IRTF observations of H_3^+ in planetary atmospheres

H_3^+ formed above the *homopause - thermosphere/ionosphere*

Very efficient radiator - "H_3^+ thermostat"

$H_2 + h\nu / e^- \rightarrow H_2^+ + e^-$

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

$N_a(h) = N_{a0}\, e^{[-h/Ha]}$

$H_a = [kT/m_a g]$

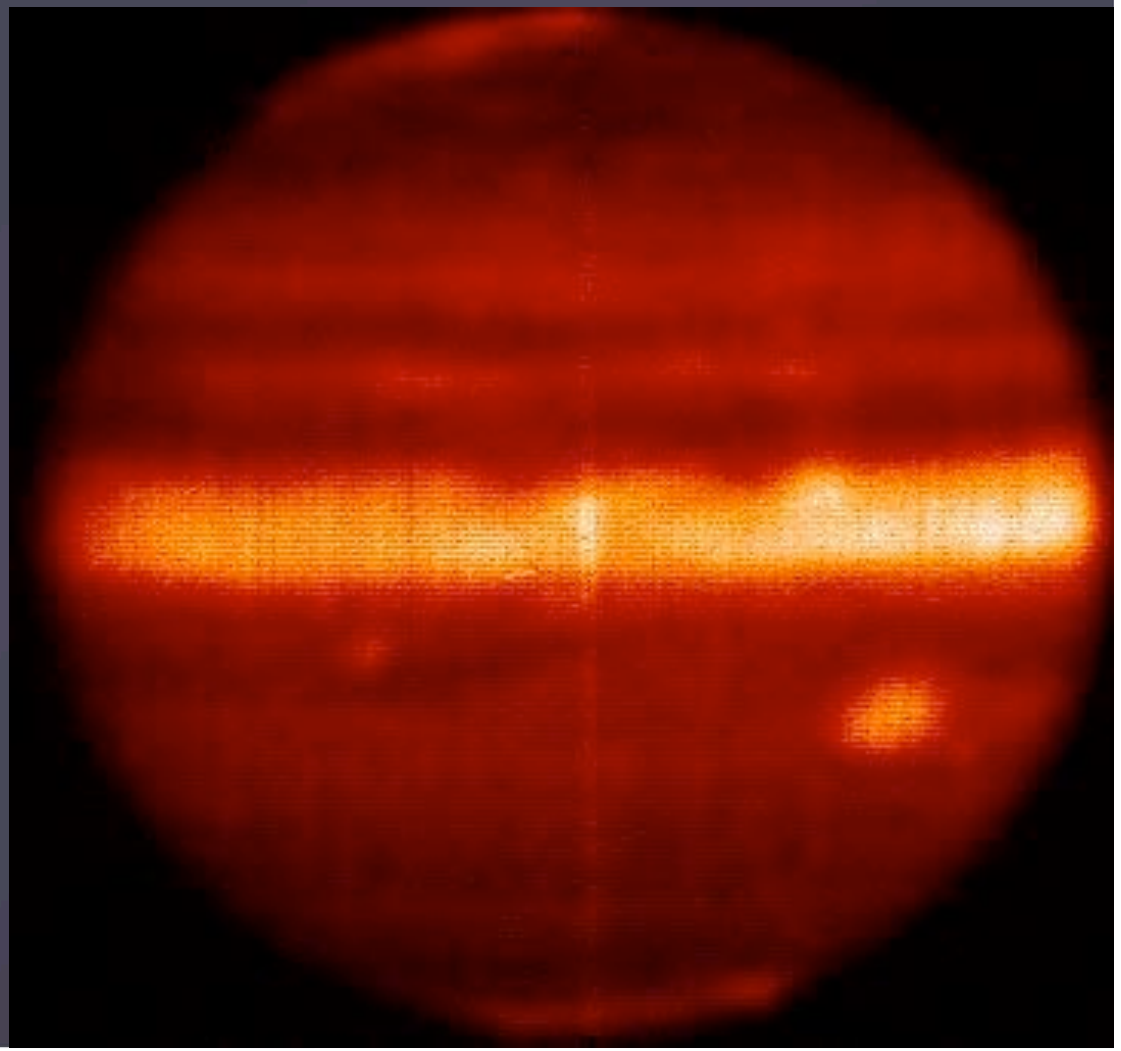
Pressure $< 1\mu$bar

$N(H_2) < 10^{18} m^{-3}$

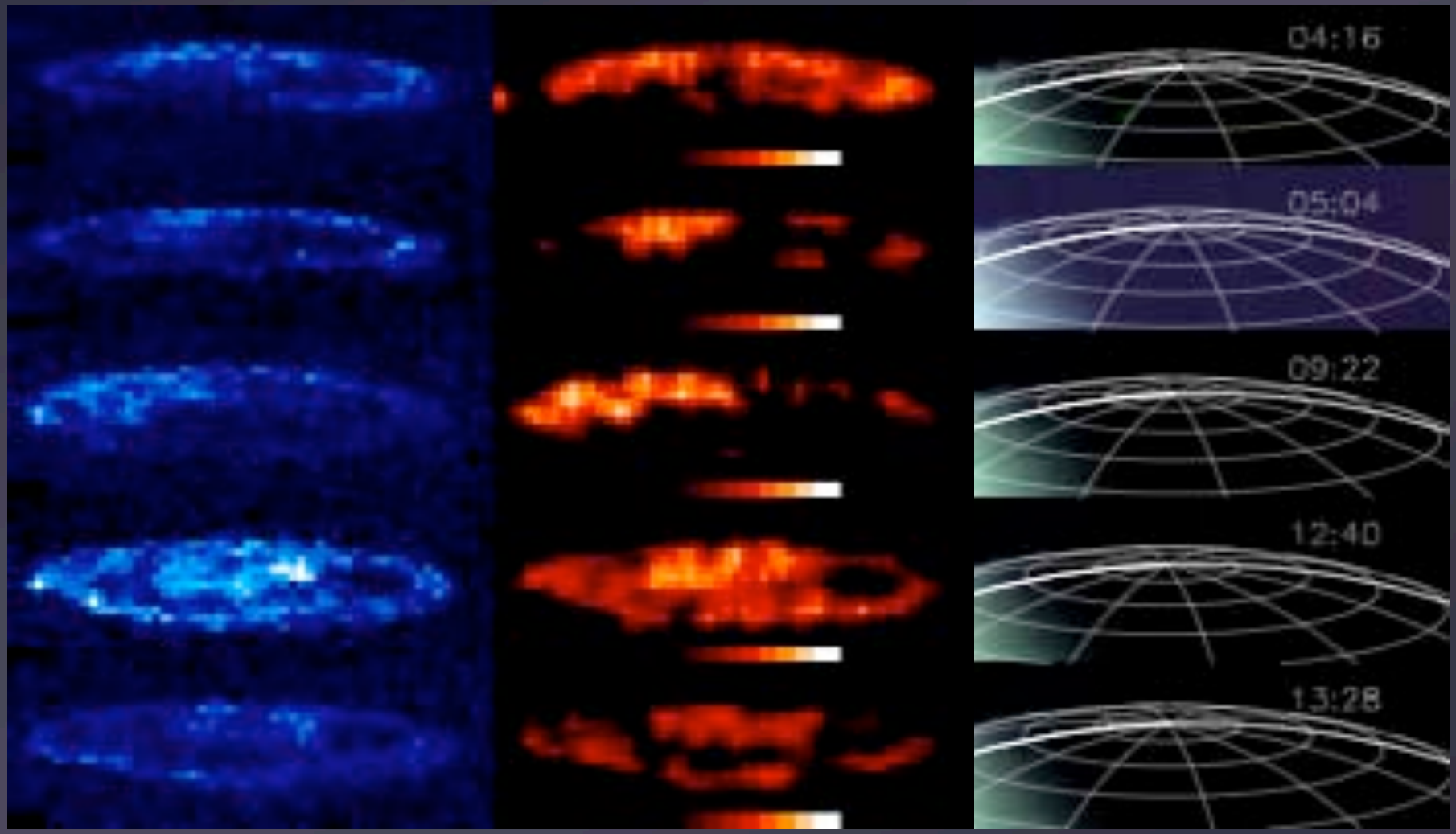
Temperatures:

