Planetary Science from Balloon-Borne Platforms: the Case for Venus Observations

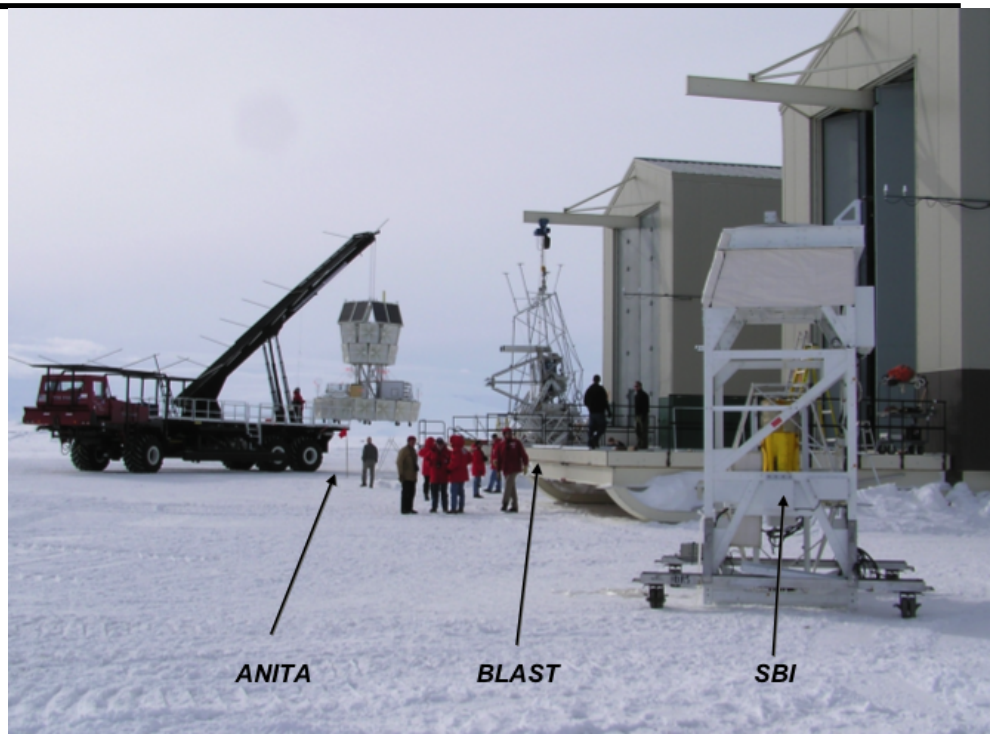
Eliot Young, Mark Bullock, Con Tsang (*SwRI*); Karl Hibbitts (*JHU/APL*), Tibor Kremic (*NASA/Glenn*)

Outline

- Balloon Capabilities
- Advantages for a Venus Observer
- Balloon Missions: What YOU Need to Build
- Future Developments to Watch

Balloon Payload Capabilities

- Size, Weight & Power
- Flight Duration
- Atmospheric Opacity
- Daytime Sky Background



Shown here: 3 solar-powered payloads staged in Antarctica for LDB flights of 2-6 weeks. Helium balloons of 40 million ft^3 will lift these 4000 - 6000 lb payloads to float altitudes of 120,000 ft (35 km), above 99.5% of the terrestrial atmosphere.

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- **Flight Duration**
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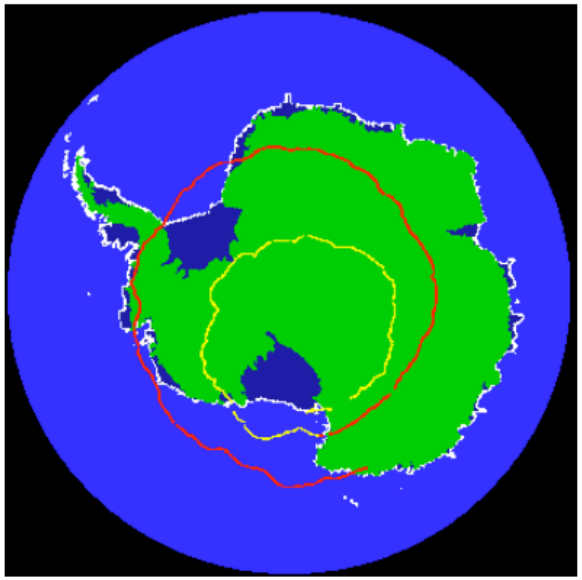
CREAM Trajectory, 19 Days 2009



- Domestic flights (Ft Sumner, NM): ~2 days;
- LDB (long duration) flights (Antarctica in Dec-Feb or Kiruna, Sweden): 20 - 40 days;
- ULDB (using super-pressure balloons) should provide 100 day flights.
- ESA is pioneering circumpolar flights from Kiruna (over Canada, US and Russia).

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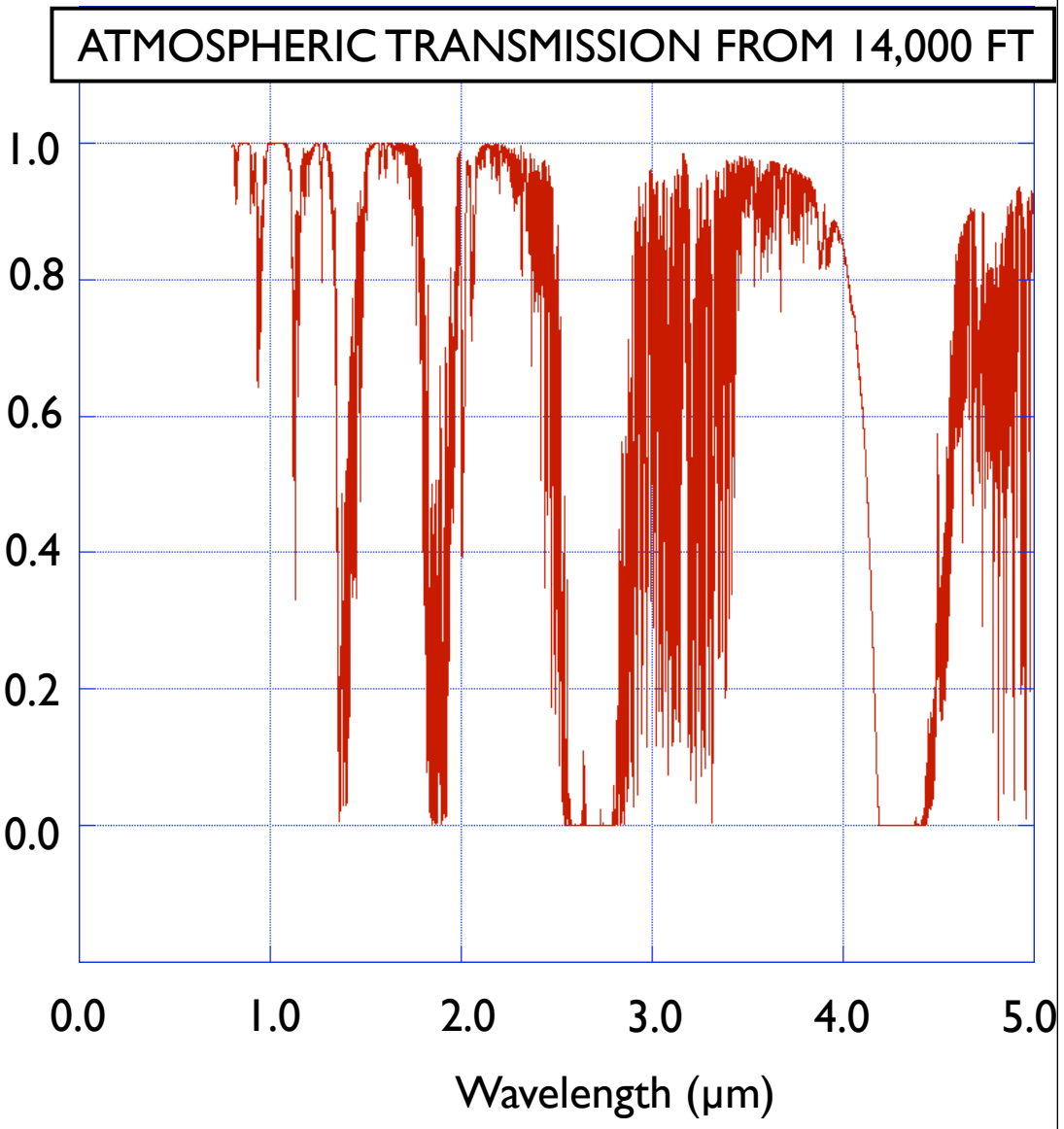

