Europa/JUICE data simulator

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Europa/JUICE data simulator

- Feed the model with an acquisition time
- Make an observation using spice kernels
- Predict the expected counts/sec

- Start with surface reflectance + background IPM model to capture signal during an observation (scan observation, stare, every kind of observation we'd be doing)

- Add extra information with additional modules:
  - Radiation
  - Star observations
  - Stellar background
  - Moon auroras
  - Neutral Cloud and Torus emission
  - Jupiter shine
  - Moons shine

- UVS Frame kernel issue:
  - FK not the way we want it. Kurt might be tackling this later with the project
  - The UVS coordinates system orientation is not the same we have been using for previous mission

Europa/JUICE data simulator

- Prioritize the modules:
  1. Surface reflectance
  2. Background IPM
  3. Emission of the moon
  4. Star Observations
  5. Stellar diffuse background
  6. Moon auroras
  7. Neutral Cloud and Torus emission
  8. Jupiter and moon shines

- Start simple (uniform albedo, basic phase function, uniform IPM map, etc..)

Proposed action plan (first milestone: July 13th)

Main routine — VH
- Select mission (Europa, JUICE)
- Read kernels from official activity plan, build and load metakernel
- Define acquisition time (t0, t1)
- Define exposure time (# of histograms within t0-t1)
- Load effective area

Surface UV-reflectance — SJ, TB
- Load albedo map (albedo vs lon/lat)
- Use basic reflectance function to start

Radiation — JK
- Simple radiation model to start
- Improve later with Gire / Juno-based radiation model

Background IPM
- Use uniform background IPM to start
- Improve later with Pryor model

Star observations — VH, MV
- Use refined IUE/Kurucz spectral database

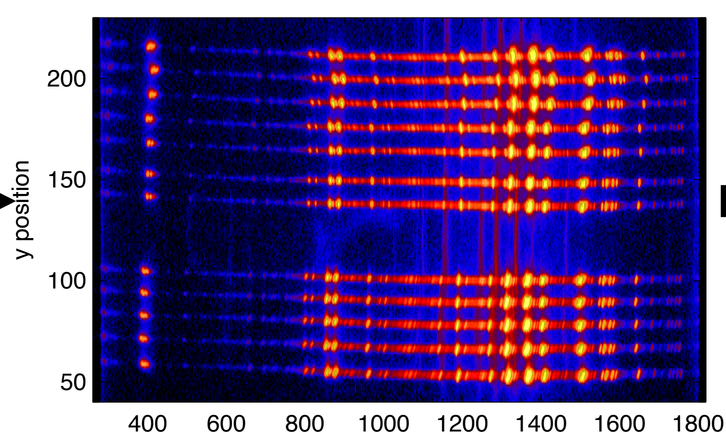
Stellar background — VH, TG
- Use LAMP illumination model
- Use Juno-UVS all-sky map

Moon auroras + plumes — LR
- Use models from Roth et al. for Io and Europa
- Use Juno-UVS observation of Ganymede auroras
- Build simple model with Volume emission and SIII-longitude variation

Neutral Cloud and Torus emission — E. Nerney, A. Steffl
- Use simple torus toy model to start
- Improve with refined model (e.g., Steffl et al., 2004)

Jupiter auroras — VH
- Use statistical auroral model based on Juno
- Satellite footprint model

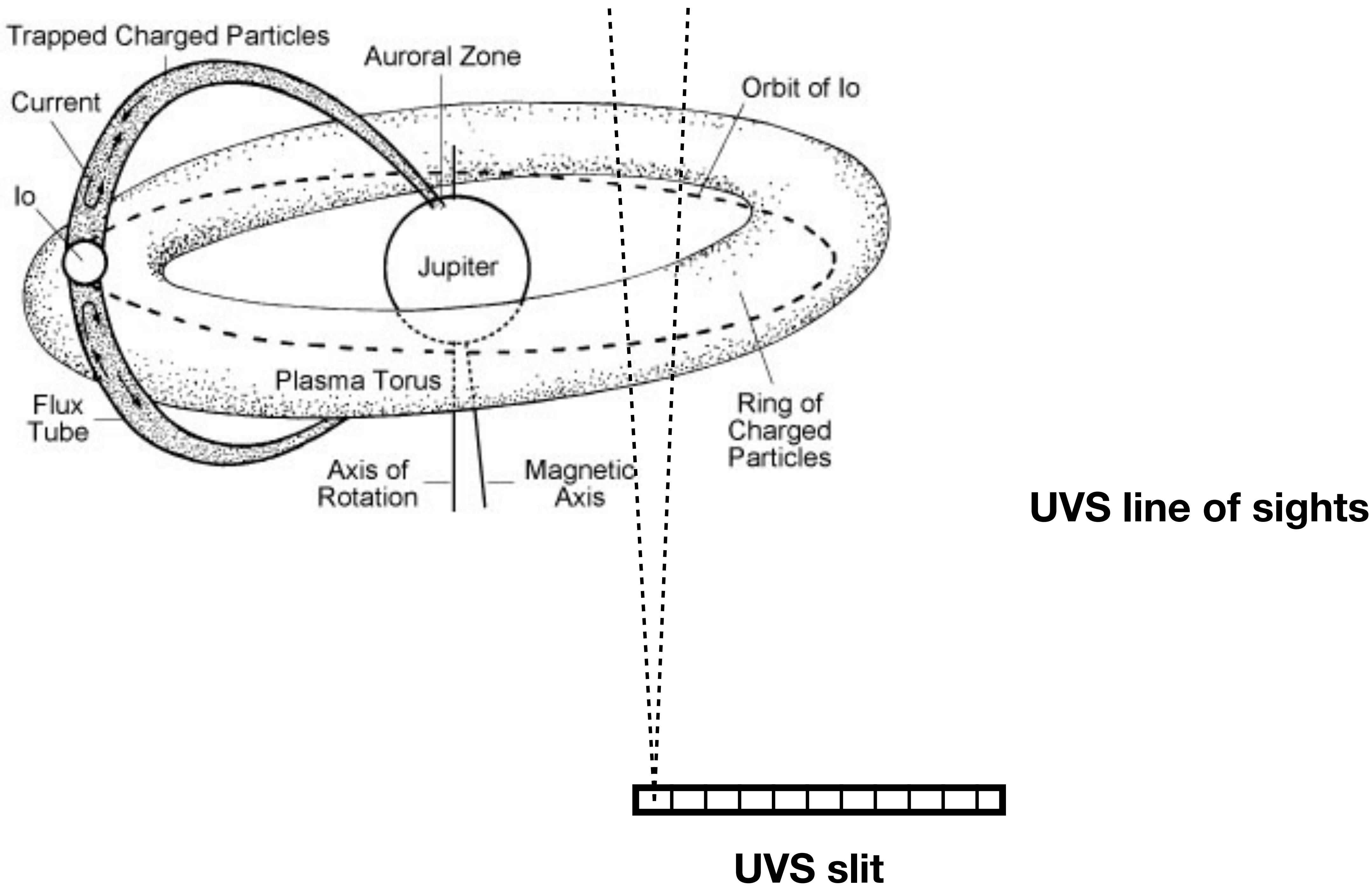
Jupiter and moon shine — KR



- Convolve to the desired spectral and spatial resolution
- Calculate the counts/s
- Estimate data volume

Torus emission implementation

- What coordinate system?
- What output the torus model will generate?



Geometry element calculations

`compute_geometry_element`, time_array_et, time_array_utc, spacecraft

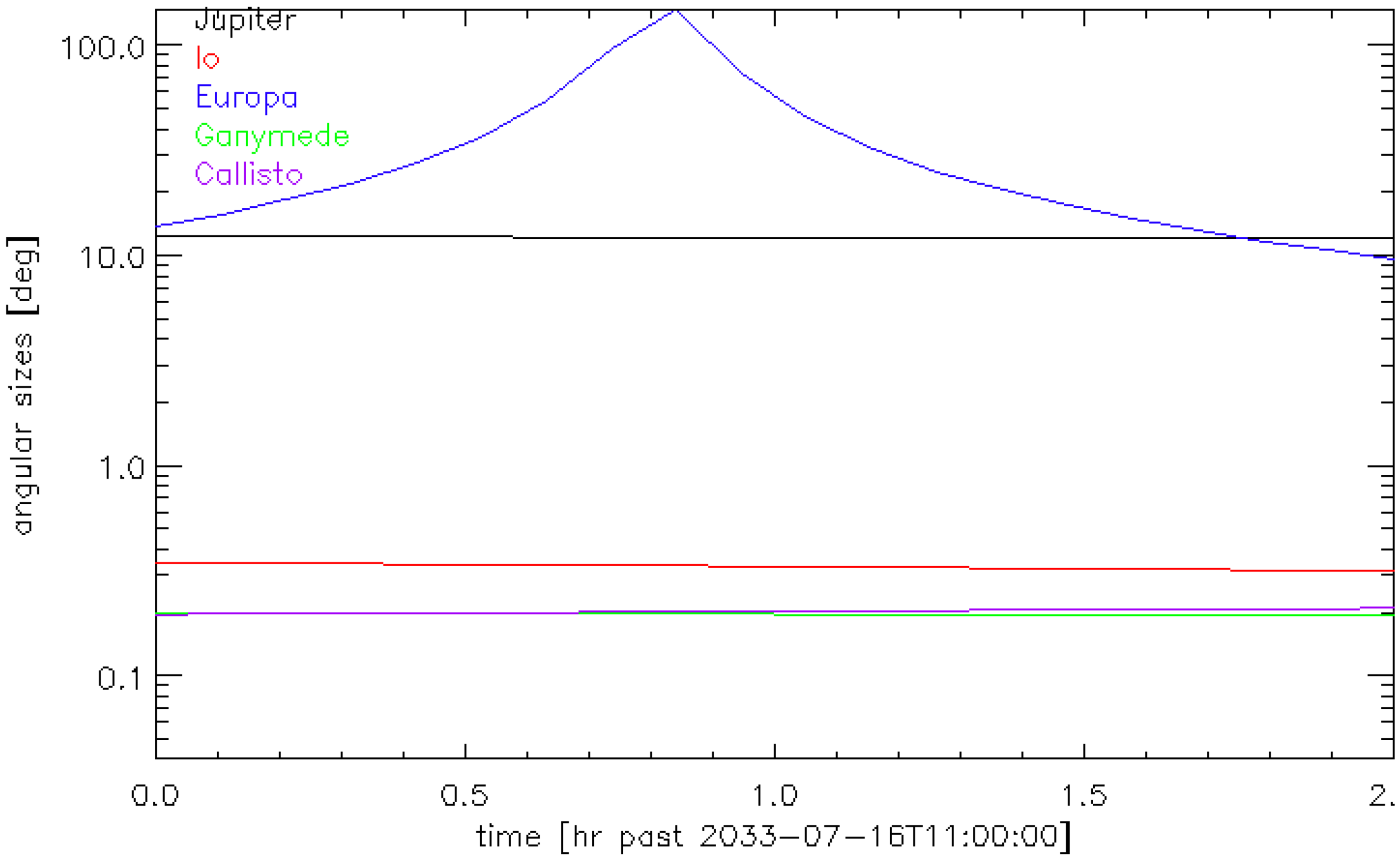
Done

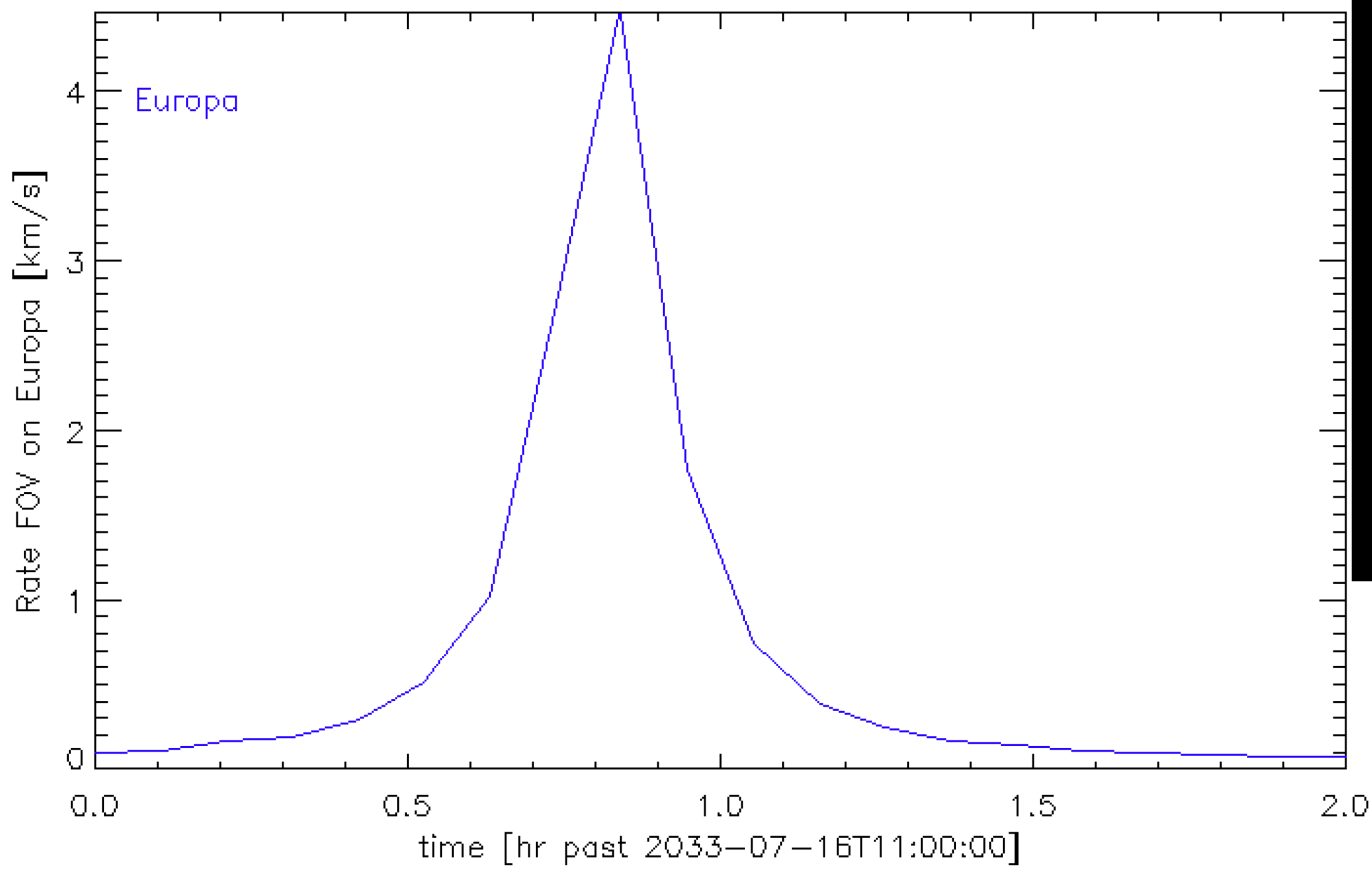
- SC range to jupiter
- Sub-SC jovian lat/lon
- Sub-solar jovian lat/lon
- Sub-earth jovian lat/lon
- Angular sizes of Jupiter, Io, Eur, Gan, Cal as seen from SC
- Sub-SC moon lat/lon (Io, Eur, Gan, Cal)
- Sub-moon jovian lat/lon
- Sub-solar moon lat/lon
- Local time moons
- Eclipse flag for moons and SC
- SC Altitude & range on the moons
- Rate of field of view moon
- Rate of field of view Jupiter
- Rate of field of view background sky
- RA/DEC looking direction
- Centrifugal latitude of moons and SC
- Moon/Jupiter - AP boresight angle
- Moon/Jupiter - SP boresight angle
- Emission angle, Incident angle
- SZA
- Phase angle
- SC magnetic field lat/lon
- Moon magnetic field lat/lon

