Auroral-related mid-infrared emission on Jupiter from IRTF-TEXES, Cassini-CIRS

Jupiter Aurora Workshop

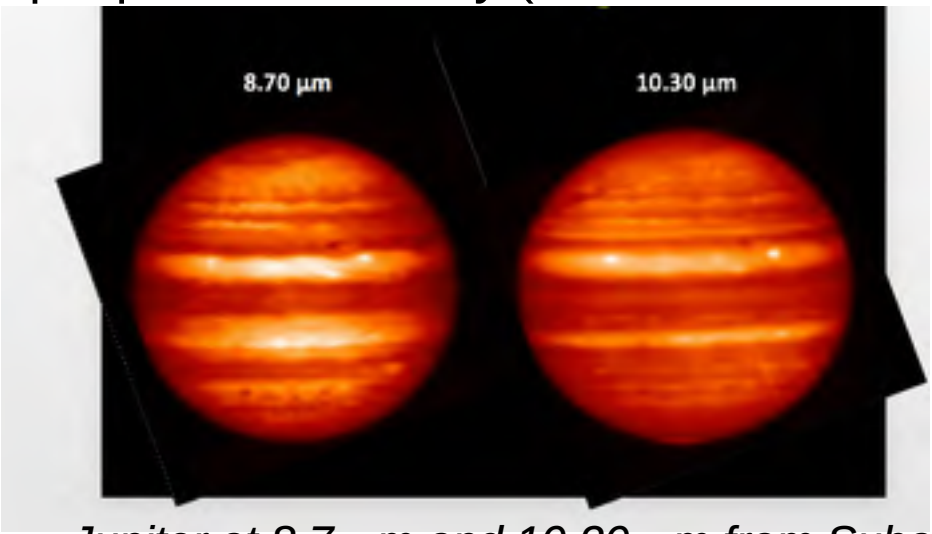
James Sinclair[1] ,Glenn Orton[1], Thomas Greathouse[2], Leigh Fletcher[3], Patrick Irwin[4], Yasumasa Kasaba[5]

[1]Jet Propulsion Laboratory, California Institute of Technology, [2]Southwest Research Institude, [3]University of Leicester, [4]Atmospheric, Oceanic & Planetary Physics, University of Oxford, [5]Tohoku University

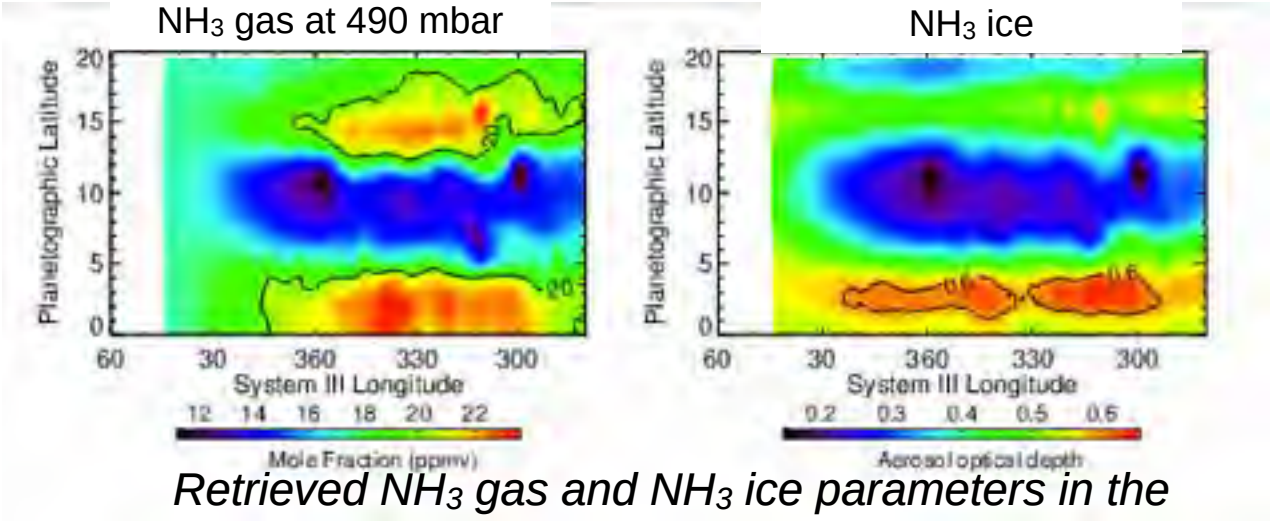
Support of Juno in the mid-infrared

Using spacecraft (Cassini, Voyager) and ground-based imaging/spectroscopy in the thermal infrared to derive meteorological parameters in support of Juno.

Tropospheric variability (Orton et al., 2015, DPS)

