New Horizons Alice Lyman Alpha Capabilities

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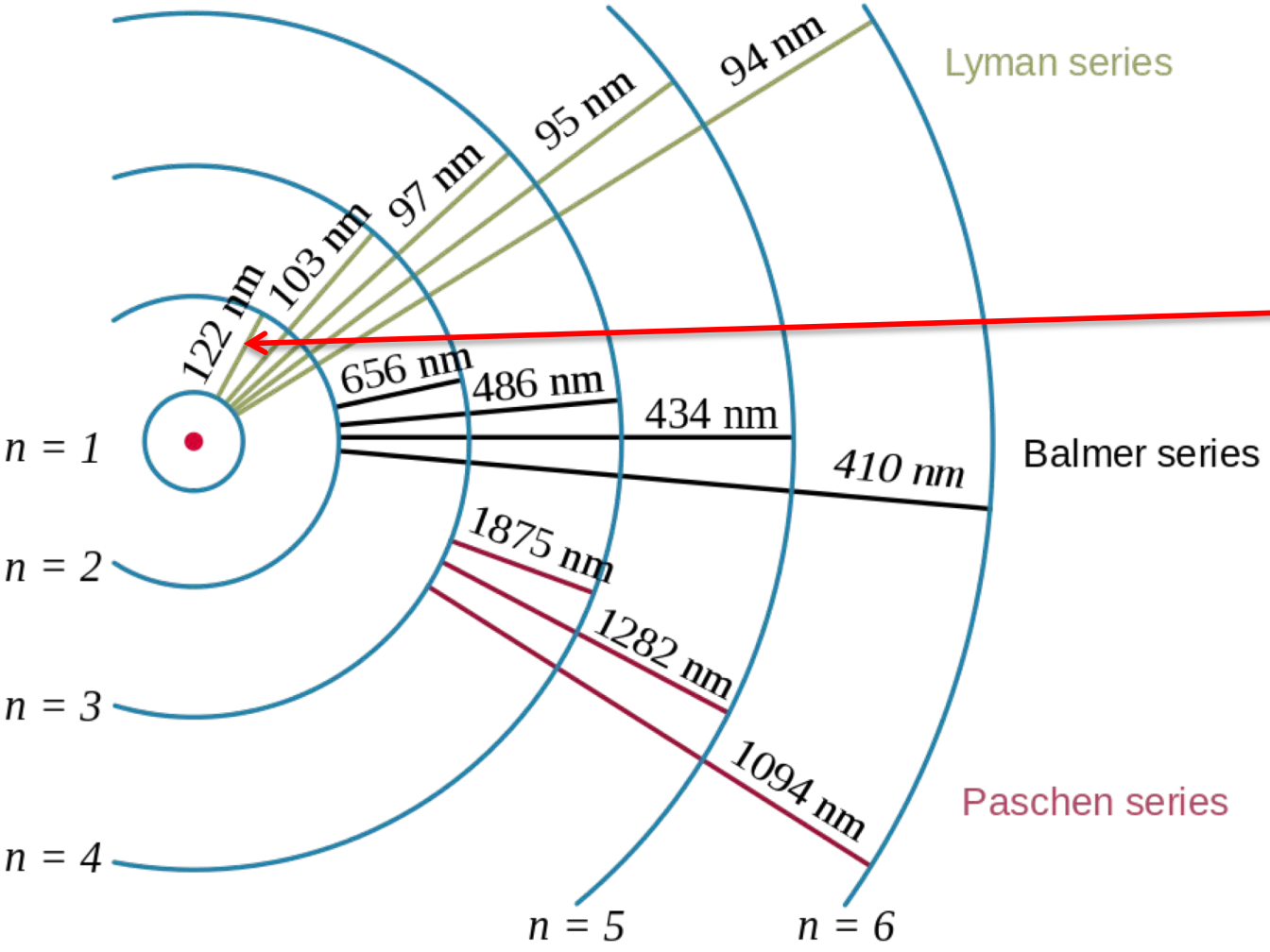
Lyman alpha

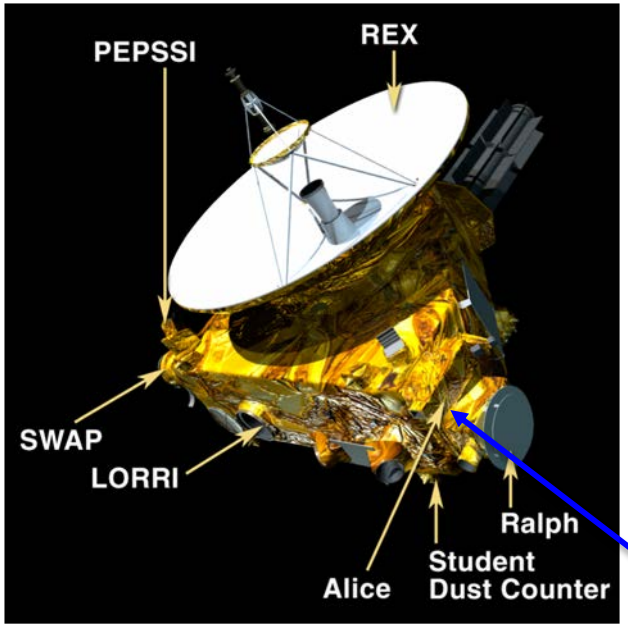


Credit: Wikipedia, A_hidrogen_szinkepei.jpg: User:Szdori

- Lyman alpha (Lya) photons result when H atoms transition from the n=2 to the n=1 electronic energy levels (121.6 nm)

- Since this is the simplest transition in the simplest atom, Lya emissions are ubiquitous throughout our solar system and the universe