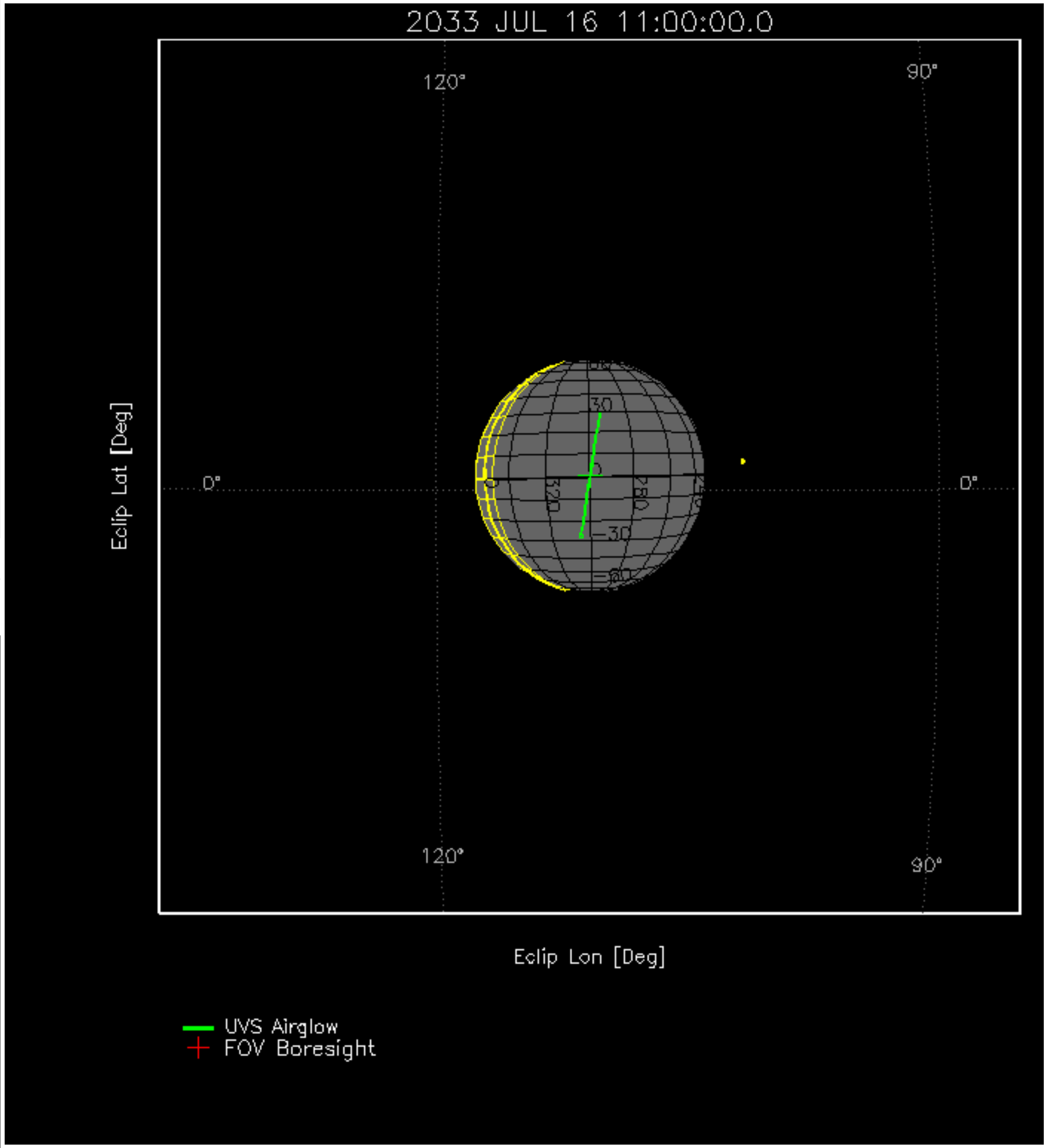
TODO

- Surface motion of moons across the field of view?
  - (How long does it take for a lat/lon point to go across the slit)
  - At a given time, how wide is the slit projected on the planet (slit width in km over time/ rate of FOV)
- Mshell of moons and SC
- If within +/- 4° on either side of the boresight and angular size > -> calculate pointing direction
- From Tommy (June 3rd email)
  - Angular size of Europa and Jupiter at start and end point of Europa transit
  - Phase angle and illumination fraction of Jupiter as seen from Juno
  - Total time for Europa to cross Jupiter from limb to limb
  - Angular rate of Europa relative to Jupiter over time of the event
  - Angular rate of Europa on the sky over time for the event
  - Angular rate of Jupiter on the sky over the time for the event.

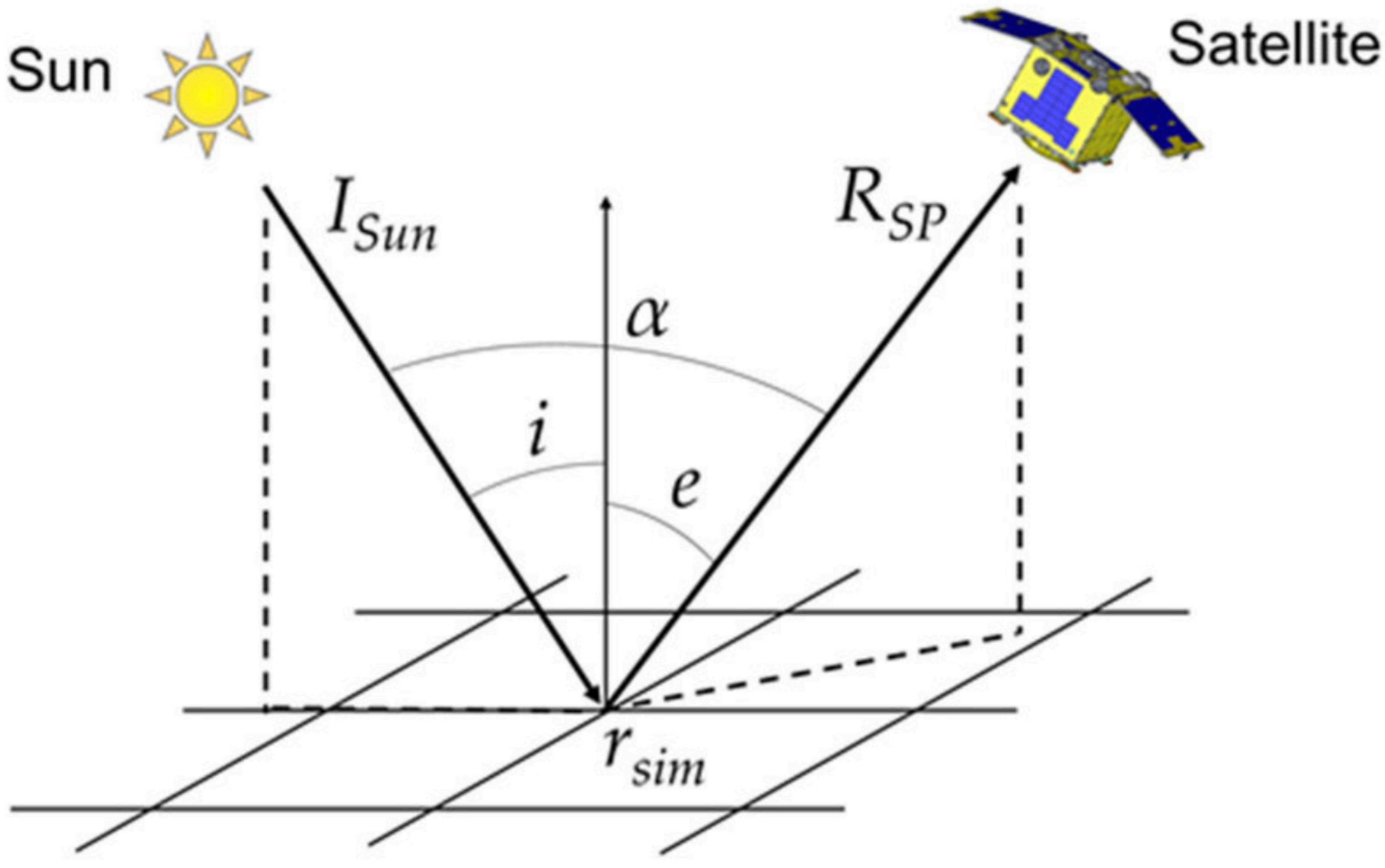
Geometry element calculations







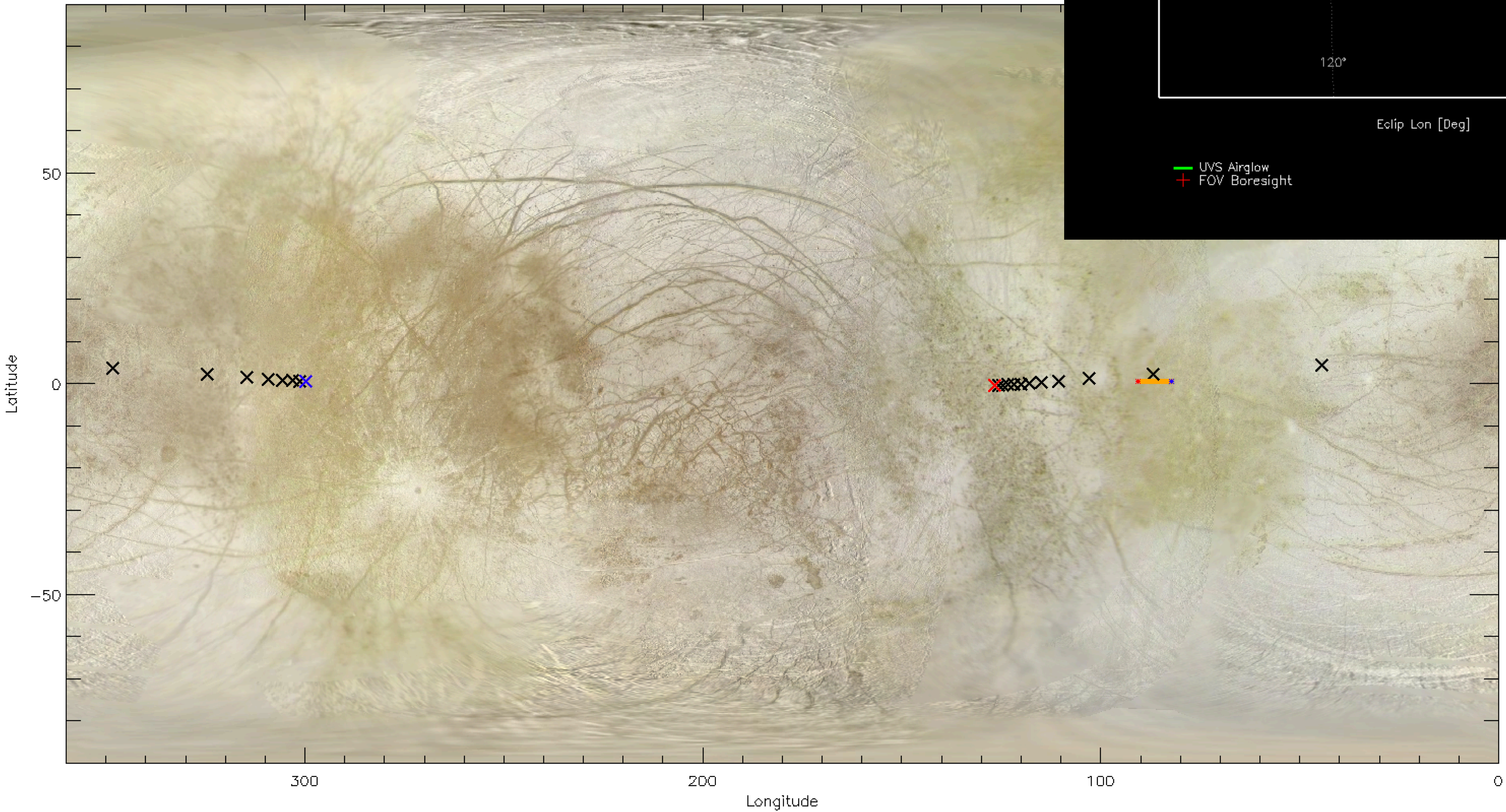
Geometry element calculations

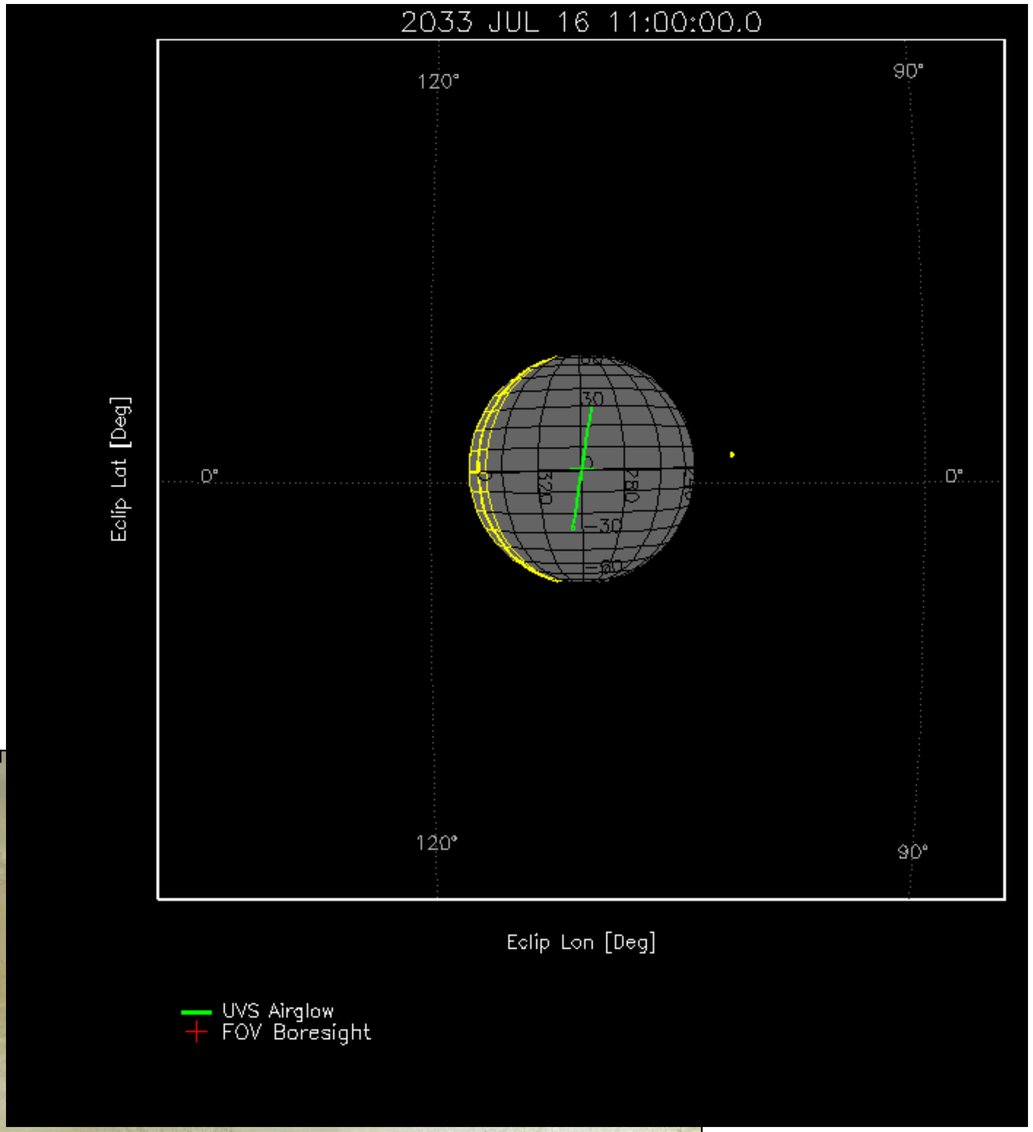


Nomenclature definition

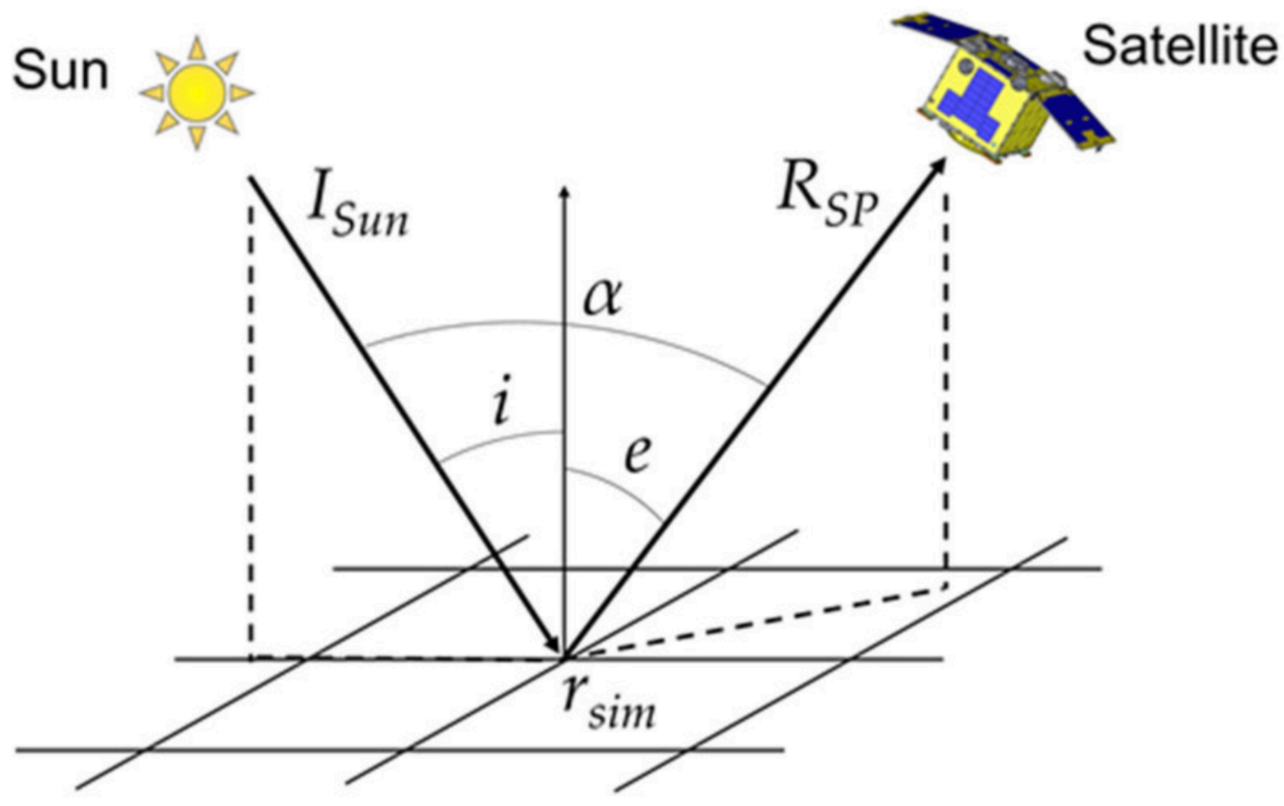
(i): solar incident angle
(e): emission angle
(α): phase angle