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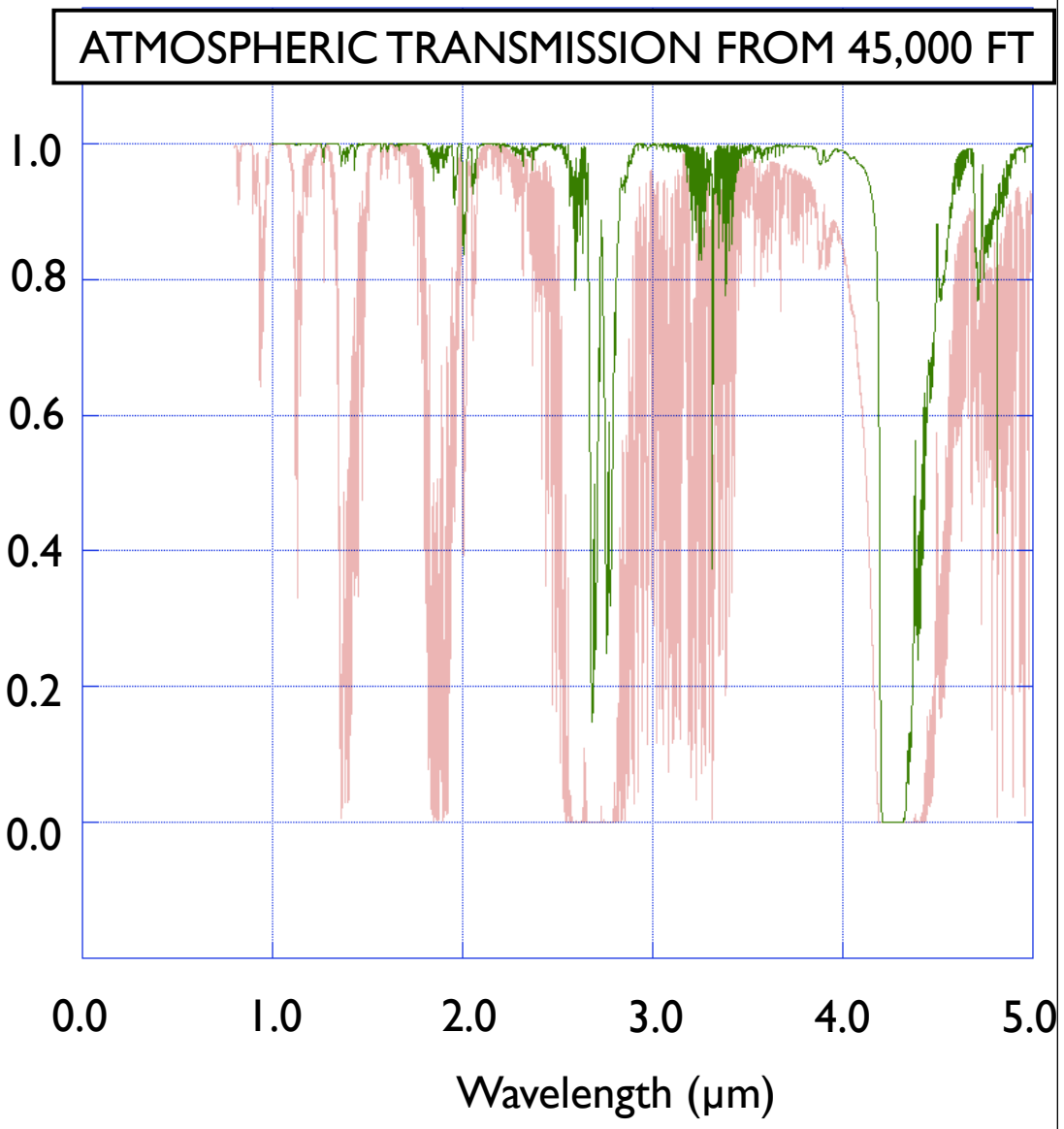

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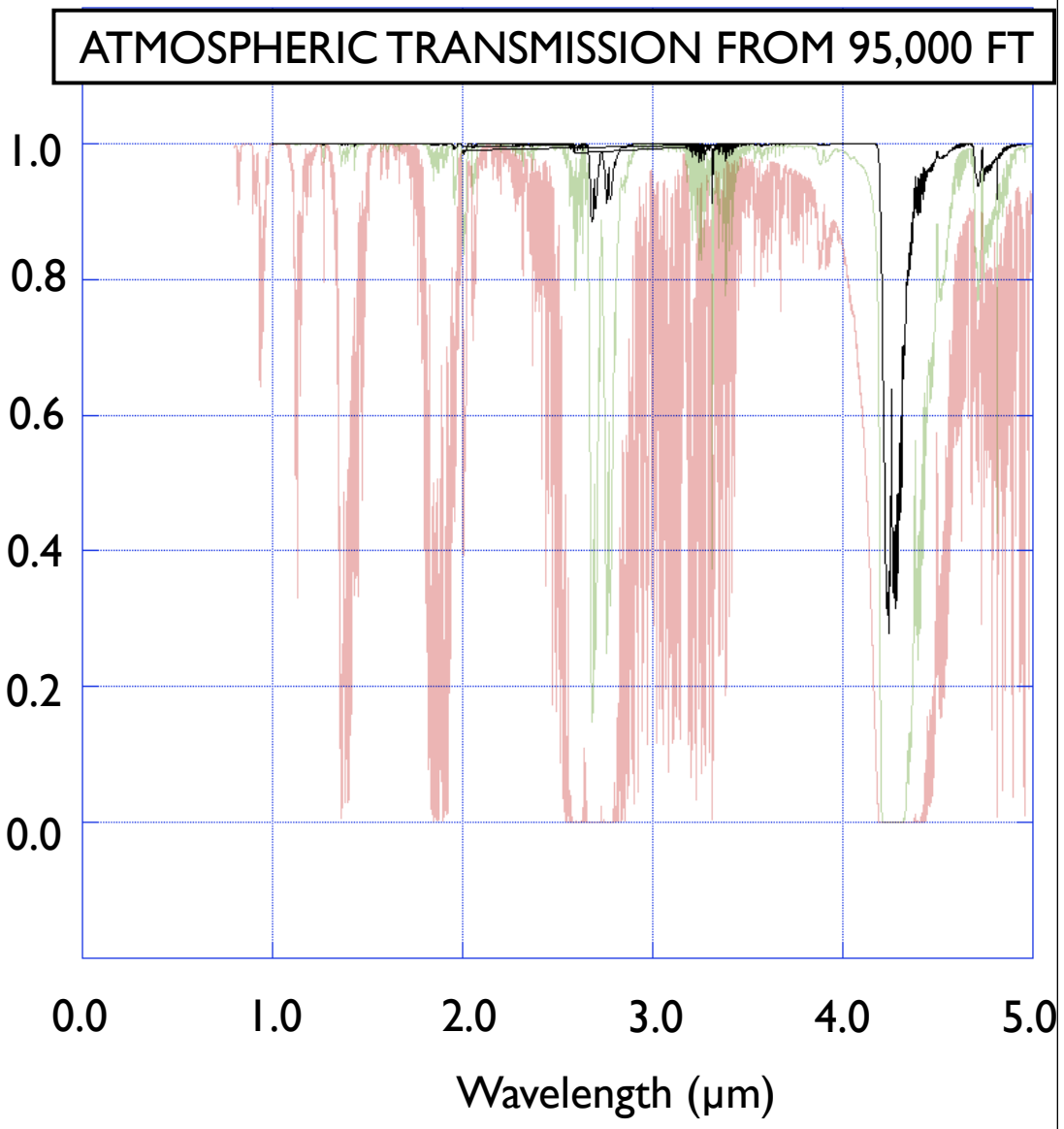

