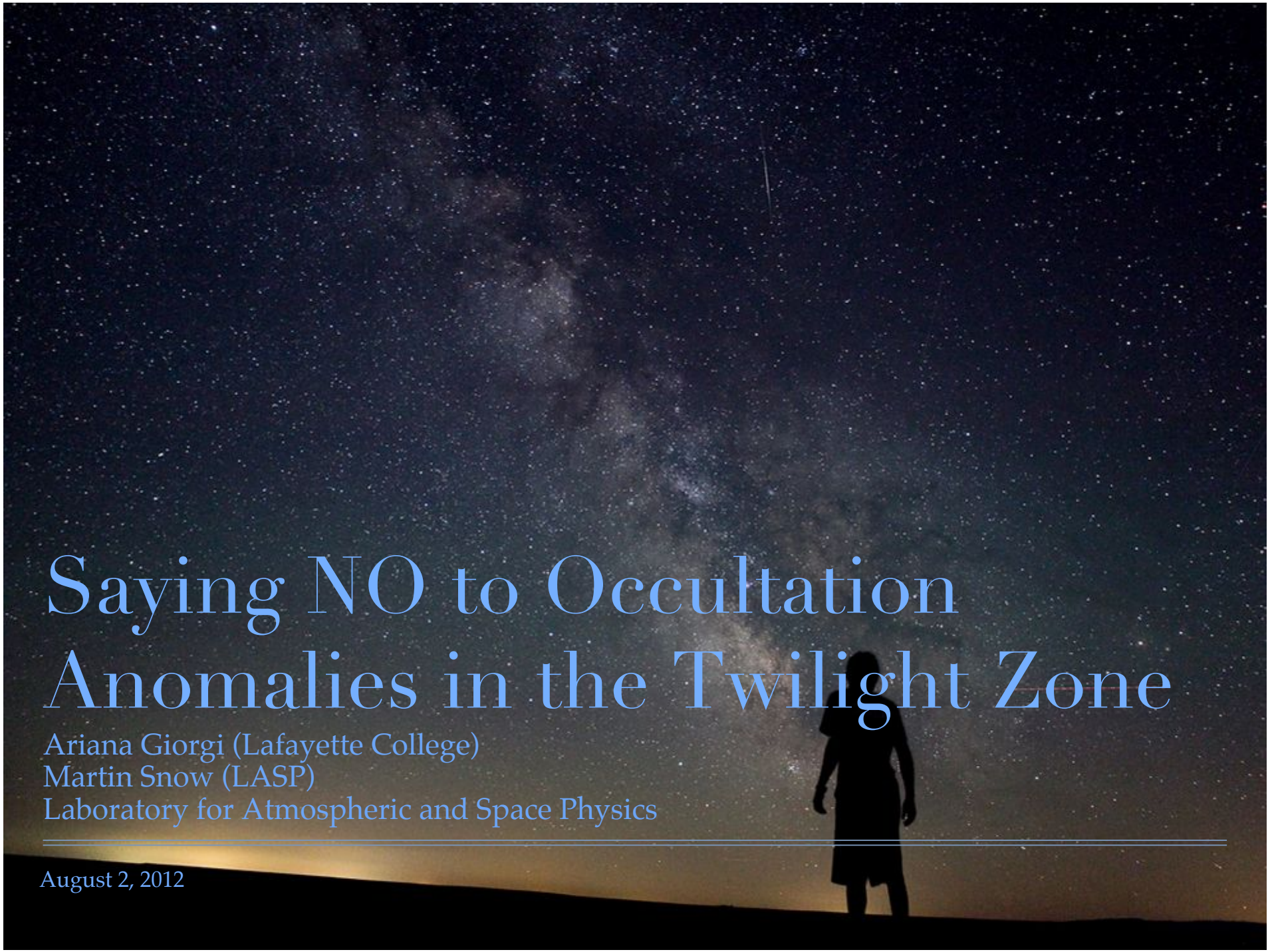

Saying NO to Occultation Anomalies in the Twilight Zone

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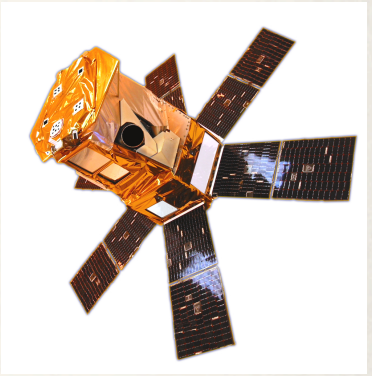
Laboratory for Atmospheric and Space Physics

August 2, 2012

SORCE AND SOLSTICE

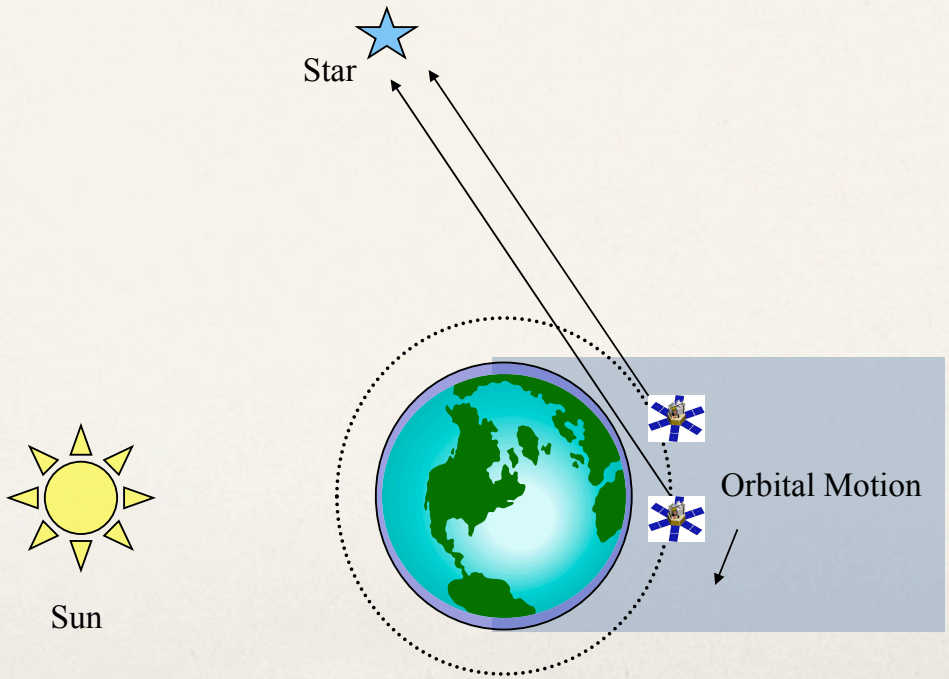
- SOlar Radiation and Climate Experiment (SORCE)
  - Launch January 25, 2003
  - Carries four instruments: SIM, SOLSTICE, TIM, and XPS
- SOLar STellar Irradiance Comparison Experiment (SOLSTICE)
  - Stellar occultation measurements in the ultraviolet at 250nm
  - Compares daily solar UV irradiance measurements to irradiance from 18 stable early-type stars