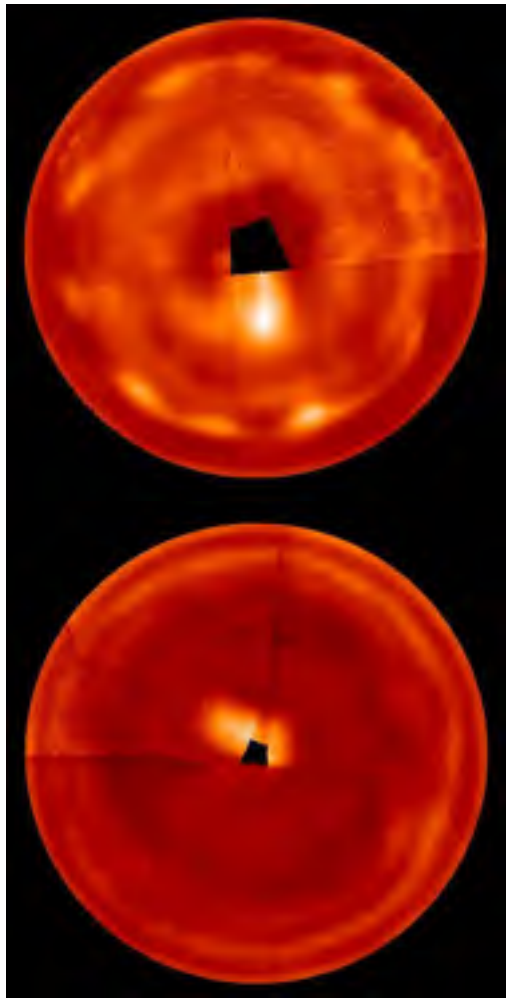


Jupiter at 8.7-µm and 10.30-µm from Subaru-COMICS in 2011



Retrieved NH_3 gas and NH_3 ice parameters in the 0.2 - 0.5 bar levels

Auroral-related emission

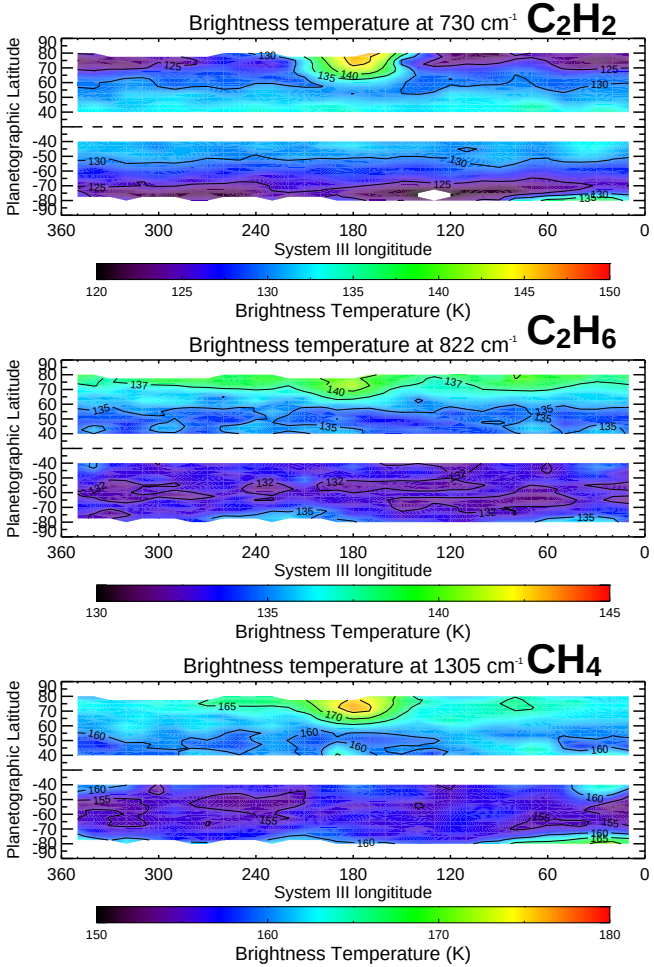


North (top) and south (bottom) polar projections of Jupiter at 7.8-µm (Jan 2017).

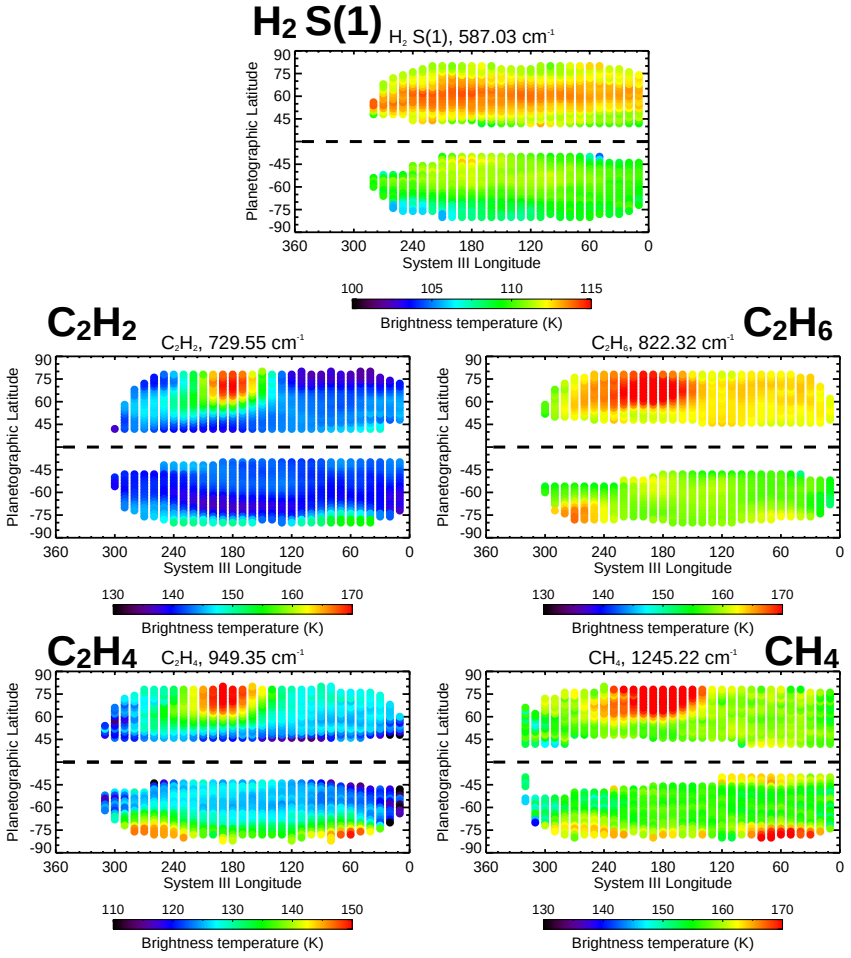
Aurora-related mid-infrared emission

- Analysing mid-infrared auroral emission using both ground-based and spacecraft spectroscopy.
    - spacecraft: Voyager-IRIS (R = 250), **Cassini-CIRS** (R = 66-4000), no telluric contamination.
    - ground-based: **IRTF-TEXES** (R = 65000-85000), higher spectral resolution (which sounds larger altitude range).

Observations from Cassini-CIRS (2000)



Observations from IRTF-TEXES (Dec 2014)

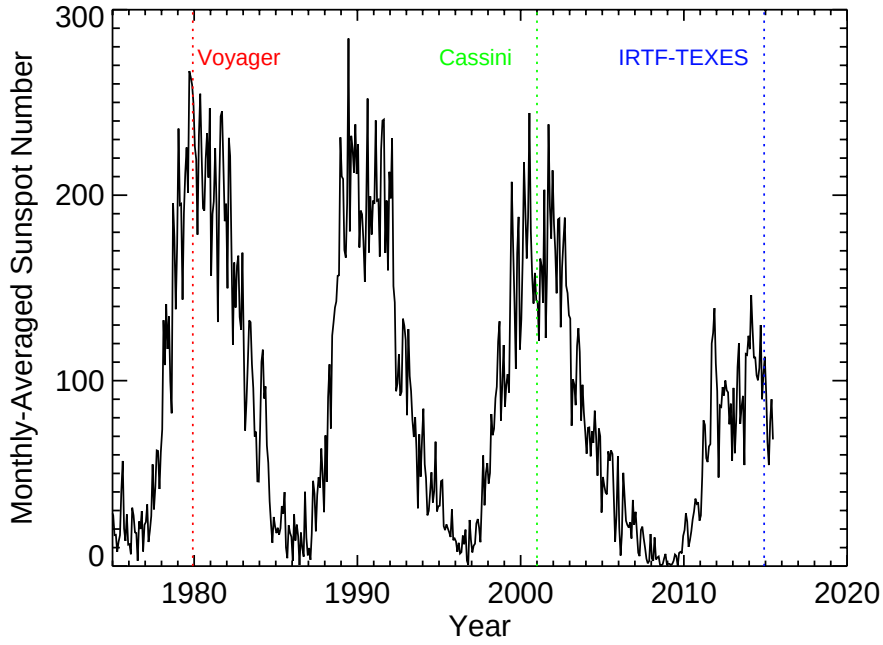


Questions

1) What mechanism yields the high temperatures in the neutral atmosphere in auroral regions?

