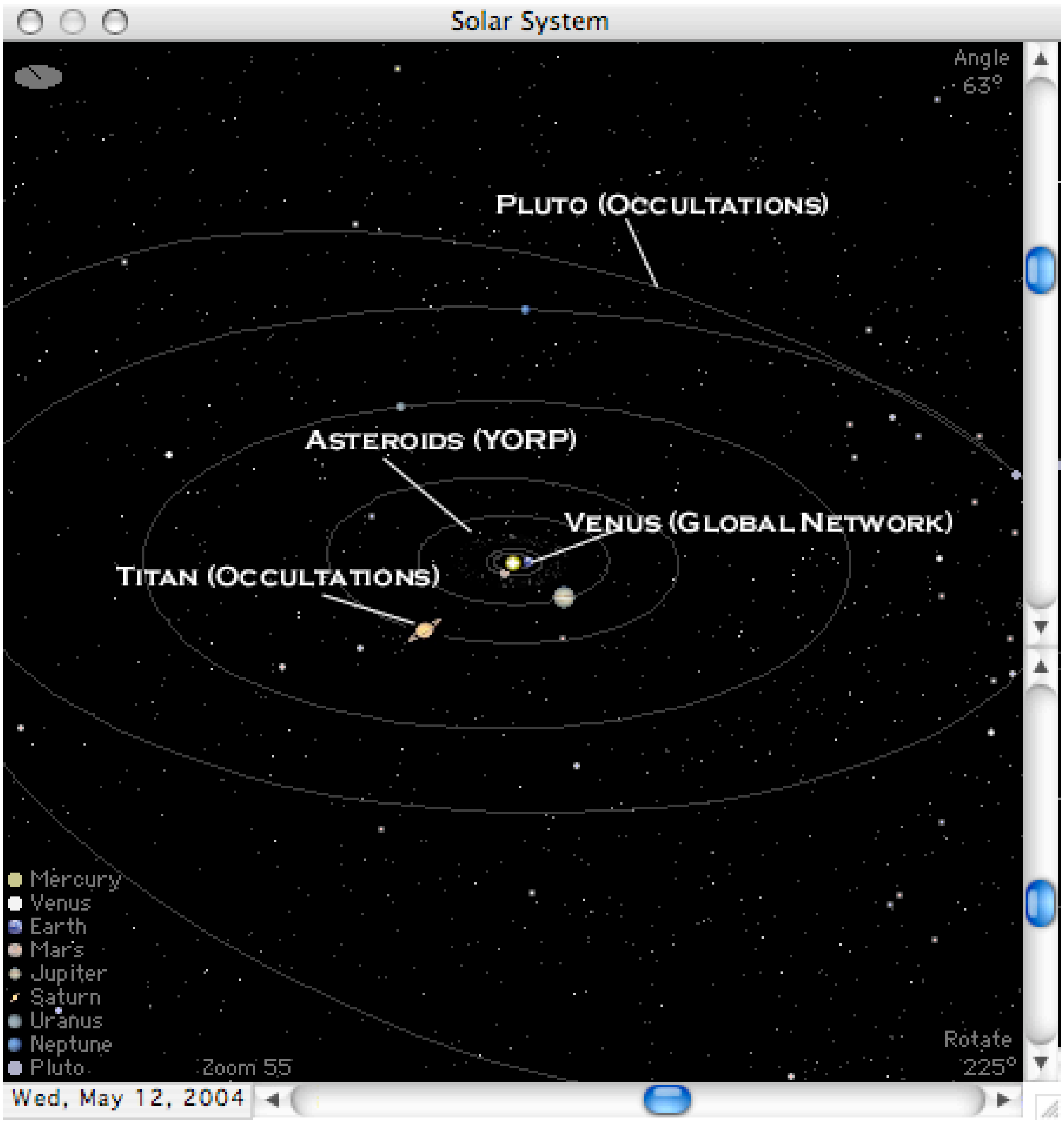
# Building the Network from the Ground Up...