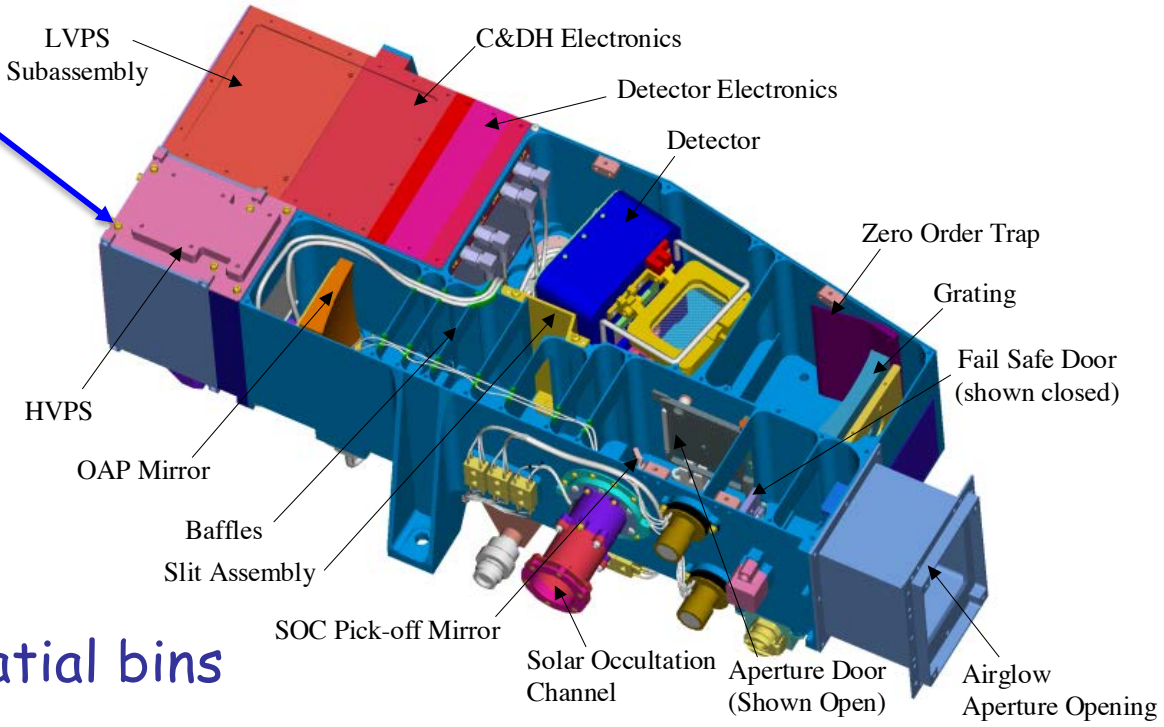
New Horizons & Alice Instrument



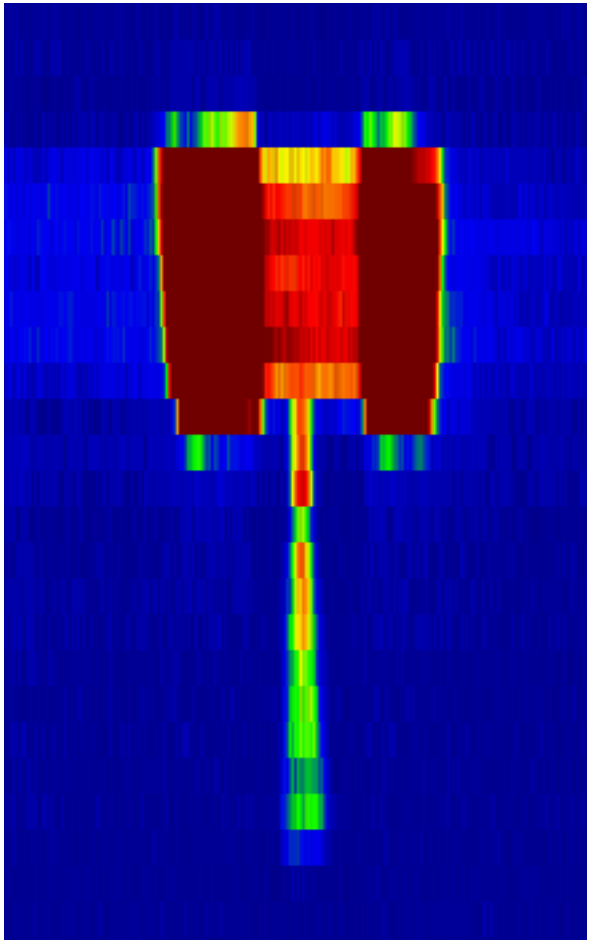
Ralph: Color Camera & NIR Spectral Imager
Alice: Ultraviolet Spectral Imager
LORRI: HiRes Panchromatic Camera
REX: Radio Science Experiment
SWAP: Solar Wind At Pluto
PEPSSI: Energetic Particles
SDC: Student Dust Counter

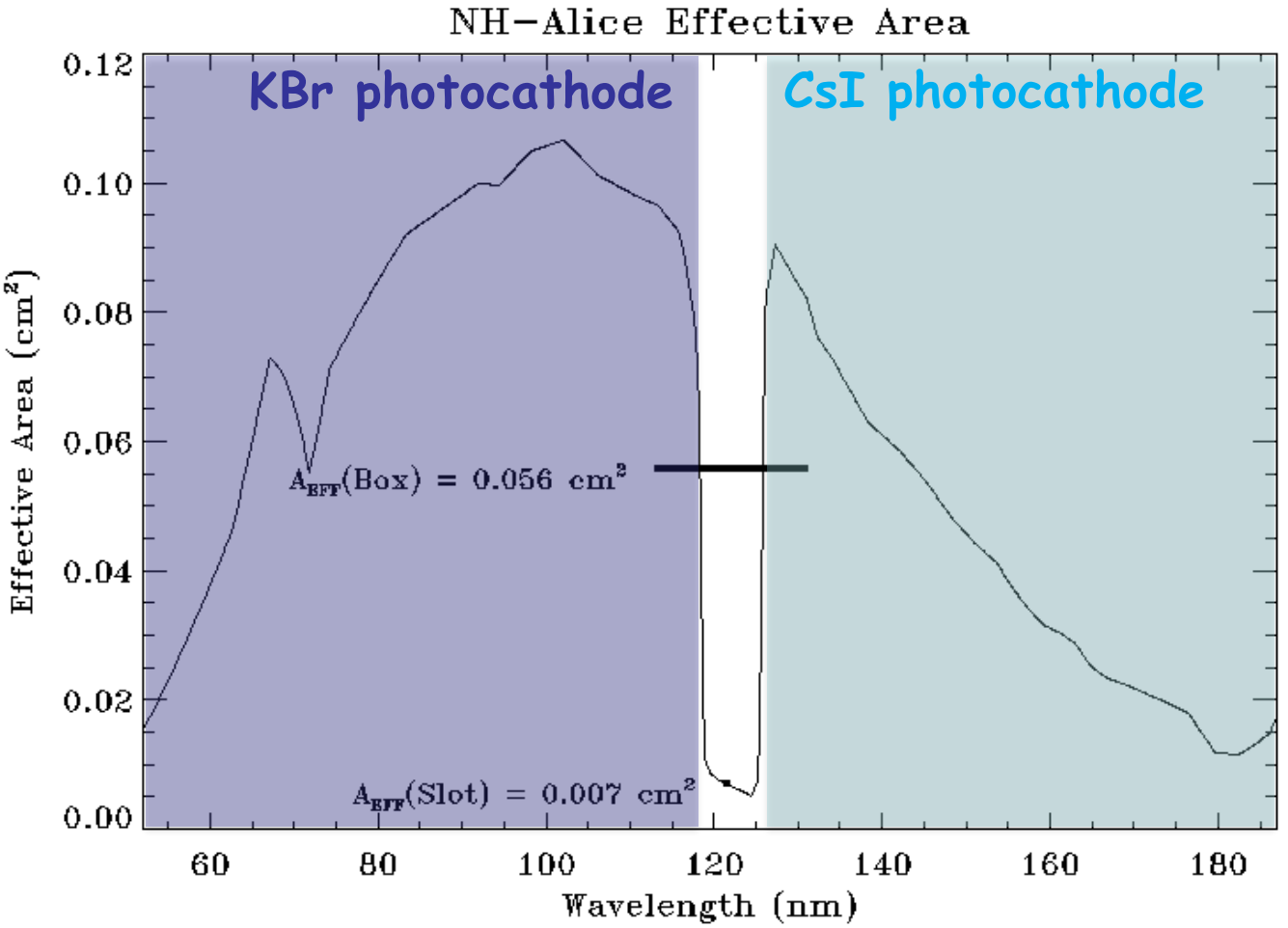
Alice Performance

Mass: 4 kg
Power: 4 W
Spectral Range: 52-187 nm
Spectral Res.: 0.36 nm
Spatial Res.: 0.6°
Aperture: 4 x 4 cm²
Binning: 1024 spectral x 32 spatial bins



