The Stratospheric Observatory for Infrared Astronomy (SOFIA) and the Transient Universe

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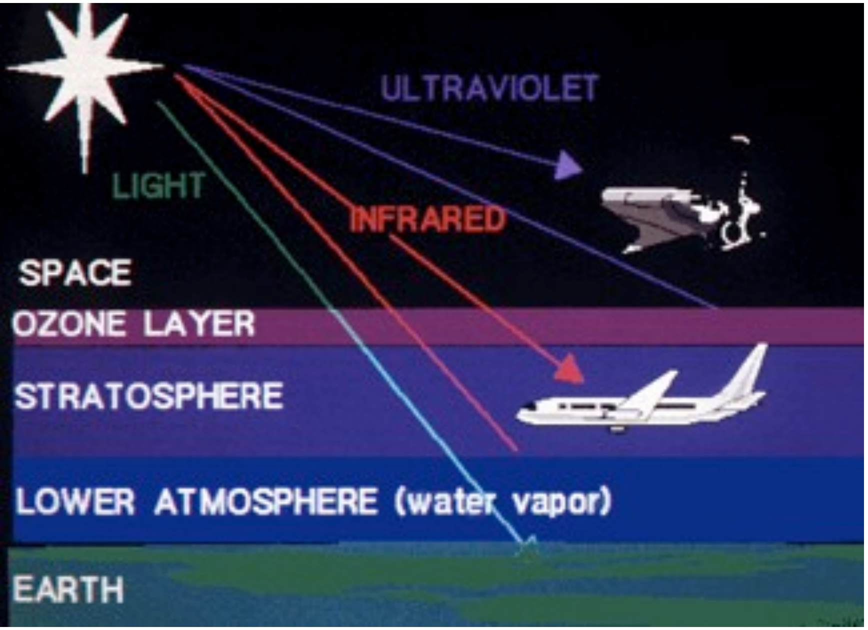
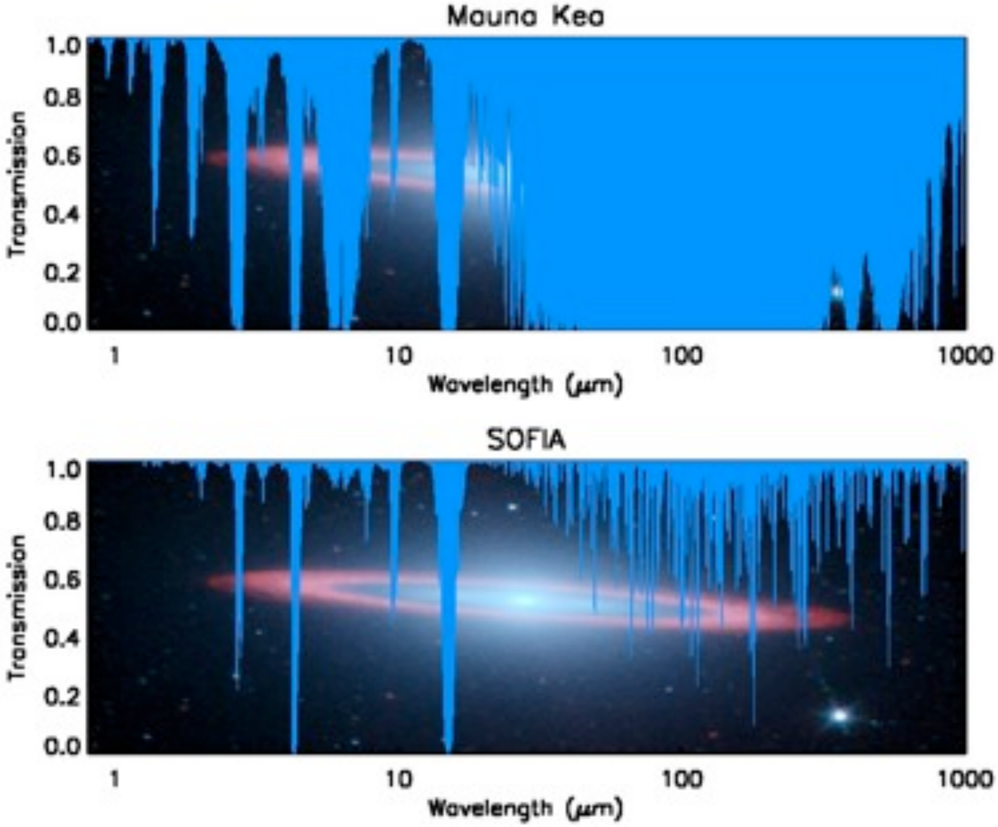
Airborne astronomy has a heritage of prompt response to transient astronomical events.

