





# Townes' Legacy and SOFIA's Science Vision

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# Outline of Material

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- Charlie Townes and Airborne Astronomy
- Gerry Neugebauer and IR astronomy
- SOFIA; Discoveries; and making SOFIA more productive
- Spectroscopy Science with the FORCAST GRISMS
- First FLITECAM spectroscopy results of SN 2014J in M82.
- Special experiments with SOFIA
- Summary





# Charles Townes and Airborne Astronomy

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- **Charles Townes died on 27 Jan, 2015 at the age of 99**
- **He has always been a supporter of Airborne IR/submillimeter Astronomy**
- **For example, in March 2014 he wrote a letter of support for SOFIA to Obama's Science Advisor, Dr Holdren**
- **He won the Nobel Prize in Physics in 1964 for the invention of the maser. Demonstrated in 1954 at Columbia University.**
- **I first meet Charlie at Caltech in about 1967**
  - **He was on the Caltech Board of Trustees**
  - **He was just moving to Berkeley to start an IR/Microwave astronomy lab.**
  - **He was very interested in our recent measurement of stars in the Center of the Galaxy.**

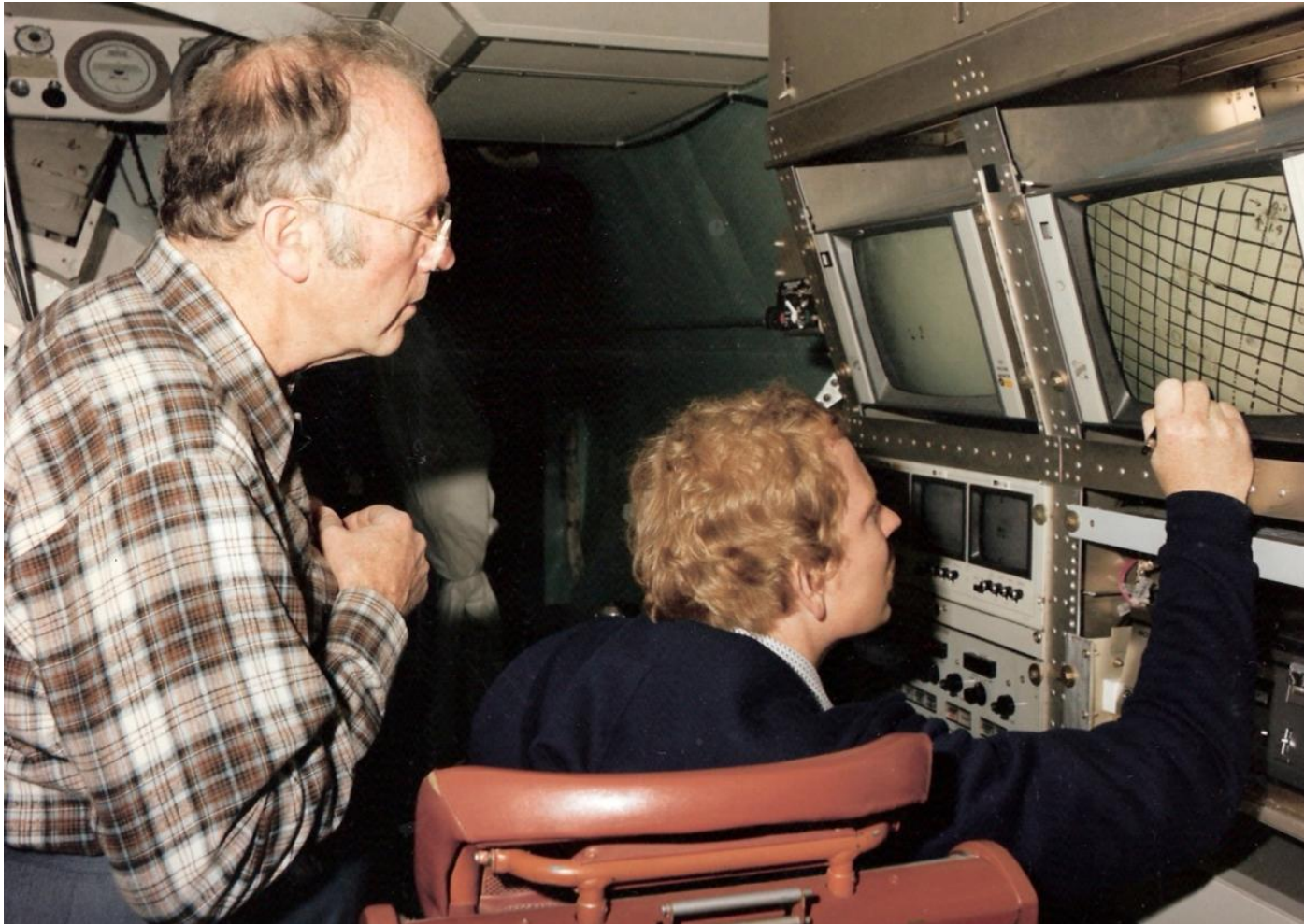




# Charlie Townes and Reinhard Genzel



## on the KAO





# Charles Townes and Airborne Astronomy



- **Charlie flew on the KAO with Graduate Students, Post Docs and other collaborators from 1978 until 1995 using Fabry-Perot Interferometers built in his lab.**
- **He had over 30 published papers on observations and discoveries**
- **First detection of high J CO and OH in the ISM**
- **First detection of OI, OIII and CII in External Galaxies**
- **First extensive maps of OI, CII, high J CO in the Galactic Center, Orion and other regions**
- **His collaborations In airborne work included: R. Genzel, J. Storey, D. Watson, M. Werner, G. Stacey, A. Poglitsch, S Madden, A. Betz, J Stutzki, Alfred Krabbe, Andy Harris and many more.**





# Charles Townes and SOFIA

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- **Charlie was one of the key people that sold SOFIA to NASA and the US congress in mid 1990's.**
- **He was the first Chair of the SOFIA Science Council 1997 to 2003.**
- **In 2006 he was our most important supporter when we were out of the NASA budget.**