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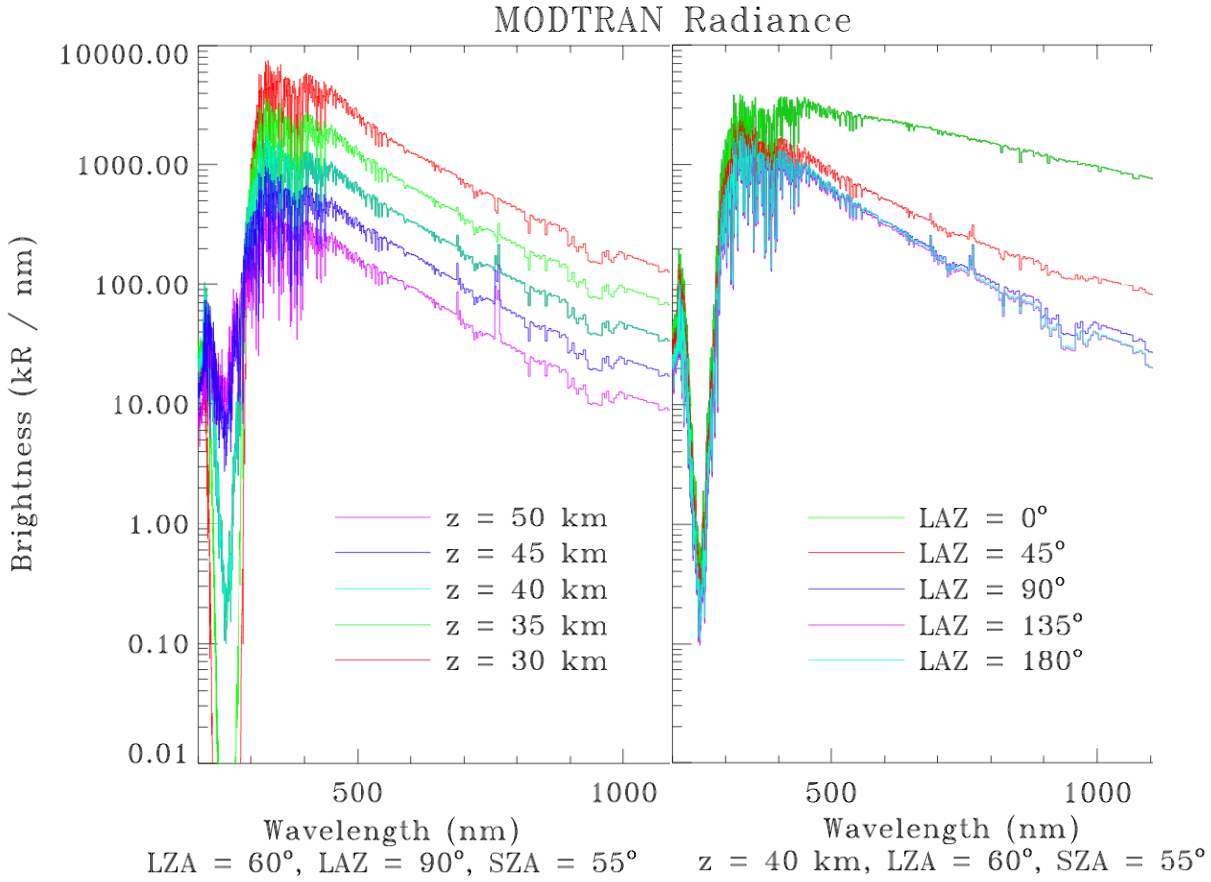
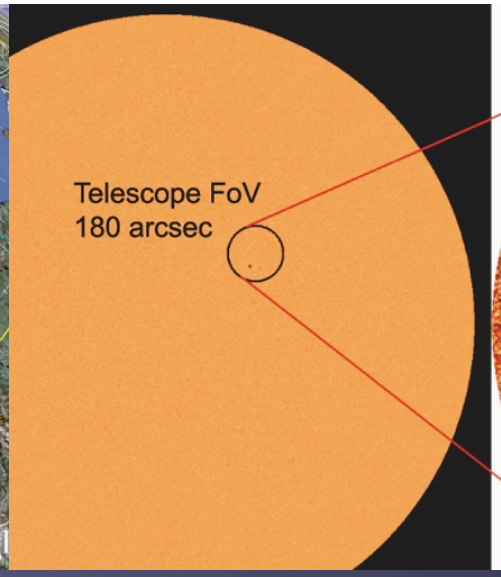
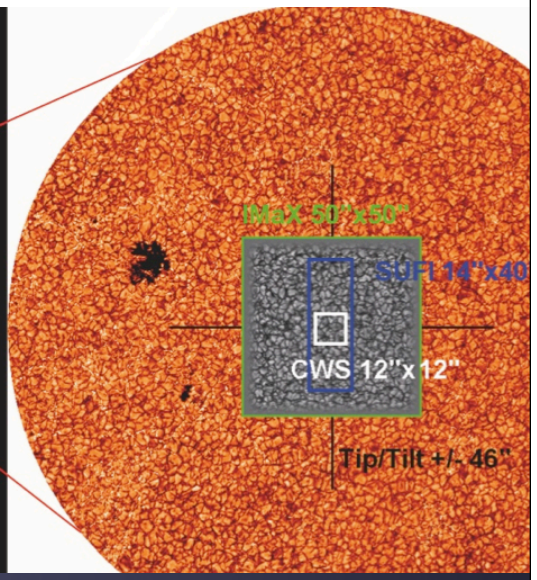


- Sky brightness decreases by 2x for every 5 km increase in altitude.
- Sky brightness is expected to drop as λ^{-4}, which it does *except* for angles near the Sun.