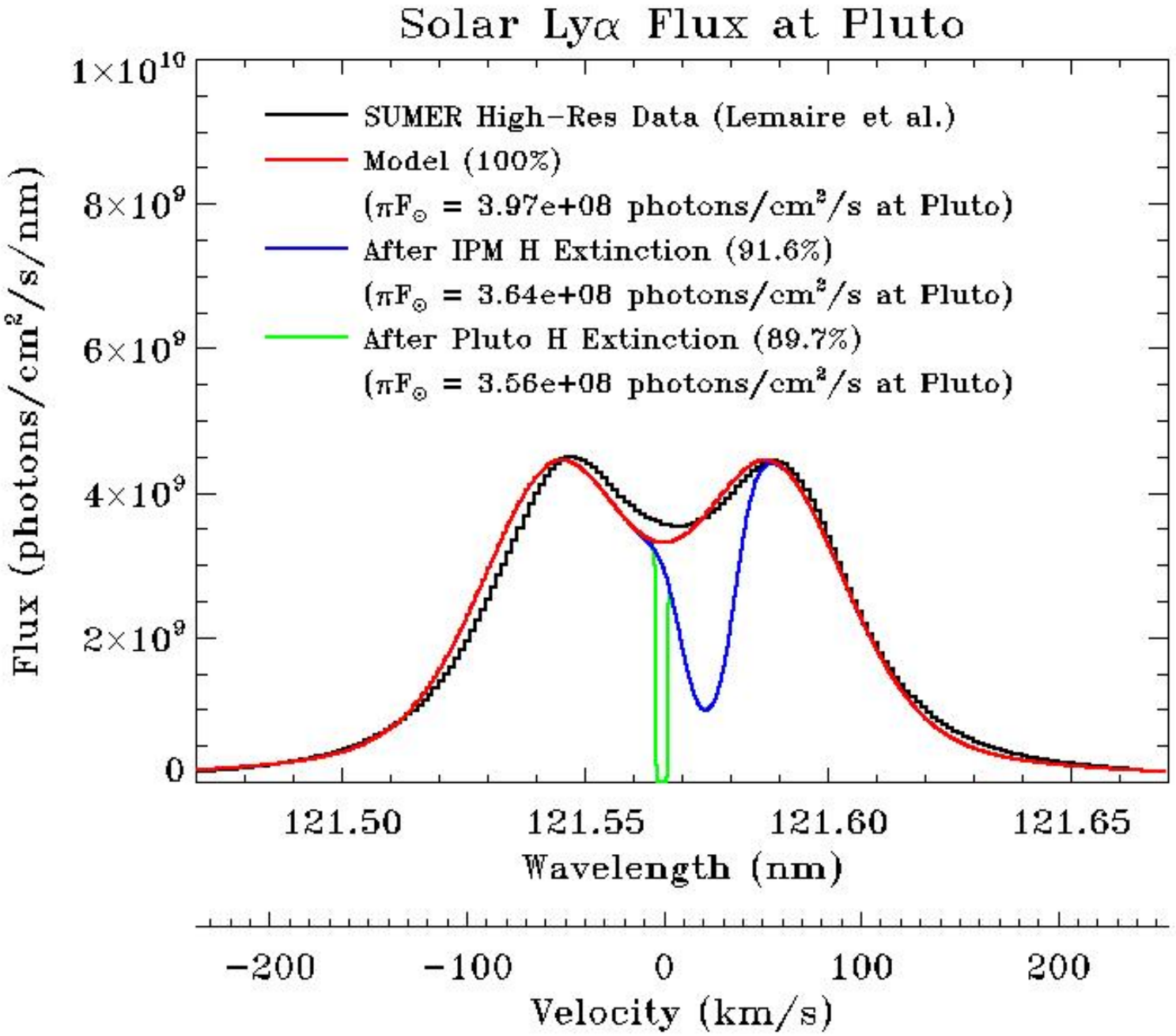
Alice Slit Shape & Effective Area





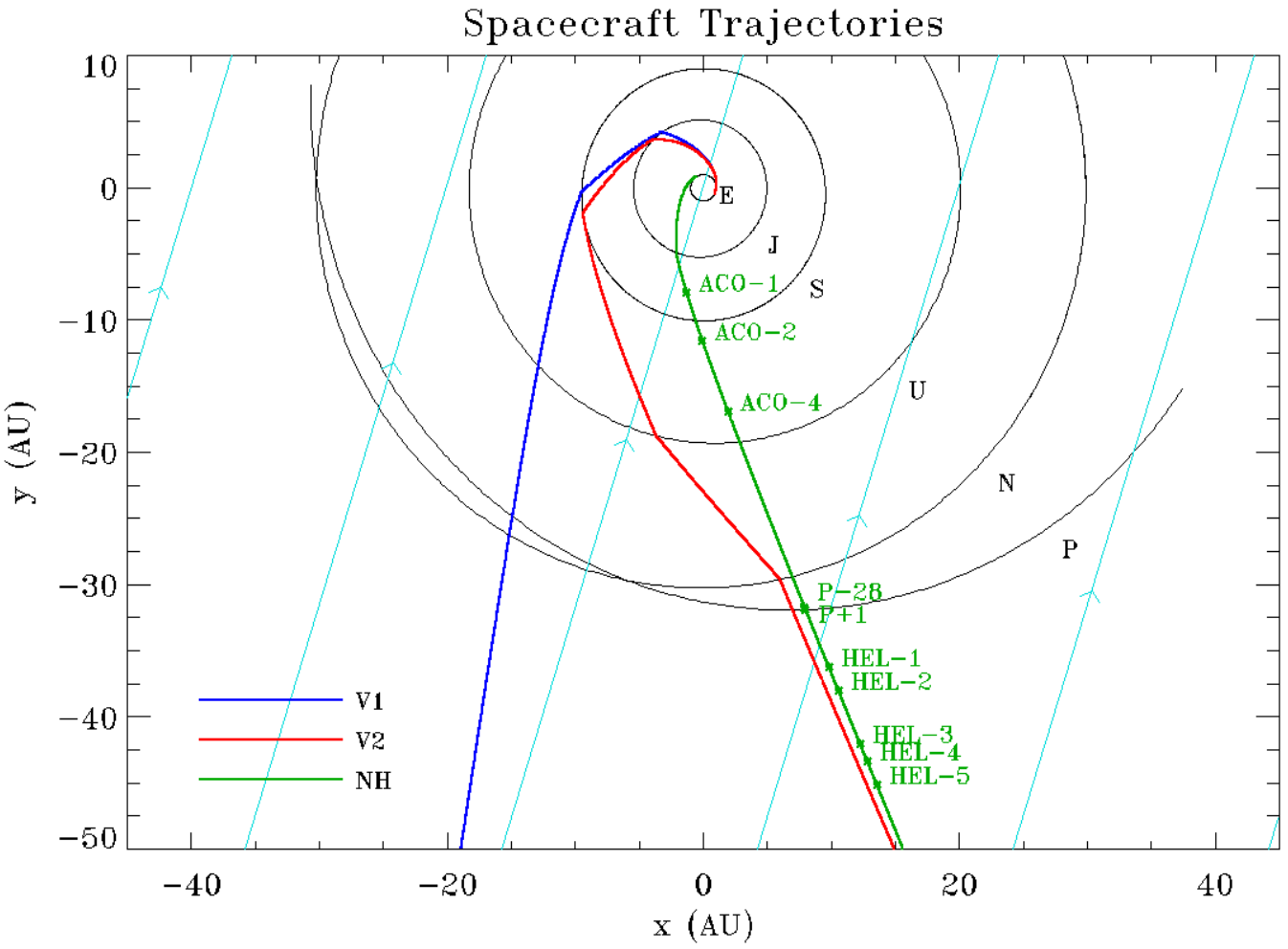
- Left: A 1-hour Alice spectral image of the upwind direction (1/28/2017) shows the 4°x0.1° "slot" + 2°x2° "box" slit shape, lit up by IPM Lyα
- Right: A_{EFF} vs. wavelength, showing the "Lyα gap" containing the slot, and the spillover of IPM Lya in the box onto the KBr and CsI photocathodes; sensitivity S = 4.9±0.1 counts/s/R (cf., for V1 UVS, S ~ 0.01 counts/s/R)

