# Ground-based Observations of Venus from Apache Point Observatory


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**Support Astronomer**
**Apache Point Observatory**

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**VEXAG – Nov 29, 2016**


**VEXAG Student/Young Career Travel Support**

# Outline

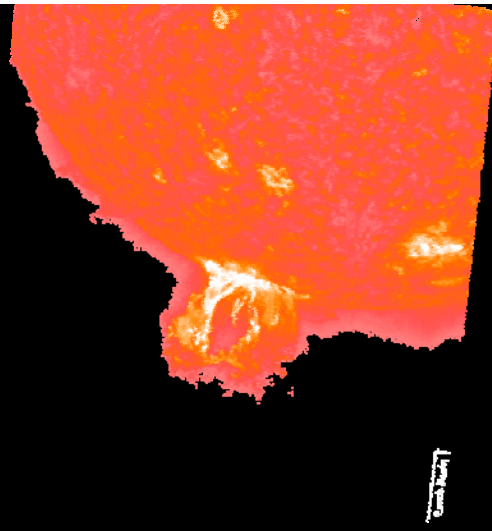
- Venus oxygen green line
- Aurora
- Solar Storms
- Ground-based observations
- Space-based observations
- Apache Point Observatory

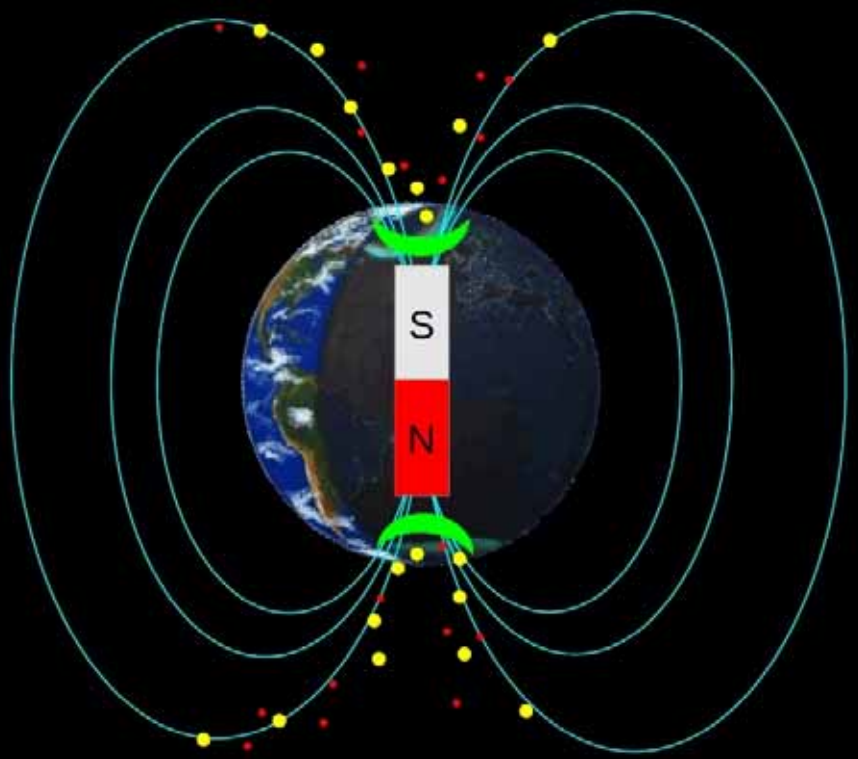
# Pourquoi?

- What is the driver behind Venus' oxygen green line?
- Probe the spaceweather-upper atmosphere interaction
- Atmospheric evolution
- Importance of ground-based observations

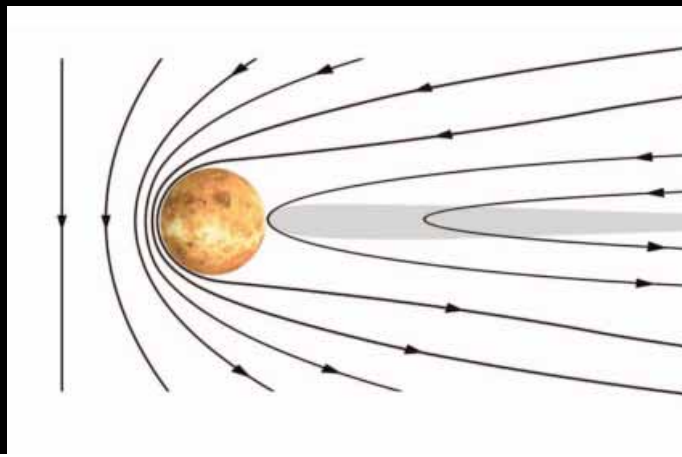
# Aurora

- Variable
- Solar wind
- Charge particle precipitation
  - Electron impact
  - Ionization/excitation



