PSI #3 : Characterize the exchange processes at the interface between the surface/subsurface and the exosphere-ionosphere

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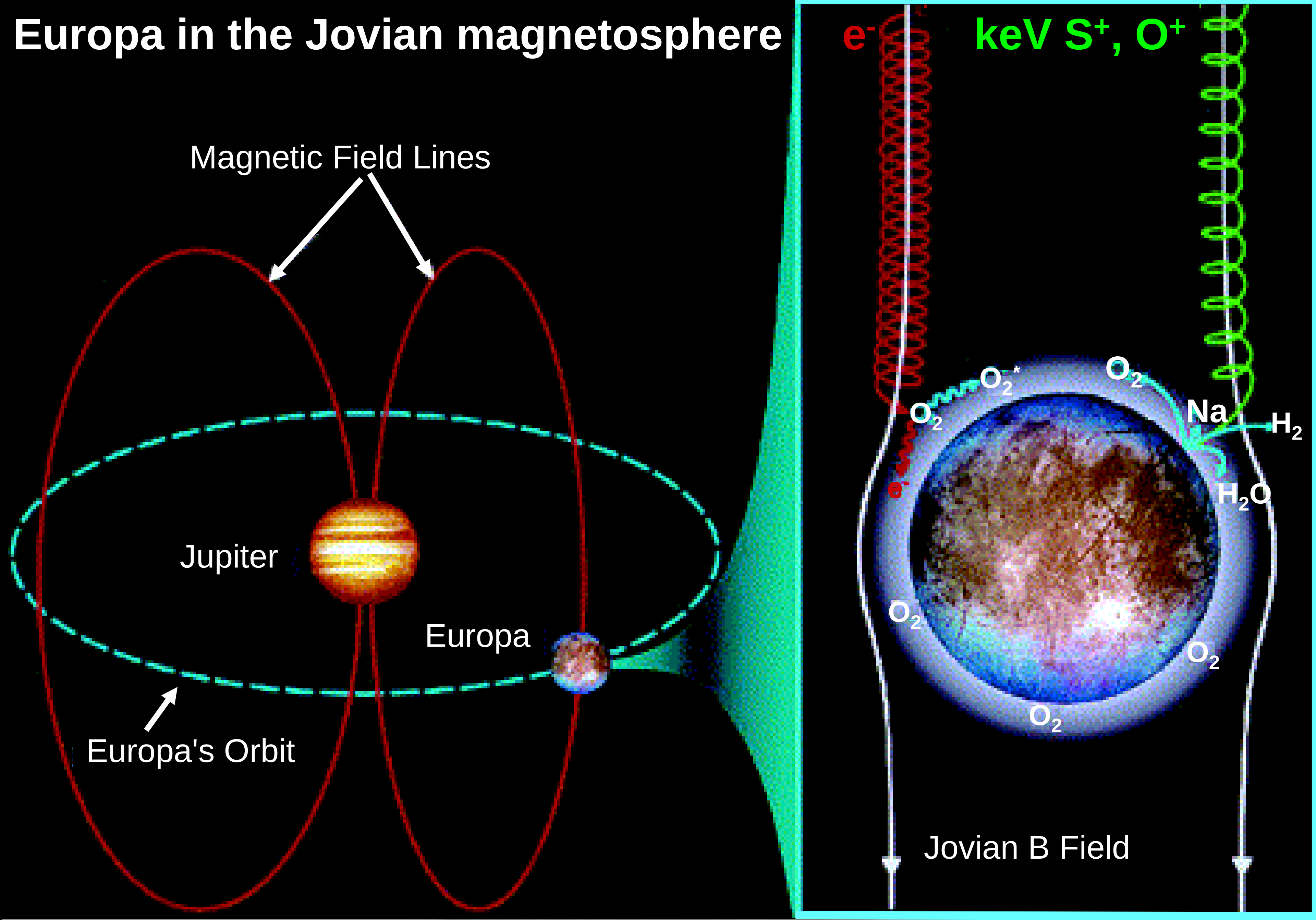
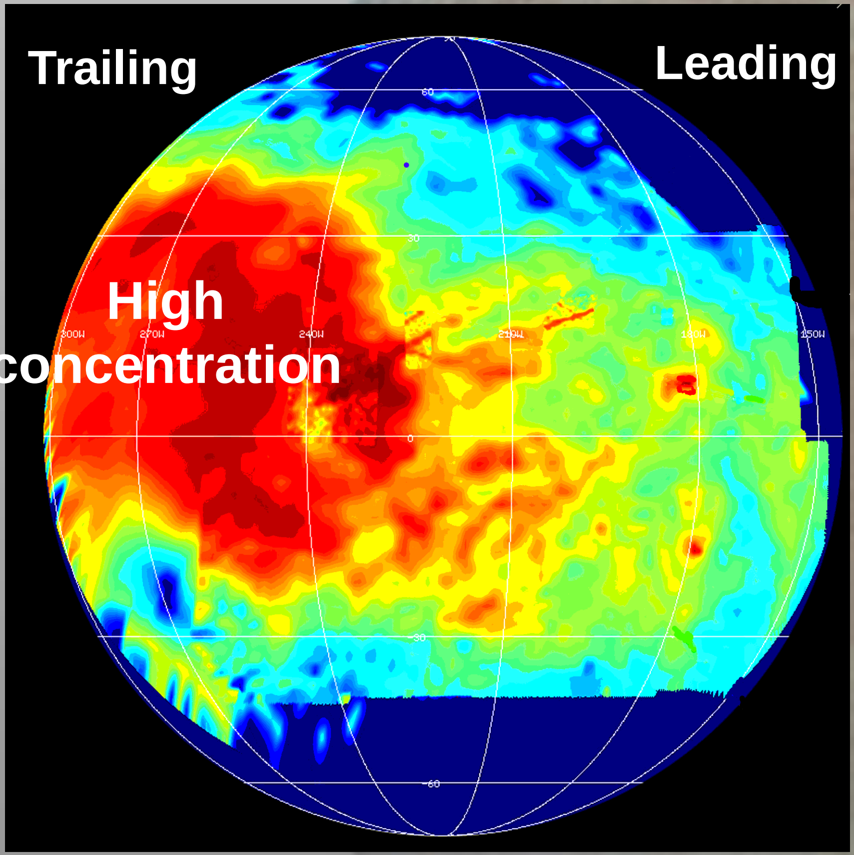
From the magnetosphere to the exosphere

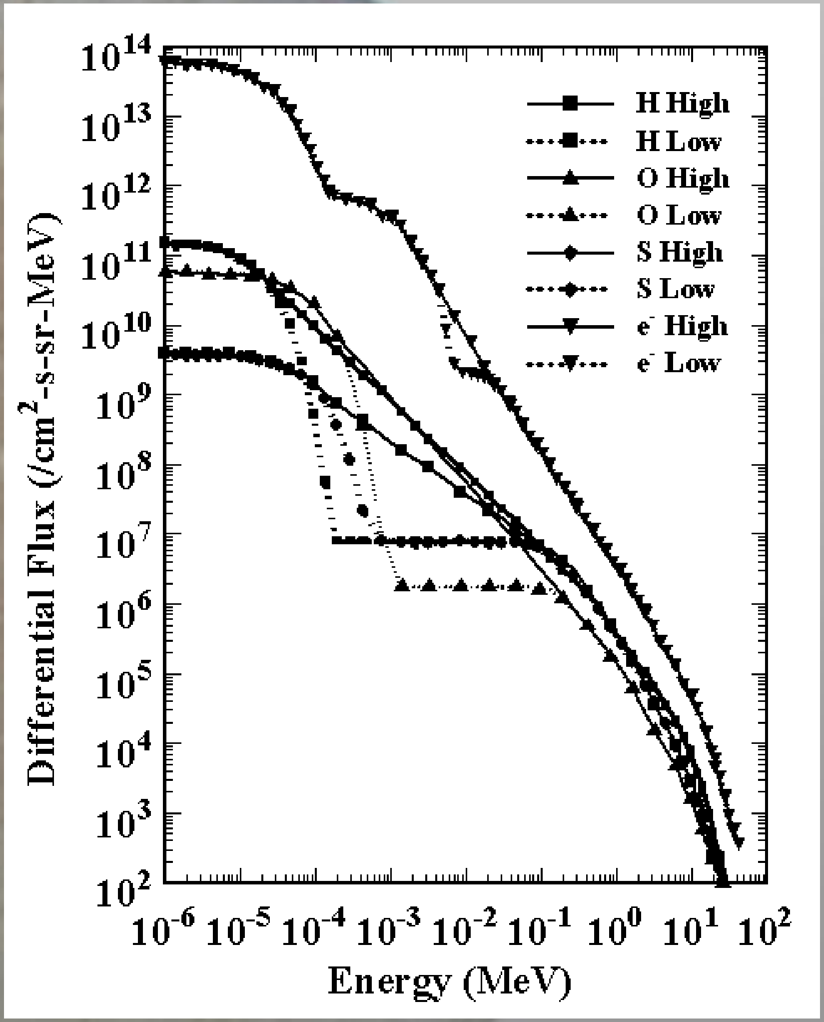
Europa in the Jovian magnetosphere



Radiation-induced surface chemistry

Hydrated sulfates on Europa (NIMS, Carlson et al. 2002)