SORCE

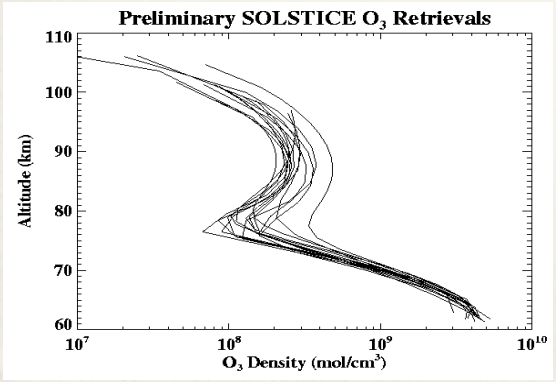
Stellar Occultation

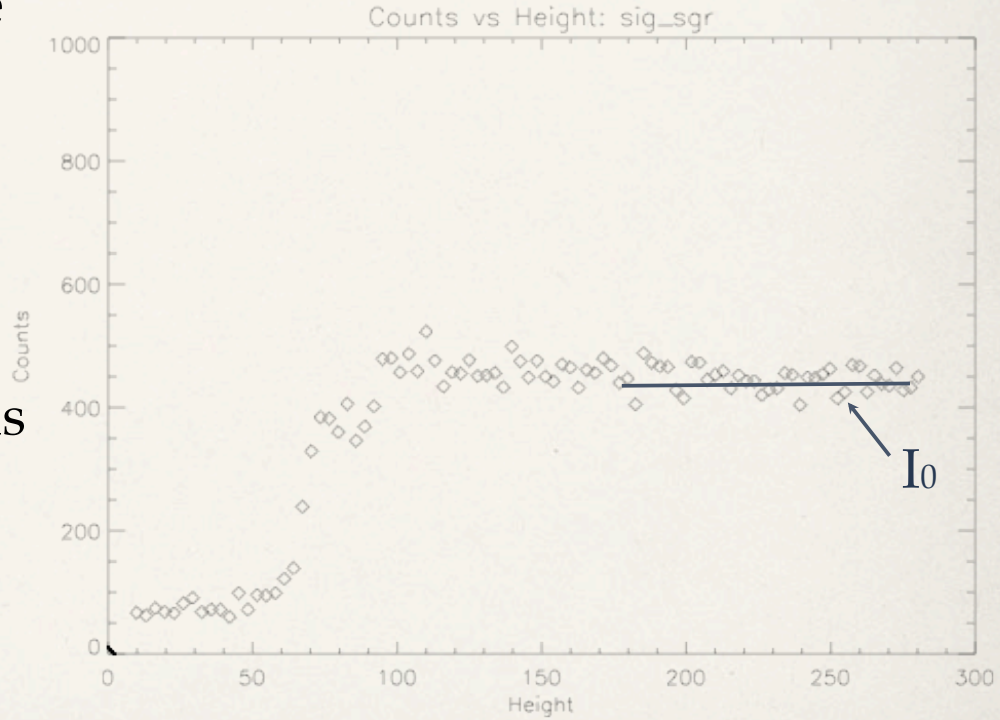
- Geometry
- Measure irradiance as the star sets behind the Earth



Normal Observation

- Counts: can be used to determine transmission
  - $T = \frac{I}{I_0}$ where I=irradiance
  - Can invert the transmission to get density
  - Purpose of these experiments is to measure ozone density

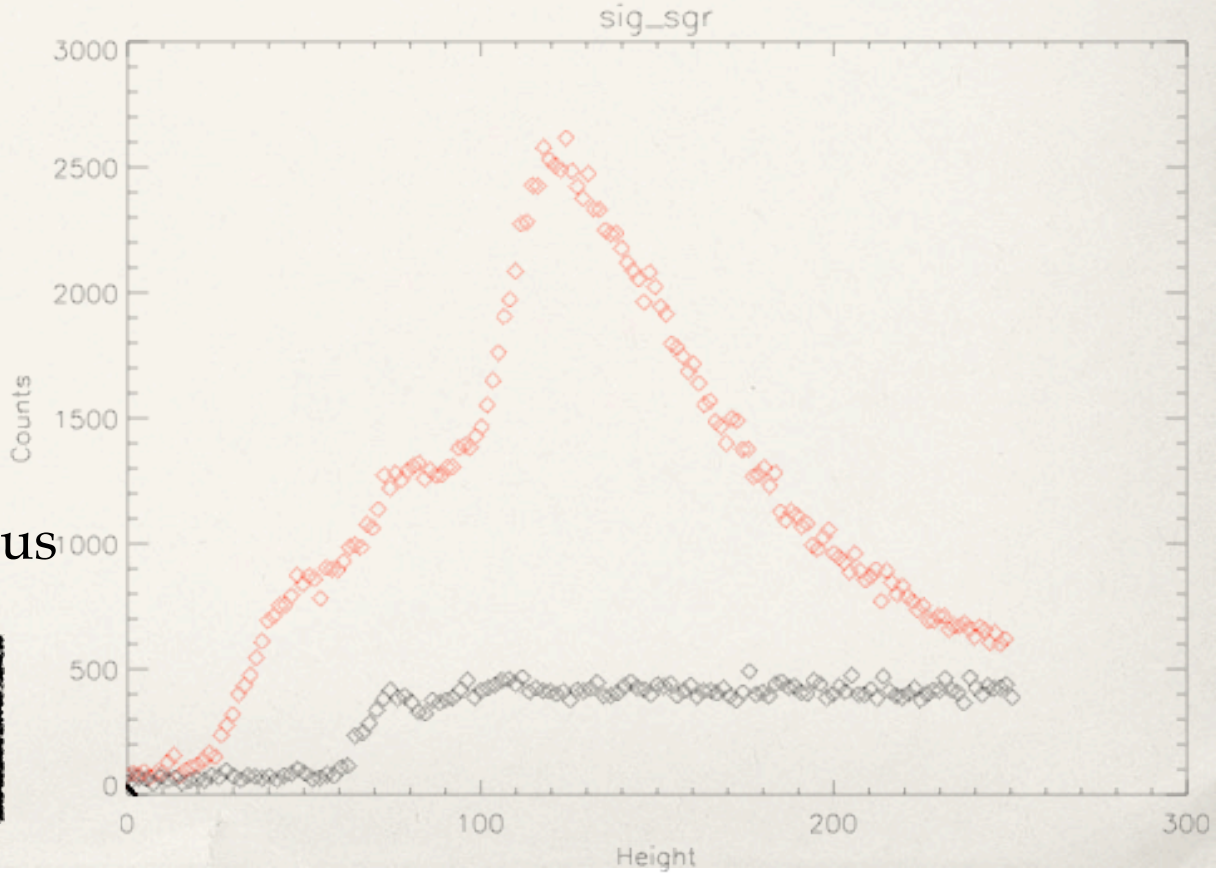




Anomalous Observation

- Anomalous observations in the data that did not fit in with the majority
- Filtered the observations
  - Fit a line to the points above 150 km
  - If slope < -1, then I considered it anomalous

