Cassini VIMS observations of Saturn's infrared aurora

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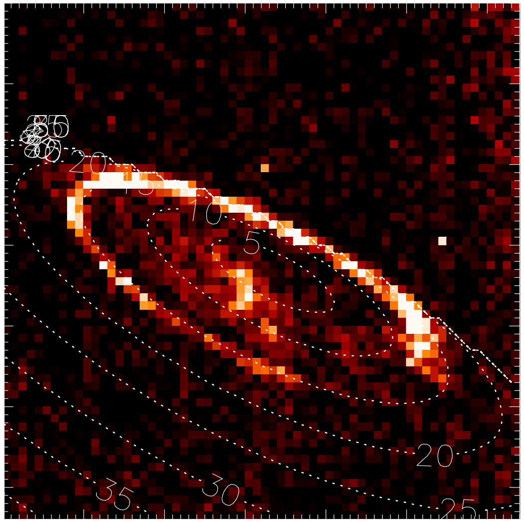
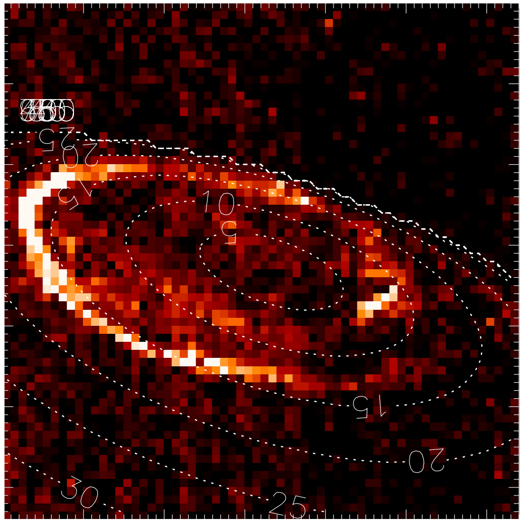
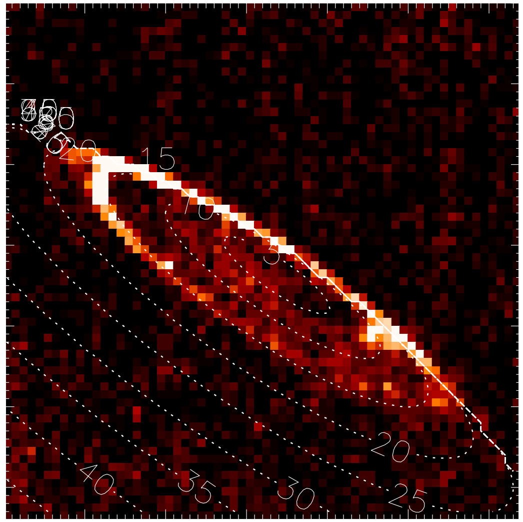
MAG-VIMS collaboration team







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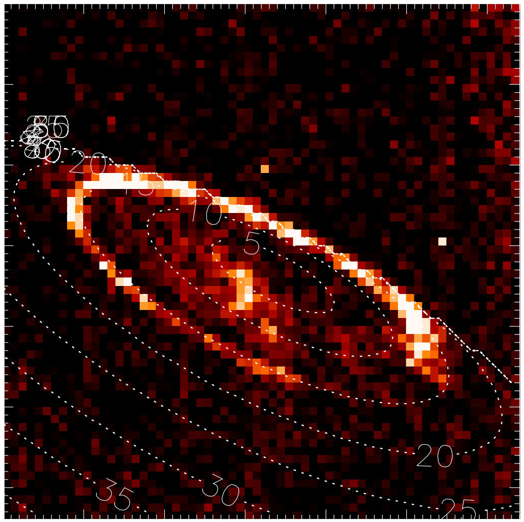
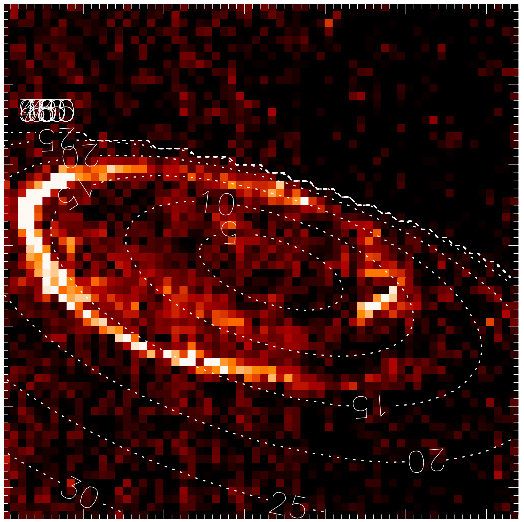
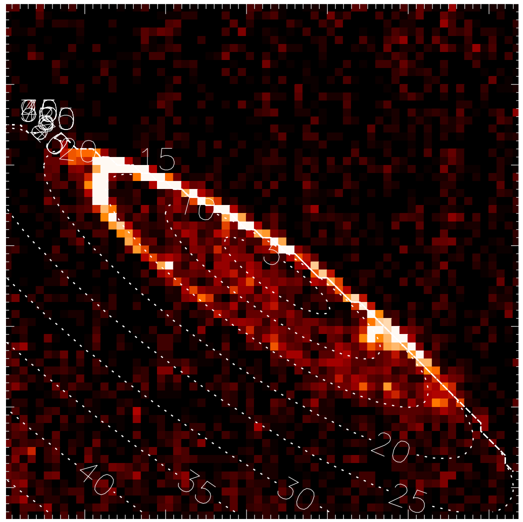
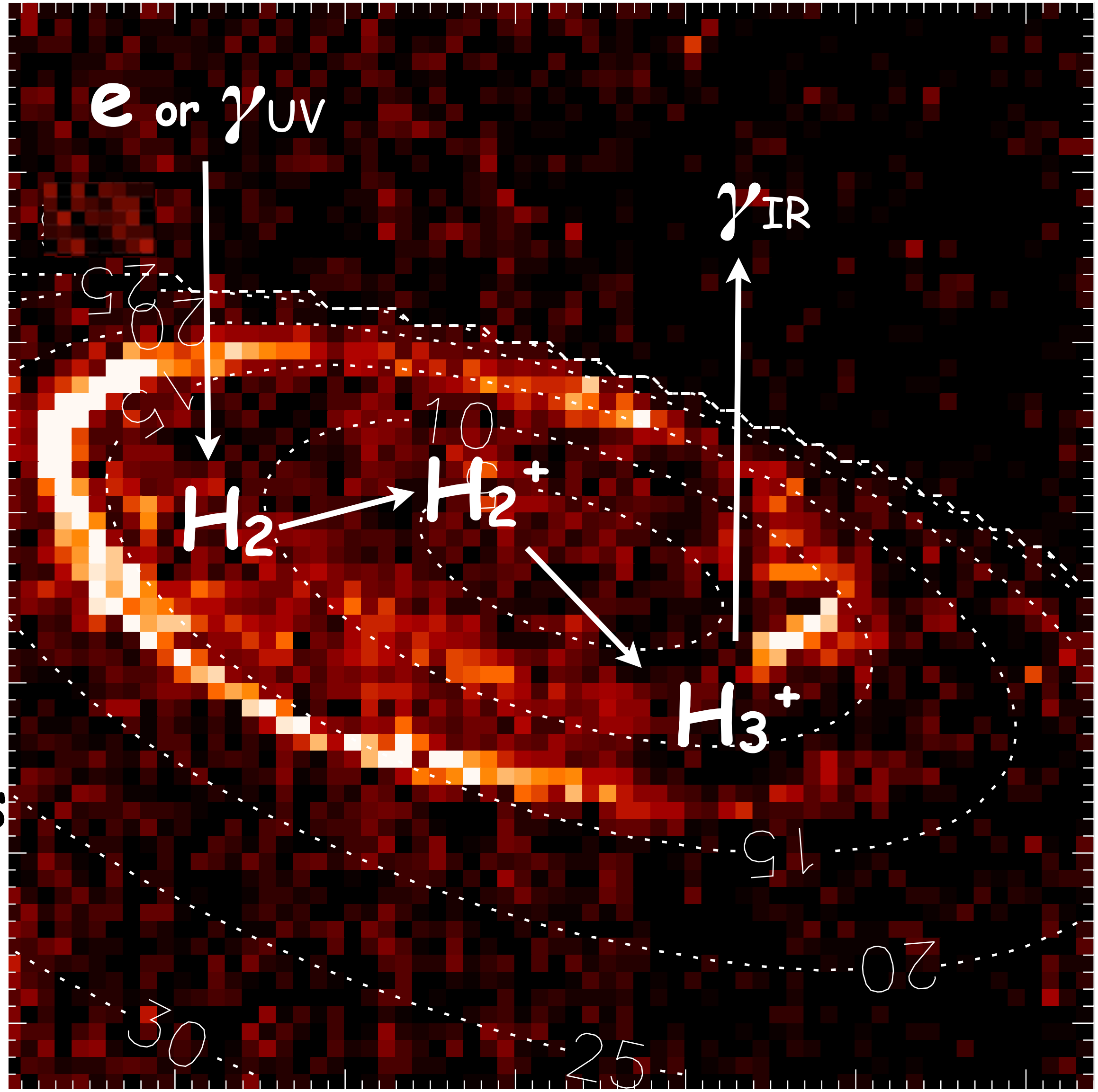
Cassini VIMS observations of Saturn's infrared aurora

