Preliminary results from IRTF–iSHELL of Jupiter's aurora during the NASA-Juno mission

Johnson, R.[1], Stallard, T.[2], and Melin, H[2]

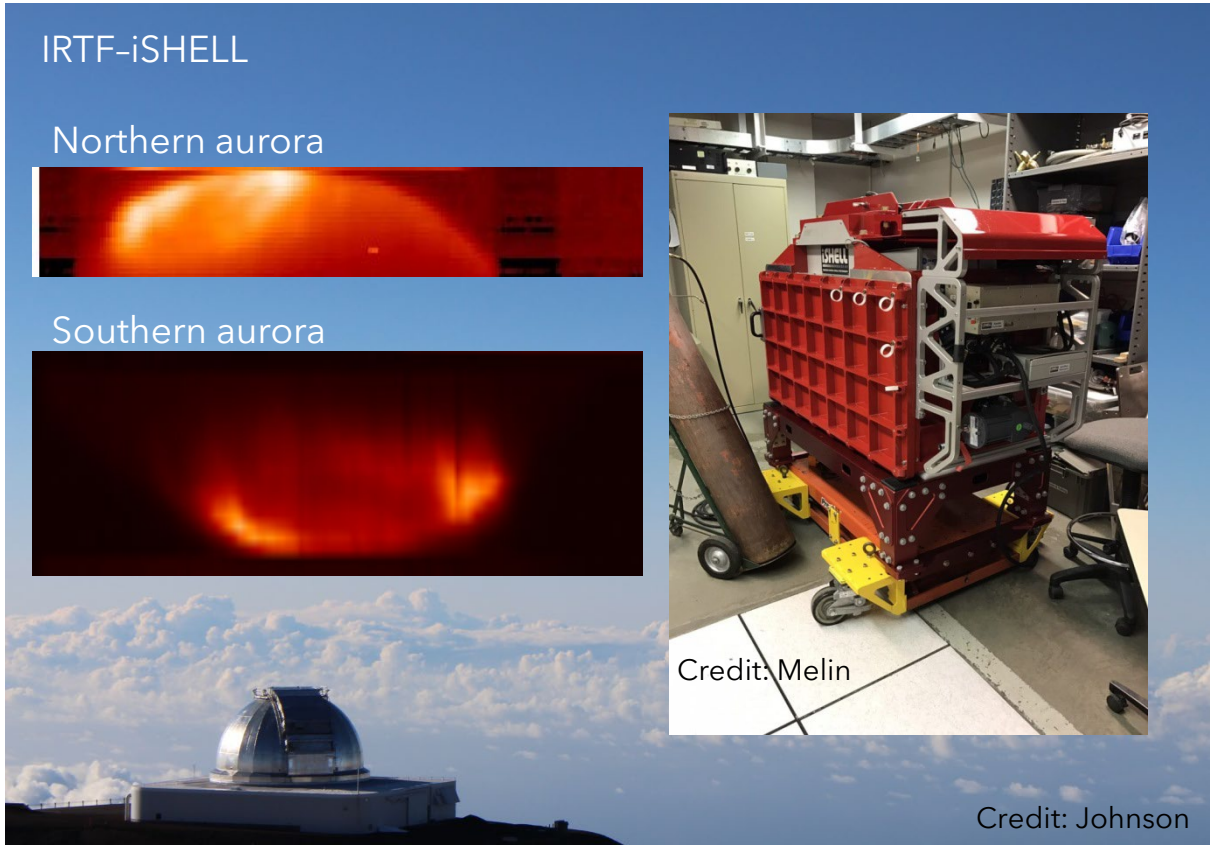
EGU 2022, 26 May 2022

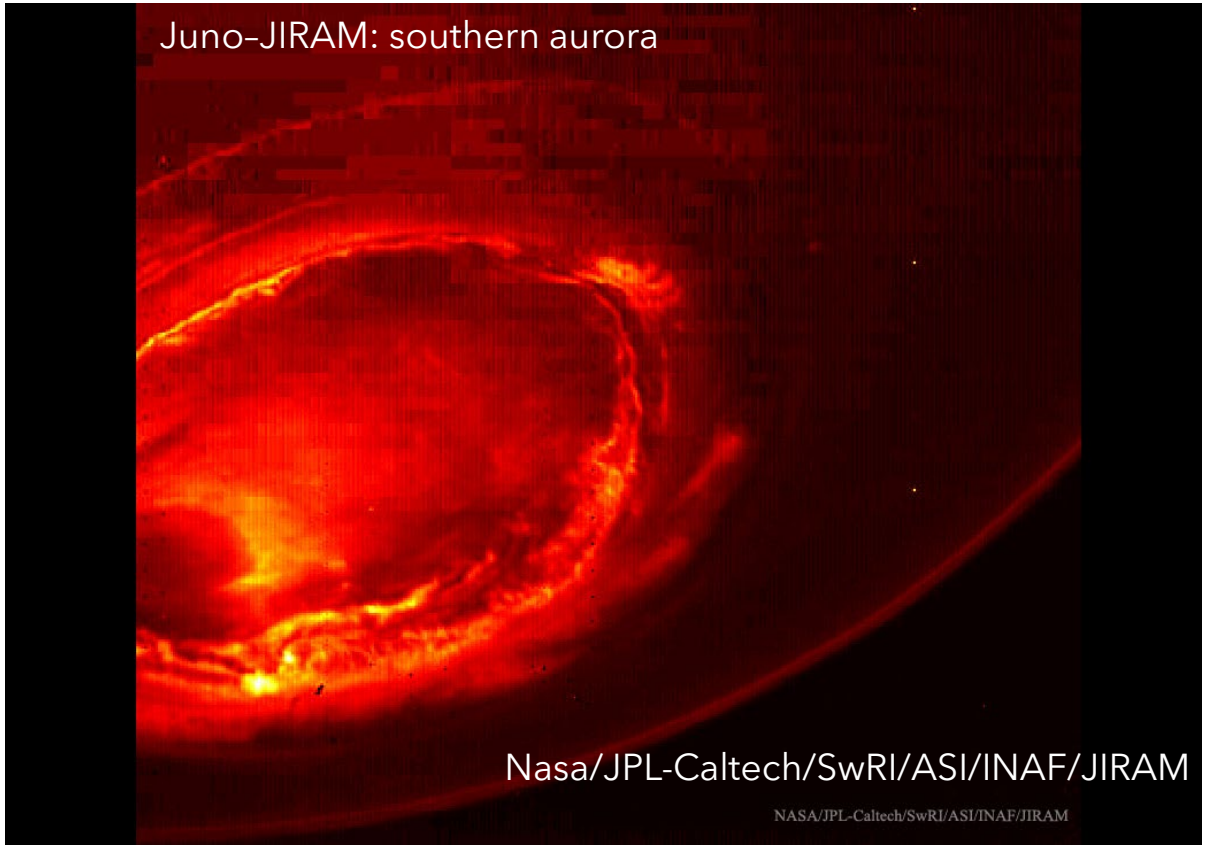
[1] Dr Rosie Johnson|roj40@aber.ac.uk|Aberystwyth University