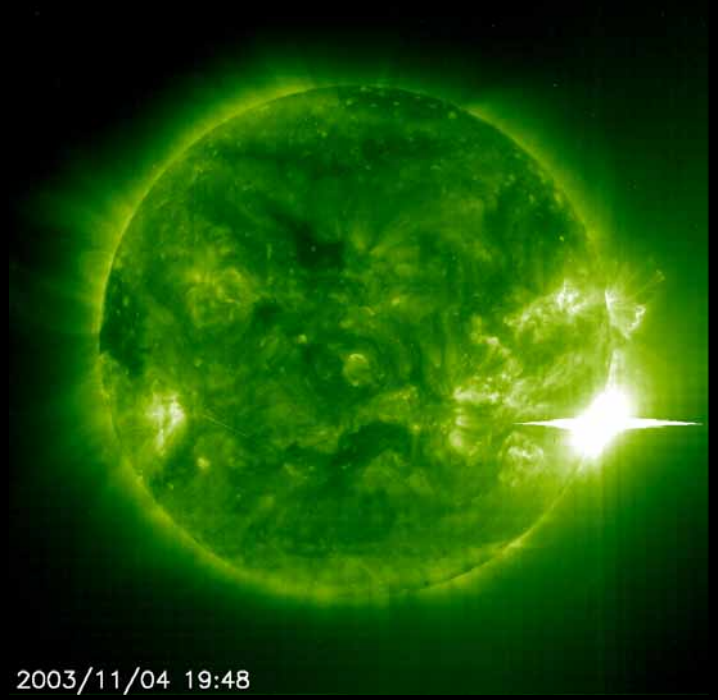


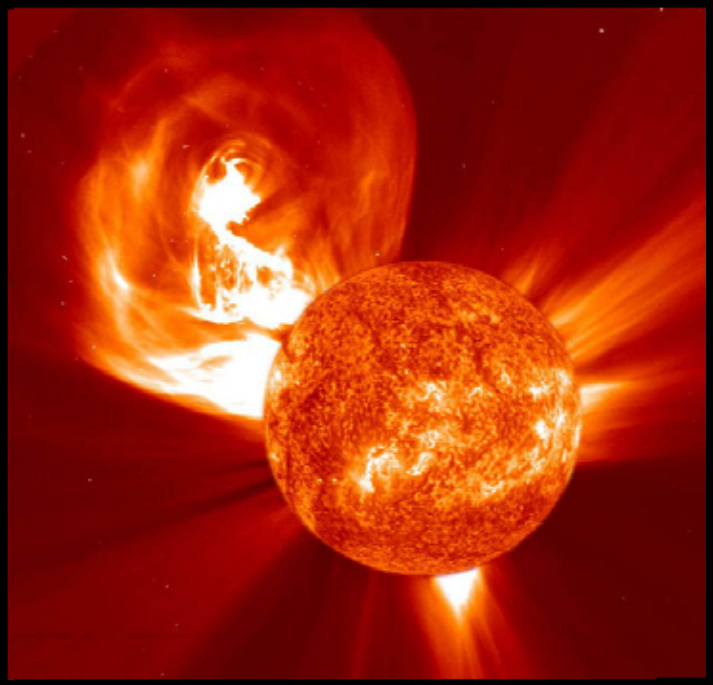

Zhang et. al 2012



# Solar Storms

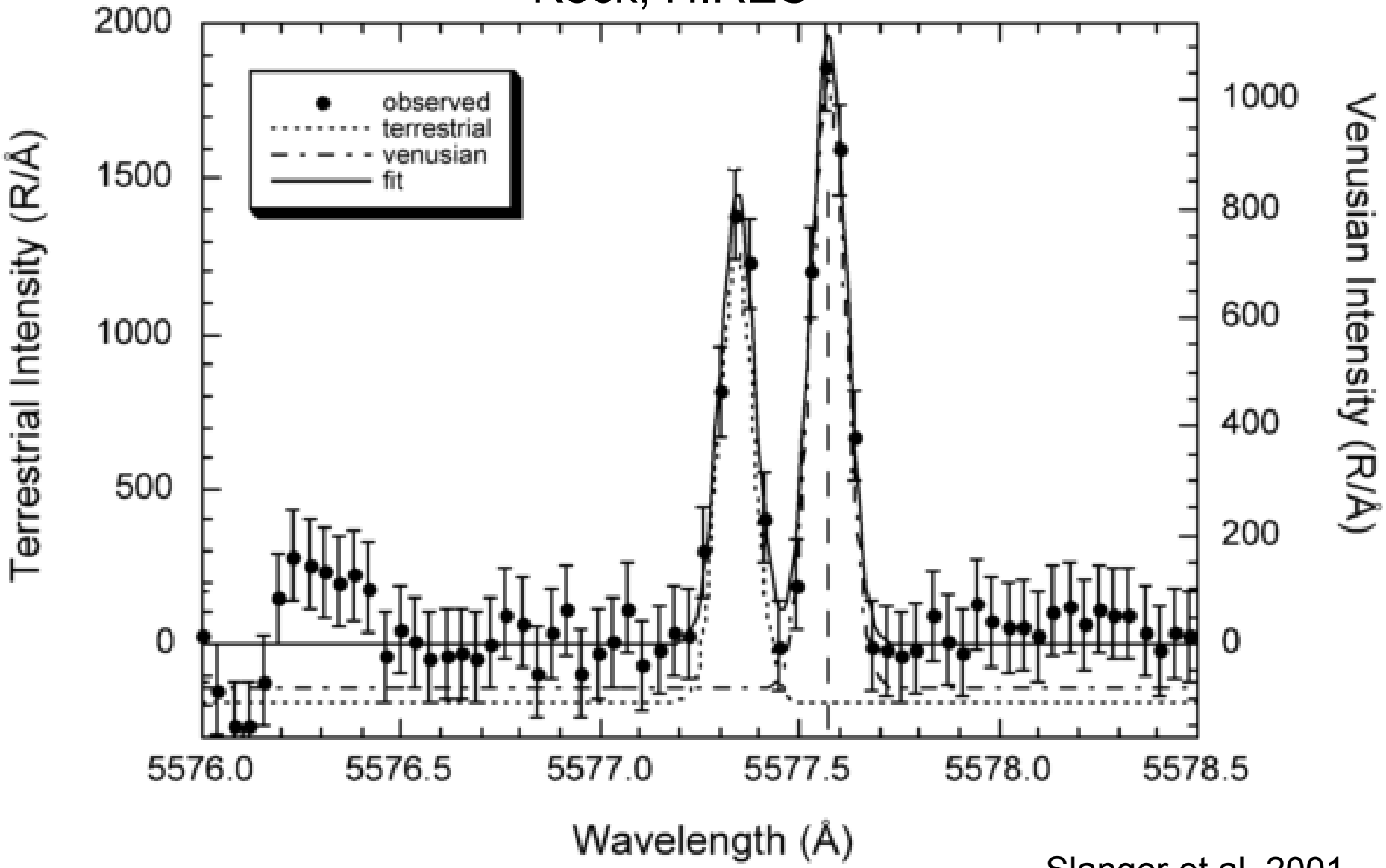
- X-class solar flares
  - Strongest flares
  - Brightest EUV emission
  - Nightglow
  - Short duration (min - hours)