Balloon Payload Capabilities

Q1: Diffraction-limited image quality from 120kft?
Q2: Can a balloon-borne telescope point well enough?
ANSWER: Yes - Consider the SUNRISE mission





- About 33 hours of observation at various positions on the Solar disk, including limb
- Several continous time series of more than 30 min length
- Achieved spatial resolution: ~0.1 arcsec, ~100 km @ solar surface
- No indication for 'seeing', static aberrations negligable, image reconstruction can handle this
- All temperatures well within design limits

Source: Peter Barthol, Max Planck Institute for Solar System Research

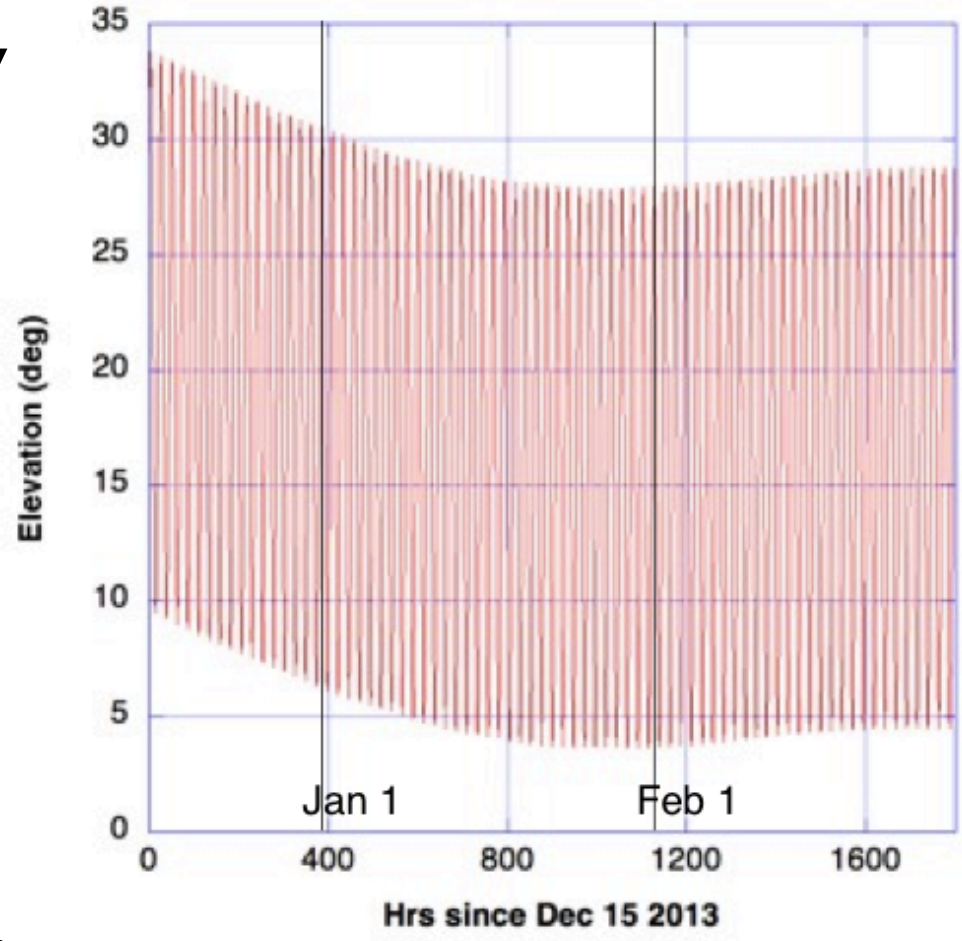
SUMMARY: Balloon Payload Capabilities

- In summary, NASA's BPO supports balloon missions up to 4 tons, float altitudes of 35 km, power limited by solar panels (kilowatts available), and durations up to 40+ days. *NASA-sponsored payloads are flown without cost to the PI.*
- Telluric transmission is excellent throughout the visible and near-IR.
- Daytime background is about 100x less than from the ground.
- One and two meter apertures should perform at the diffraction limit!

Balloons for VENUS INVESTIGATIONS

Venus: a good fit to NASA's current balloon program.

- Inferior conjunctions every 19 months – commensurate with a program of consecutive balloon missions.
- The January 2014 inferior conjunction coincides with NASA's Antarctic launch season, and Venus is *continuously observable* from Antarctica at that time.



Balloons for VENUS INVESTIGATIONS

- Cloud Tracking
- Cloud Properties
- Surface Thermal Maps
- Trace Gas Distributions
- Lightning Survey

A 40 inch aperture lets us image Venus at the 1.74 μm window with 0.44 arcsec resolution, equivalent to 100 km (at inferior conjunction). We can track clouds at 5 m/s from the IRTF, but *continuous observations* from the stratosphere should provide **1-2 m/s** rates on the nightside and **0.5 m/s** on the dayside – sufficient to resolve meridional motion.

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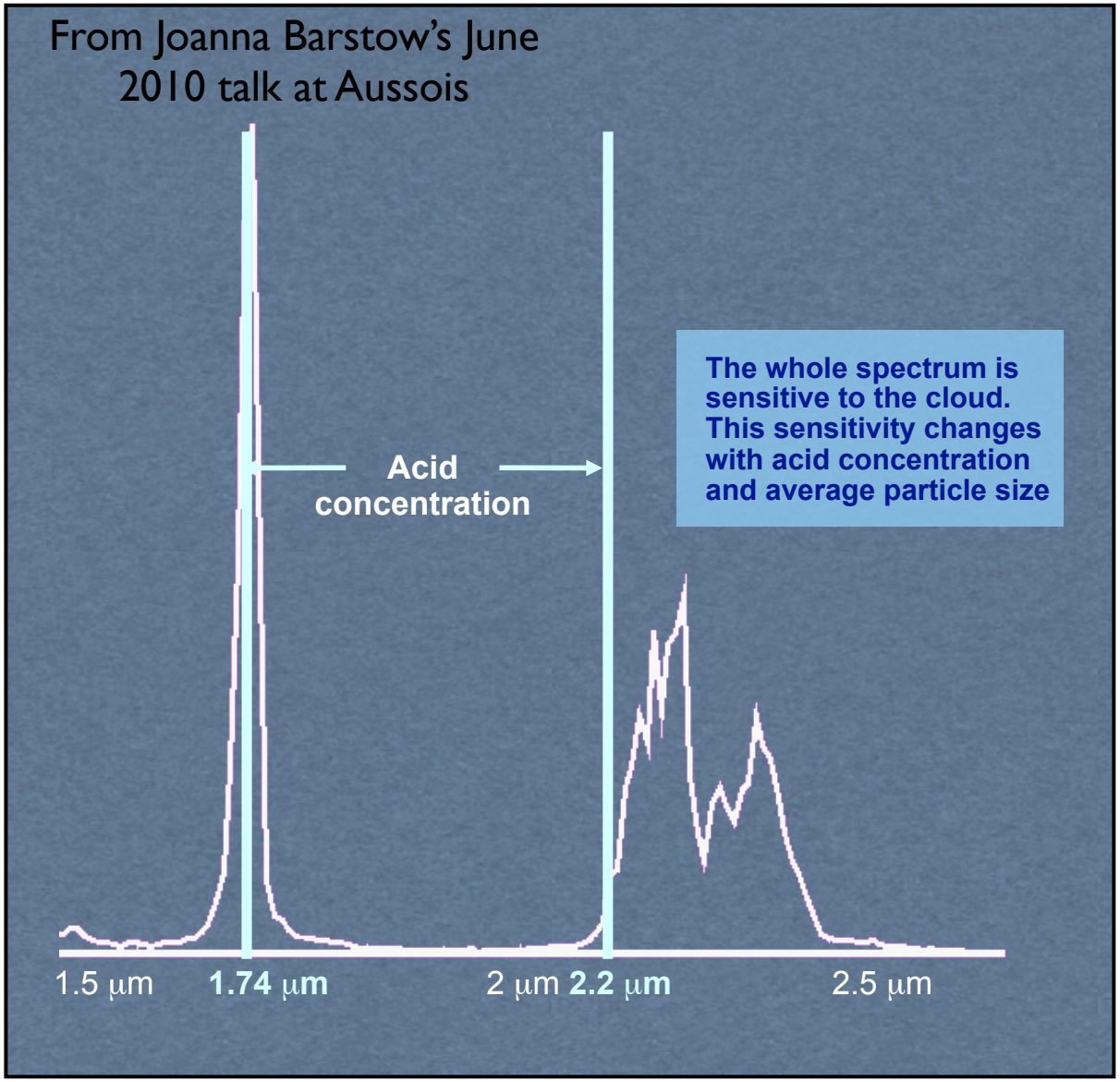