[2]University of Leicester

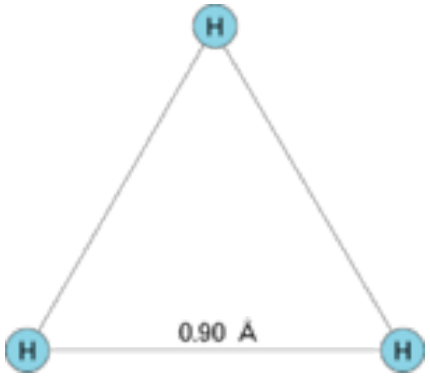
Observations

- Jupiter's northern and southern aurora was observed the long-slit Echelle spectrometer, iSHELL, available at the NASA Infrared Telescope Facility (IRTF). This data was taken while Juno took in-situ measurements of the magnetosphere as well as observing the aurora.
- These ground-based iSHELL measurements are critical as Juno–JIRAM lacks the spectral resolution to measure the Doppler shift of the H_3^+ spectra, from which the line-of-sight (LOS) velocity can be derived, and the ionospheric flows inferred.





H_3^+



- H_3^+ is readily created in hydrogen rich atmospheres (such as Jupiter's) through a fast reaction, beginning with ionisation:

$$H_2 + hv \rightarrow H_2^+ + e$$

$$H_2 + e^* \rightarrow H_2^+ + e + e$$

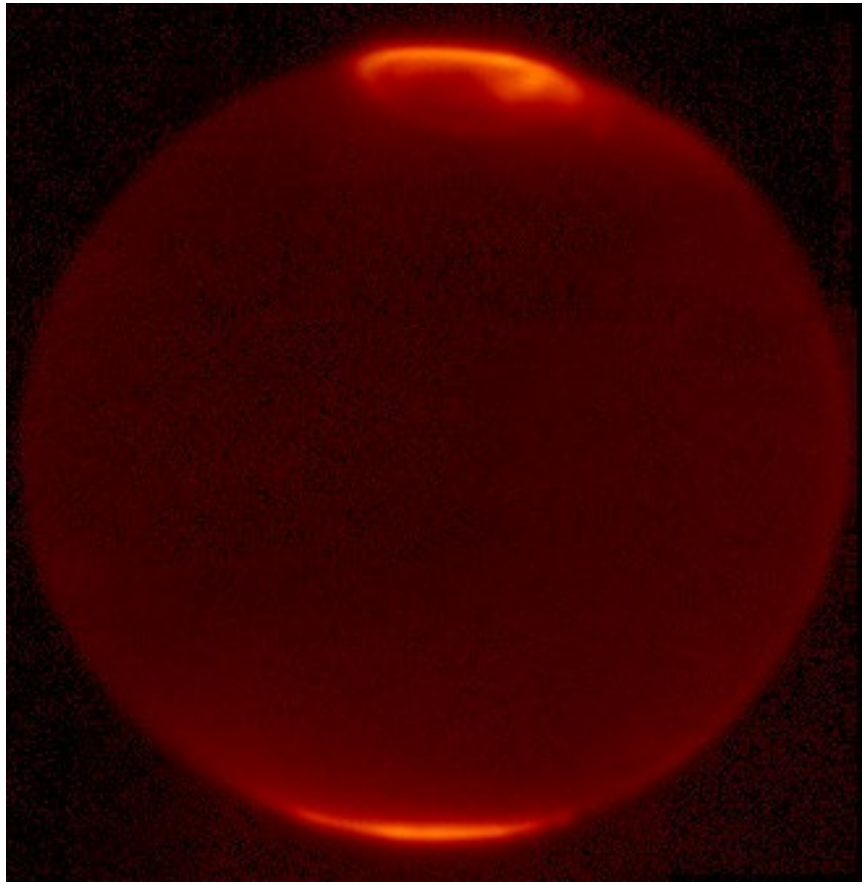
$$H_2^+ + H_2 \rightarrow H_3^+ + H$$

- And destroyed through dissociative recombination:

$$H_3^+ + e^+ \rightarrow H_2 + H$$

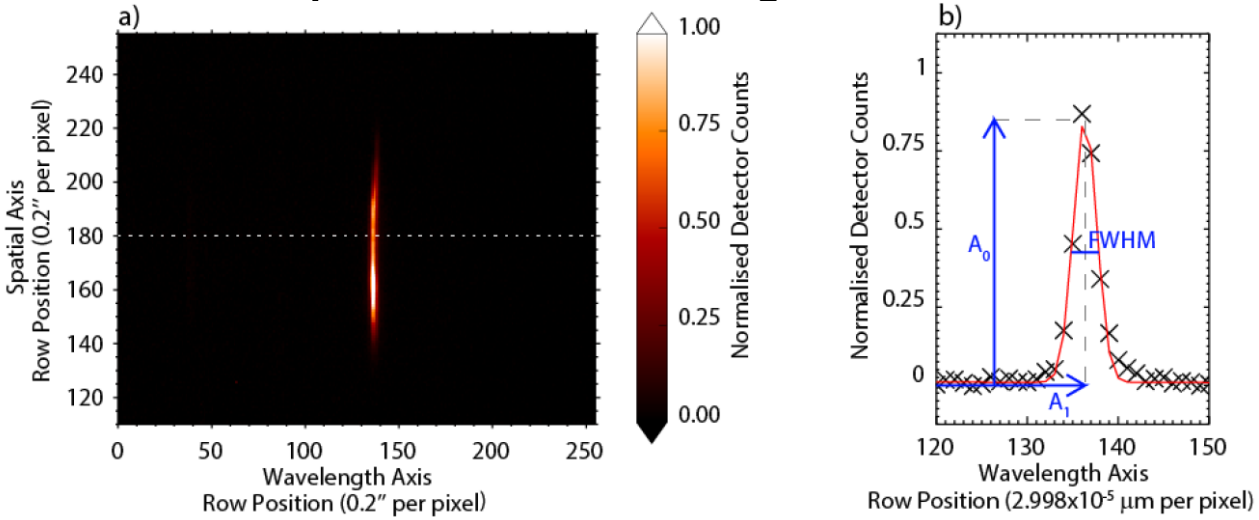
$$H_3^+ + e^+ \rightarrow H + H + H$$

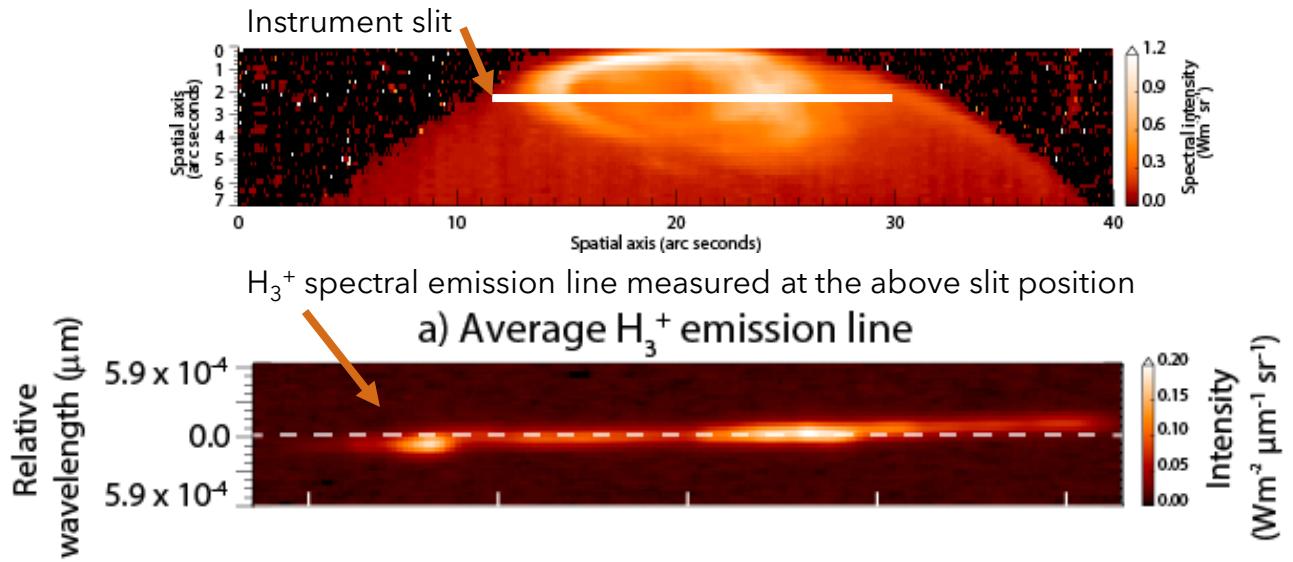
- At the equator lifetime is ~1.6 hours and in the auroral regions its on the order of tens of seconds.
- H_3^+ spectroscopy:
  - No permanent dipole because its three hydrogen atoms in an equilateral triangle, therefore no pure rotational spectrum.
  - Centrifugal forces distort the triangle producing a very small, temporary dipole which causes ro-vibrational excitation.