- Coronal mass ejections (CMEs)
  - Plasma ejection
  - Aurora
  - 1 - 2 day arrival time

# Keck, HIRES



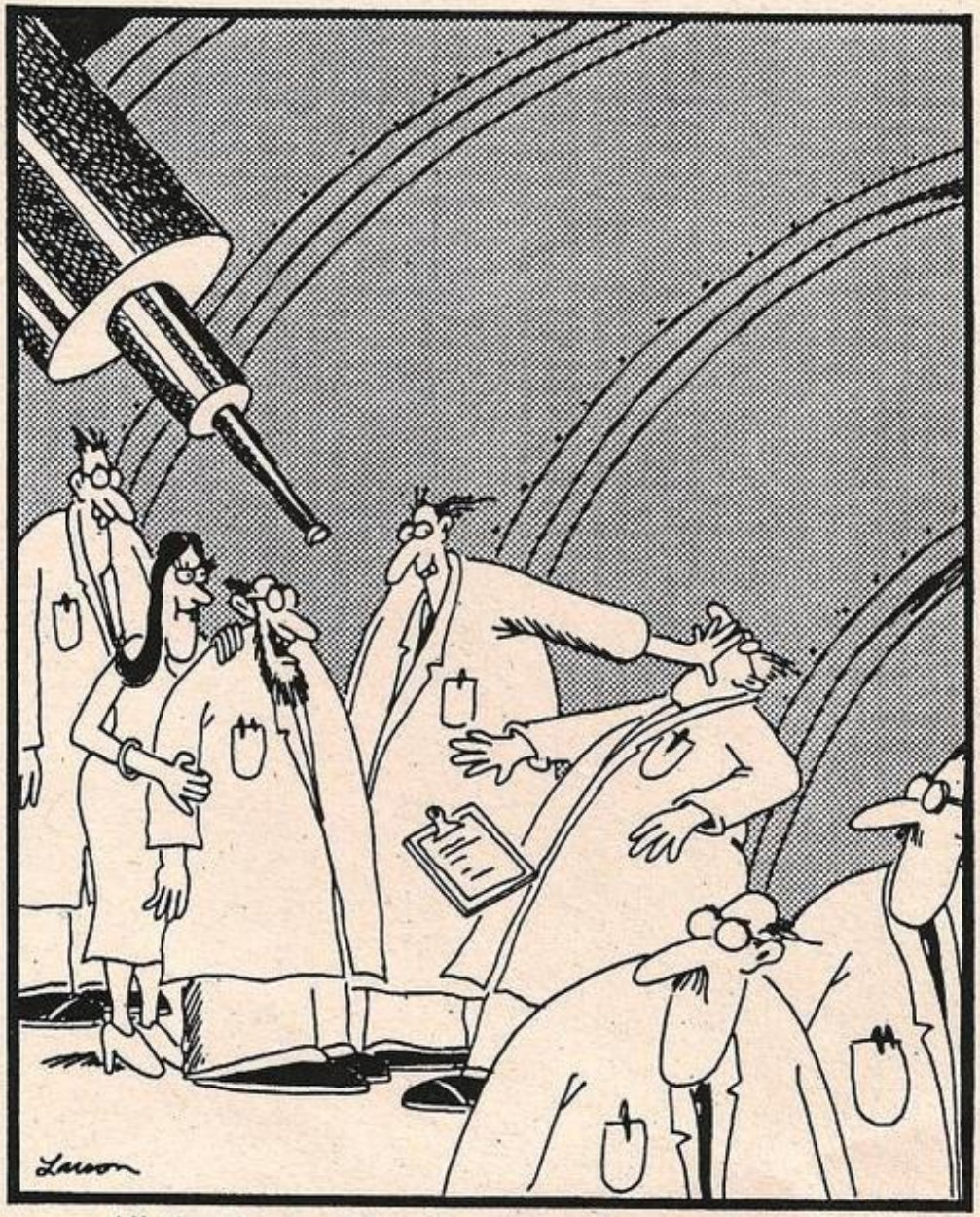

Slanger et al. 2001

# Apache Point Observatory

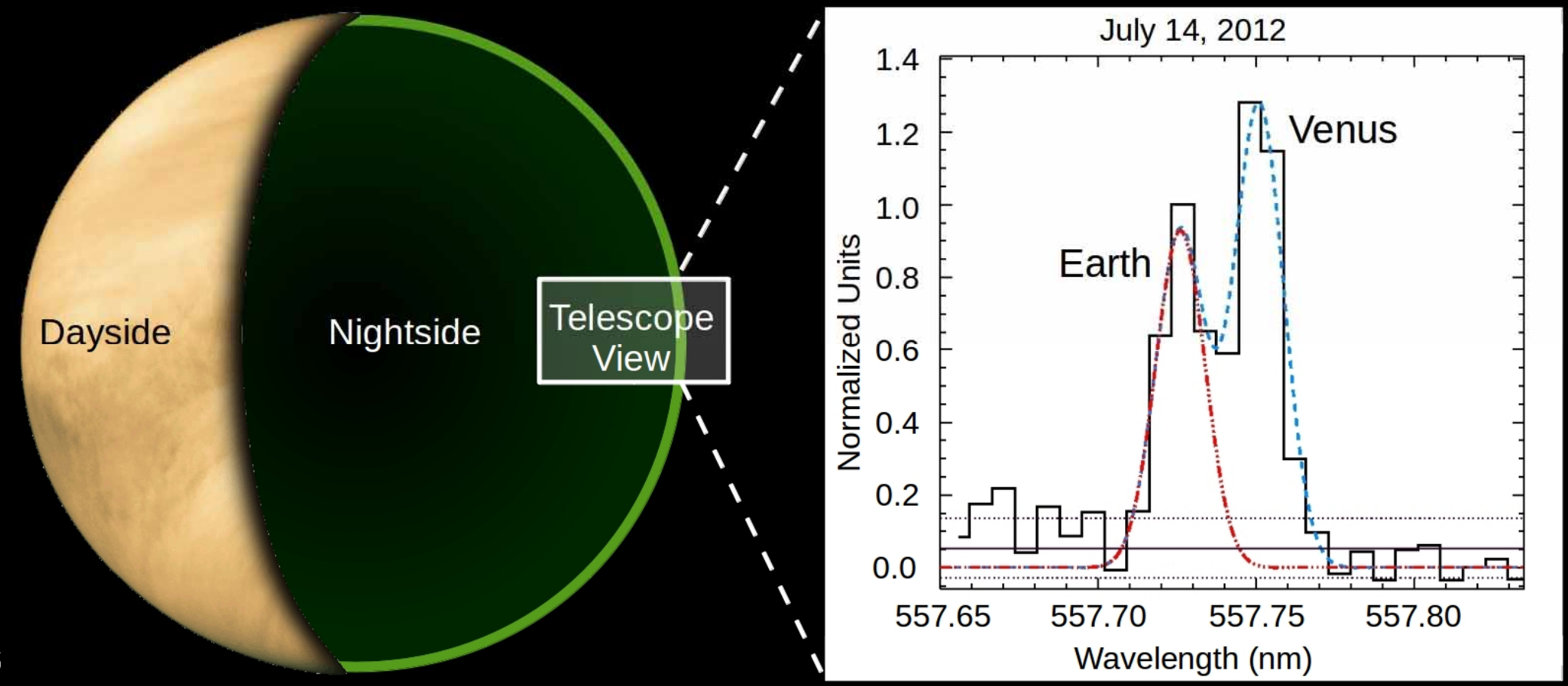
- 3.5m Astrophysical Research Consortium (ARC) Telescope
- ARC Echelle Spectrograph
  - High resolution
  - R ~ 35,000