Time range
07/16/2033 10:00:00 - 13:00:00





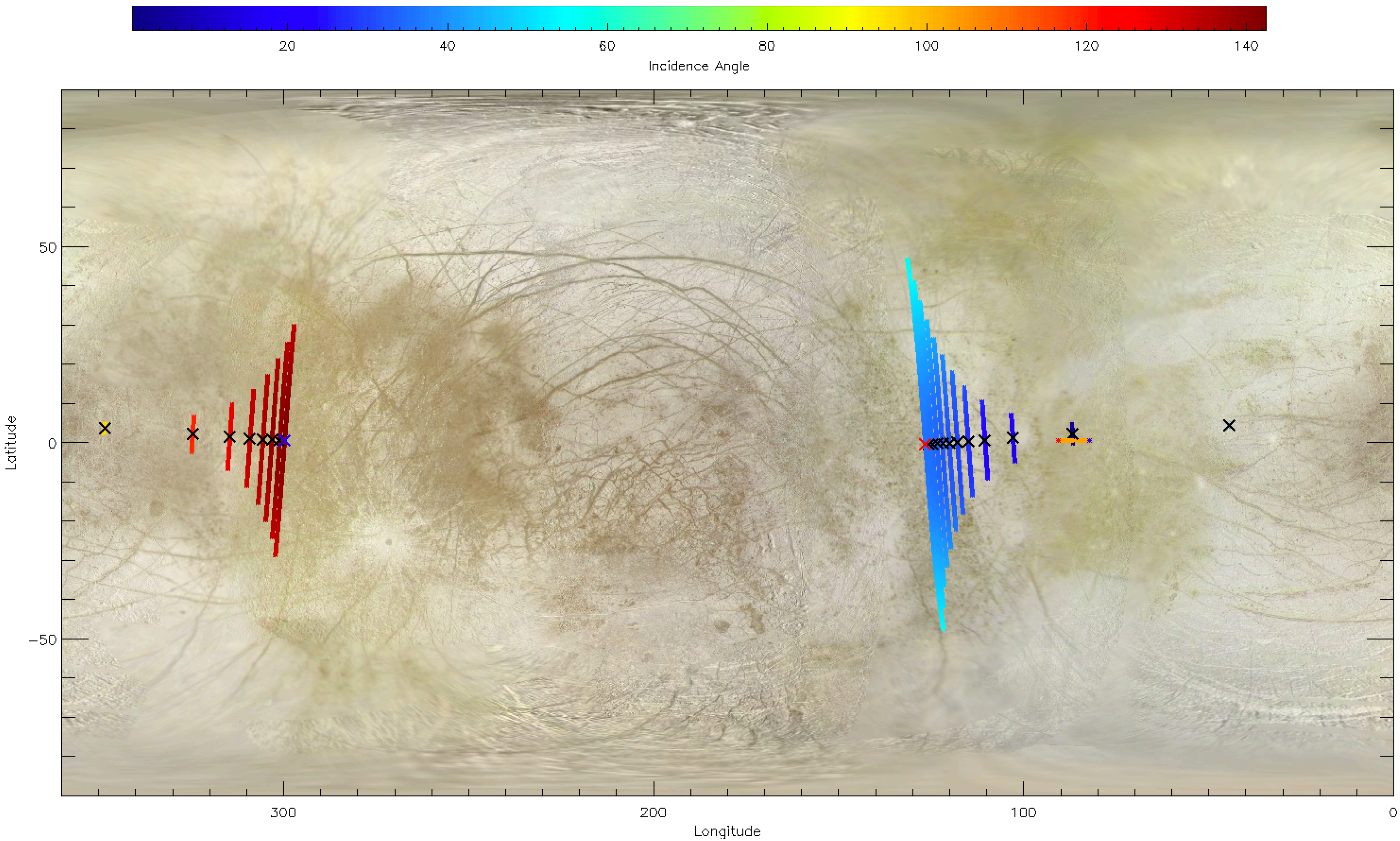
Geometry element calculations



$$F_{UVS} = A\ \frac{I_{SUN}\ \sigma_{PSF}}{R_{SP}^2}$$

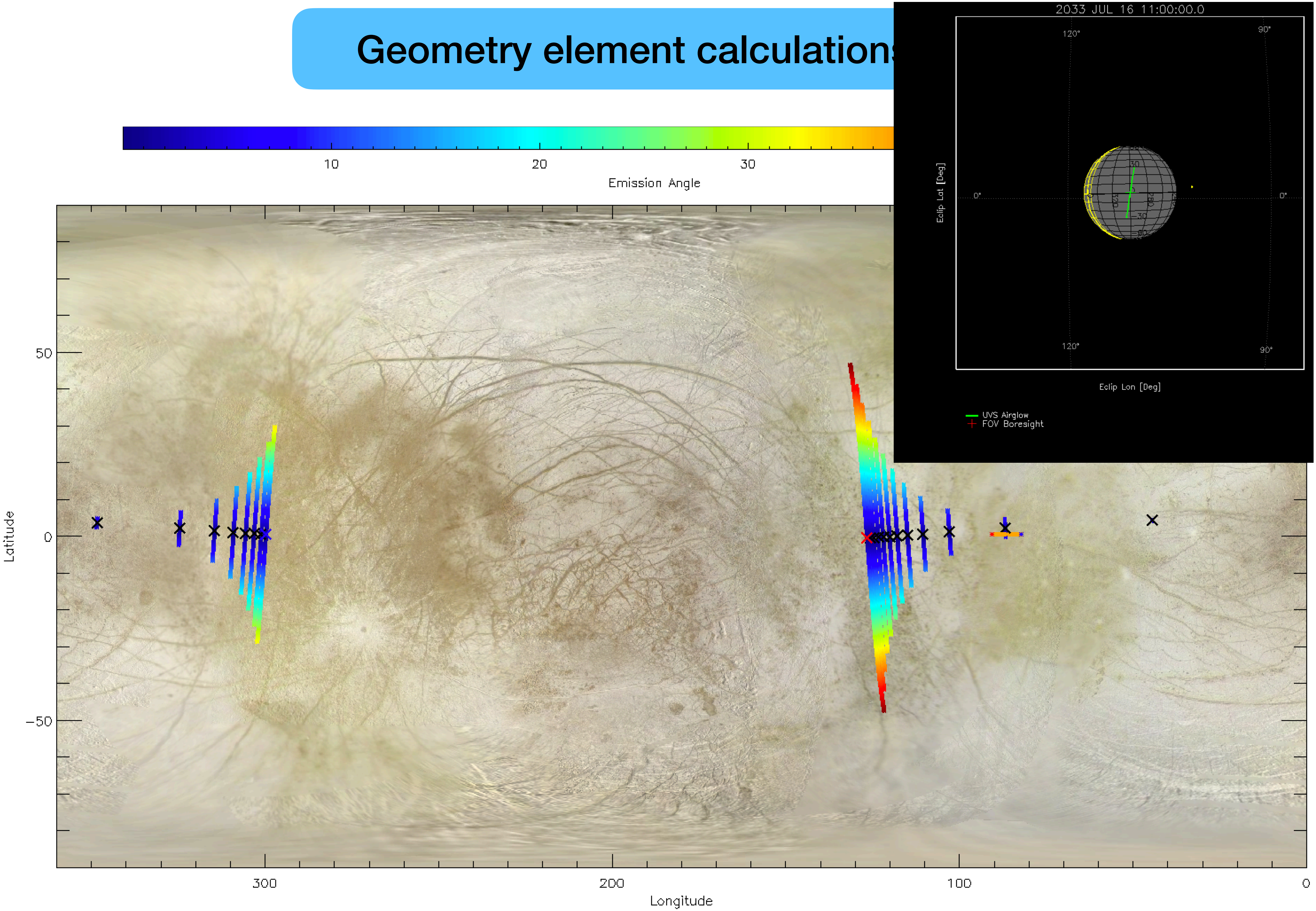
F_{UVS} = Flux received by UVS [photons/s/m^2]
I_{SUN} = Solar irradiance at Europa [photons/s/m^2]
σ_{PSF} = Area on surface subtended by UVS 0.1° PSF [m^2]
$\sigma_{PSF} = \pi * (R_{SP} * \tan(0.1°/2))^2$
R_{SP} = Distance from source to spacecraft [m^2]

Geometry element calculations



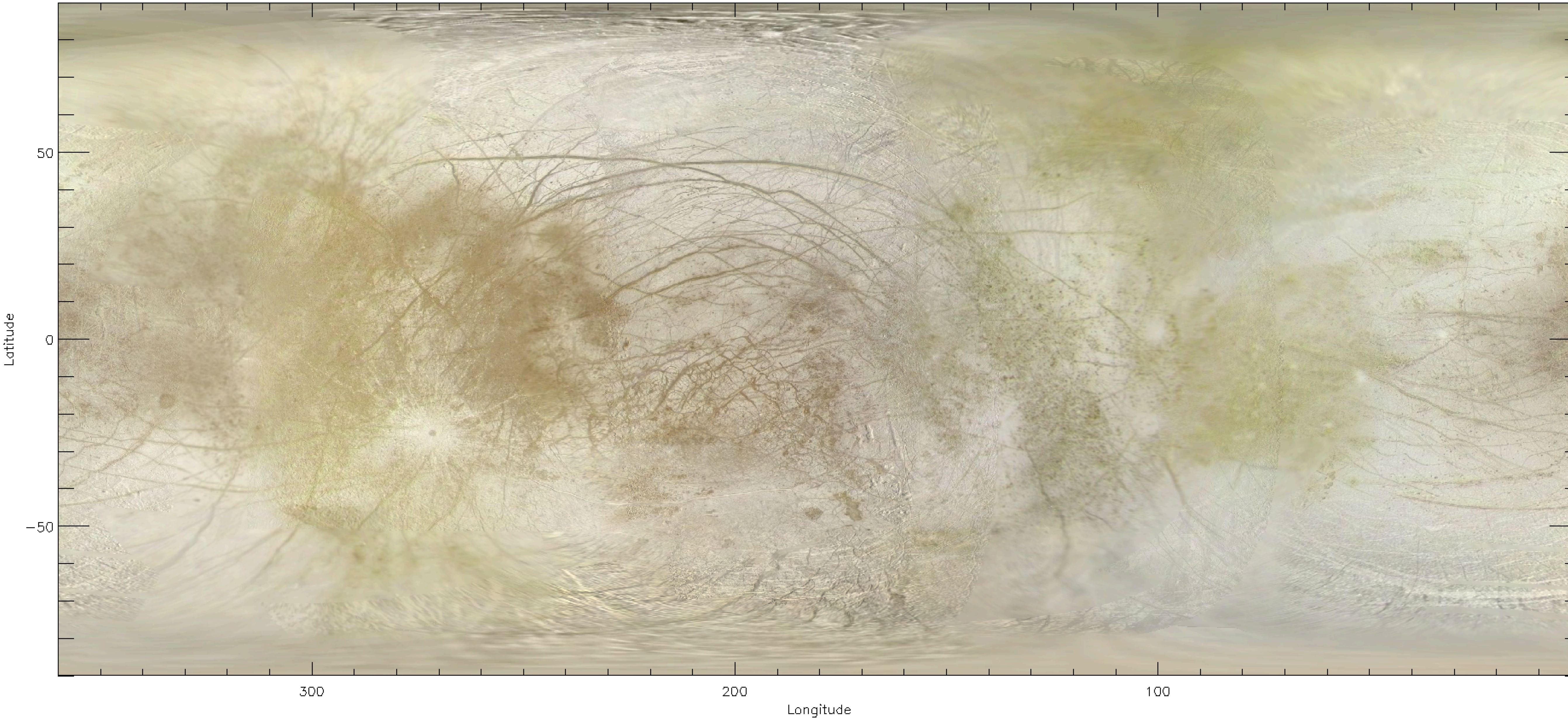
Incidence angle decrease as UVS looks closer to the subsolar point

Geometry element calculations

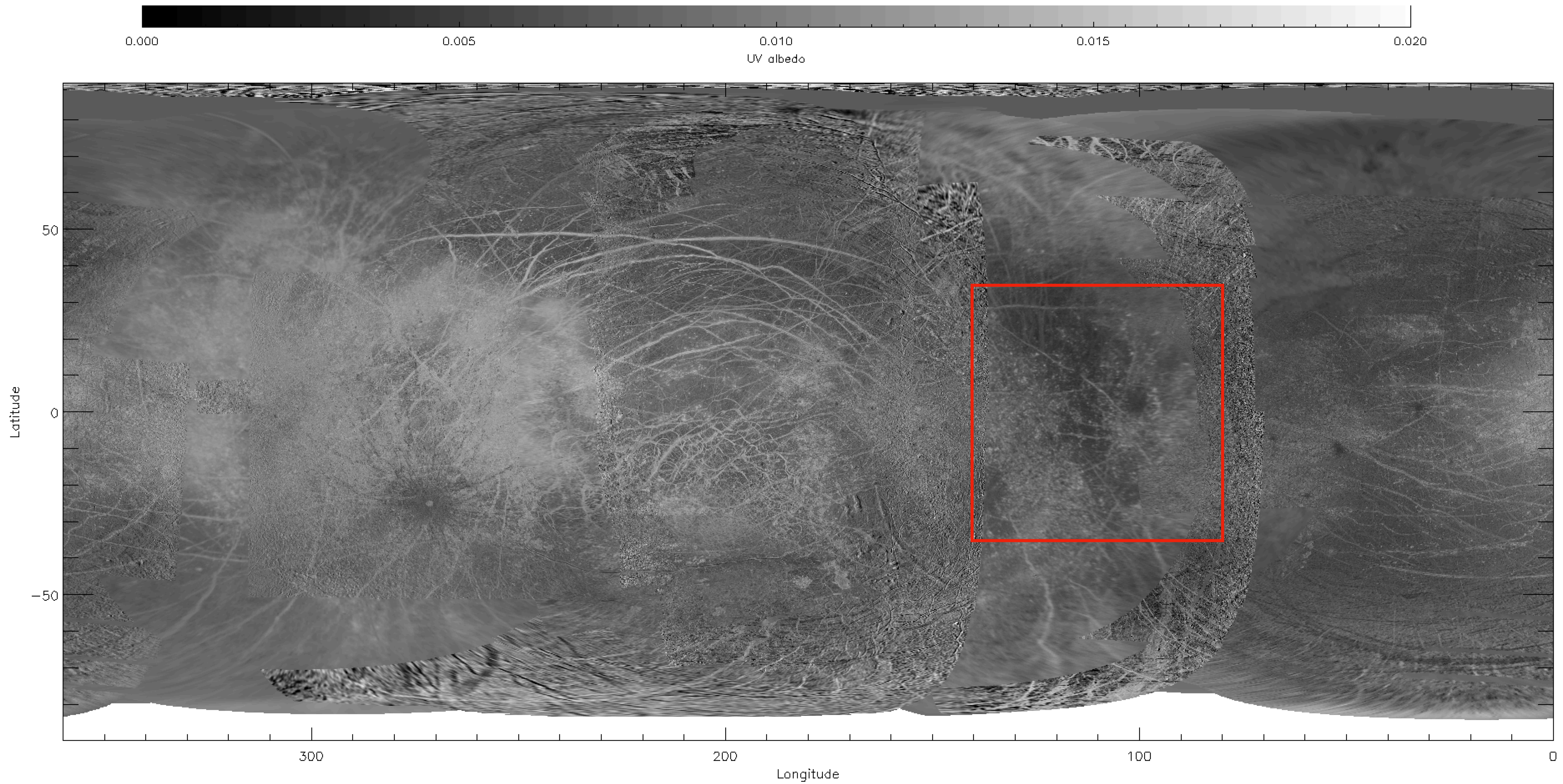


Emission angle increase as UVS looks away from the subSC point

Visible map



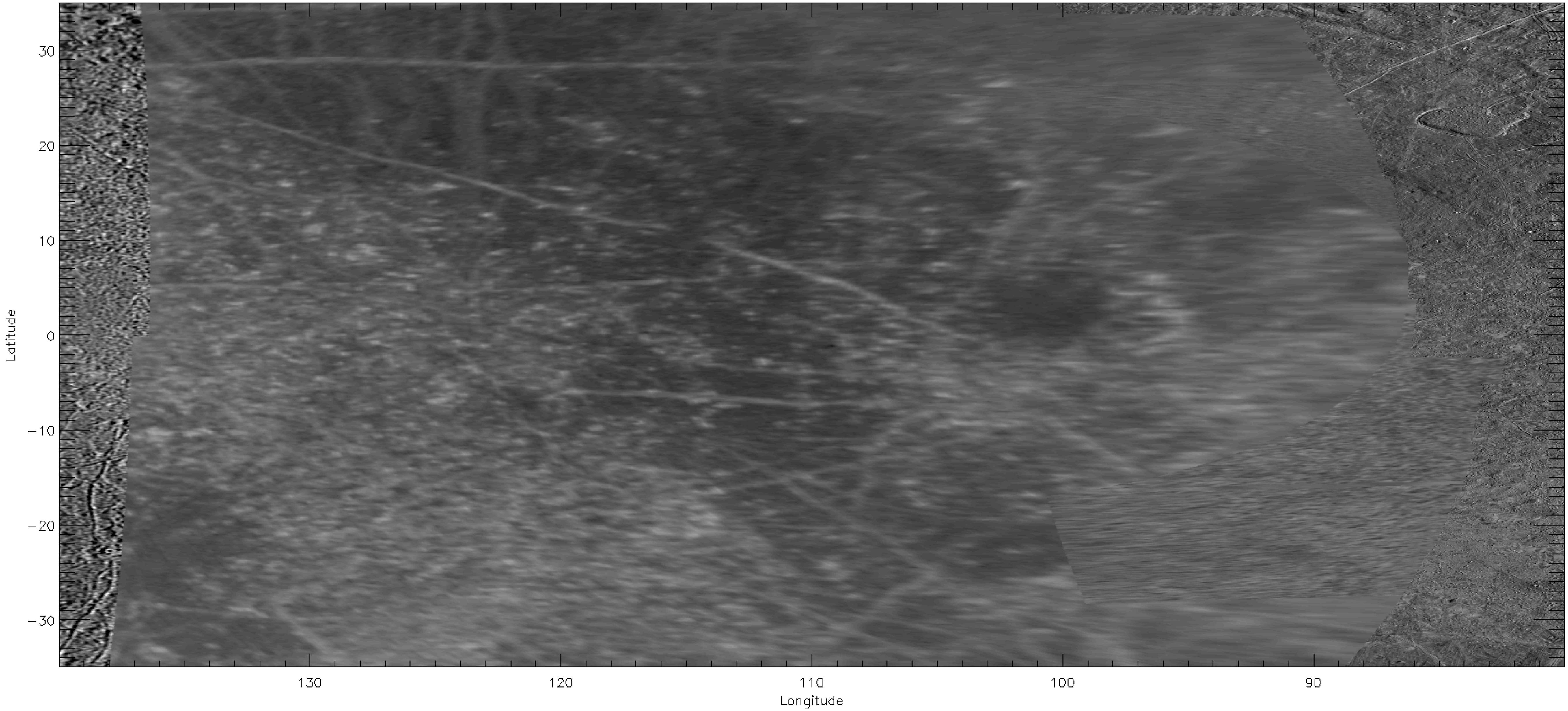
UV albedo map



- Normalize the pixel brightness values between 0 and 1
- Invert and scale from 0 to 0.02