- *Go where you need to go when you need to go*
- *Take instruments that are scientifically relevant*
- *Get above the clouds and most of the water*
- *Permit real time observation planning*
- *Offer "hands-on" space science*



Airborne Astronomy



Stratospheric sky is largely transparent in optical and IR.

Routine access to clear skies, at desired times and places.

Large telescopes and cutting edge instruments.

Eclipse chasing in B17

Convair 990 - Galileo

0.3m LearJet Observatory

0.9m Kuiper Airborne Observatory

SOFIA Overview

- 2.5 m telescope in modified Boeing 747SP aircraft
- Service to 45,000 feet - above > 99.8% of obscuring water
- Joint Program between the US (80%) and Germany (20%)
  - Ops: Science at NASA-Ames; Flight at Dryden FRC in Palmdale
  - >120 8-10 hour flights per year

SOFIA open-door flight December 18, 2009

First light this April!

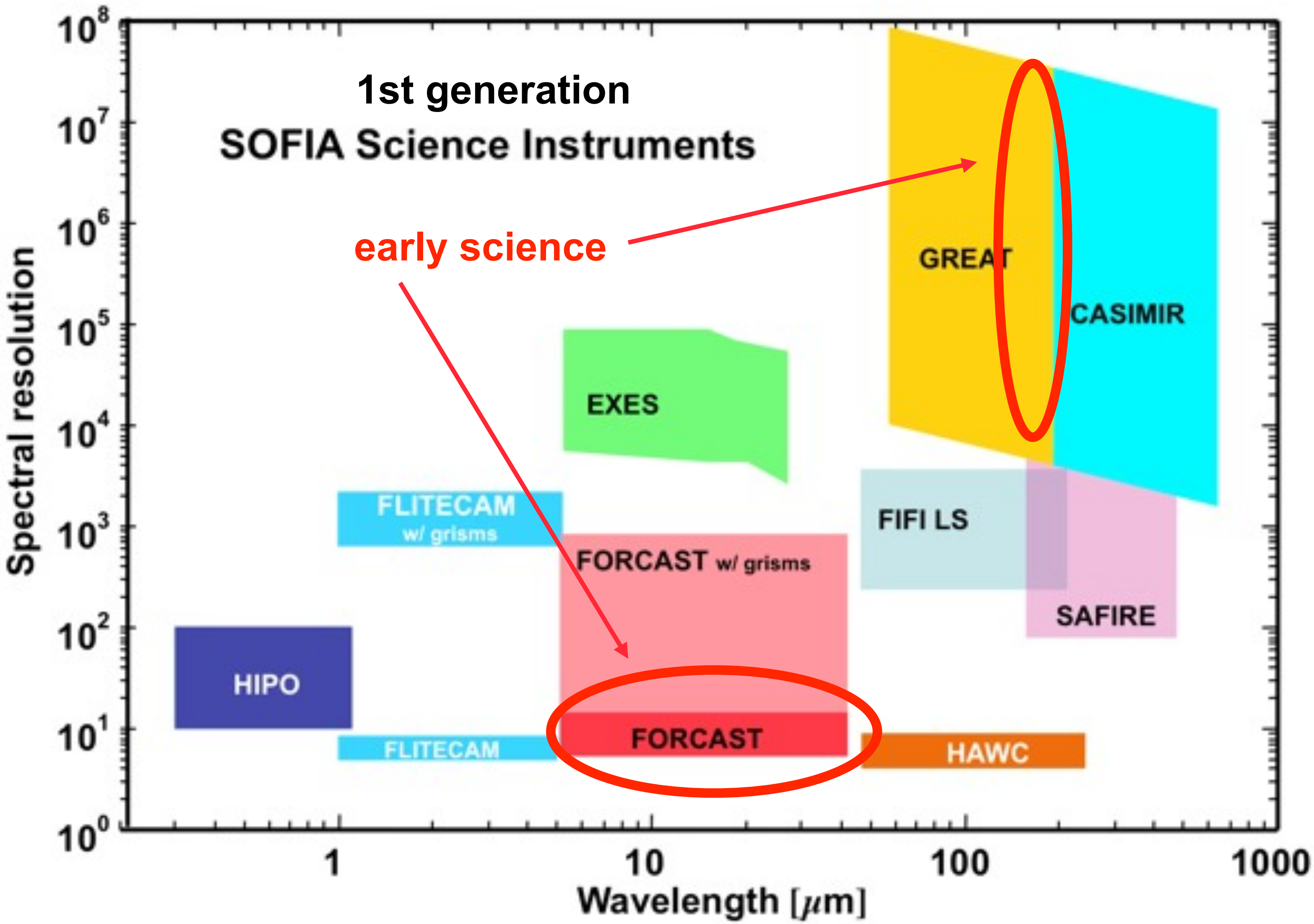
First instrument already delivered to ops facility