2) Do auroral processes affect the concentrations of C_2H_2, C_2H_4, C_2H_6?

3)Does the auroral-related mid-infrared emission vary with (time) solar cycle?



<u>To address these questions:</u>

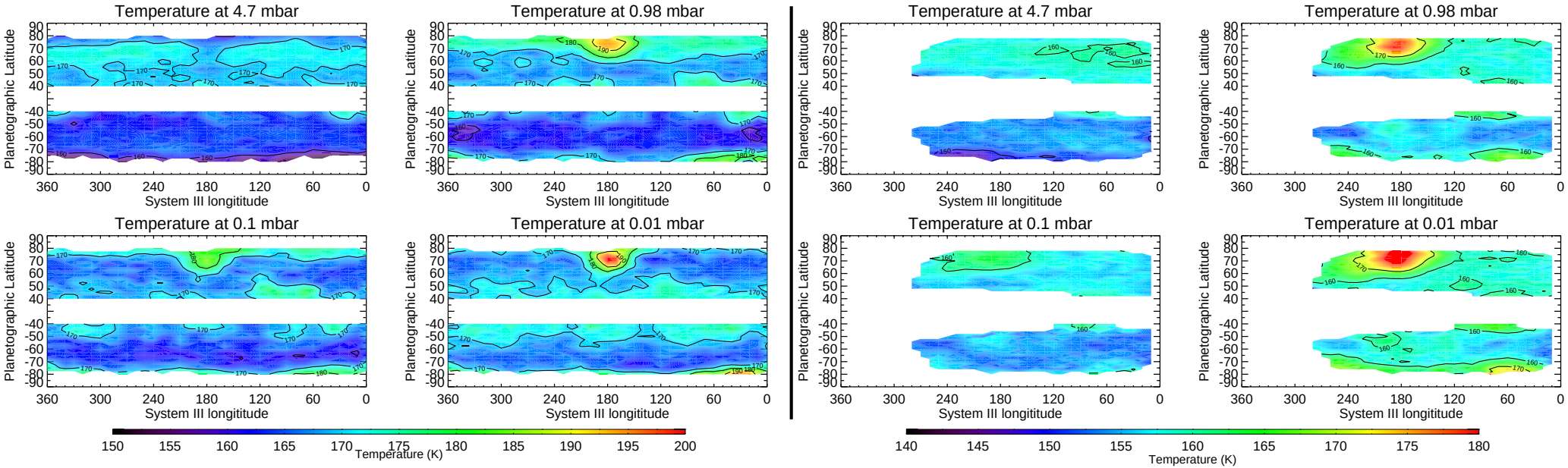
- Perform retrieval analysis of Cassini-CIRS and IRTF-TEXES spectra.

- Retrievals of the vertical profiles of temperature, C_2H_2, C_2H_6 performed using Nemesis (Irwin et al., 2008), an radiative transfer inversion code.

Temperature results

Cassini-CIRS (Δν = 2.5 cm^{-1}, 2000)

IRTF-TEXES (Δν = 0.0015 cm^{-1}, 2014)

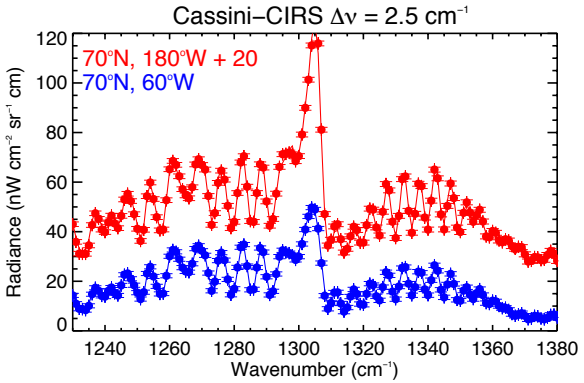


- No auroral-related stratospheric heating at pressures of 4.7 mbar or higher (Flasar et al., 2004).
- Auroral-related heating at pressures from ~1 mbar to ~10 μbar (at least over range in pressures sounded in the mid-infrared).
- Larger enhancements in temperature at 10-μbar and 0.98-mbar level, **less at 0.1 mbar.**

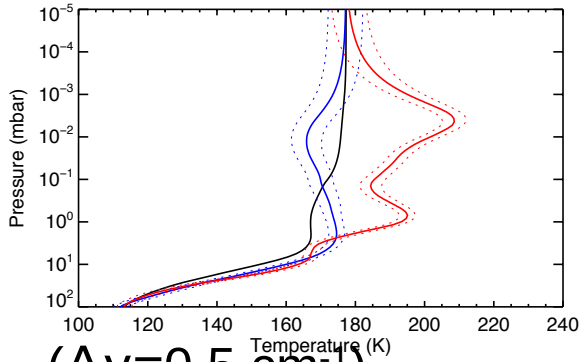
Temperature results

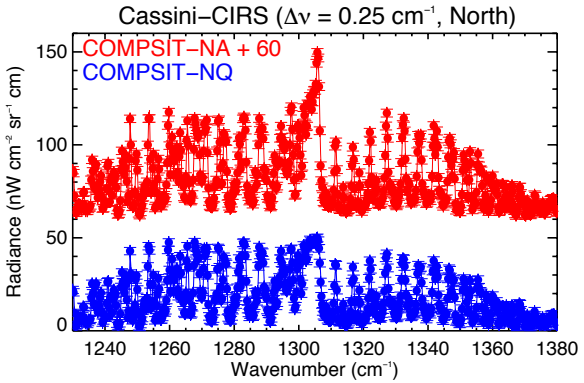
In both CIRS and TEXES results:

- Temperature maxima at 1 mbar.
- Temperature maxima at 10-µbar (but may be an artefact of the temperature the *apriori).*
- Temperature minima at 0.1 mbar where there is less altitudinal sensitivity in the spectra?