  - 3500 – 10,000 Å
- Two 6-week windows / 2yr
- 2010 – 2015

# Apache Point Observatory

- Importance of ground-based observations
  - Response time
  - Target of Opportunity
- Storm chasing



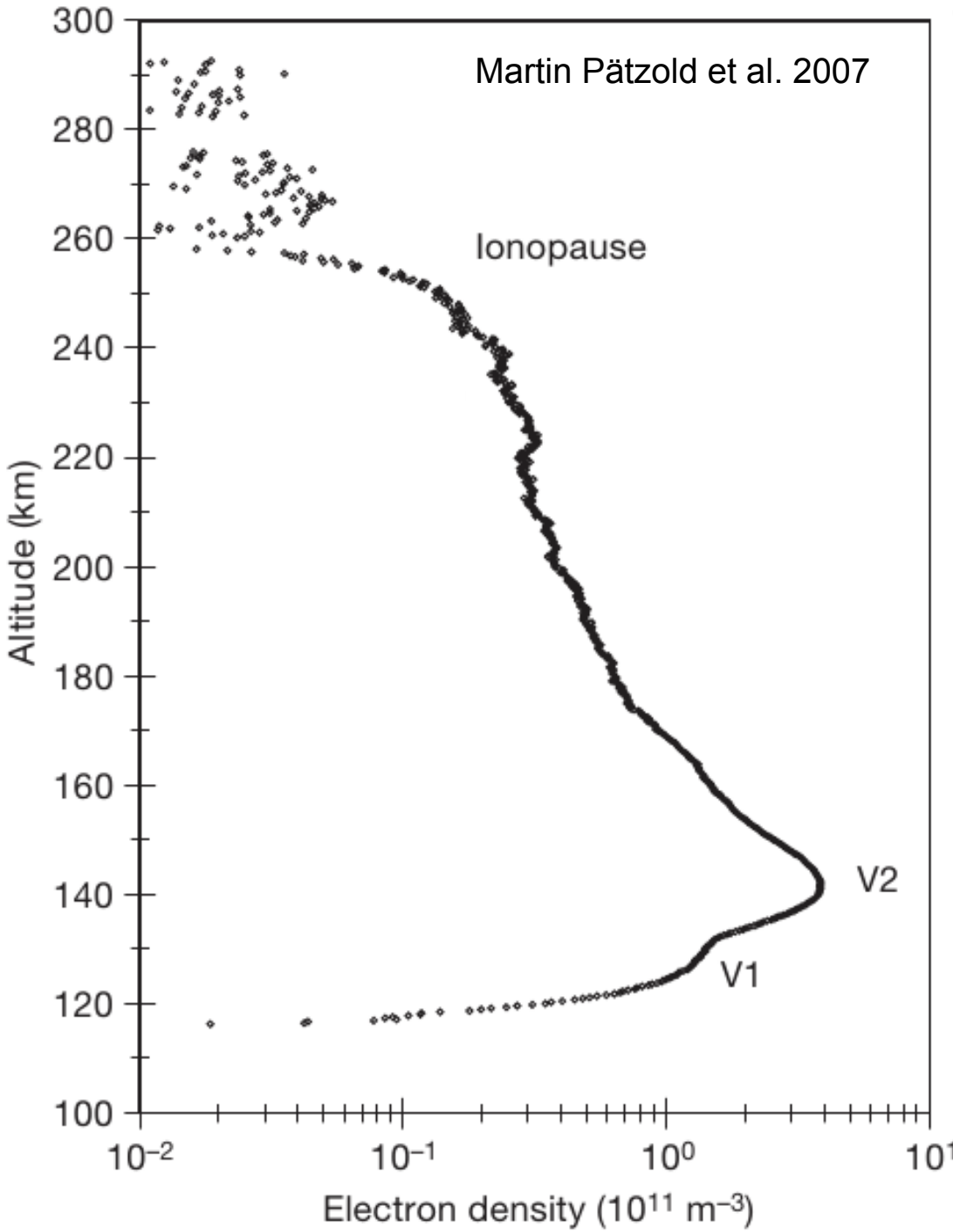
All day long, a tough gang of astrophysicists would monopolize the telescope and intimidate the other researchers.