8 first generation instruments R = 10 - 10^8 , λ = 0.6 - 800 µm

Early science
- ***"Short" science - summer 2010 ; limited capabilities, shared risk***
- ***"Basic" science - early 2011 ; full capabilities, call in April***

- **Ramp up to 1000 flight hours/year by 2014 (more than 2x KAO)**

http://www.sofia.usra.edu/



1st generation
SOFIA Science Instruments
early science
GREAT
CASIMIR
EXES
FLITECAM
w/ grisms
FIFI LS
FORCAST w/ grisms
SAFIRE
HIPO
FORCAST
FLITECAM
HAWC
Spectral resolution
Wavelength [μm]
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
1
10
100
1000

FORCAST

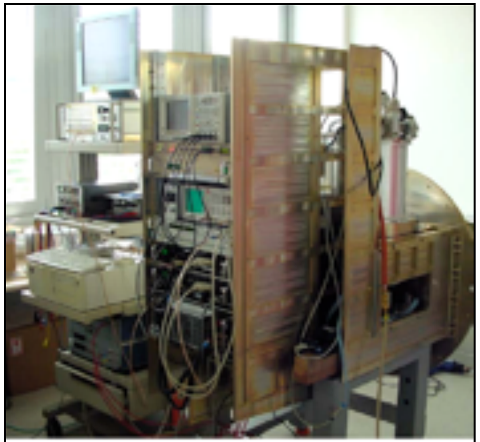
<u>F</u>aint <u>O</u>bject infra<u>R</u>ed <u>CA</u>mera for the <u>S</u>OFIA <u>T</u>elescope

- **Mid IR, two-channel camera**
- **0.75”/pixel 4-8 μm,16-40 μm**

GREAT

<u>G</u>erman <u>RE</u>ceiver for <u>A</u>stronomy at <u>T</u>erahertz frequencies

- **Heterodyne spectrometer**
- **Dual-channel 1.6-1.9 THz, 2.4-2.7 THz**



Lab-picture of GREAT equipped with the KOSMA 1.9THz channel

- **SOFIA New Instrument Workshop - Asilomar, June 2010**

  “Scientific Opportunities For New Instrumentation”

  http://www.sofia.usra.edu/Science/workshops/asilomar.html

Be there!