- **He personally introduced me to both Hans-Peter Roeser (Hawaii 1982) and Rolf Guesten (Mid 1980s at Berkeley GC meeting).**
- **He will be missed.**







# Gerry Neugebauer (1932-2014) on the KAO in 1976



Eric Becklin, Mike Werner, Ian Gatley, Gerry Neugebauer (1976)







# Gerry fixing the Dewar while others watch on the KAO



*Figure C12. Graduate student Ian Gatley, Eric Becklin, Gerry Neugebauer, and Gordon Forrester (Caltech), 1976, making in-flight repairs to their far-infrared photometer.*





# “Recipes” for (SOFIA) Discoveries

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- **How are Discoveries made.**
  - **New capabilities (mainly instruments)**
  - **Surveys are usually important**
  - **Often it is a accident or a mistake (shows there are lots of discoveries out there.)**
- **Use the observatory more like a physics lab rather than a multi-user observatory**





# Vision for SOFIA



- **There are some obvious areas where SOFIA will be the best for the next 10 to maybe 20 years.**
  - **Wavelength 30 to 300 microns (balloons are the only real competition and they are risky and limited)**
  - **Spectroscopy gives the highest gains because of the relatively high background radiation  $T > 240\text{K}$ . Can also support large instruments.**
  - **Innovative instruments are a key with large a multiplex such as heterodyne arrays or MKID spectrometers**
- **SOFIA must allow rapid (risky) instrument development!!**
- **Give new and upgraded Instruments more telescope time!**





- **How to get better Science**
  - **Work around conservative astronomy TACs (Dave Allen's story)**
  - **Larger multi-year proposals**
  - **More Director's discretionary time (increase to 20 to 30%) I will give examples later.**
  - **Increase the user pool. More incentives to international astronomers. More \$ to US proposers.**



# SOFIA Productivity



- **Get more science published quickly. Follow GREAT with a large team and a considerable amount of telescope time.**
- **We are not a “Great Observatory”. Control the tendencies to archive all data for all future users.**
- **Limit the pipelines. Good users learn how to get their data reduced.**





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# Some recent timely Spectroscopic Science with SOFIA