Solar Ly Line Profile



New Horizons Trajectory & IPM Data

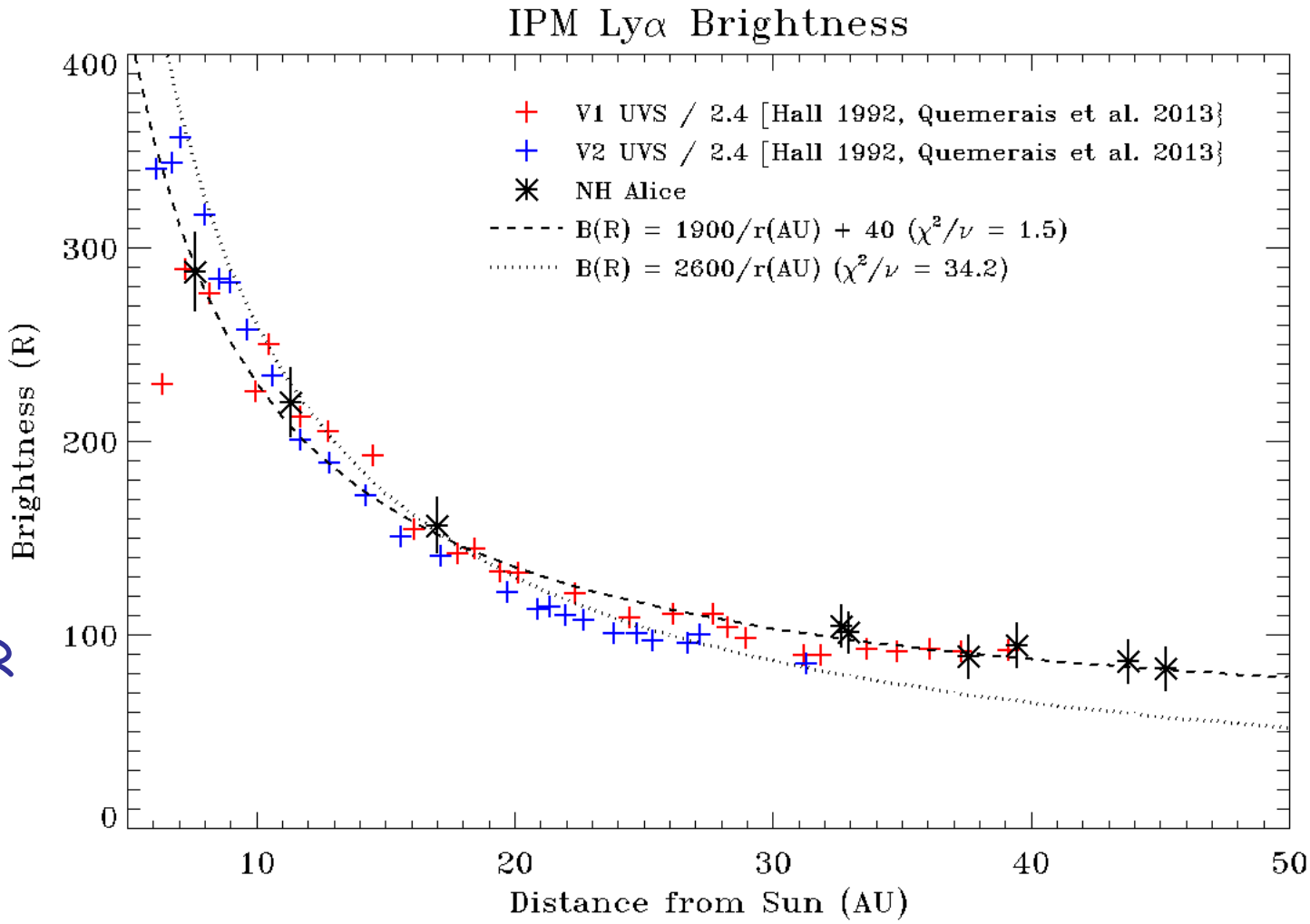
- IPM Lyα observations on a single great circle were made with Alice 3 times during cruise to Pluto, at solar ranges of 7.6, 11.3, & 17.0 AU
- Two 6-great-circle Lyα scans of the sky were made near the Pluto flyby, at solar ranges of 32.7 & 32.9 AU, and similar scans are made every year or or so (labelled "HEL", for heliophysics)



- The first 5 were on 1/28/2017 (37.6 AU), 9/19/2017 (39.5 AU), 3/3/2019 (43.8 AU), 8/30/2019 (45.2 AU), and most recently, on 4/27/2020 (47.2 AU)