UV albedo map + Lambertian reflectance

$$I/F = B_0$$



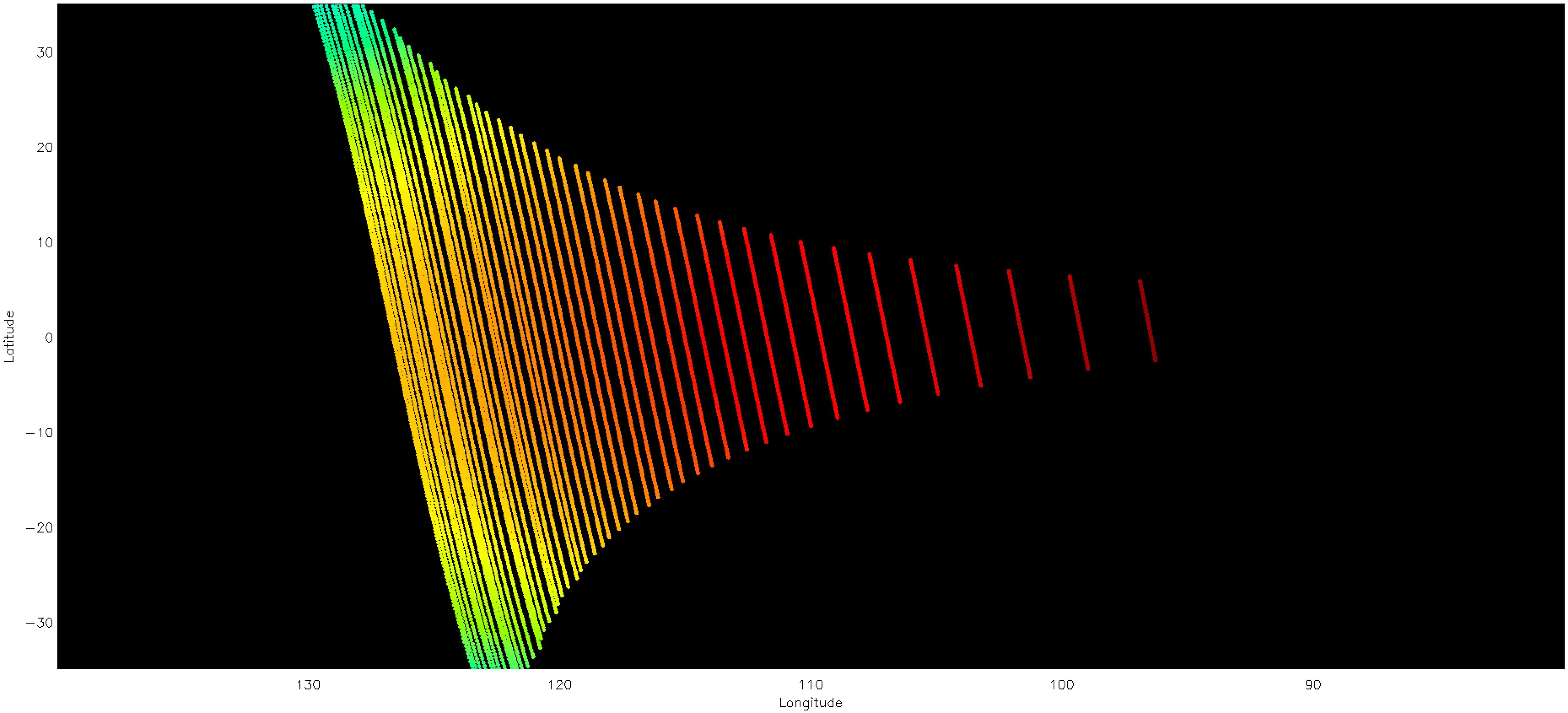
F = Incident flux

I = Reflected flux

B = Albedo

Constant UV albedo map + Minnaert reflectance

$$I/F(\mu_0, \mu) = B_0 \cdot \mu_0^k \mu^{k-1}$$ **+ Constant albedo**



- B0 = albedo (for a lunar photometric function is geometric albedo)
- Mu0 = cos(incidence angle)
- Mu = cos(emission angle)
- k fit photometric parameter dependent on solar phase angle
- Lambert surface has k = 1, low-albedo surface with Lomel-Seeliger scattering law has k ~ 0.5

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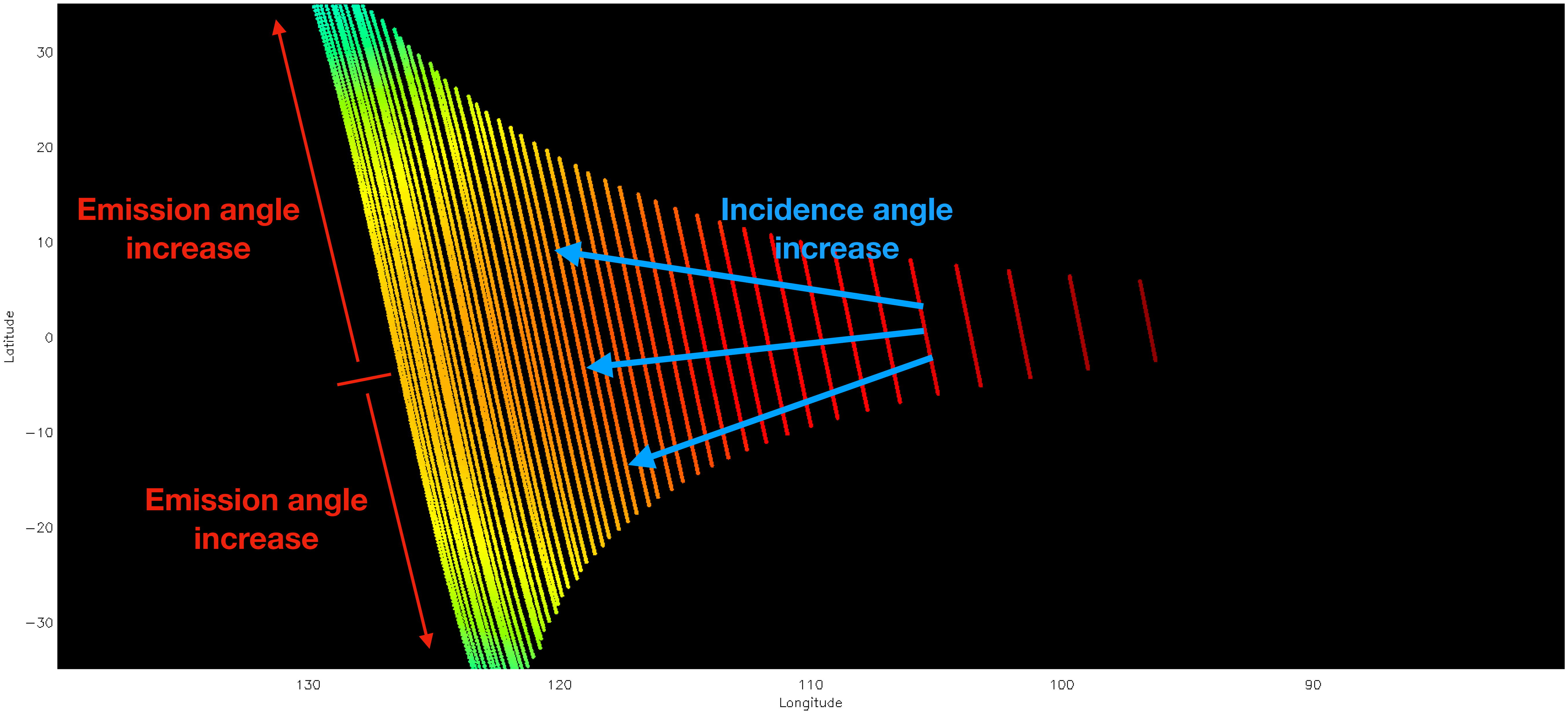

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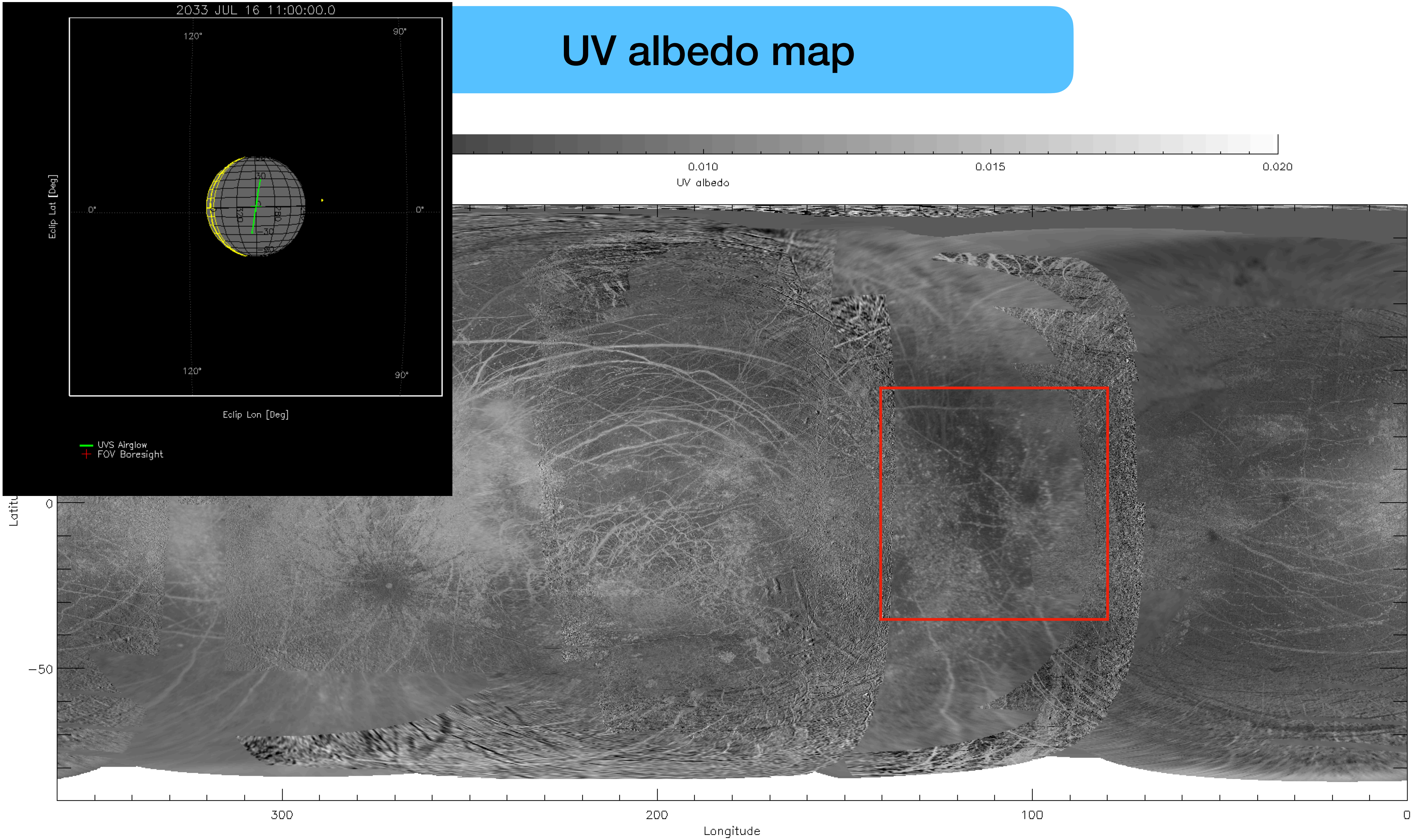
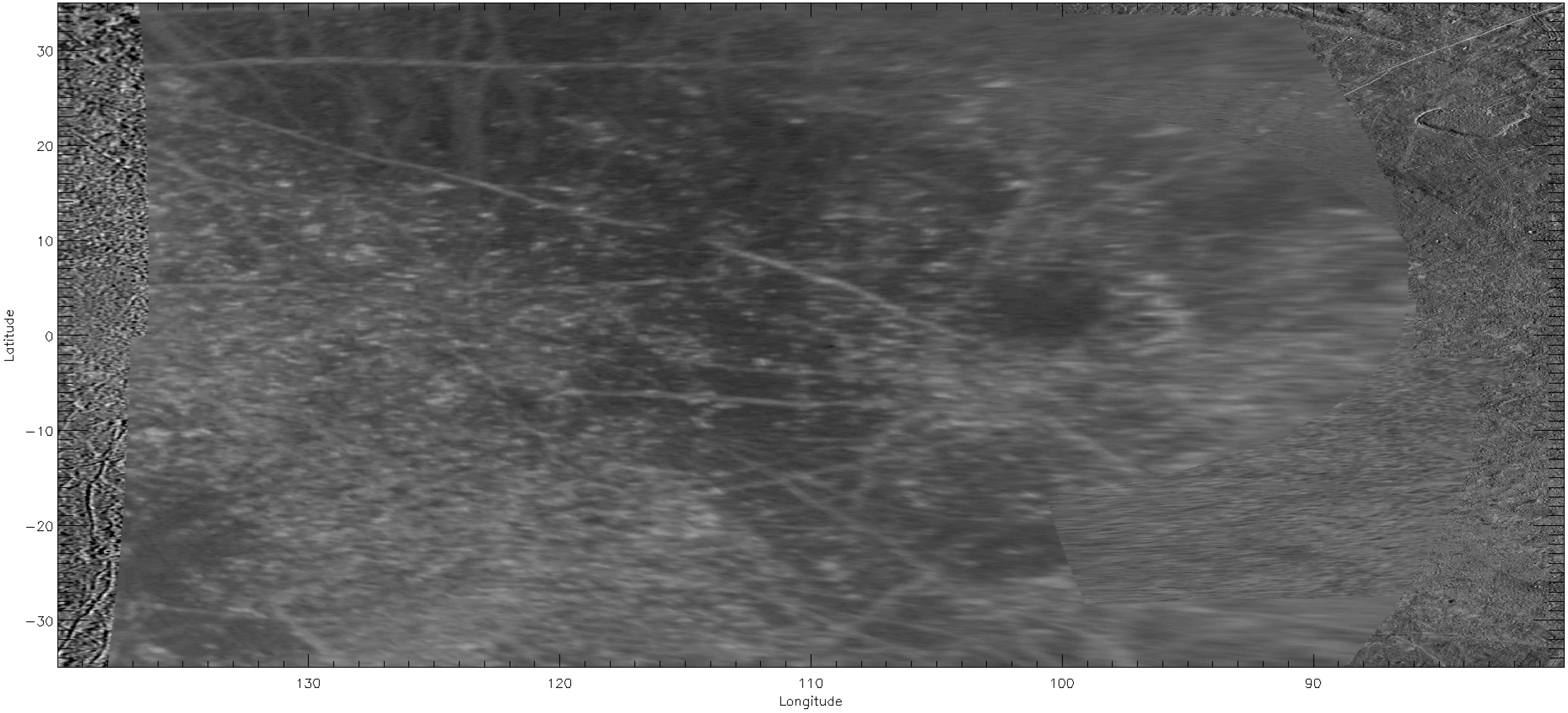
UV albedo map