⇒ Magnetospheric irradiation effects

Differential flux upstream of Europa (Cooper et al. 2005)

Europa's atmosphere and Torus

Species observed in atmosphere :

O_2 (~10^{15} cm^{-2}), Na (10^{10} cm^{-2},), K (10^9 cm^{-2})

Species observed in Torus :

H_2 (4.2×10^{33}), O (4.0×10^{32})

= 3× (Io torus O + S) = 200-1000 Europa atmosphere

Additional Volatiles Observed in the Surface:

O_2, SO_2, CO_2 (Will sputter with ice like Na)

Non-volatiles:

H_2O, H_2O_2

Sulfur, Sulfate, Carbon, Carbonate, CN,

Organics, Minerals?

Atmospheric loss rates predicted from models:

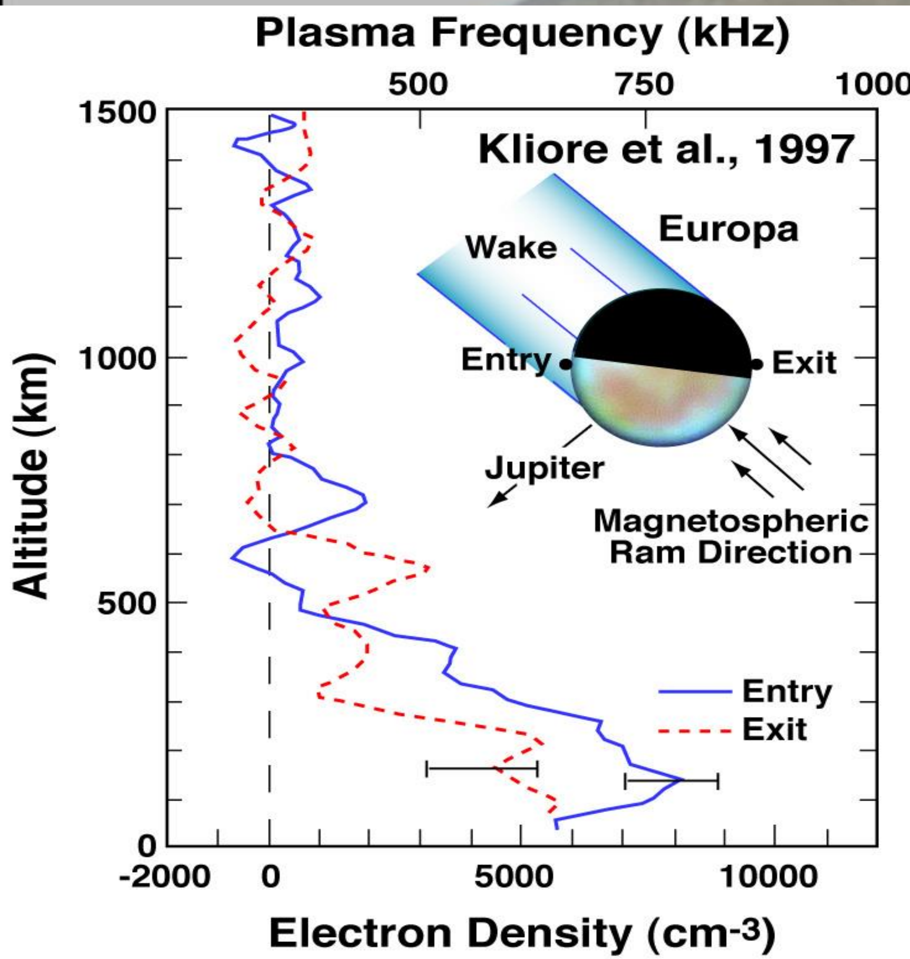
~5×10^{26} O+O_2/s + ~2×10^{26} O/s +

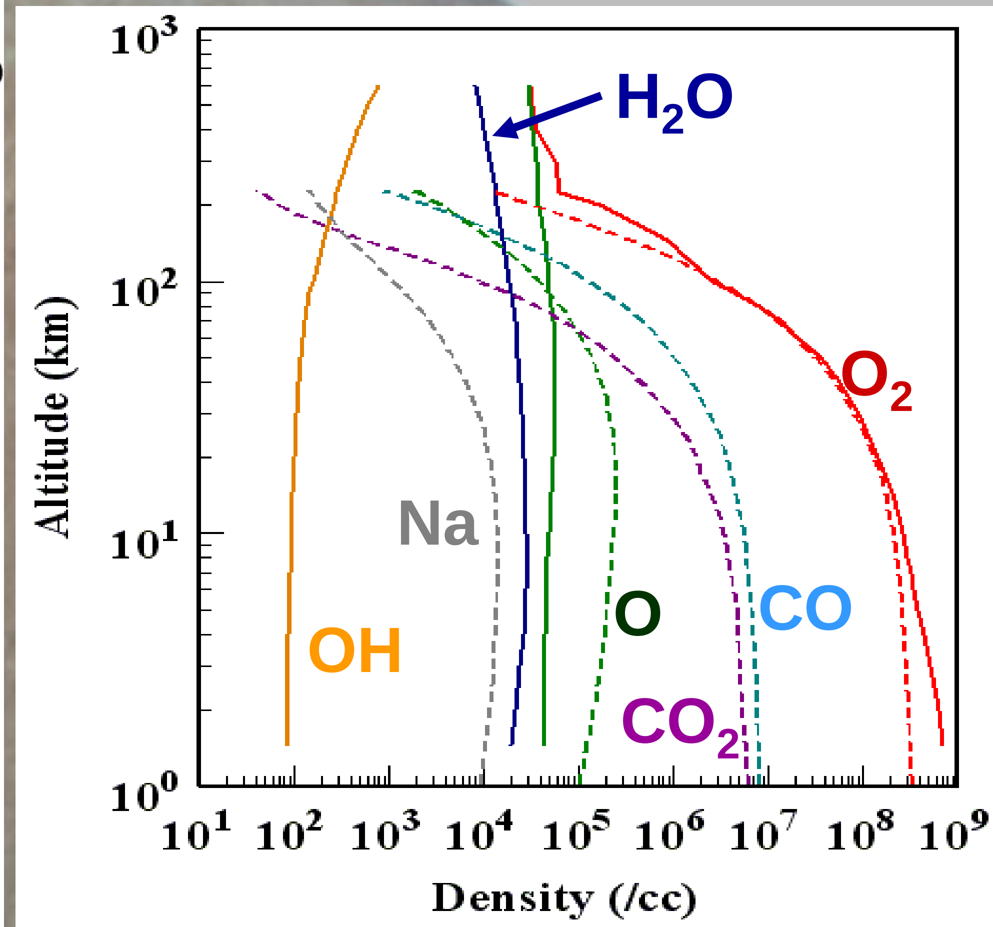
~1×10^{26} H/s + ~1×10^{26} H_2O/s + ~1×10^{25} OH/s (Smyh & Marconi 2006)

~1.2×10^7 Na/cm^2/s (Leblanc et al. 2005)