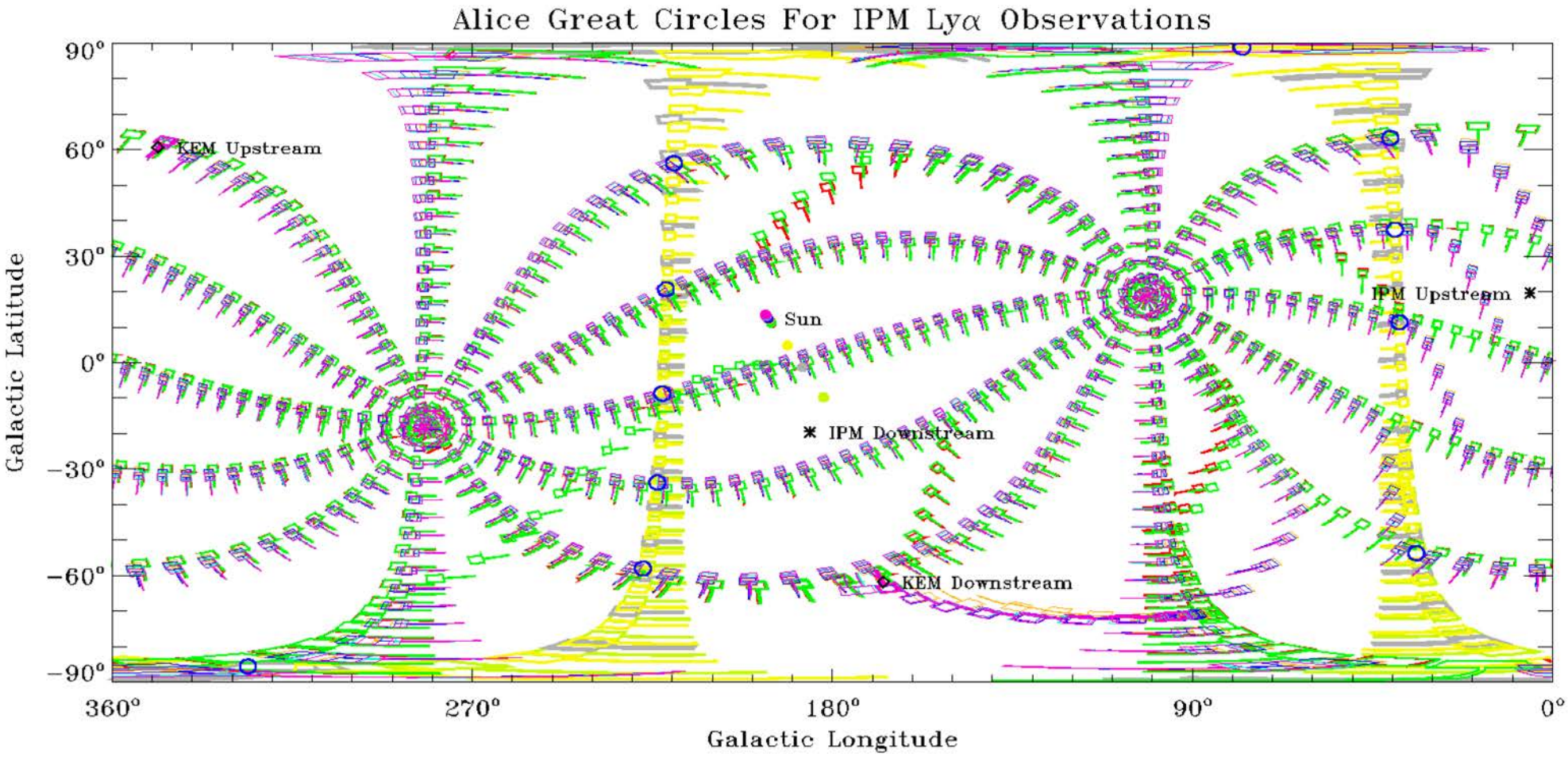
IPM Lyα vs Sun Distance

- The IPM Lya brightnesses are scaled by 3.0×10^{11} / F_{SUN} (photons/cm^2/s at 1 AU)
- The upstream-looking NH data are quite reasonably fit by a d_{SUN}^{-1} profile plus a constant ~40-R source further upstream (as suggested by Hall et al. [1993])



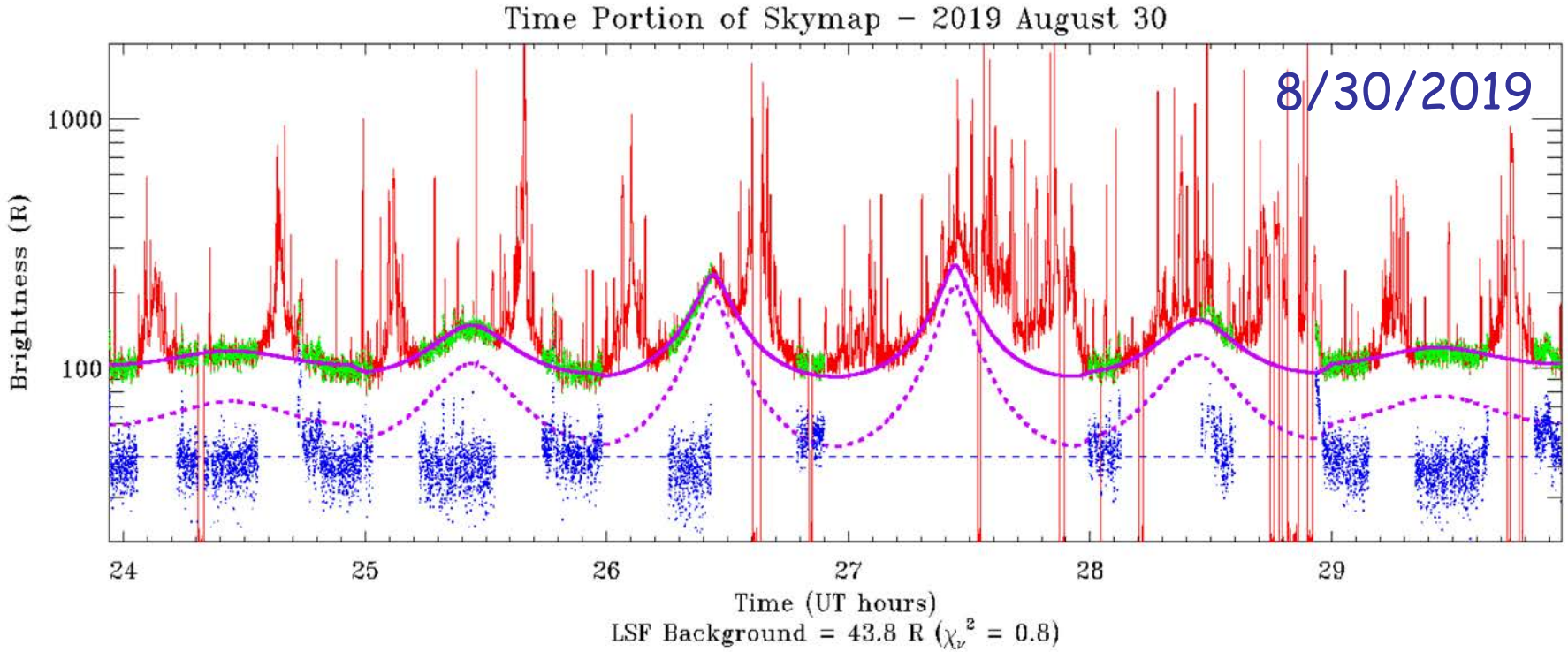
- Scaling of Voyager 1 data down by 2.4x (as suggested by Quémerais et al. [2013]) works very well, although it has been challenged by Ben-Jaffel & Holberg [2016]