Jupiter	900-1100K
Saturn	400-600K
Uranus	500-750K

SPEX Guide Dog L' filter

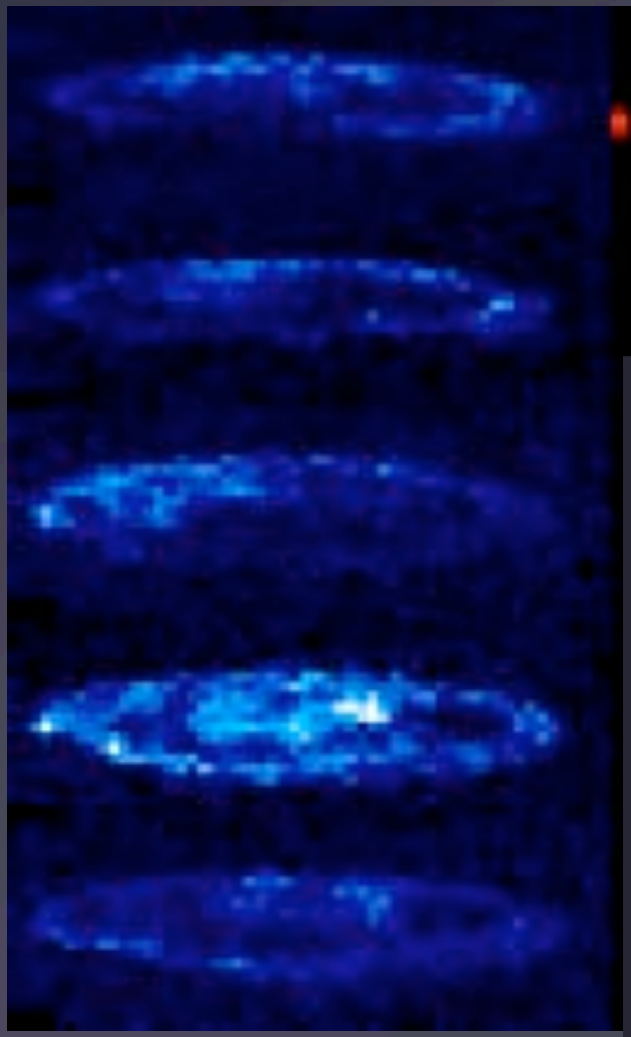


Cassini mission support - VIMS

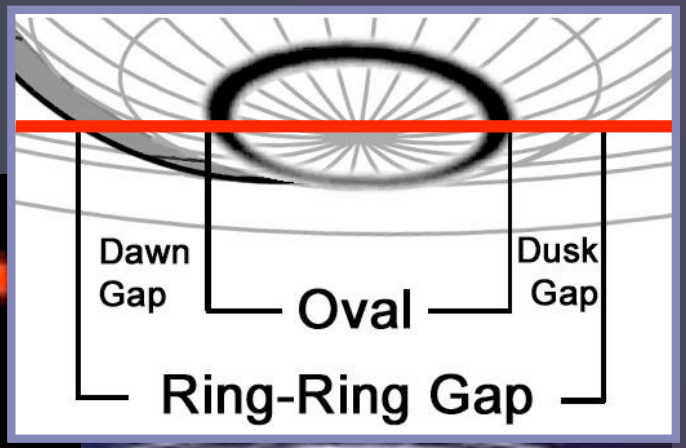


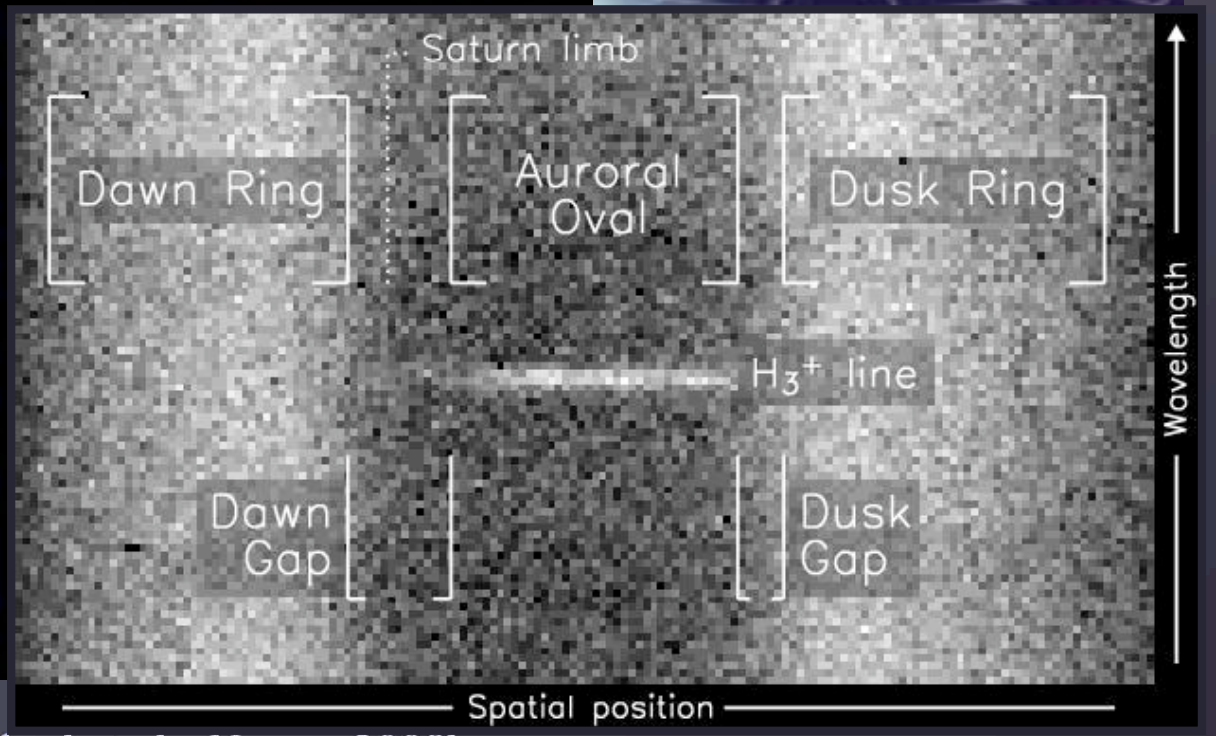
June 9, 2007, published in Stallard et al., *Nature* 2008b

