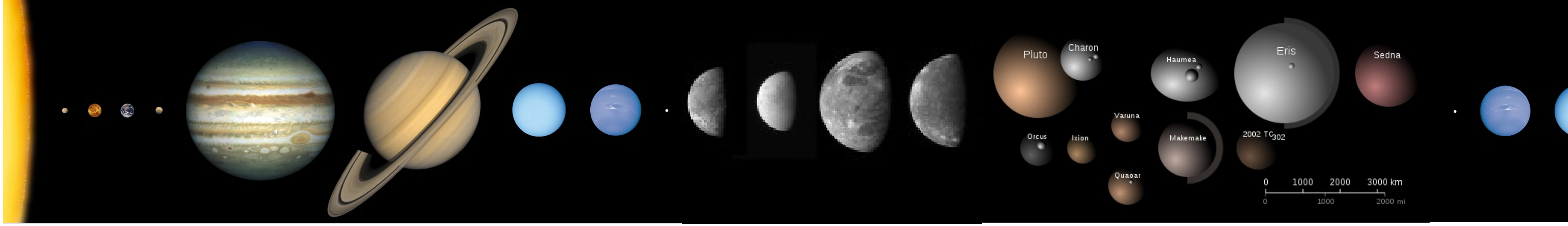

Solar system studies with the SMA

Arielle MOULLET, Mark GURWELL and the SMA team

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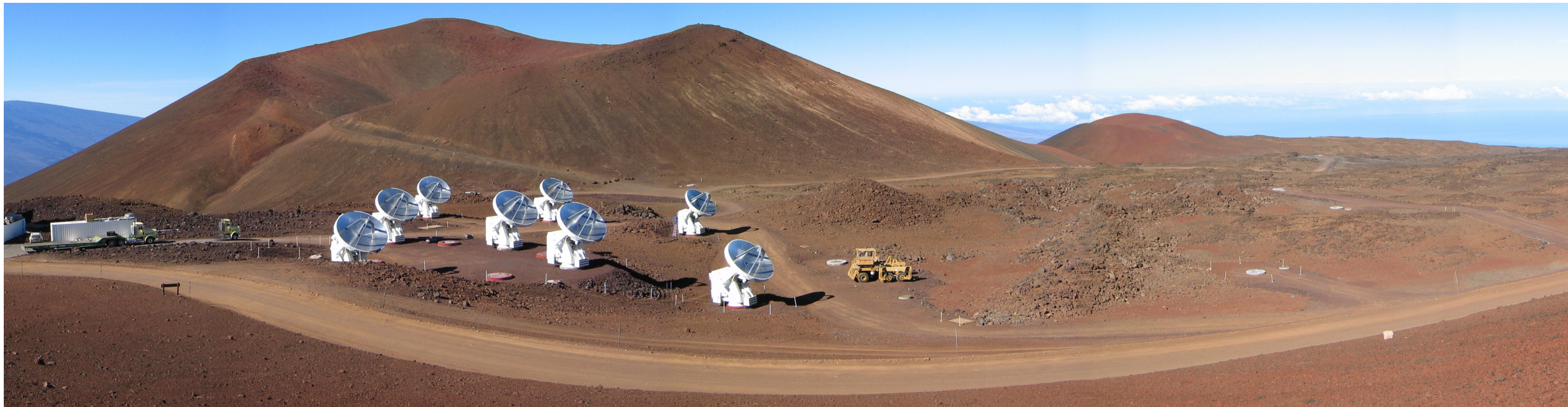
SMA
ACADEMIA SINICA IAA



The solar system at mm wavelengths

- Thermal continuum emission from surfaces on bodies with little/no atmosphere : Mars, Mercury, asteroids and Kuiper Belt objects.
  → **albedo, emissivity, size, thermophysical properties**

- Collisionally induced pseudo-continuum emission from thick deep atmospheres (~1 bar)

- Rotational lines of molecular atmospheric species (CO, HDO, H2O, SO2)
  → vertical profiles of **abundance, temperature** (1-bar-1microbar)
  → **dynamics** via Doppler-shift mapping