KEY
Red: Anomalous Emission
Black: Normal Emission

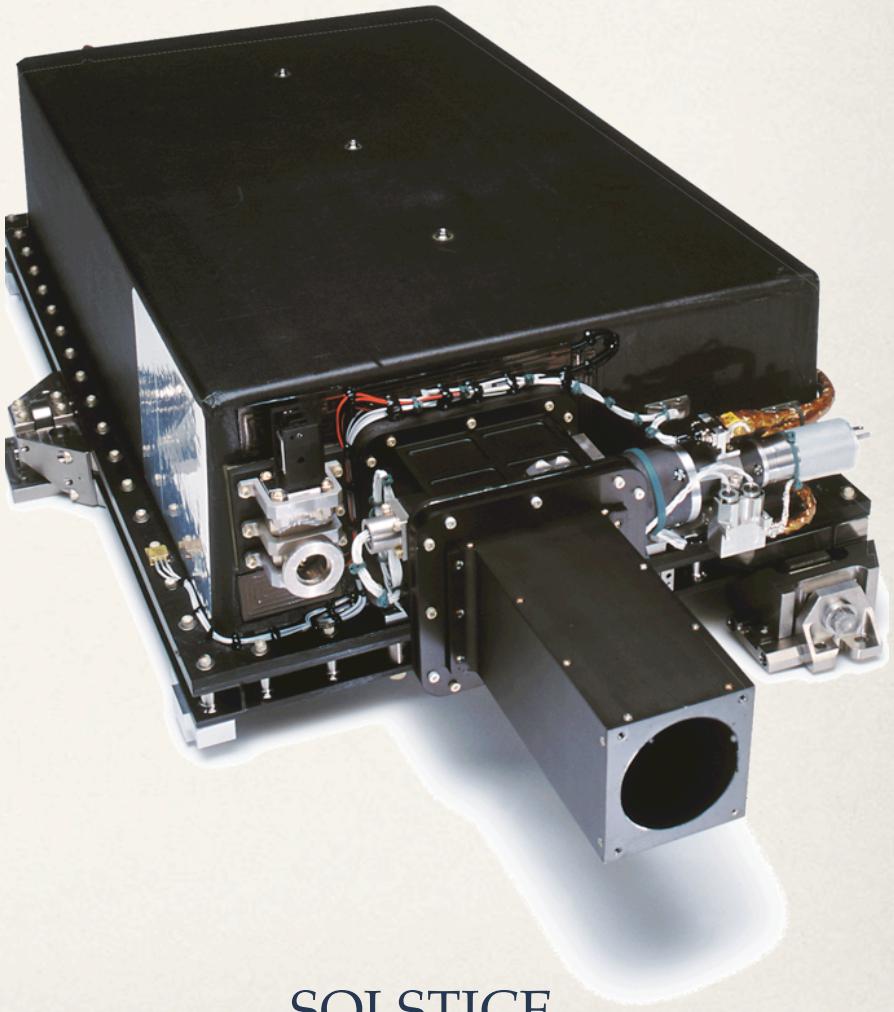


Anomalous Observations

Emission # :	Date	Local Time	Hemisphere	Tangent Pt Height (km)	Star Name
1	Nov 21, 2004	0:21	S	124.197	sig_sgr
2	Nov 25, 2004	23:25	S	107.266	sig_sgr
3	Nov 27, 2004	22:47	S	94.083	sig_sgr
4	Dec 25, 2004	0:10	N	166.463	alf_lyr
5	Dec 29, 2004	22:40	N	112.836	alf_lyr
6	Jun 23, 2005	2:09	S	90.642	alf_vir
7	Aug 24, 2005	1:42	S	74.013	dlt_sco
8	Nov 20, 2005	1:32	N	144.063	alf_lyr

SOLSTICE Instrument

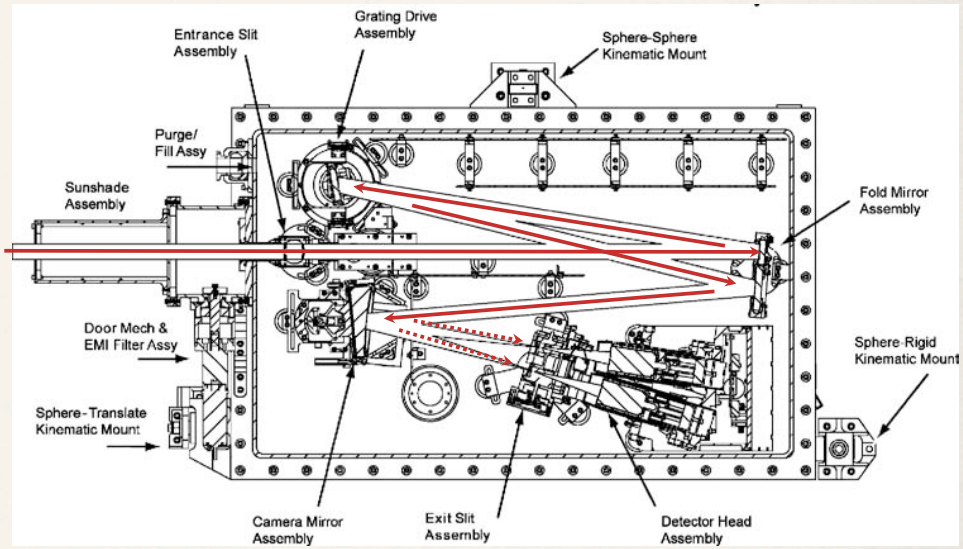
- Measures middle and far ultraviolet
  - MUV: 180-300nm
  - FUV: 115-180nm



SOLSTICE

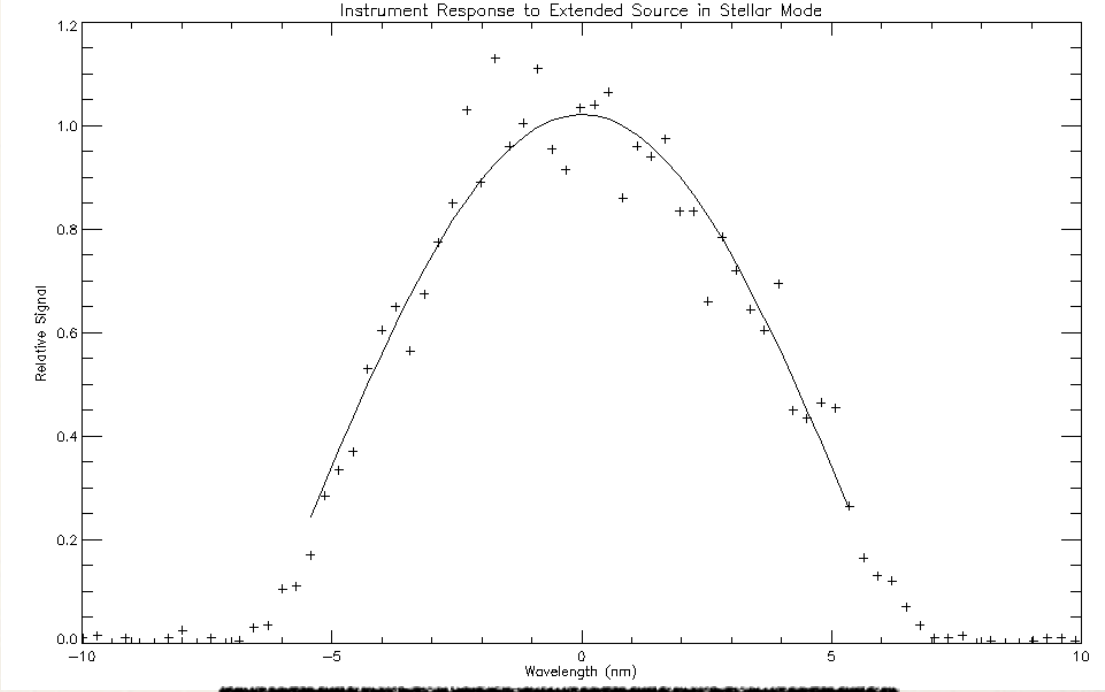
SOLSTICE Layout

- Light hits one of two detectors
- Mirror changes position to switch between detectors
- Both detectors read data at the same time
  - Light hits one, while the other is subjected to environment



Wavelength Distribution

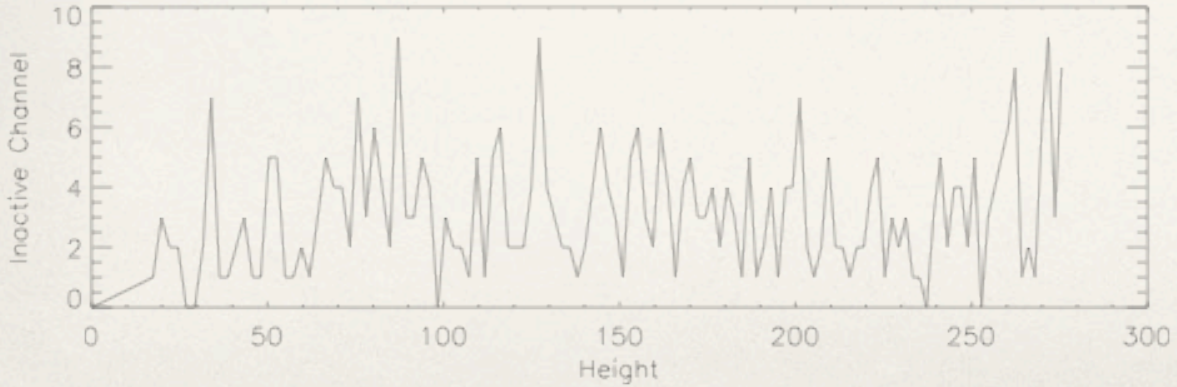
- As wavelength changes, amount of signal decreases
  - Wavelength doesn't occupy as much of the aperture
- For low resolution spectrum, any wavelength in range will be detected



KEY
This graph shows what % of wavelength deviation will be received

SOLSTICE Instrument

- Thought one explanation for anomalous observations may be background environment
  - Areas of radiation
- Inspected inactive channel
  - Looking for counts over 20/30
  - Found nothing concerning - rule out inactive channel