## in the context of various planetary observations

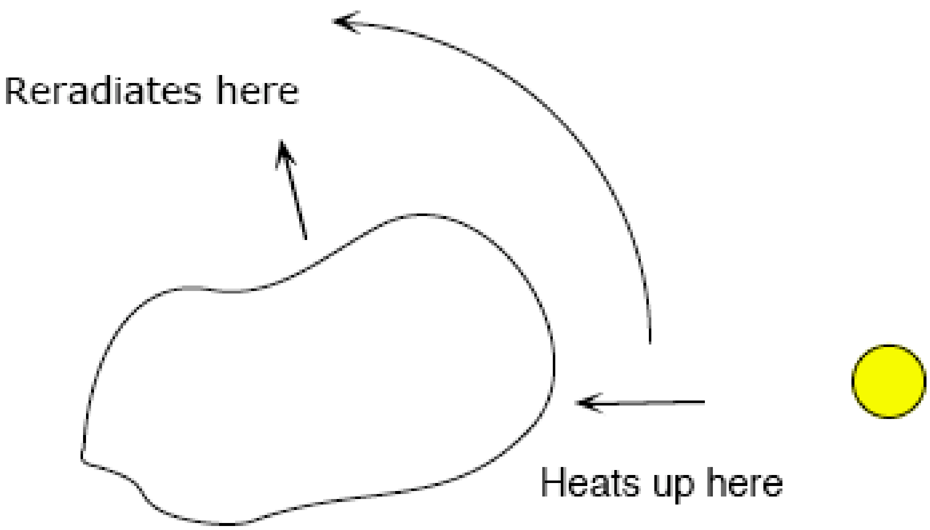



## *ASSORTED TOPICS*

- YORP & Asteroid spin states
- KBO and Asteroid Binaries
- Occultations (Titan, Pluto, etc.)
- Global Campaigns

## 1. Asteroids, Yarkovsky Effect, & YORP

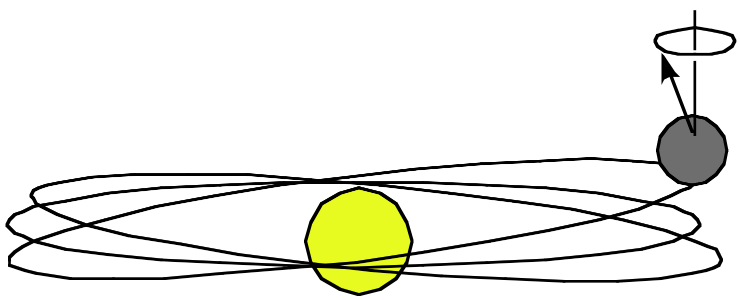
*Aside: What **is** the Yarkovsky effect?*




A spinning asteroid will experience weak but continuous thrust due to thermal photons.

*OK, but what is YORP?*

YORP describes the expected trapping of a small asteroid's spin state into a resonance that is commensurate with its orbital precession period.



If the asteroid has an aspherical shape, then the Yarkovsky effect can change its obliquity.

As the obliquity changes, the spin precession period changes.

When the spin precession period scans through an orbital precession period, the spin vector gets trapped in the resonance (but ONLY for prograde rotators).

*Prediction*:
Retrograde rotators should have spin vectors all over parameter space. *Prograde* rotators will preferentially have spin vectors that correspond to certain precession periods.

These prograde spin states are called *Slivan States*, because Steve Slivan's tenacious observations confirmed the effect.

NOTE:
Steve's observations of asteroid lightcurves were made over several years, primarily with small telescopes, e.g., the telescope at Colby College.

## 2A. ASTEROID & KBO BINARIES

Binaries are useful because they:

1. Constrain origin scenarios, and
2. Yield object masses & densities.

Some binaries are discovered through lightcurves, but a more direct way is to use adaptive optics. NEOs binaries often found with radar-based shape models (about 15 to date).

Here is an example where a big telescope with adaptive optics is the most effective tool. Ideally **all asteroids and KBOs** could be imaged at 1/20th of an arcsec resolution to look for binaries.

## 2B. ASTEROID & KBO SIZES, ALBEDOS & THERMAL SURFACE PARAMETERS

First cycle SPITZER proposals often need coordinated ground-based photometry.

Example: Irregular satellites of Jupiter or Saturn. How big are they, how bright are they, and do they have rock or dusty regoliths?