Ion Density

Neutral Densities

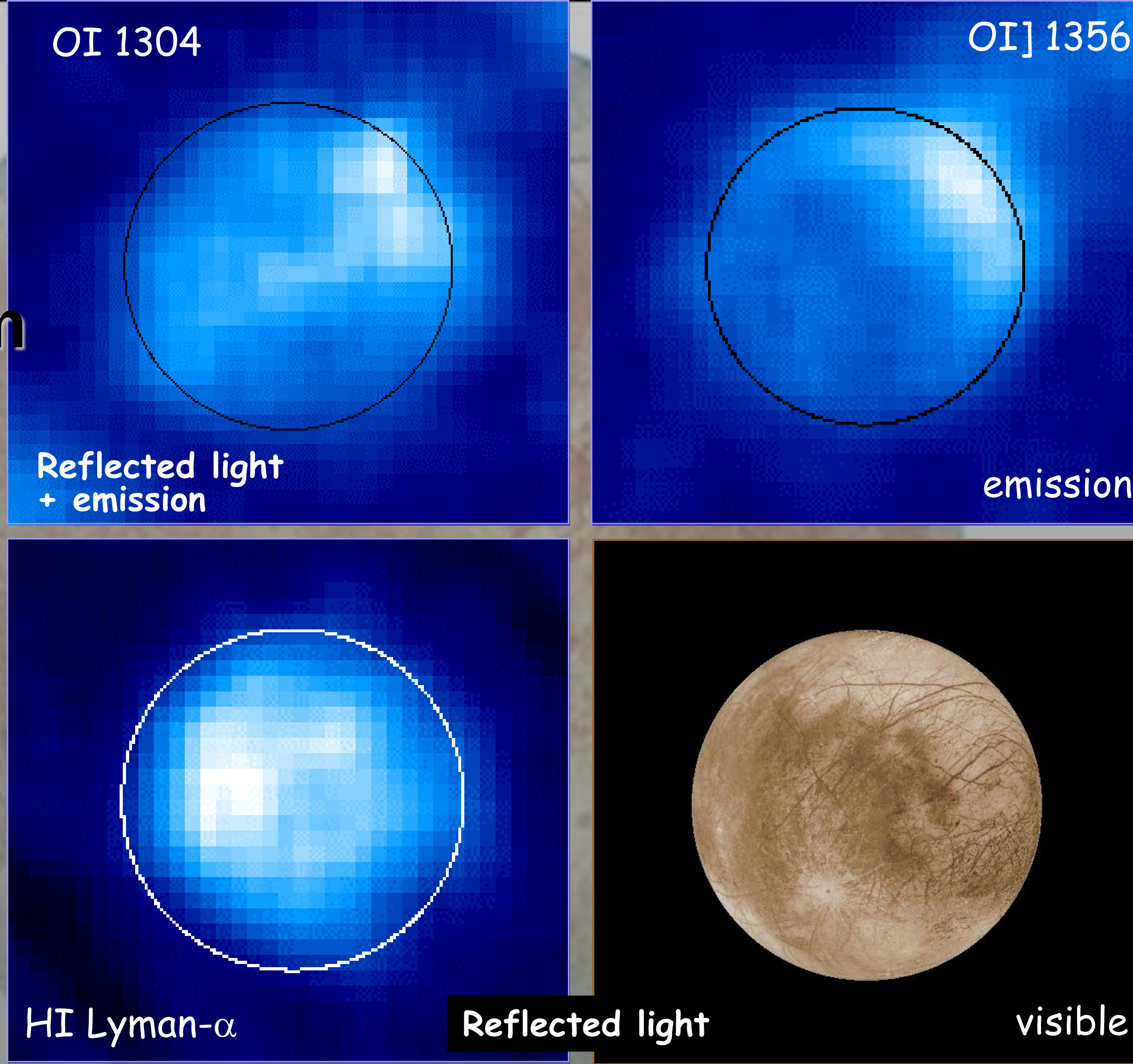




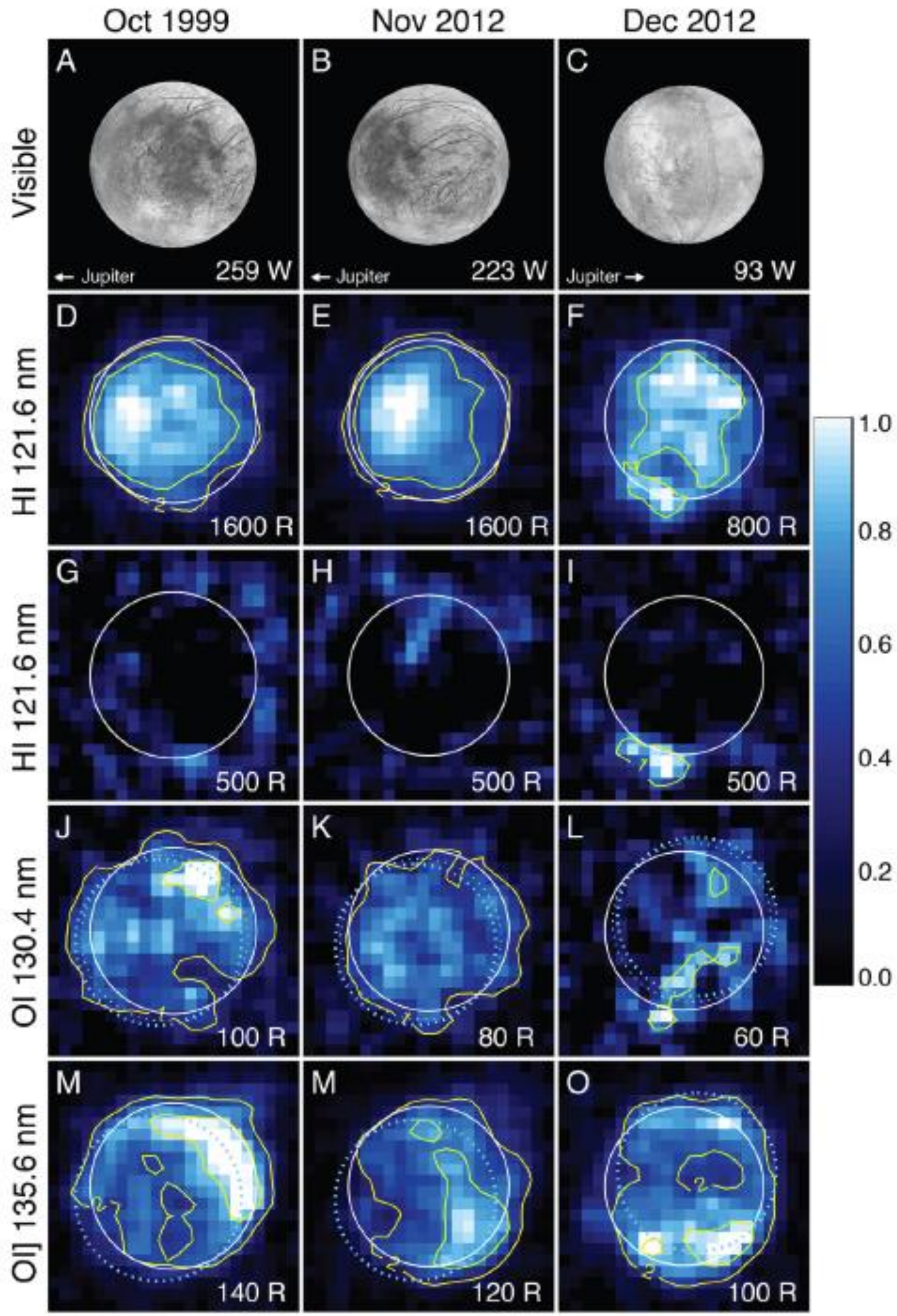
Entry/Exit asymmetry: Photo-ionization or latitude dependency effects?