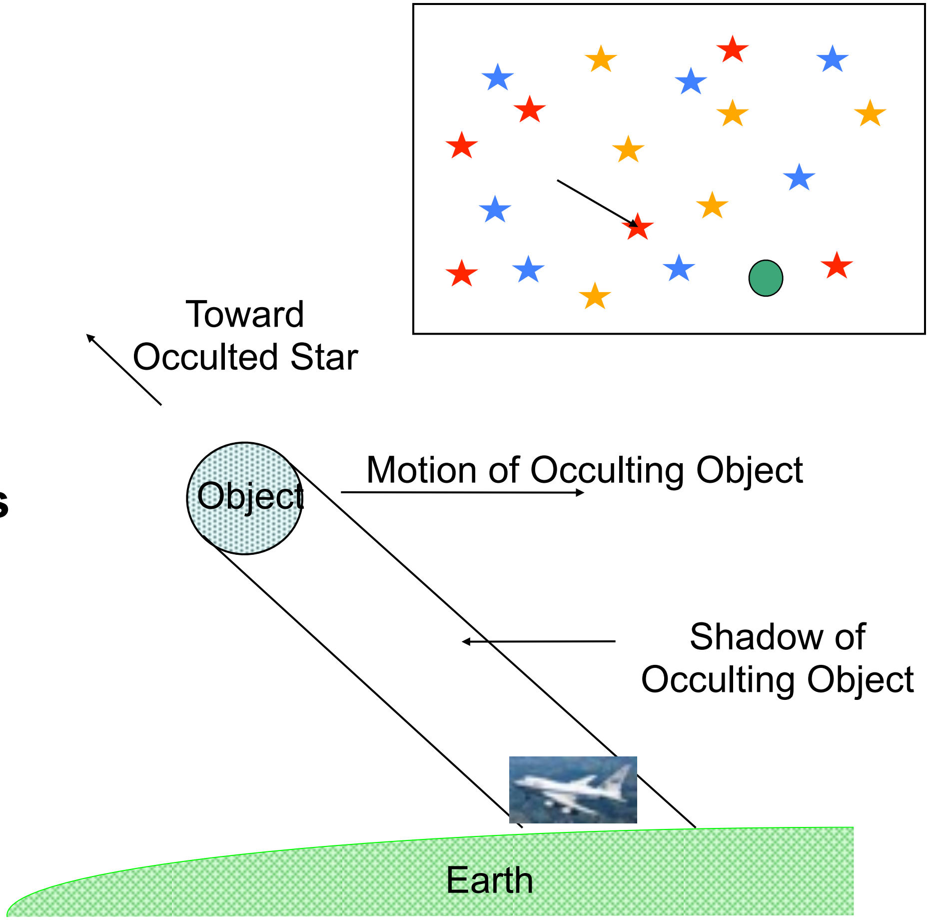
- **Call for 2nd generation science instruments - late 2011**

Occultation Astronomy with SOFIA

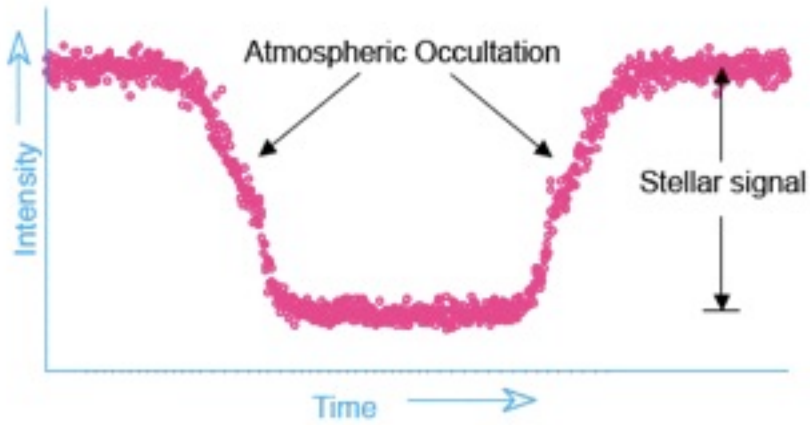
Helping determine the properties of small Solar System bodies

- Occultation studies probe sizes, atmospheres, satellites, and rings and small bodies in the solar system.

- SOFIA can fly anywhere on Earth to position itself in the occultation shadow. Hundreds of events available per year compared to a handful for fixed ground observatories.