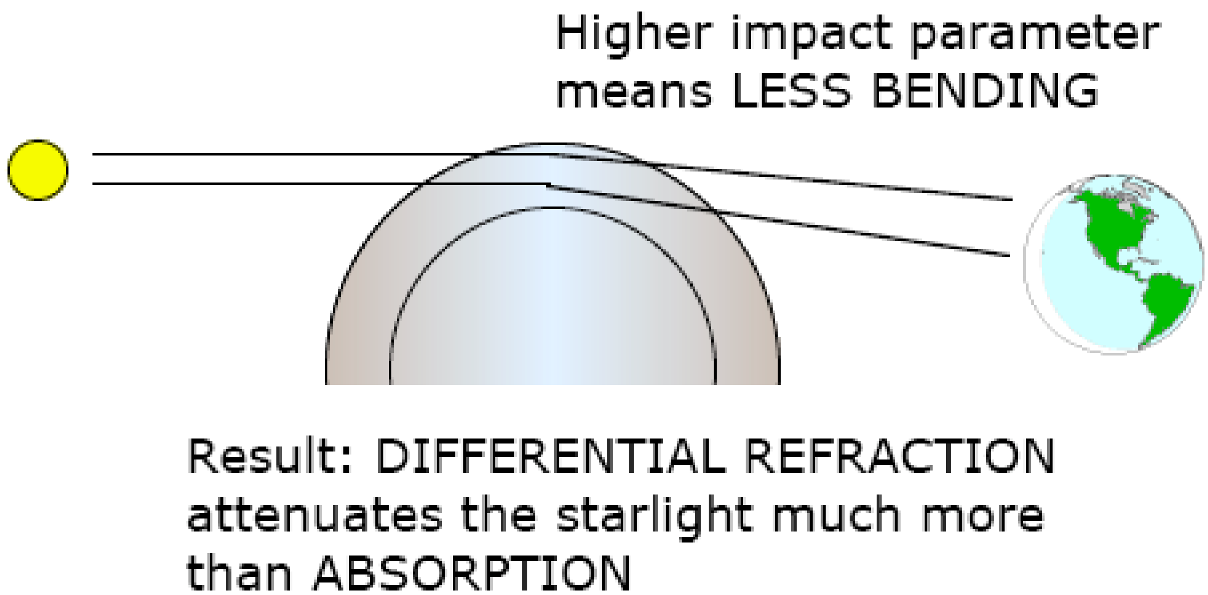
Coordinated groundbased observations need to be (a) simultaneous or (b) capable of characterizing the object’s lightcurve.

# 3. OCCULTATIONS

(P126A Prediction for the 20 JULY 2004 Pluto Occultation)

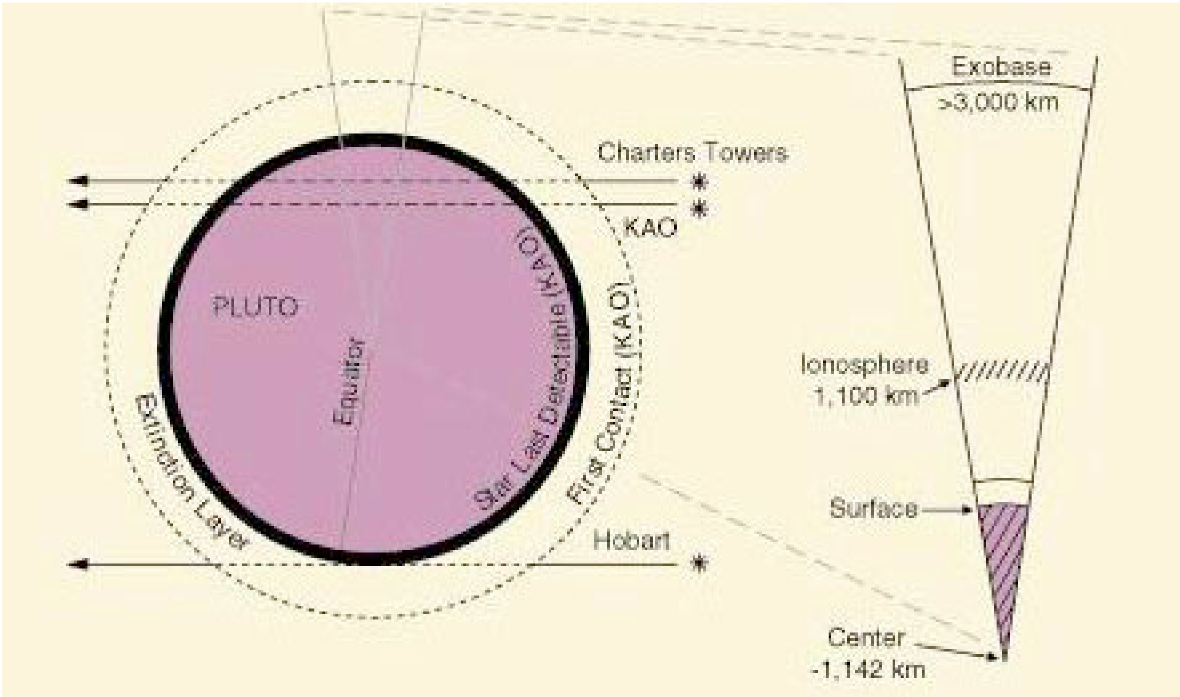
(show plans for 22-inch portable telescopes)

Occultations are very sensitive ways to probe an object's upper atmosphere.