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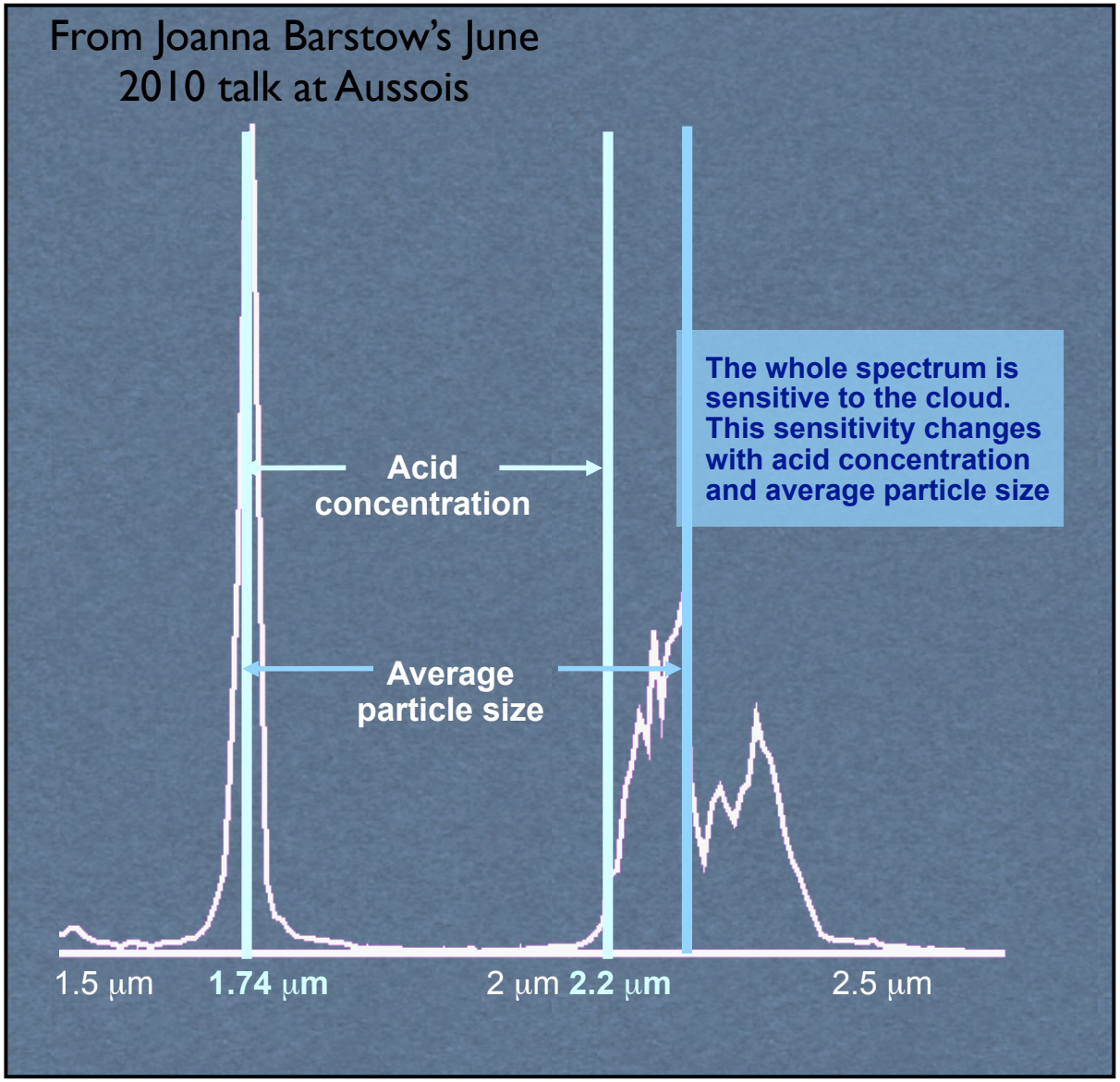

