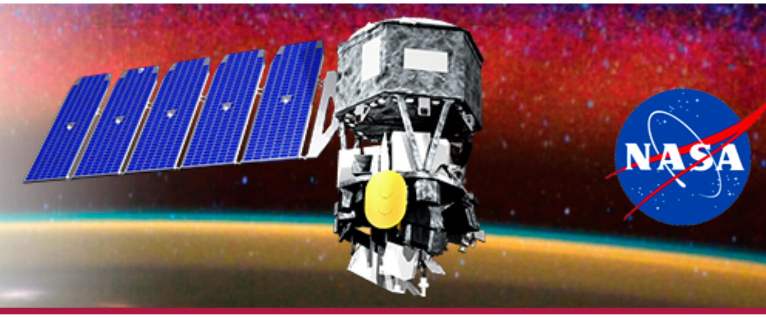
Ionospheric Connection Explorer



The Ionospheric Connection Explorer

Instruments and Analysis

Thomas J. Immel

UC Berkeley

Brian Harding

U Illinois Urbana-Champaign

ICON is a NASA Explorer mission to understand the unpredictable nature of the IT system

Ionospheric Connection Explorer

Mission Summary	
Cost	$145M (FY11) $163M (RY)
Launch vehicle	Option B (Pegasus), Eastern Test Range
Spacecraft	LEOStar-2, 3-axis stabilized, no consumables
Launch	February 2017
Orbit	575 km circular, 27° inclination
Ground segment	Berkeley Ground Station, WGS, Santiago
Mission & Science Ops	24 months Phase E Operated from UCB

- Prime Contractor
- Project Management
- UV Instruments (2)
- Payload Electronics
- Payload Integration
- E/PO
- Operations

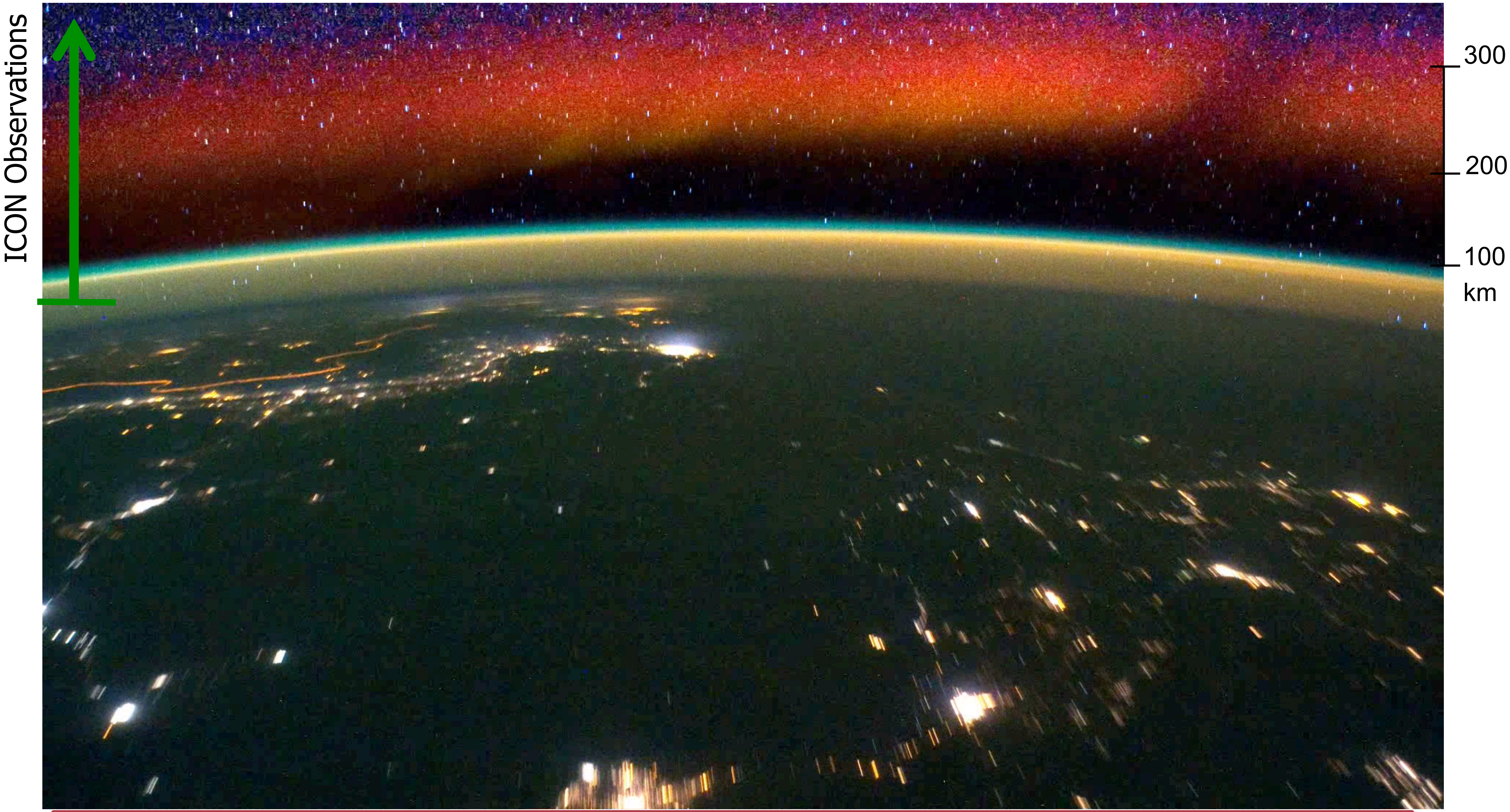
- LEOStar spacecraft
- Observatory I&T
- Payload Structure

- Wind and Temperature Interferometer
- Ion Velocity Meter

Inst. Cameras
Payload Test

FUV Cal.

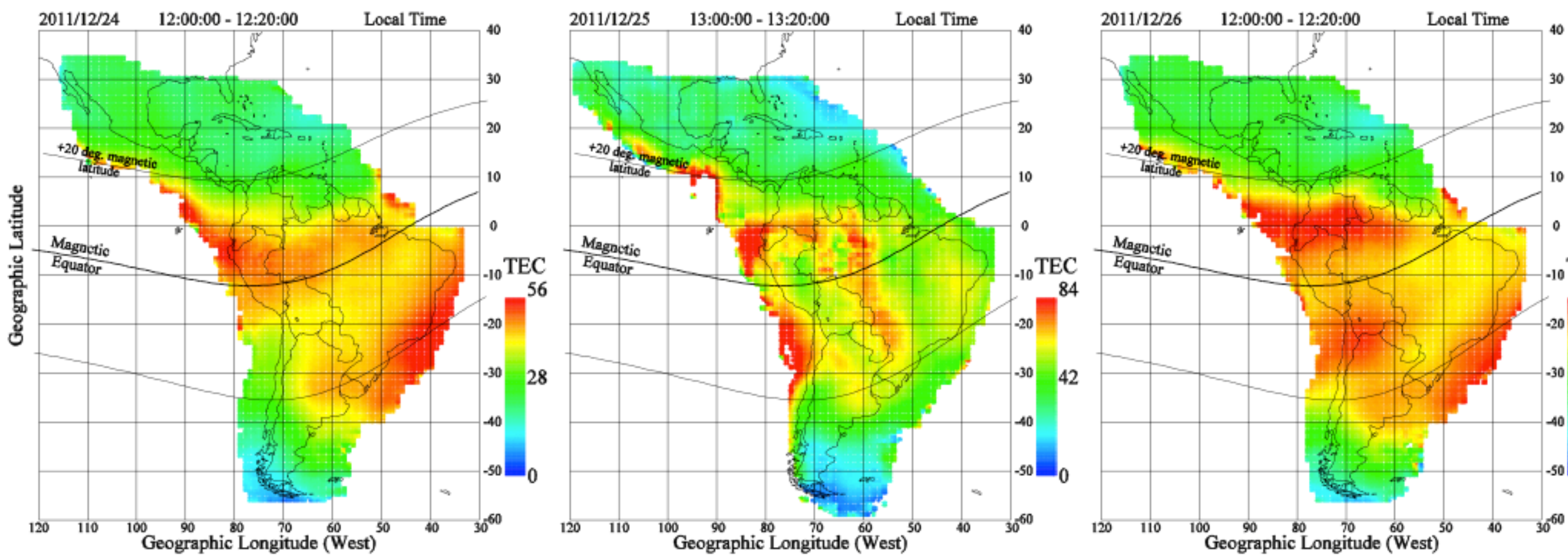
The Ionospheric Connection Explorer – Understanding the link between our Atmosphere and Space



ICON explores a frontier in science:

How our space environment is controlled by terrestrial weather

Current knowledge cannot account for what is observed in Near-Earth space.



- LISN Network TEC – PI Cesar Valladares, Boston College
- Outstanding day-to-day variability in equatorial ionosphere while Dst = 0 nT
- Cause unknown!

We continue to see behavior of the ionosphere that is completely unexpected.

ICON's Science Objectives require measurements of both drivers and responses.

The Ionospheric Dynamo, driven by the neutral atmosphere, governs the motion of the plasma:

- We need to measure the **drivers**:

Neutral winds that carry the energy and momentum that drives the dynamo.

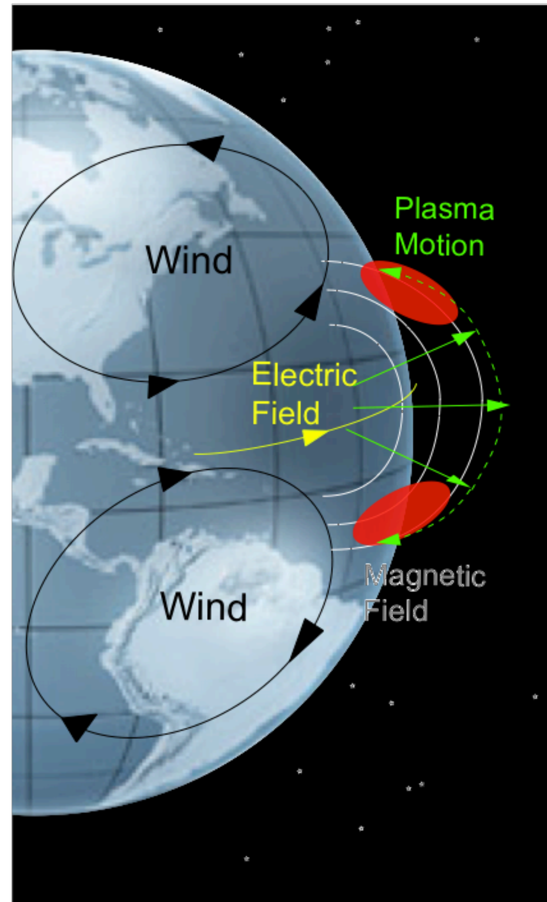
Composition of the atmosphere that controls the chemical production and loss rates of plasma.

Temperature of the atmosphere that reveals the atmospheric waves entering space from below.

- along with the **responses**:

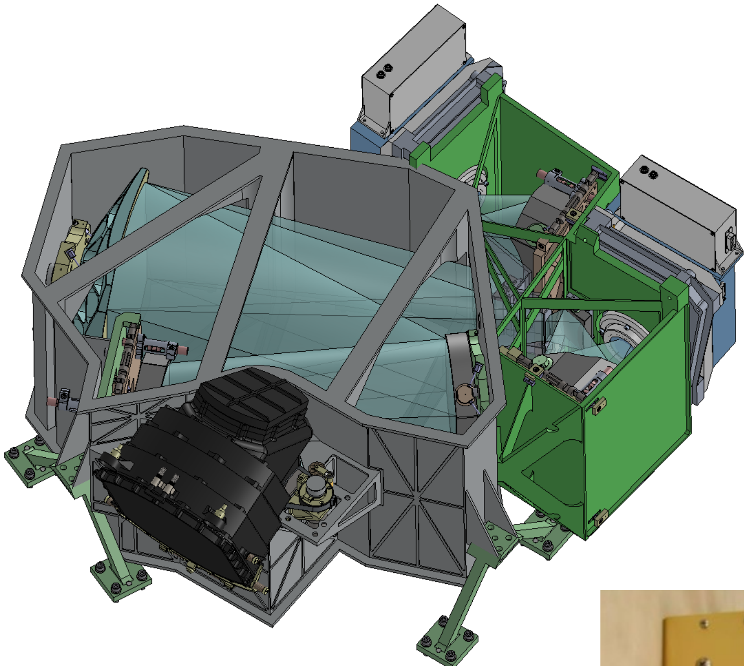
Electric fields and **plasma motion**, both the result of the wind dynamo forcing.