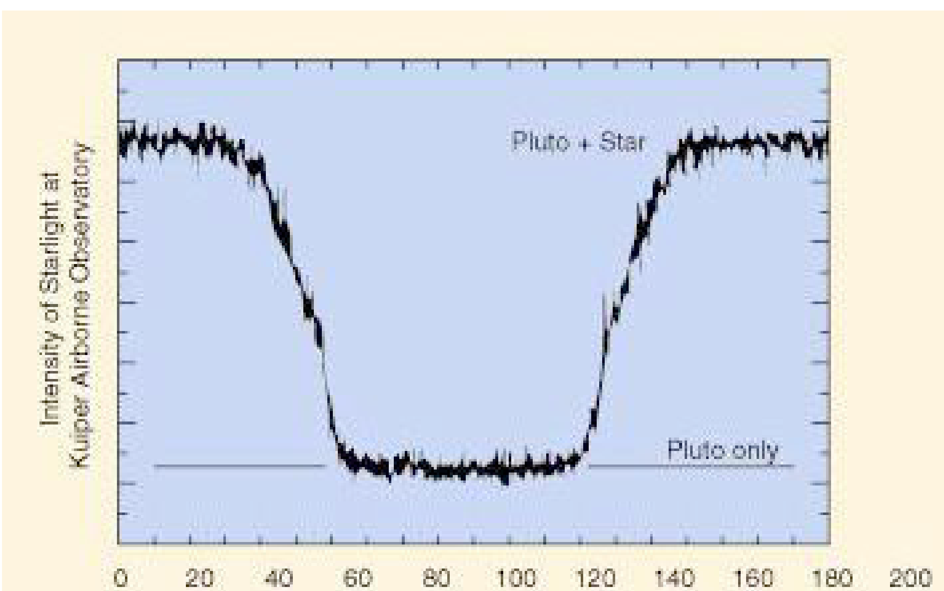



"*The occultation lightcurves provide information on Titan's atmosphere at altitude levels between about 250 and 600 km above the satellite's surface. This corresponds to pressure levels of about 250 and 0.15 μbar, respectively. The atmospheric layers below 250 km are inaccessible because the stellar flux is then too much refracted...*" (Sicardy et al. 1999, The Structure of Titan's Stratosphere from the 28 Sgr Occultation)

In other words, a planet's atmosphere (with a roughly exponential profile for the index of refraction) is a weak divergent lens.




Pluto occultations were observed in 1988 and 2002.

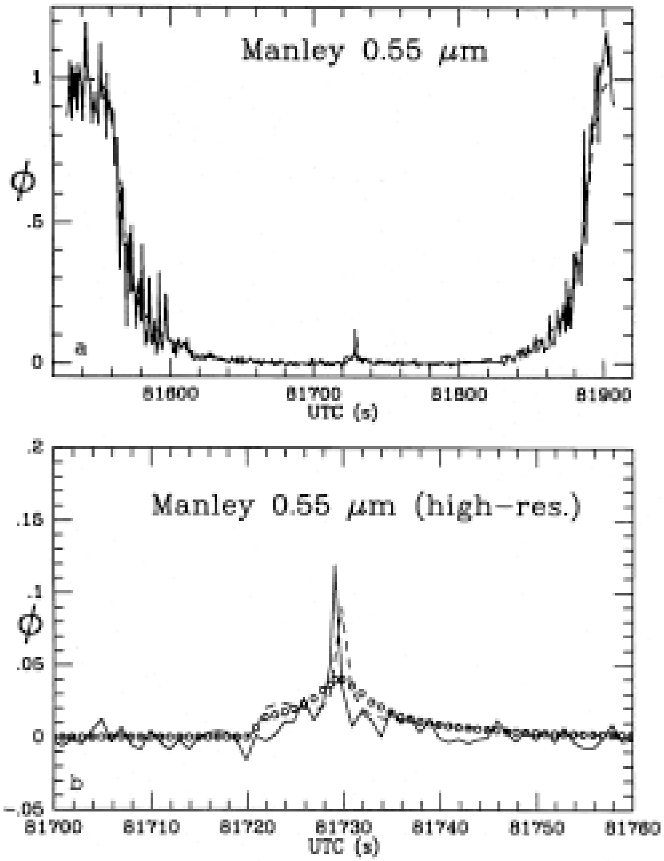



The *slope* gives you a Temperature profile.