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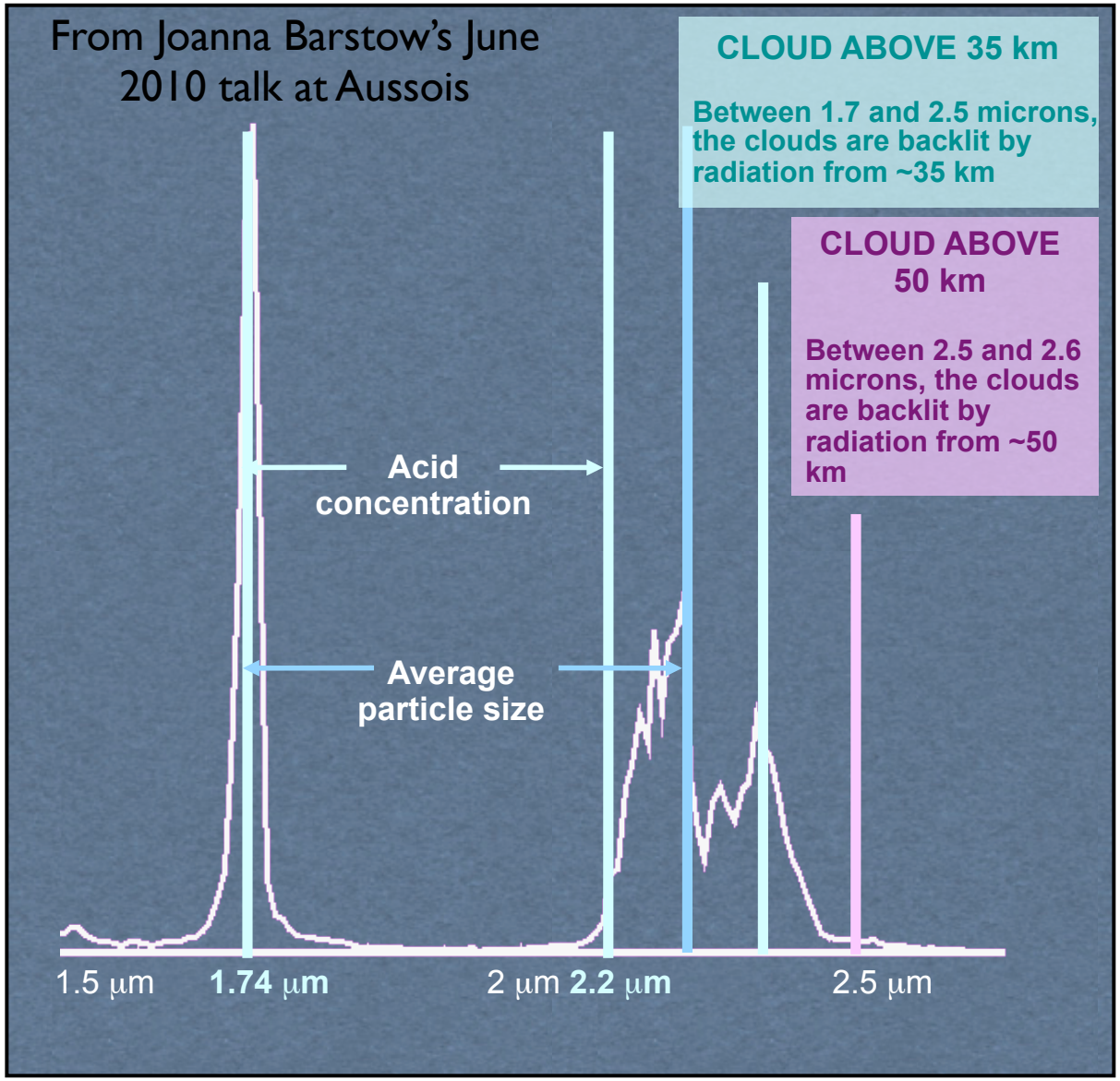

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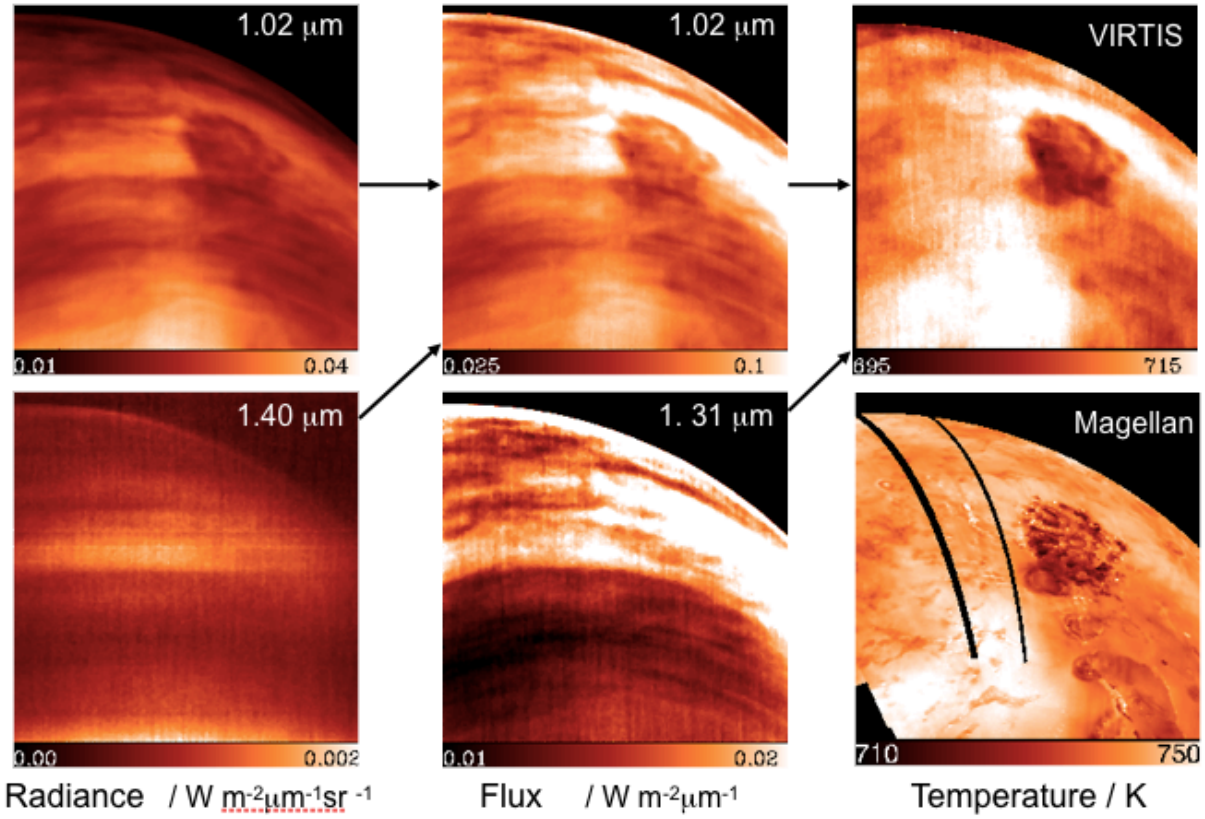
While windows at 1.74 and 2.25 - 2.45 μm are most diagnostic for clouds in the middle and lower cloud decks, shorter wavelengths are more sensitive to thermal flux from the hot surface.

Data Processing - 'Declouding'



From Joern Helbert's May 2011 talk at the Venus Balloon Virtual Workshop: <data.boulder.swri.edu/efy/venus11>