Cassini mission support



CSHELL H_3^+ velocity measurements since 2003





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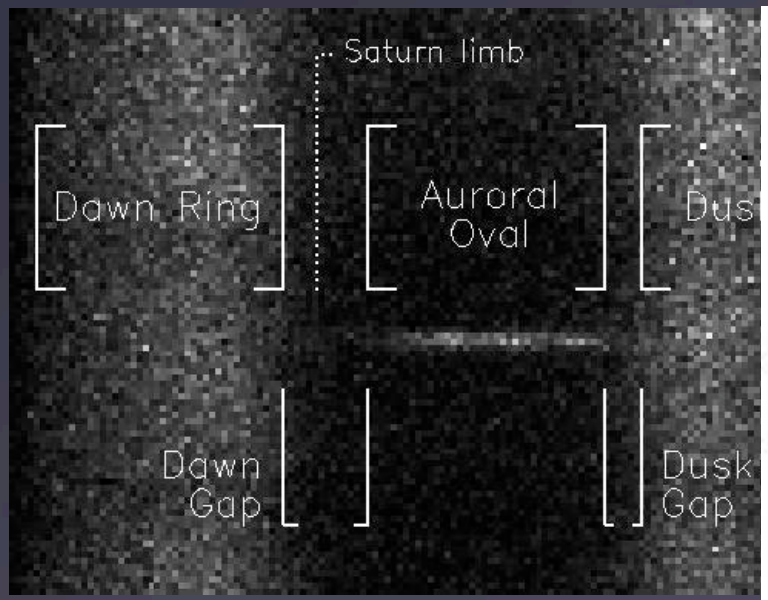
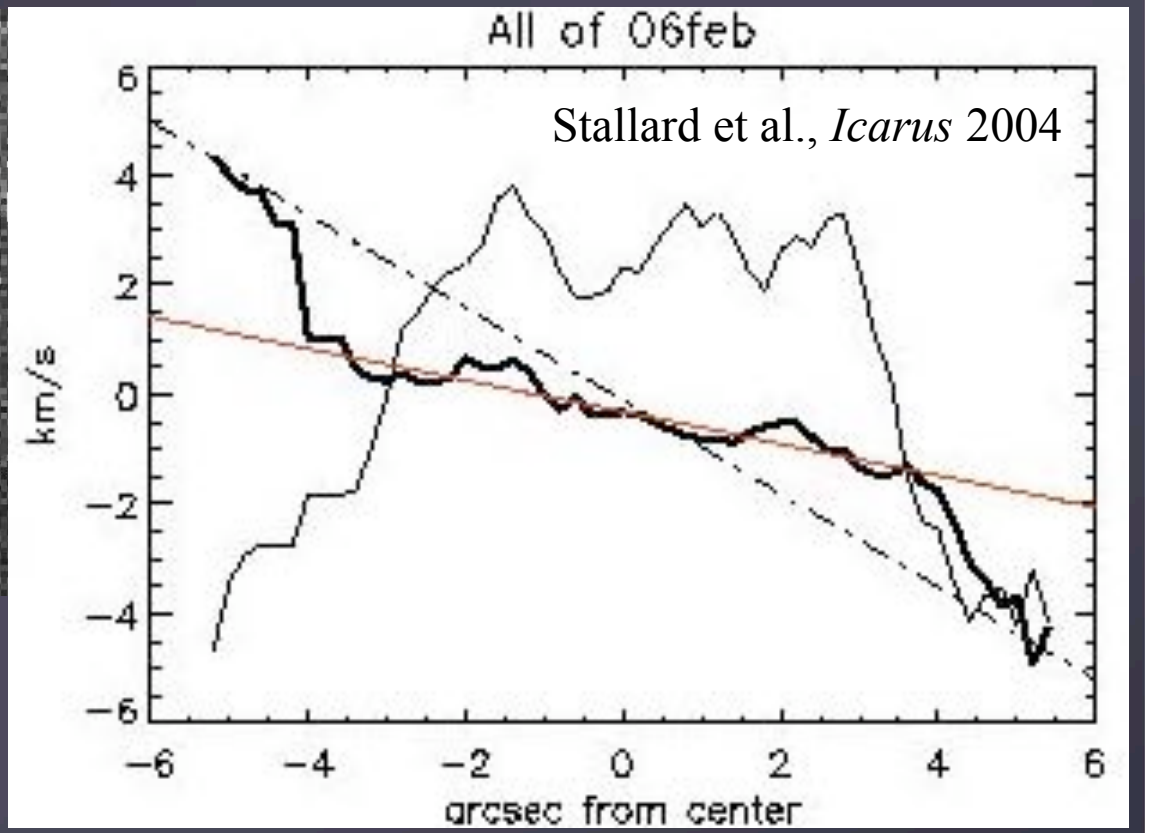
Magnetosphere - atmosphere coupling