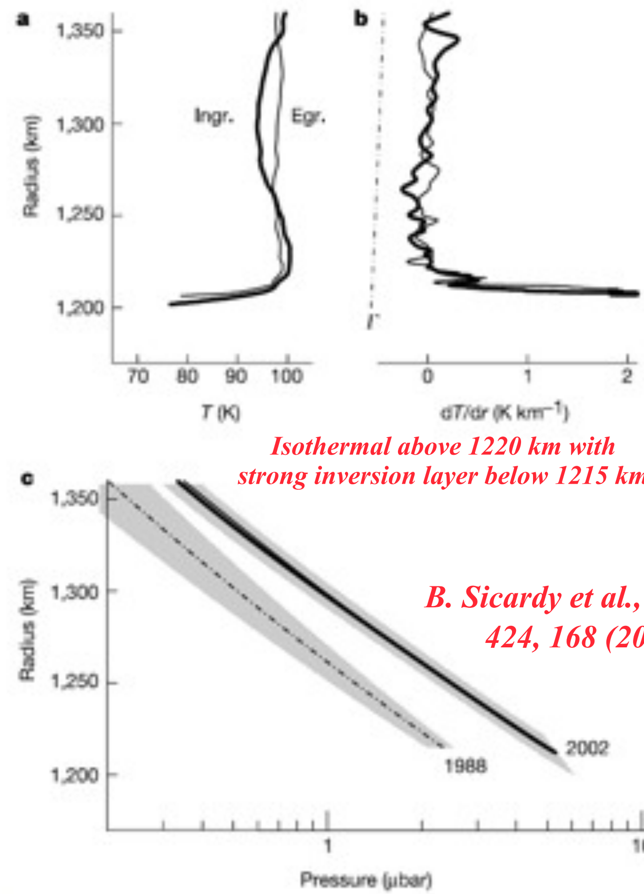


Occultations and Atmospheres



This occultation light curve observed on the KAO (1988) probed Pluto's atmosphere

J. L. Elliot et al., Icarus 77, 148-170 (1989)



Isothermal above 1220 km with strong inversion layer below 1215 km

B. Sicardy et al., Nature, 424, 168 (2003)

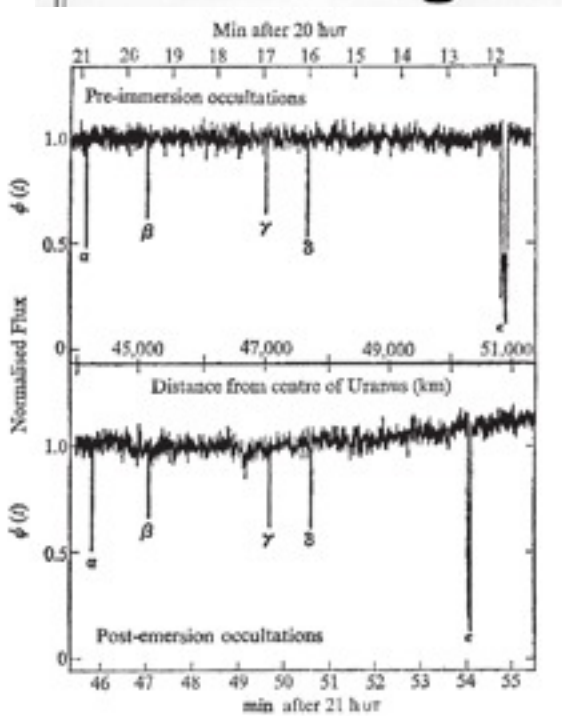
Figure 2 Temperature and pressure profiles of Pluto's atmosphere derived from the inversion of the P131.1 light curve. This inversion[17] assumes a spherically symmetric and transparent atmosphere. It first provides the atmospheric refractivity profile, then the density profile for a given gas composition, and finally the temperature profile, assuming an ideal gas in hydrostatic equilibrium. We assume for Pluto a pure molecular nitrogen[6] atmosphere.

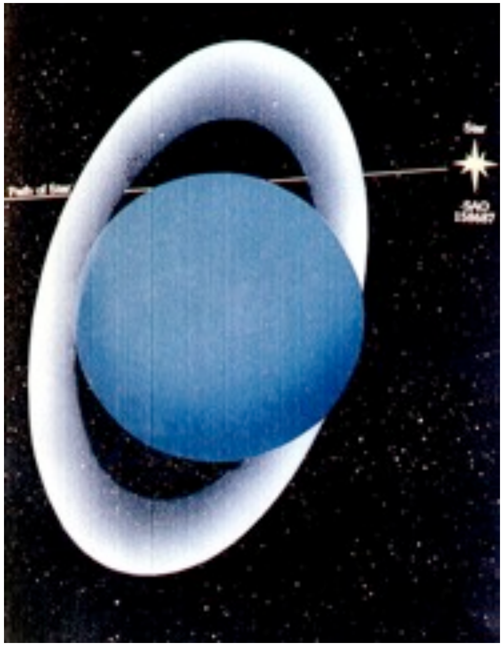
Occultations: Rings and Moons


Uranus' Rings: The Story of a Discovery

— Sun Photo by Liz Warner

THE TEAM: Researchers Edward Dunham (l.), James Elliot, and Douglas Mink examine the unexpected signal pattern produced on the charter recorder by the outermost ring of Uranus.