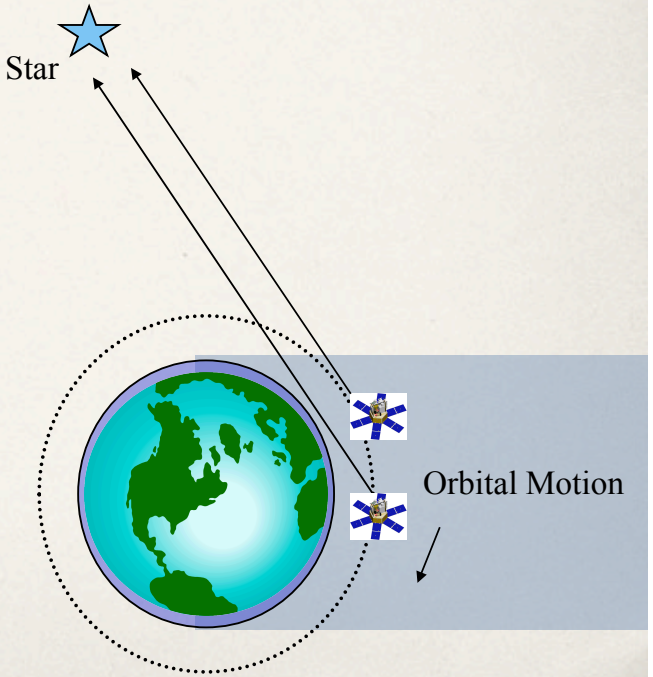


For this inactive channel, the dark rate is about 3, normal statistical variance

SOLSTICE Instrument

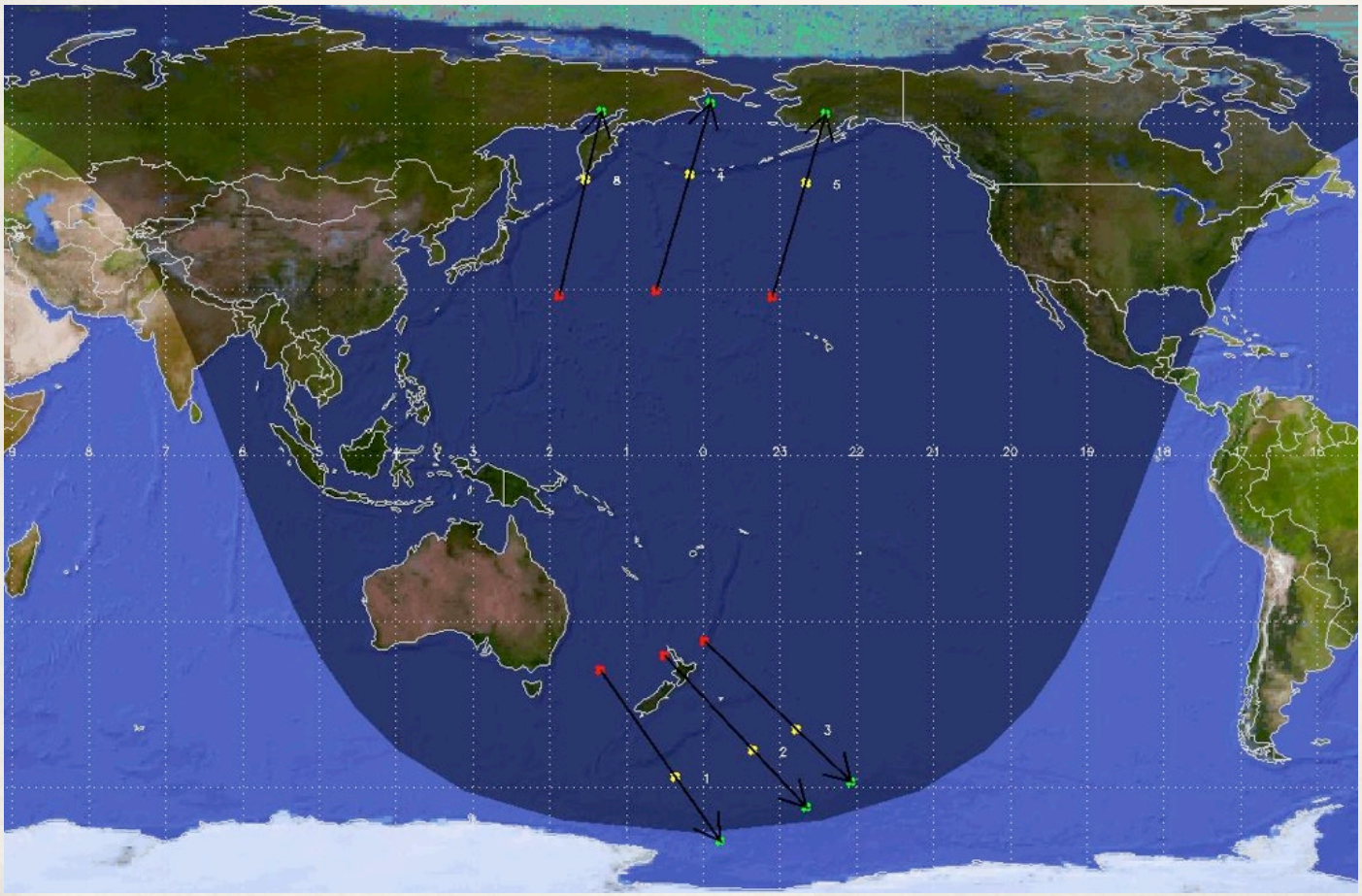
- The occultations are scheduled to occur during the nighttime of the orbit
- From geometry, if line-of-sight is out of sunlit part of atmosphere then there is nothing to scatter the sunlight
  - Rule out observations that clearly lie in the sunlight since this may be the case
  - Some anomalous observations are close to terminator while others are not

Sun



Map of Anomalous Occultations

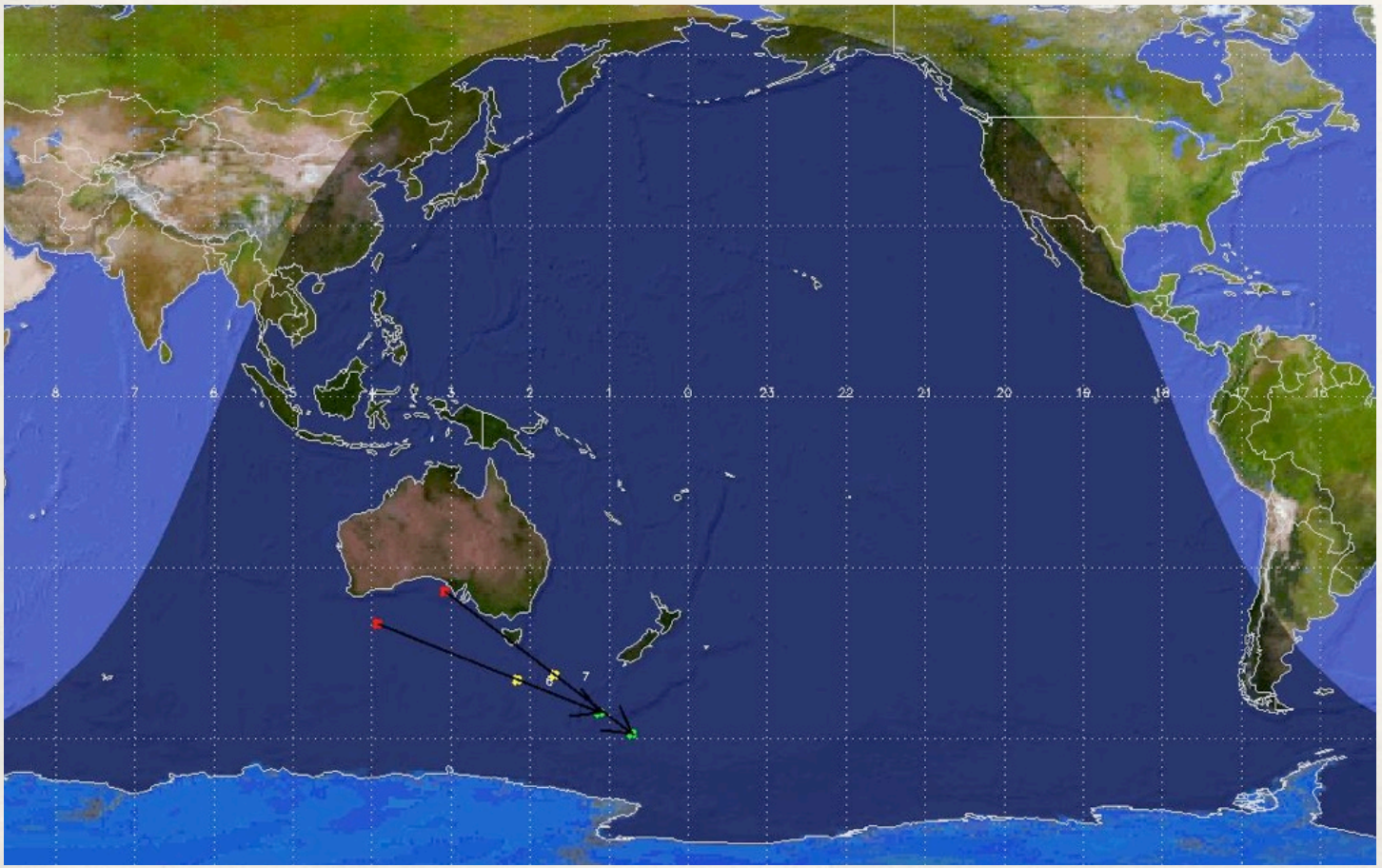
Northern Winter (November/December)