$\Omega_{ion} = 0.34\ \Omega_{sat}$

$\Rightarrow E(r) = [\Omega_{Sat} - \Omega_{ion}]r \times B_{Sat}$

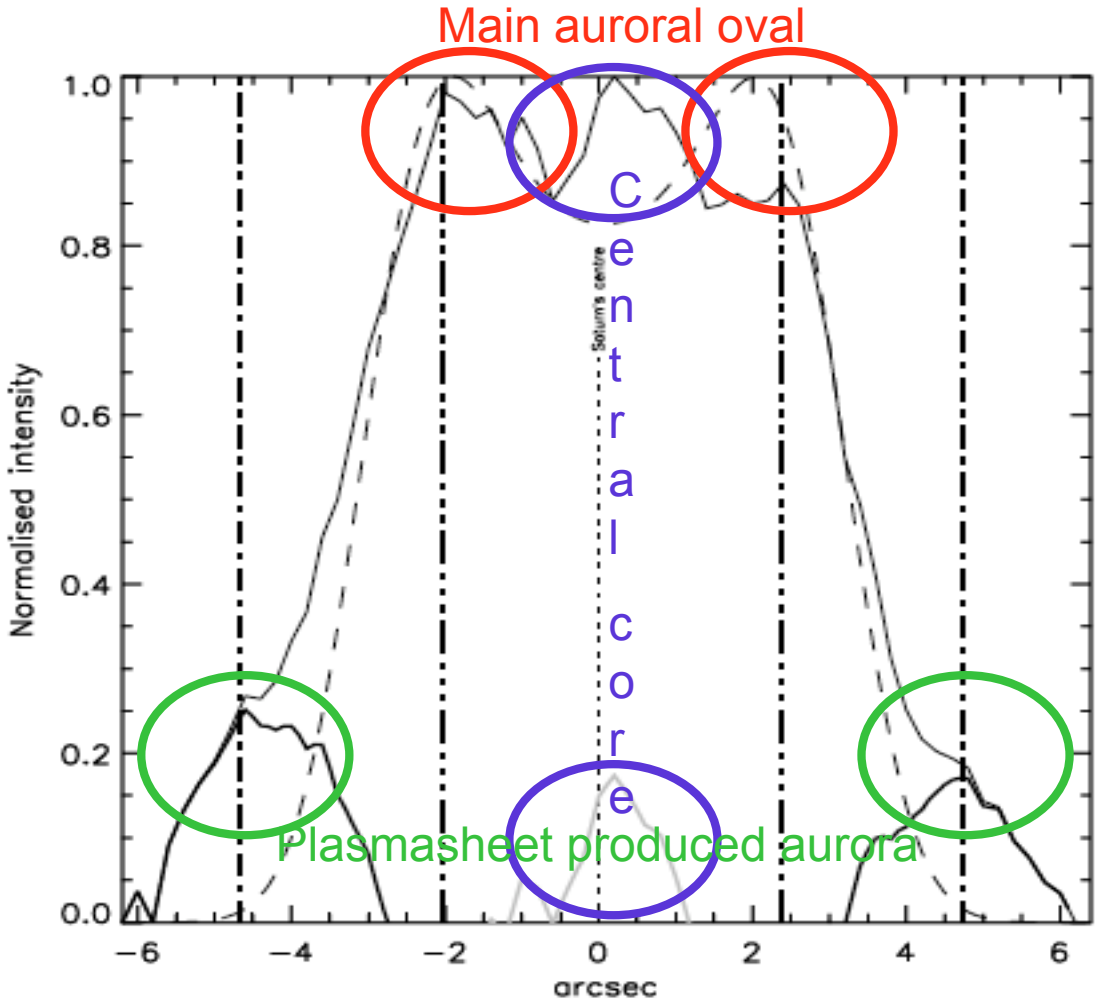
$\Rightarrow$ Joule heating + ion drag

Magnetospheric heating = n x 10^{12}W planetwide

Magnetosphere - atmosphere coupling

Dawn

Dusk



Stallard et al., *Nature* 2008a

JUNO - 2016

Polar orbits

Magnetometer— MAG (GSFC/JPL)