This occultation light curve observed on the KAO in 1977 shows the discovery of a five ring system around Uranus

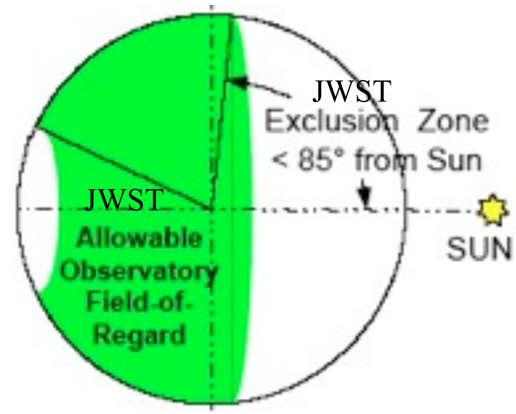
J. L. Elliot, E. Dunham, and D. Mink, Nature 267, 328-330 (1977)

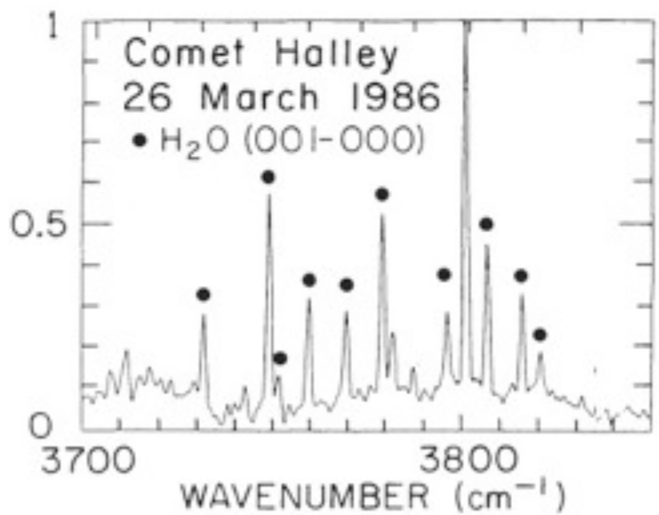
Comets in the Inner Solar System

JWST exclusion zone <85º from Sun
(Herschel “ “ <60º “ “)

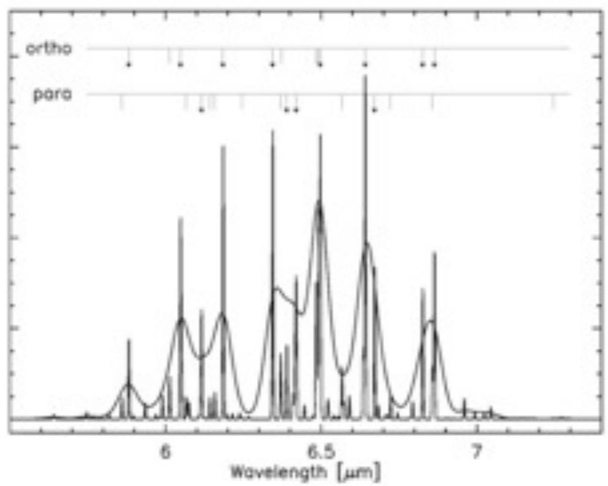
Cryogenic infrared observatories are strongly constrained by solar exclusion zone.

With elevation limit of 20º, SOFIA can reach much closer to the Sun. Pointing limited.