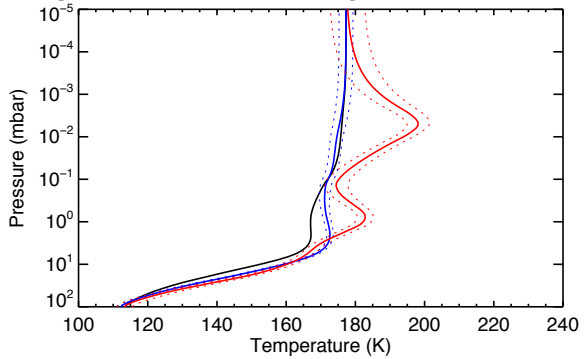


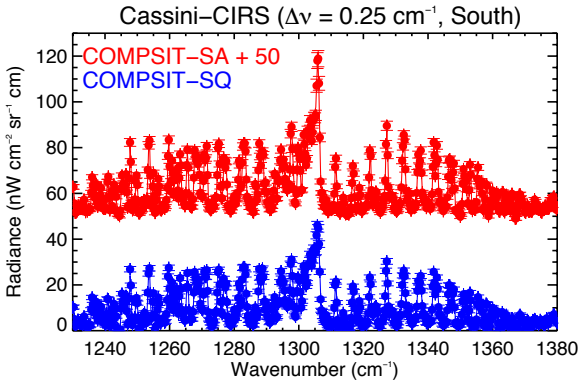
(Δν=2.5 cm-1)



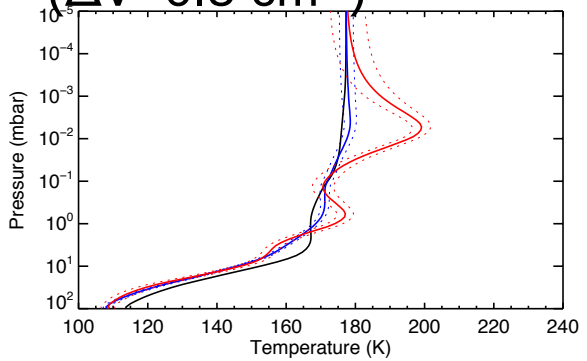


(Δν=0.5 cm-1)





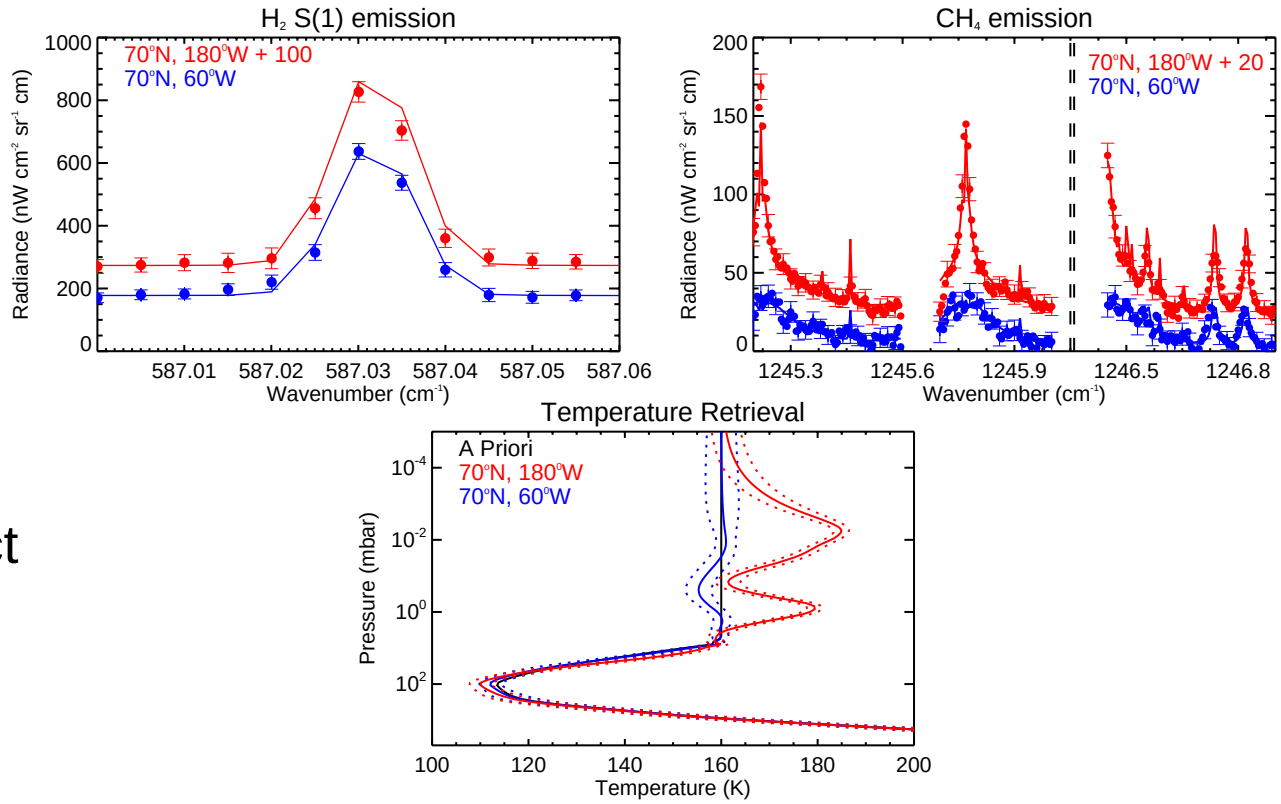
(Δν=0.5 cm-1)



Temperature results

In both CIRS and TEXES results:

- Temperature maxima at 1 mbar.
- Temperature maxima at 10-µbar (but may be an artefact of the temperature the *apriori).*
- Temperature minima at 0.1 mbar where there is less altitudinal sensitivity in the spectra?



Temperature results

<u>Test alternative temperature a priori profiles to determine robustness</u>

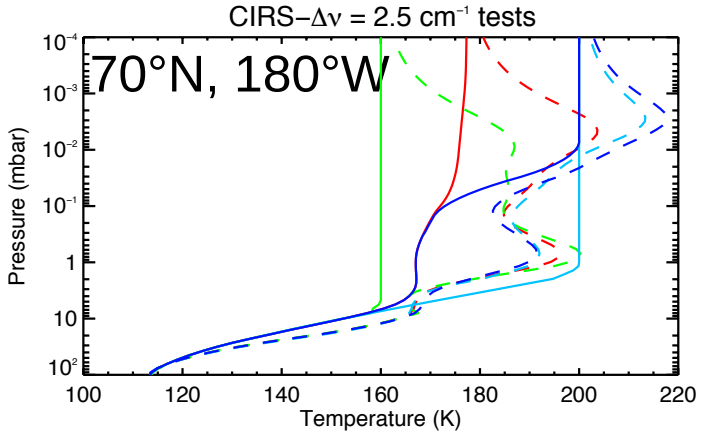
Tested: - nominal (shown on red)
- an isotherm of 160 K (green)
- an isotherm of 200 K (cyan)
- nominal but with a 200 K isotherm above the 10-μbar level (blue)