KEY
Red: Satellite Location
Yellow: Tangent Point Location
Green: Location where line-of-sight reaches edge of atmosphere

Map of Anomalous Occultations

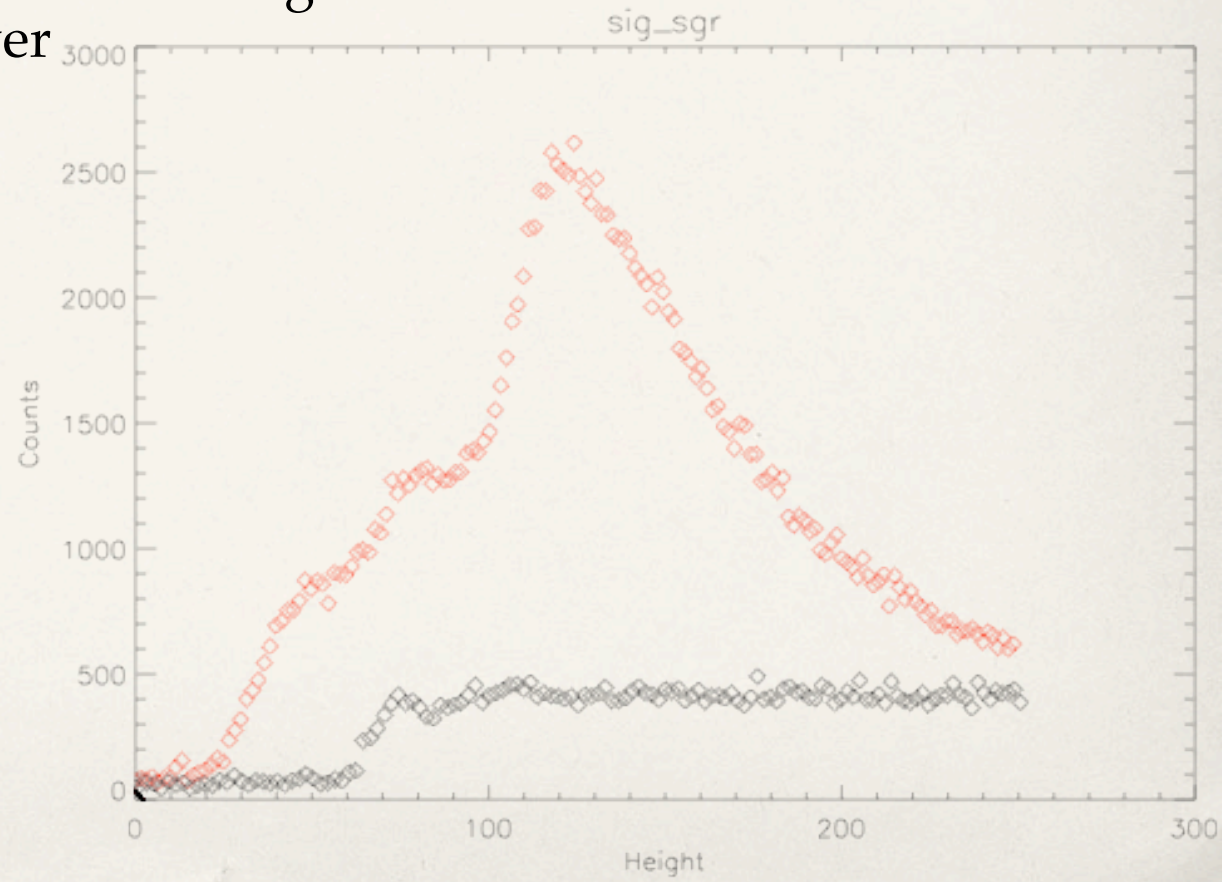
Northern Summer (June / August)



KEY
Red: Satellite Location
Yellow: Tangent Point Location
Green: Location where line-of-sight reaches edge of atmosphere

Modeling the Emission

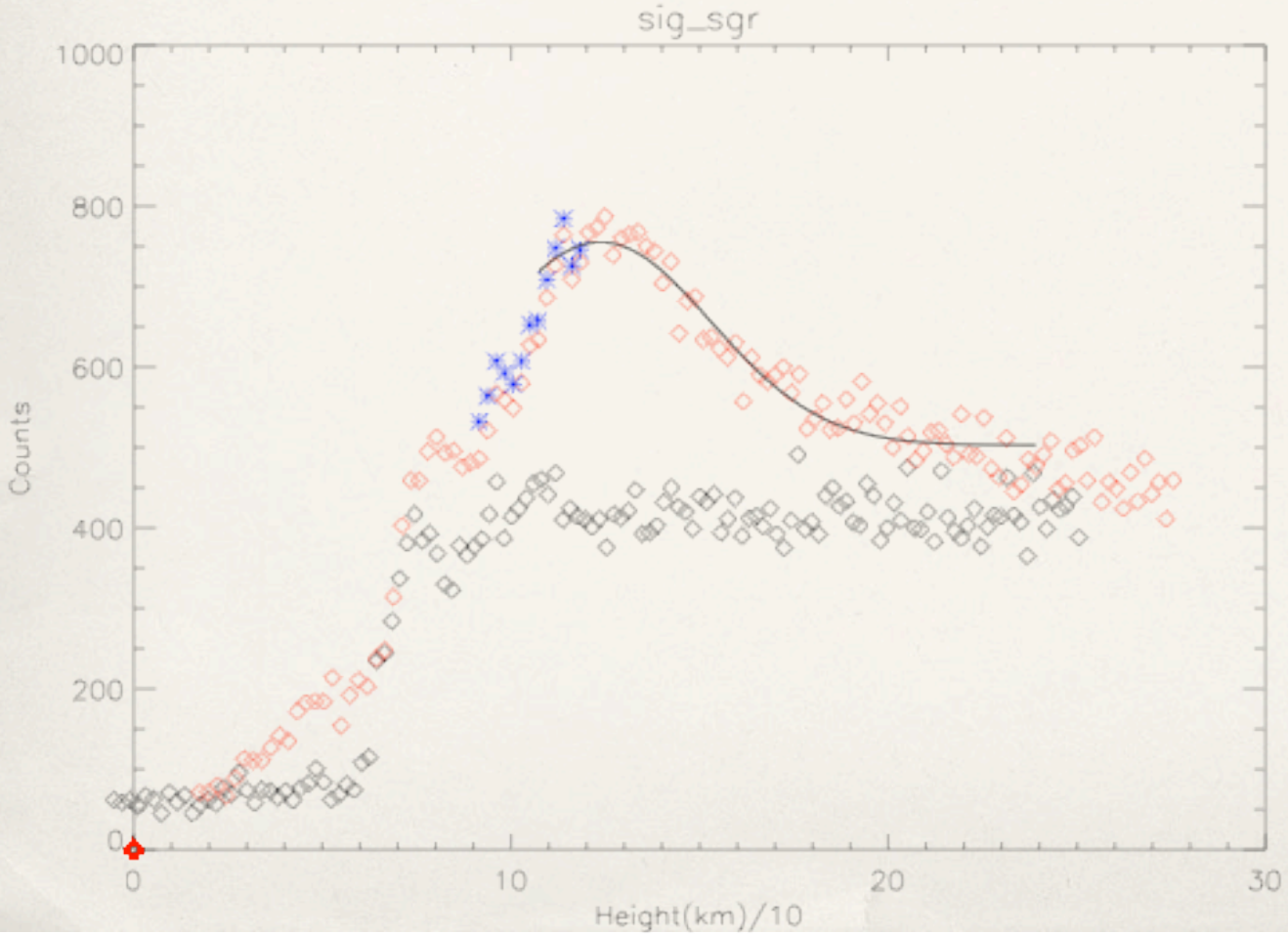
- Fit a Gaussian curve to the modeling in order to determine characteristics of the layer producing the emission
- To improve fit, I accounted for ozone absorption
  - ~ 60-90 km