1. Introduction to IR auroral observations with VIMS
2. Different morphologies compared to the UV
3. Typical location of the IR main oval
4. Latitudinal and hemispheric variations in IR intensity
5. SKR phase modulation of IR aurora
6. Ongoing and future studies

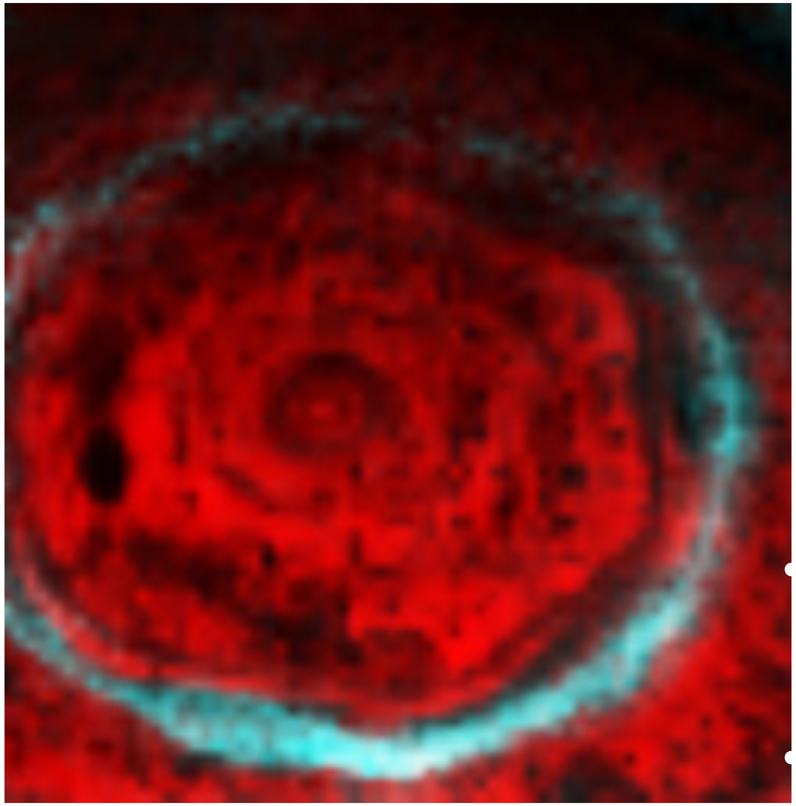
1.1 Saturn's infrared aurora

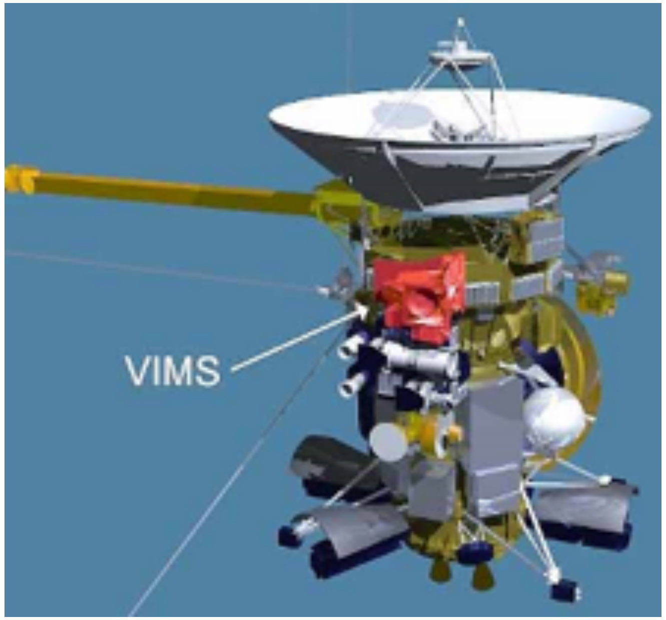
- Emissions from ro-vibrational transitions of the H_3^+ ionized molecule.
- Atmospheric H_2 is ionized by incident electrons or solar UV.
- Peak emission wavelengths are 3-4 μm.



1.2 Cassini Visual and Infrared Mapping Spectrometer

- Infrared spectral coverage: 0.85 – 5.1μm in 256 bands.
- Field of view: up to 32 x 32 mrad (64 x 64 pixels).
- Located on Cassini remote sensing palette with ISS, CIRS, UVIS.
- Full description: Brown et al. (2004).





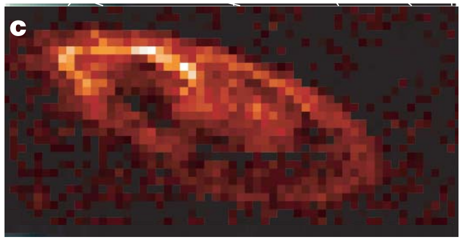
- VIMS accumulates images by taking a full spectrum pixel-by-pixel.
- Typical image accumulation time is tens of mins.