Gray et. al 2014

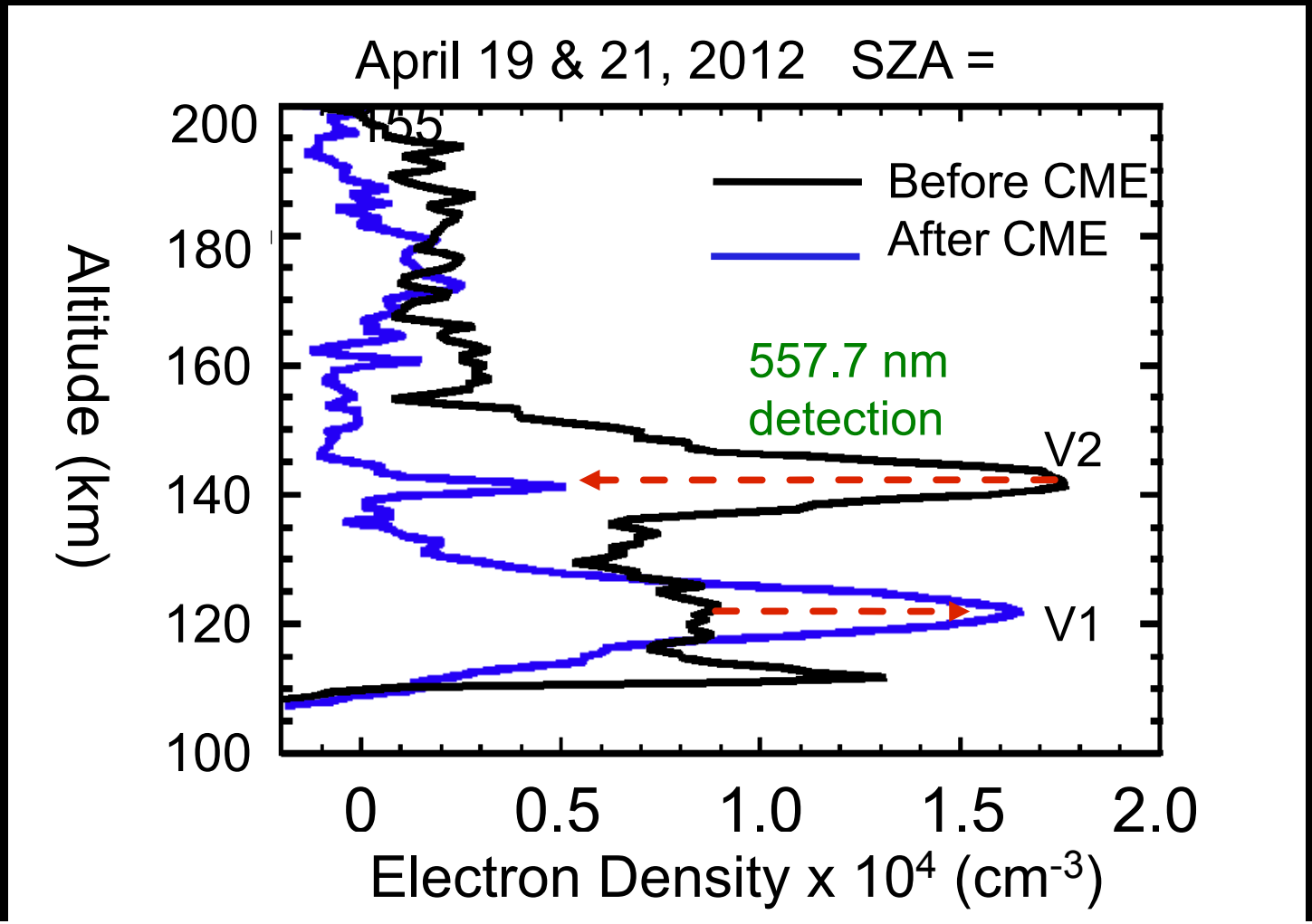
# Venus Express - VeRa

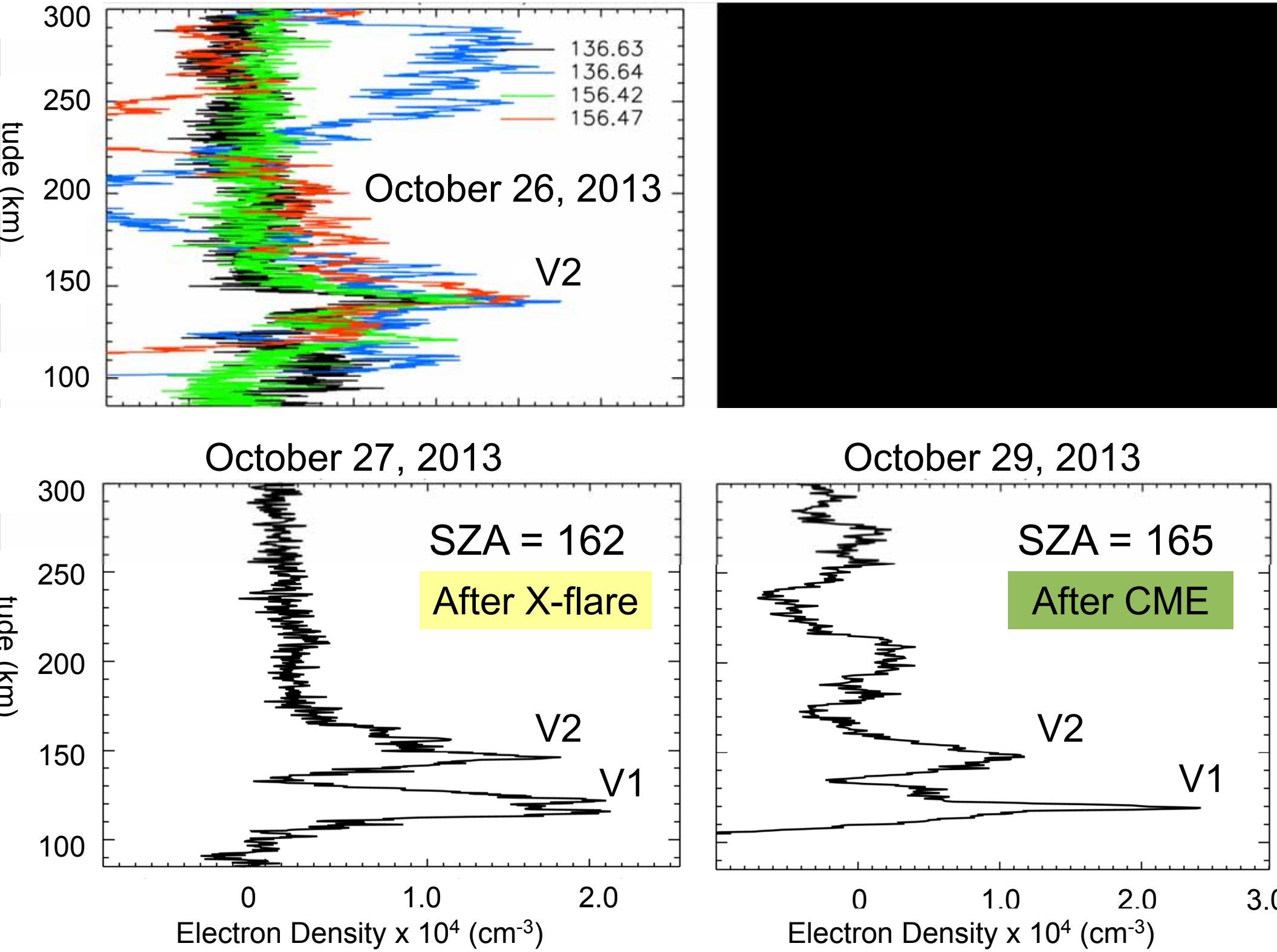
- Ionosphere
- Electron density profiles
- Dayside
  - Persistent V1 and V2 layers
  - Solar flux
- Nightside
  - Variable
  - Ion flow across terminator



# Venus Express - VeRa

- Changes in nightside V1 and V2 layer
- Decrease V2 electron density
- Increase in V1 electron density
- Is it real?