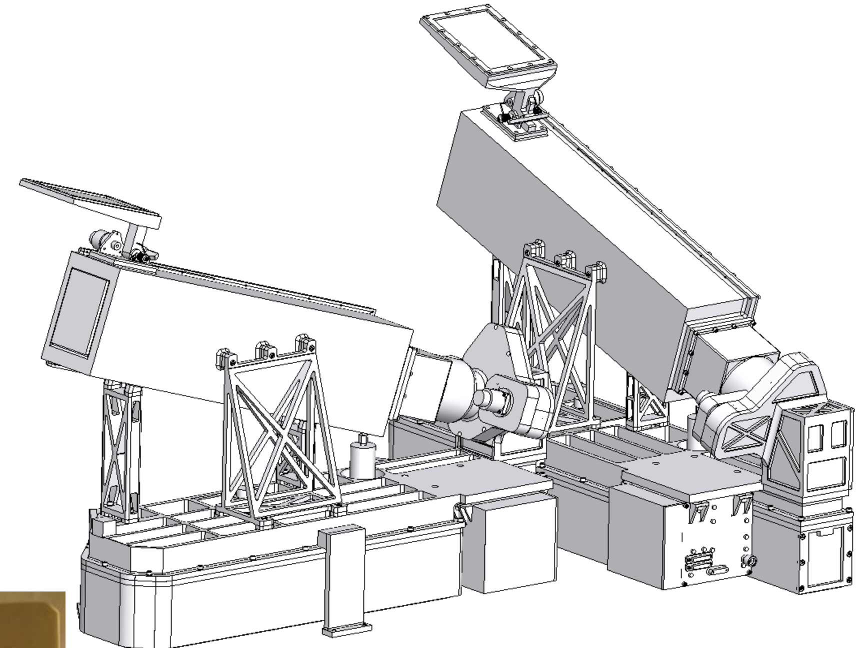
Plasma density of the ionosphere, the combined result of solar production and plasma motion.

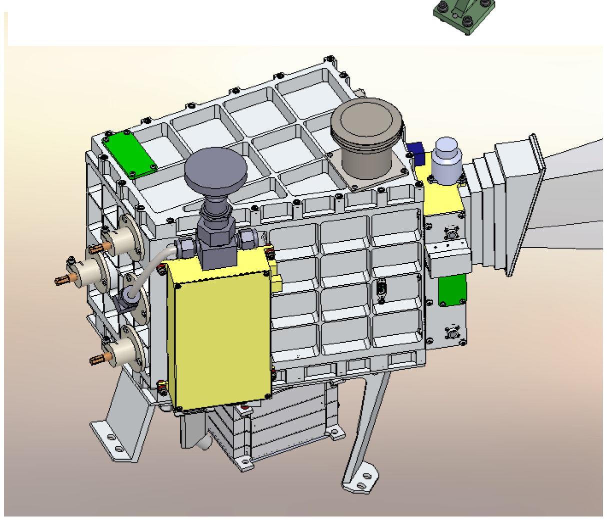


> To understand the ionospheric dynamo, the drivers and response must be measured **at all relevant altitudes and at the same time.**

ICON carries four instruments that make the necessary measurements.





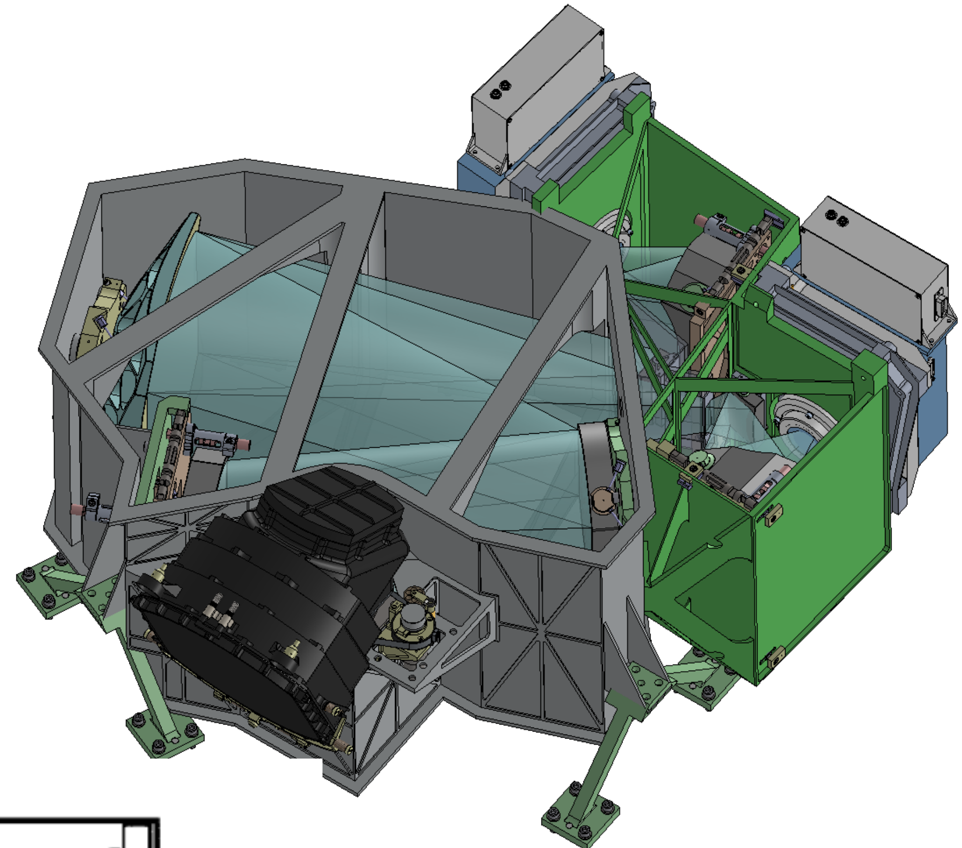


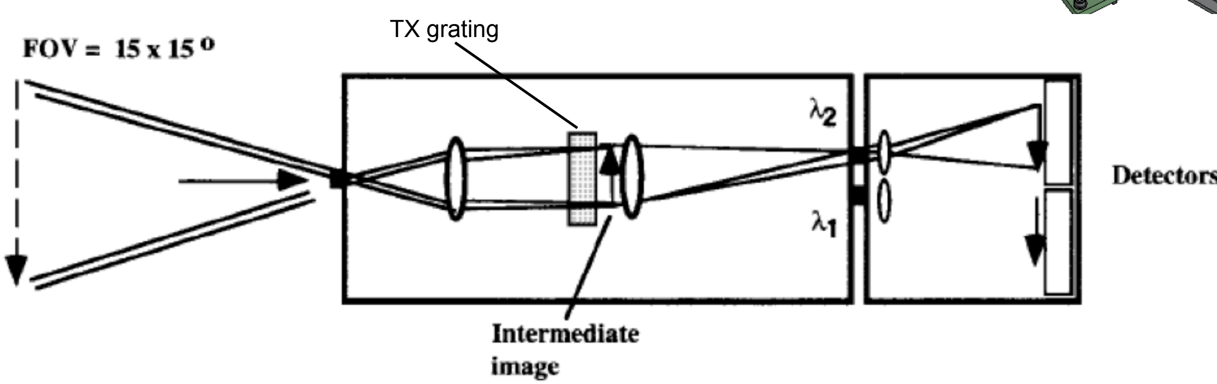
- MIGHTI Neutral wind and temperature profiler
- FUV Neutral composition profiler and nighttime plasma density profiler
- IVM in-situ electric field/plasma motion and
- EUV daytime plasma density profiler

Instrument #1: ICON FUV Spectrographic Imager

PI: Stephen Mende – Berkeley

- **Provides nighttime NmF2 and HmF2 with continuous 12 second readout.**
- **Provides daytime thermospheric composition (O and N2).**
- **Imaging mode at nighttime for resolution of plasma structure.**
- **Measures the altitude intensity profile of atomic oxygen (<u>OI @ 135.6 nm)</u> and molecular nitrogen (<u>N2 LBH ~150 nm</u>) emissions on the limb in the thermosphere.**

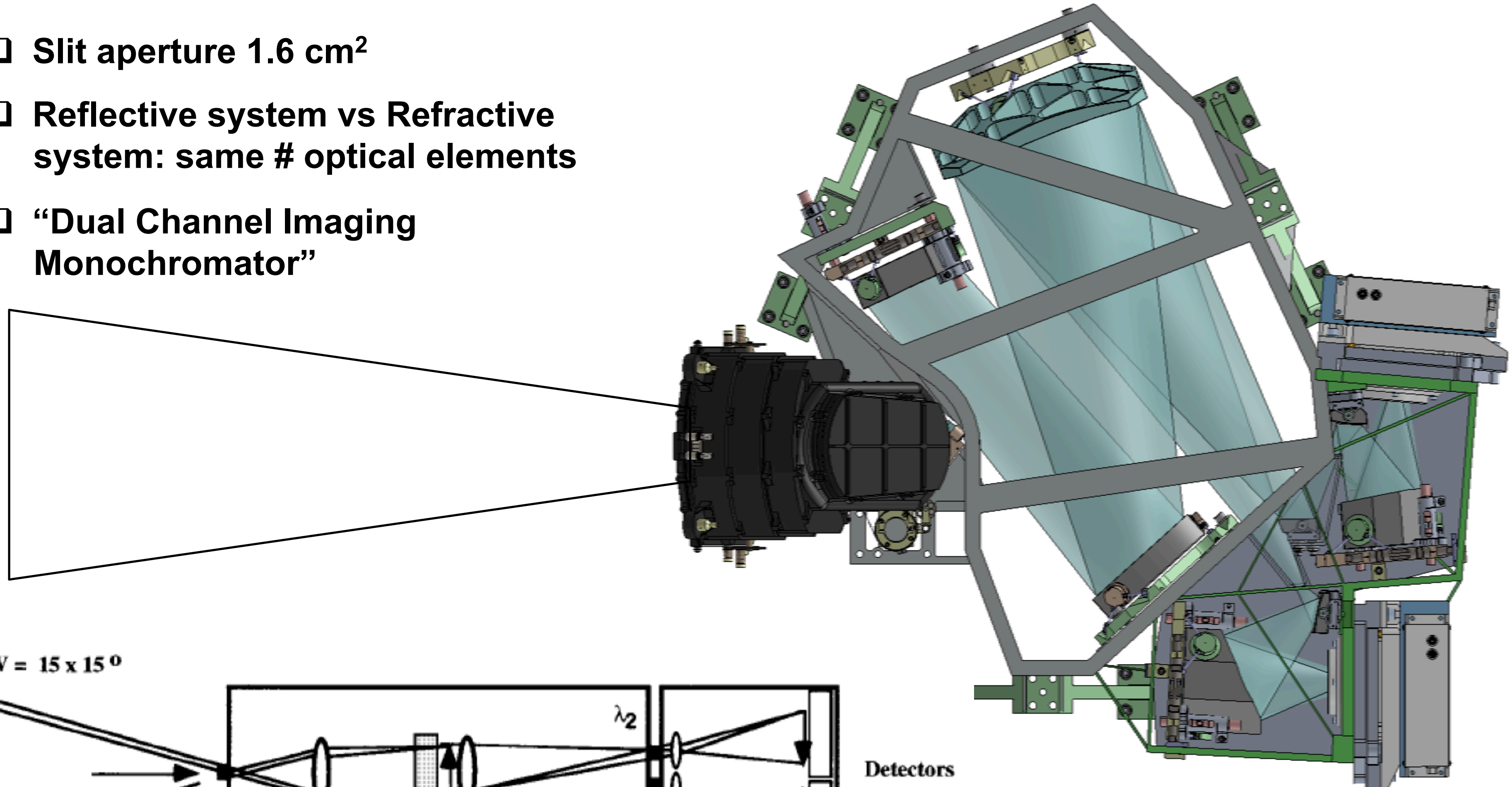


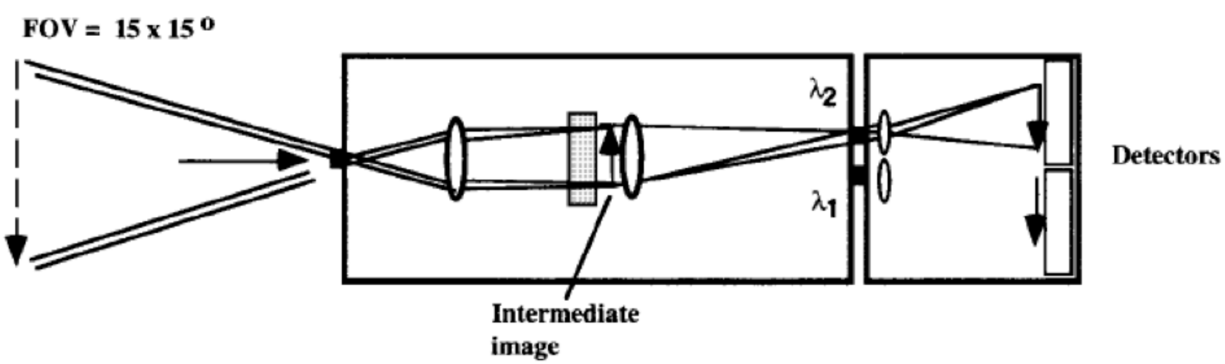


FUV design based upon IMAGE FUV with,
- Czerny-Turner Spectrometer
- Dual MCP-CCD detectors.