1.3 VIMS infrared wavelengths

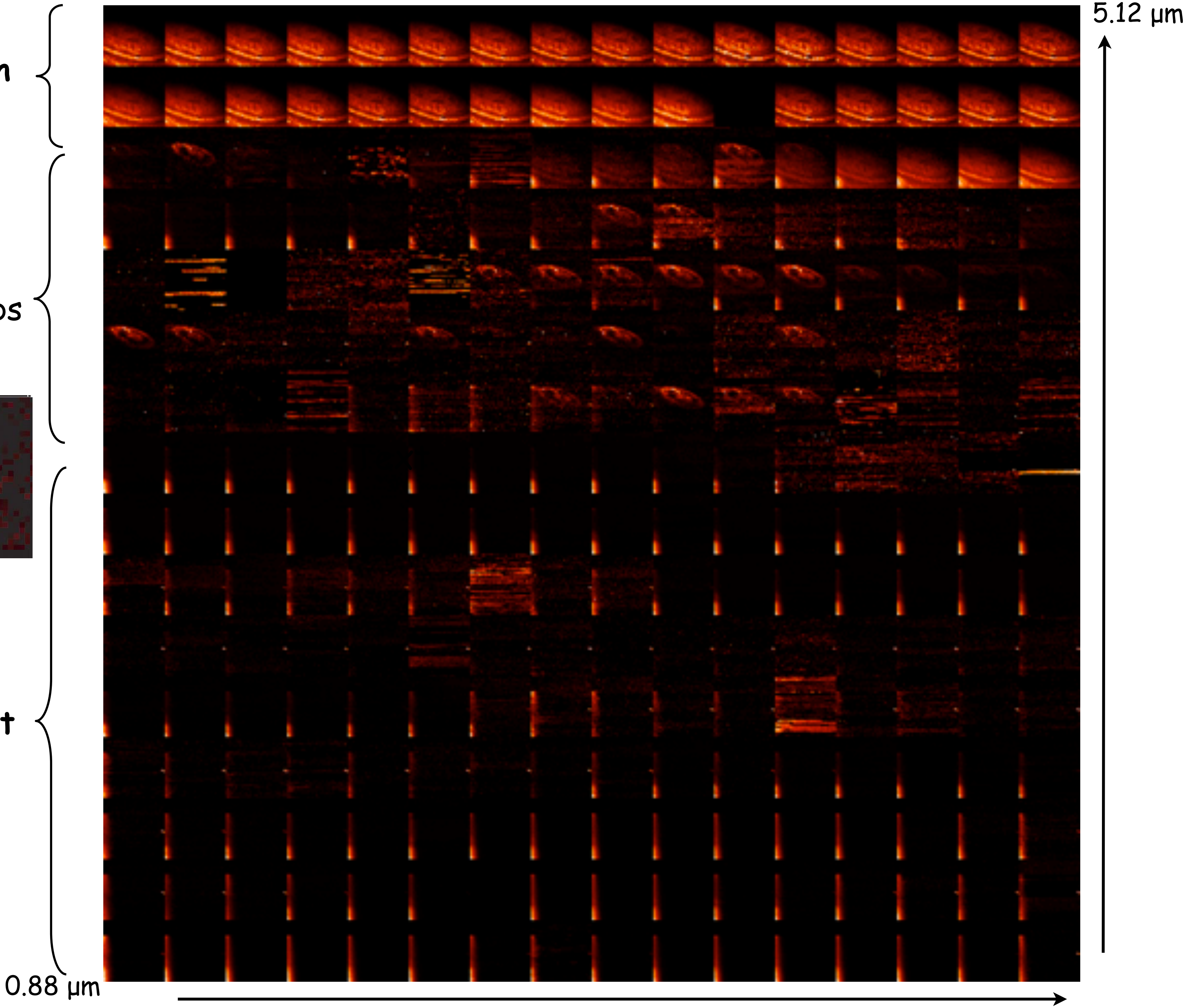
Thermal emission

Auroral emission

- methane absorbs sunlight



Reflected sunlight



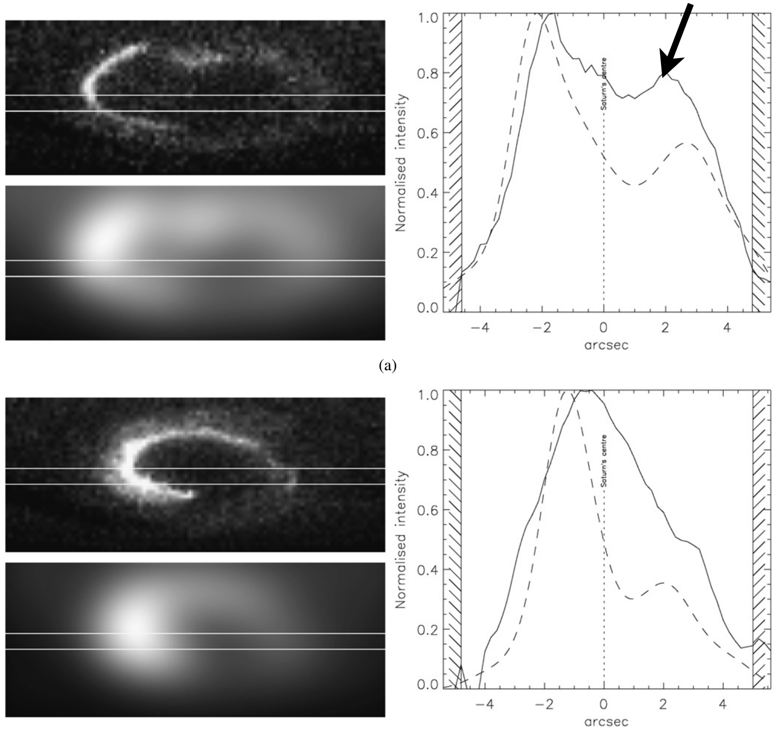
1.4 Ground-based and VIMS observations

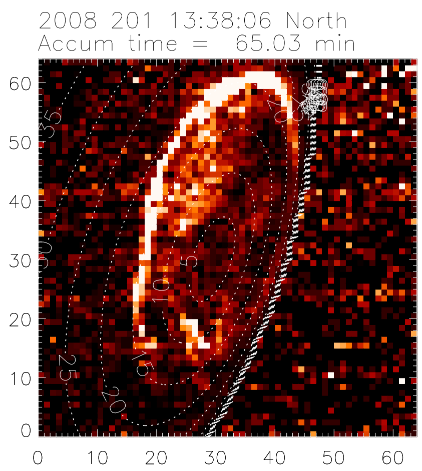
Example auroral image

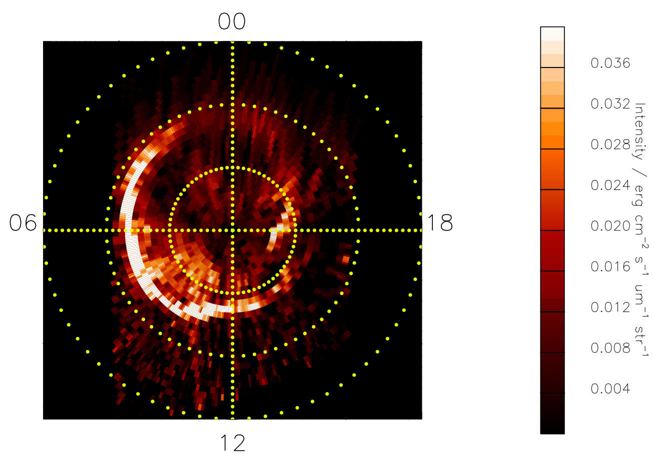
IR intensity across slit

slit

Stallard et al. (2007)

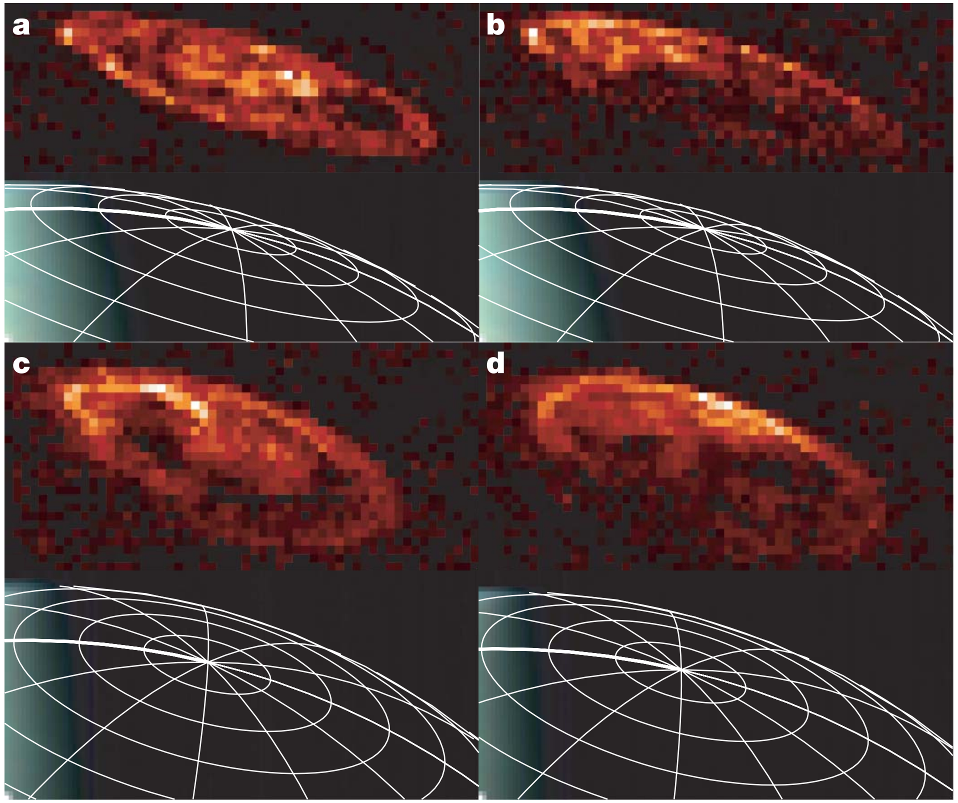






- Some Saturnian IR auroral wavelengths can be observed using ground-based telescopes.
- VIMS has lower spectral resolution (~16 nm) than these, but its observations have higher spatial and temporal resolution and are not affected by Earth's atmosphere.