Energetic Particle Detector—EPD (APL)

UV Spectrometer— UVS (SwRI)

Jovian Auroral Distributions Experiment— JADE (SwRI)

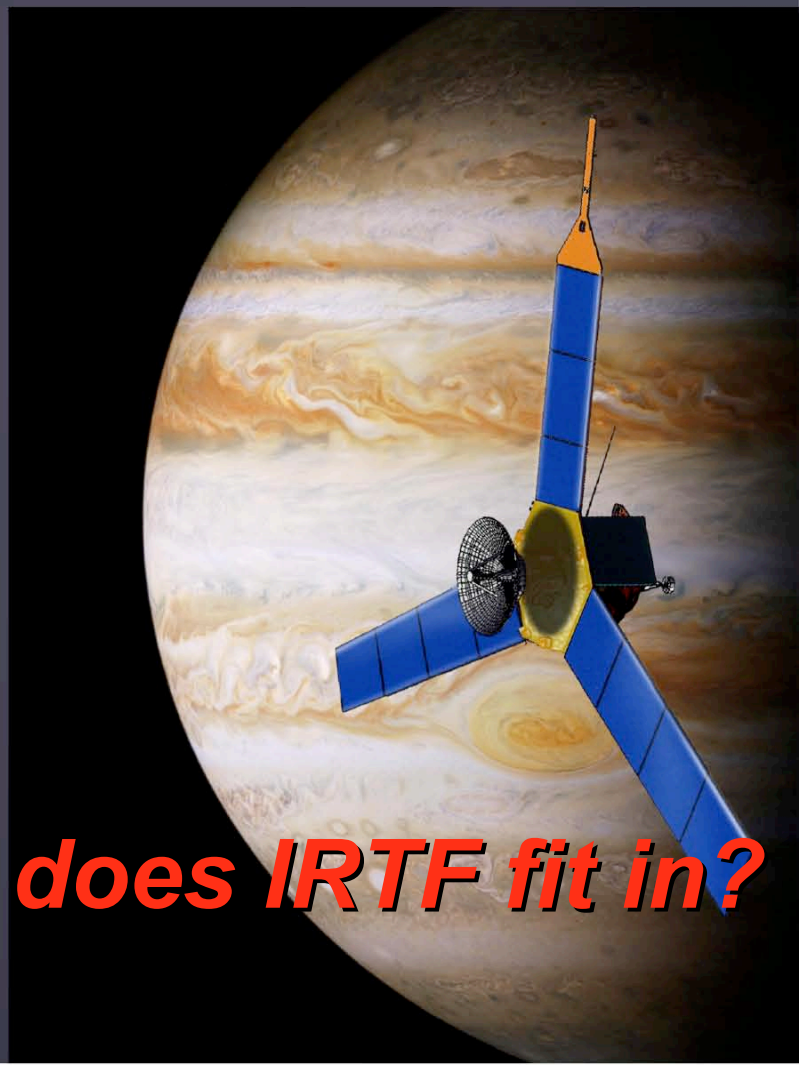
JERAM - infrared spectral imaging - ASI

Microwave Radiometer— MWR (JPL)

Gravity Science (JPL)

Waves (U of Iowa)

Visible Camera - JunoCam (Malin)



How does IRTF fit in?

H_3^+ : i-SHELL & JUNO

Wavelength resolution λ/Δλ ~ 80,000 @ 3.953μm

(Effective velocity resolution ~ 100 m/s)

Slit ~ 25" plus Imager!