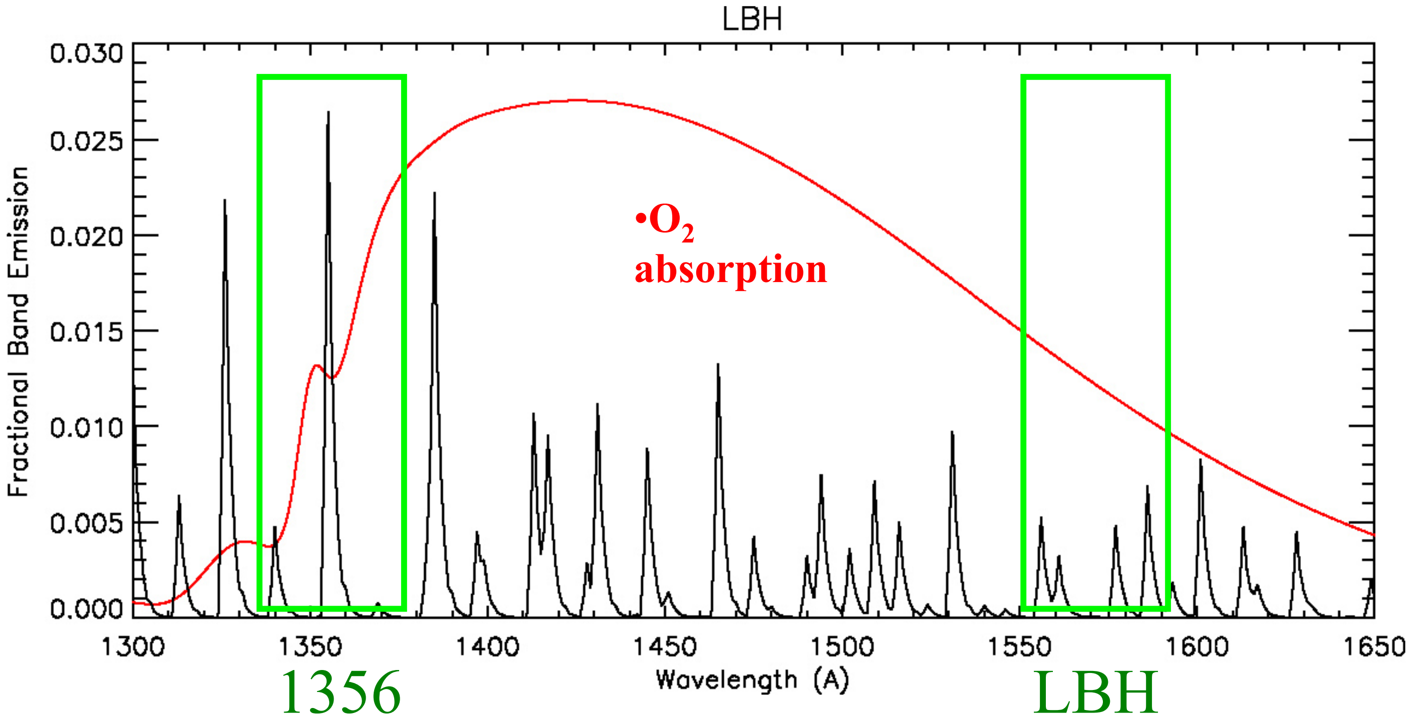
Instrument #1: ICON FUV Spectrographic Imager

- Slit aperture 1.6 cm^2
- Reflective system vs Refractive system: same # optical elements
- "Dual Channel Imaging Monochromator"





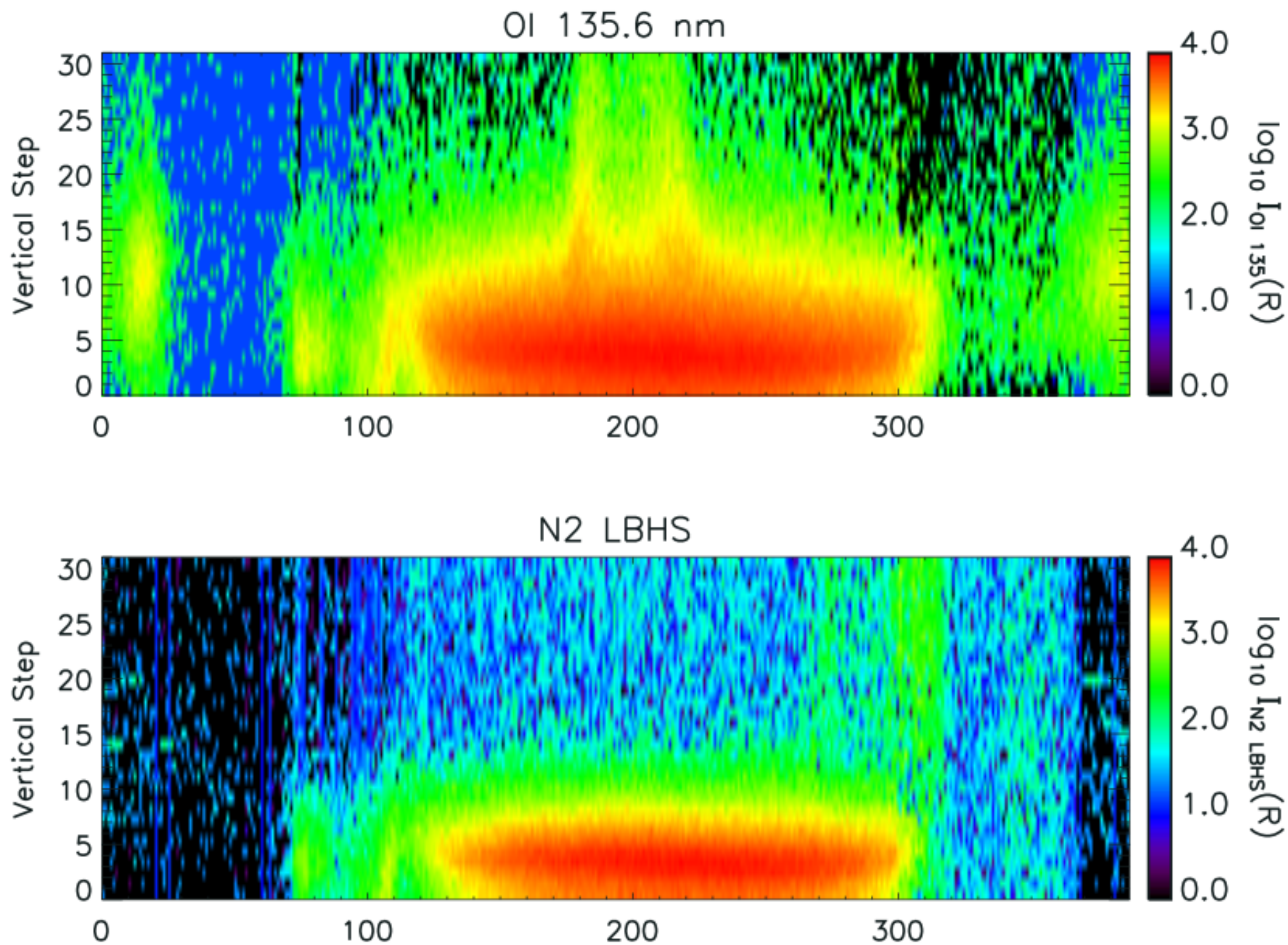
Instrument #1: ICON FUV Spectrographic Imager



- ❑ Targets are 135.6 and a portion of the N2 Lyman-Birge-Hopfield emissions.
- ❑ Passbands selected to make instrument buildable.
- ❑ Useful result is that absorption of FUV light by O2 is similar at both wavelenghts.

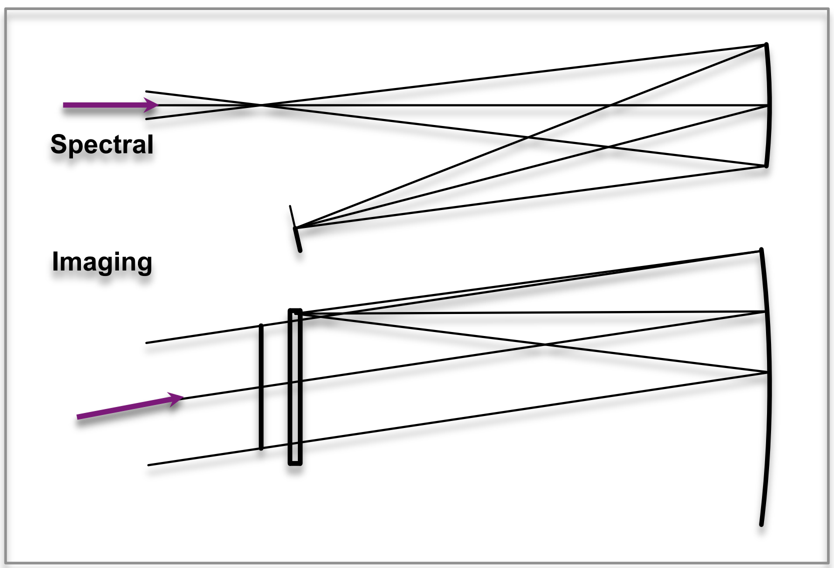
Instrument #1: ICON FUV Spectrographic Imager

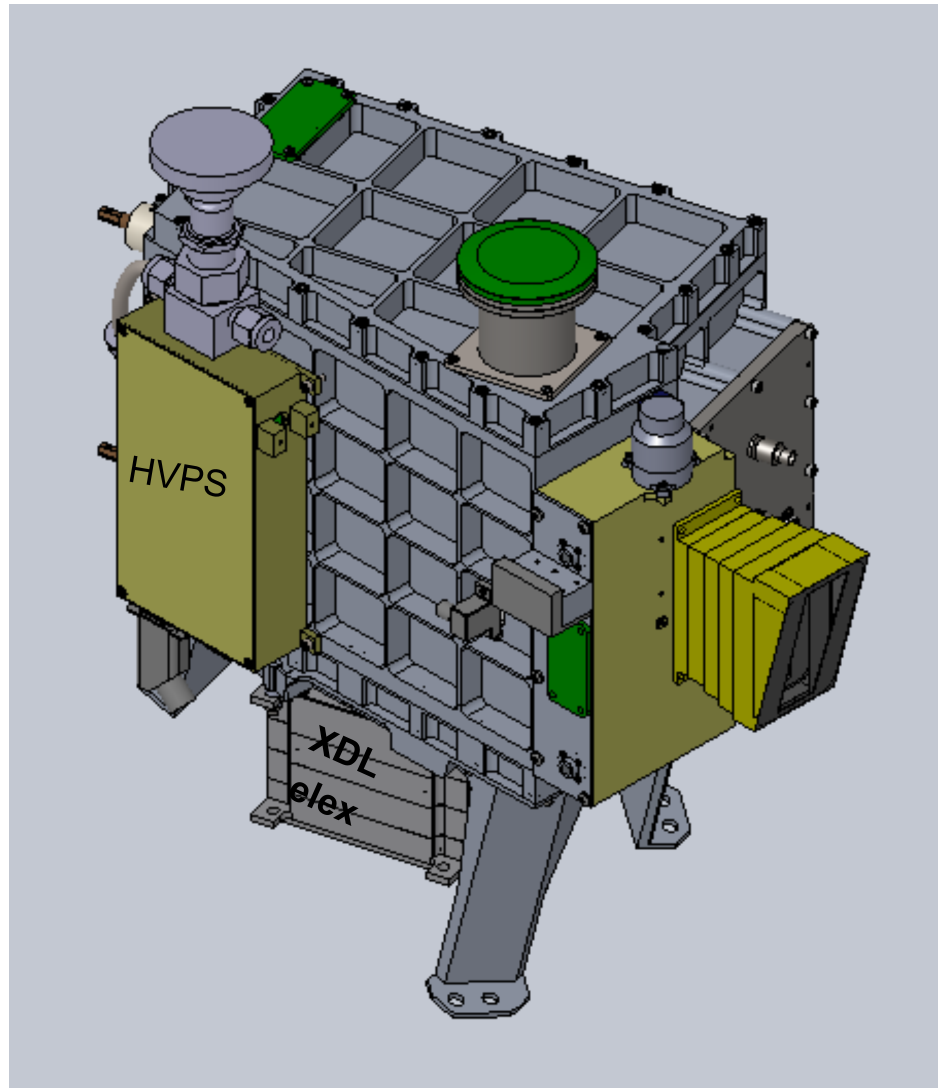
- ICON implements continuous Limb imaging similar to TIMED GUVI viewing capability.
- O and N2 retrieved using forward radiative transfer models and NRL-MSIS.
- NmF2 and HmF2 retrieved at nighttime.