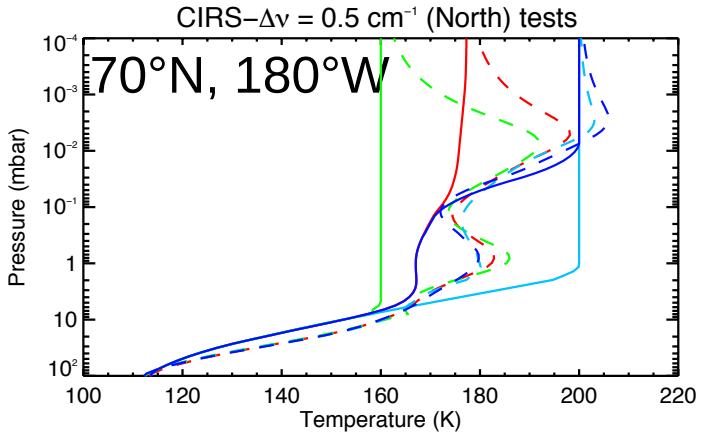
<u>Conclusions:</u>

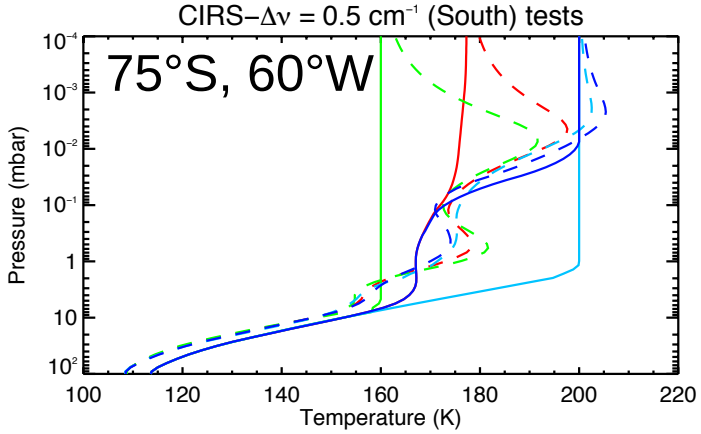
- Temperature maximum at 10-μbar was an artefact of the nominal a priori: most likely an isotherm at pressures lower than 10-μbar.

- Temperature maxima at ~1 mbar level and temperature minima at ~0.1 mbar appears robust regardless of initial assumptions.

  → Temperature maxima at ~1 mbar a result of auroral 'soot' or haze particles which are heated by sunlight.



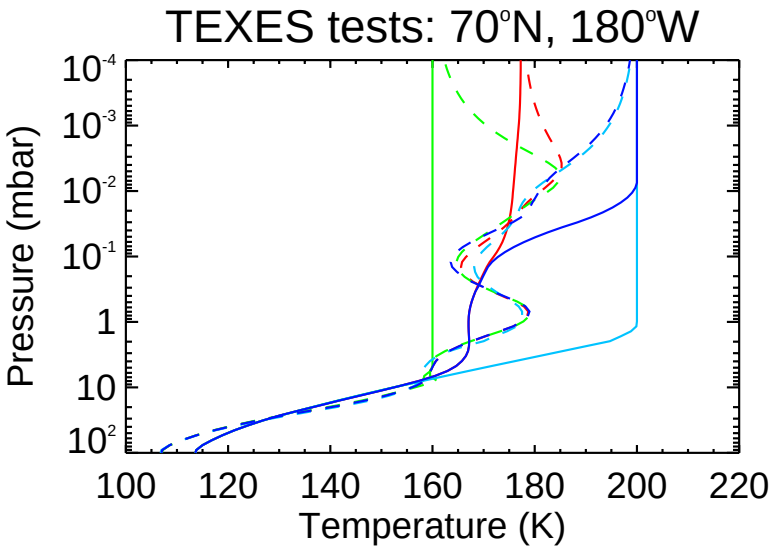




Temperature results

<u>Test alternative temperature a priori profiles to determine robustness</u>

Tested: - nominal (shown on red)
- an isotherm of 160 K (green)
- an isotherm of 200 K (cyan)
- nominal but with a 200 K isotherm above the 10-µbar level (blue)

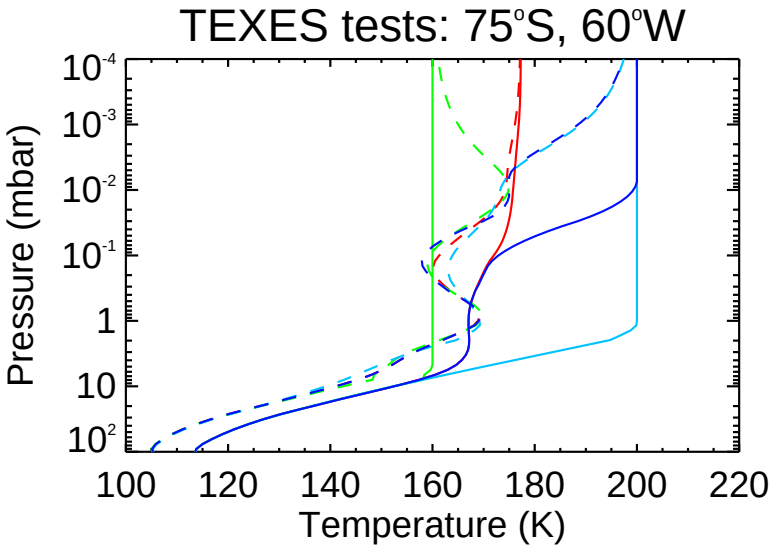


<u>Conclusions:</u>

- Temperature maximum at 10-µbar was an artefact of the nominal a priori: most likely an isotherm at pressures lower than 10-µbar.

- Temperature maxima at ~1 mbar level and temperature minima at ~0.1 mbar appears robust regardless of initial assumptions.

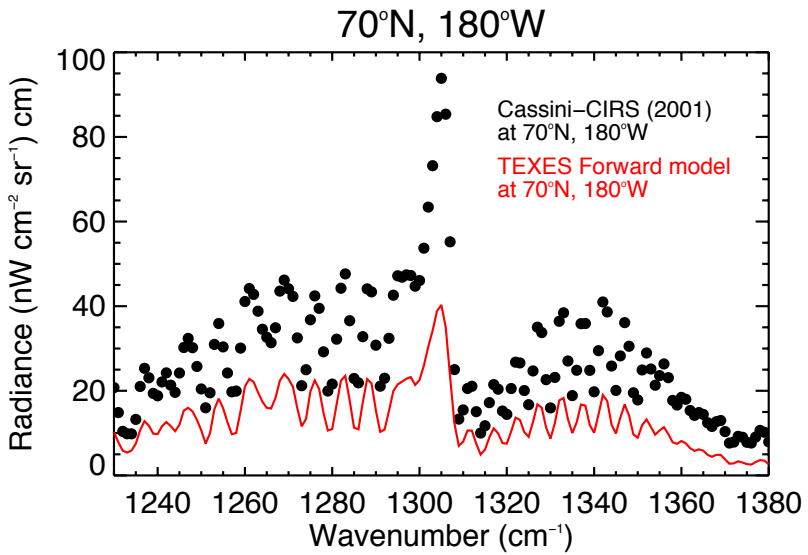
  ➡ Temperature maxima at ~1 mbar a result of auroral ‘soot’ or haze particles which are heated by sunlight.