# Nova Del Outburst of 2013

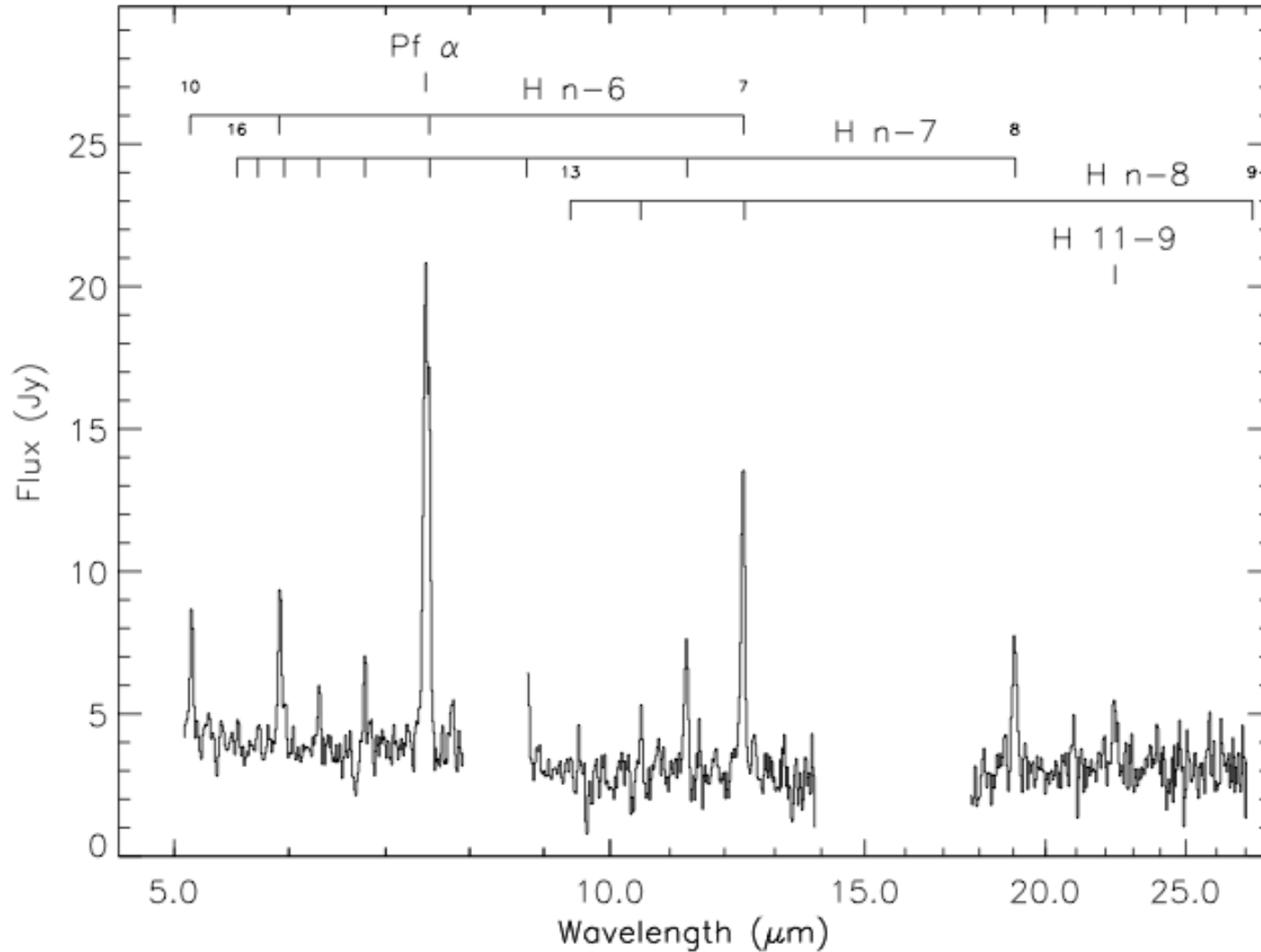
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- **Gehrz et al put in a proposal to observe recurrent Nova with the FORCAST GRISMs if in outburst occurred.**
- **On 13 Aug 2013 V339 Del was discovered to be in outburst**
- **Erick Young activated the Target of Opportunity (ToO) FORCAST GRISM and Imaging observations.**
- **Goal was to look for strong IR metallic forbidden lines.**
- **Observations were taken on 10 Sept 24 days after maximum visible light.**







