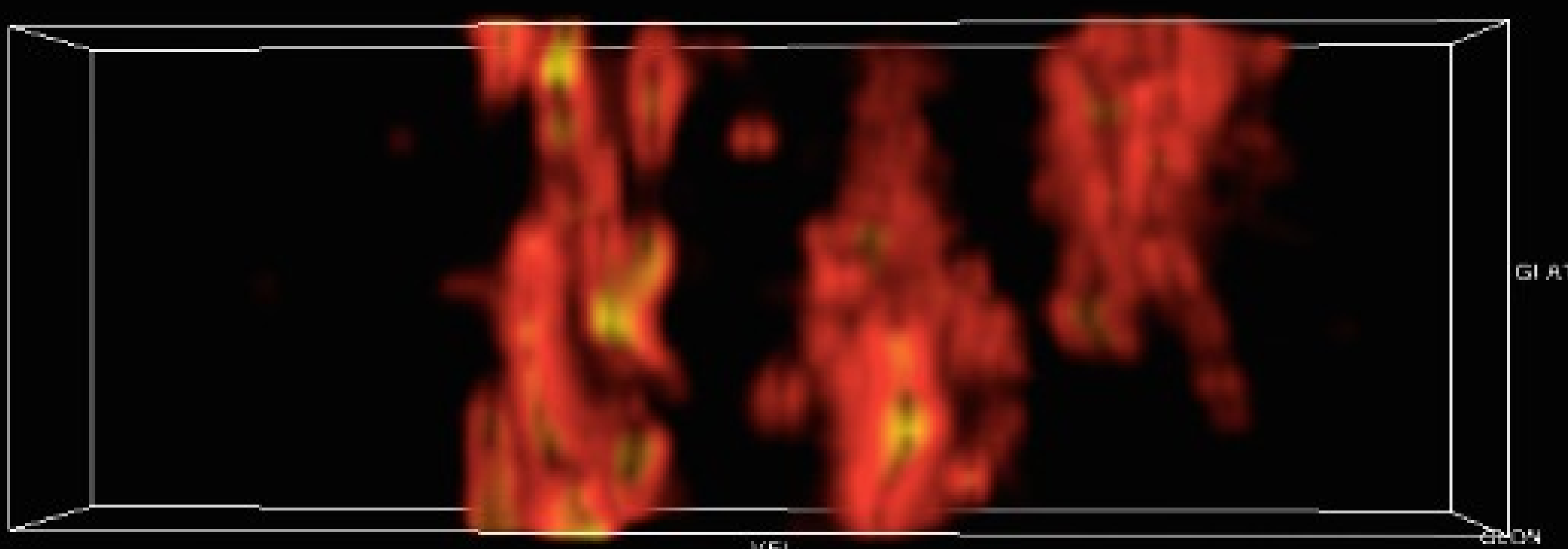


High resolution (heterodyne) spectroscopy turns ordinary 2D maps of the sky into a 3D map of the Galaxy...



With the data cube viewed in velocity space, spiral arms are immediately visible and structure along the line of sight disentangled.