Jupiter at ~4 microns.Credit: Connerney and Stallard

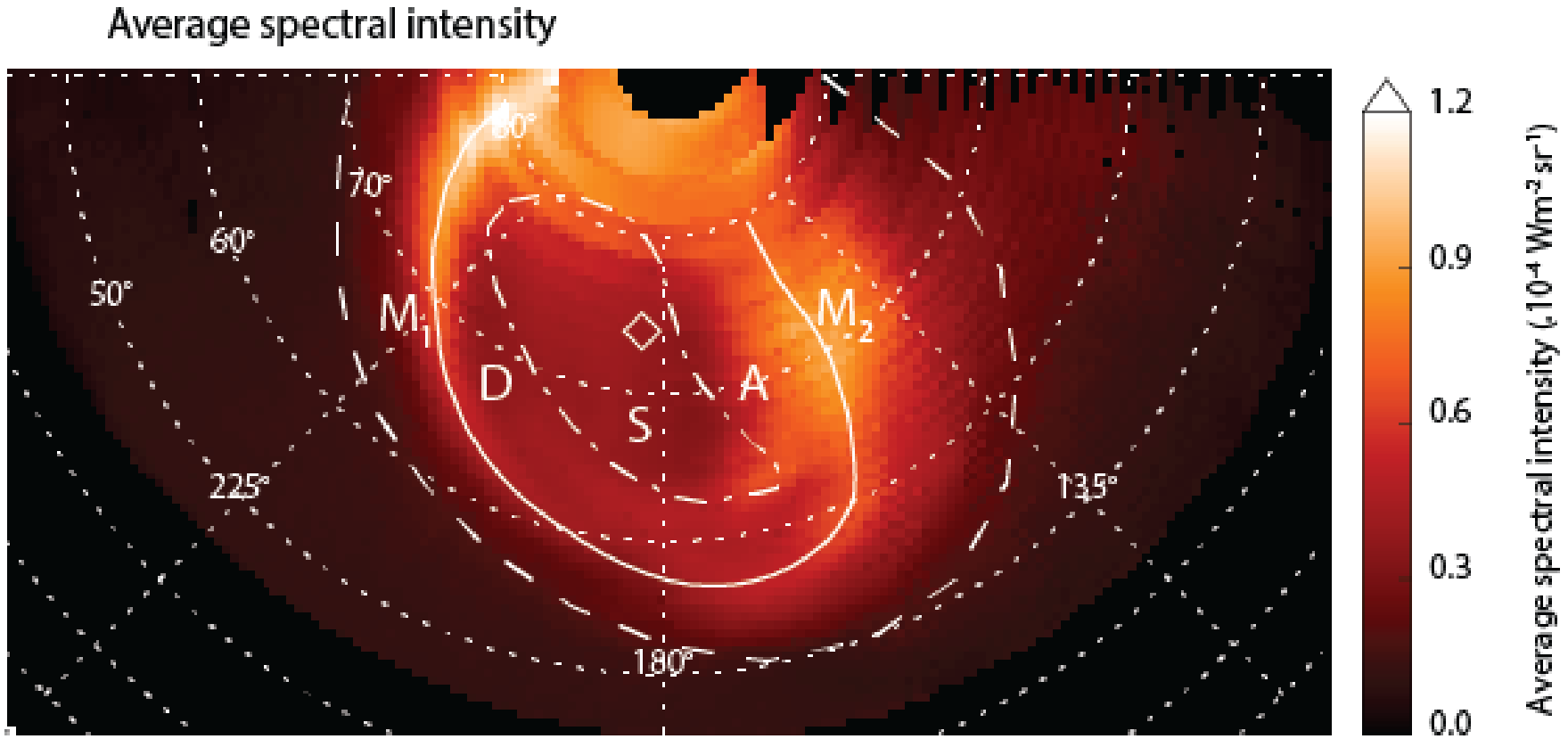
Observing the IR aurora of Jupiter with H_3^+





- The telescope is moved so that the slit of instrument scans the whole auroral region
- Gaussian is fitted to every spatial position along the emission line for each slit position:
  - The intensity is derived from the coefficient A_0, which is the height of the gaussian.
  - The LOS velocity is derived from the Doppler shift, which is measured using the coefficient A_1

Mapping the H_3^+ properties onto polar projections
Data: Very Large Telescope (VLT)–CRIRES 31 Dec 2012