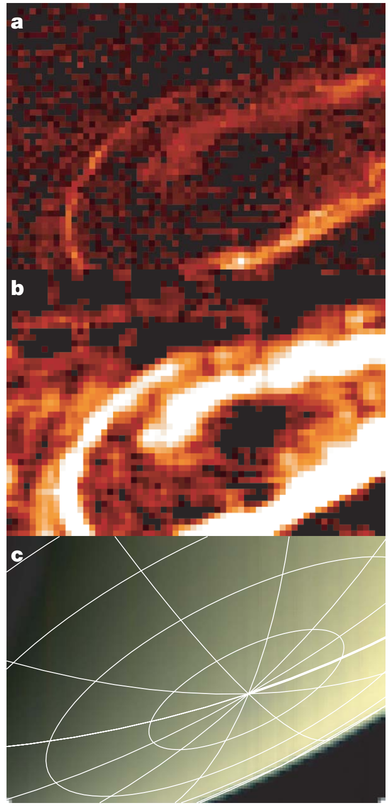
2. Complex structure in Saturn's IR aurora



← Northern hemisphere polar infilling.

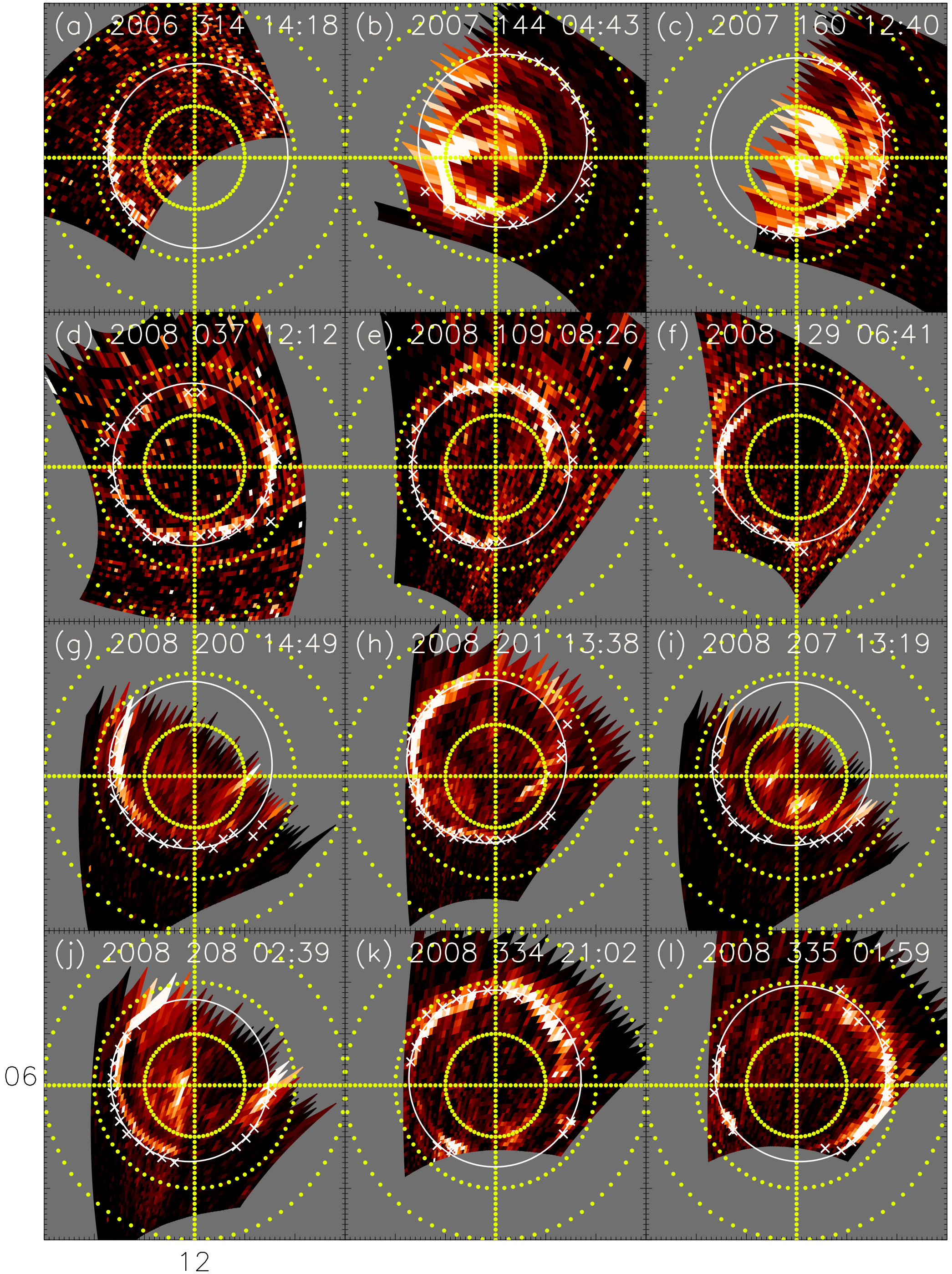
Southern hemisphere contracted spiral. →

Stallard et al. (2008)

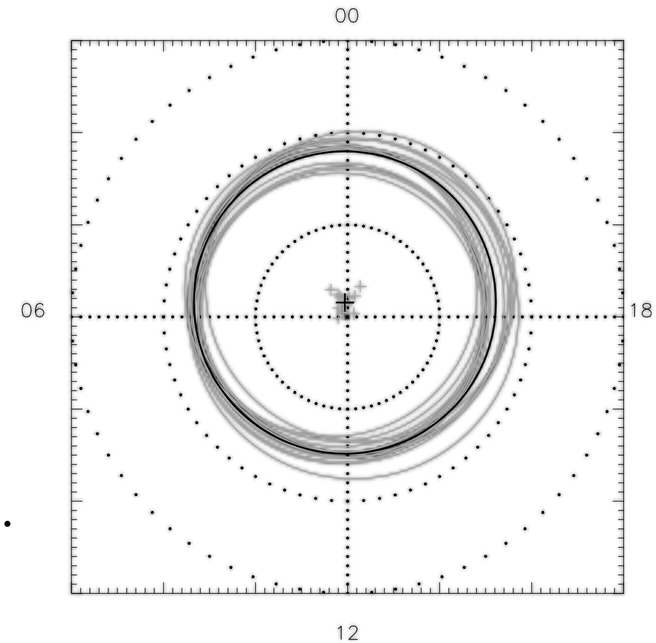


- Intense IR emission poleward of and separated from the main oval has been observed, unlike any polar features seen in the UV.
- A high-latitude spiral morphology was attributed to an interval of magnetospheric compression by comparison with past UV studies.
- The presence of a lower-latitude extended arc was also suggested and linked to inner magnetosphere dynamics.

3.1 Characterising the IR main oval location

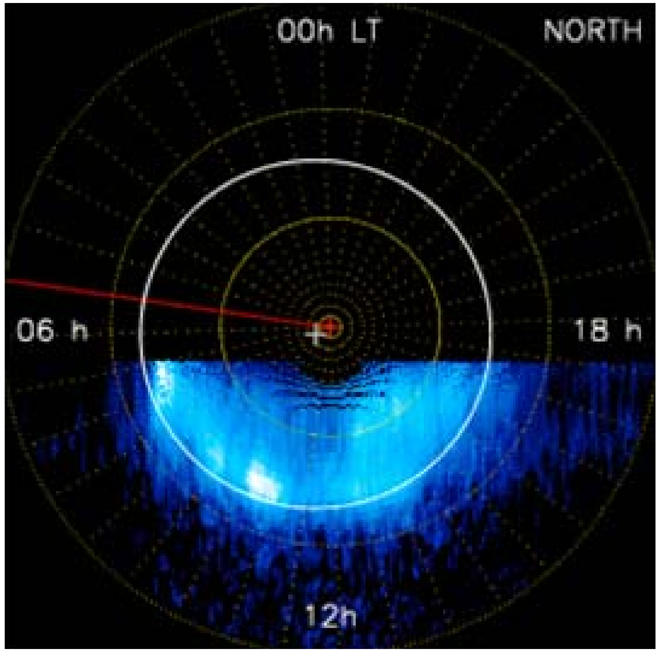


- The equatorward boundary of the northern IR main oval was characterised using a best-fit circle method.
- This is the first time the IR auroral location could be accurately determined, facilitated by VIMS.