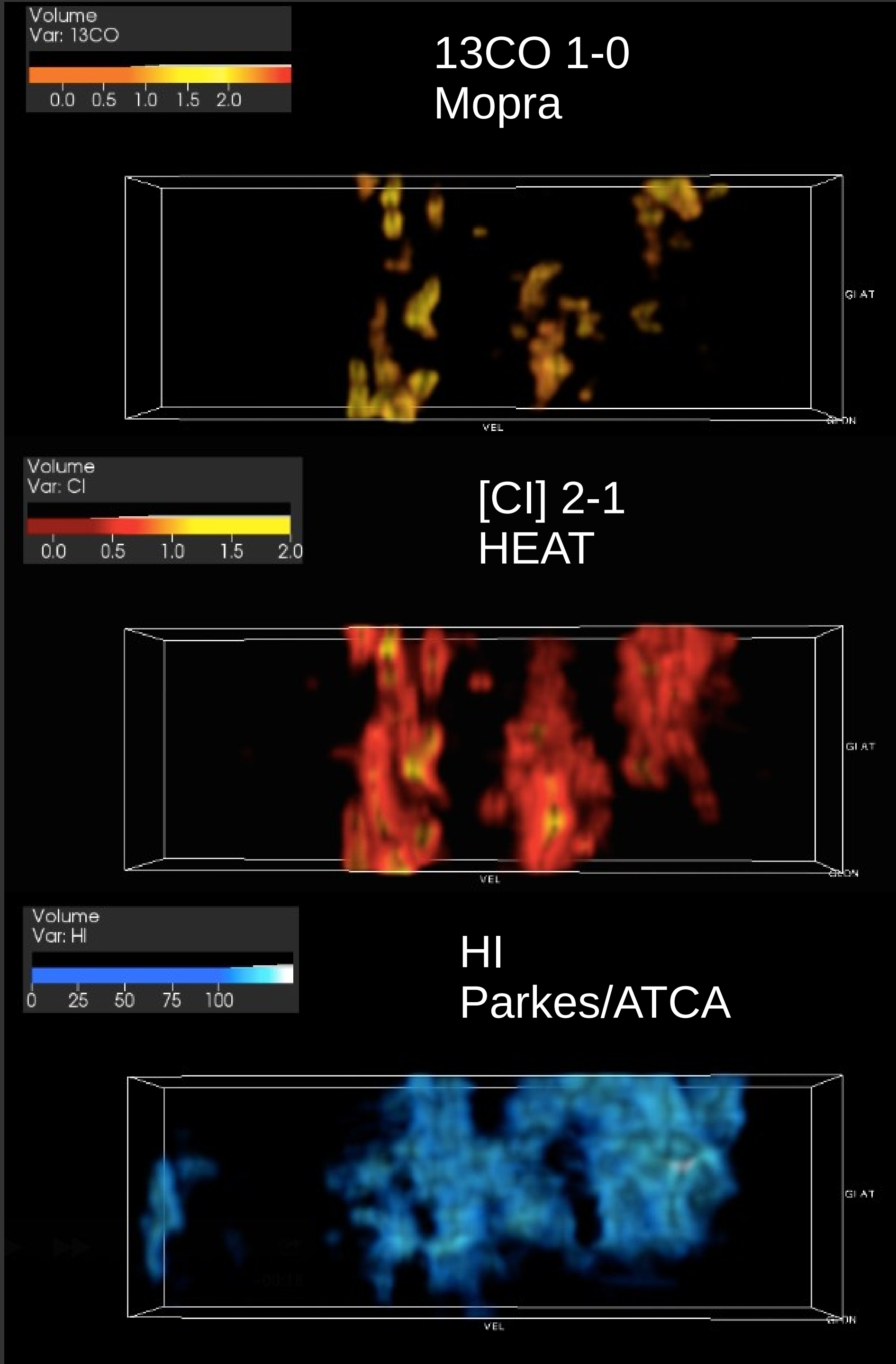
Galactic latitude



velocity

Atomic carbon is actually more extended than CO emission.

Much of the Galactic H_2 is faint or absent in CO but is recovered in [CI] and [CII].



First Science Results

For 40 years, astronomers have used mm-wave CO emission to determine the properties of star forming clouds. **HEAT shows that much of the elemental carbon in dark clouds is actually atomic carbon.** There is maybe 50% more star forming gas in the Galaxy than previously thought!

Implications:

- Clouds are fractal, filamentary, complex in structure, letting UV light permeate and keeping more of the cloud's carbon **atomic** (but hydrogen **molecular**).

- 30 to 50% of molecular gas is bound up in translucent clouds that have been completely missed in CO surveys.

- We may be observing the formation of molecular clouds for the first time. Newly formed molecular clouds haven't had time to form CO yet... and are seen best in atomic (and ionized) carbon.

- Atomic and ionized carbon will be even more crucial in metal-poor star forming gas – HEAT's observations of the LMC can be used as a template to explore how the very first stars and galaxies formed.