Accounting for Ozone

- Fit an exponential line to the star observation data
- Checked to see if transformation was appropriate
  - Look at the adjustment for the star observation
- Goal was to adjust the stellar signal to account for loss of transmission from ozone between ~ 60 and 100 km
  - Make a more symmetrical curve for a better Gaussian curve
- Averaged the best-fit line of each star to create one line

Accounting for Ozone



KEY
Black: Star Observation
Red: Anomalous Observation
Blue: Correction for Ozone Absorption

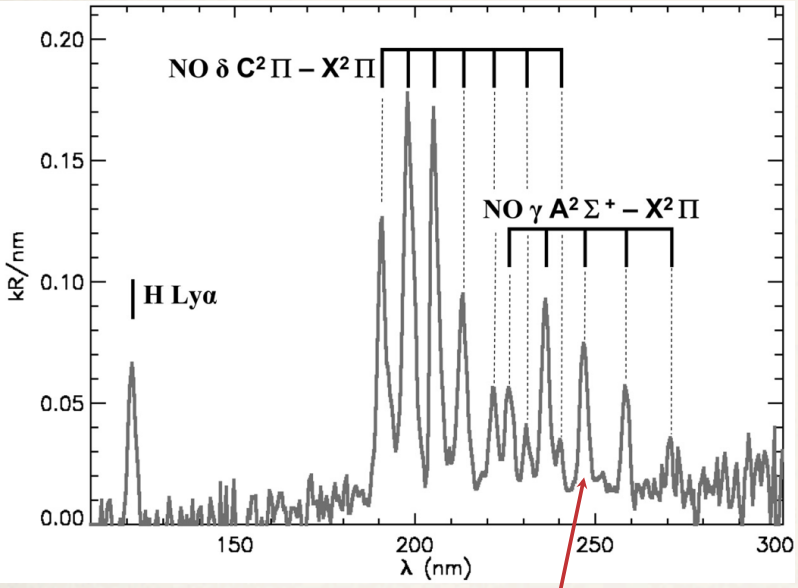
Locations of Observations

Locations of Anomalous Observations

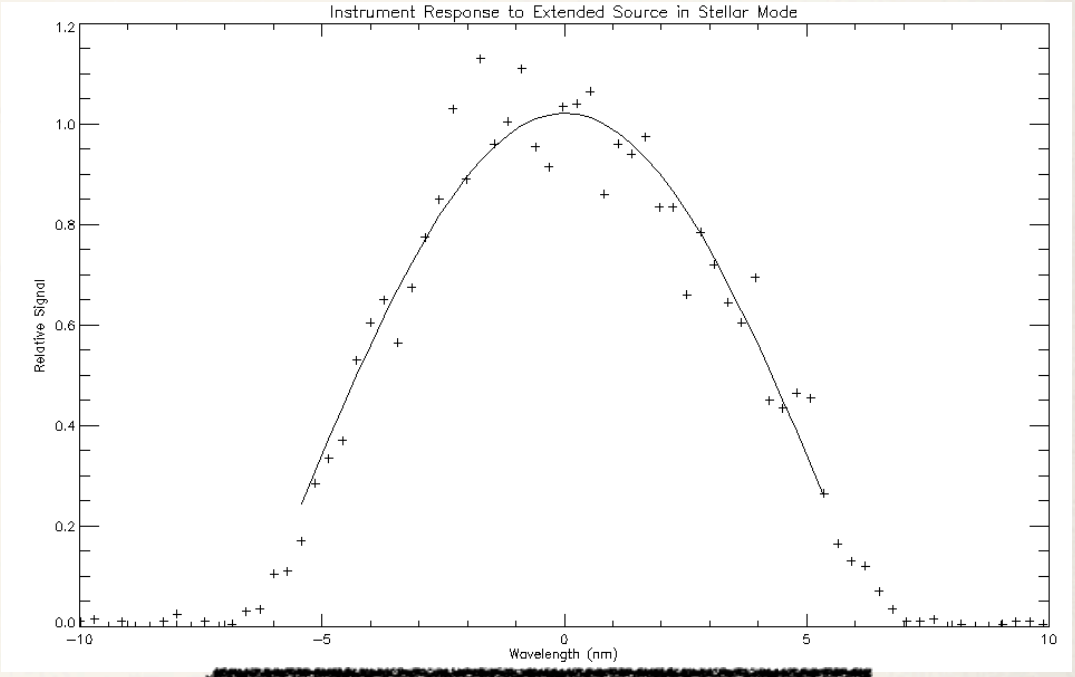
Atmospheric Cause

- Likely emission source could be nitric oxide (NO)
- Background reading on NO and NO densities (Barth, et al)
  - Equatorial Region
    - Solar soft x-rays in lower thermosphere btw 100-150 km
    - There is an increase around ~120km during geomagnetic storms
  - Auroral Region
    - Auroral electrons precipitate into thermosphere
    - Correlate with magnetospheric activity
- Maximum density of NO is btw 60-70 deg

Nitric Oxide Wavelength



(Bertaux, et al)



KEY
This graph shows what % of wavelength deviation will be received

Atmospheric Cause

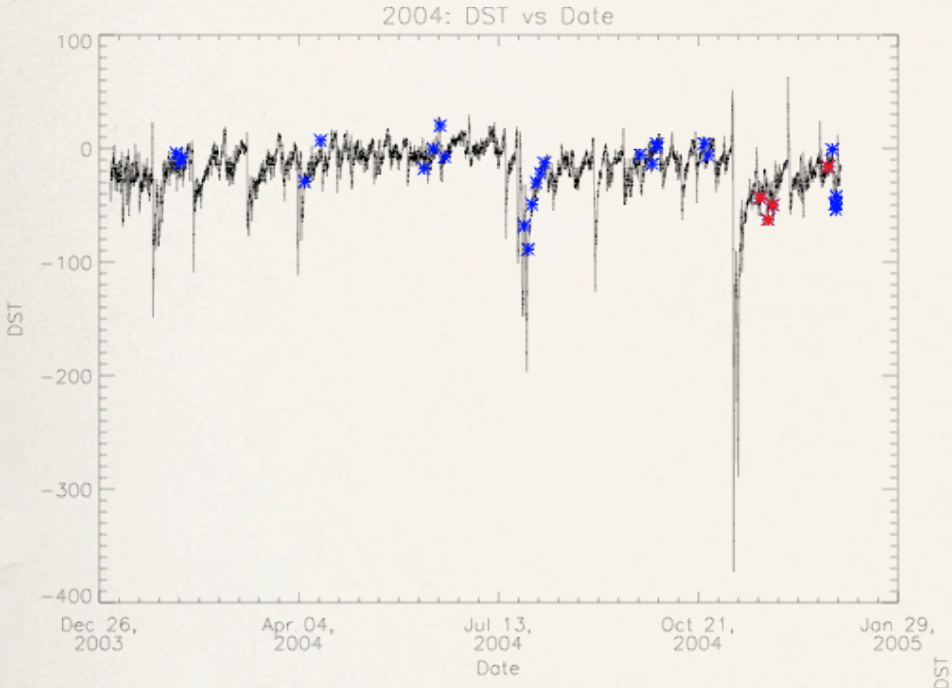
Mars Express

- NO emission has been seen during the night on Spectroscopy for Investigation of Characteristics of Atmosphere of Mars (SPICAM) via stellar occultations (Bertaux, et al)
- Suggests NO can emit ultraviolet in nightside from chemiluminescence
  - Chemiluminescence: emission from light resulting from chemical reactions
  - O & N atoms in dayside thermosphere are transported to nightside
  - Descend vertically and produce gamma, delta bands of NO
- This motion is expected in winter polar mesosphere