The 1988 event was best observed from the Kuiper Airborne Observatory

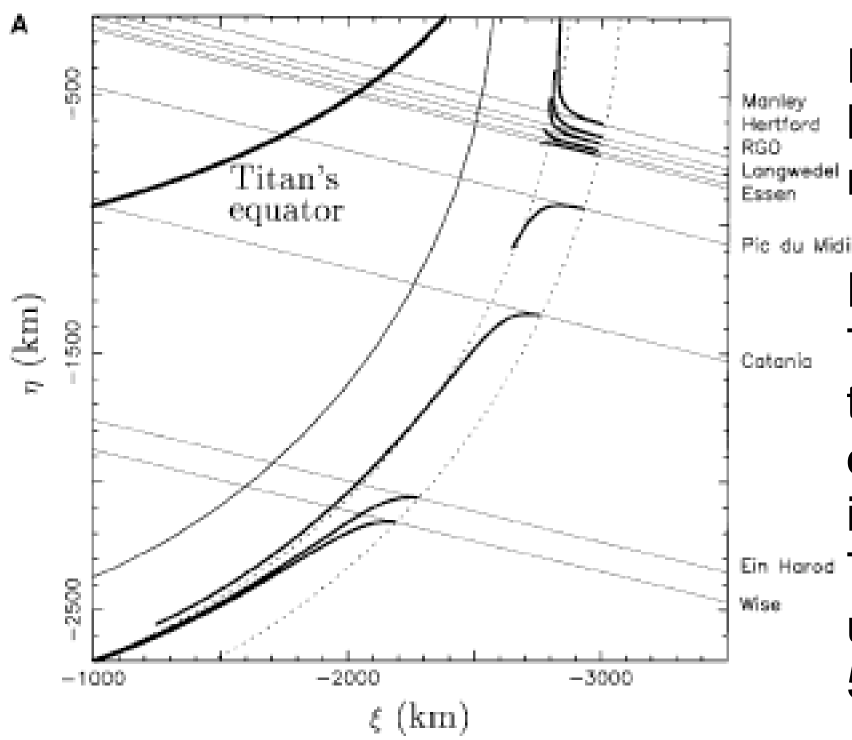
POINT 1:
Occultations of small objects often require
(a) deployable telescopes, and
(b) low read-noise, high frame rate CCDs.

*More about Occultations: The Central Flash*
An atmosphere generally acts as a weak divergent lens, but it can focus the starlight onto a detector when the star is COMPLETELY BEHIND the disk.
Example: Titan (with AO).




The 1989 Titan/28-Sag occultation was observed from many sites.

Some sites (those near the CENTER of the shadow) saw CENTRAL FLASHES.

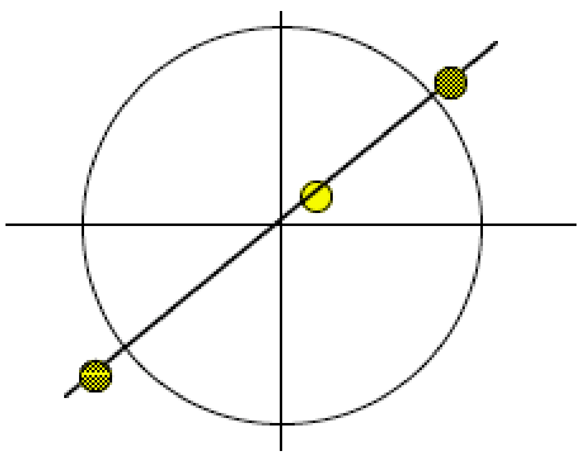


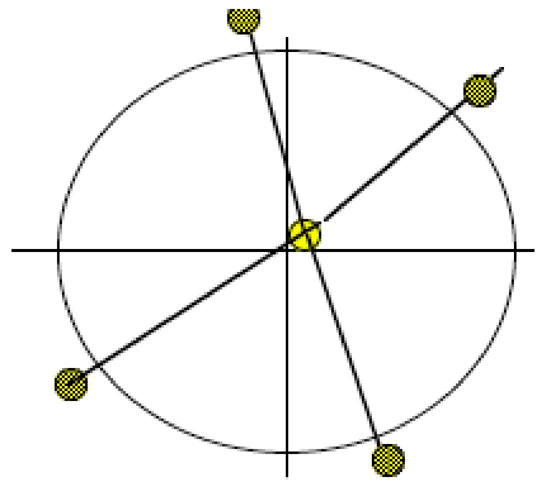

Observing Requirements:

For small bodies, high-speed, low-noise photometry.