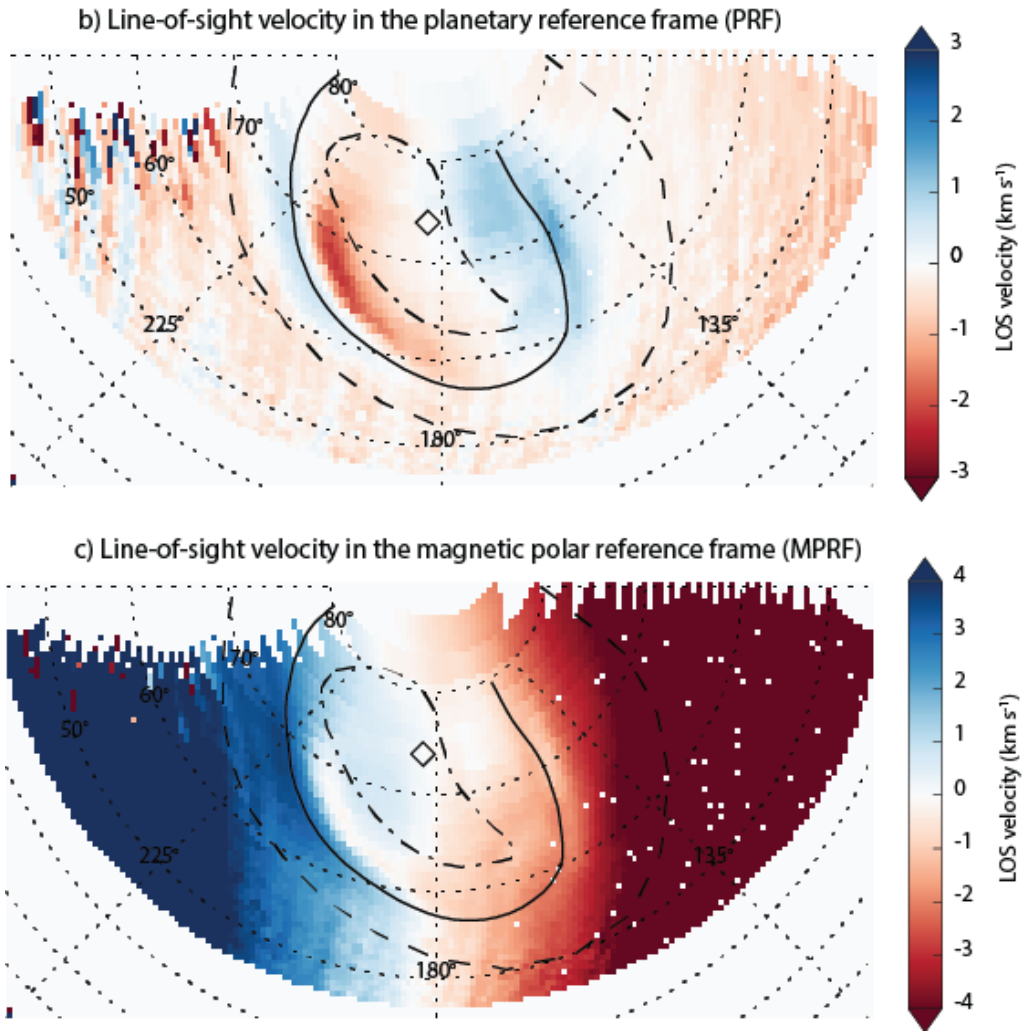


Johnson et al. (2017)

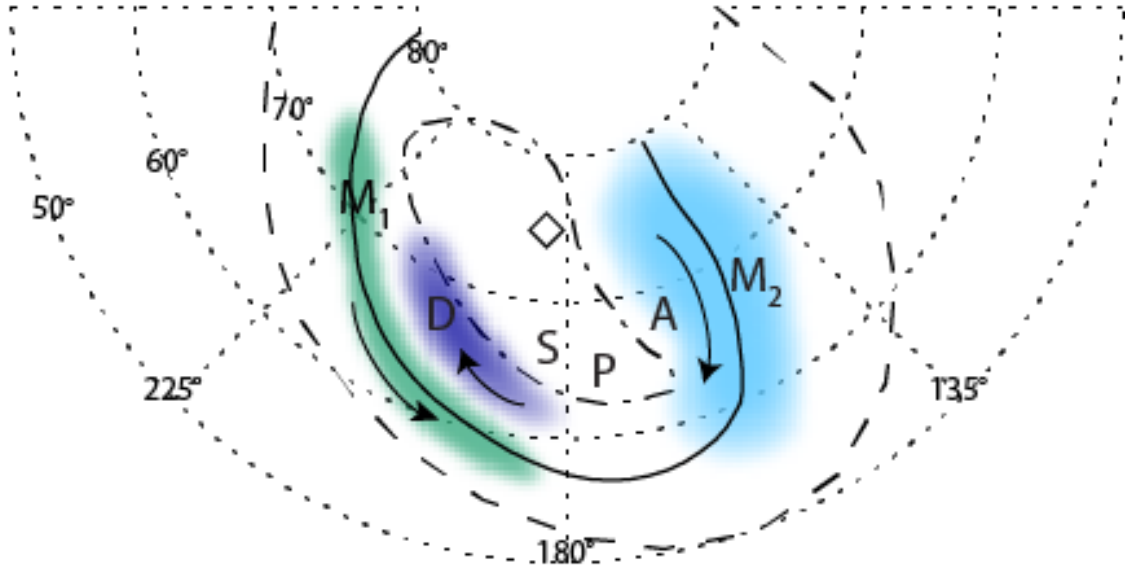
M_1 - Narrow section of main auroral emission
M_2 - Diffuse section of main auroral emission
D - UV dark region
S - UV swirl region
A - UV active region

◇ Auroral centre (Grodent et al., 3003)
Io magnetic footprint (Grodent et al., 2008)
Peak in IR spectral intensity
Region of stationary H_3^+ ions (Stallard et al.,2003)

Auroral ionospheric flows in Jupiter's northern aurora (VLT–CRIRES)



Johnson et al. (2017)