Solid 1D: Shematovich et al. (2005)
Dashed 2D: Wong et al. (2006)

Europa Oxygen Spatially Non-uniform



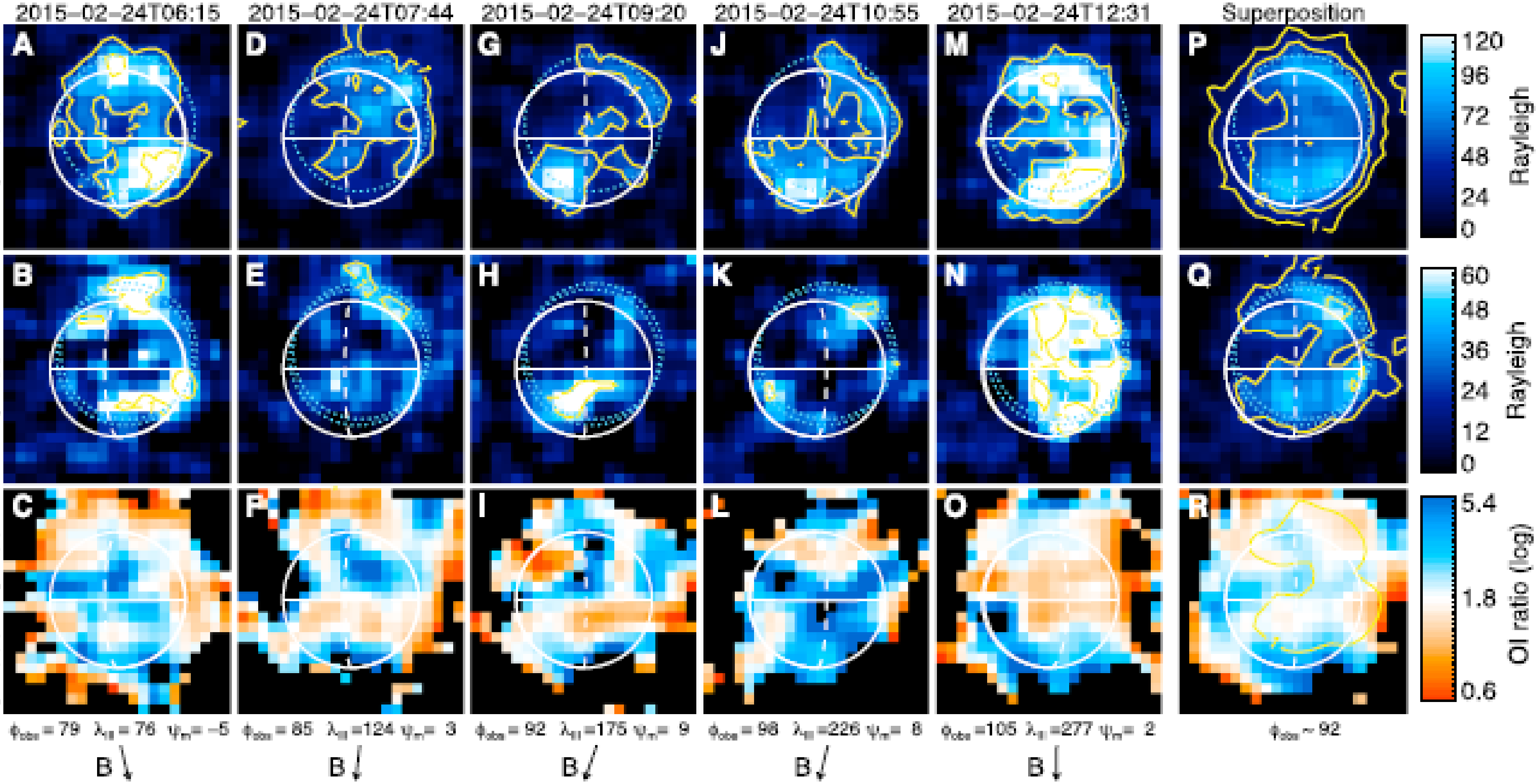
McGrath et al. (2004)



Roth et al. (2013)

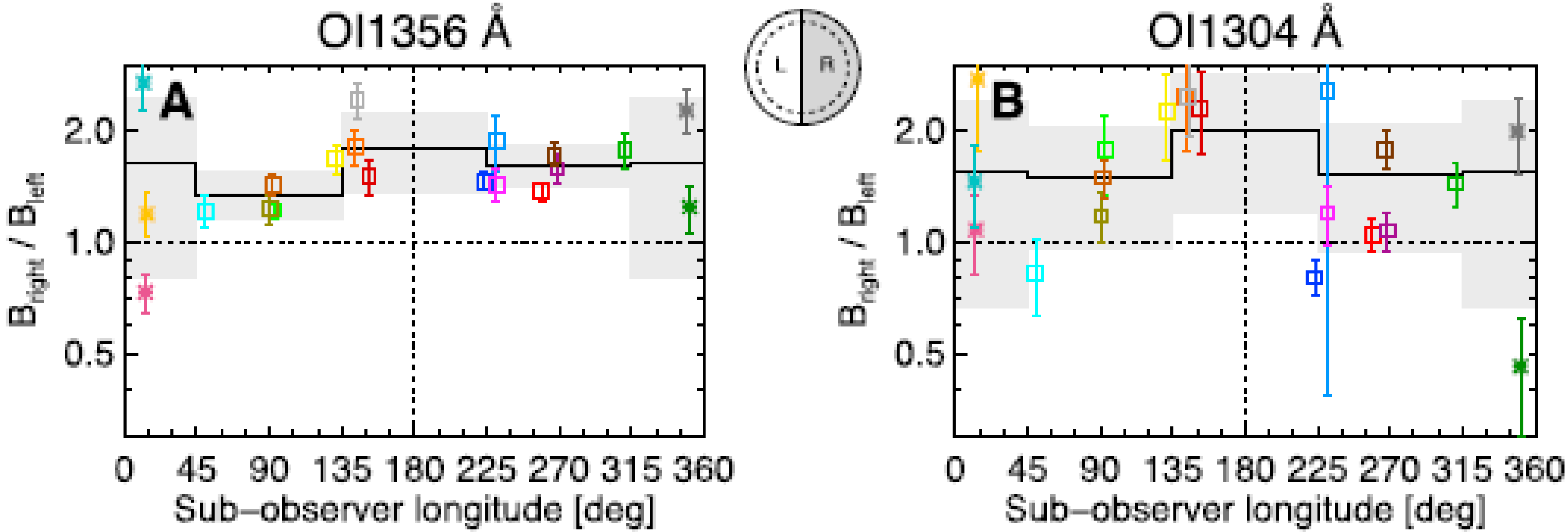
” …significant coincident surpluses of hydrogen Lyman-α and oxygen OI 103.4 nm emissions above the Southern hemisphere in December 2012. ”

“Nondetection in November and in previous HST images from 1999 suggests varying plume activity…”



Roth et al. (2015)

"Both brightness and aurora morphology undergo systematic variations correlated to the periodically changing plasma environment."



Roth et al. (2015)