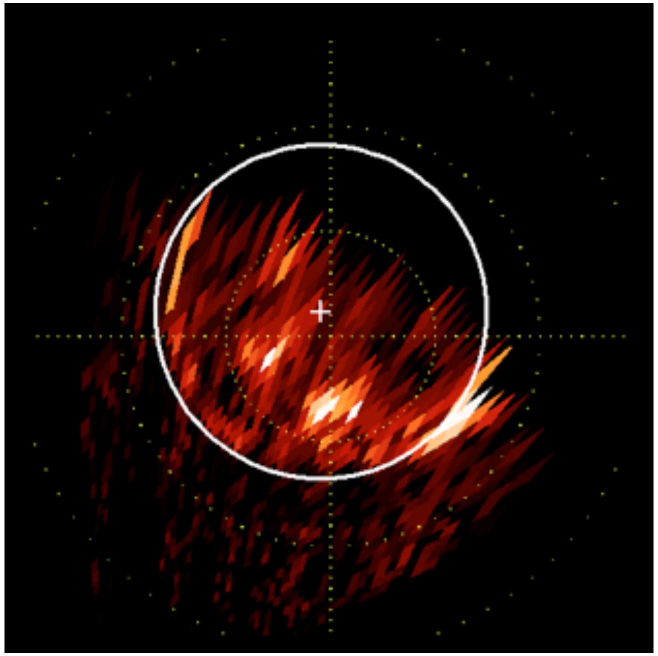


Badman et al. (2011)

3.2 Comparison with northern UV main oval

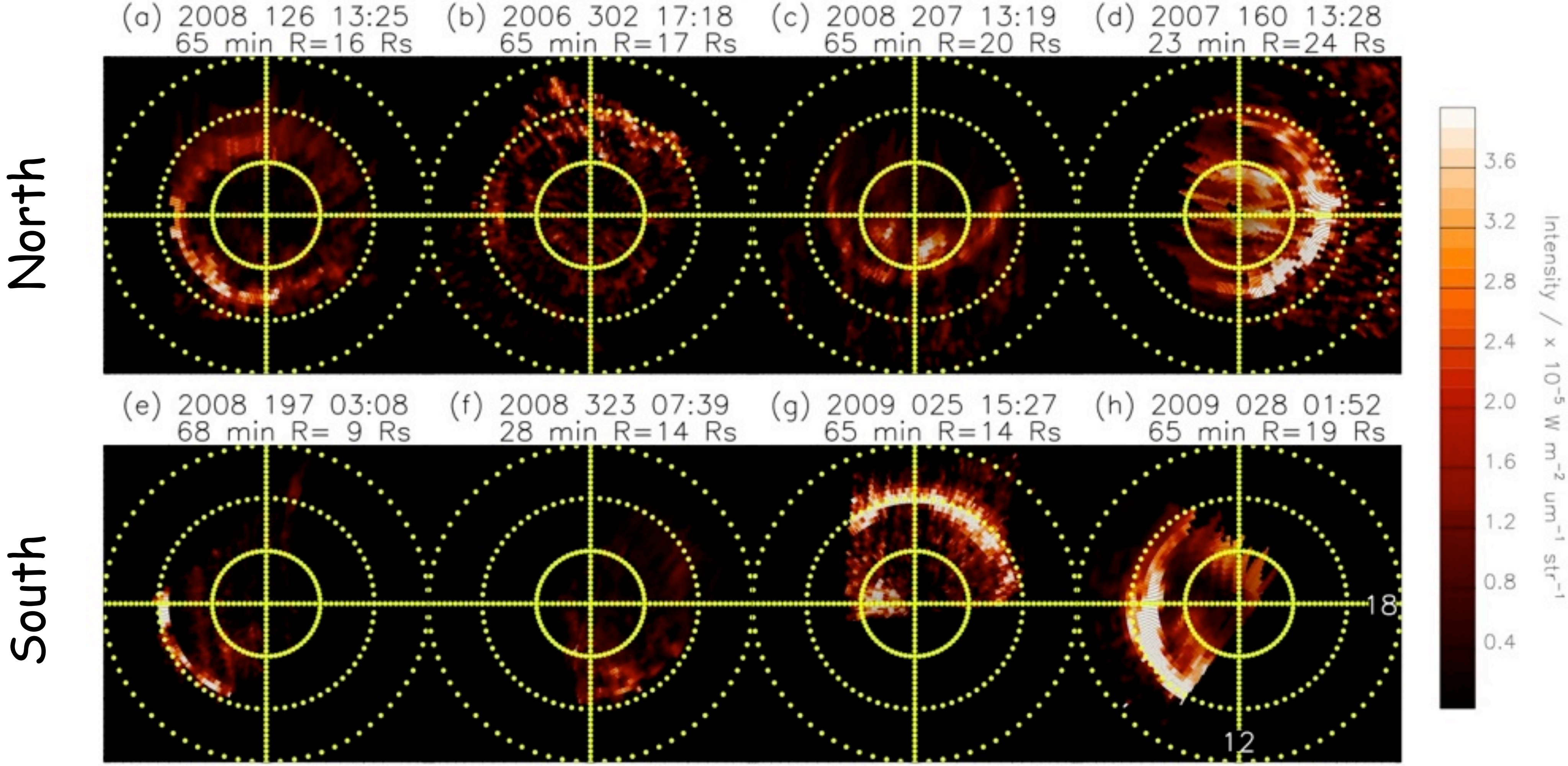


	IR VIMS: Badman et al. (2011)	UV HST: Nichols et al. (2009)
radius	$16.4 \pm 0.2°$	$16.3 \pm 0.6°$



- The best-fit circle radius, anti-sunward offset and dayside latitude all agree with measurements made of the UV aurora (Nichols et al., 2008, 2009; Badman et al., 2006).
- This indicates a common field-aligned current origin for the UV and IR main ovals, despite the different emission mechanisms.
- Also see Melin et al. (2011), this session.