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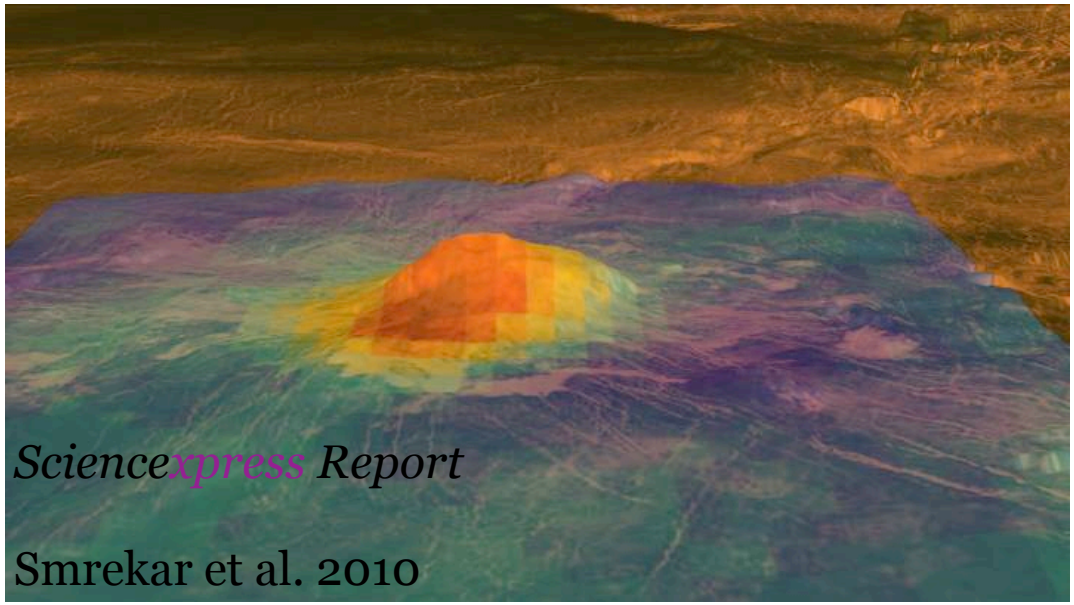
Surface emissivities measured in CO_2 windows at 1.02, 1.18, 1.26(?), 1.31 and 1.40 μm can be compared to Magellan topography maps. Venus Express results show three southern-hemisphere surface emissivity anomalies that are co-located with volcanic features.



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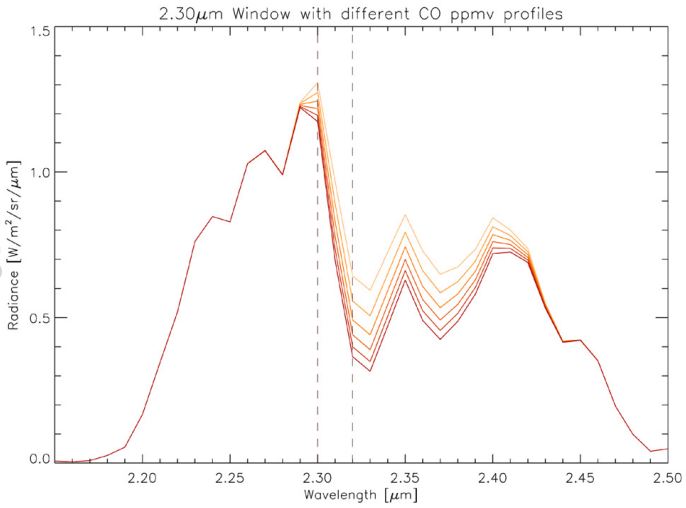
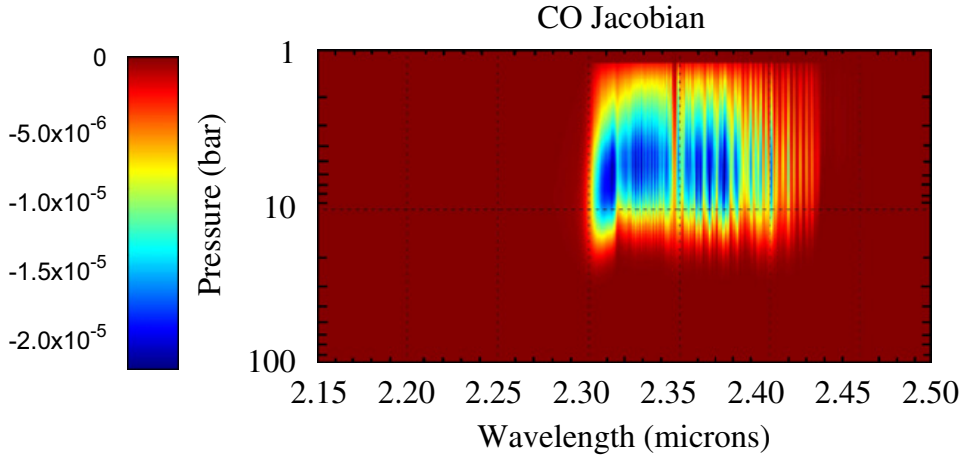


The 2.25 - 2.45 μm window is diagnostic of tracers like CO, OCS and H_2O.



A CO Jacobian shows sensitivities to CO abundances as a function of wavelength and altitude (pressure).

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AKATSUKI's (LAC) has filters and a 50kHz fast exposure mode to search for lightning.

Lightning & Airglow Camera **LAC**		16°	8 x 8 APD (50kHz sampling in lightning mode)
777.4 nm (night)	4.2 nm		OI lightning
552.5 nm (night)	4.7 nm		O_2 HerzbergII ariglow
557.7 nm (night)	3.1 nm		OI airglow
630.0 nm (night)	3.5 nm		OI airglow

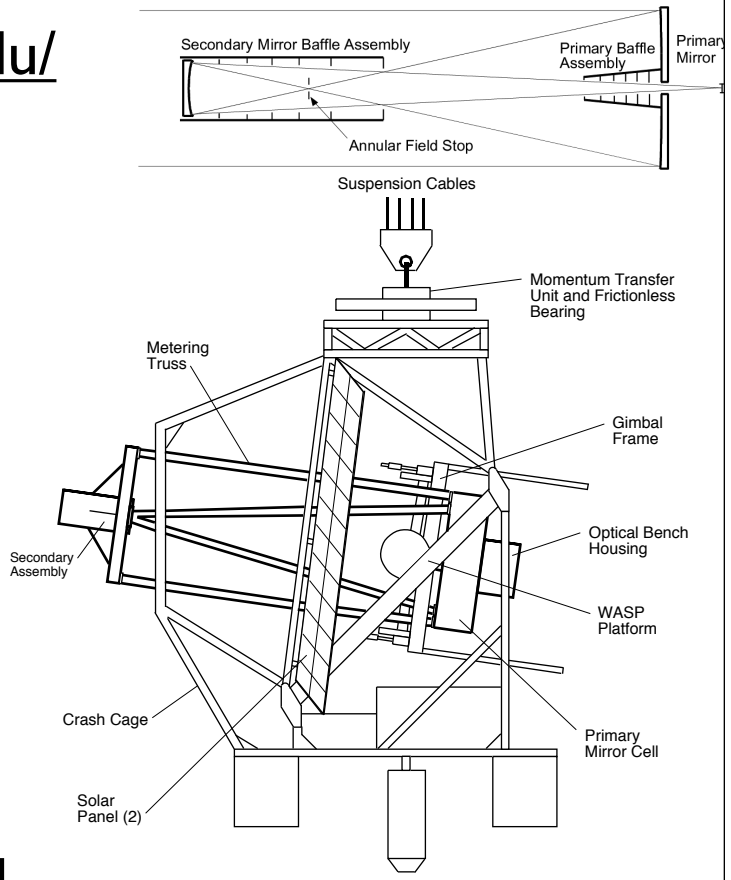
- Sky background at 120,000 ft: how does photon shot noise preclude seeing flashes?
- On the other hand, the expected spatial resolution (about 30 km on Venus) helps to isolate local flashes.

SUMMARY: Stratospheric Investigations of Venus

- 50 days of continuous cloud tracking at the 1 m/s level (night side) or 0.5 m/s (day side) will provide key data sets to constrain meridional motions and angular momentum transport.
- Interacting chemical and dynamical processes (e.g., in regions of upwelling/downwelling) can be measured at the 100 km scale by mapping trace gases and cloud characteristics.
- Surface emissivity anomalies are a key test of surface activity near volcanoes. Let's look at northern hemisphere terrain (at 60 km resolution).
- Search for lightning and possibly characterize it.