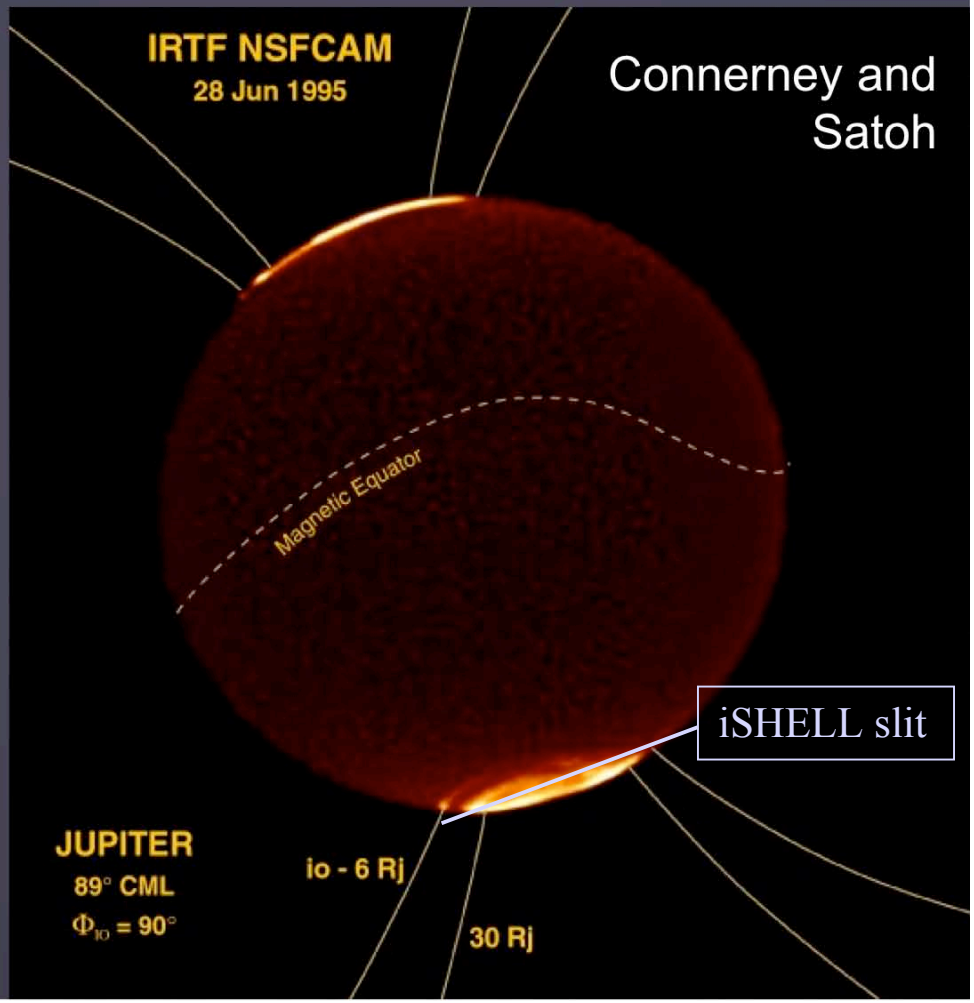
***Ion* Velocities**

***Ion* vertical profiles**

Conductivity

Joule heating & ion drag

iSHELL will complete the magnetosphere - ionosphere - atmosphere coupling mechanism

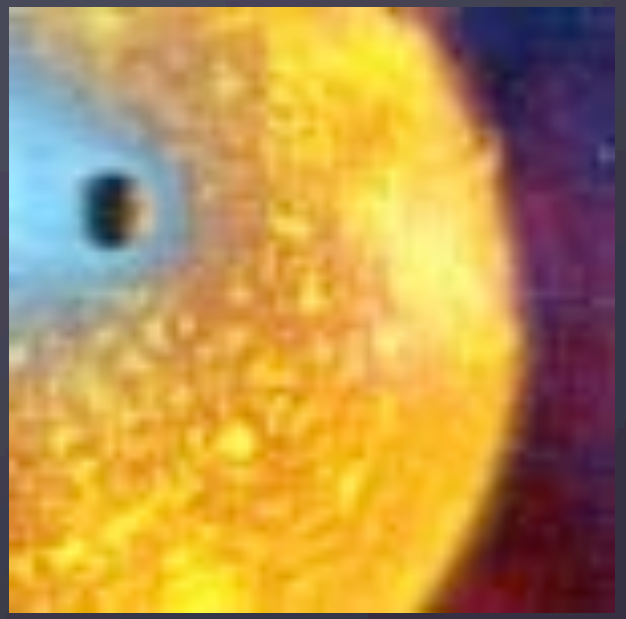


H_3^+ in exoplanets

Many large exoplanets found close to star

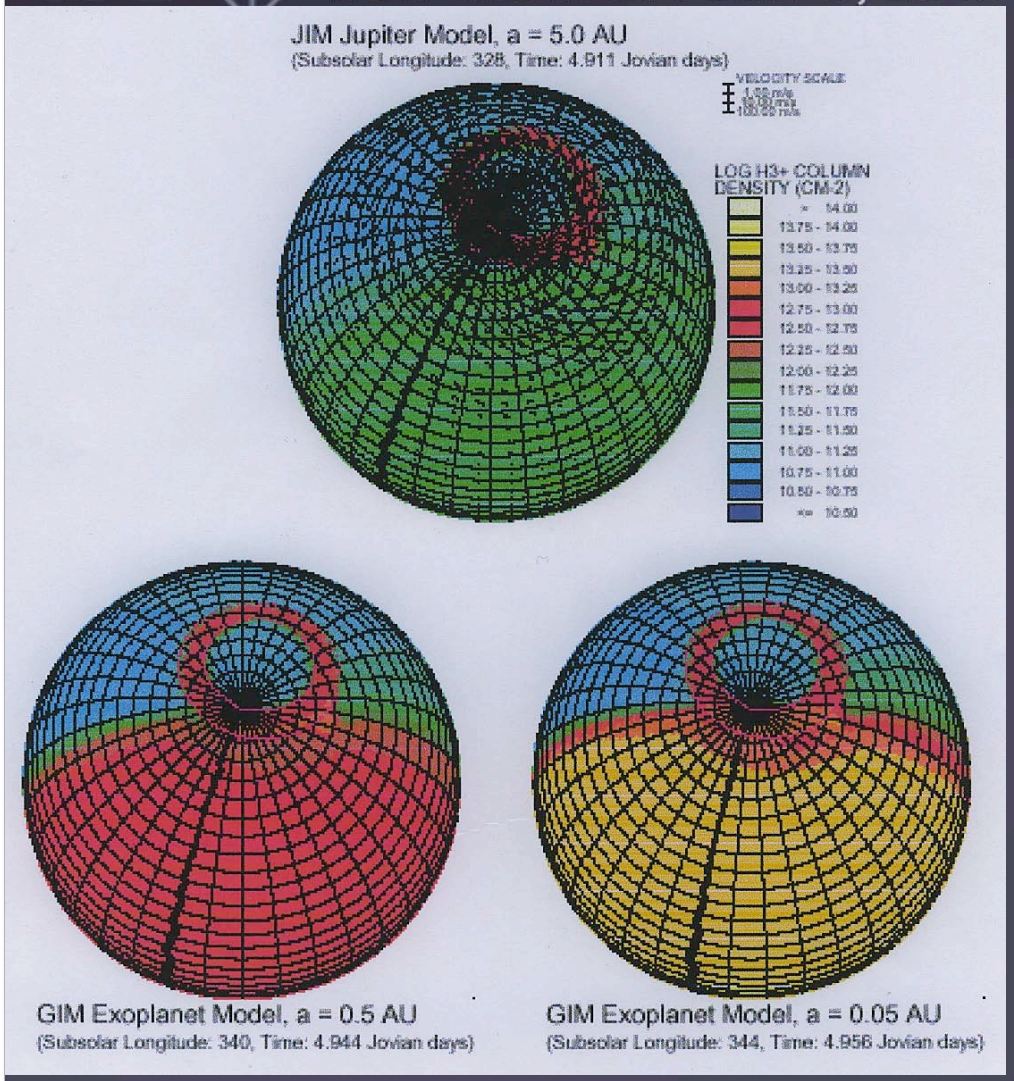
d ~ 0.5 - 0.05a.u.