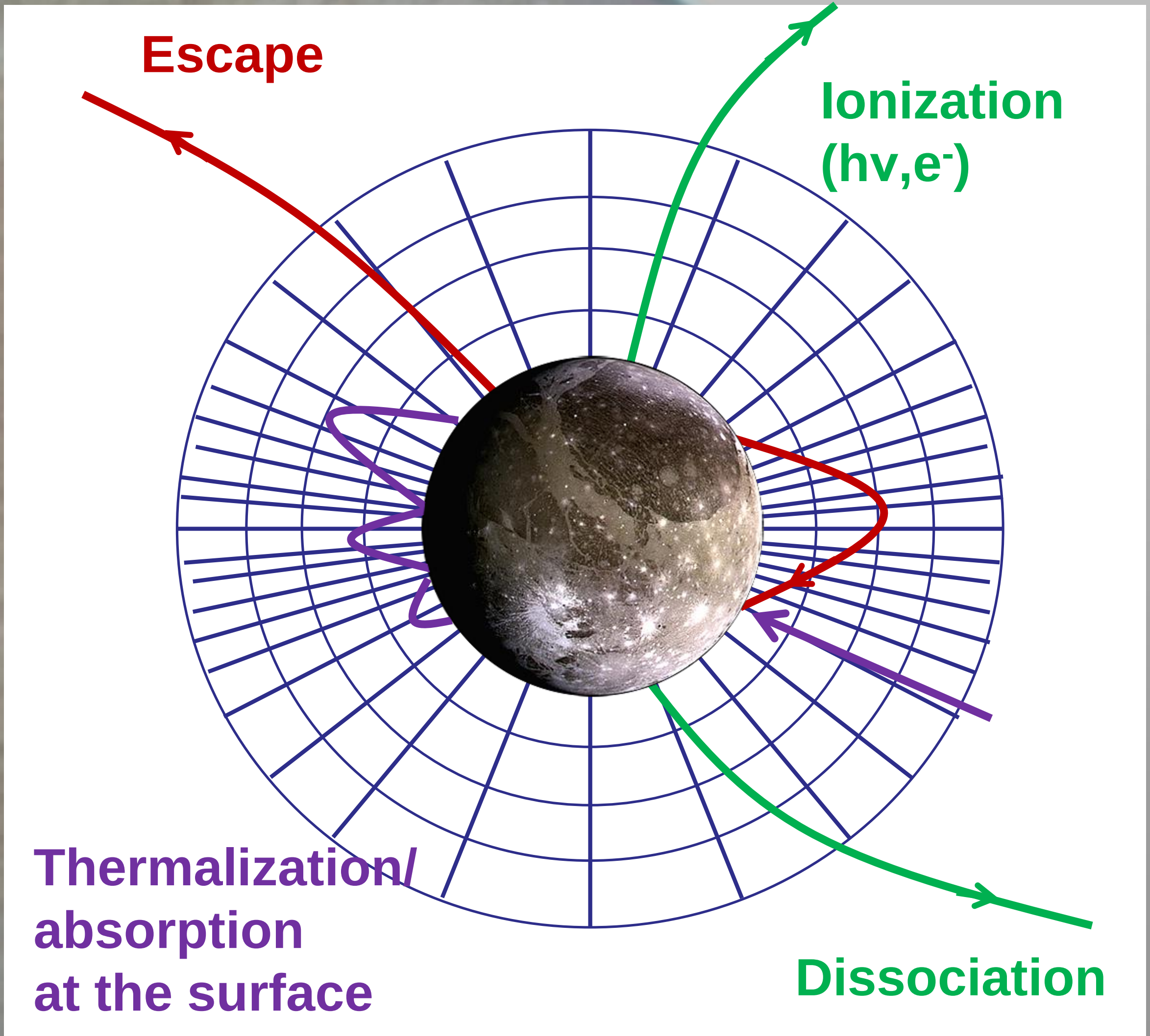
“The dusk side is consistently brighter than the dawnside with only few exceptions, which cannot be readily explained by obvious plasma physical or known atmospheric effects.“

“Europa’s bound atmosphere is dominated by O_2.”

“…a more extended atomic O corona, but O_2 prevails at least up to altitudes of ~900 km. “

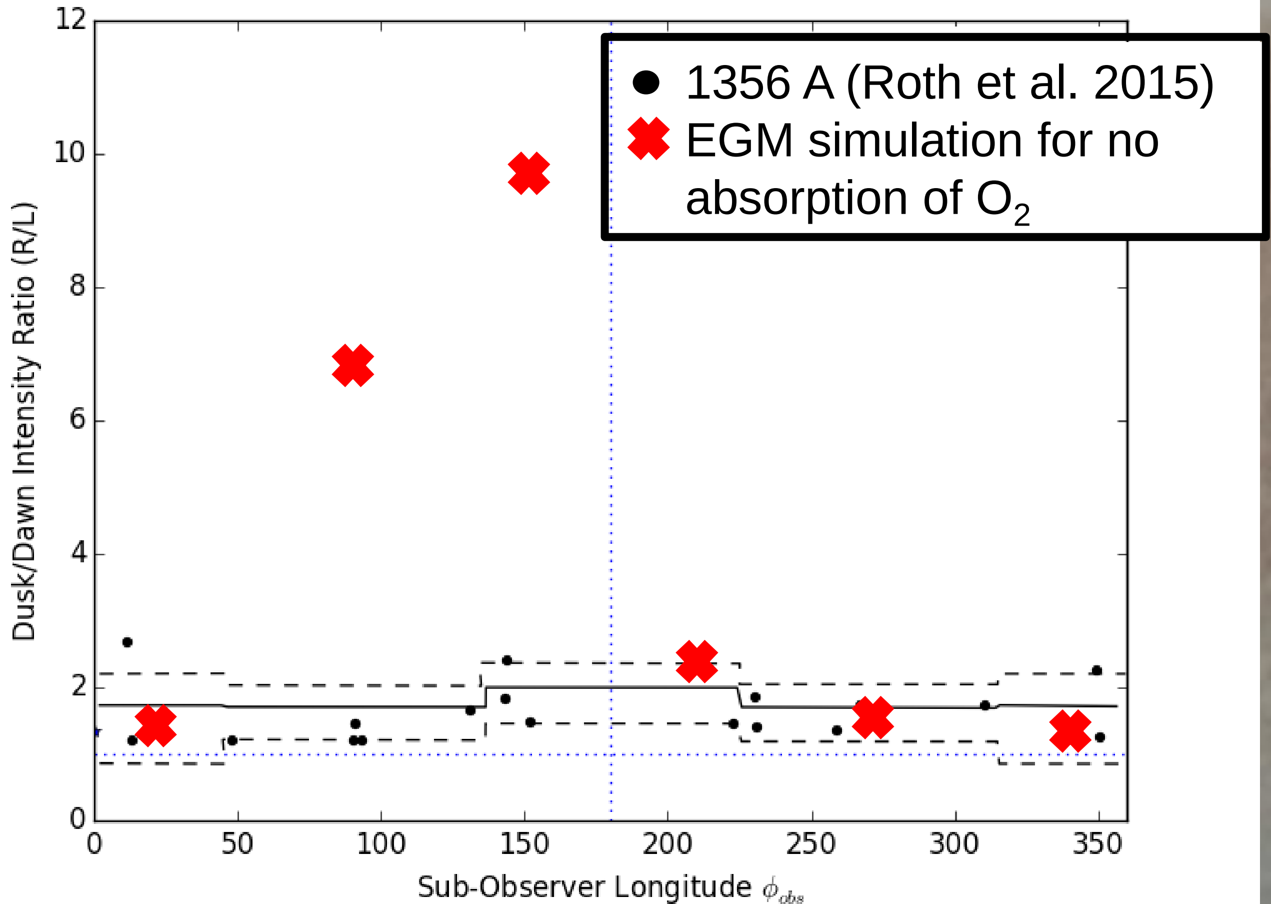
A 3D model of Europa's exosphere: EGM)

- Parallelized Monte Carlo approach for H_2O, H_2, O_2, H, O, OH
- Sublimation + Sputtering
- Surface reservoir
- Europa's rotation and Jupiter gravity
- Collisions can be included but are neglected for most of the runs



Turc et al. (2014), Oza et al; (2016)

Origin of the Dawn-dusk asymmetry in oxygen exosphere.