Minnaert reflectance model



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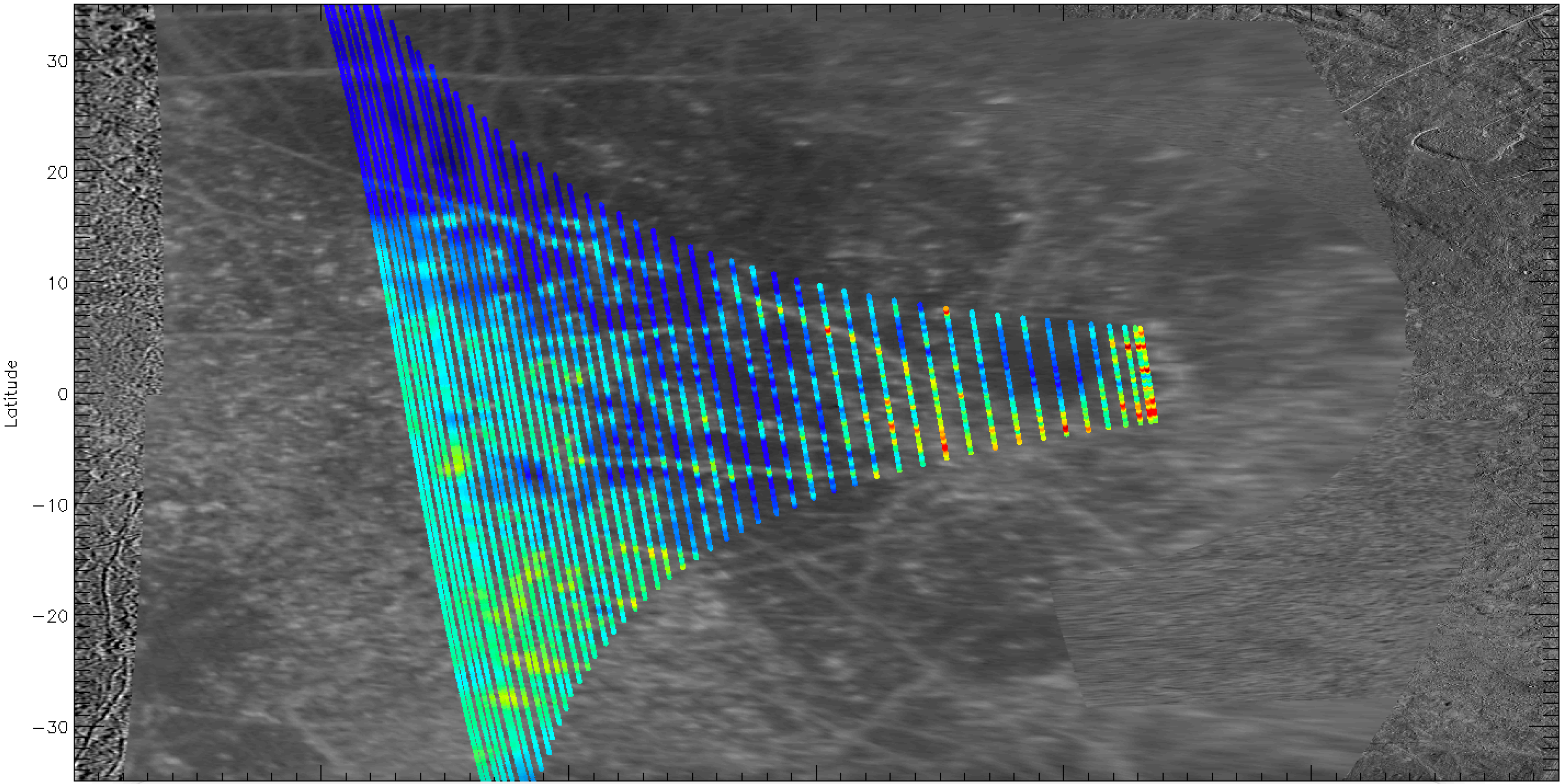
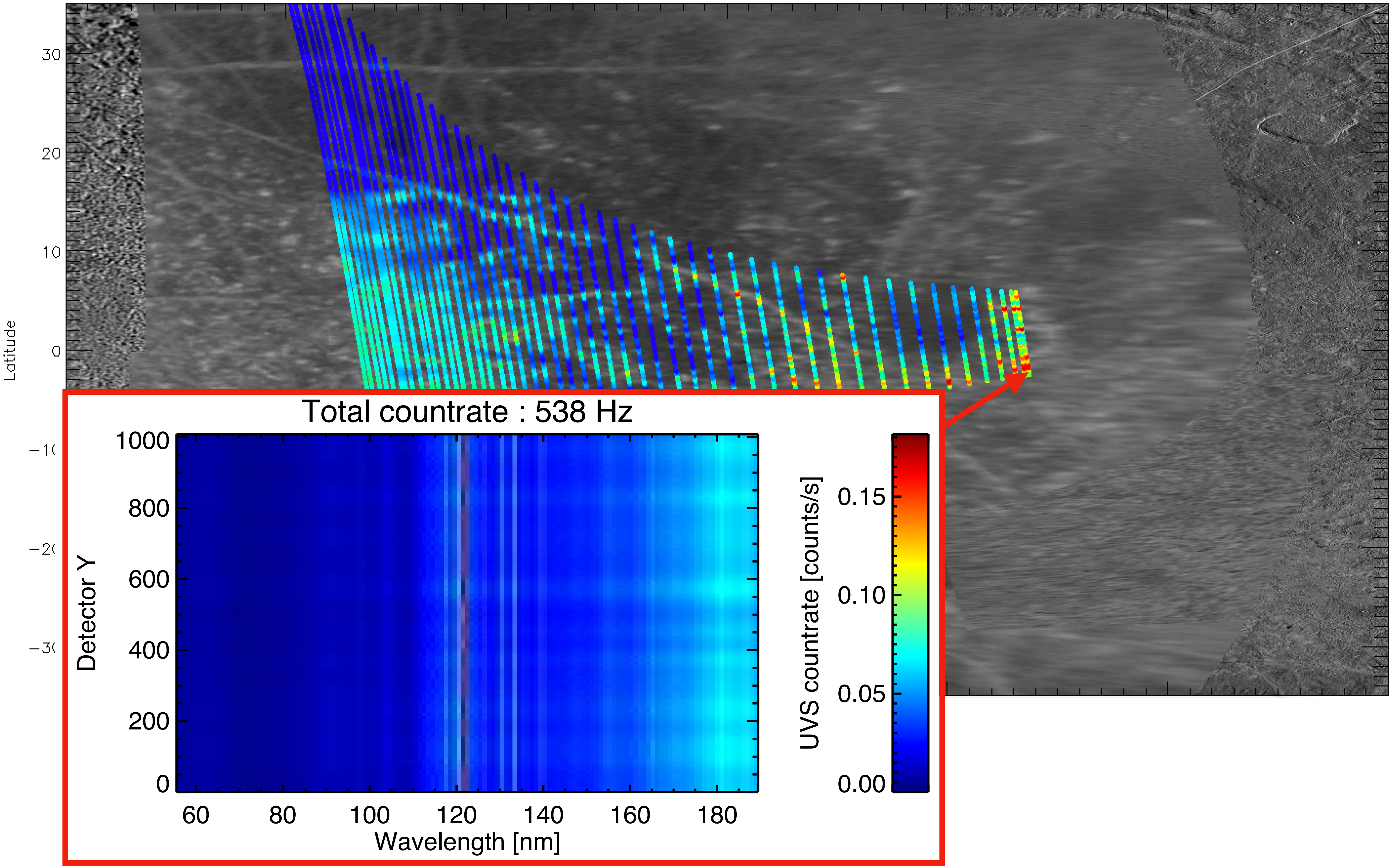
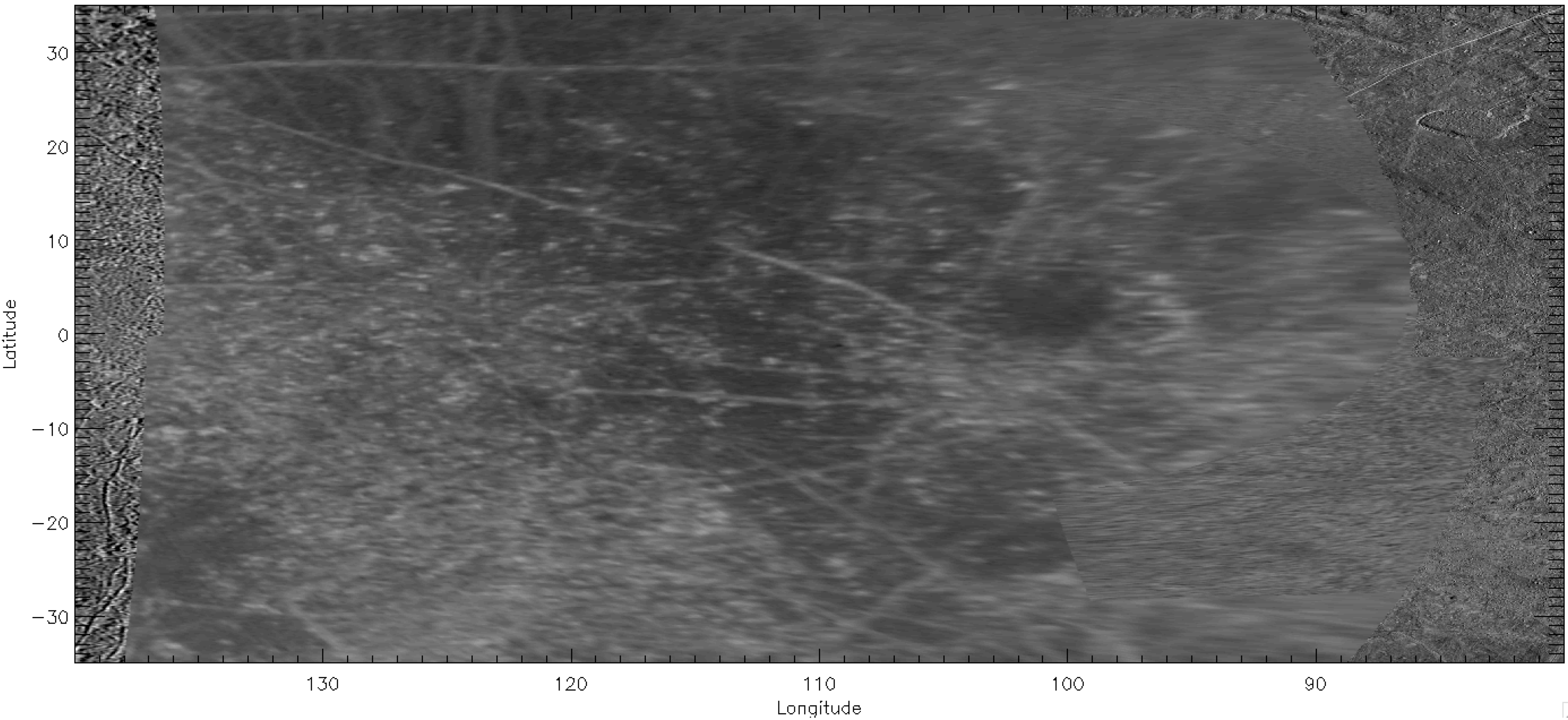
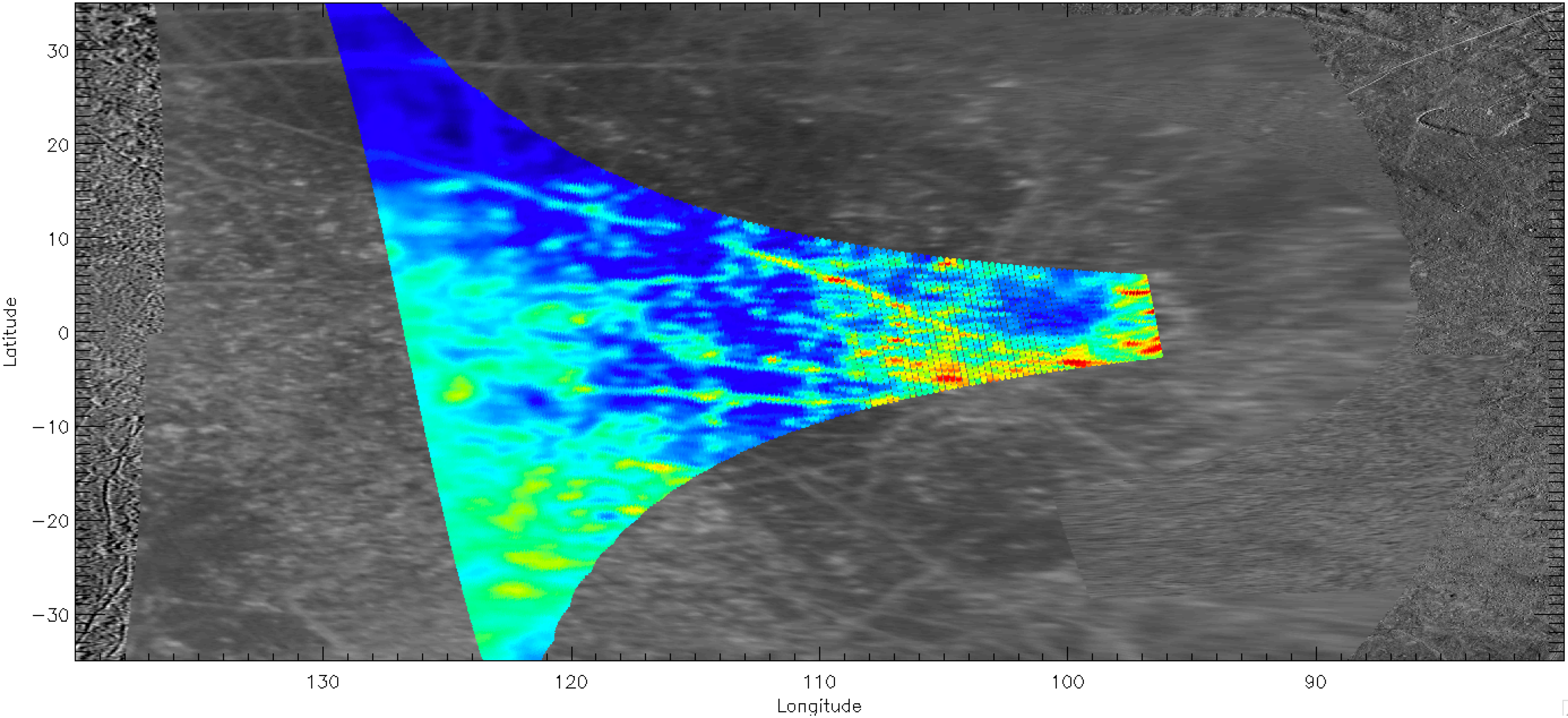