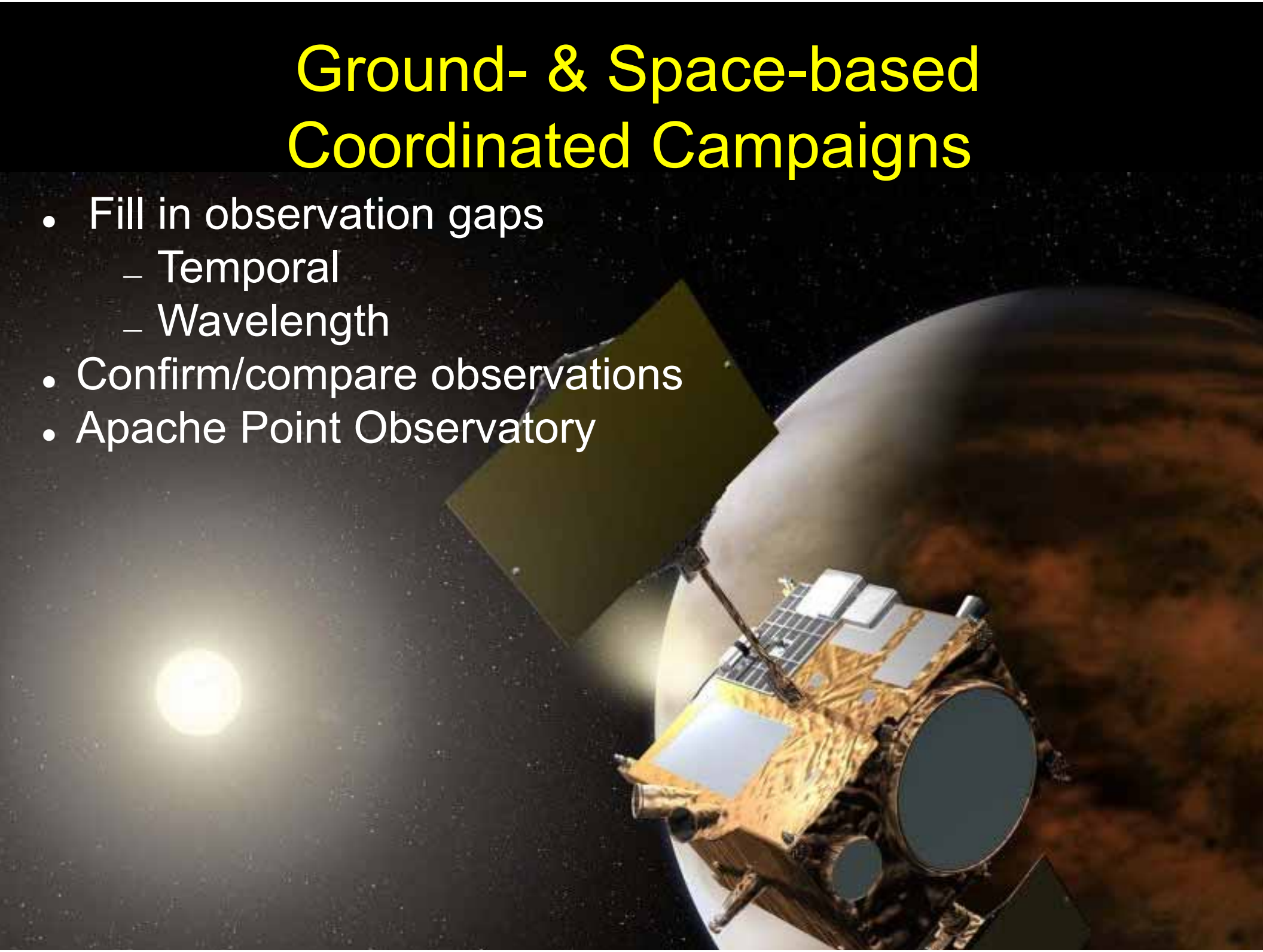

300
250
200
150
100
tude (km)
136.63
136.64
156.42
156.47
October 26, 2013
V2
October 27, 2013
SZA = 162
After X-flare
V2
V1
0
1.0
2.0
Electron Density x 10⁴ (cm⁻³)
October 29, 2013
SZA = 165
After CME
V2
V1
0
1.0
2.0
3.0
Electron Density x 10⁴ (cm⁻³)

# Science Conclusions

- Green line a unique aurora
- Most intense after large CMEs
- O + e likely source of green line emission
- Space-based observations show increase in:
  - Nightside V1 and V2 layers
  - Nightside electron precipitation flux and energy
- Made possible by ground- and space-based observations

# Ground- & Space-based Coordinated Campaigns

- Fill in observation gaps
  - Temporal
  - Wavelength
- Confirm/compare observations
- Apache Point Observatory

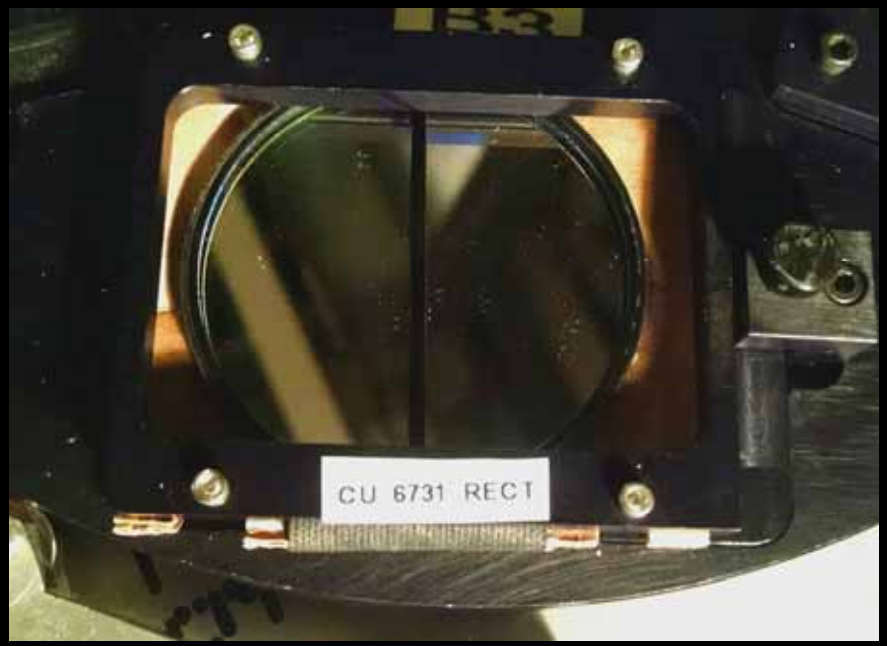


# Benefits of APO

- Easy to apply for time
  - Simple proposal process (1-3 paragraph science justification)
  - Time allocated in quarters
  - Applications due ~6 weeks before quarter
  - Fractional nights
- User friendly remote observations

# Benefits of APO

- Flexible to changes (dates, instruments)
- We can “Martian” your needs
- User friendly remote observations
- BUT, need to be part of a member institute




# APO Member Institutes

- University of Washington
- University of Colorado, Boulder
- New Mexico State University
- John Hopkins University
- University of Virgina
- Georgia State University
- University of Oklahoma
- University of Wyoming
- <u>Leasing Partners</u>
  - Adler Planetarium
  - Williams College
  - Bucknell
  - Colgate