For others (like Titan), the ability to resolve the object is very important. For Titan, allows useful events with 5x fainter stars.

An image of the star appears at Titan's limb wherever isobars in the atmosphere are perpendicular to the projected line from the occulted star.



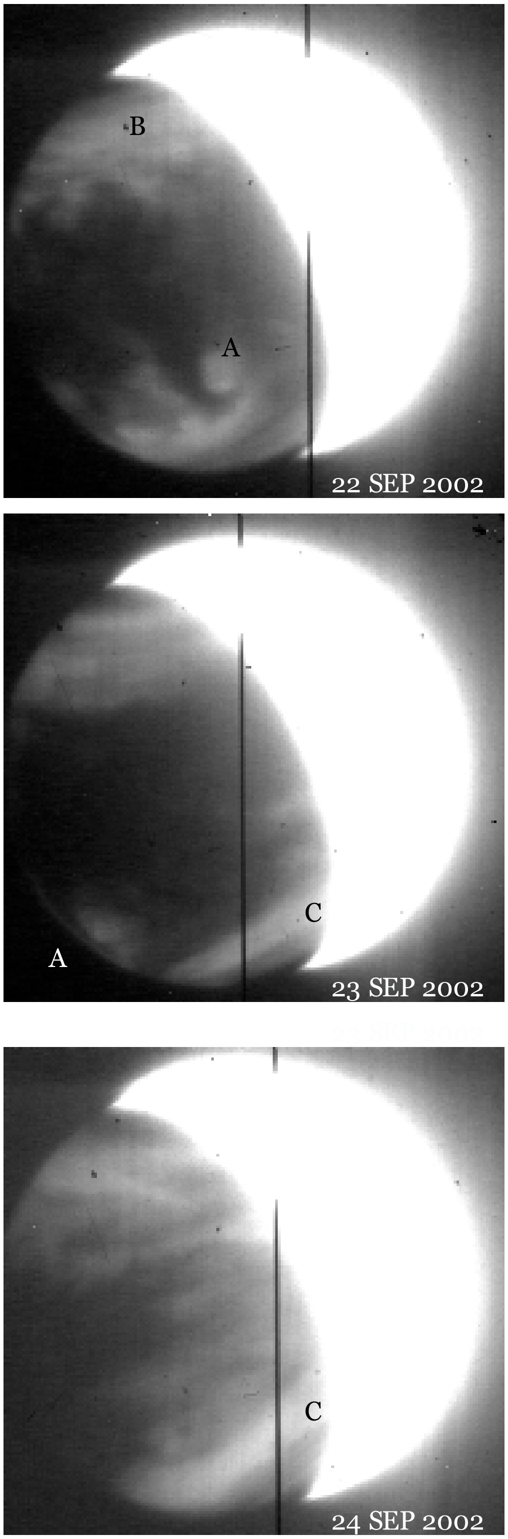


CIRCULAR CASE: The central flash could, in principle, be quite bright if star passes near center, since large sections of Titan's limb would refocus the star.

OBLATE CASE: Several ghost images of the star should be visible when the star itself is behind Titan.

(show Antonin Bouchet’s occultation movie)