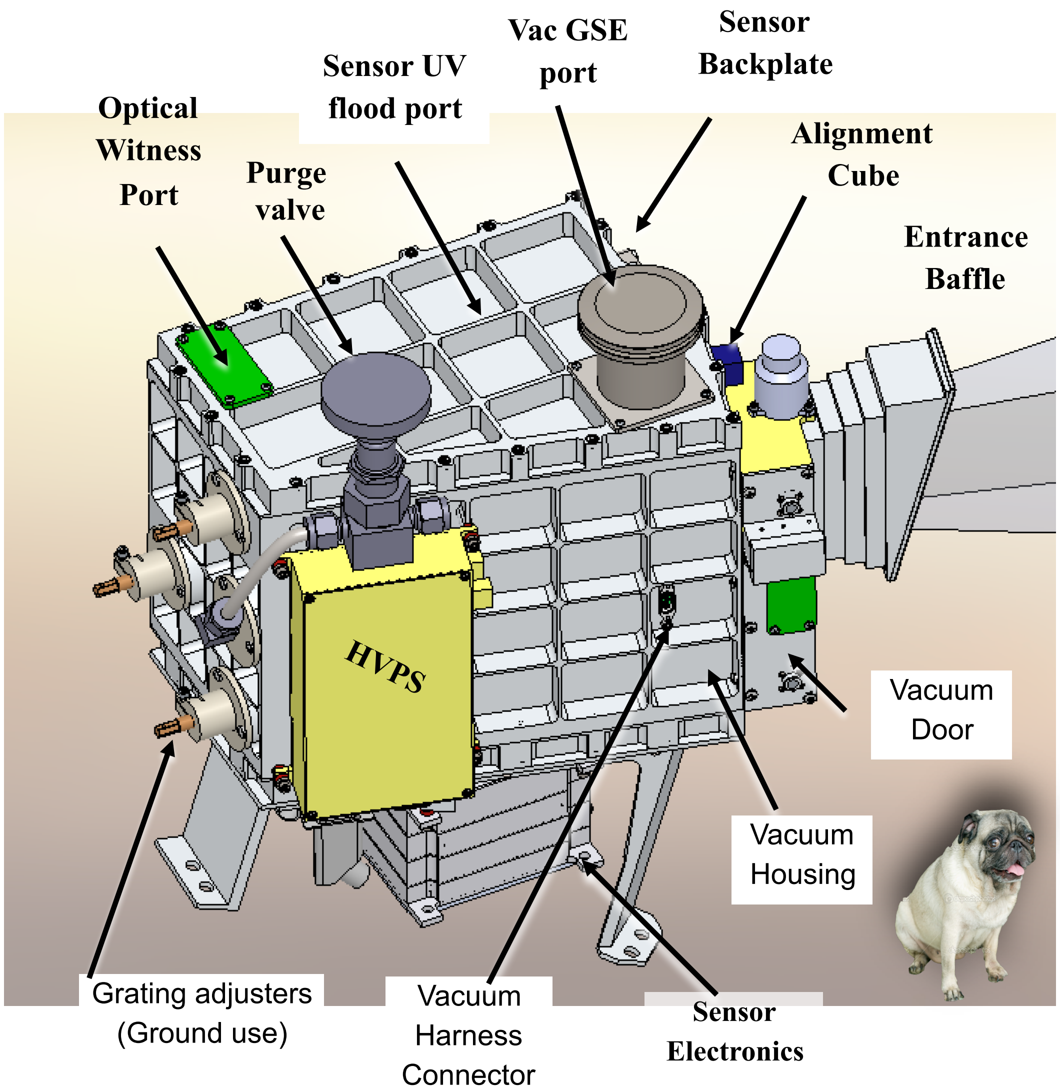
Instrument #2: ICON EUV Spectrographic Imager

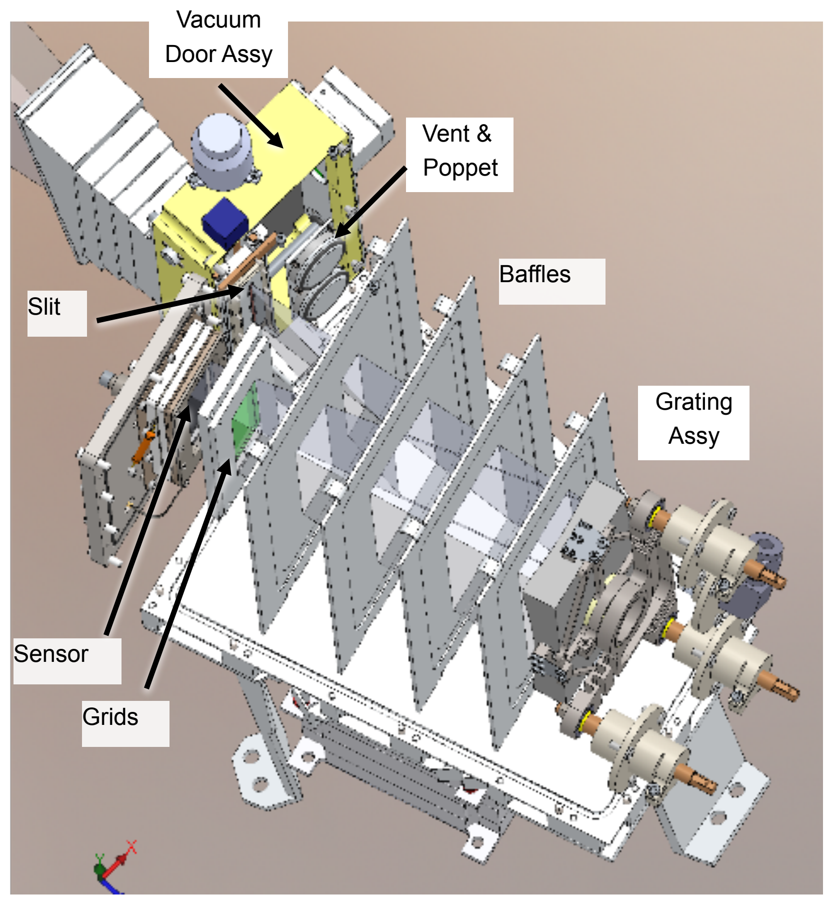
- PI : Jerry Edelstein - Berkeley
- **Provides NmF2 and HmF2 with each daytime observation (12 seconds)**
- **Measures the altitude intensity profile and spatial distribution of ionospheric <u>O+ emissions @ 83.4 nm</u> and <u>61.7 nm.</u>**



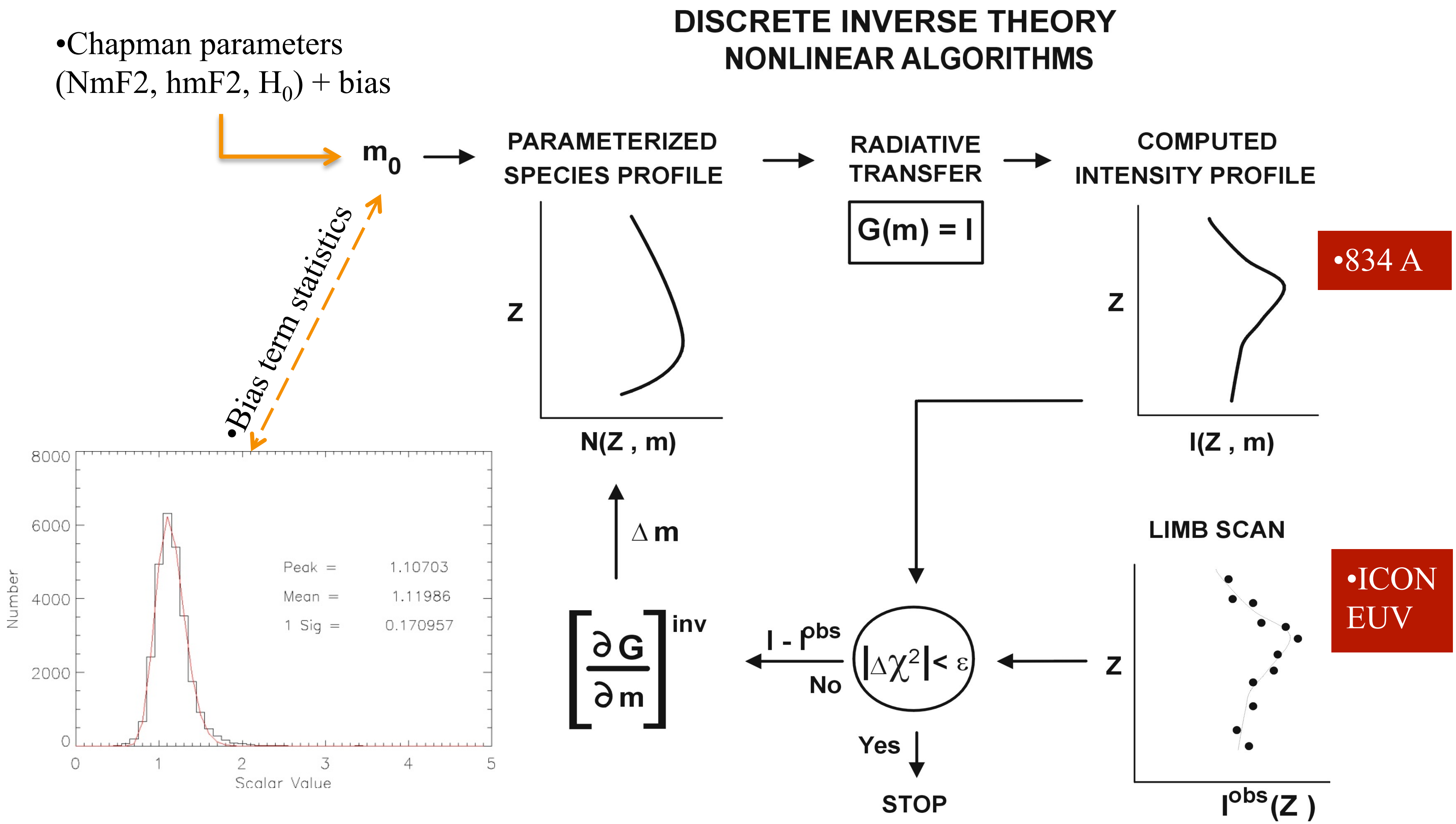


EUV Instrument Description





EUV Retrieval of daytime ionospheric density profile

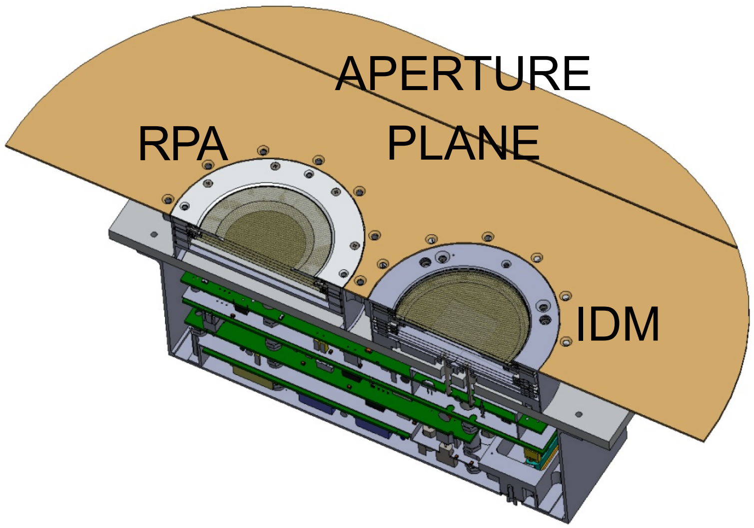


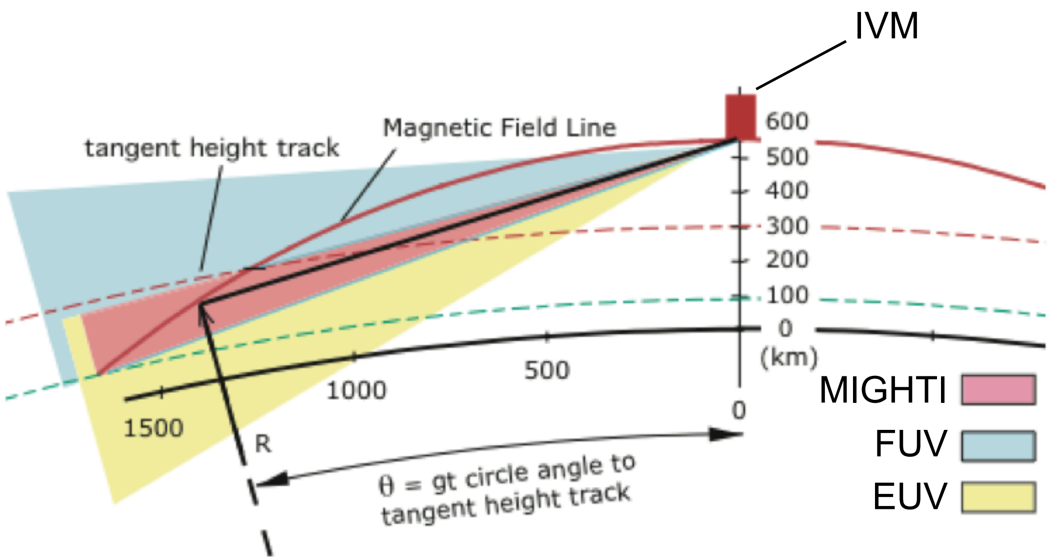
Instrument #3: ICON Ion Velocity Meter

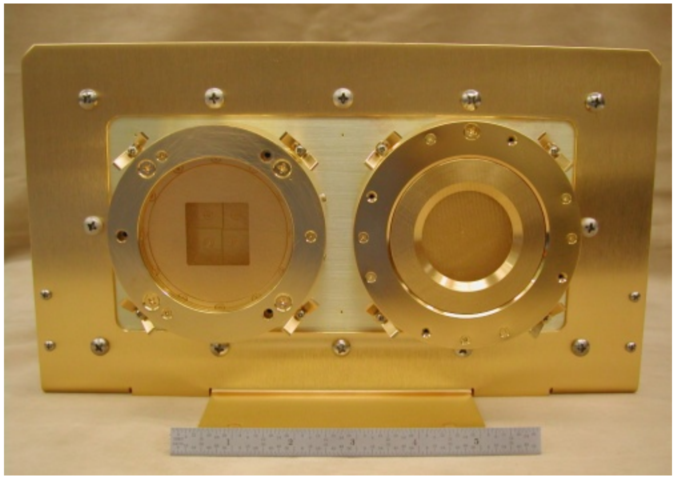
PI : Rod Heelis, U. Texas at Dallas

- **Provides Vi every second.**

A combined Retarding Potential Analyzer and Ion Drift Meter (RPA, IDM) measures the in-situ 3D velocity vector of the local plasma.