Great Circles



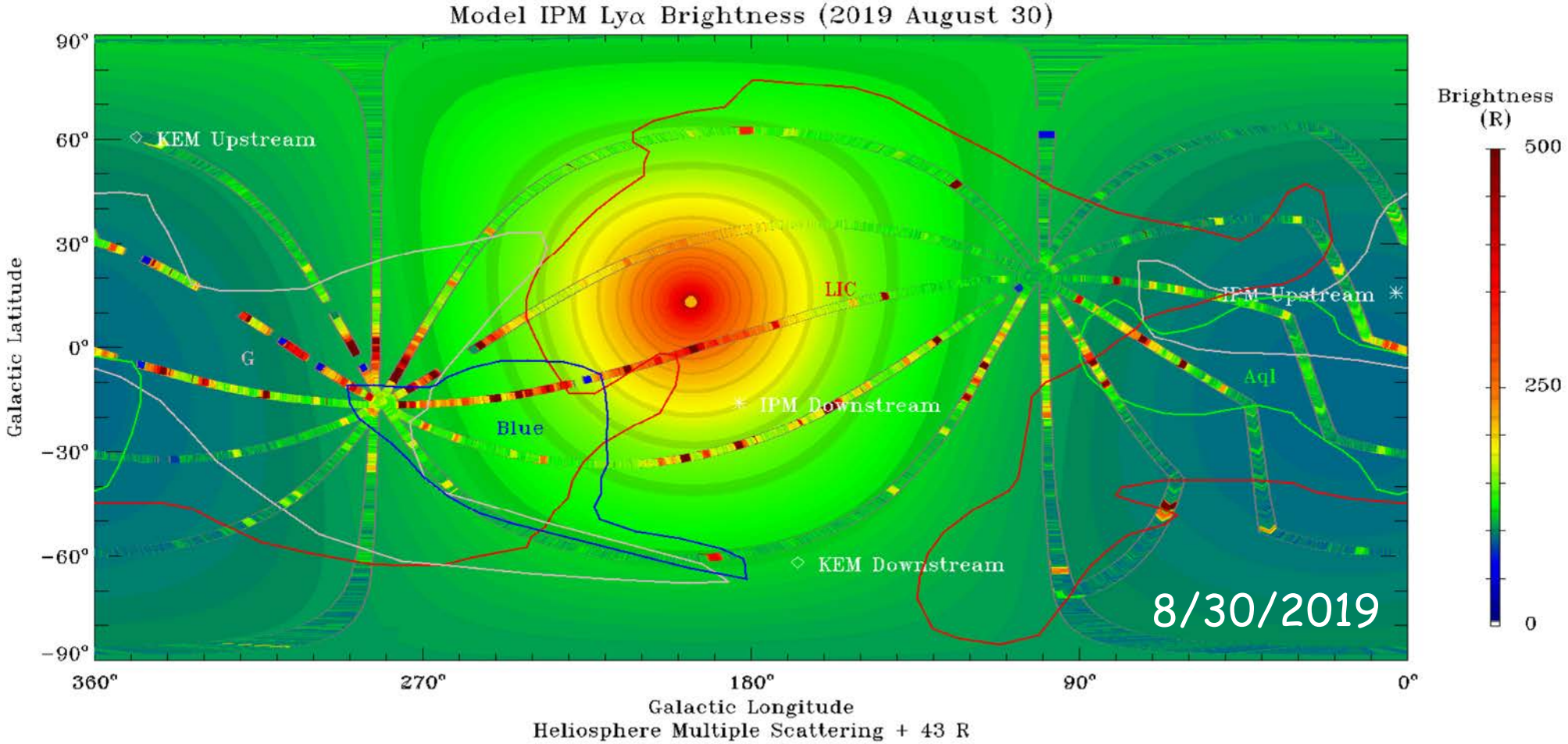
- IPM Lyα observations on a single great circle were obtained during ACOs in cruise to Pluto, at solar ranges of 7.6, 11.3, and 17.0 AU
- Seven 6-great-circle IPM scans have been made since the Pluto flyby
- The 1- and 6-great-circle scan intersections (blue circles) provide a record at solar ranges from 7.6 to 47.2 AU in 11 directions on the sky

Ly Background Scan



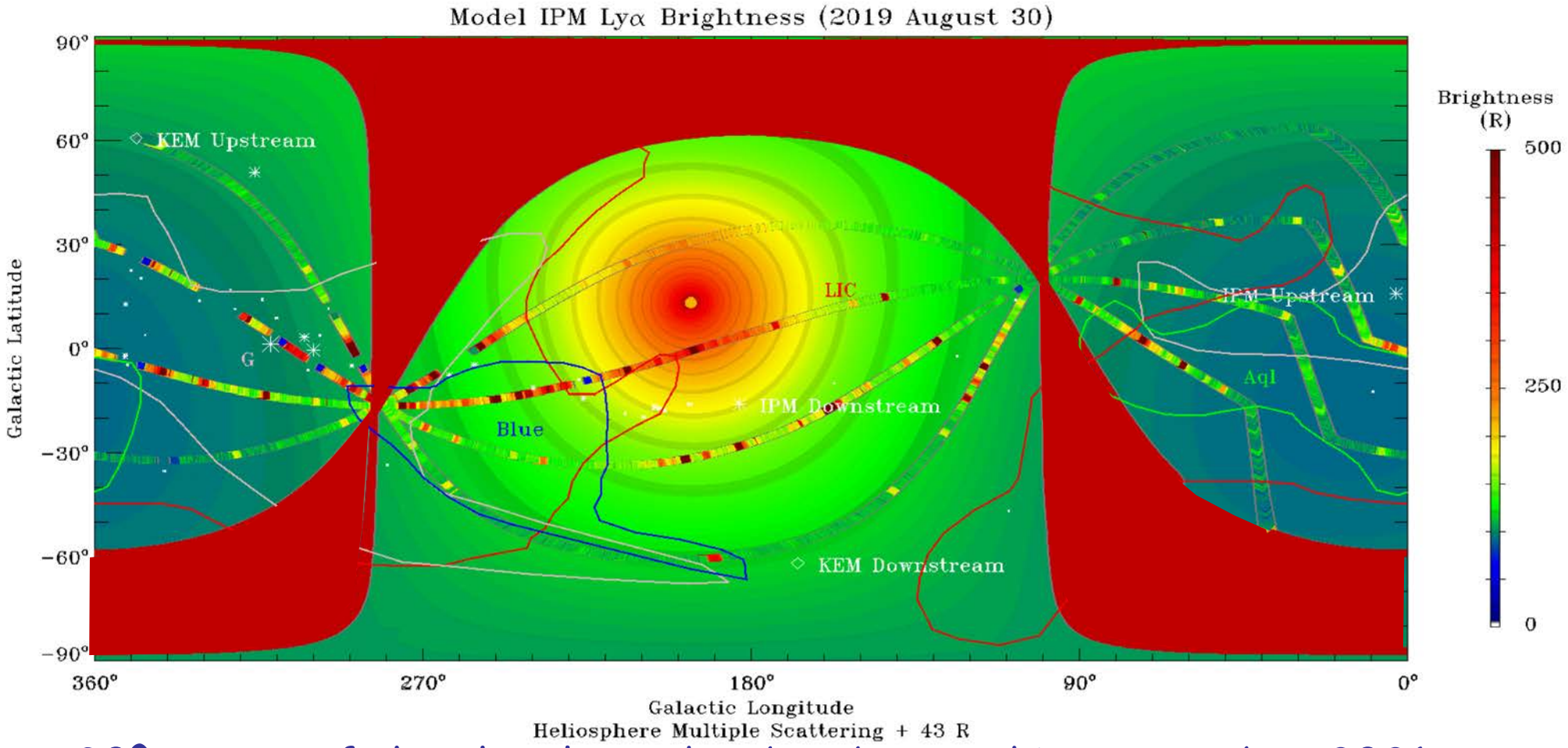
- This plot shows how the total count rate data during a particular 6-great-circle scan (red) look when plotted versus time, and how stars can be mostly filtered out to leave the Lya background (green)
- When a model of the heliosphere-scattered solar Lya (dashed purple) is subtracted from the observed Lya background, the residual (blue) is very well fit by a constant background, here at a brightness of ~43 R
- Adding this constant to the scattered solar Lya (solid purple) fits the New Horizons Alice observations (green) very well