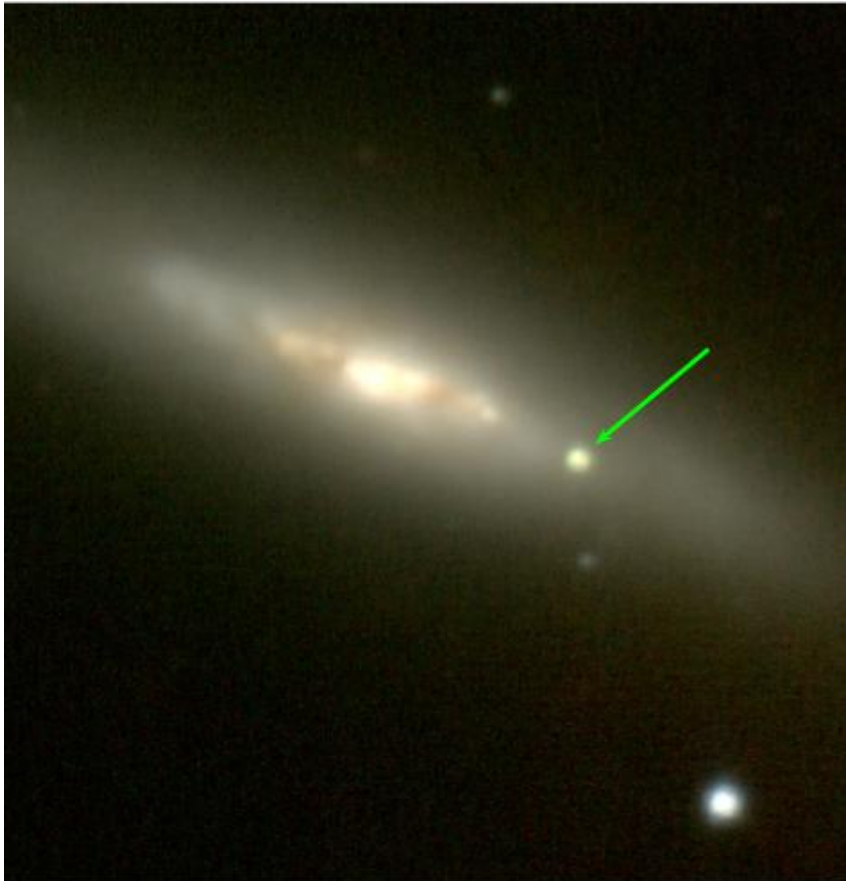


# SOFIA



- **Results reduced by Vacca and Helton show only Ionized Hydrogen emission.**
- **The density is too high ( $>E7$  per cc) and the metal lines are quenched.**
- **Gehrz is surprised that [NeII] is not seen based on other nova.**
- **A draft paper is being worked on.**