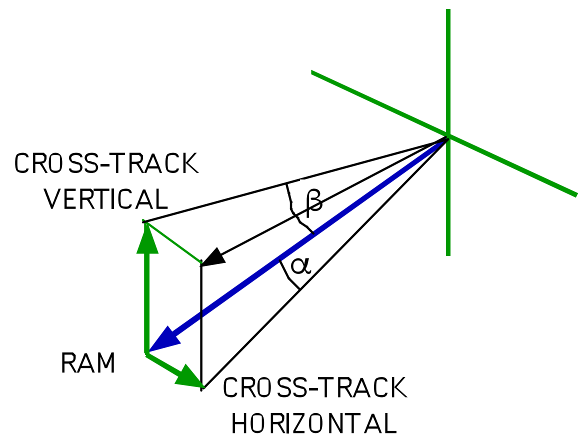


- Design very similar to CINDI on Air Force C/NOFS mission

Instrument #3: ICON Ion Velocity Meter

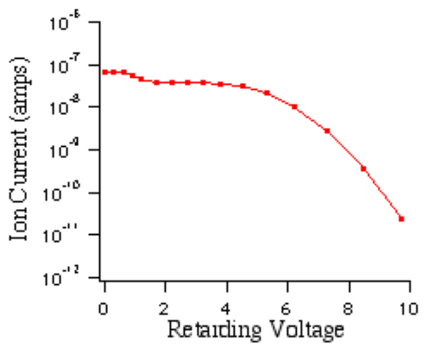
Measurement Technique: Current through apertures directed into satellite **V** measured with high precision.

- ❑ Precision comparison of currents on 4 plates in a square aperture give the cross track measurement
- ❑ Current through retarding grid provides ram energy/ion temperature/ion velocity



Retarding Potential Analyzer (RPA)

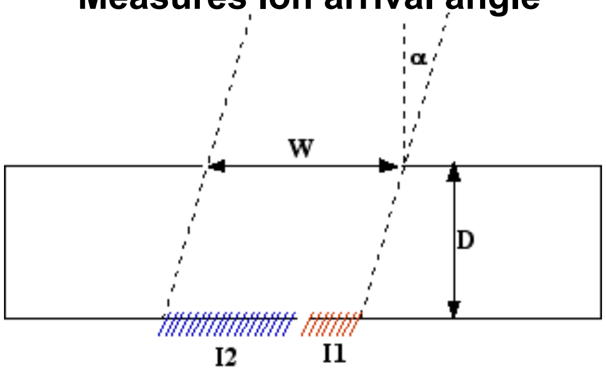
Measures ram energy as a function of retarding voltage



$$KE = \frac{1}{2}m\left(V_{s_r} + V_r\right)^2 + e\psi$$

Ion Drift Meter (IDM)

Measures Ion arrival angle



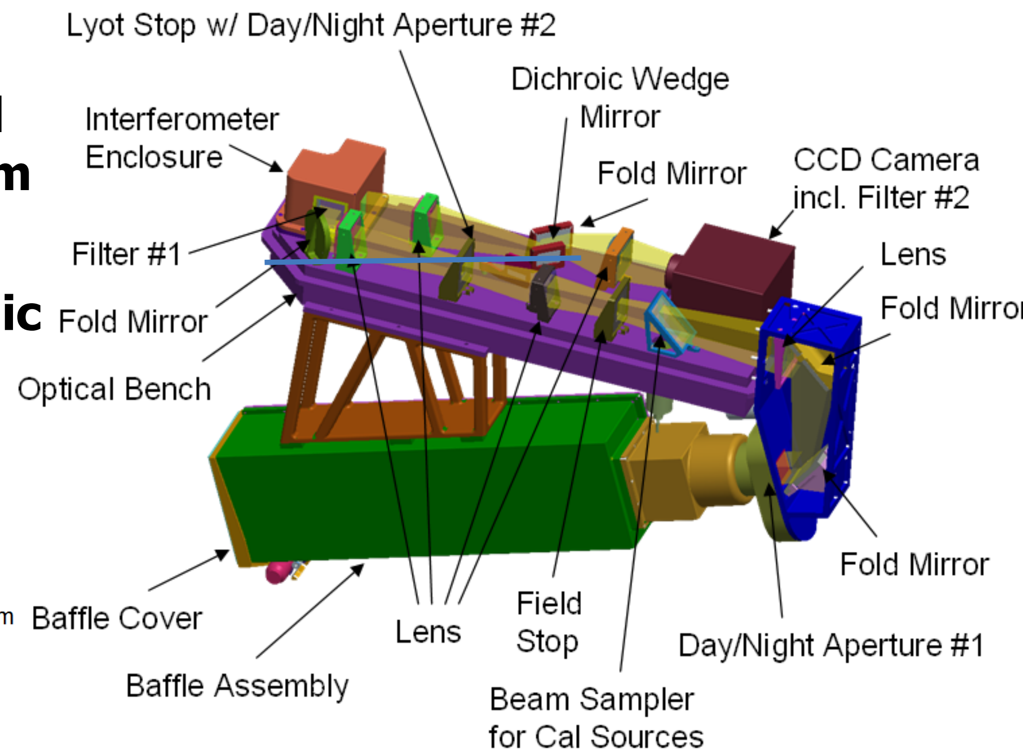
$$V_h = \left(V_{s_r} + V_r\right)\tan\alpha$$

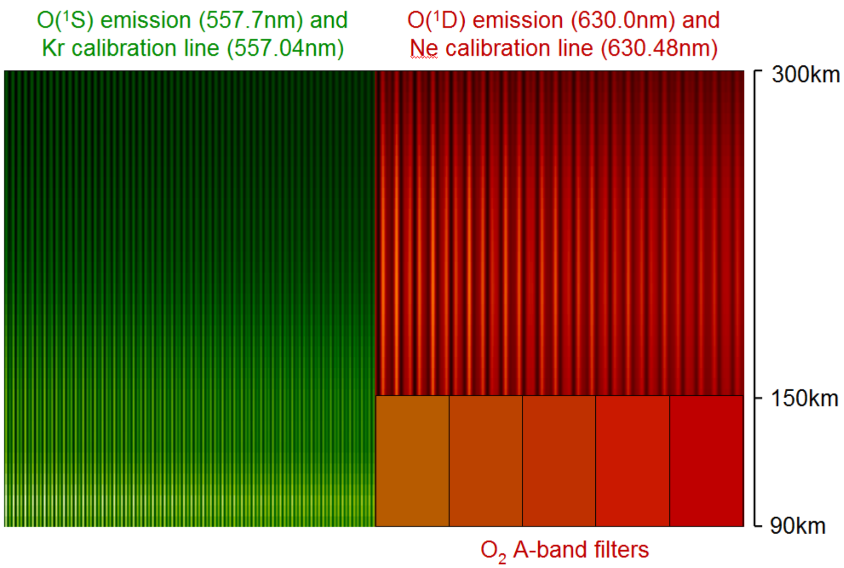
$$V_v = \left(V_{s_r} + V_r\right)\tan\beta$$

Instrument #4: Michelson Interferometer for Global Heterodyne Thermospheric Imaging – MIGHTI

PI : Chris Englert – Naval Research Lab

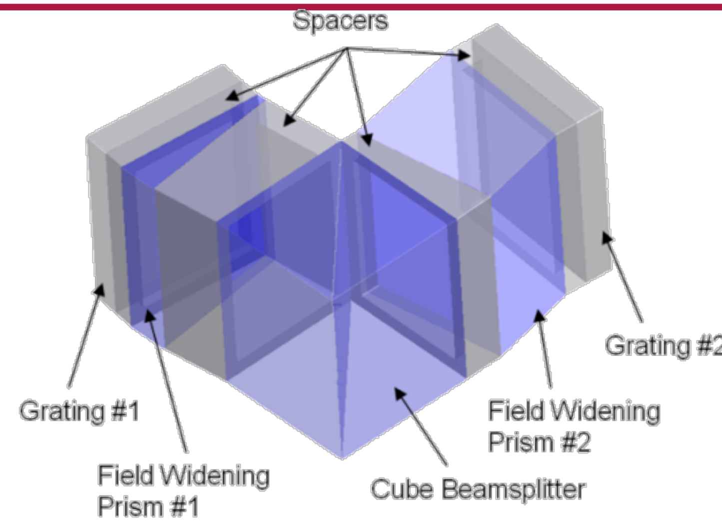
- **Provides Neutral Winds in the 100-300 km range, and Neutral temperatures in the 100-120 km range.**
- **Measures Doppler shift of atomic 557.7 and 630.0 nm lines, and rotational temp of O_2 at 762.0 nm.**

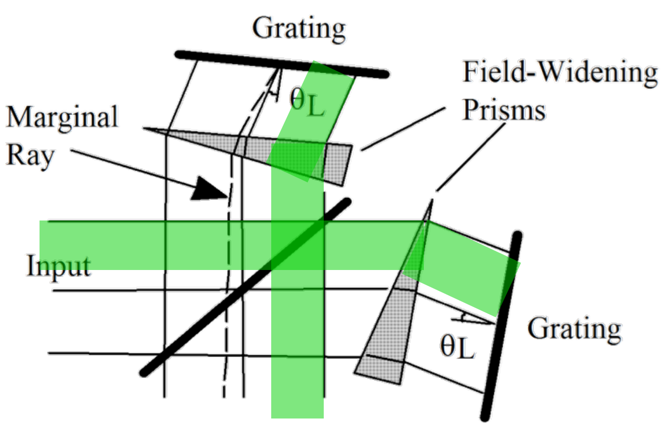


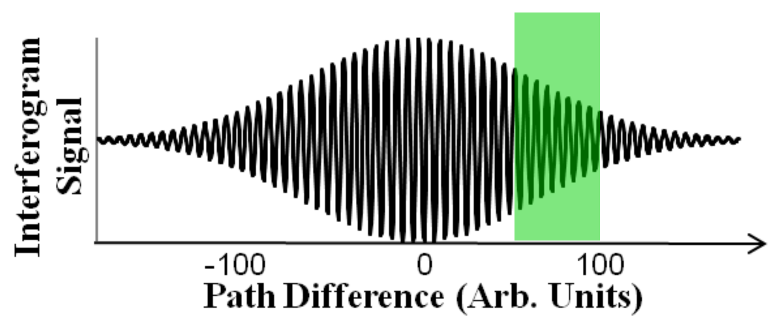


The MIGHTI interferometer is a modified Spatial Heterodyne Spectrometer

MIGHTI is based upon the SHIMMER Instrument (Englert et al, GRL, 2008): SHIMMER was a near-UV **traditional SHS** (equal-length-arm design) whereas the MIGHTI spectrometer is a visible-band **multiwavelength Doppler Asymmetric Spatial Heterodyne (DASH)** design.