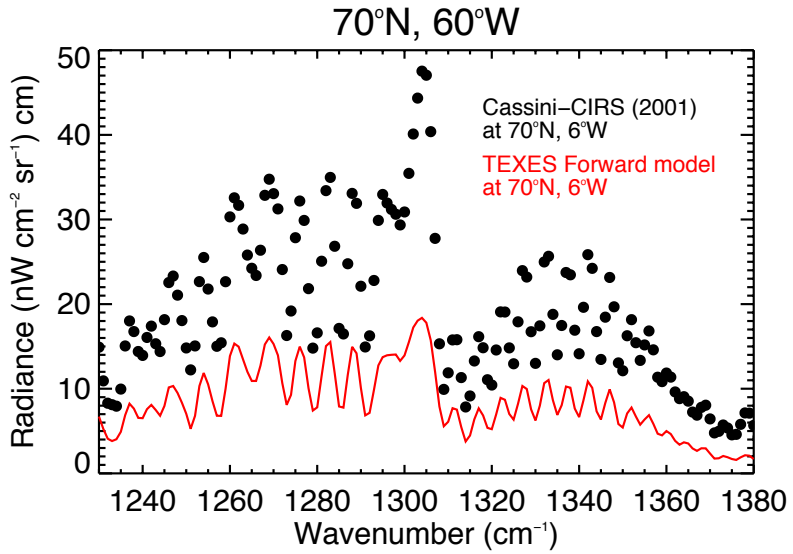


Solar cycle variation?

Solar activity twice as high in 2000 (during CIRS flyby) compared to 2014 when TEXES spectra were acquired. Is auroral-related emission higher when solar activity is higher?

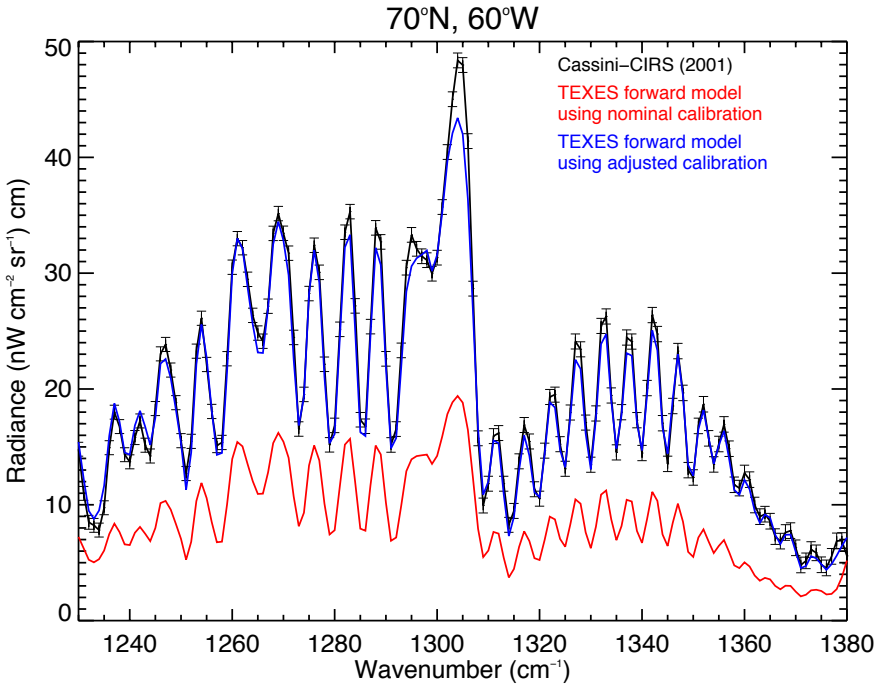
- TEXES temperature results forward modelled at same spectral resolution and emission angle as CIRS Δv=2.5 cm^{-1} observations.
- CIRS radiances in CH4 emission about 2 x brighter than TEXES at 70°N, 180°W.
- **BUT**, a similar offset in radiances at 70°N, 60°W where auroral processes should have no effect?
- Systematic offset in TEXES and CIRS radiances
  - blurring of auroral features by diffraction/seeing.
  - radiometric calibration issues?

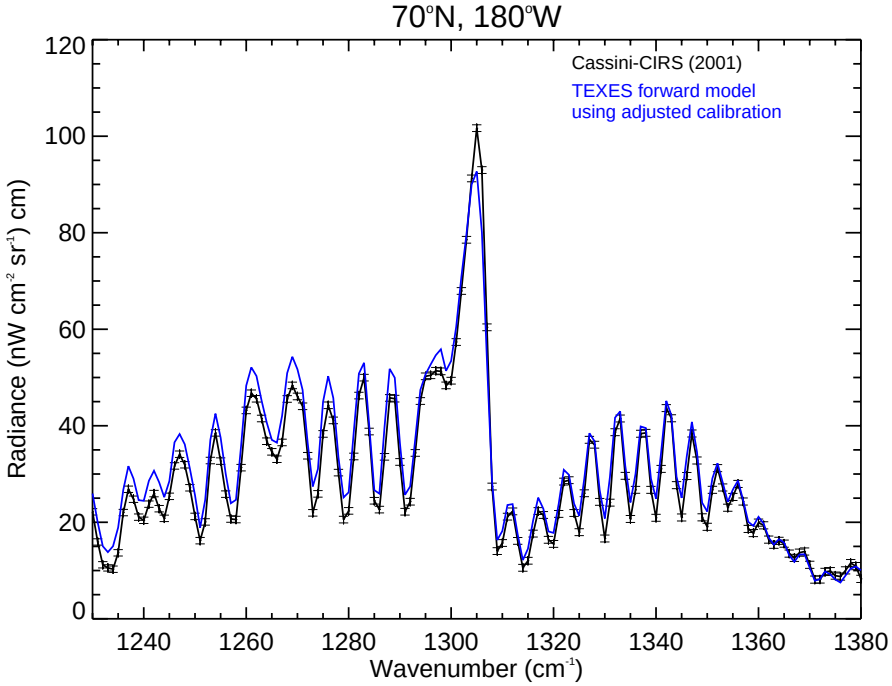




Solar cycle variation?

- All TEXES radiances scaled by offset in radiance required to match TEXES and CIRS radiances at 70°N, 60°W.
- Perform temperature retrievals (again) of TEXES spectra at 70°N, 180°W using adjusted calibration and compare with CIRS.
- **CH_4 emission at 70°N, 180°W appears very similar during periods of different solar activity.**
- Aim to confirm this using awarded TEXES time in May 2016.