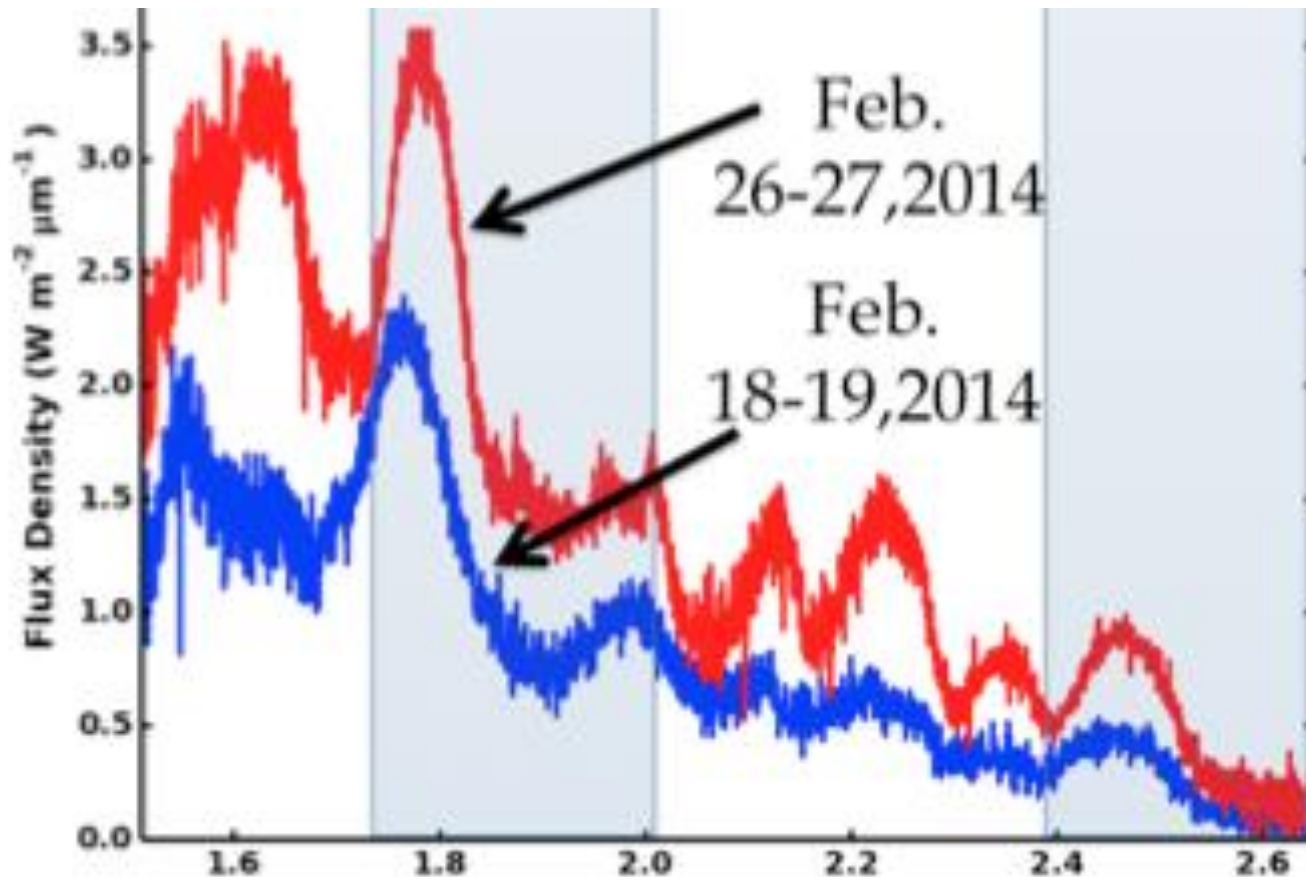
- Supernova Type Ia went off in Jan 2014
  - Starting taking data at T+36 days
  - Spectroscopy + imaging
  - Activated accepted ToO proposal and Director time ToO proposals.
- Coverage  $R \sim 1200$  spectra from 1 to 3.3 microns
- Results are now in Press (Vacca et al 2015 ApJ)