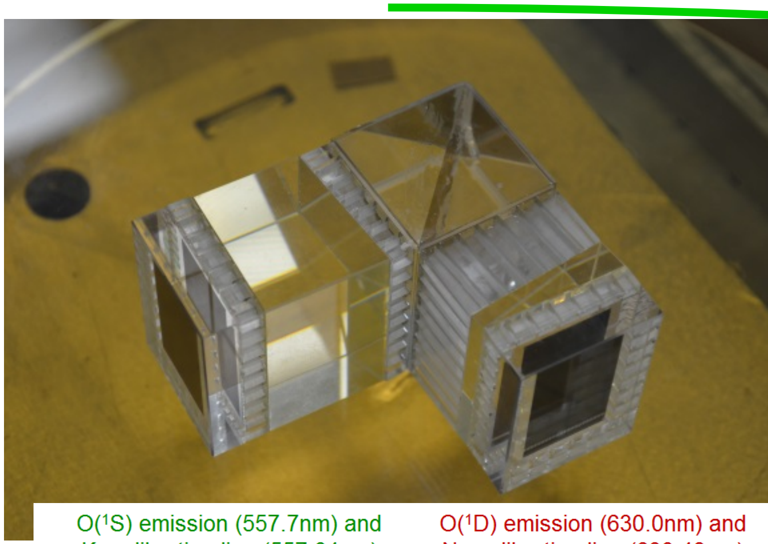
Traditional SHS measures full interferogram
Useful for retrieving spectra.
However, Doppler shift information is located around optimum path difference in interferogram.

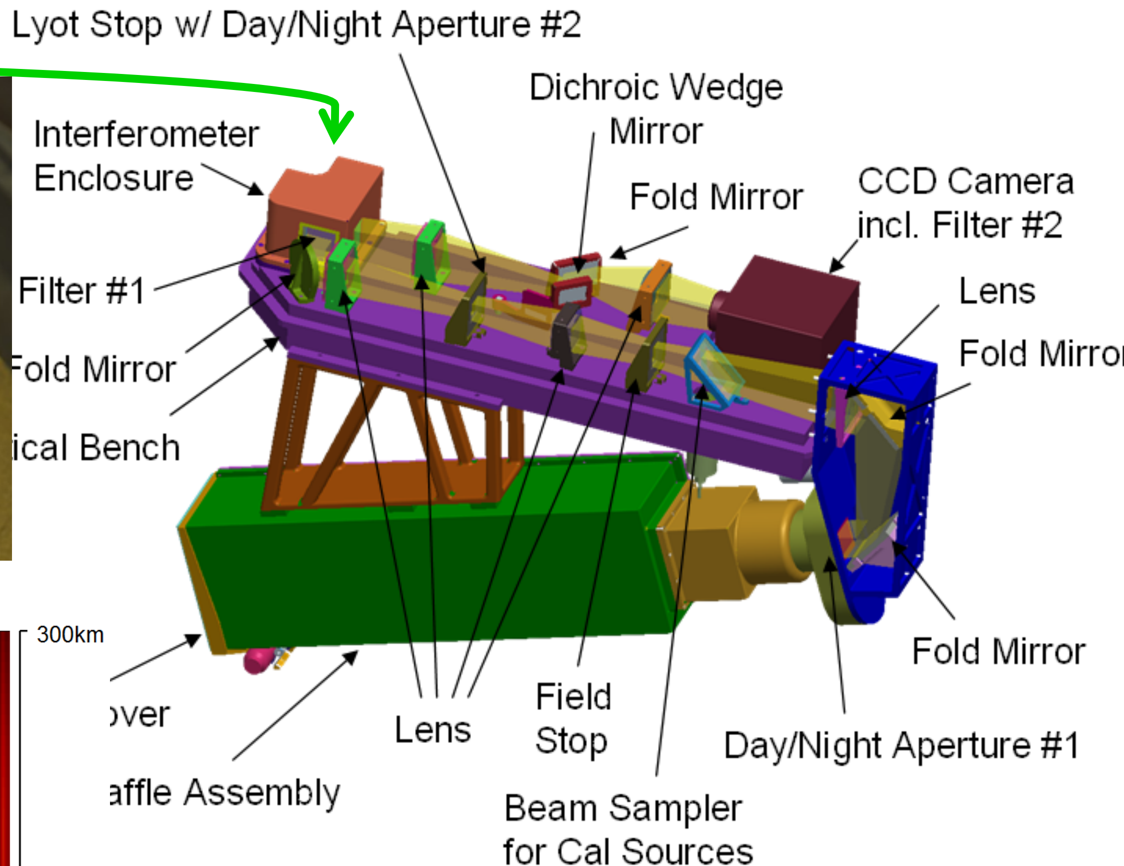
DASH measures the portion of the interferogram that is optimized for the wind measurement.

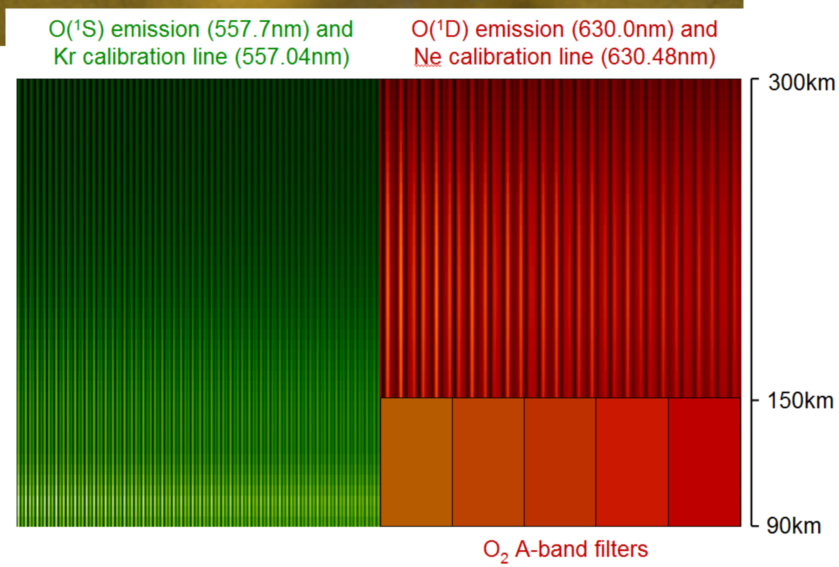
The fringe frequencies observed by SHS and DASH instruments are the same.

DASH interferometers are SHS interferometers optimized for wind measurements

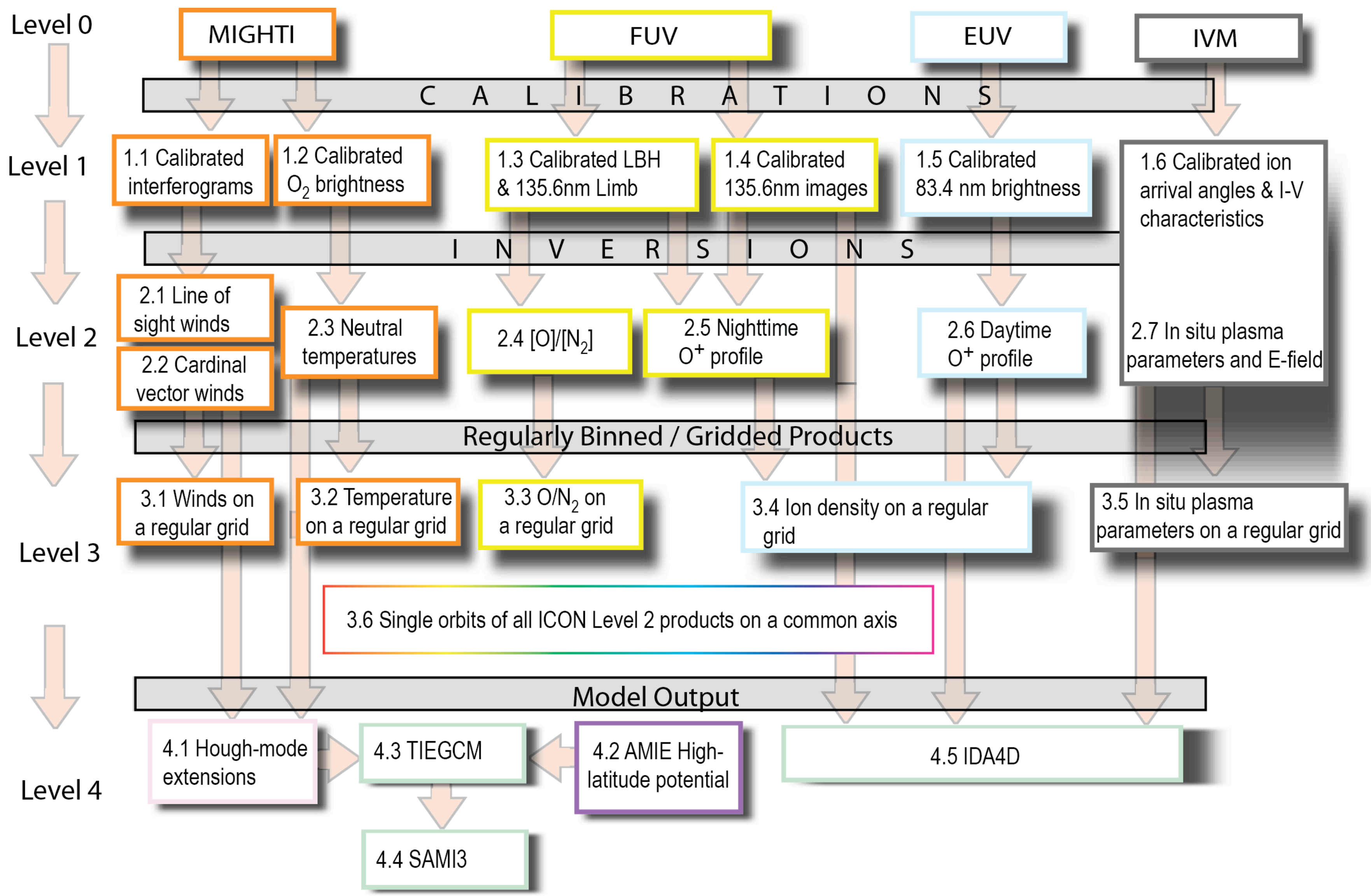
Instrument #4: Michelson Interferometer for Global Heterodyne Thermospheric Imaging – MIGHTI



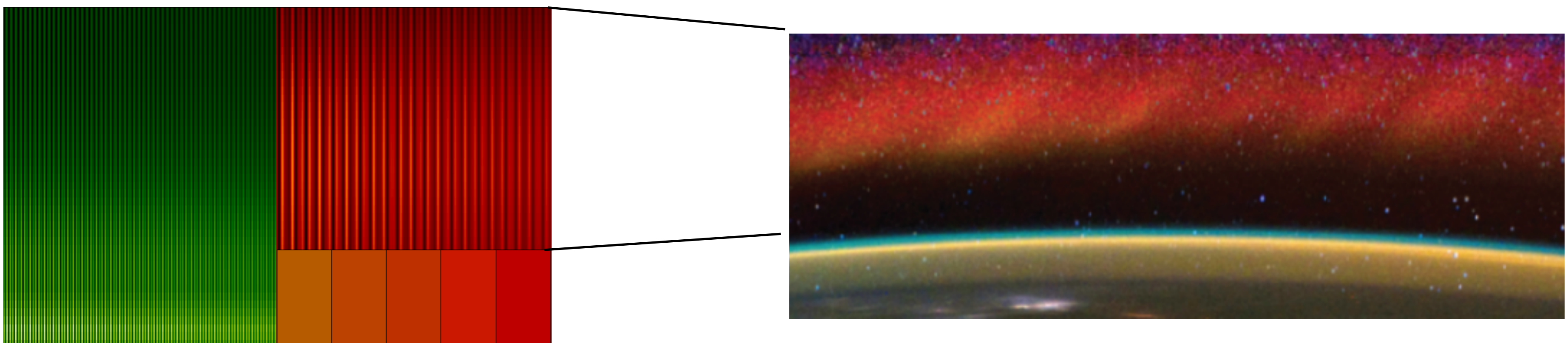


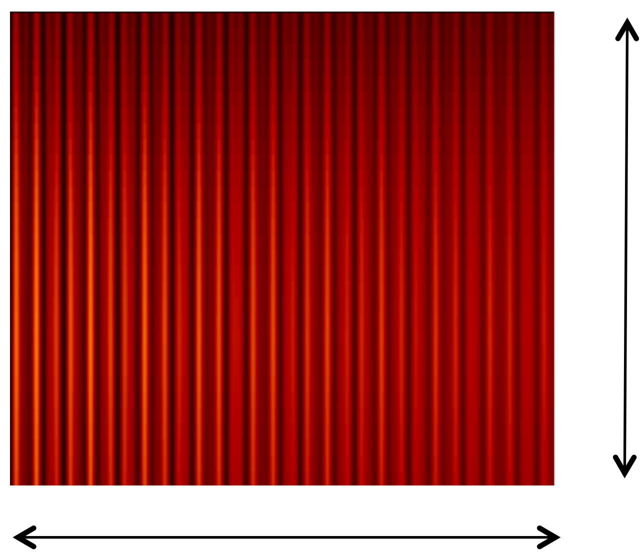


ICON Data Processing



What does MIGHTI actually measure?