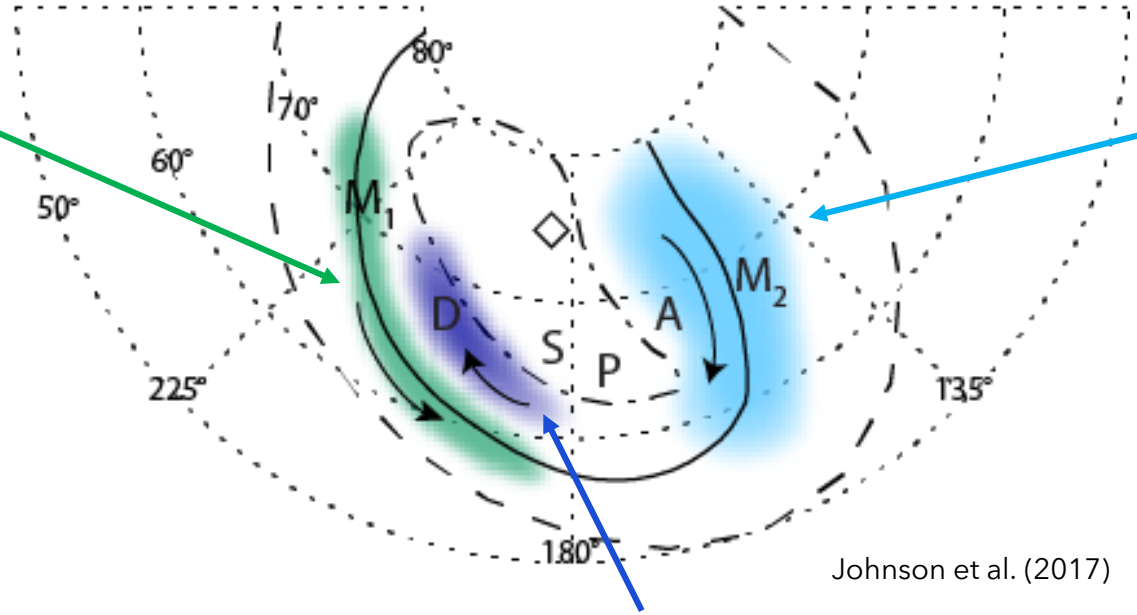


Johnson et al. (2017)

Auroral ionospheric flows in Jupiter's northern aurora (VLT–CRIRES)

- **Super-rotating flows** in the dawn-side of the main auroral emission
- Could be caused by :
  - **driving from a dynamically changing thermosphere** following a solar wind compression (Yates et al., 2014)
  - **or the increase in angular velocity of magnetic field lines** past corotation as they rotate into the dawn sector of the magnetosphere and are compressed.

Schematic of ionospheric flows measured by VLT-CRIRES 12 Dec 2012



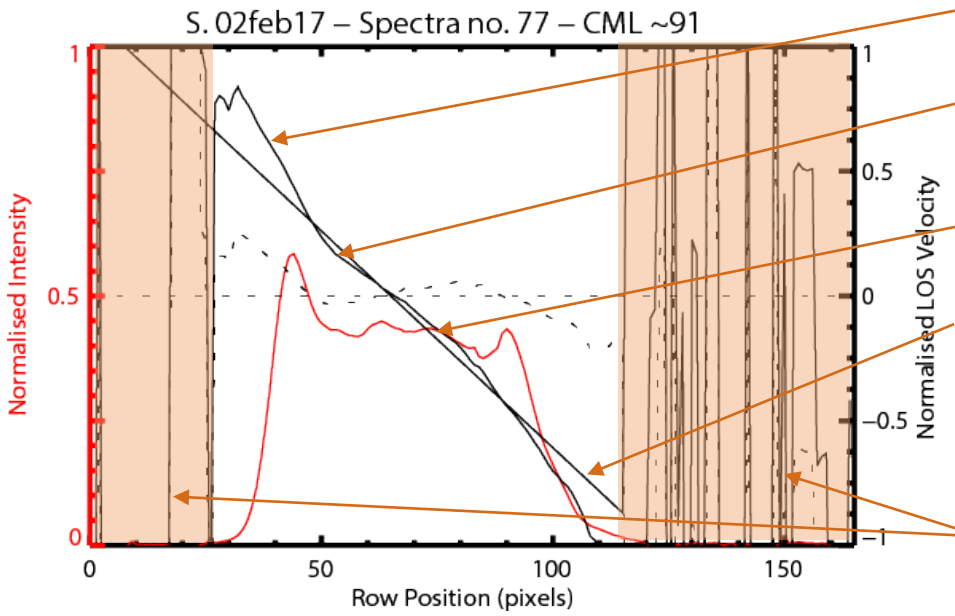
Johnson et al. (2017)

- **Sub-rotating flows** in the dusk-side of the main auroral emission.
- **In agreement current understanding of the generation of the aurora** (eg: Cowley and Bunce, 2001)

- A region of **stationary H_3^+** ions (relative to the magnetic pole) in the polar aurora.
- Previously located coincident to the UV swirl region, now observed coincident with UV dark region, which is also dark in the IR.
- Stationary region is **due to coupling to the solar wind** either through:
  - a Dungey-like process where a single convection cell is confined by the Vasyliunas cycle (Stallard et al., 2003, Cowley et al., 2003)
  - or through solar wind viscous flow interaction (Delamere and Bagenal, 2010).

Are similar flows seen in the Southern aurora?