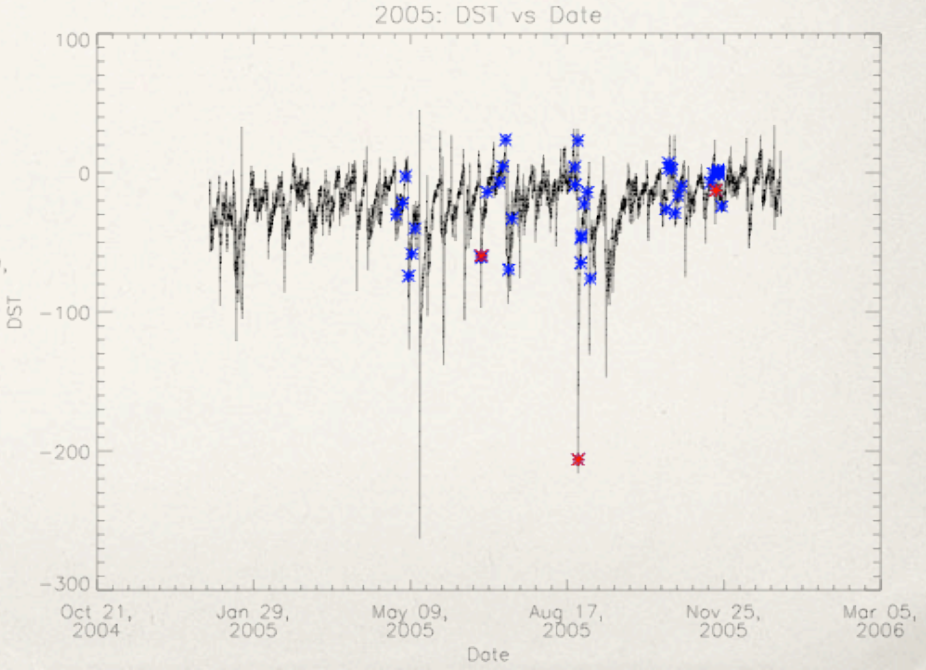
Geomagnetic Activity

- Thought to try and correlate these anomalous observations with geomagnetic activity
- Compared against 5 different indices
  - DST, Kp, AE, IMF, Solar proton events
  - Solar proton events (proton storms): Dates of proton storms did not correlate with observations
- Compared anomalous observations against normal occultations of similar latitude to try to identify a difference

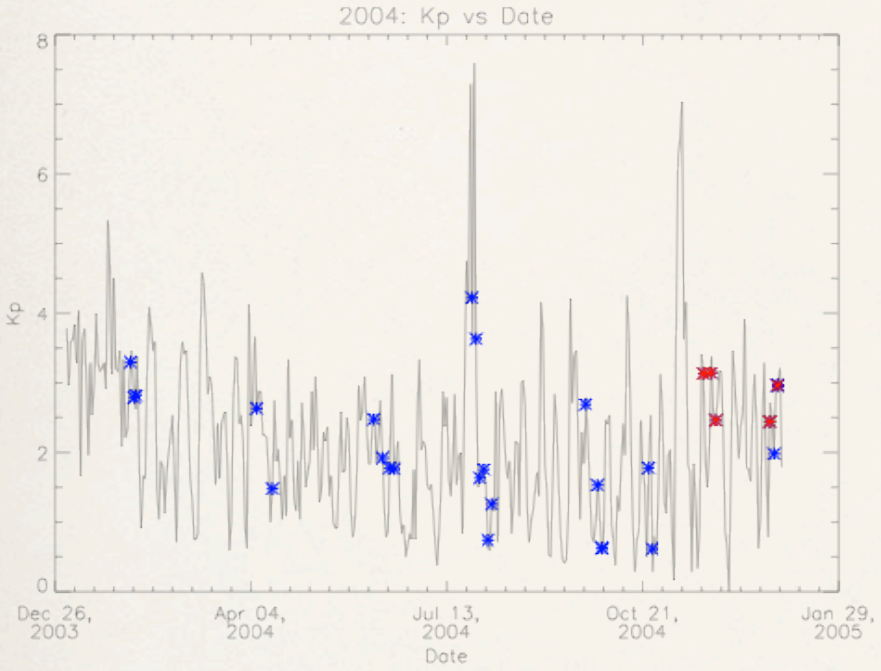
DST
(Disturbance Storm Time)



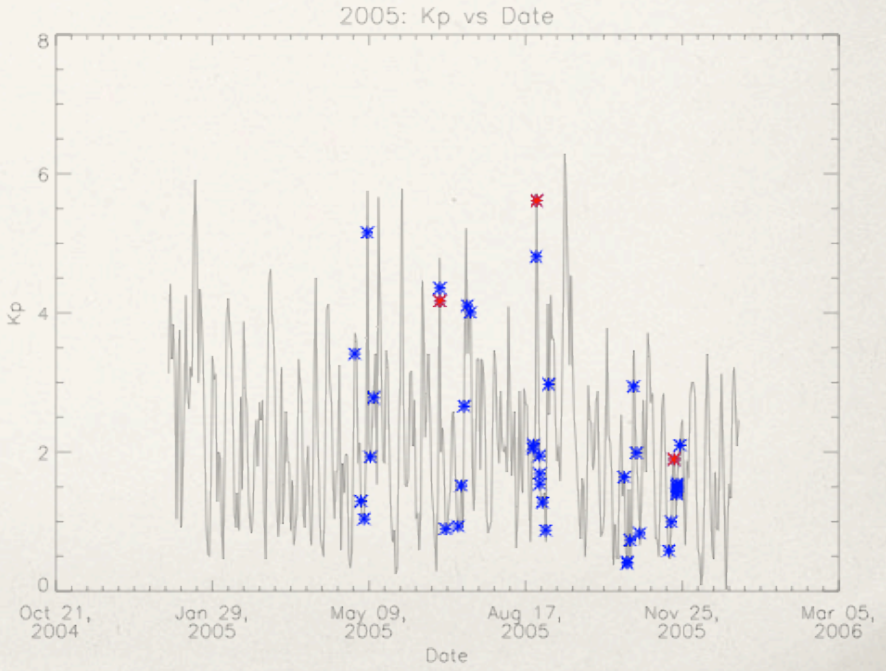
KEY
Red: Anomalous Observation
Blue: Star Observation at similar latitude



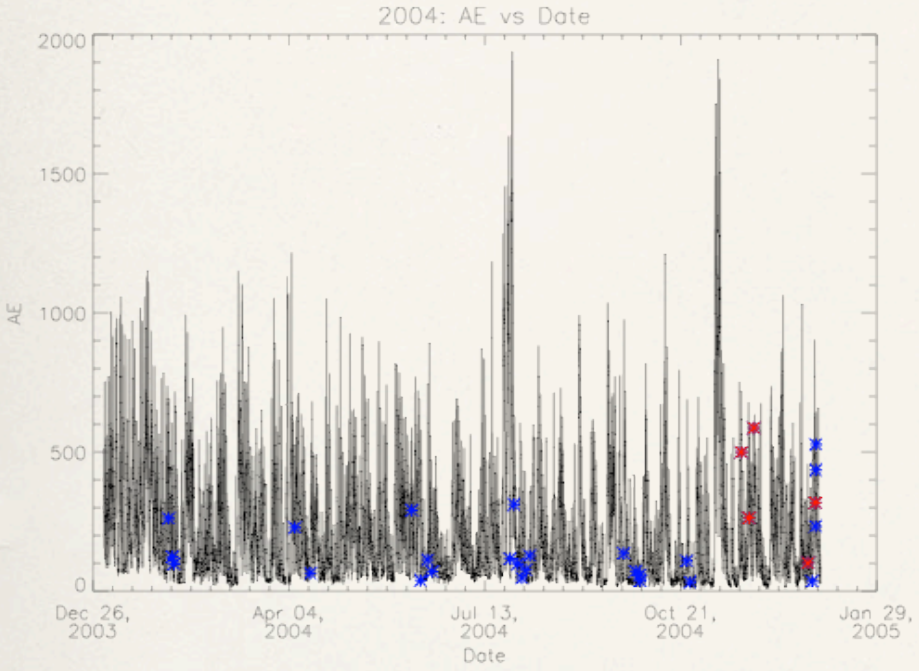
Kp; Planetary K (Measures Geomagnetic Storms)