4.1 Hemispheric and latitudinal variations



Bright main oval, dim polar region

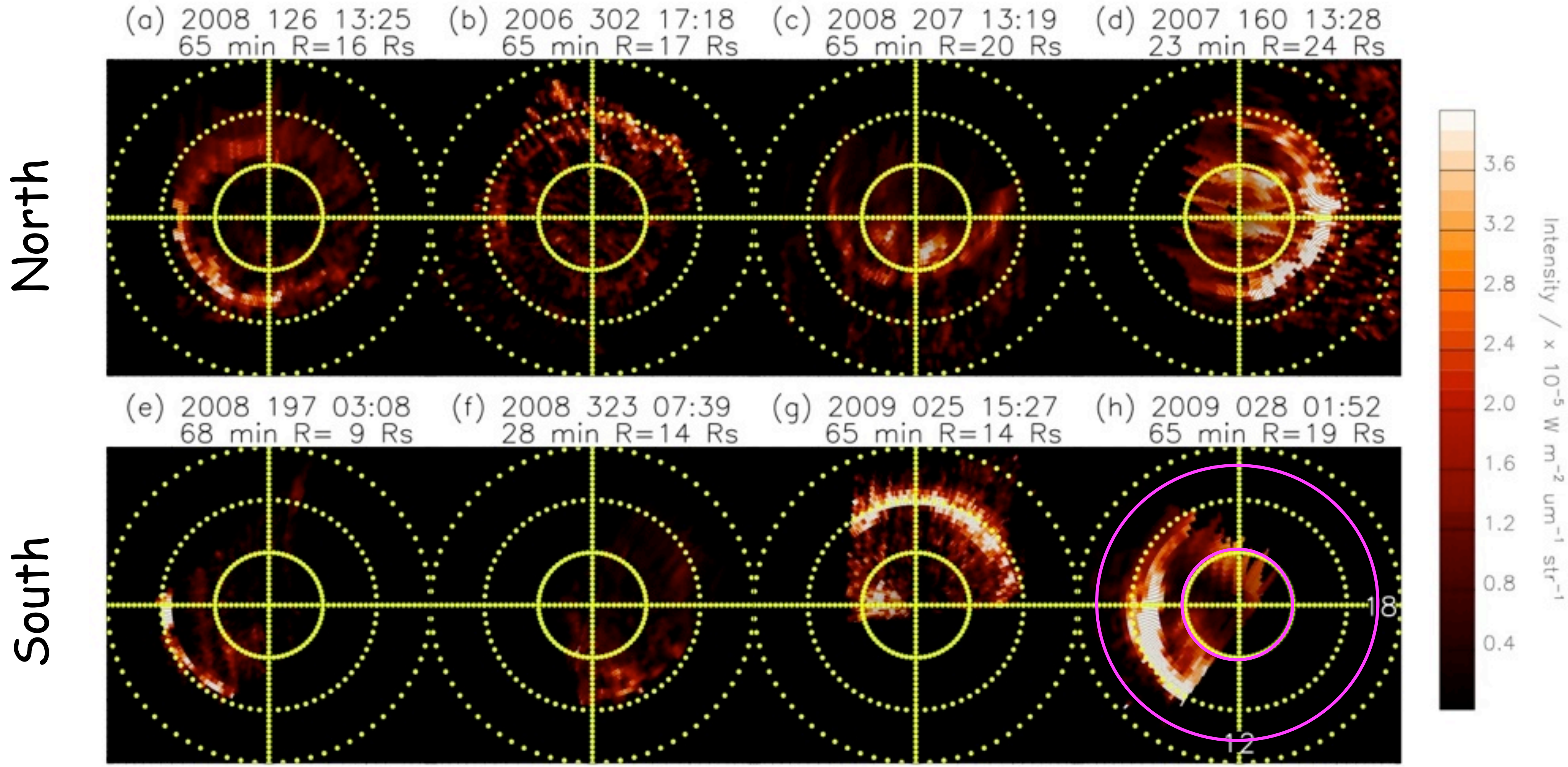
All low intensity, some main oval arcs

Intense main oval and bright polar spots

Intense main oval and polar infilling

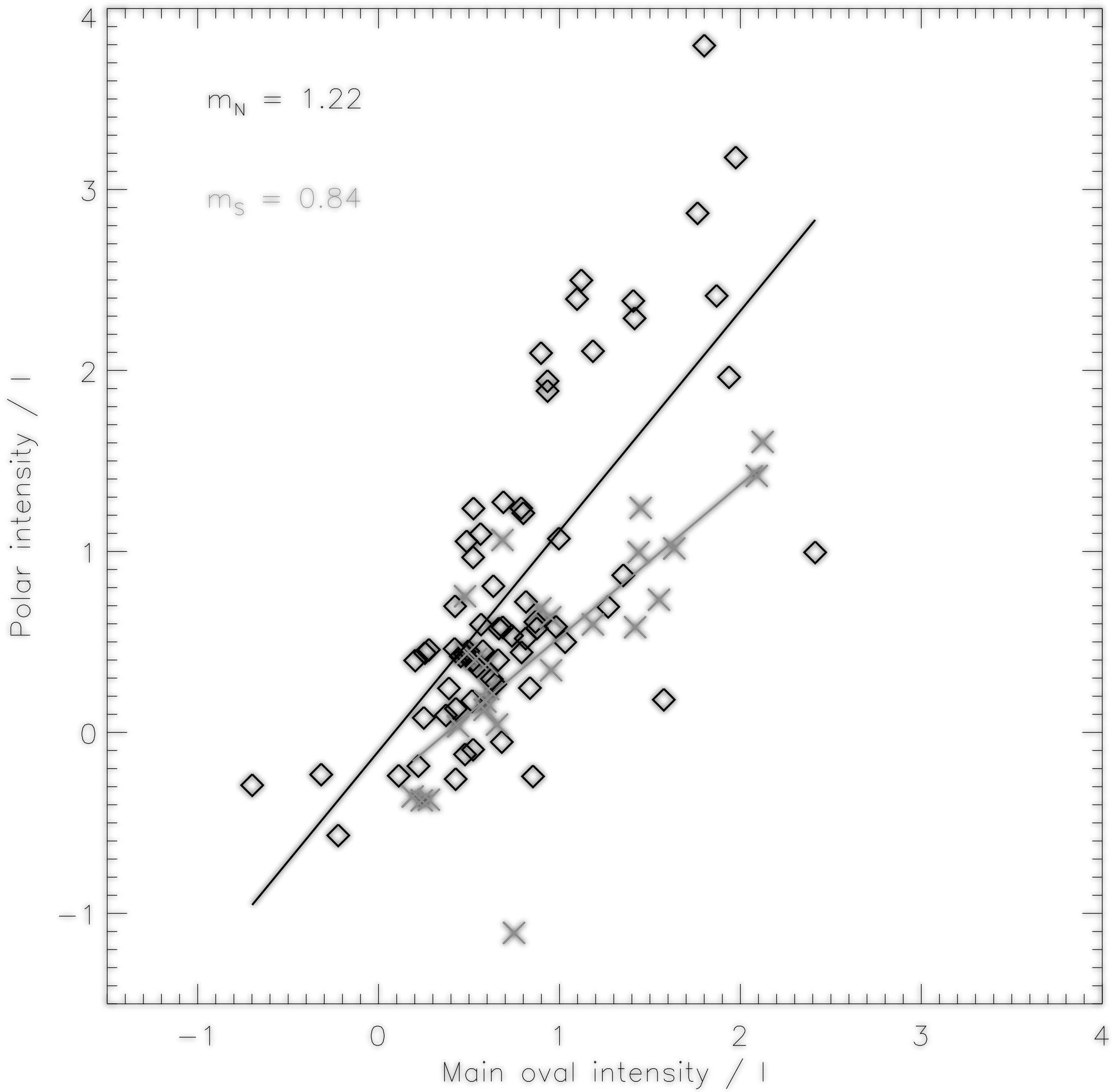
All pre-equinox images i.e. southern summer, θ_{SS}~-19° → -3°.

4.1 Hemispheric and latitudinal variations



- Main oval latitudinal location and width are variable.
- Define 'main oval' region by 10°<θ<25° colat and 'polar' region as θ<10°. Find average intensities in these regions (NB this underestimates the 'real' auroral intensity).

4.2 Hemispheric and latitudinal variations

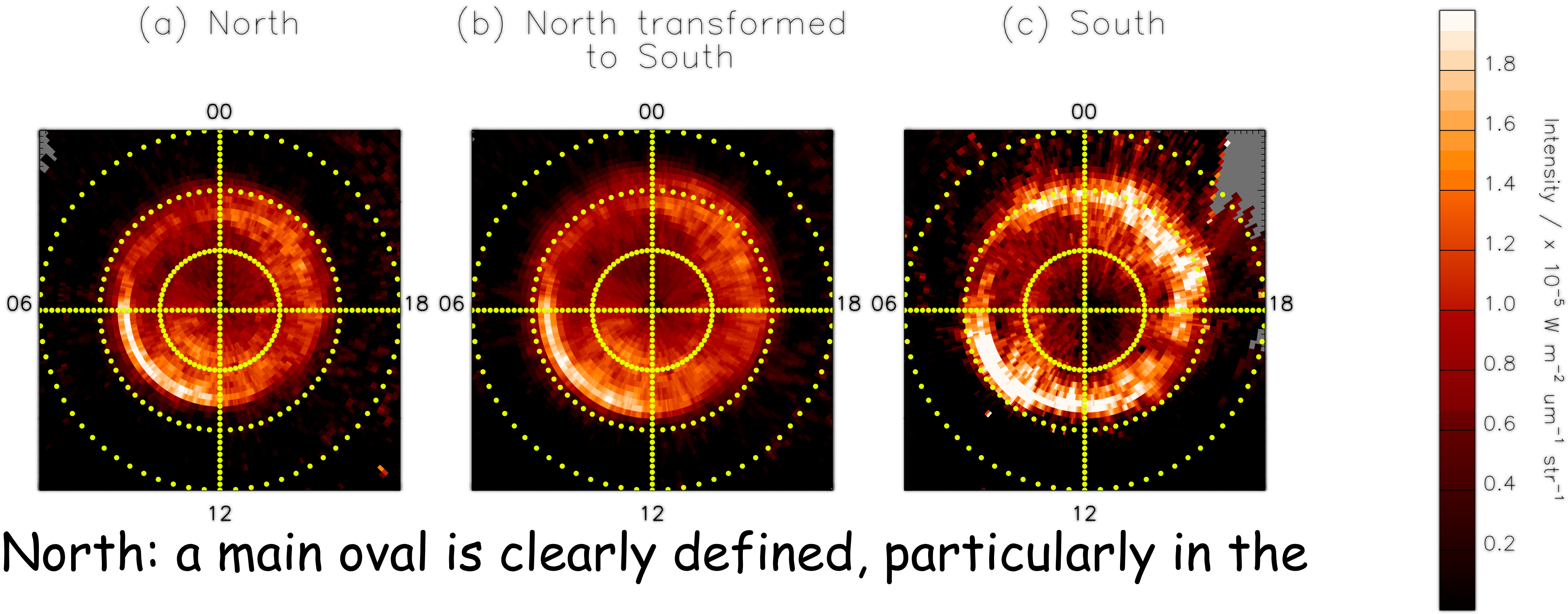


Badman et al., submitted

- North:
- Main oval < 2.4 I
- Polar < 3.8 I
- Polar > Main oval in 30/67 images (45%)