IPM Lyα in Galactic Coordinates



- The same 6-great circle scan by Alice, is shown here against a model Lya IPM background (which includes multiple scattering of solar Lya and 43 R of galactic Lya background); the fit indicates the constant background is not just in the upstream direction, but is seen in all directions
- The colored outlines mark the boundaries of prominent LISM clouds

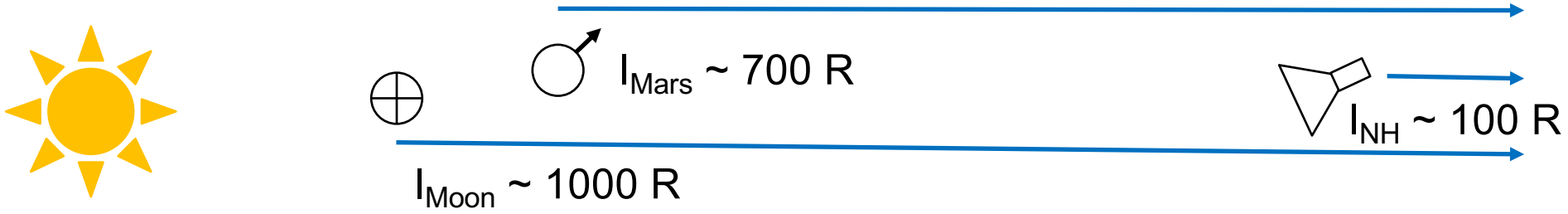
2nd Extended Mission (KEM2) Plans



- A 30° sector of the sky planned to be observed in September 2021 as a "proof-of-concept" observation for an all-sky map (at 2° resolution) is indicated by the crimson region between the 2 great circles
- If successful, the rest of the map (except for near-Sun directions) will be filled in sometime in the KEM2 mission