At what point does atmosphere heat up and escape like HD209458b?



Steve Miller UCL

H_3^+ in exoplanets



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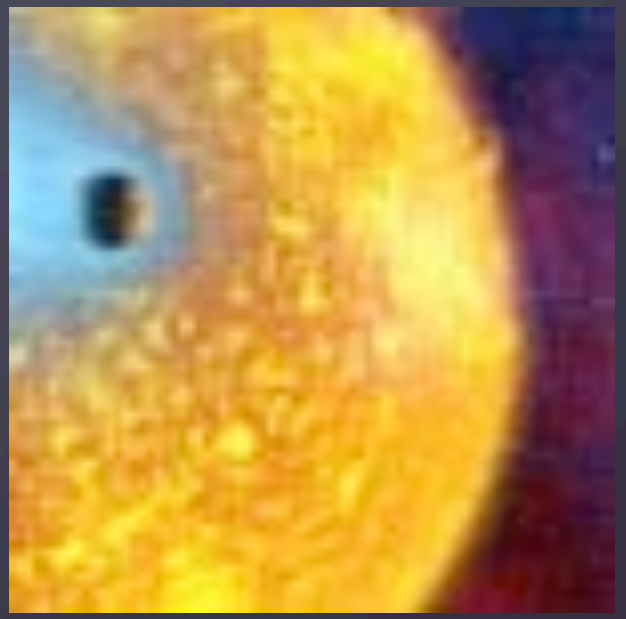
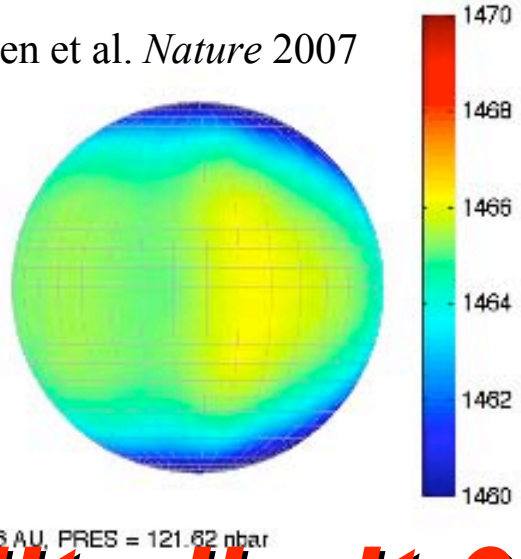