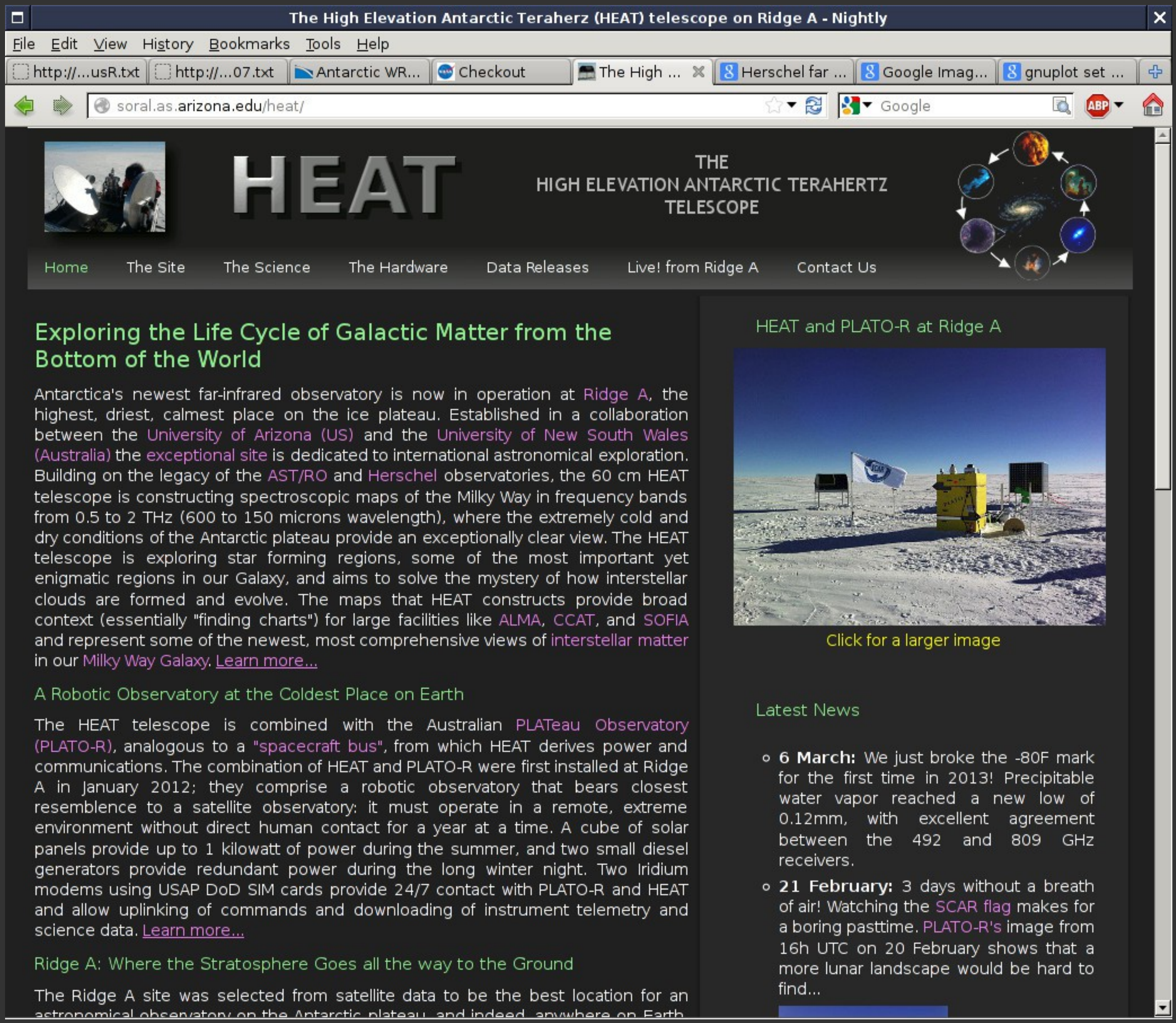
Much more to come!

All site-testing and astronomical data is publicly available, with no proprietary period. We want everyone to use it!

Data Release 1 (DR1) is available and DR2 will arrive by end of July!

8 square degrees of the Galaxy so far, plus strip map of the LMC

Data releases 1-2 times per year for the life of the project.



http://soral.as.arizona.edu/heat/

Summary

- HEAT and PLATO-R are deployed to Ridge A and are delivering excellent data. DR1 was May 2014, DR2 in July 2014!
- PLATO is revolutionizing scientific capabilities on the high Plateau
- The next major servicing mission to Ridge A should increase again the complement of HEAT receivers, throughput, and high frequencies
- 2015-16: First [CII] spectra from the ground, with the first autonomous helium temperature (4K) receivers?
- 2017-: Deploy both HEAT telescopes as a THz interferometer...

Exciting times ahead – stay tuned!