Minnaert reflectance model

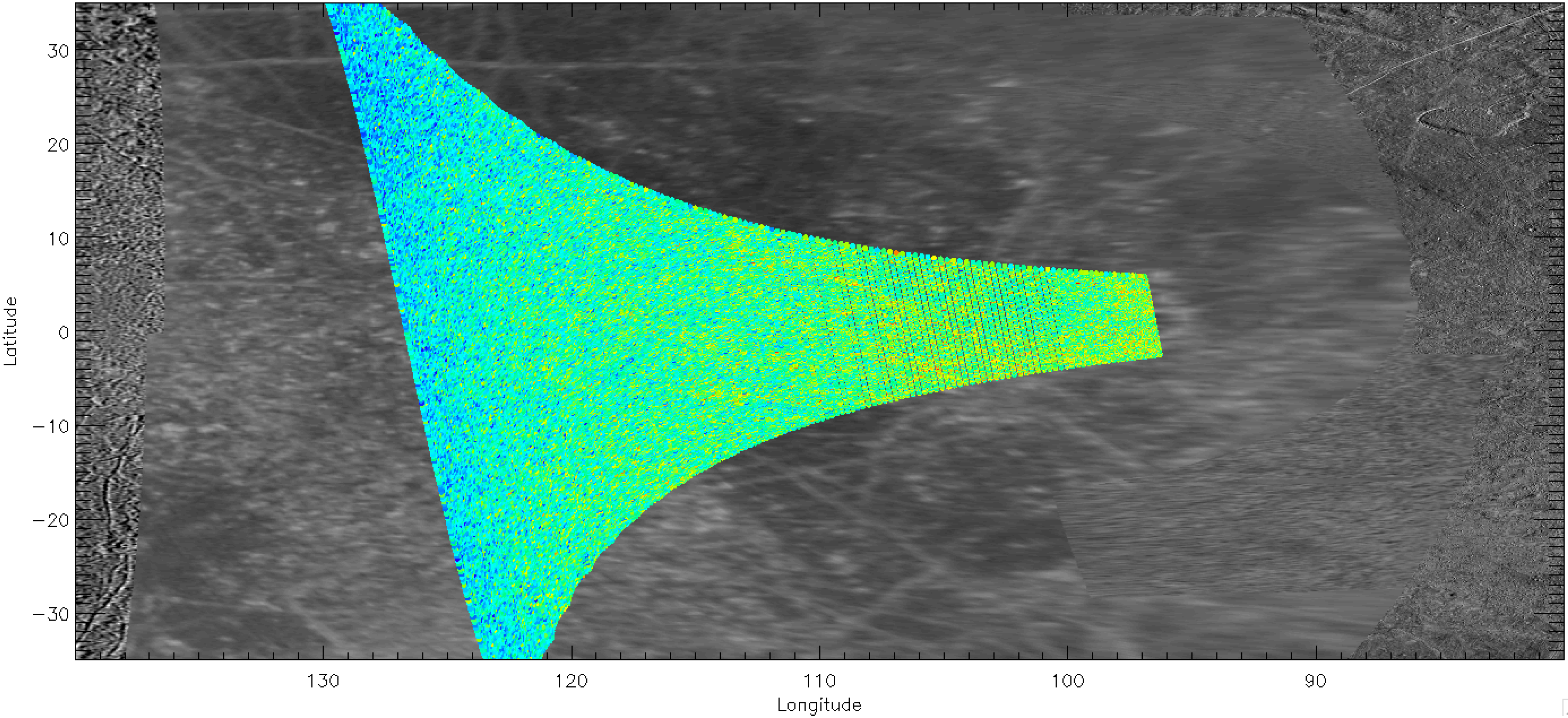


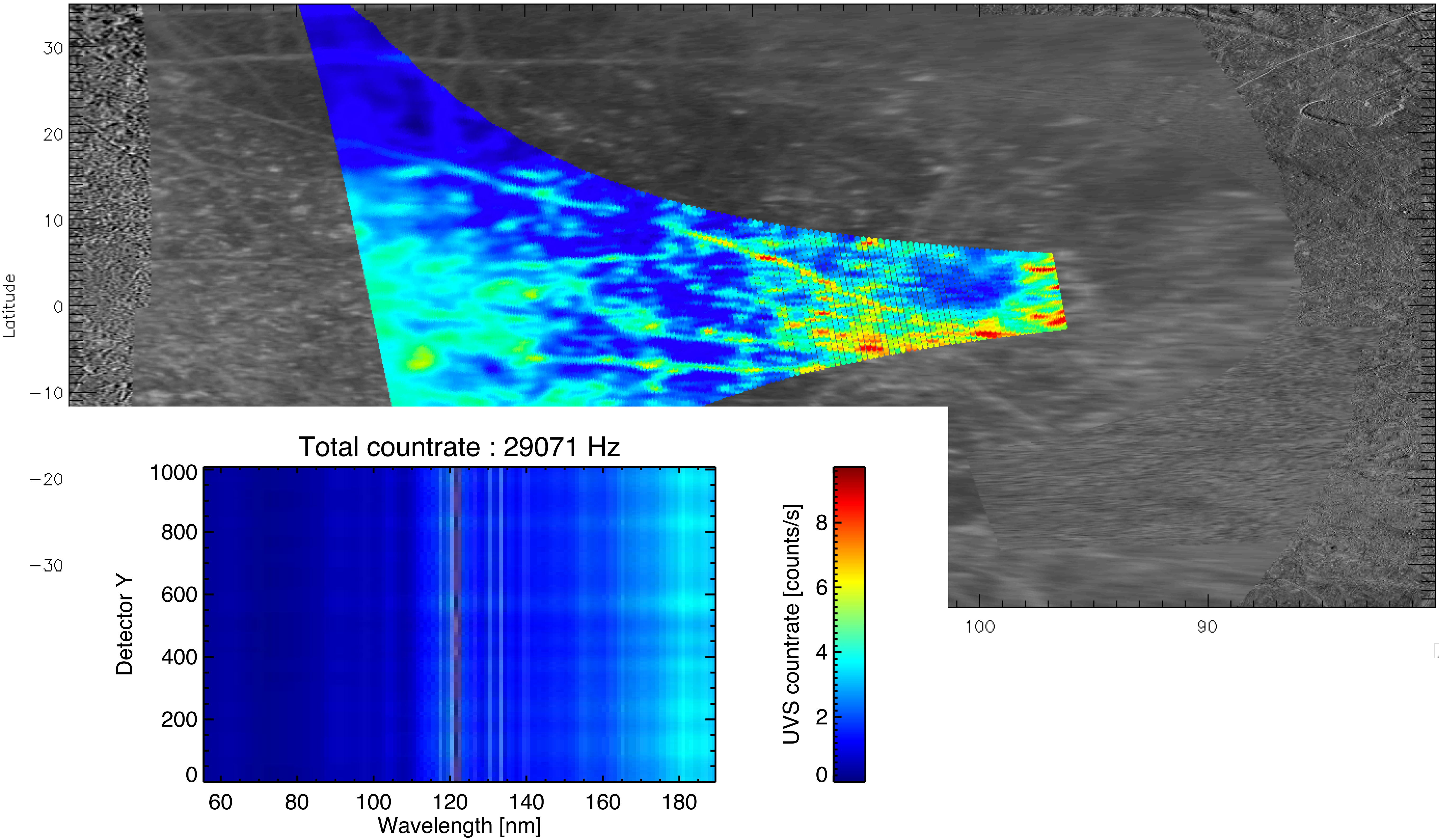

30
20
10
0
−10
−20
−30
Latitude
130
120
110
100
90
Longitude

Reflected sunlight

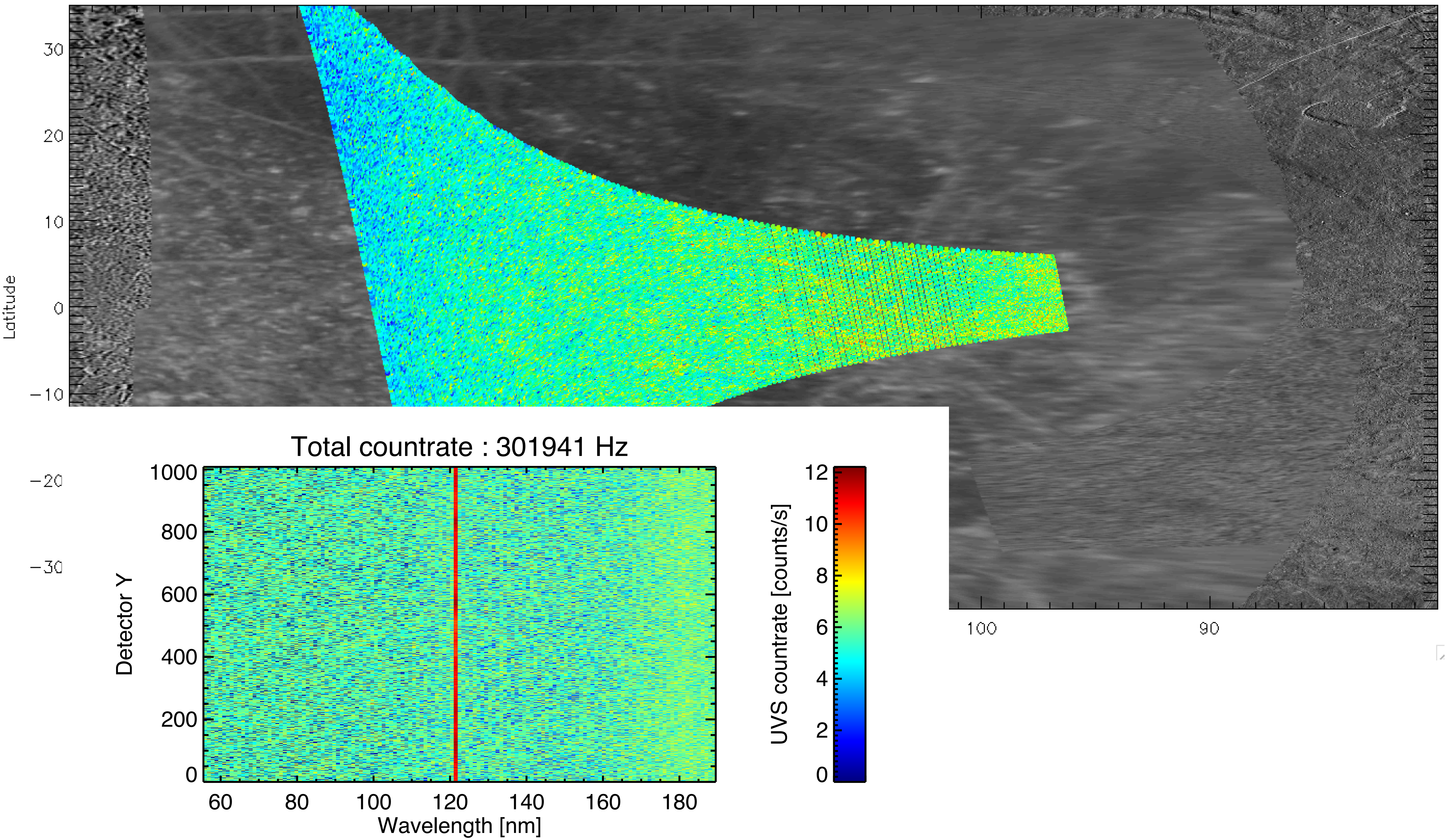


Reflected sunlight + Radiation



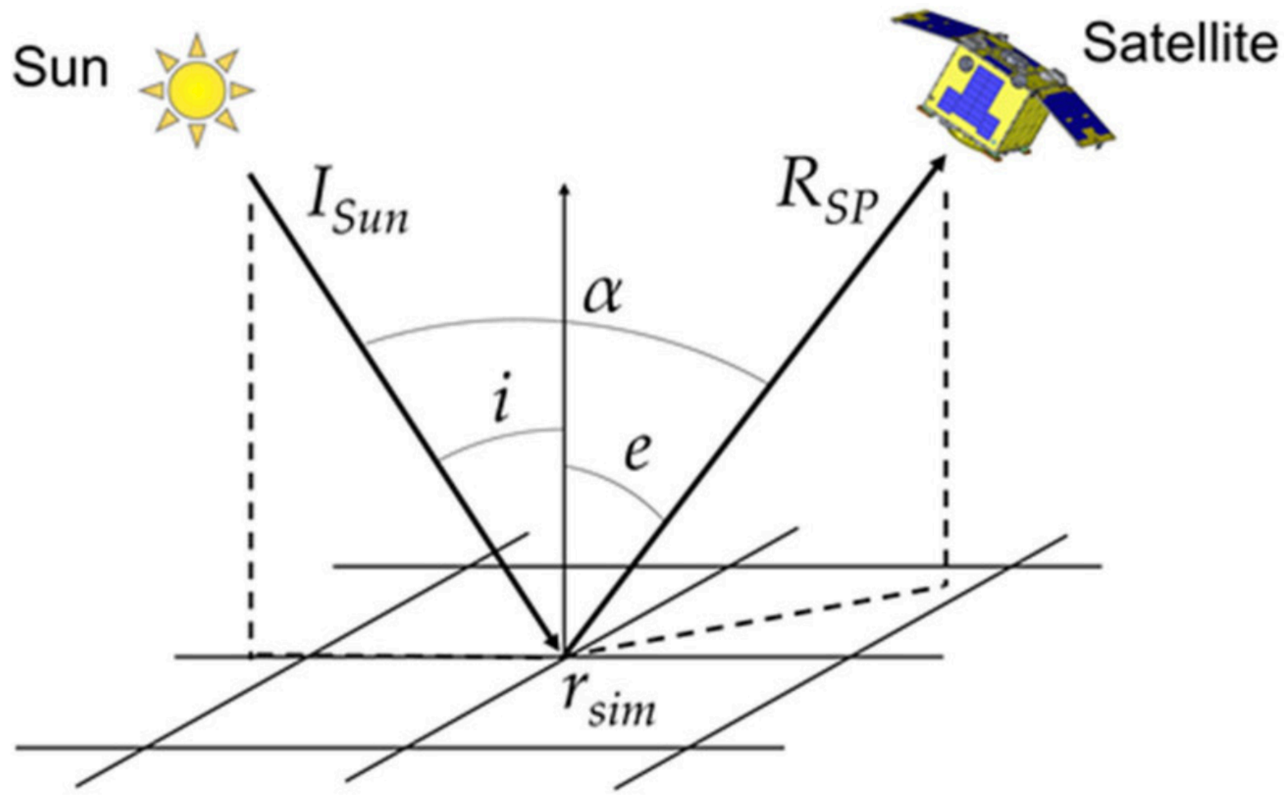


Reflected sunlight only



Reflected sunlight only + Radiation

Geometry element calculations



$$F_{UVS} = A \, \frac{I_{Europa} \cos i}{4\pi}$$

$$C_{UVS} = F_{UVS} \times \epsilon \times \Omega_{pixel}$$

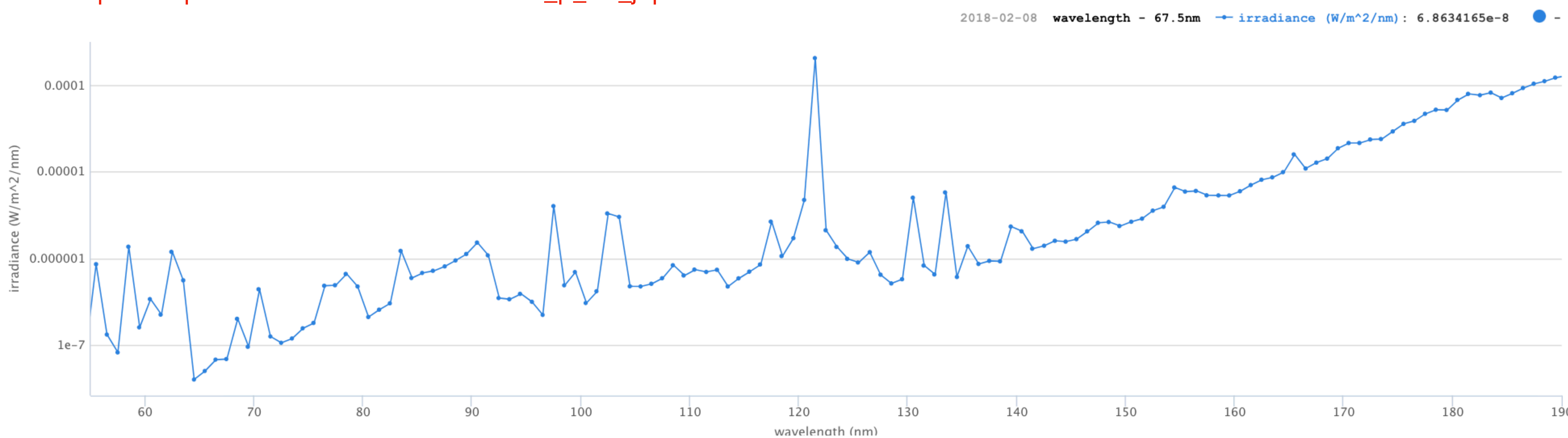
F_{UVS} = Flux received by UVS [photons/s/m^2]
C_{UVS} = countrate measured by UVS [counts/s]
i = incidence angle at viewing point
A = Albedo
I_{Europa} = Solar irradiance at Europa [photons/s/m^2/sr]
ε = effective area [m^2]
Ω_{pixel} = angular size of a UVS pixel (0.13 mrad/pixel)

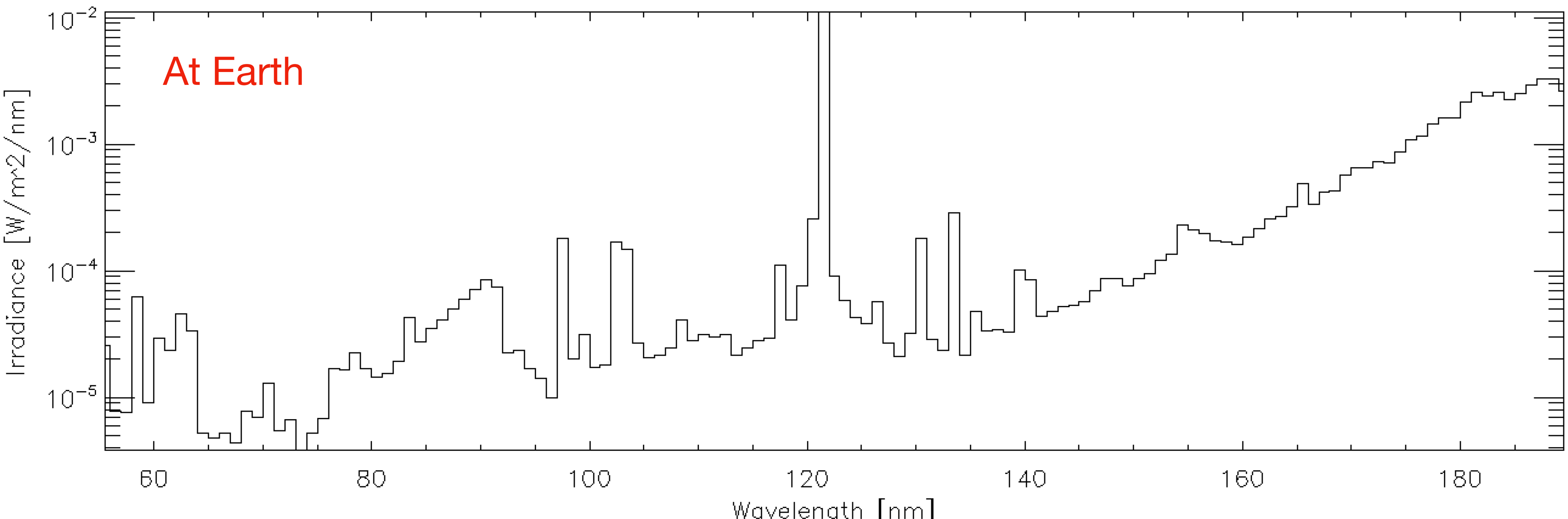
Solar Spectrum

FISM-P Jupiter Solar Spectral Irradiance, Spectrum

This model is for Jupiter. Please note, the XUV portion of the spectrum has not yet been calculated. This work utilizes data produced collaboratively between AFRL/ADAPT and NSO/NISP