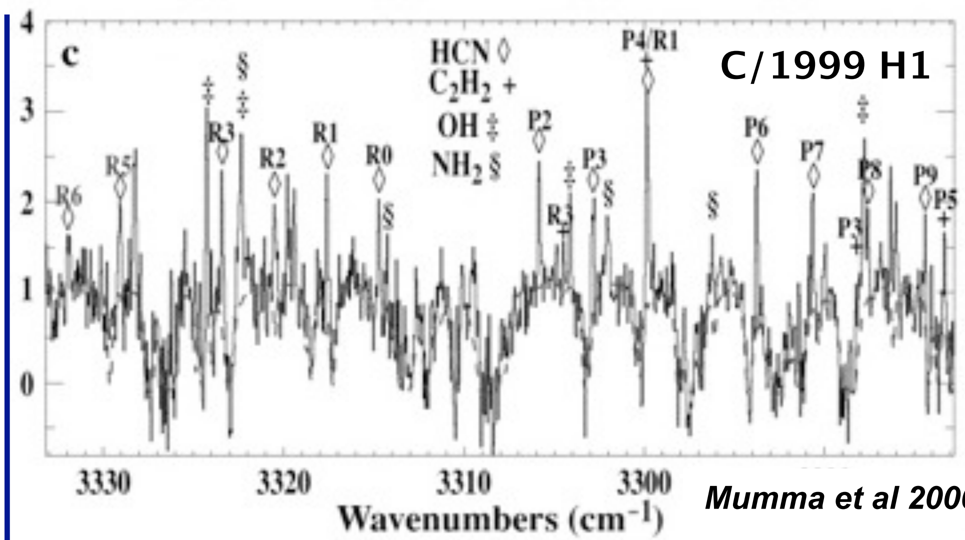




Production rate of water and organic volatile emission is strongly enhanced at <1AU for comets. The inner solar system is particularly revealing of comet composition.

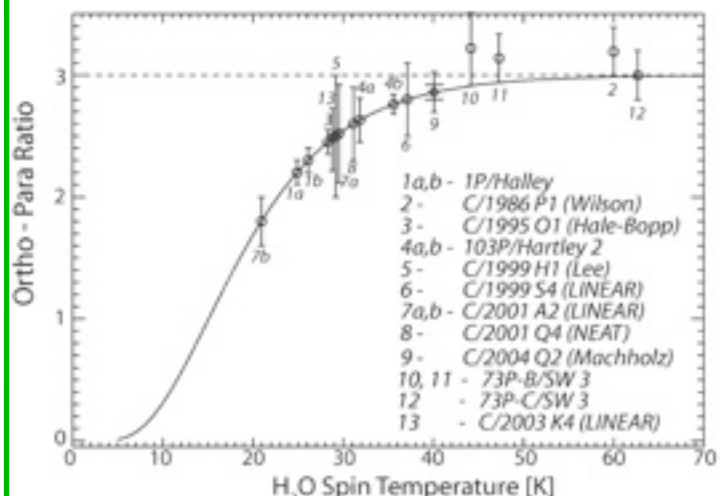


Woodward et al. 2007



Mumma et al 2000

The spectrum of cometary volatiles is especially rich in the inner solar system, with strong representation from organics.

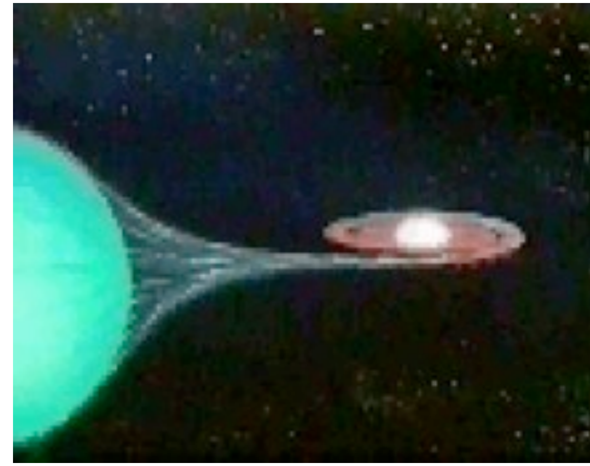


Bonev et al. 2007

Ortho/para ratios are indicative of ice formation temperature.