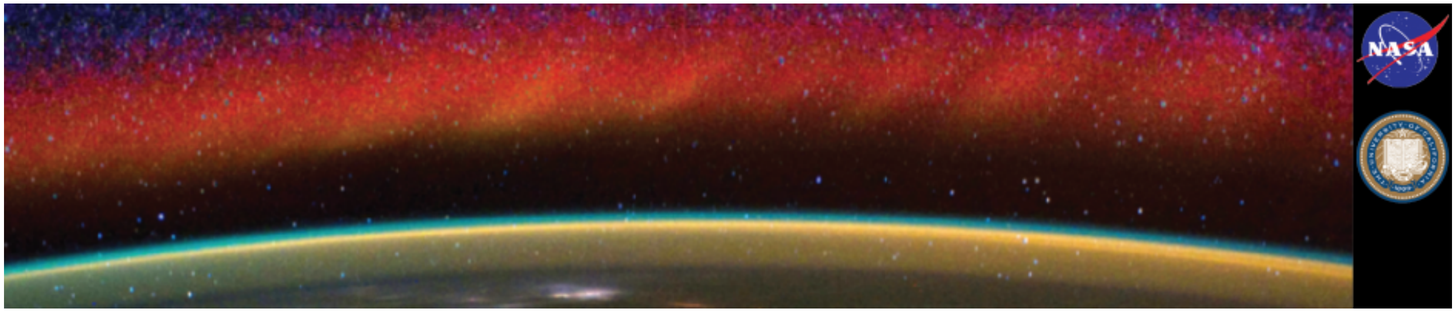


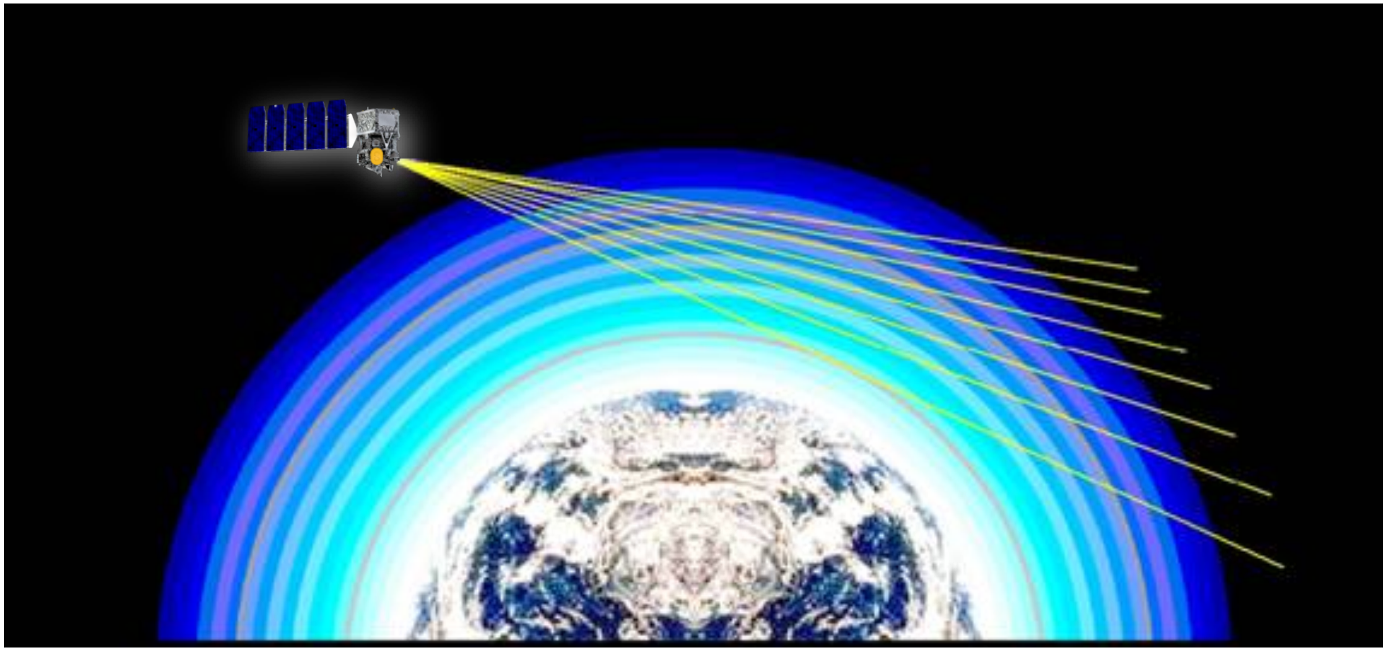


"Altitude" information

Spectral Information (and therefore, wind information)

Limb measurements are line-of-sight integrals

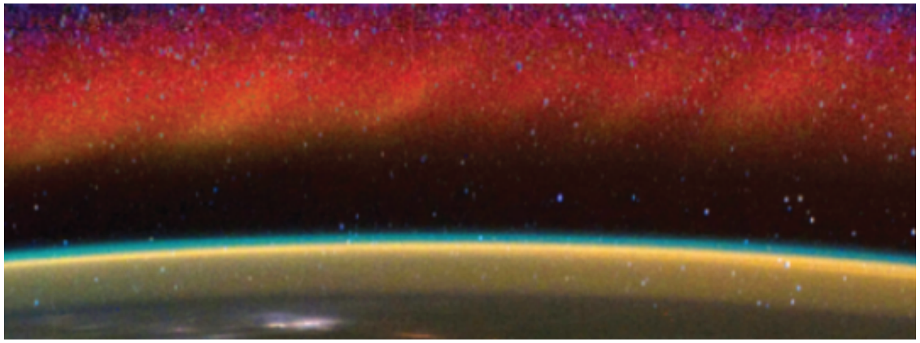




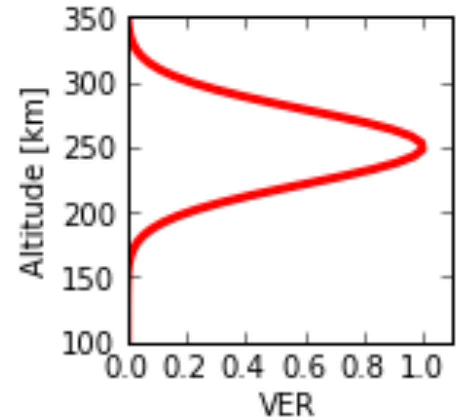
How to get altitude information from line-of-sight integrated quantities?

Abel inversion on limb measurements

- Simpler problem: Retrieve airglow *intensity* profile (not wind)



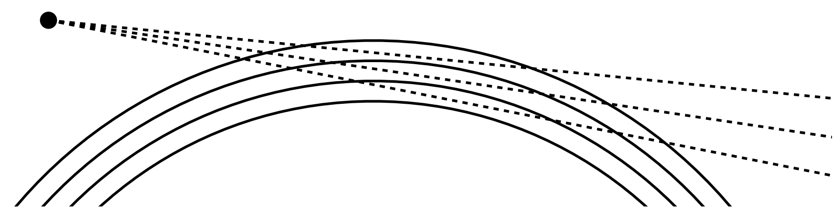
?



- Assuming spherical symmetry, there is a classic analytical result: Abel transform. In practice, measurements are discrete:

$$f(\theta_j) = \int_0^{\infty} I(r)\, dl = \sum_{i=1}^{N} \int_{l_i}^{l_{i+1}} I(r)\, dl \approx \sum_{i=1}^{N} (l_{i+1} - l_i)\, I(r_i)$$

Assume atmosphere is piecewise constant in altitude:

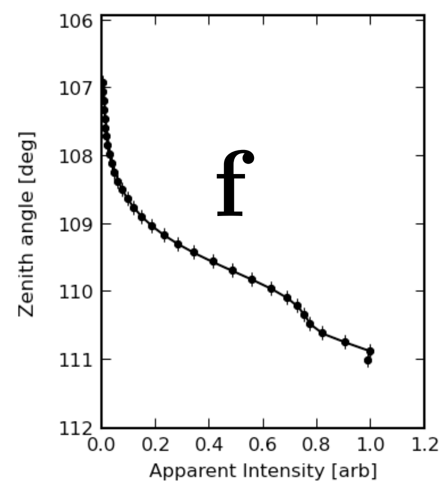


Abel inversion on limb measurements

- Stack measurements to form matrix equation, which can be inverted (either directly or using more advanced techniques):

$$f(\theta_j) = \sum_{i=1}^{N} (l_{i+1} - l_i)\, I(r_i) \xrightarrow[j=1,2,...,M]{} \mathbf{f} = P\mathbf{I}$$

$$\mathbf{I}^* = P^{-1}\mathbf{f}$$



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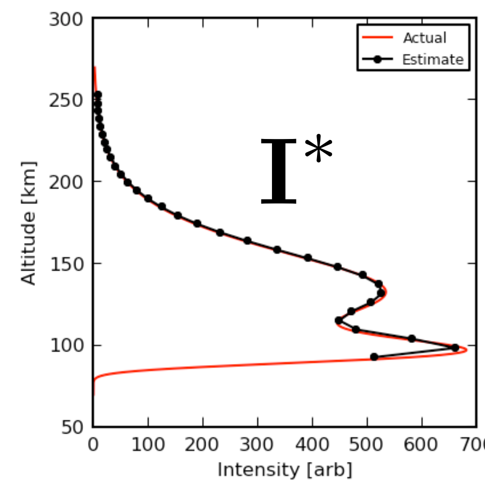
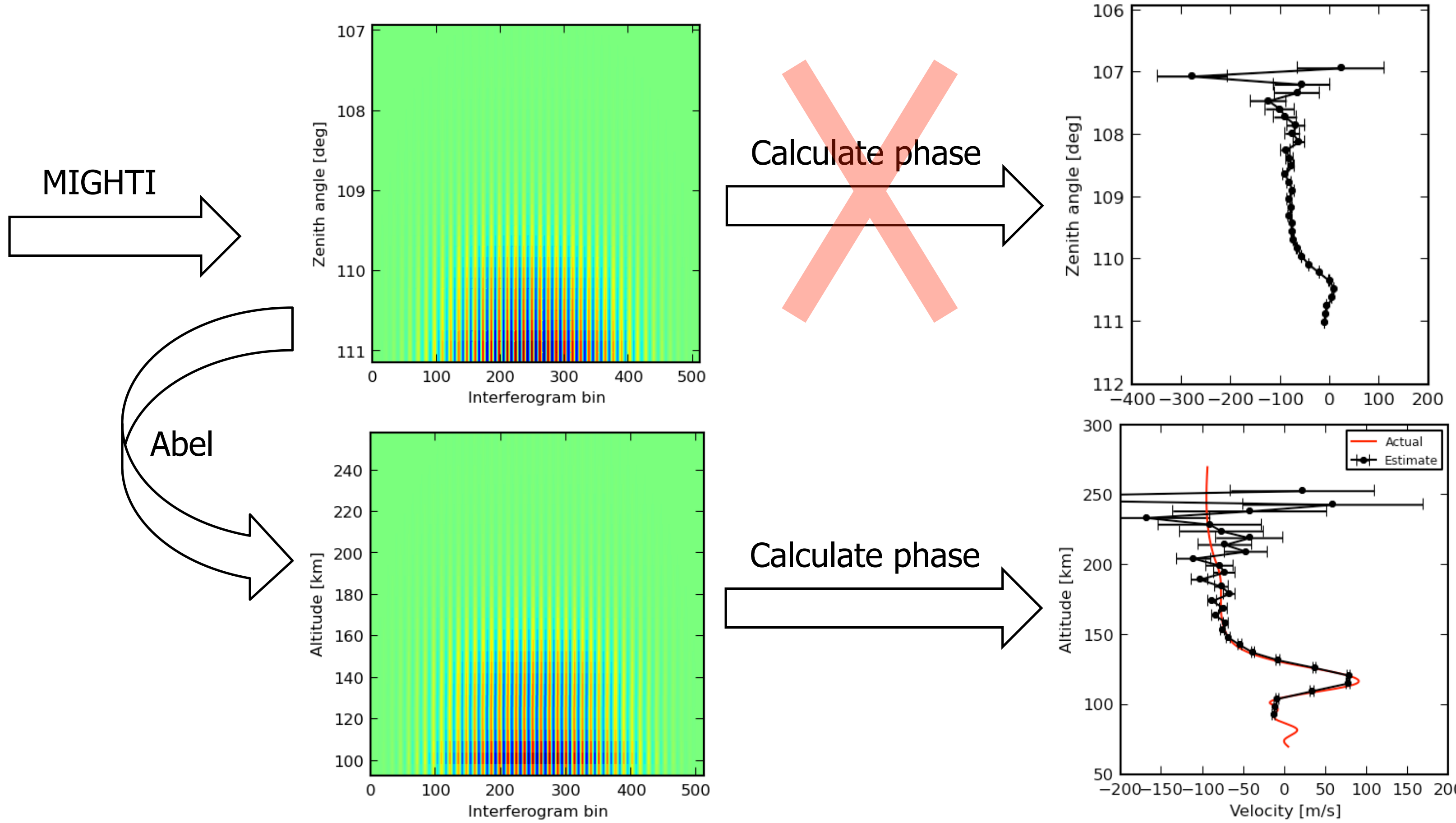