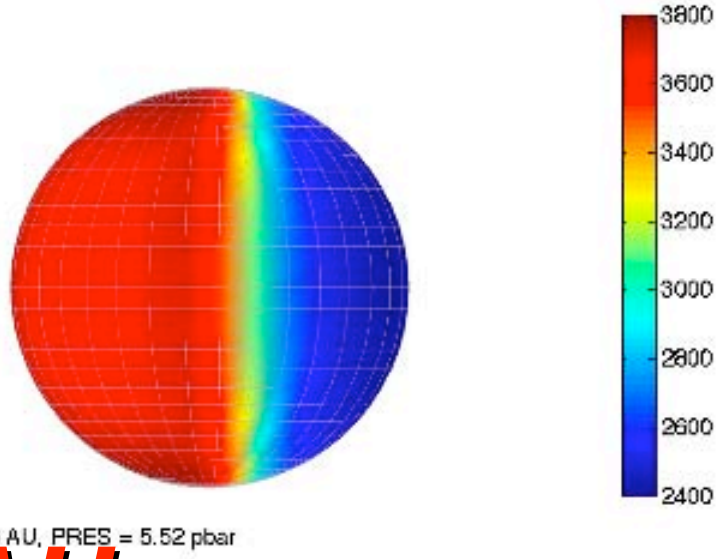
More hν creates more H_3^+

More H_3^+ more cooling - thermostat

Koskinen et al. *Nature* 2007

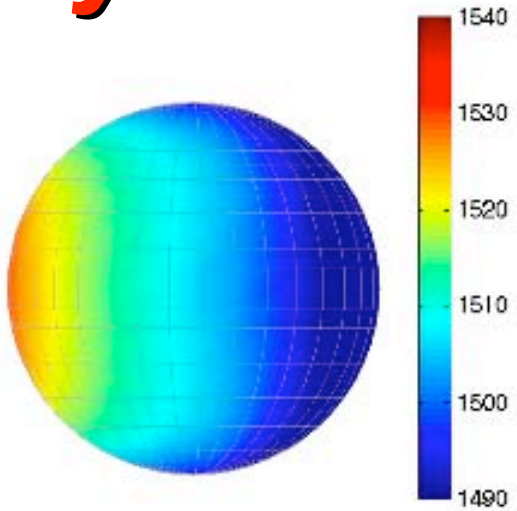


DIST = 0.16 AU, PRES = 121.62 nbar

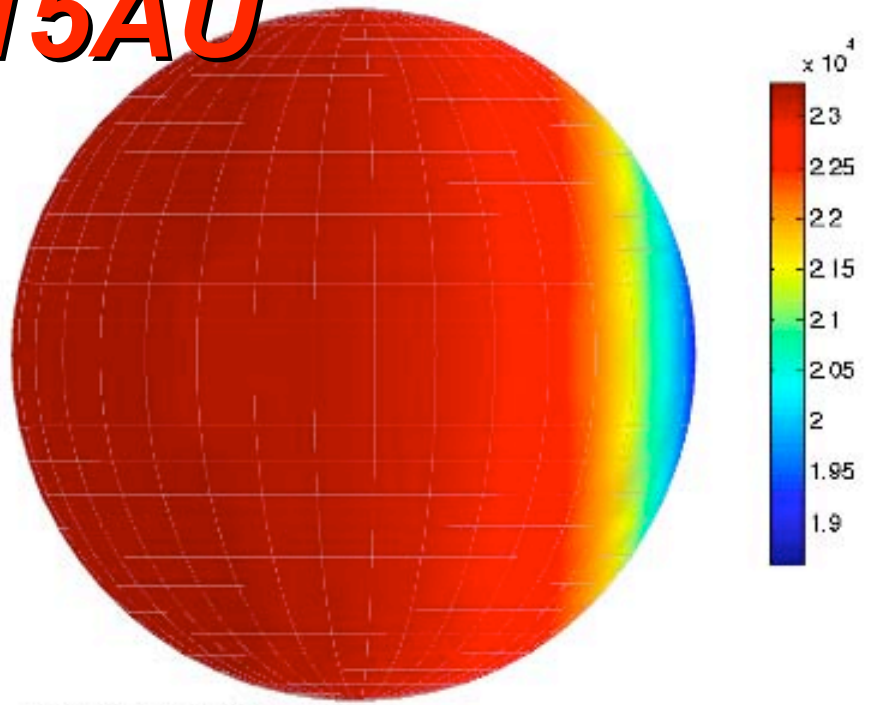


DIST = 0.16 AU, PRES = 5.52 pbar

Stability limit 0.15AU



DIST = 0.14 AU, PRES = 121.62 nbar



DIST = 0.14 AU, PRES = 5.52 pbar

Ribas et al., *Astrophys J.* 2005

Table 1 | The *Sun in Time* targets and thermospheric stability limits

Name	HD	Type	Age (Gyr)	F (erg s^{-1} cm^{-2})	Limit (AU)
EK Dra	129333	G1.5 V	0.1	513.5	1.68
p^1 UMa	72905	G1.5 V	0.3	129.3	0.84
k^1 Cet	20630	G5 V	0.65	51.1	0.53
b Com	114710	G0 V	1.6	16.0	0.30
The Sun	....	G2 V	4.6	4.64	0.16
b Hyi	2151	G2 IV	6.7	2.9	0.13

Ribas et al., *Astrophys J.* 2005

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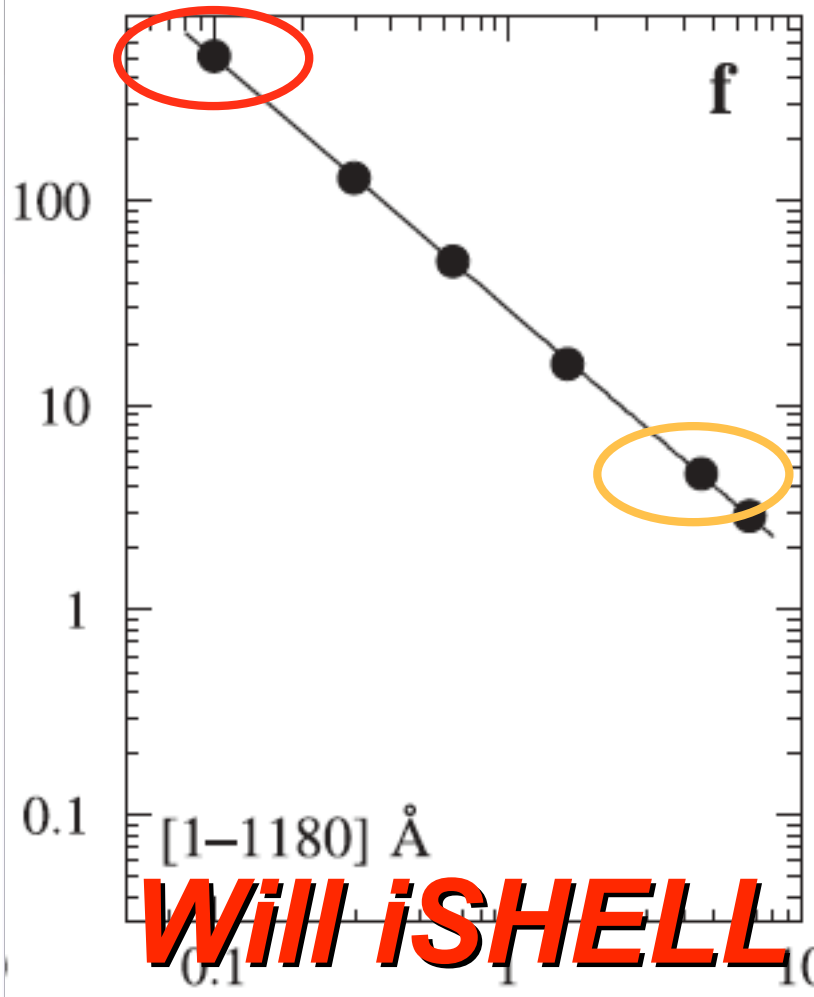

Prior to 100myr, did Jupiter & Saturn have an HD209458b phase?

Will iSHELL see exoplanet H_3^+?

APL IRTF MOWG: Feb. 26, 2009 Steve Miller UCL

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Takeshi Oka

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Jonathan Tennyson
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Renee Prange
Daniel Rego