PRELIMINARY RESULTS: IRFT-iSHELL 02 Feb 2017



Super-rotation

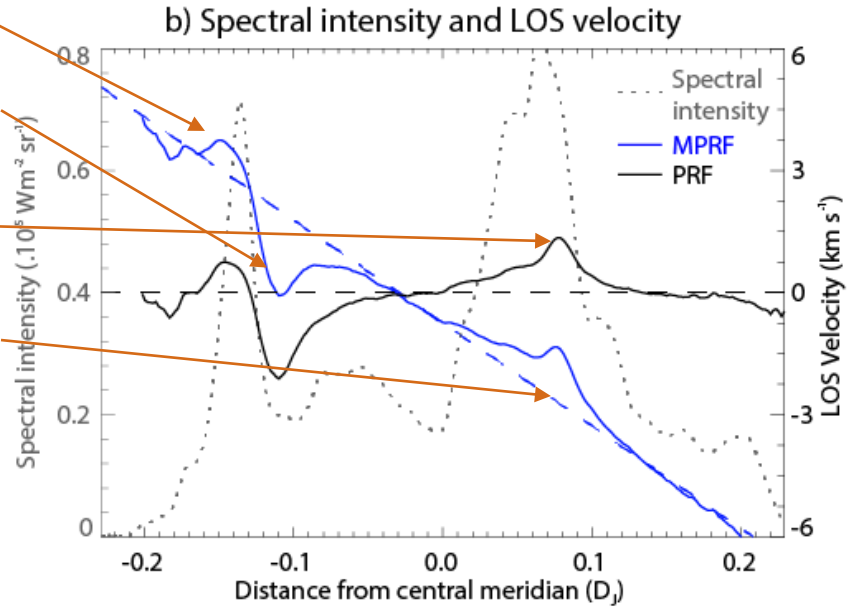
Stationary region

Sub-rotation

Line of corotation

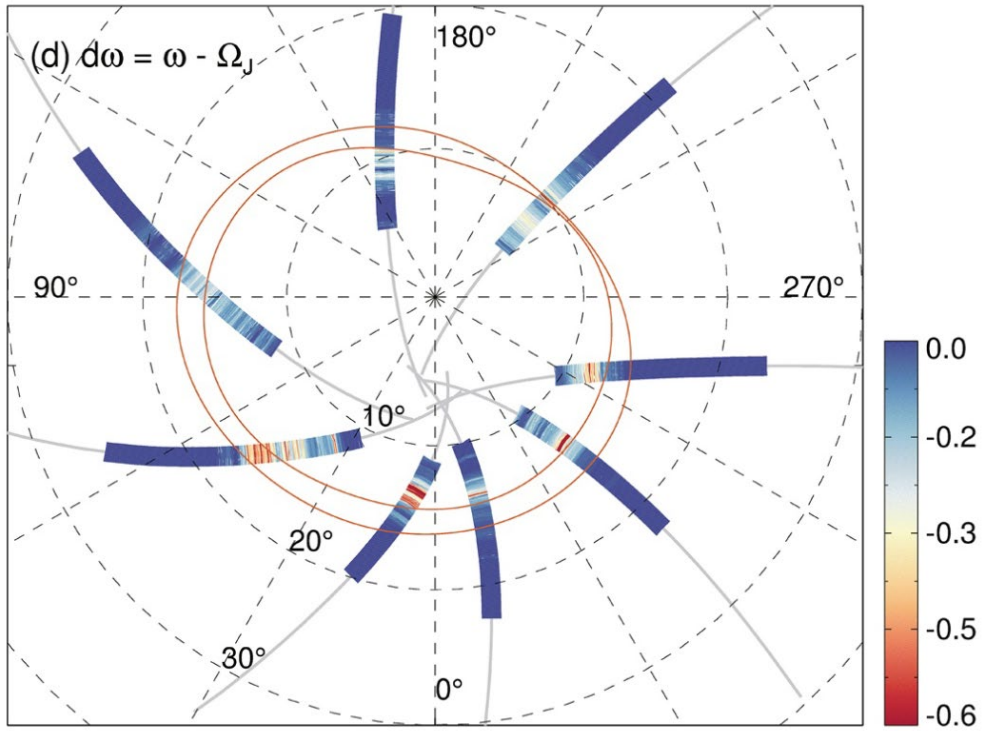
Noise off the limb of the planet

VLT-CRIRES 31 Dec 2012 (Johnson et al., 2017)