From https://lasp.colorado.edu/lisird/data/fism_p_ssi_jupiter/





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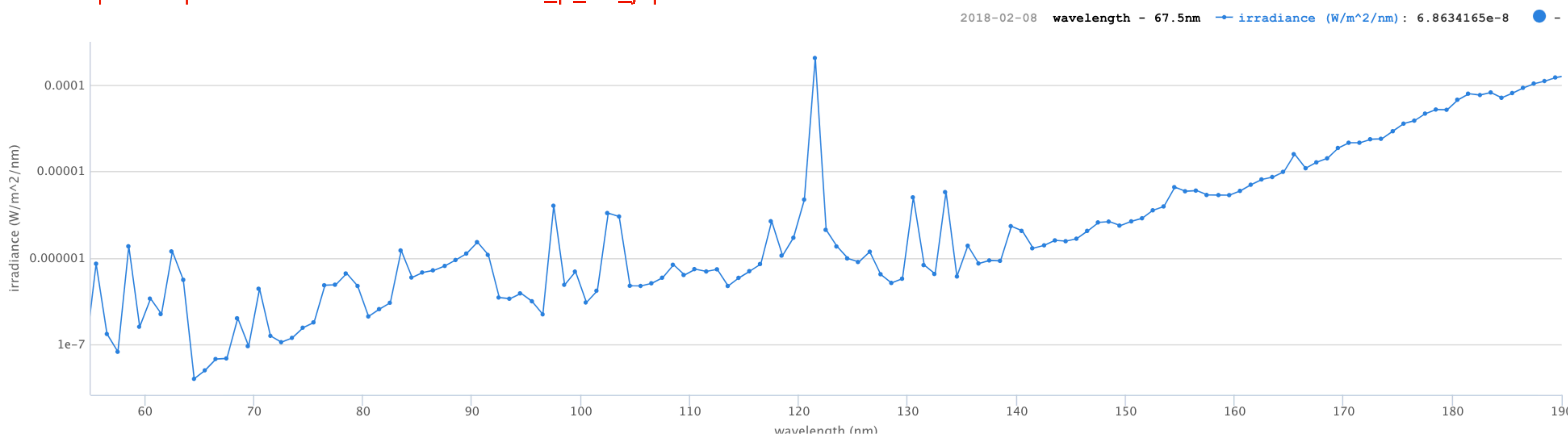
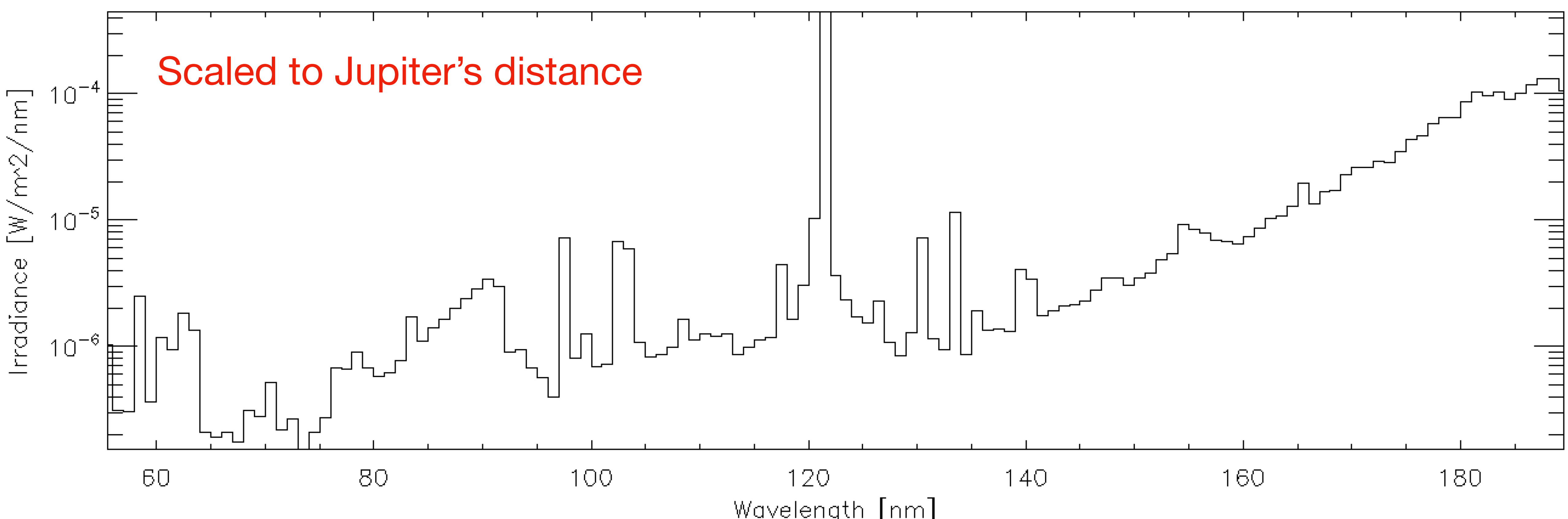
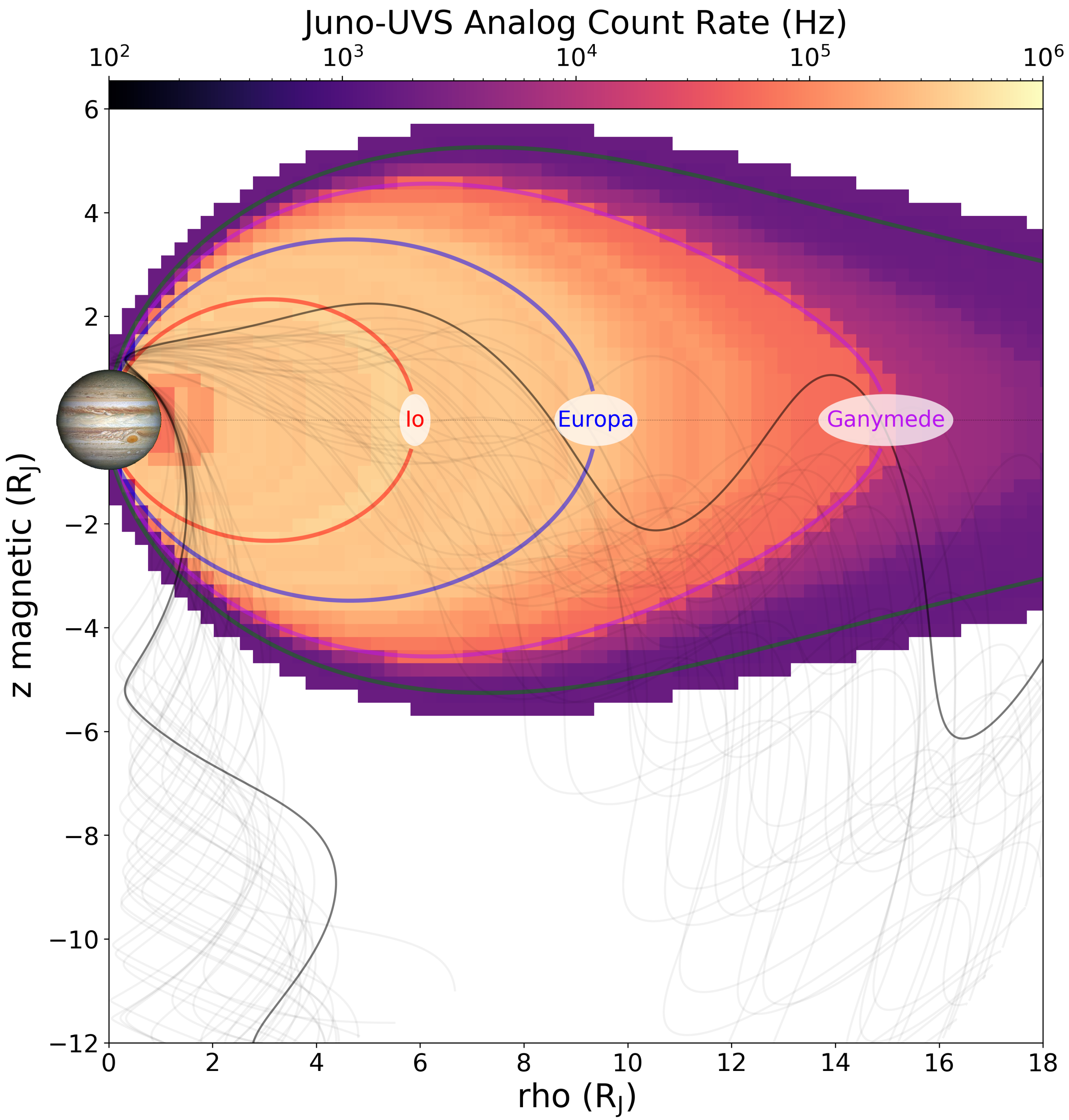




Radiation model



Juno-UVS Analog countrate empirical model (J. Kammer)

Europa-Clipper Apojove: 30-50 R_J ?

Surface UV-reflectance

Geometry needed:

- SubSC Moon lat/lon
- Subsolar Moon lat/lon
- Albedo map
- UVS looking direction on moon?

Surface UV-reflectance

Geometry needed:

- SubSC Moon lat/lon
- Subsolar Moon lat/lon
- Albedo map
- UVS looking direction on moon?

Radiation

Geometry needed:

- SC Mshell
- SC jovian SIII lat

Background IPM

Geometry needed:

- UVS looking direction Ra/Dec?

Star observations

Geometry needed:

- UVS looking direction Ra/Dec?

Background IPM

- Model background from Pryor et al., 2008
- Refined map after the NH measurements?

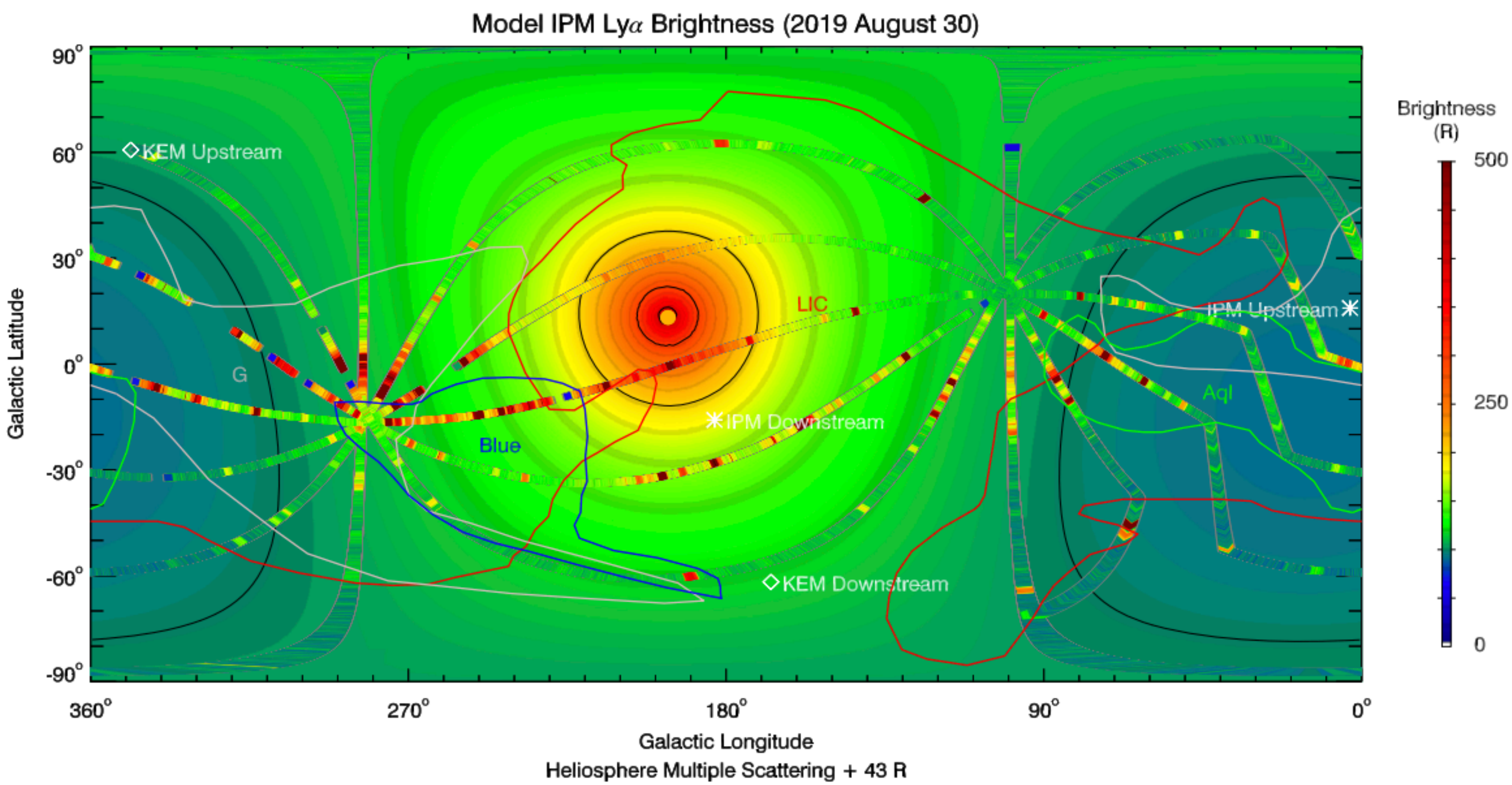
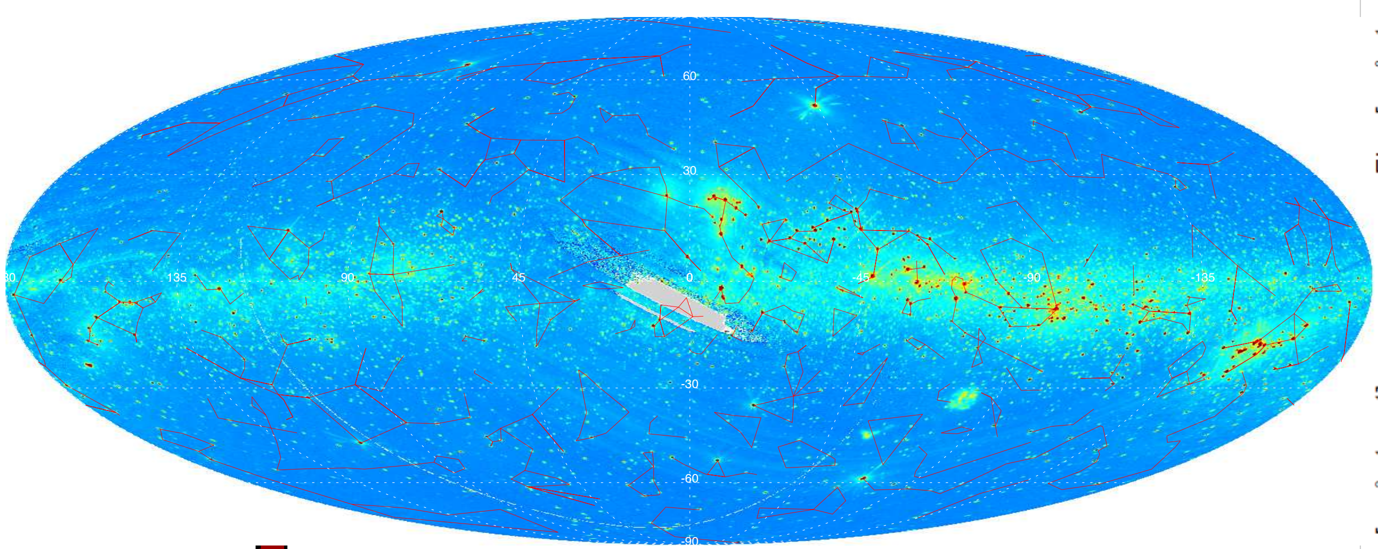


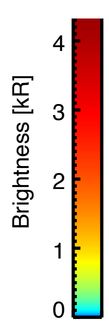
Figure 6. Six-great-circle scan of 2019 August 30 overlaid on a model background (which includes multiple scattering of solar Lyα and a 43 R offset). The location of the Sun is marked by an orange dot. The outlines of the four nearest local interstellar medium clouds (LIC, G, Blue, and Aql, as described by Redfield & Linsky (2008) are overlaid for comparison.