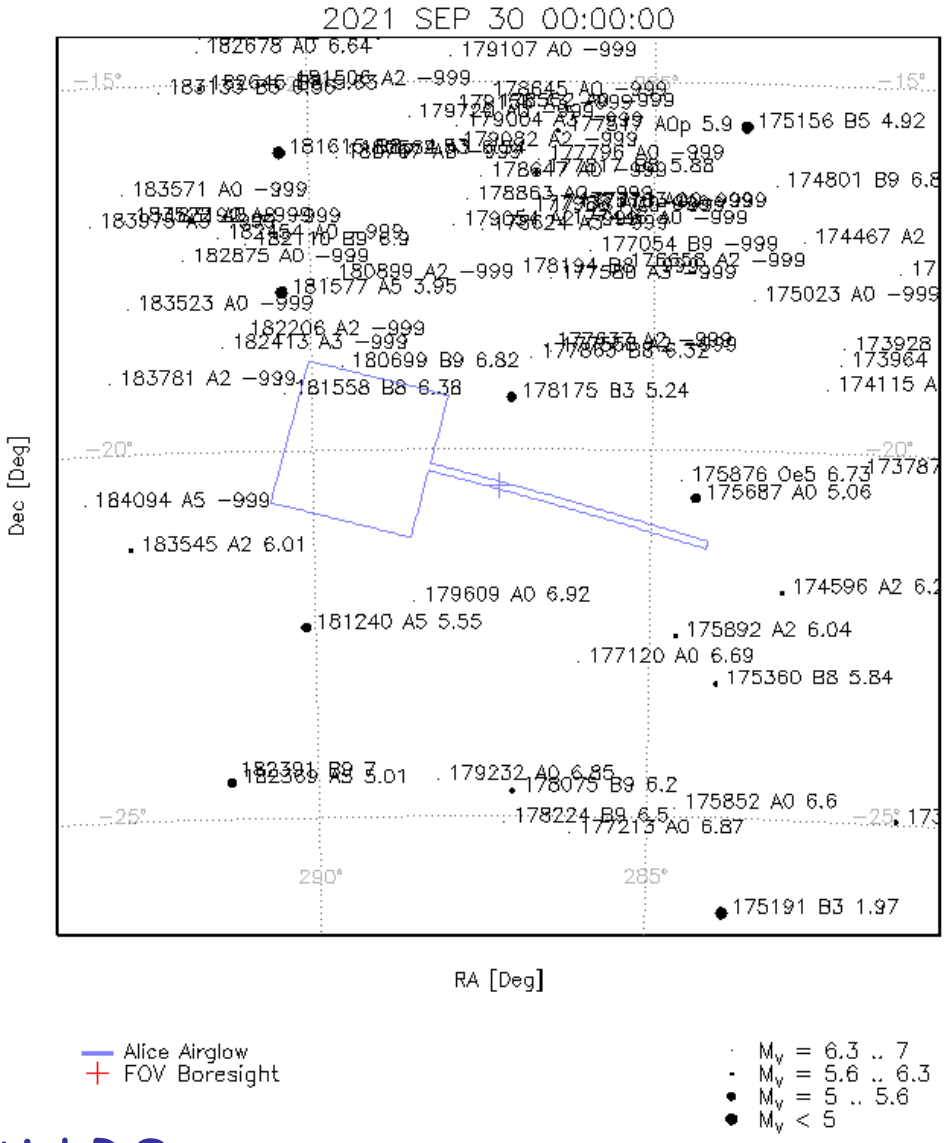
Point-to-Point H Column Density

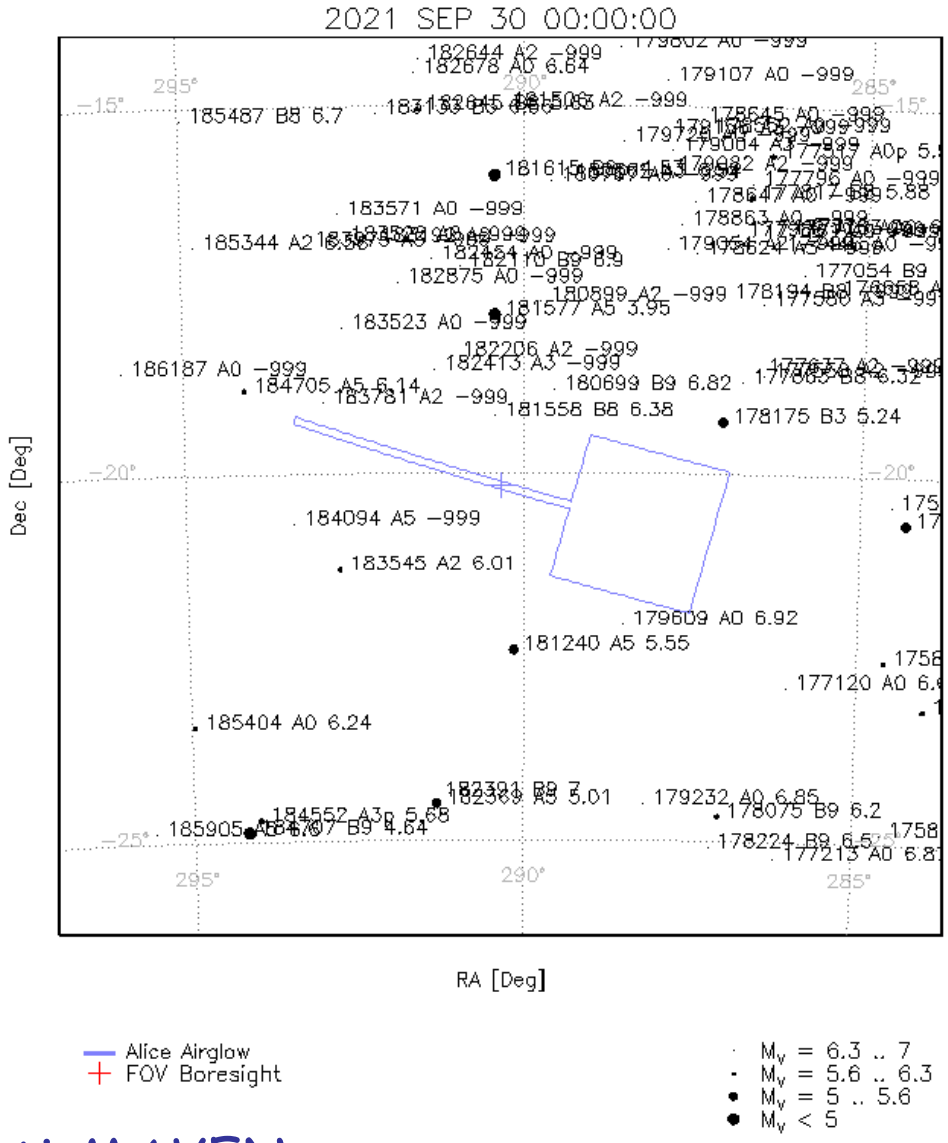
- Two spacecraft observing the Lya background toward and away from each at same epoch -> H column density between them -> a strong constraint on outer heliosphere models
- Alice cannot point close to the Sun, toward LRO-LAMP at the Moon, or MAVEN-IUVS at Mars -> use "one-sided" experiment where both spacecraft look away from the Sun



- Brightness difference (e.g., $I_{Mars} - I_{NH}$ or $I_{Moon} - I_{NH}$) depends only on the solar Lya flux (routinely monitored from Earth) and H column density between the spacecraft (Quémerais et al., *J. Geophys. Res.*, **119**, 8017, 2014)

Point-to-Point H Column Density

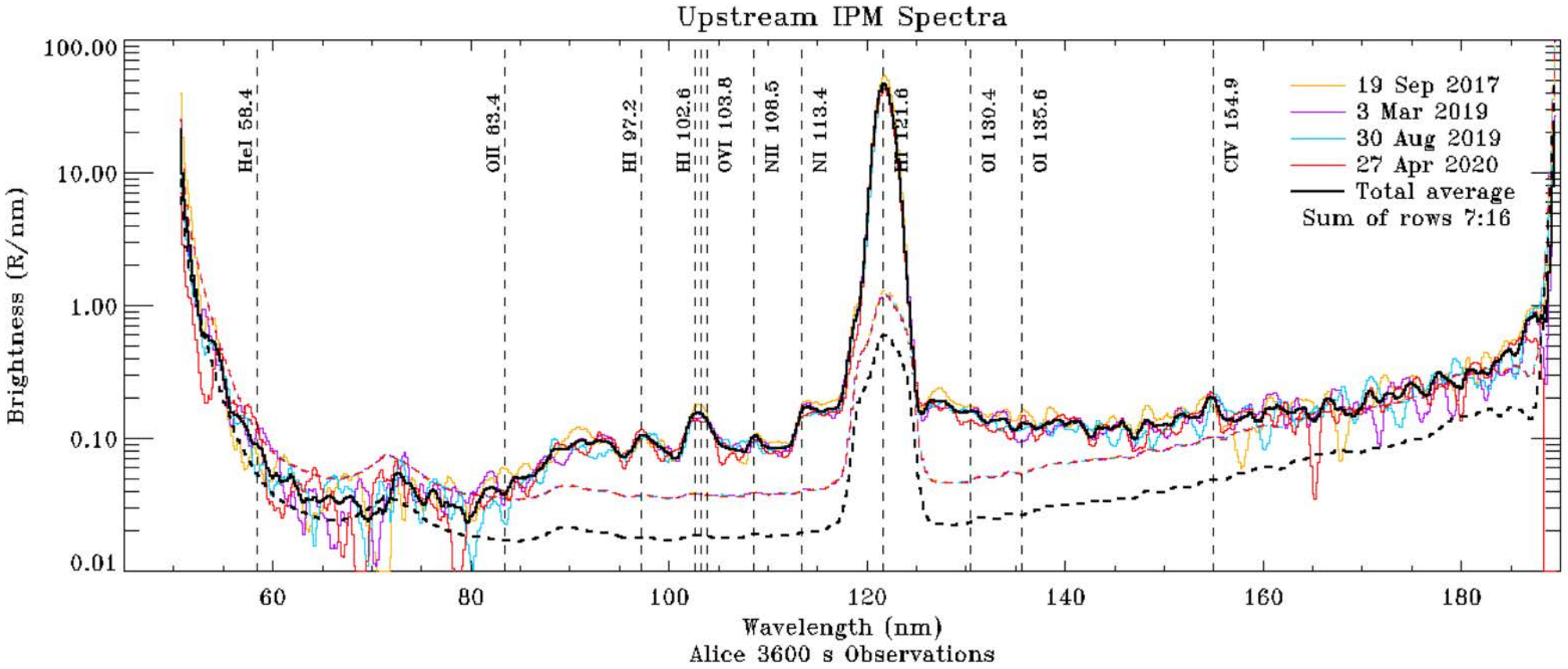




Anti-LRO
(α=287.253°, δ=-20.498°, Roll=-80°)

Anti-MAVEN
(α=290.336°, δ=-20.175°, Roll=+100°)

IPM Scan Spectra



- Along with each 6-great-circle count rate observation, 1-hour upstream & downstream spectra are acquired, to search for non-Lya emissions
- The IPM line of He 584 is marginal, but Lyβ is clearly seen
- The Lya/Lyβ ratio was uncertain; the Alice data support Voyager results
- Other lines are only suggestive (e.g., NII 108.5, CIV 154.9 nm), but such observations will continue during KEM2

Conclusions

- New Horizons Alice scans of the interplanetary medium (IPM) Lya emissions provide a useful update on Voyager results, and scaling of V1 data (as suggested by Quémerais et al. [2013]) makes NH Alice data consistent with Voyager UVS data
- The upstream-looking and all-sky NH data are reasonably well fit by IPM models of scattered solar Lya plus a uniform ~44 R distant source which is likely the galactic background
- The ~44 R galactic Lya background provides a useful measure of the local Lya absorption coefficient of interstellar dust, which is the primary absorber of galactic Lya emissions; we find $k_{DUST} \sim 0.18$ kpc^{-1} at Lya
- We will continue the observing strategy of great circles (Lya only) plus long stares near upstream and near downstream directions (full spectra), about once per year until the New Horizons end of mission
- For the 2nd Extended Mission we are also planning to 1) produce an all-sky Lya map (at 2° resolution), and 2) make point-to-point H column density measurements between NH and spacecraft at the Moon & Mars