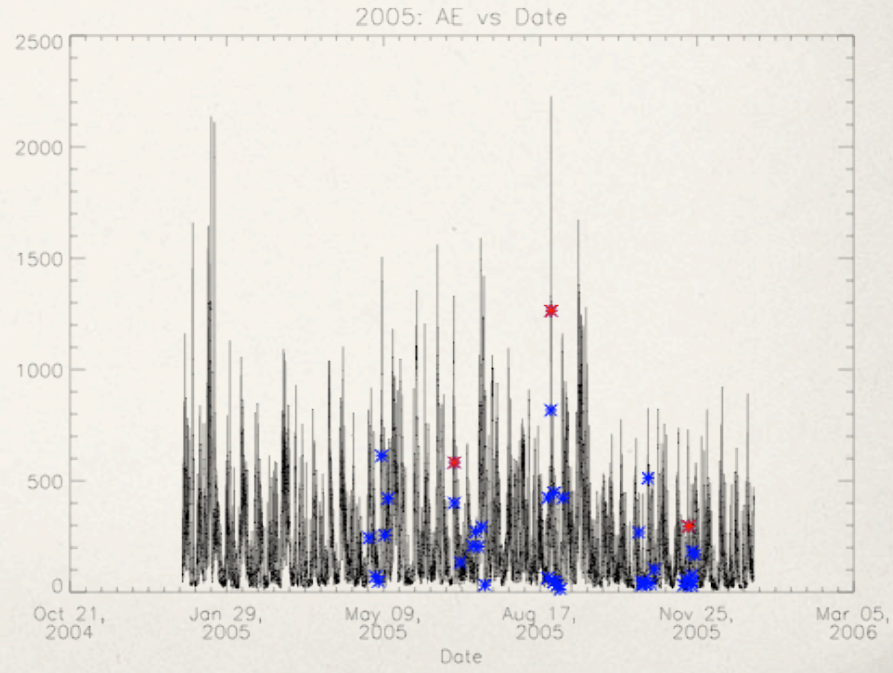
KEY
Red: Anomalous Observation
Blue: Star Observation at similar latitude



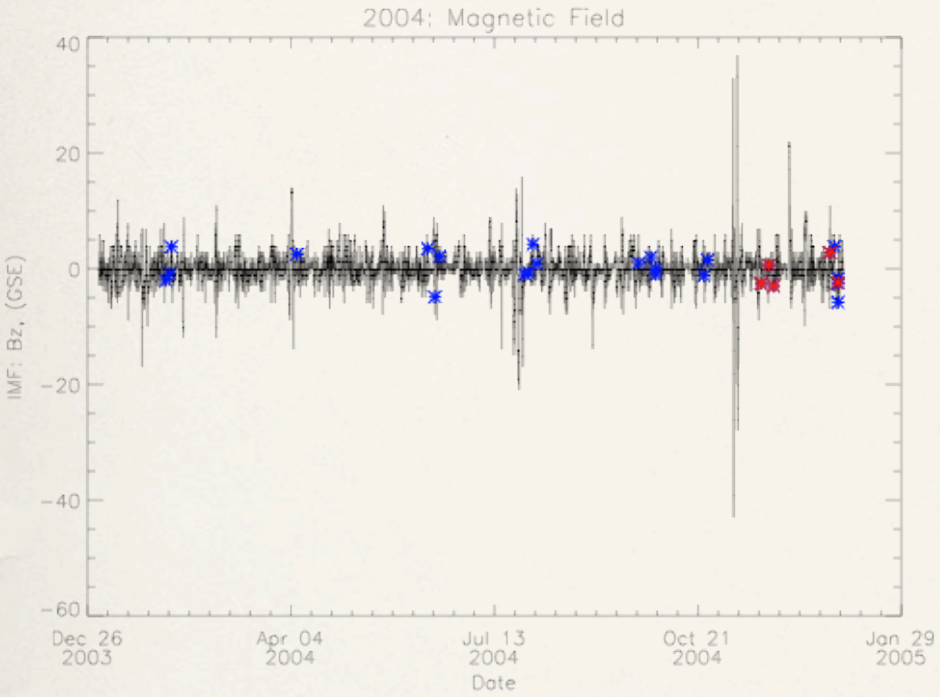
Auroral Electrojet (Auroral Zone Magnetic Activity)



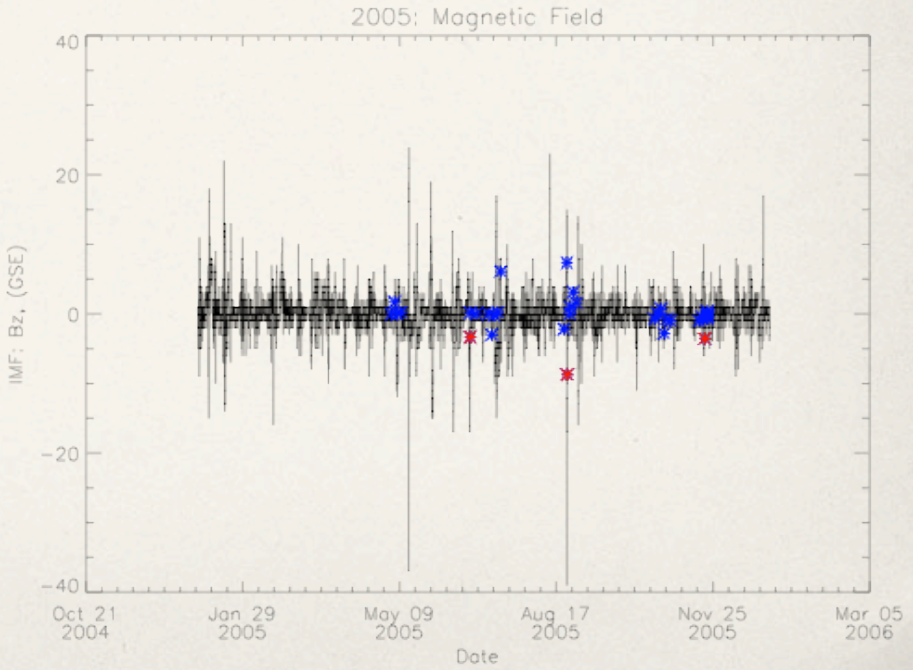
KEY
Red: Anomalous Observation
Blue: Star Observation at similar latitude



IMF (Interplanetary Magnetic Field)



KEY
Red: Anomalous Observation
Blue: Star Observation at similar latitude



Conclusions/Future Research

- High possibility that observations are a result of chemiluminescent NO emissions from O & N
  - Further research should be done with data to determine ways to confirm
- Though no strong correlation with indices, cluster that occurs predominately during Nov/Dec
  - Further inspection between seasonal events

Emission # :	Date
1	Nov 21, 2004
2	Nov 25, 2004
3	Nov 27, 2004
4	Dec 25, 2004
5	Dec 29, 2004
6	Jun 23, 2005
7	Aug 24, 2005
8	Nov 20, 2005

Acknowledgments

- LASP REU Program
  - Marty Snow, Erin Wood
- SORCE

References

- Barth, C. A, et al. "Global Observations of Nitric Oxide in the Thermosphere." Journal of Geophysical Research 108.A1 (2003): n. pag. Print.

- Bertaux, Jean-Loup, et al. "SPICAM on Mars Express: Observing Modes and Overview of UV Spectrometer Data and Scientific Results." Journal of Geophysical ResearchS90 111.E10 (2006): 18-22. Print.