Conclusions

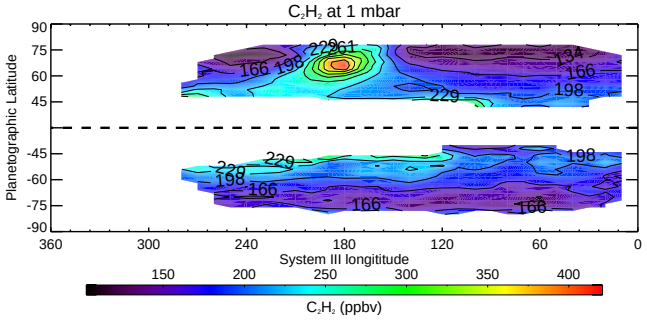
- Retrievals of the vertical temperature profile from both Cassini-CIRS and IRTF-TEXES spectra indicate a maximum in temperature at the 1 mbar level in both northern and southern auroral regions.

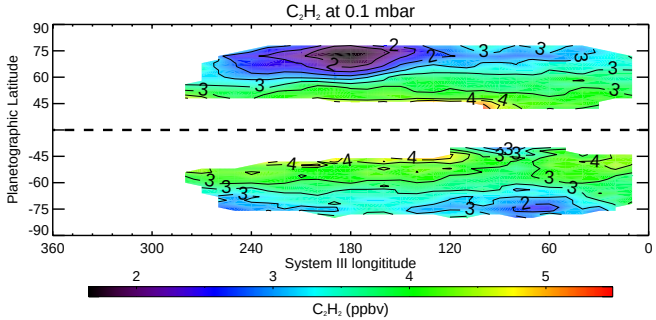
- This feature is considered to be a result of auroral-produced haze particles/ aerosols/‘soot’ which are heated by sunlight.

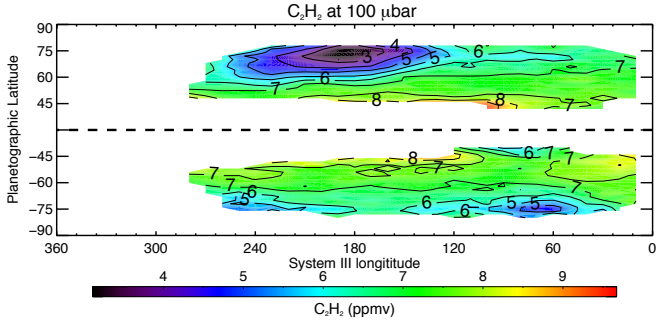
- Temperatures at pressures lower and including 10-µbar are likely isothermal due to joule heating.

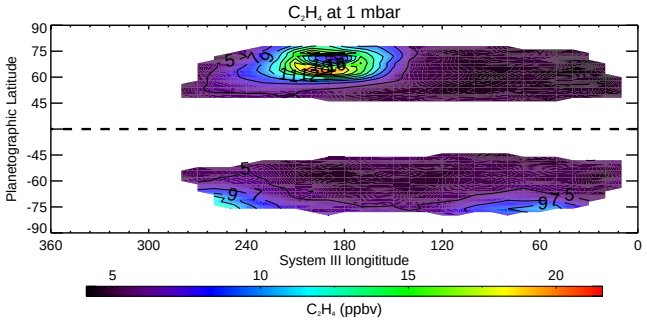
- No difference in auroral-related CH_4 emission between 2014 and 2010 (where solar activity was different).