# 4. OBSERVING VENUS



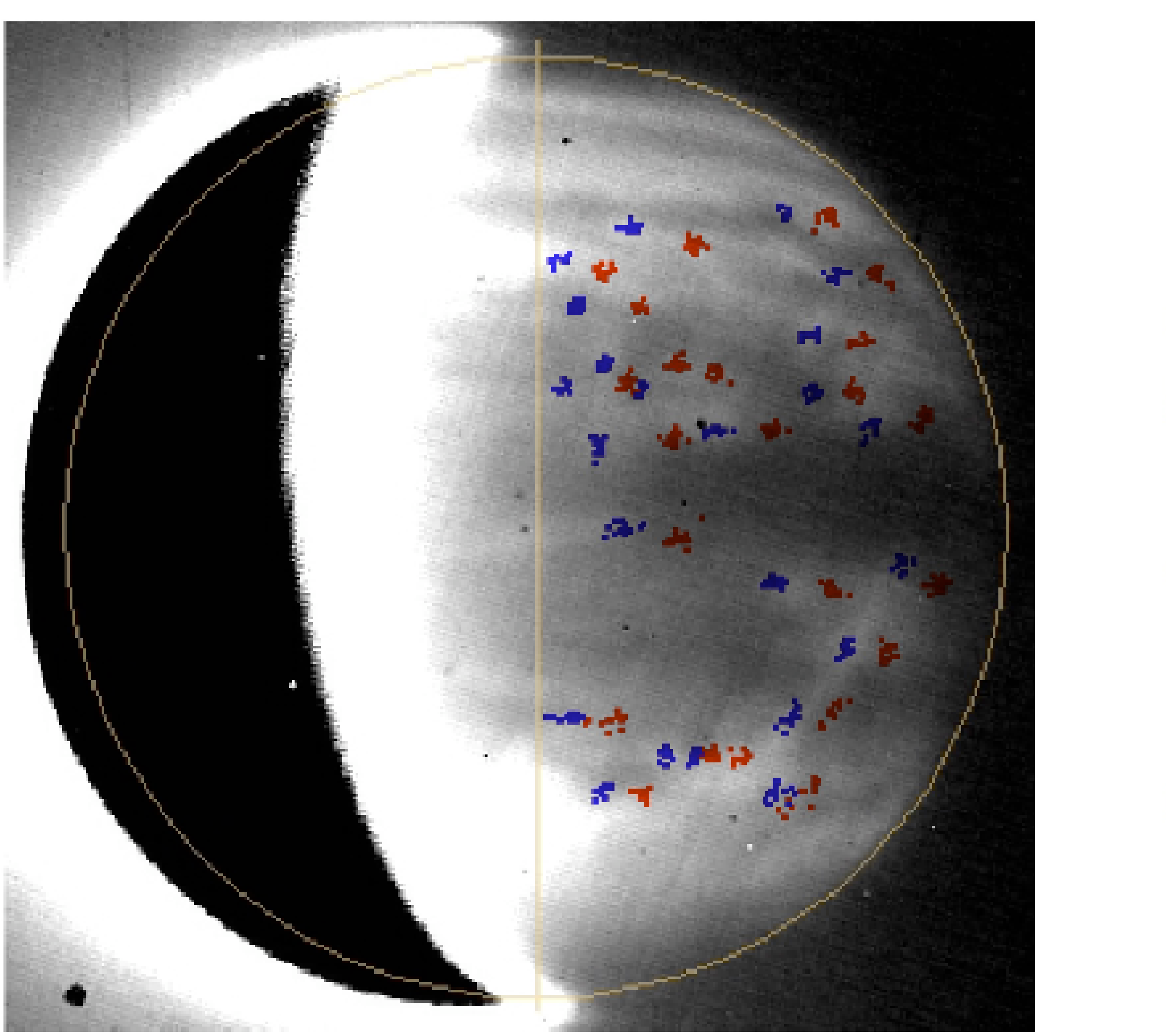

*GOAL*

Explain why Venus's atmospheric rotation (about 6 days) is so much faster than the solid body rotation (224 days). Watch clouds to explain momentum transfer