# FLITECAM and HIPO together



## (FLIPO): Supernova 2014J in M82 (Vacca et al in Press)

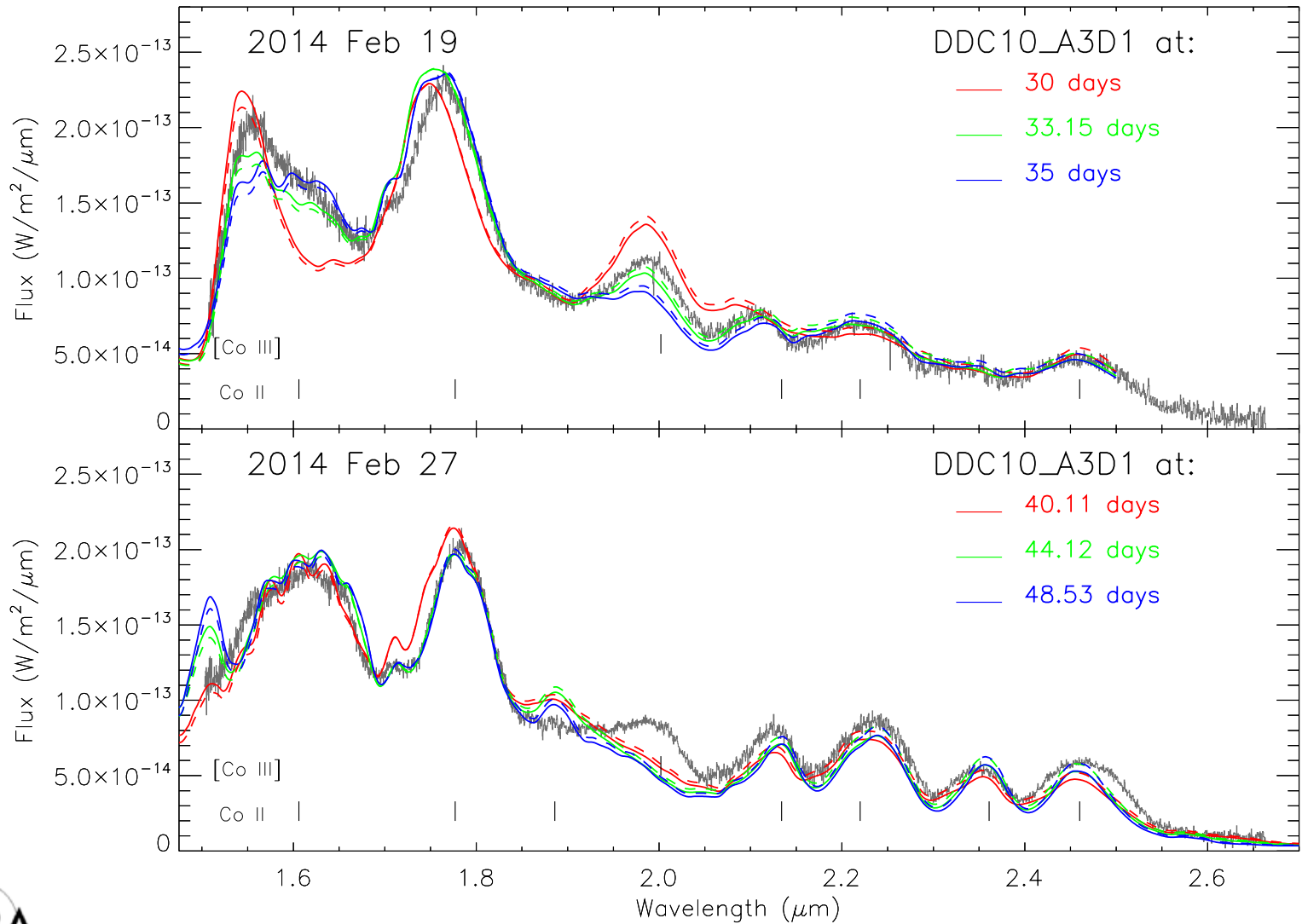




# FLITECAM SN2014J Data



Vacca et al. 2015 (In Press)