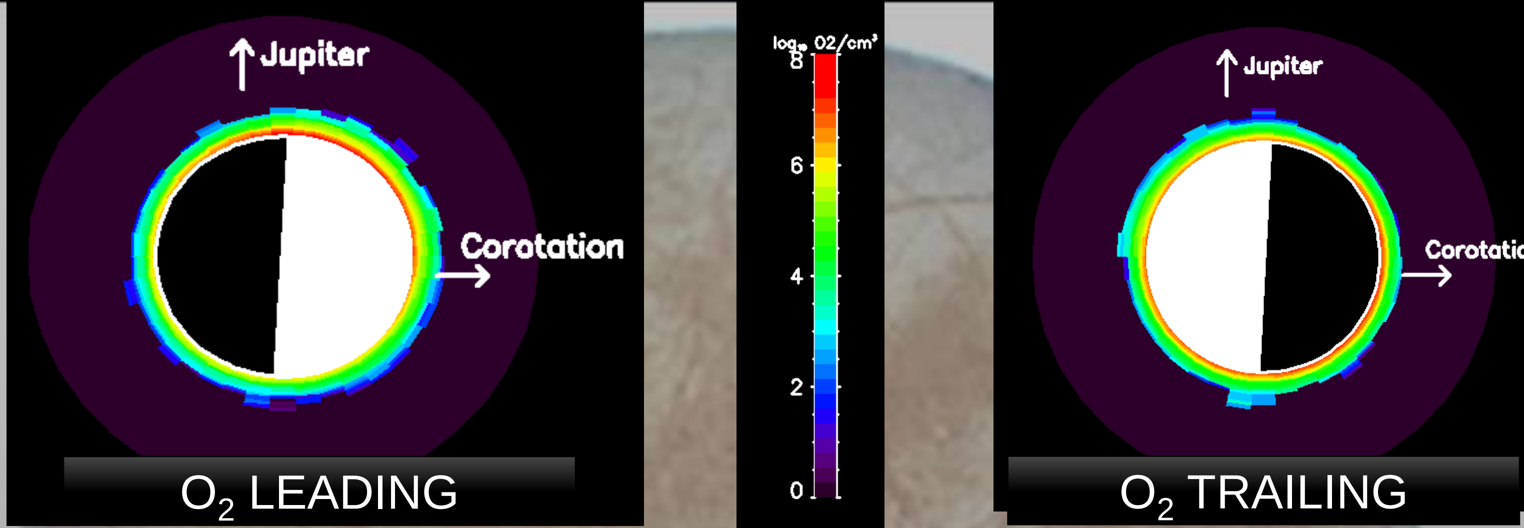
Oza et al; (2016)

The EGM predicts a dawn/dusk asymmetry as observed, due to

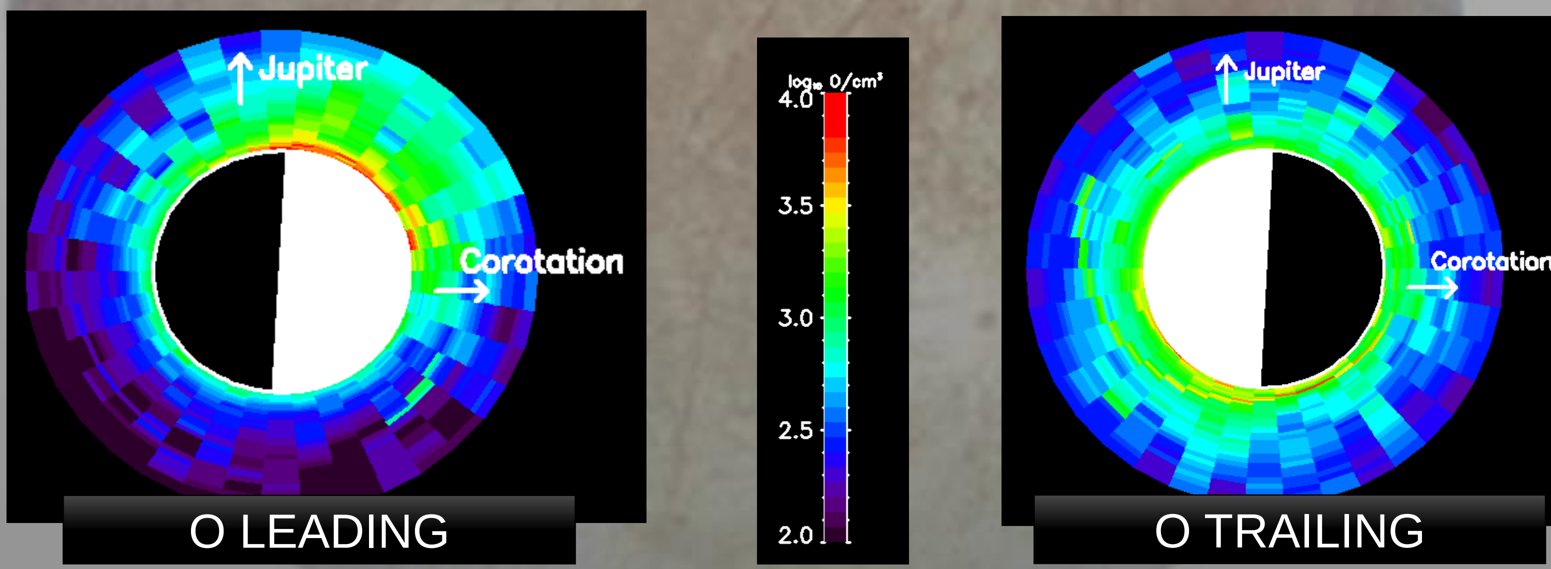
- **O_2 transport with time scale of the order of Europa rotation,**
- **rotation of main sources of O_2.**

The absorption controls the size of the dawn/dusk asymmetry.

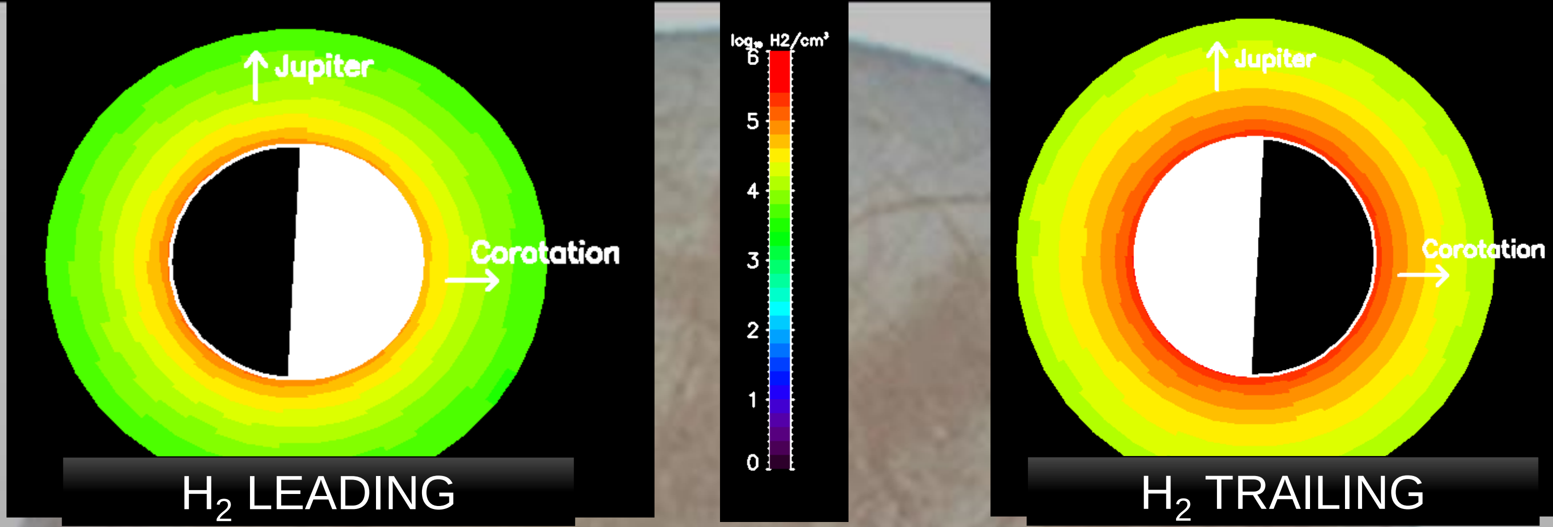
⇒ The spatial distribution of O_2 depends on Europa phase angle.