(Gladstone et al., 2021)

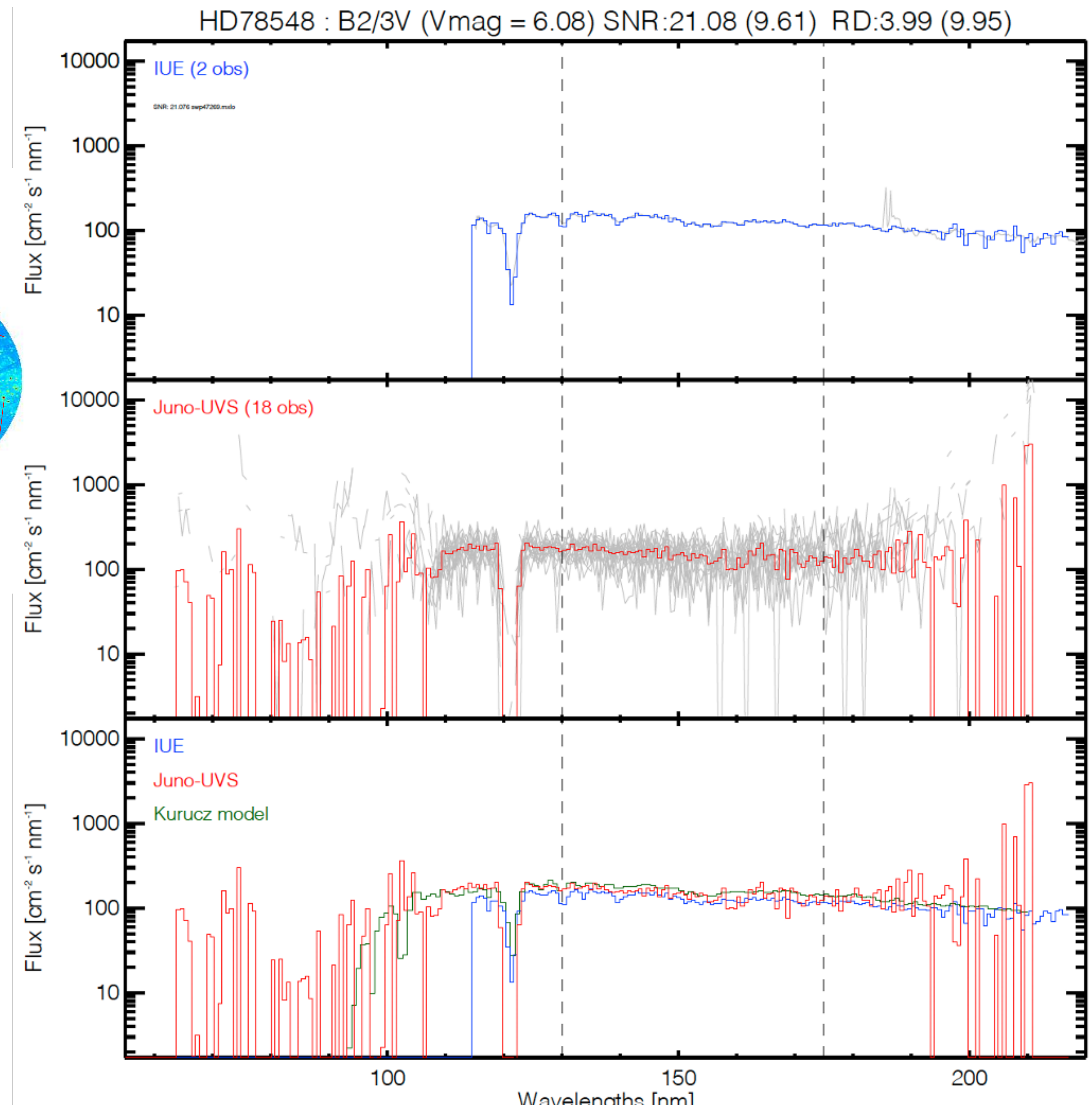
Stellar Background

- Either use:
  - Juno-UVS all sky map (limitation in region with bright stars)
  - Individual stellar sources (IUE, Juno-UVS, HST,…)



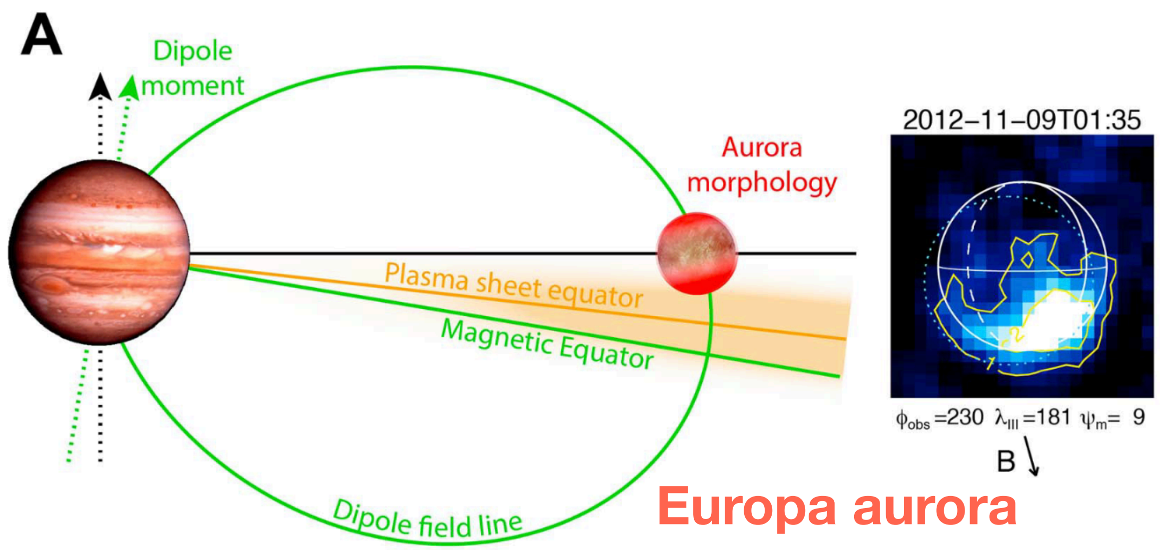


All-sky integrated UV-brightness map (Juno-UVS)

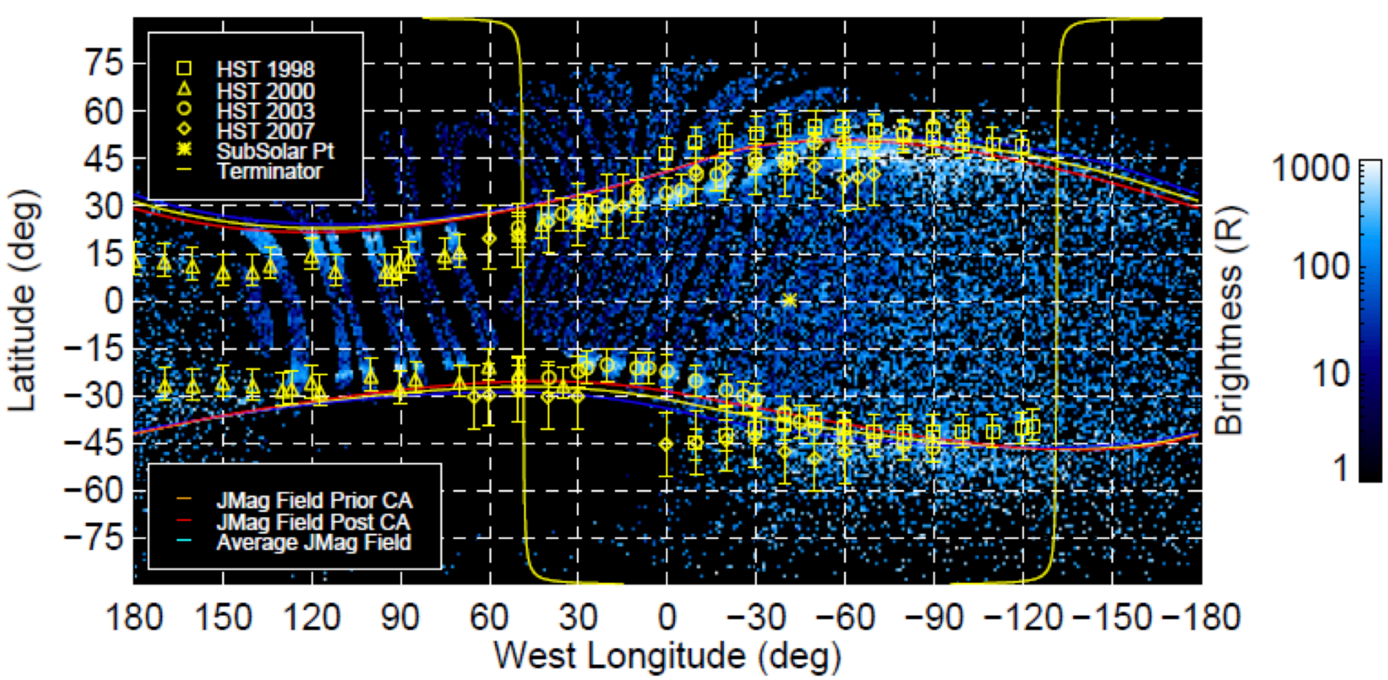


Moon auroras

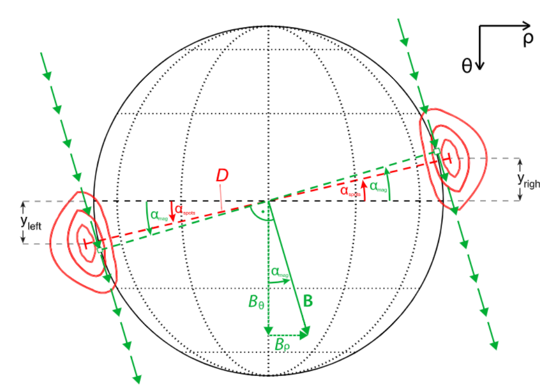
- Variation of the moon aurora geometry as a function of the moon SIII longitude
- Create simple model for Io, Europa & Ganymede that includes:
    - SIII longitude variation
    - Average Volume emission rate

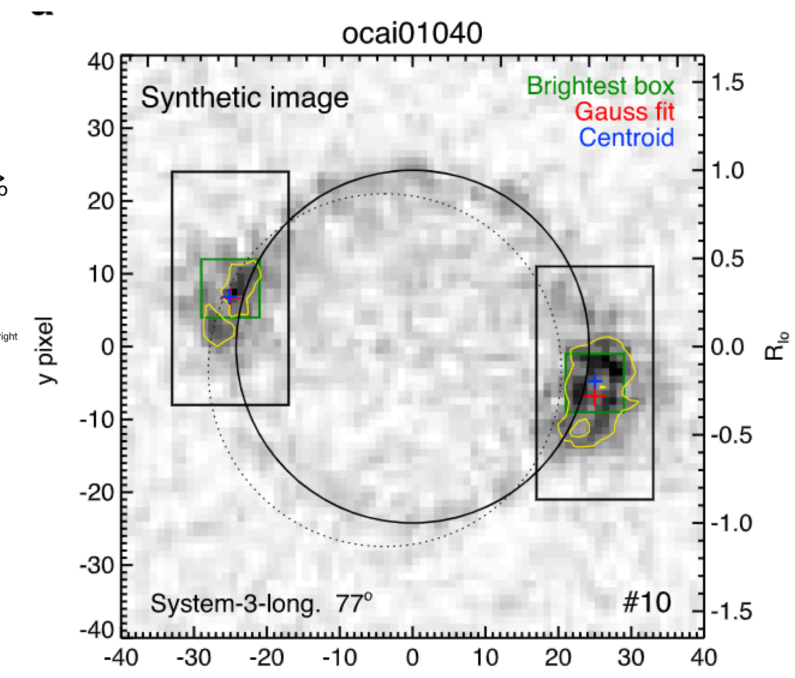


Europa aurora (Roth et al., 2015)



Ganymede aurora (Greathouse et al., in prep.)

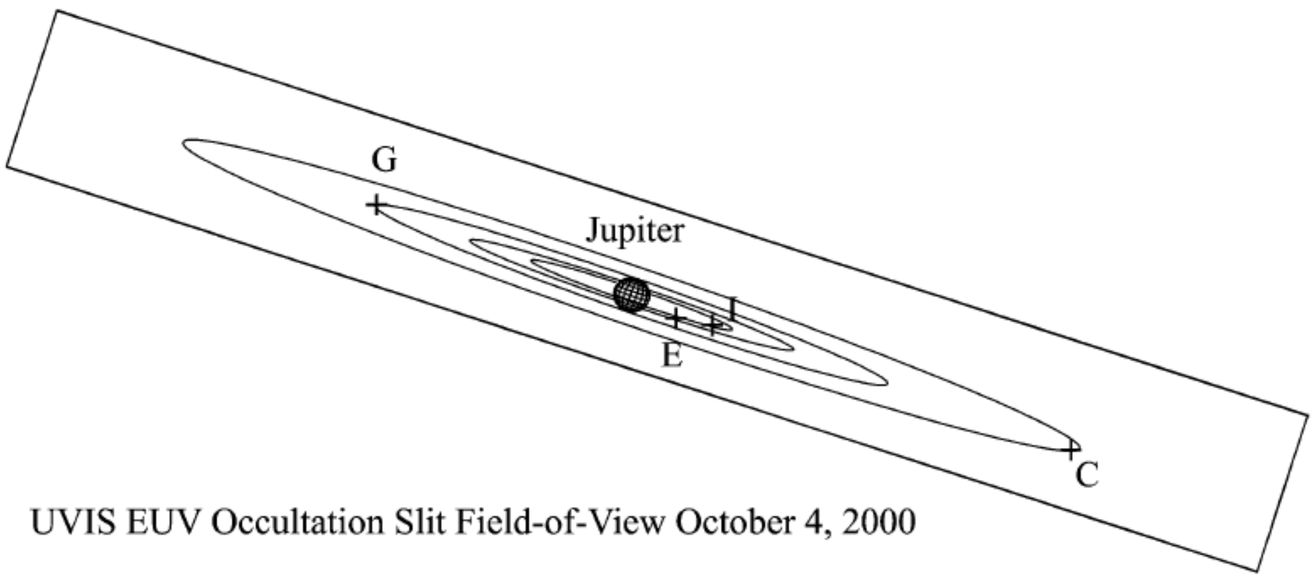




Io aurora (Roth et al., 2016)

Torus Emission

- Use previous Cassini-UVIS observations (Steffl et al., 2004a, 2004b)



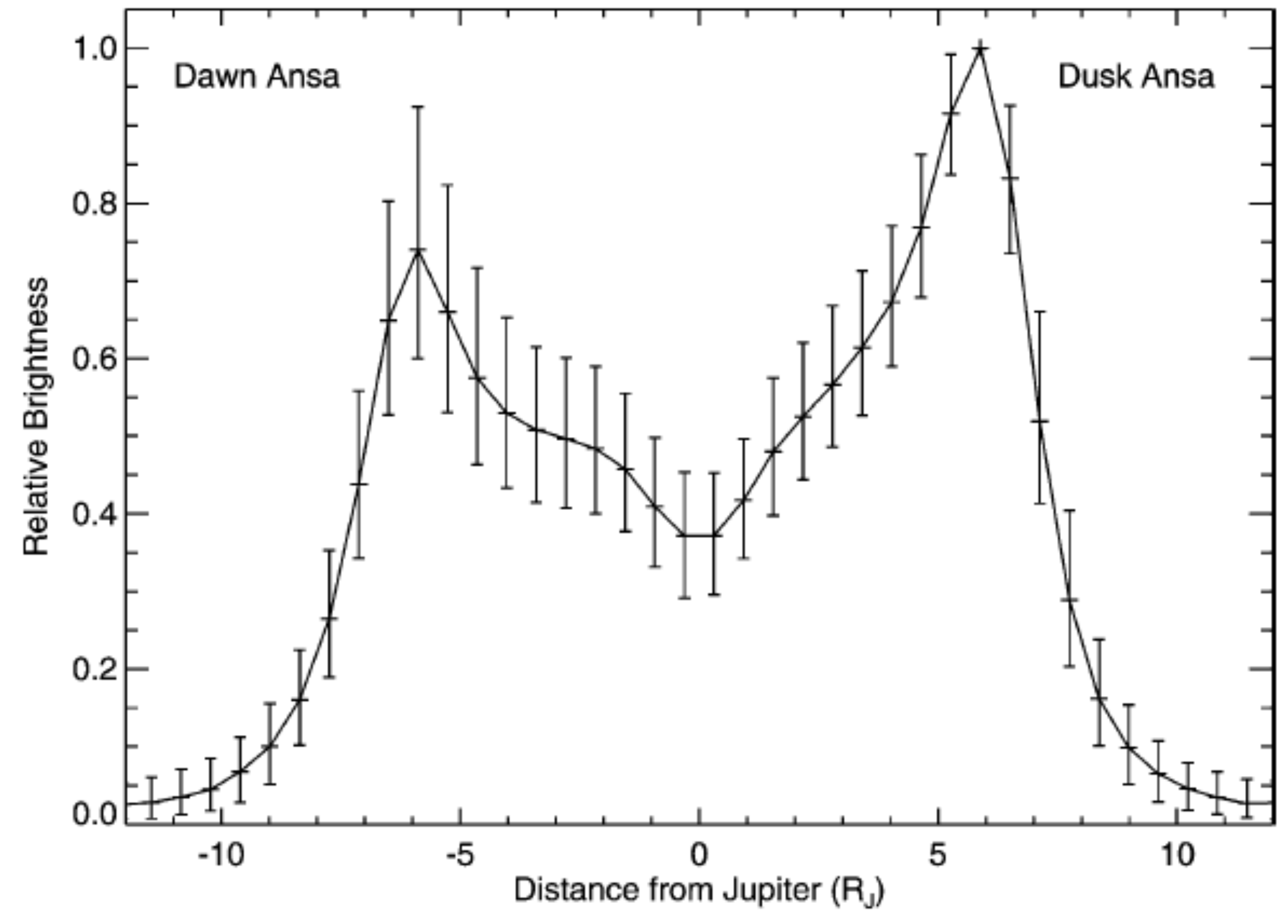


Fig. 6. Total UVIS EUV channel (561–1181 Å) spatial profile. The dawn ansa is to the left while the dusk ansa is to the right. The error bars represent the intrinsic 1-σ variance of the Io torus, i.e., the instantaneous observed spatial profile lies within the error bars 68% of the time.