# SOFIA and SN 2014J in M82

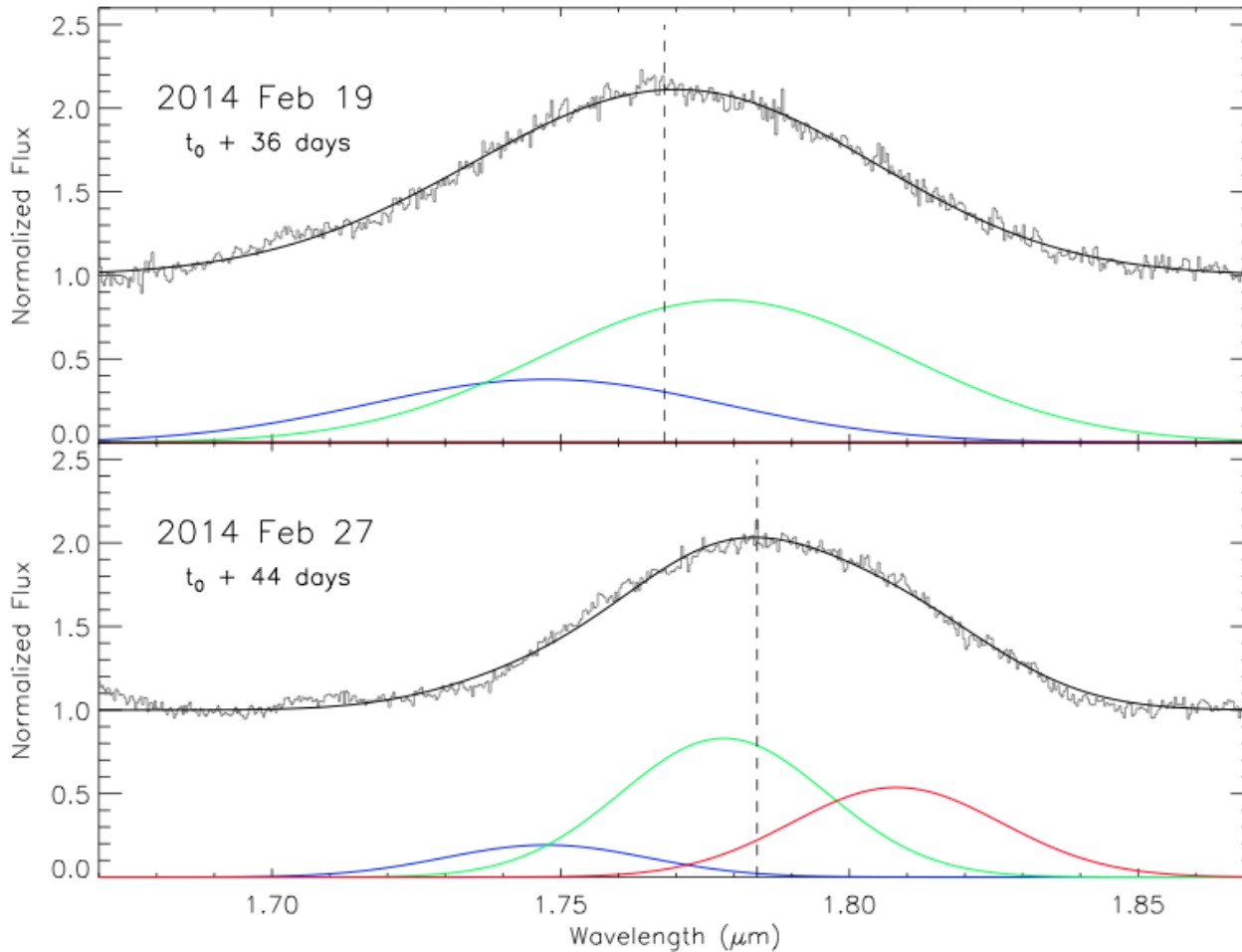


- **The strong line near 1.8 microns is identified as ionized Cobalt [Co II] (radioactive).**
- **Line width is  $\sim 10,000$  km/sec.**
- **The models of Dessart et al show that the line is a blend of 3 lines.**
- **The wavelength shift seen in their models is due to the changes strengths of the 3 lines. The physics of the line changes is not discussed in the SOFIA paper.**





# Shift of the wavelength of the 1.77 micron emission line vs time.







# Special Experiments on KAO



- **The KAO did several special experiments.**
- **The most noteworthy was the occultation of Uranus and the discovery of the rings (Elliott and Dunham).**
- **The KAO also observed 2 Solar Eclipses in the 30 to 650 micron continuum.**
- **Determined the Height and Temperature of the extreme Solar limb (Lindsey etal)**
  - **Sun's limb is higher than the standard model**
  - **The temperature is lower than the Concord obs. (Beck etal).**