- South:
- Main oval similar to north
- Polar lower than north
- Polar > Main oval in 2/25 images (8%)

4.3 Average IR intensity maps

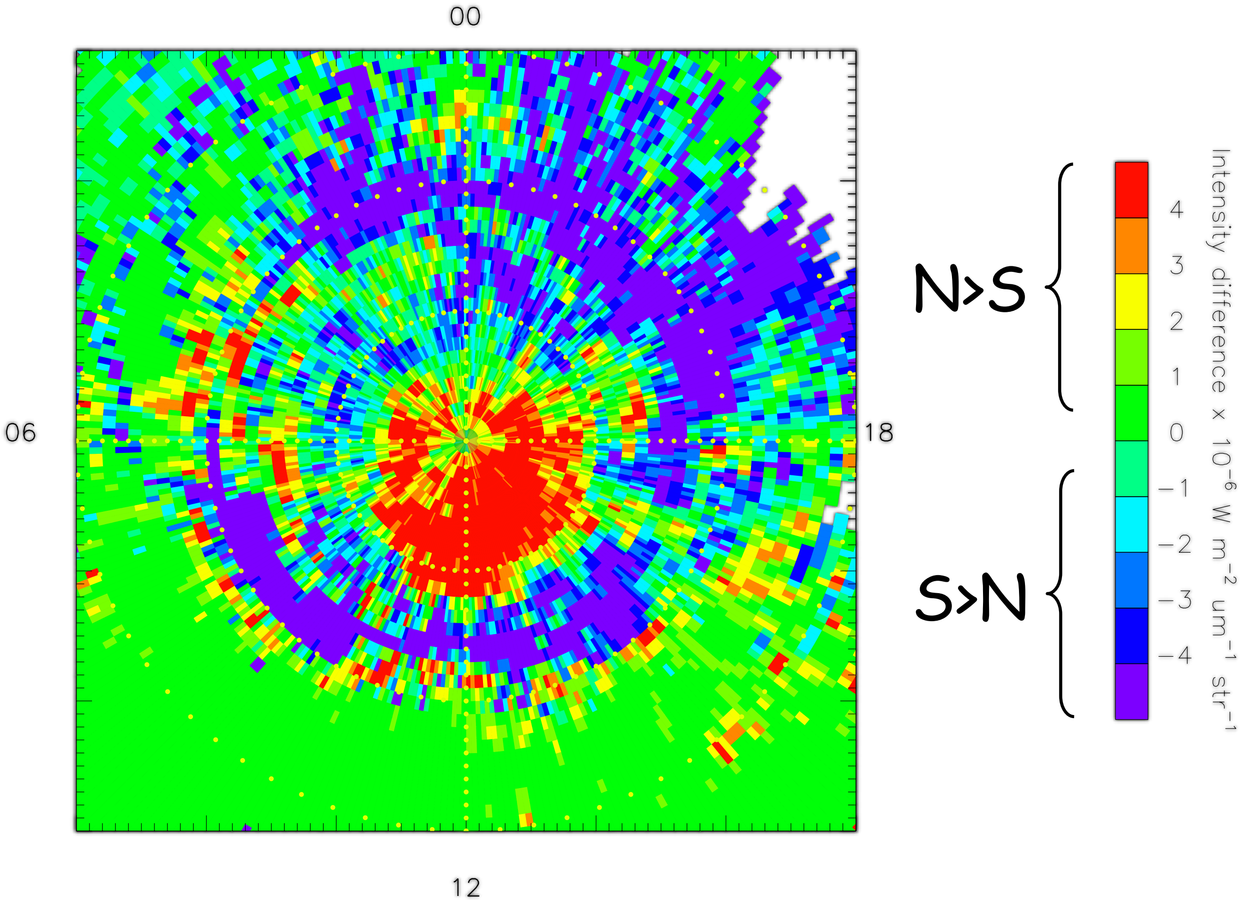


- North: a main oval is clearly defined, particularly in the dawn-noon region (~2 I).
- The polar region is bright compared to lower latitudes. The intensity is comparable to much of the main oval emission (1 I).
- South: a main oval is clearly defined and brightest in the pre-noon and post-dusk regions (~2 I).
- Lower latitudes are dark, but so is the dayside polar region.

Badman et al., submitted

4.4 Interhemispheric intensity difference

Difference between north and south (N-S):

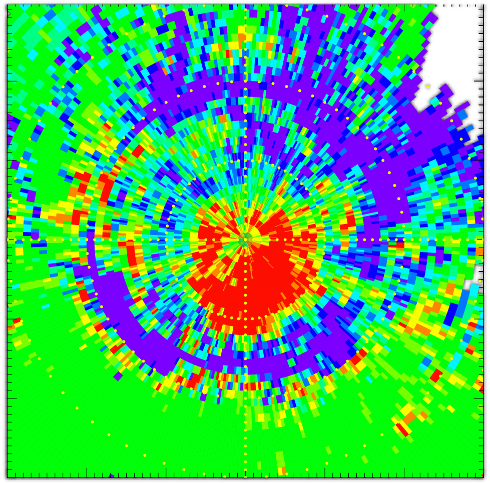


- Northern hemisphere is more intense in the polar region.
- Southern main oval is more intense at most LT.
- Differences are ~20% of typical intensity.

- Maximum differences are +1.2 I (polar) and -3.2 I (main oval).
- These are comparable to the typical intensities observed in these regions and therefore highly significant.