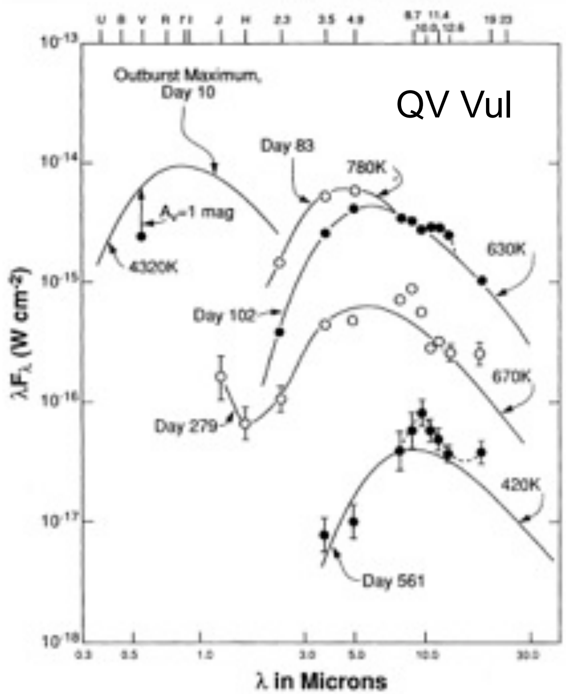
SOFIA and Classical Nova Explosions

What can SOFIA tell us about gas phase abundances and dust minerology in classical nova explosions?

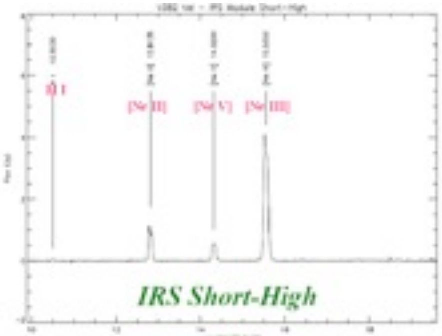


- *Amorphous carbon*
- *SiC*
- *Amorphous silicates*
- *Hydrocarbons*

Gehrz et al. 1992 (Ap. J., 40, 671)



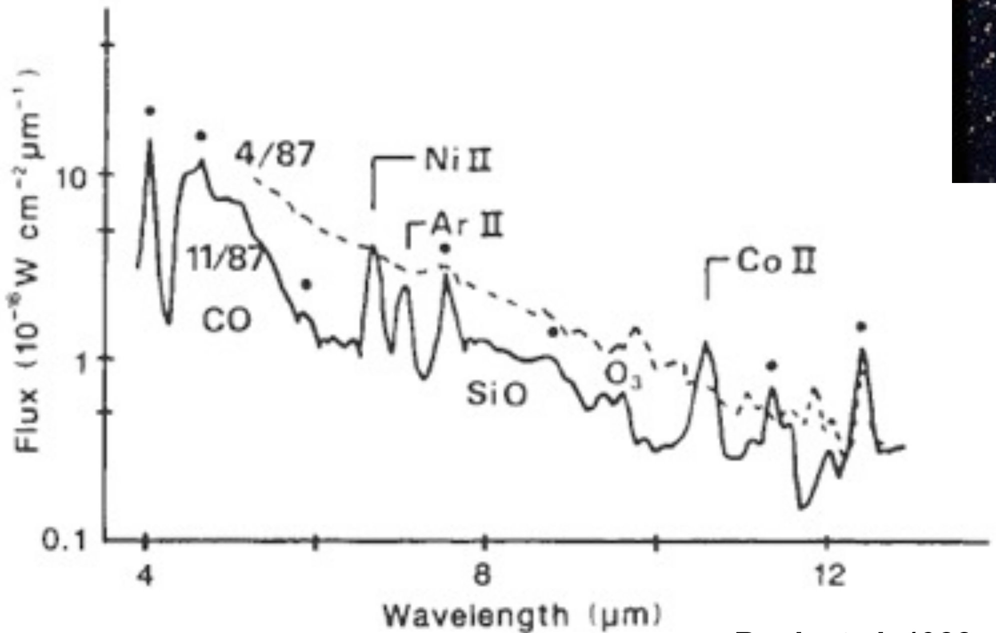
Nova V382 Vul



- **Gas phase abundances of C, N, O, Mg, Ne, Al**
- **Spectral R and λ coverage of dust components**
- **Kinematics of the ejection**
- **Contributions to ISM clouds and primitive solar system**

SOFIA and Local Supernovae!

What can SOFIA tell us about the energetics of supernovae?



Rank et al. 1988

- **Heavy elements produced in advanced nuclear burning stages**
- **Dust echoes from heated ISM**
- **Dust formation in outflow.**

SOFIA will bring …

flexible planning,
observational convenience,
atmospheric transparency,
and cutting edge instrumentation
to studies of the transient universe.

Stay tuned!