Building a Reusable Stratospheric Platform

- 2009 LCANS workshop (www.boulder.swri.edu/LCANS09/talks.html) concluded that there needs to a "facility telescope in the stratosphere."
- NASA's CSBF is, in fact, working towards this goal: they already provide important infrastructure: communications, telemetry, coarse pointing (±1°), and with soon-to-be-tested Wallops Arc-Second Pointing System (WASP), a fine pointing system.
- To provide a cost effective data stream, we (VEXAG) should support (endorse?) a pointed telescope that can (a) provide diffraction-limited observations and (b) allow investigator instruments (e.g., imaging FTS, etc.)



Upcoming Inferior Conjunctions

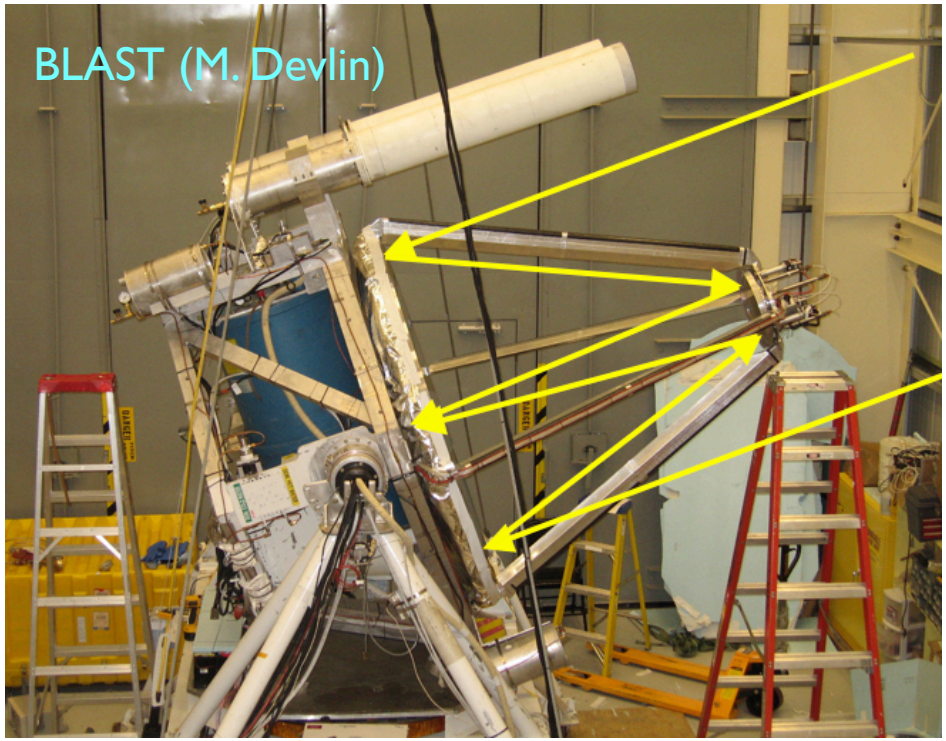
Date	*Venus' Declination*
06-JUN-2012	+22.5°
11-JAN-2014	-16.5°
15-AUG-2015	+06.5°
25-MAR-2017	+09.5°

Some Future Technologies to Watch

- OTCCDs (orthogonal transfer CCDs) to provide solid-state fine steering capabilities (e.g., as used on PanSTARRS).
- Avalanche HeCdTe arrays to provide very low read noise IR detectors.
- Super-pressure balloons to enable LDB missions through day/night cycles (more relevant to faint night-time targets).
- Recent attempt at a circumpolar flight from the Esrange site in Kiruna, Sweden (new venues for month-long flights).

Balloon Missions: What YOU Need to Build

- NASA's CSBF (Columbia Scientific Balloon Facility provides the SIP (Support Instrument Package, provides communications, coarse pointing and power for short flights) and will provide WASP (Wallops Arc-Second Pointing system) and payload integration, thermal-vac test, launch, operation and recovery.
- What YOU need to provide:
  - Gondola & Telescope
  - Power (for LDB), typically solar cells
  - Fine pointing
  - C & DH
  - Thermal control



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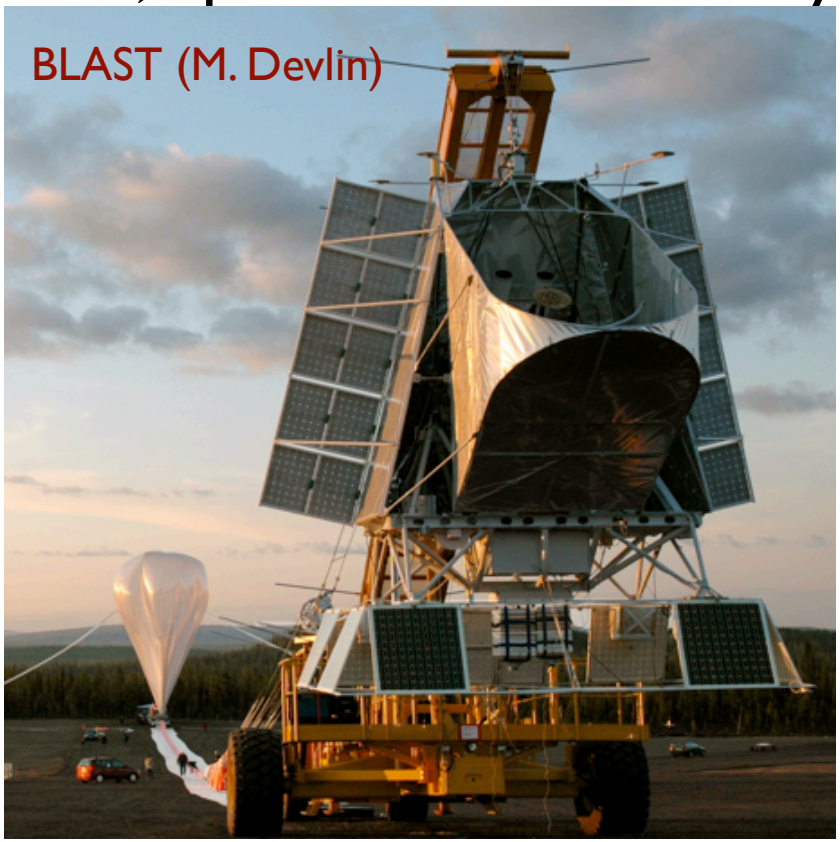

Balloon Missions: What YOU Need to Build

QUESTION: To whom do you send your suborbital proposal?
ANSWER: Planetary Astronomy (Hi, Kelly...). *All other divisions of SMD can propose to* NASA/APRET (Astrophysics Research and Enabling Technology), due April 30, 2012. "Awards range from under $100K per year for focused, limited efforts (e.g., data analysis) to more than $1M per year for extensive activities (e.g., development of science experiment hardware)."

COST EFFECTIVENESS OF BALLOON MISSIONS:
We recently priced a gondola and stabilized 1-m telescope at $2M. This is a *small* amount compared to most missions, but a *large* amount for an R & A program.