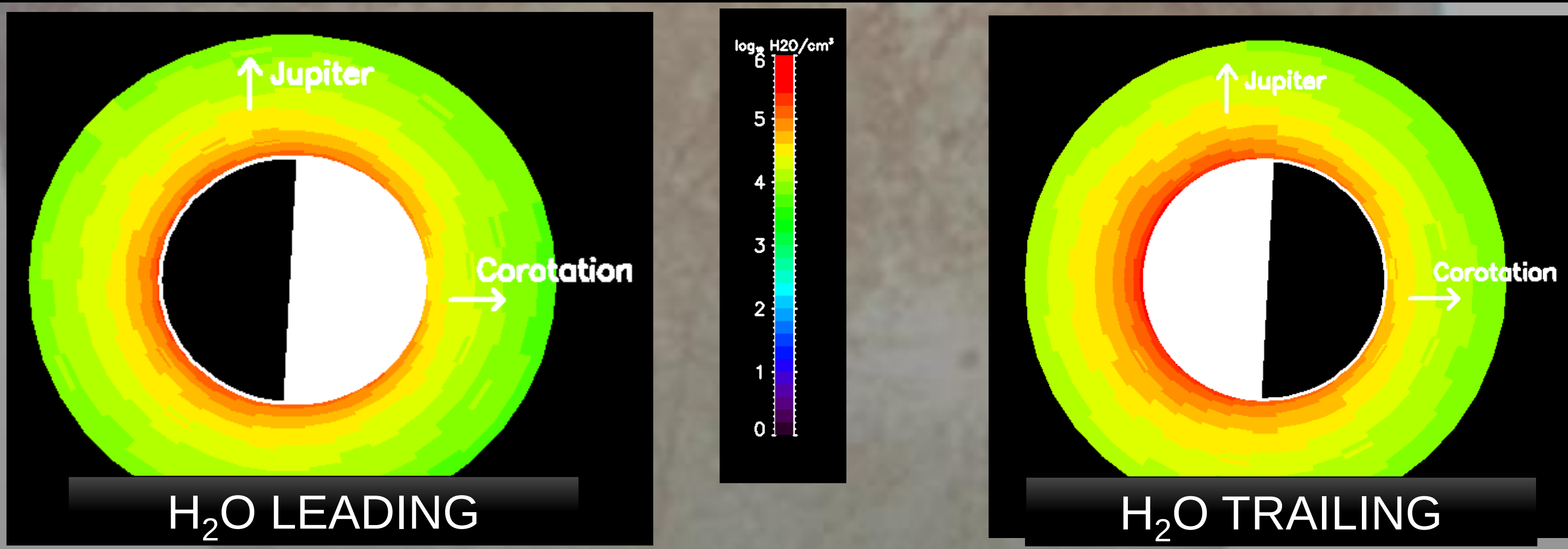
O_2 migrates slowly from day to night. Its spatial distribution is highly related to its ~half rotational period previous history.



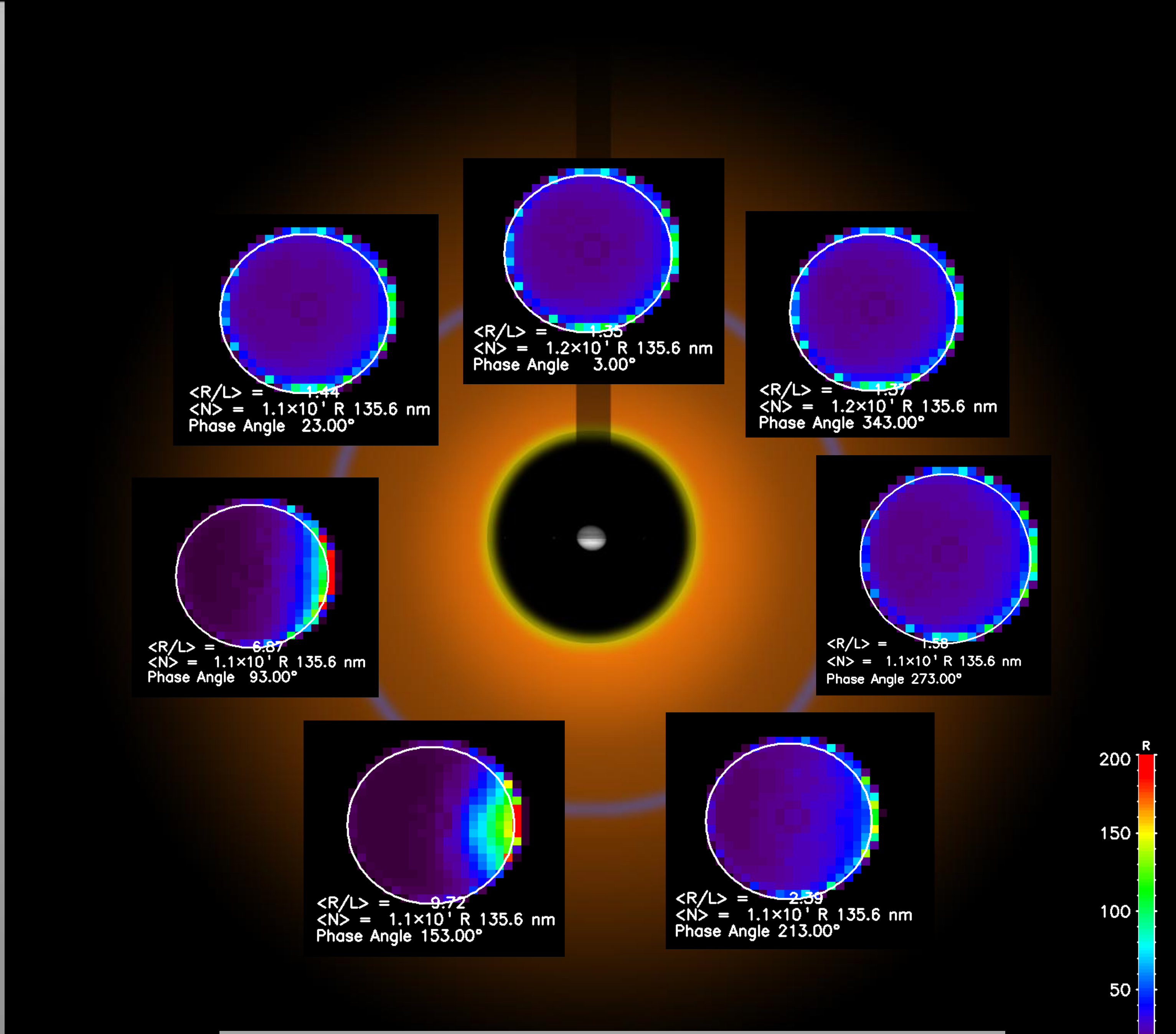
O is essentially produced from O_2. O density is larger than O_2 density above few hundreds km (collisions populate higher altitudes in O_2).



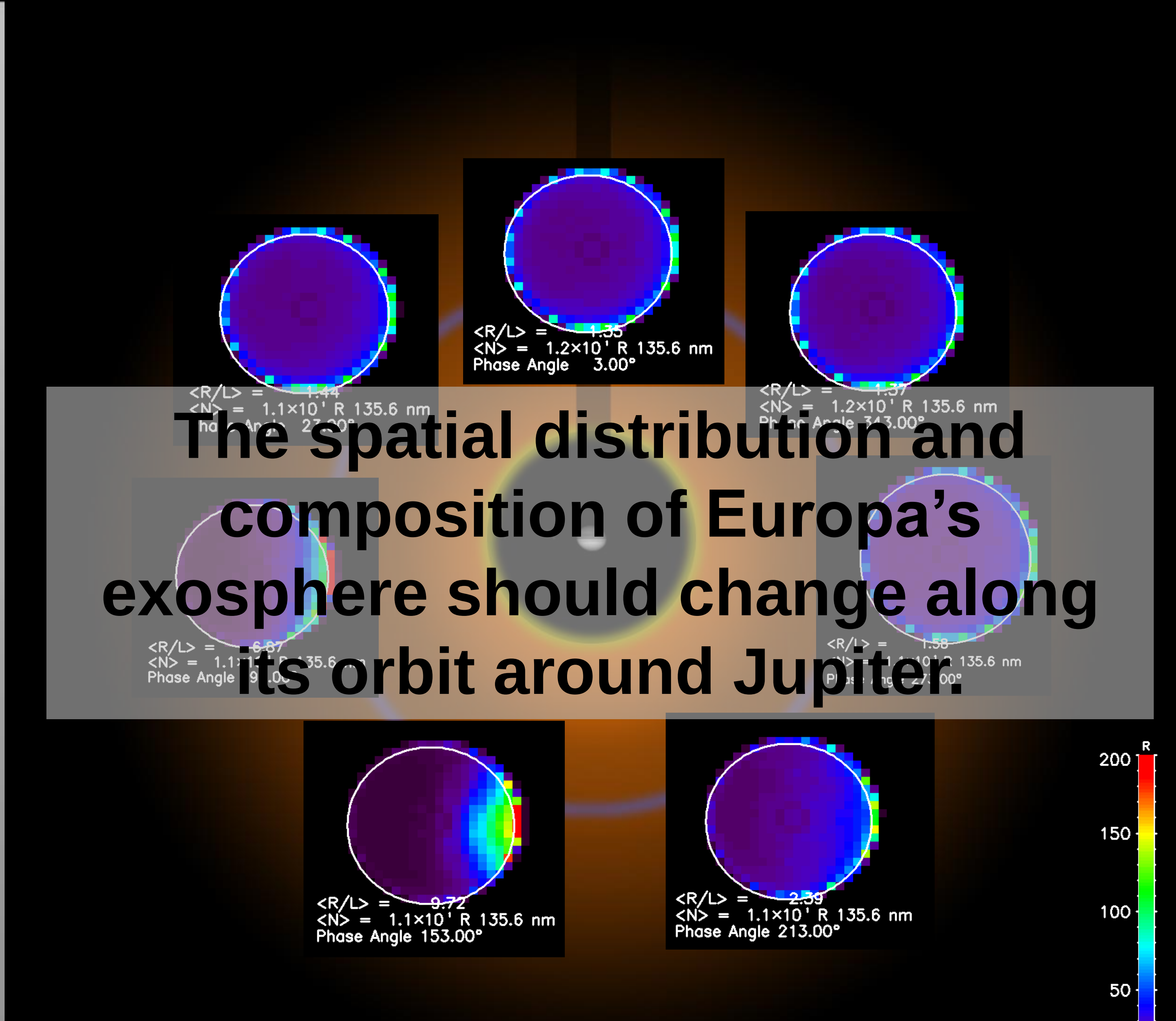
H_2 shows nominal day/night asymmetry. No dawn/dusk due to rapid migration and no absorption.