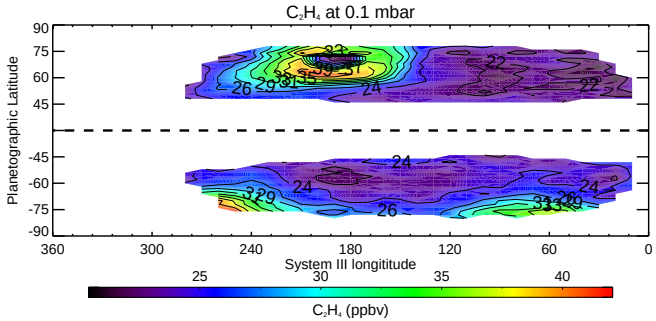
Hydrocarbon results

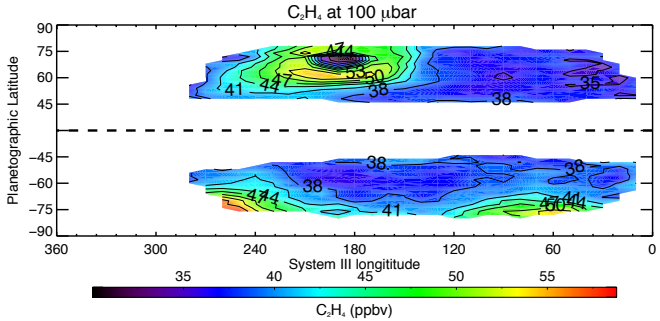


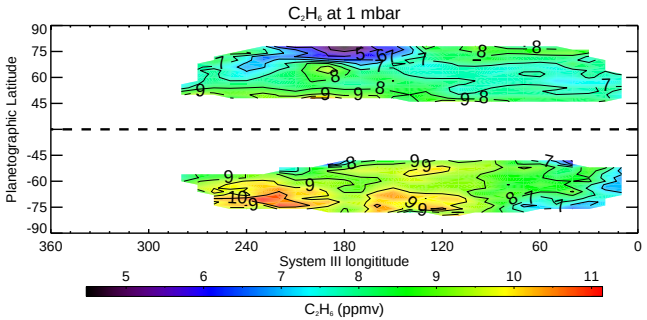


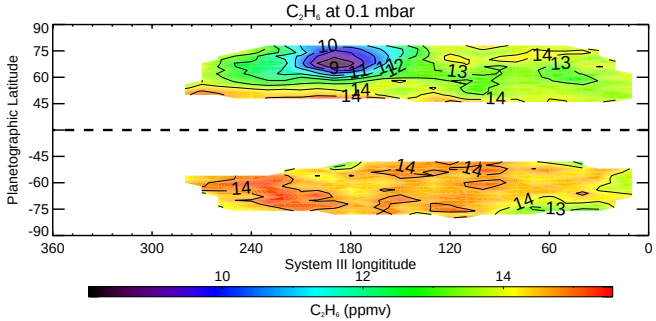


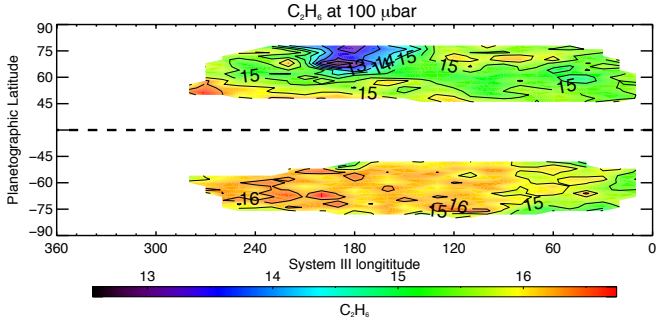


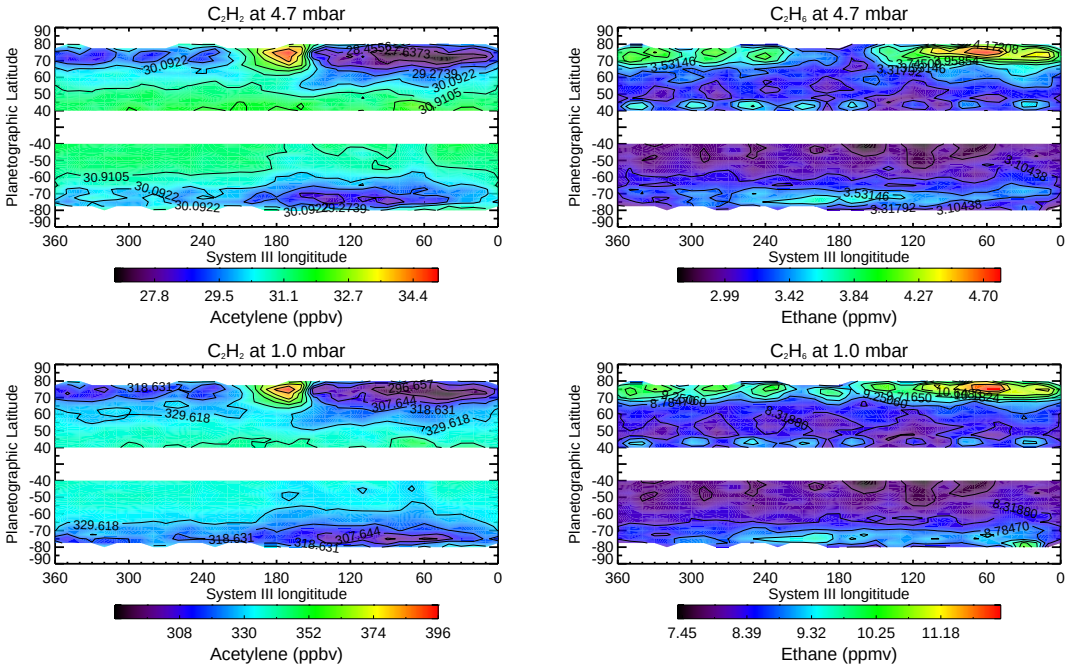




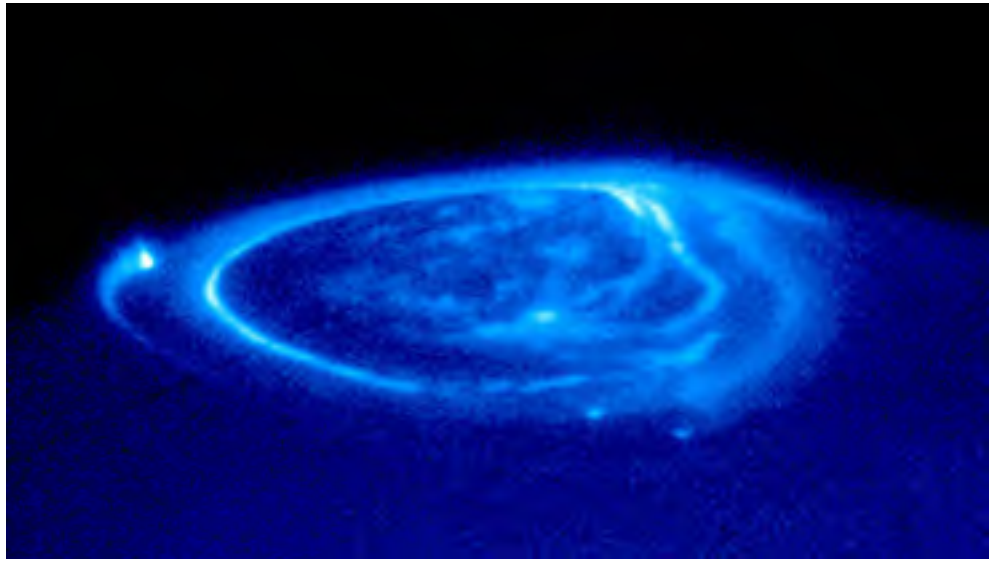




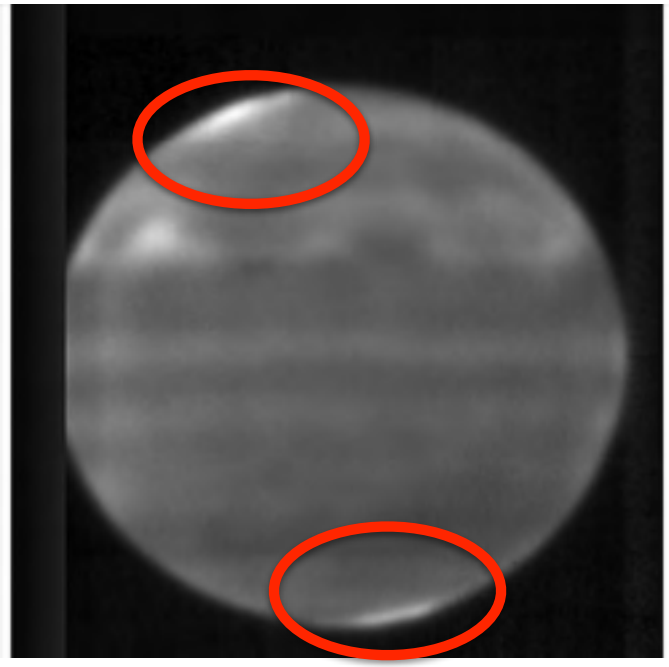



C2H2 at 4.7 mbar
C2H6 at 4.7 mbar
C2H2 at 1.0 mbar
C2H6 at 1.0 mbar
Planetographic Latitude
System III longitude
Acetylene (ppbv)
Ethane (ppmv)
27.8 29.5 31.1 32.7 34.4
2.99 3.42 3.84 4.27 4.70
308 330 352 374 396
7.45 8.39 9.32 10.25 11.18

Aurora-related mid-infrared emission



HST-STIS (Ultraviolet)



Jupiter from Subaru-COMICS in January 2017 at 7.8-μm:

- Jupiter's aurora also appear bright in the mid-infrared.
- Enhanced CH_4 emission (temperature probe) indicates auroral processes elevate temperatures in the neutral stratosphere.
- Enhanced emission of further hydrocarbons such as C_2H_2, C_2H_4 and C_6H_6 indicates possible auroral influence on photochemistry in the stratosphere.