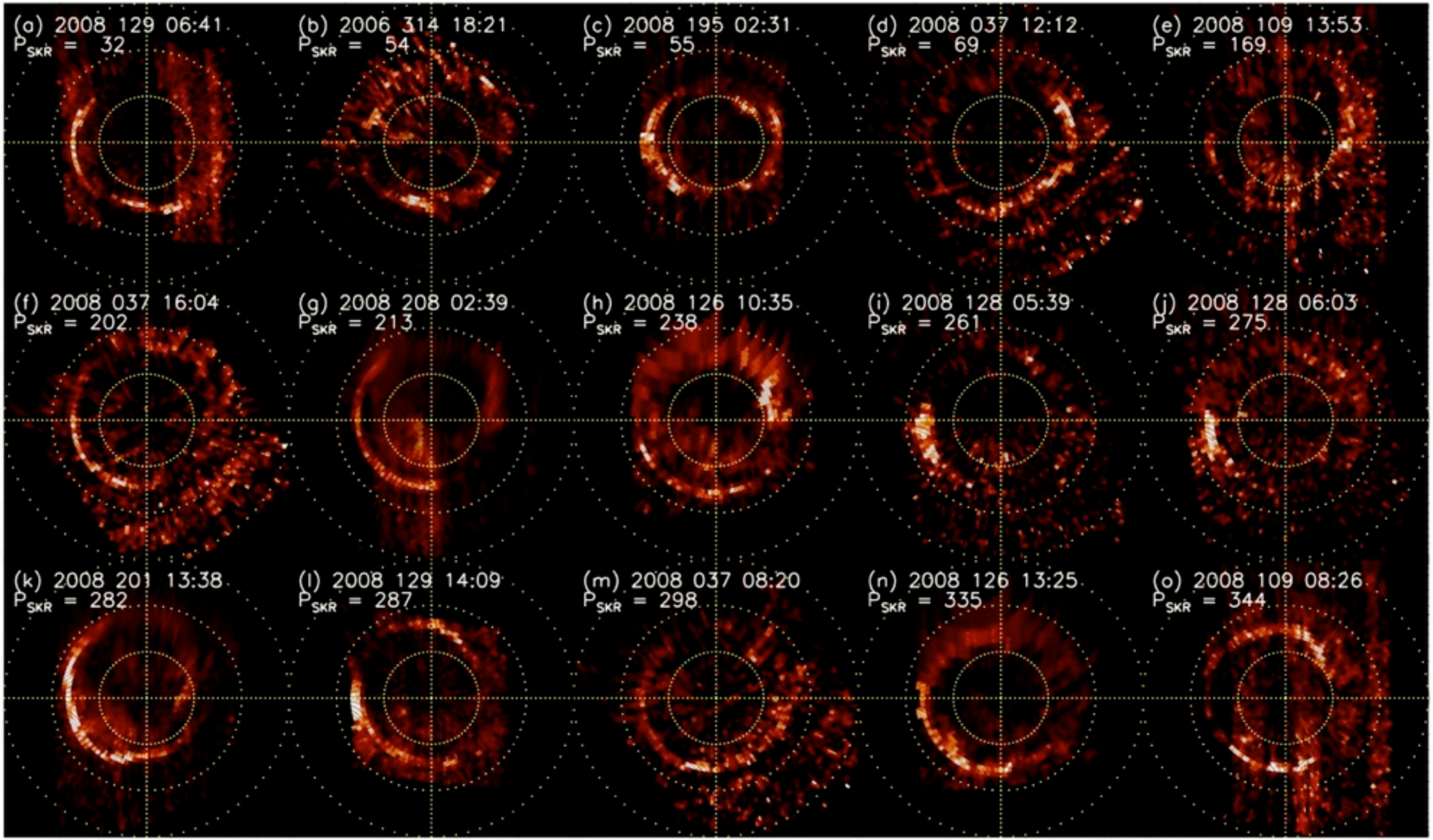
Badman et al., submitted

4.5 Interhemispheric & latitudinal variations



- Main oval: South is more intense than North.
- Polar: North is more intense than South.
- More intense polar emissions are observed when the main oval is also more intense.
- Polar emissions can be as intense as the main oval.
- The images are not simultaneous therefore the differences can be temporal.
- A preferred orientation of the solar wind (toward the Sun) would favour 'polar rain' precipitation and H_3^+ production on high-latitude open field lines in the northern hemisphere (Yeager and Frank, 1976) over the southern hemisphere.
- Increased conductivity in the sunlit southern hemisphere (pre-equinox) would increase Joule heating in the main oval region and thus cause more intense IR (temperature-dependent) emissions.

5.1 Northern aurora at different SKR phase

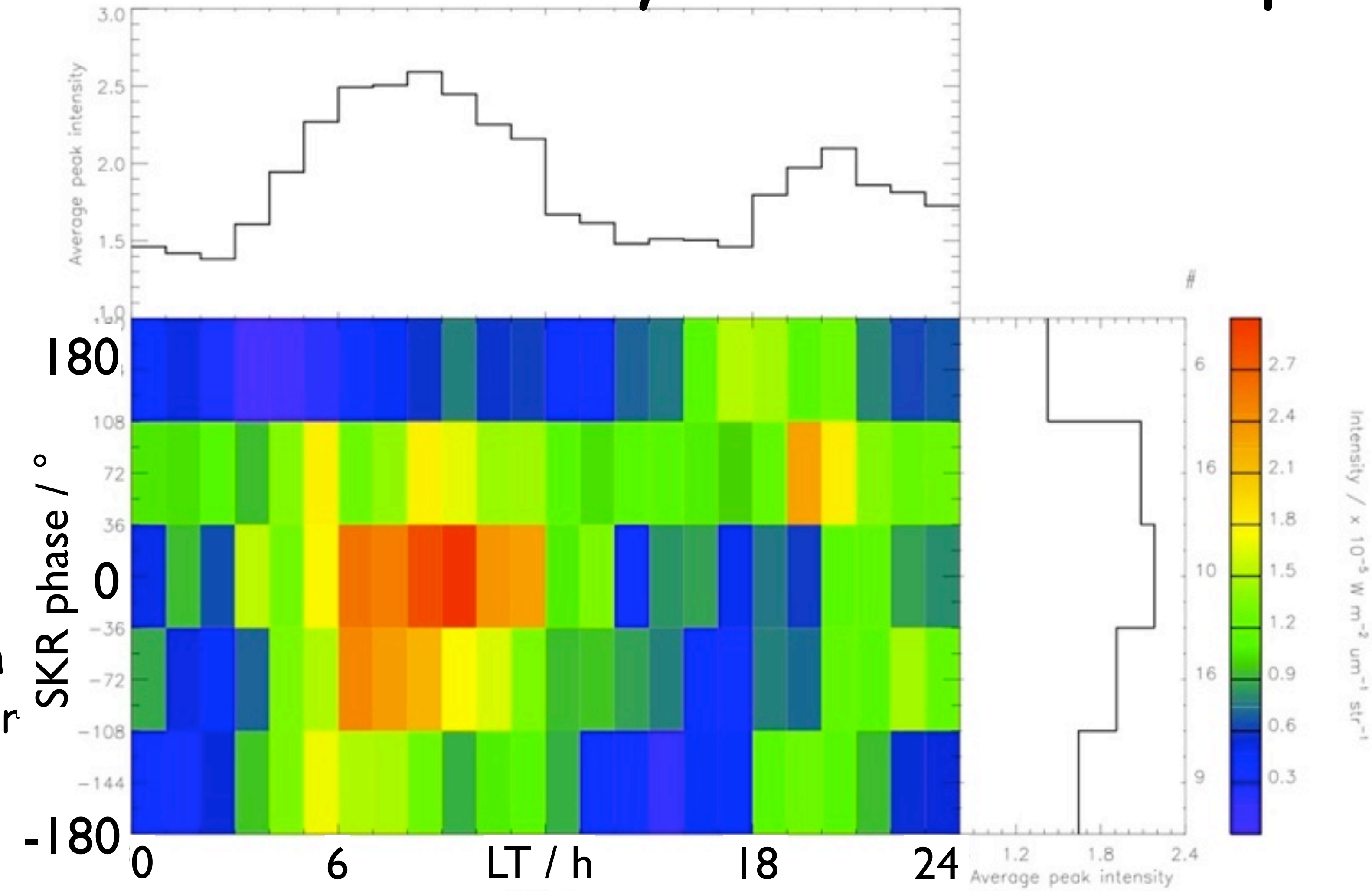


- Extract maximum auroral intensity per hour of LT and compare to SKR phase.

5.2 Peak infrared intensity vs LT and SKR phase

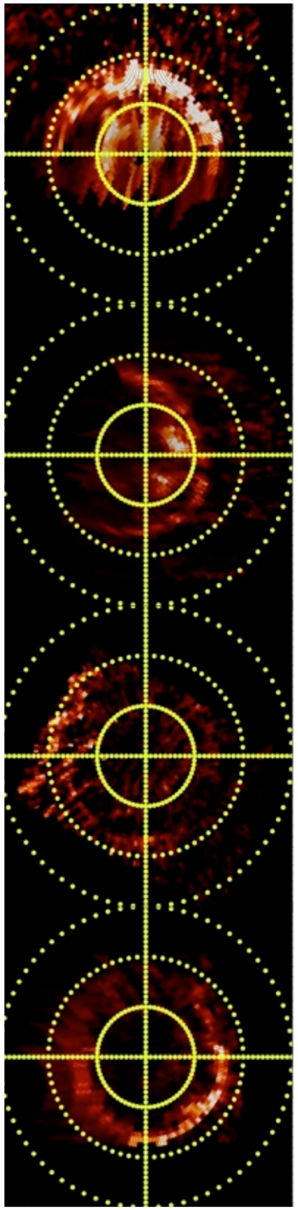
Analysis of northern images only.

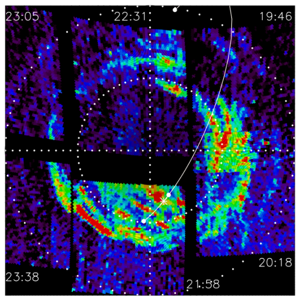
φ_{SKR} intervals of 72° including image integration time of ≤70 min or ≤40° rotation.



- Intensity peaks in dawn to noon sector, like UV and SKR.
- Intensity peaks at φ_{SKR}~0° i.e. when SKR power is maximum.
- Evidence of a slope i.e. intensity maximum rotating through LT with φ_{SKR}? (Lamy et al., 2009, 2011, Nichols et al., 2010)

6. Ongoing and future studies





- Determining interhemispheric and latitudinal variations in IR intensity - isolate seasonal effects with future northern summer image analysis.
- Modelling the effects of hemisphere (i.e. magnetic field strength) and season on auroral field-aligned currents (Tao et al., poster 130).
- Comparing UV, IR, ENA and radio emitted power (Lamy et al., poster 126).
- Comparing structure of near-simultaneous UVIS and VIMS images (Melin et al., talk 57 in this session).
- Analysing IR auroral morphology with in situ plasma and field measurements to understand the M-I dynamics (Badman et al., poster 131).

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