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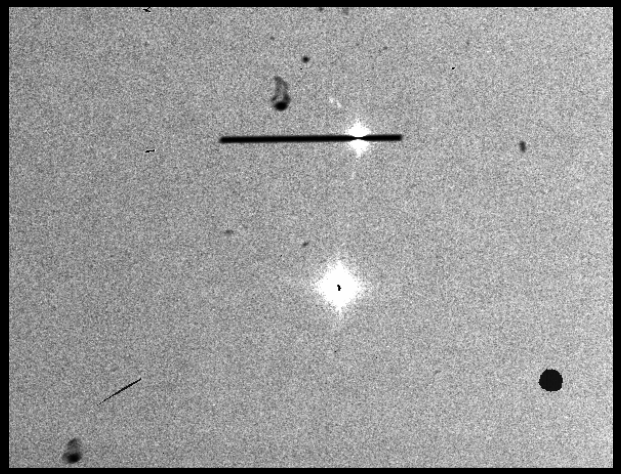
# Instruments – IR

- TripleSpec - Spectrograph
  - 0.95 – 2.46 um
  - R ~ 2500 – 5000
  - Problems



- NICFPS (Near-Infrared Camera & Fabry-Perot Spectrometer) - Imager
  - 0.99 – 2.25 um (narrow & wide band filters)
  - FOV ~ 4.58' x 4.58'

# Instruments – Visible Imagers

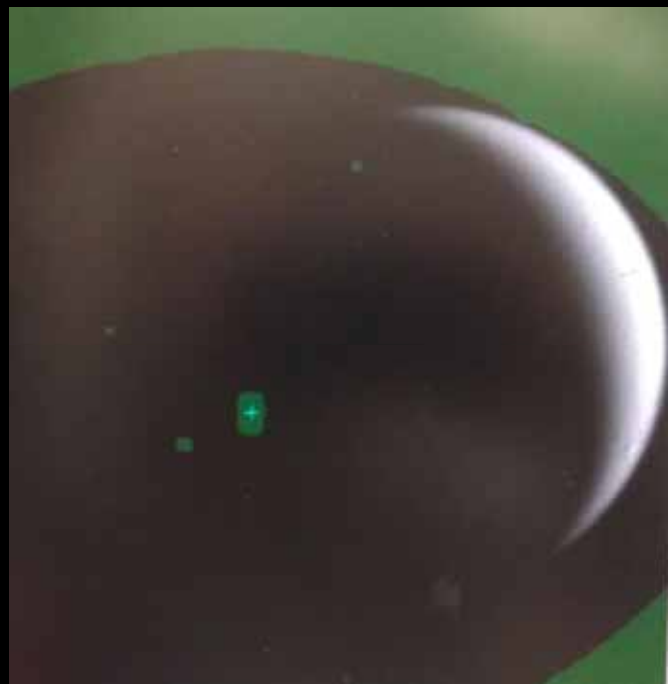
- ARCTIC (ARC Telescope Imaging Camera)
  - Filters - http://filters.apo.nmsu.edu/index.php
  - FOV ~7.5 arcmin
  - Plate Scale ~ 0.228 "/pixel, binned 2x2

- AGILE
  - High-speed time-series CCD photometer
  - Filters
  - FOV ~ 2.2 arcmin
  - Plate scale ~ 0.258 “/pixel

# Instruments – Visible Spectrographs

- DIS (Dual Imaging Spectrograph)
  - R ~ 300 – 1200
  - Variable wavelength centers
  - 5 filter imaging mode

- ARCES (ARC Echelle Spectrograph)
  - 350 – 1000 nm
  - High resolution (R~32000)



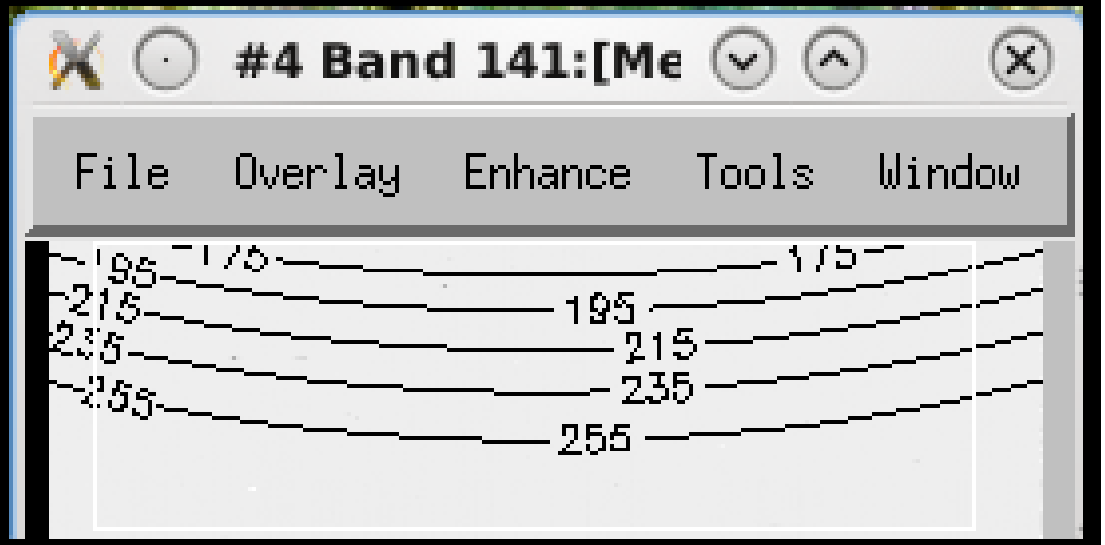
# Conclusions

- APO offers high quality science with versatility
- Interested in collaborations
- Make the proposal/observing process easy


Thank You!

# Space-based Observations – VIRTIS

- Limb observations
- February 14, 2014 CME
- Green line detected from APO
- Lower limit of 5000 R




Alt + 100km