H_2O leading/trailing asymmetry due to change in albedo, sputtering, and lack of migration due to efficient absorption.



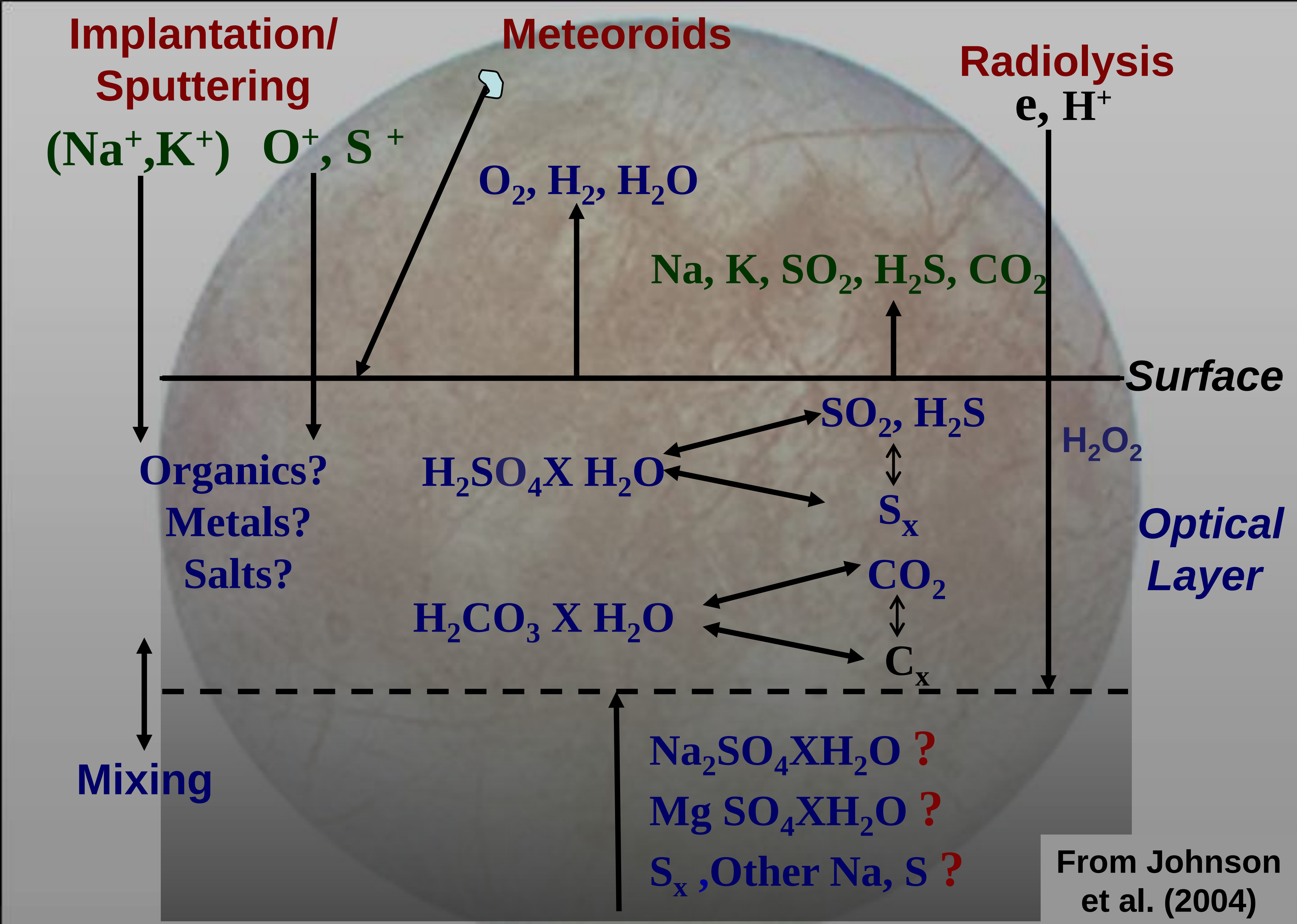
Orbital evolution of O_2 emission



The spatial distribution and composition of Europa's exosphere should change along its orbit around Jupiter.

Orbital evolution of O_2 emission

From the exosphere to the surface


Implantation/ Sputtering
Meteoroids
Radiolysis
e, H^+
(Na^+,K^+) O^+, S^+
O_2, H_2, H_2O
Na, K, SO_2, H_2S, CO_2
Surface
SO_2, H_2S
H_2O_2
Organics?
Metals?
Salts?
H_2SO_4X H_2O
S_x
Optical Layer
CO_2
H_2CO_3 X H_2O
C_x
Mixing
$Na_2SO_4XH_2O$?
Mg SO_4XH_2O ?
S_x ,Other Na, S ?
From Johnson et al. (2004)

What measurements?

Objective

What are the origins of Europa's exosphere?

Approach

<u>How is Europa's exosphere today?</u>

- ***Composition (major and trace species)***
- ***Spatial distribution (relations with magnetosphere, phase angle and surface)***
- ***Evolution (Jupiter and Europa periods time scale)***

<u>What are the main drivers of its formation?</u>

- ***Role of the magnetosphere/Sun/dust***
- ***Role of the Surface/subsurface***

How is Europa’s exosphere today?

- ***Composition (major and trace species)***

Density of the neutral exospheric species

From few cc to 10^8 cm^{-3} up to 100 amu

Density of the ion exospheric species (eV range)

From few 10^{-2} to 10^4 cm^{-3} up to 50 amu

- ***Spatial distribution (relations with magnetosphere, phase angle and surface)***

Spatial resolution of few tens of km horizontally and few km in altitude (depending on species).

Full coverage at few phase angles

- ***Evolution (Jupiter and Europa periods time scale)***

From one hour to few 10s of hours for major species

What are the main drivers of its formation?

- ***Role of the magnetosphere/Sun/dust***

Ion and electron densities (keV range) with spatial resolution and on hour time scale

Dust density and composition with spatial resolution and on few hour time scale

Coverage of Europa's exosphere during eclipse

- ***Role of the Surface/subsurface***

Latitudinal and longitudinal coverage at different phase angles for major and trace species

Spatial resolution of few tens of km horizontally and few km in altitude for trace species; of hundred km horizontally and ten km in altitude for major species