*BASIC IDEA*

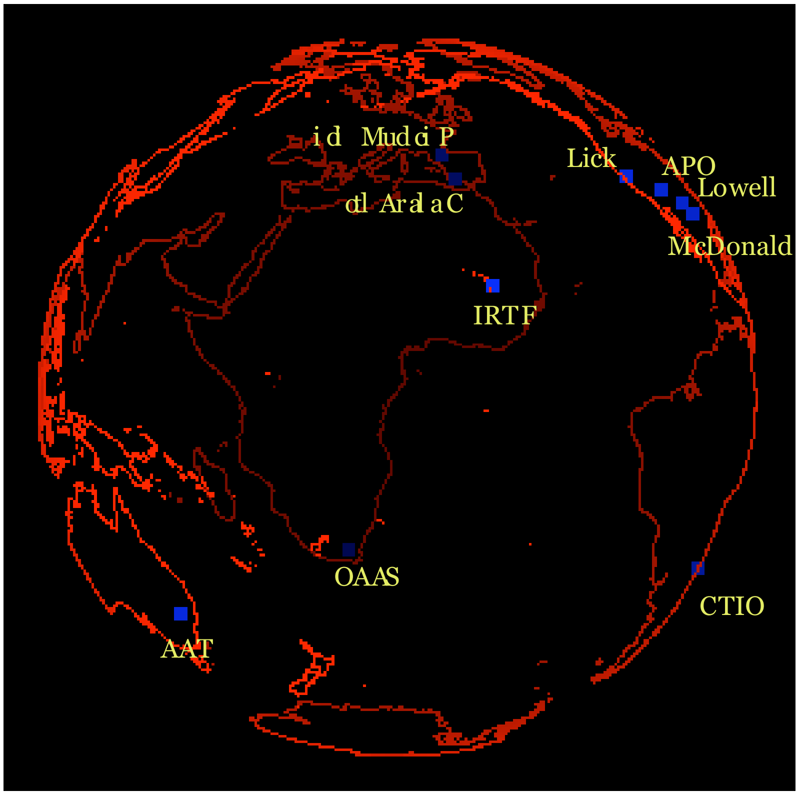
Thermal radiation from the surface or lowest scale height escapes through various spectral windows. The lower cloud deck (at ~48 km) silhouettes radiation from below.

For Venus, it’s important to combine observations from various longitudes.



Example: images from APO (Apache Point, New Mexico) and IRTF (Mauna Kea), separated by about 3.5 hours in longitude.

# A Network of Venus Observing Sites




Measurement of wind fields requires sites spaced around the world.

Just recently (May 4 - 10, 2004), we combined observations from AAT, HCT (Himalayan Chandra Telescope), Mt Abu, NOT (Nordic Optical Telescope), APO, and the IRTF.

> On Mon, 10 May 2004, Dr. B.C.Bhatt wrote:
>
> > Dr. Eliot
> >
> > We continued our Venus observations today also. This evening/night
> > (May 10, 2004) had small cloud patches all over the sky in the evening
with
> > little high winds. The sky improved much and became clear once it gets
dark.
> > Initially some venus images might have effected by moving cloud patches.
> >
> > Please find enclosed herewith the 2 Nos. of jpg images of Venus observed
> > today on May 10, 2004. the other details are as under:
> >
> > Telescope: 2-M HCT at IAO, Hanle-Ladakh, India, remotely operated from
> > CREST-IIA, Hoskote, Bangalore (the mirror is covered half with straight
> > flaps to avoid saturation in the darker part (region of interest) of
Venus).
> >
> > IR-Camera: 18 micron pixel, 512 X 512 format HgCdTe array,
> > Mode of Observations:DCS(Gain:6.21+-0.8 e/ADU, Readout Noise:35.1+-1.4e)
> > Image Scale: 0.21 arcsec/pixel (Camera-A, FOV 1.8X1.8 sq arc-min)
> > Filter: CO (Narrow Band filter, CWL= 2307NM, BW=20.5NM)
> >
> > Image 1:  venus_may10_4s, exp time: 4 sec, UT:13:24:36
> > Image 2:  venus_may10_8s, exp time: 8 sec, UT:15:06:35
> >

Date: Sun, 09 May 2004 06:40:19 -0500
From: Sanjay Limaye <sanjayl@ssec.wisc.edu>
To: Eliot Young <efy@boulder.swri.edu>
Subject: Re: Going To Town

Hi Eliot,

The links to HCT and Mt. Abu and their home institutions
are on the followig URL:

tellus.ssec.wisc.edu/obs.html

Both sites are very supportive of our observations and I
think we can all benefit from more collaborative efforts.
 They have had difficulties in getting some detectors from
the US, I understand, and those are the kind of issues
that should be brought up in the US-India meeting in June
in Bangalore.

## SUMMARY POINTS

- Global longitudinal coverage becoming available. We're very happy with our collaboration with HCT.

- A 14-inch Meade is only $5.5K, but weighs 250 lbs. International shipping costs are typically $2.5K. Consider new 0.7 meter telescopes, 100 lbs, GOTO capabilities, cost about $16K.

- With respect to large telescopes, the IRTF model (remote observing, flexible scheduling) would be *very* useful.

- SOFIA will be a powerful resource for planetary observations (deployable, opportunities for mid-IR). Other sub-orbital programs? Alternatively, follow-ons to STEDI (3 programs for $24M)?

Contact info: Eliot Young, efy@boulder.swri.edu