- Aside: This is one example of discretizing a "Fredholm integral of the first kind" into a matrix equation (common in remote sensing)

$$f(x_j) = \int h(x_j, y) I(y) dy \xrightarrow[j=1,2,...,M]{} \mathbf{f} = H\mathbf{I}$$

Abel inversion on interferograms

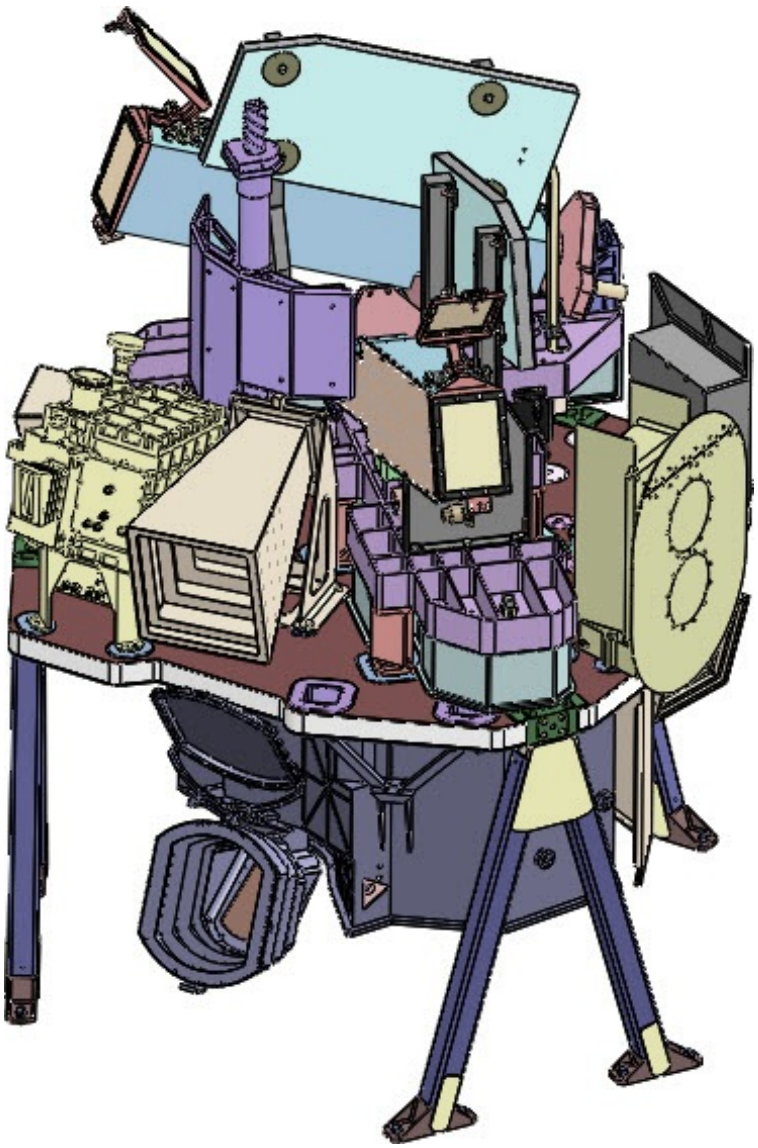
- ❑ MIGHTI Problem: Retrieve wind profile, not intensity
- ❑ One Abel inversion per spectral bin (identical to one Abel inversion per interferogram bin because of Fourier transform relationship).

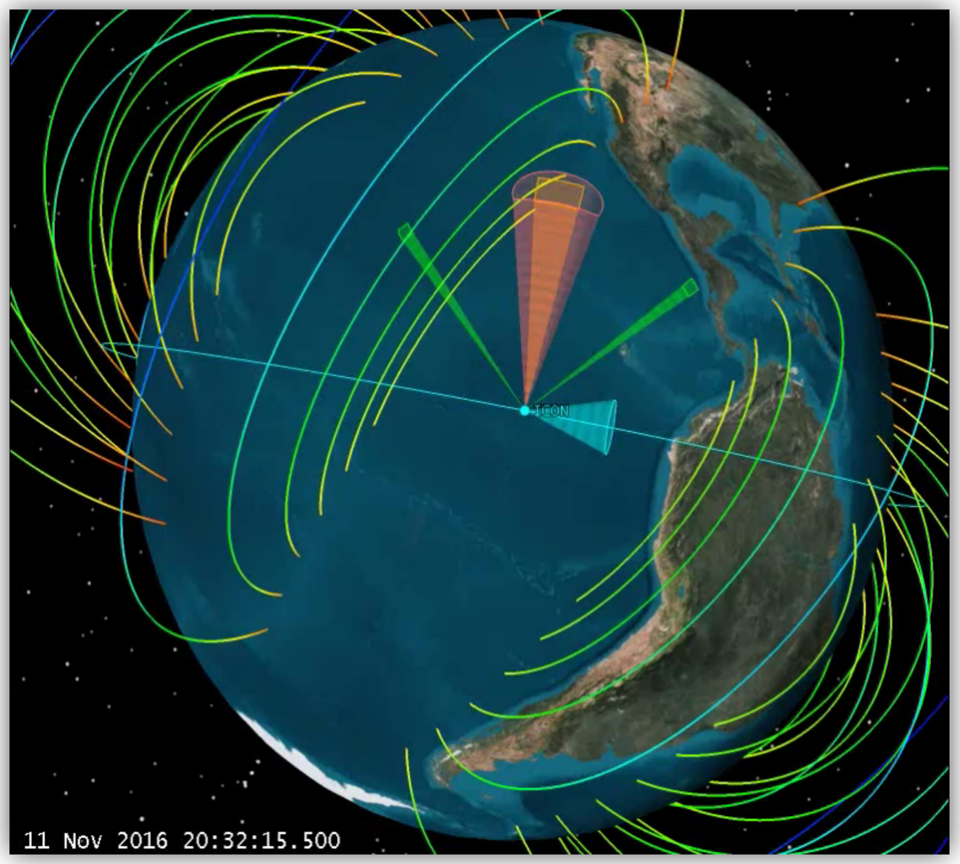


Other topics

- ❑ What if we don't assume spherical symmetry?
  - After all, it's the non-symmetric properties that we are trying to measure.
- ❑ Combining line-of-sight wind profiles from MIGHTI fore and aft to estimate vector wind profile.

ICON Payload

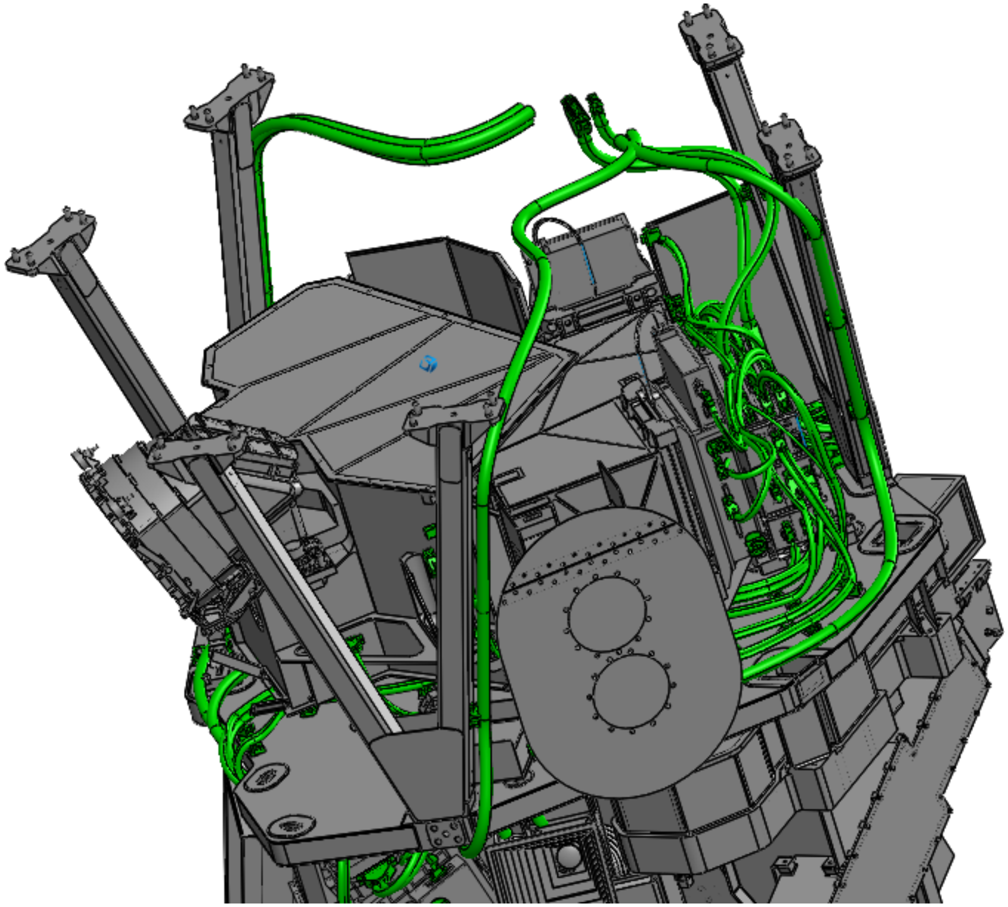


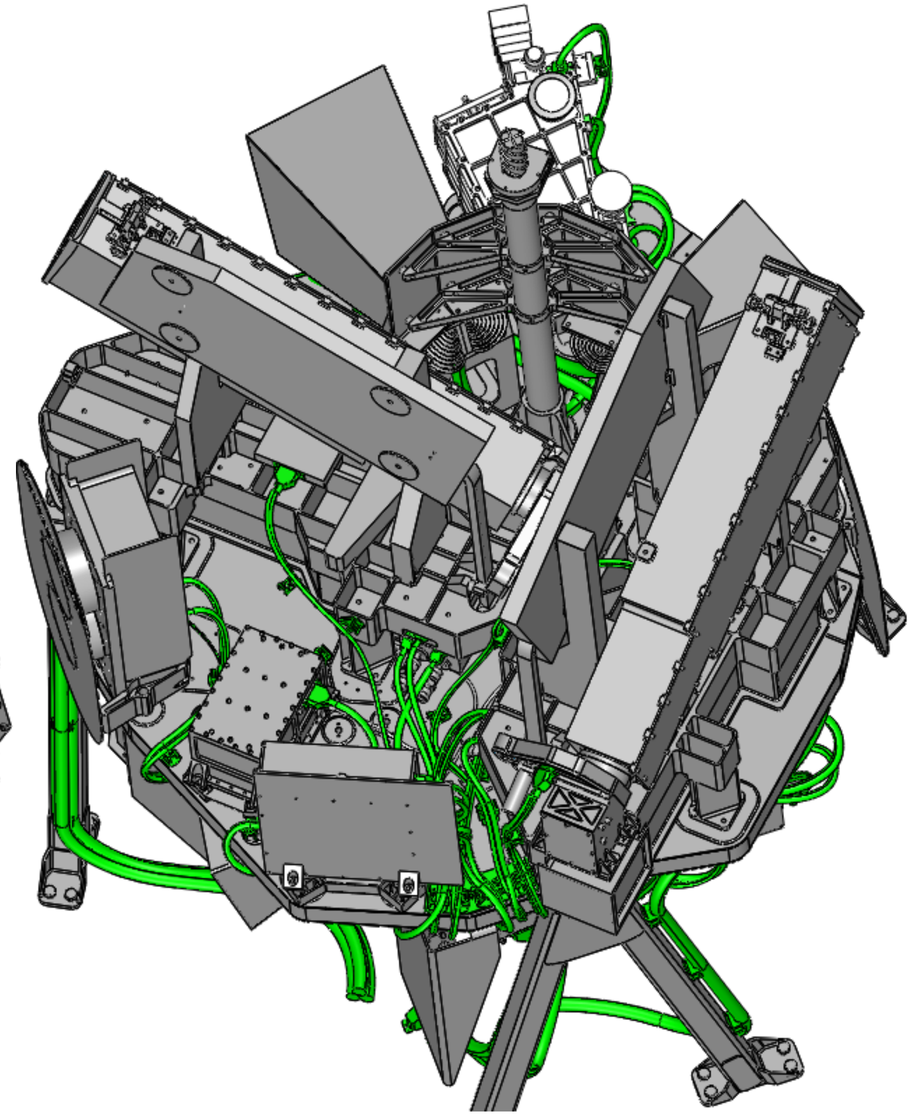


Observation Mode #1 : Survey

- Ion Velocity Meter pointed to "ram", imaging instrument views to port.
- Operates in this configuration >90% of mission.

Harness Accommodation





ICON will be a breakthrough science mission for NASA