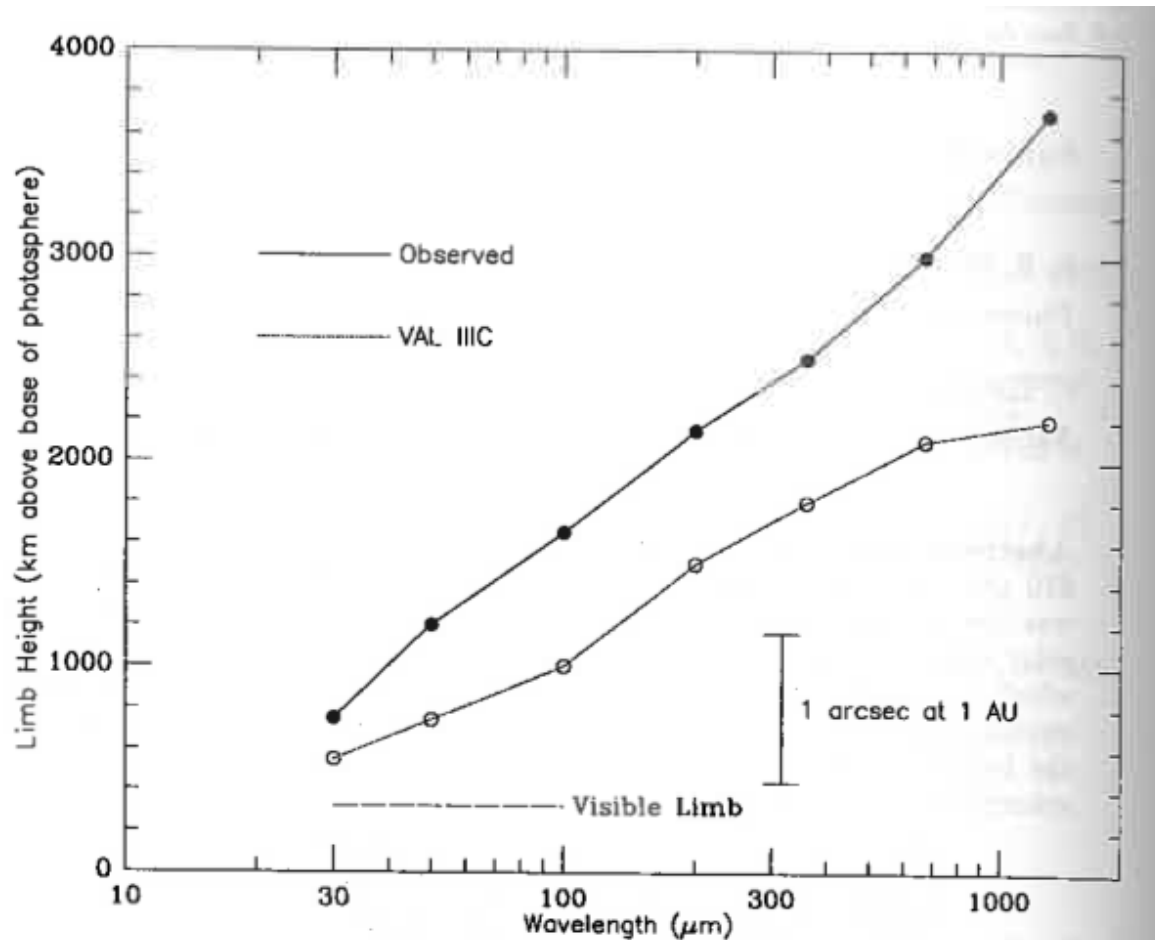
# Eric, Mike and Charlie on KAO for the 1988 Solar Eclipse



Figure C80. Eric Becklin (UCLA), Mike Werner (NASA Ames), Charlie Lindsey (University of Hawaii), 1988. Lindsey developed a full aperture sun filter for the KAO primary mirror. Here he's prepared to observe the solar eclipse before, during, and after totality.



# KAO 1982, 1988 and Hawaii JCMT 1991 Eclipse Solar Limb Height verse Wavelength





# SOFIA Special Experiments

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- **Pluto Occultation of June 2011. Hit the center line, atmosphere still there.**
- **FliteCam, HIPO and FDC Pluto Occultation of June 29 2015, two weeks before the New Horizons fly by.**
- **This Friday there is a total Solar Eclipse in Northern Europe**
- **Will SOFIA be able to observe a future eclipse to make unique measurements? I hope so!**





# Summary

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- **SOFIA is now producing good science, although more publications are needed.**
- **The best way to expand SOFIA's capabilities is with new instrumentation**
- **Extra Funds may mean additional partners**
- **Creative use of the Observatory could lead to some unique science**
- **Other new ideas should also be discussed.**





# Backup

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# ToOs, DDTs, and YOU



## ToOs:

- Submitted during a call for proposals
  - **Cycle 4 call soon! End of April 2015**
- Known targets, unknown timing
  - Known novae, Comets, etc.
- (Potentially) unknown targets and/or unknown timing
  - Comets, new (super)novae, etc.
- Data proprietary period same as for the Cycle

## DDTs:

- Outside the normal call for proposal period
  - [http://bit.ly/sofia\\_ddt](http://bit.ly/sofia_ddt)
- Extraordinary/unique events
  - Can still be covered by a ToO
- Brief science case sent directly to SMO Director and SOFIA Help Desk
- Data will have NO proprietary period

Example: Pluto Occultation in June 2015!

More details after March 2015 (pending astrometry updates)