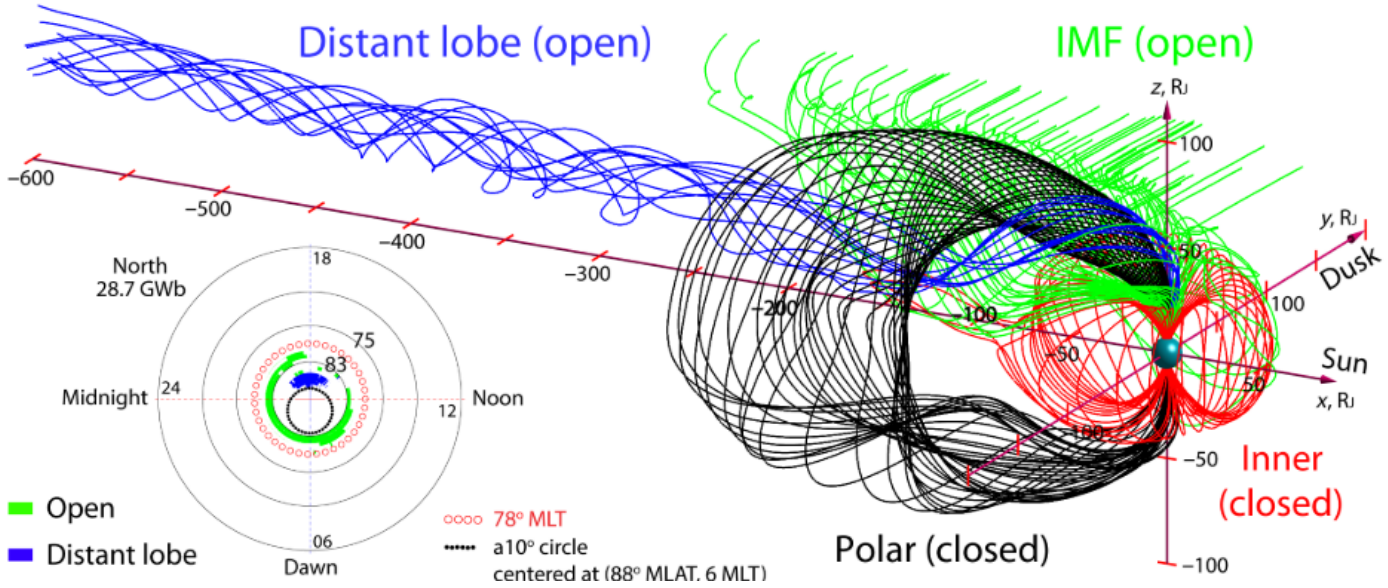


- Note that further work regarding the position of the slit on Jupiter needs to be completed for iSHELL data and final LOS velocity calibration is not complete.
- Southern auroral flows shows some evidence of similar flows as in the northern aurora: is this expected?

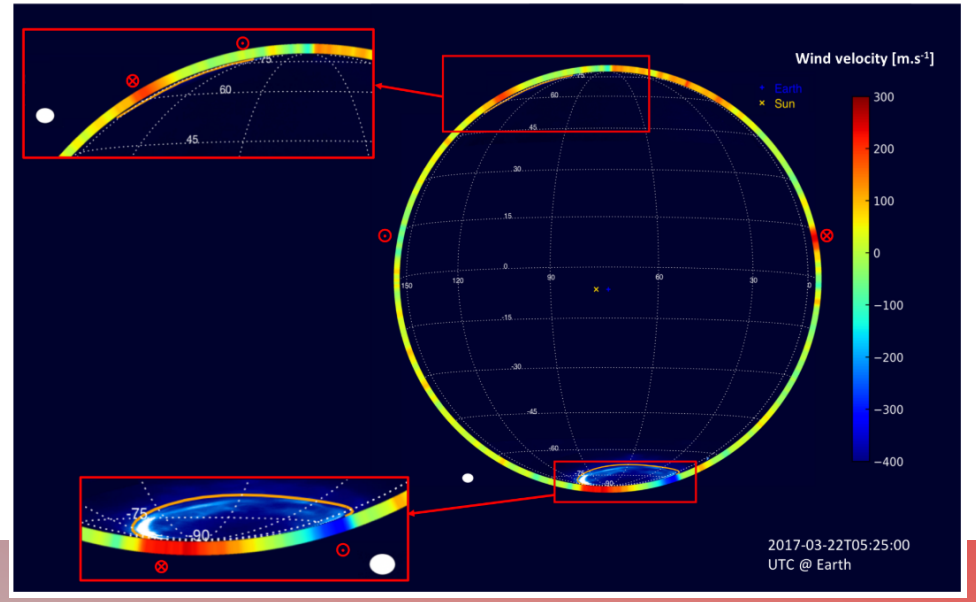
Next steps: compare H_3^+ data to Juno data and other models.



Wang et al. (2021) model using first 9 Juno PJs: Angular velocity of the ionospheric plasma, normalized to planetary rotation about the magnetic pole.



Zhang et al. (2021) model suggests that Jupiter's open flux could be stretched into a crescent-like structure poleward of the main emission and that the rotation of the system should produce a twisted-bundle of closed flux in the dawn sector either of which may produce the H_3^+ stationary region.



Cavalie et al. (2021): LOS velocity measurements from the stratosphere. Sub-rotation observed, particularly in the south.

Conclusions

- Previous ground-based H_3^+ studies have identified several significant ionospheric flows in Jupiter's auroral region.
- Some evidence of ionosphere flows similar to those in the northern aurora were seen in the preliminary iSHELL data, however, the data still requires further calibration and analysis. There are 12 days of observations to analyse in total.
- The next steps will be to compare the ionospheric flows inferred from the H_3^+ observations to Juno data using the model by Wang et al. (2021), other magnetosphere models such as Zhang et al. (2021) and stratospheric data Cavalie et al. (2021).

Discussion points

- The region coupled to the solar wind (stationary H_3^+ region) in the northern aurora is confined to the UV dark region. The preliminary data of the southern aurora seems to suggest that there might be a stationary H_3^+ region in a similar location to its counterpart in the northern aurora. Is this expected considering the differences between the northern and southern aurora?
- Are there any other data-sets or models that would be useful to compare with the H_3^+ results once the data analysis is completed?

References

- Cavalie et al. (2021) https://doi.org/10.1051/0004-6361/202140330
- Cowley et al. (2003) https://doi.org/10.1029/2002GL016030
- Cowley and Bunce (2001) https://doi.org/10.1016/s0032-0633(00)00167-7
- Delamere and Bagenal (2010) http://dx.doi.org/10.1029/2010JA015347
- Johnson et al. (2017) https://doi.org/10.1002/2017JA024176
- Stallard et al. (2003) http://dx.doi.org/10.1029/2002GL016031
- Wang et al. (2021) https://doi.org/10.1029/2020JA029085
- Yates et al. (2014) http://dx.doi.org/10.1016/j.pss.2013.11.009
- Zhang et al. (2021) https://doi.org/10.1126/sciadv.abd1204