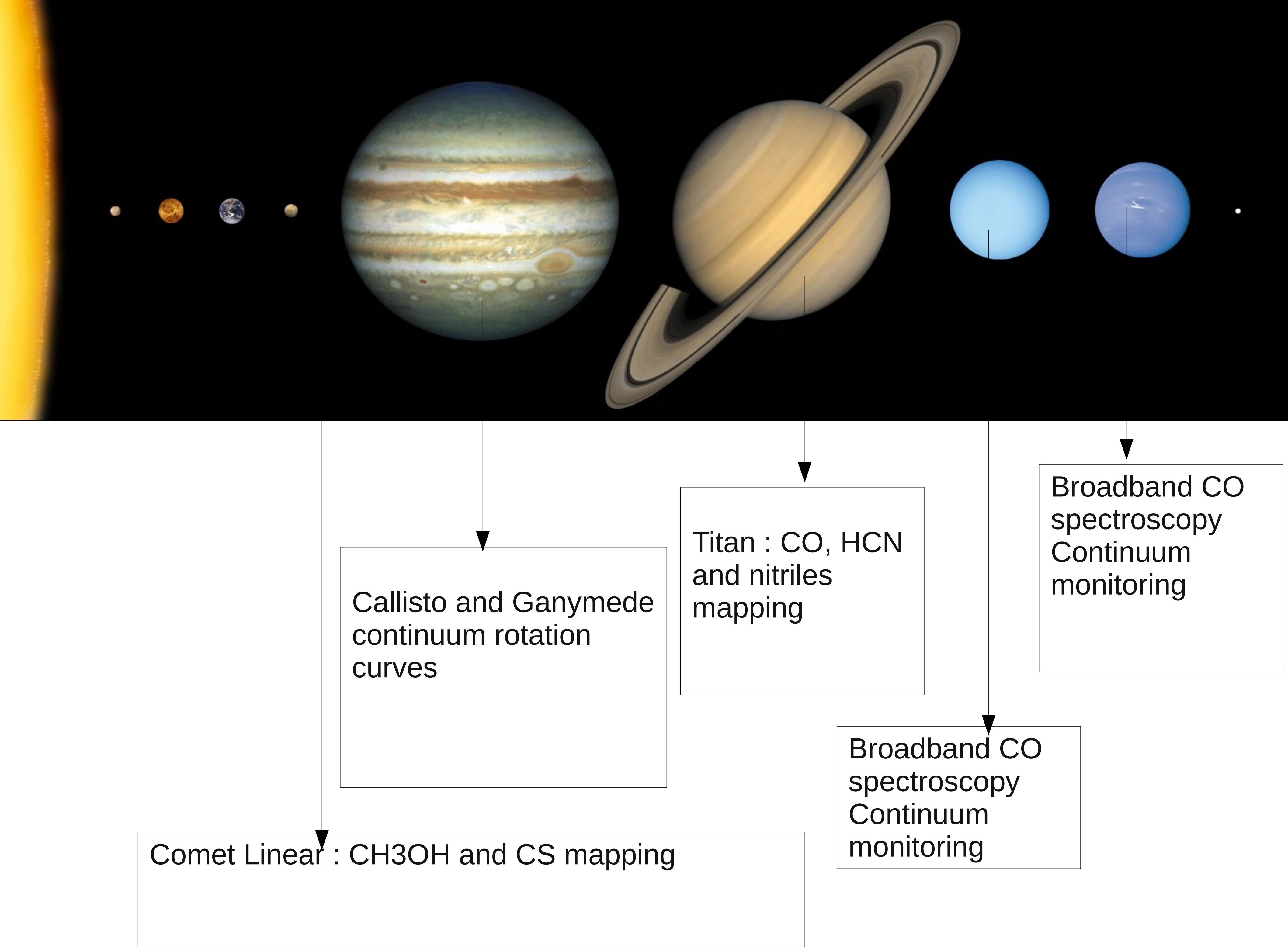
SMA performances

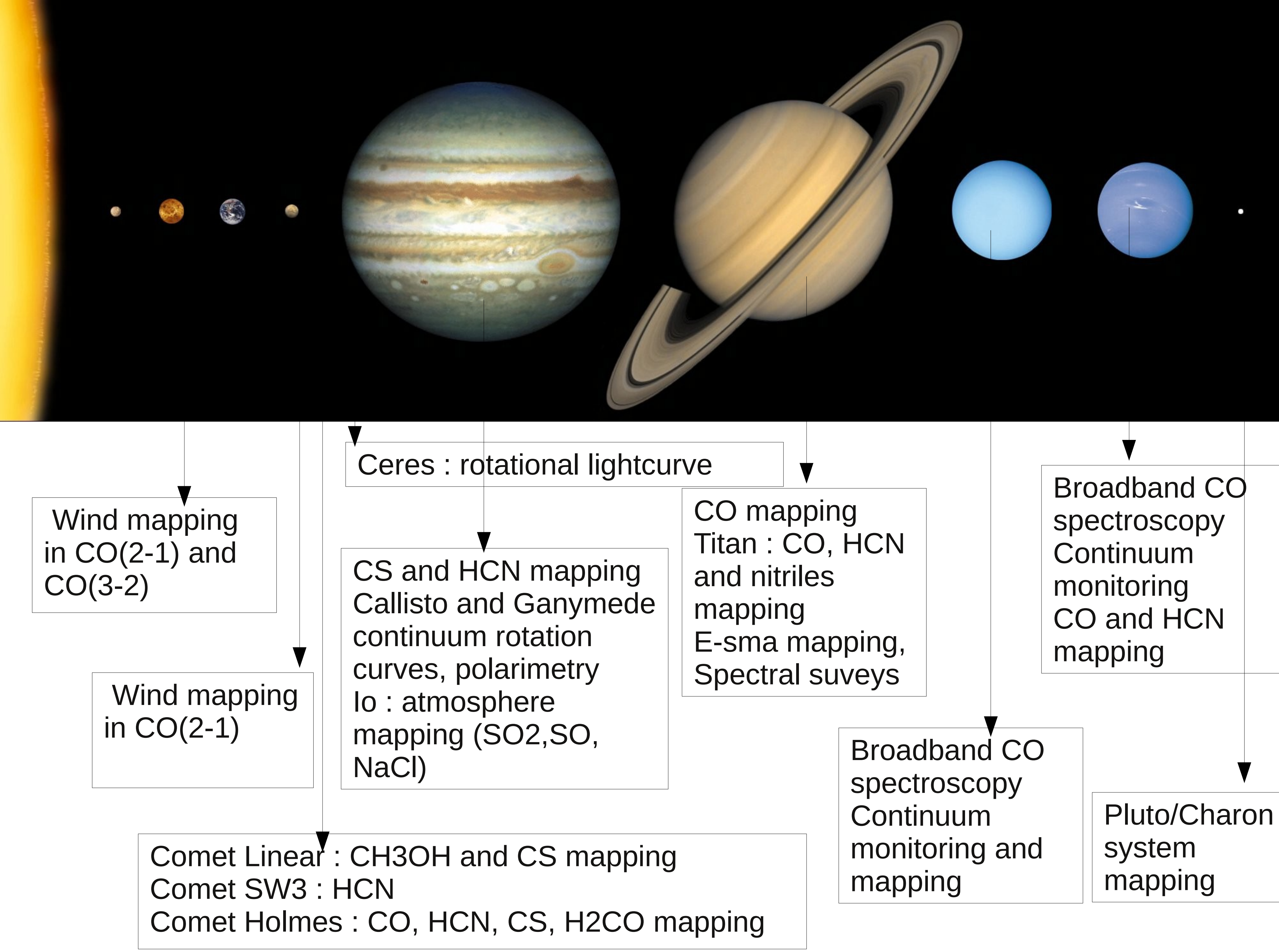
- Spatial resolution down to 0.3“, e-SMA : 0.2“
  mapping on sources as small as Titan (0.8“)

- Relatively large primary beam (52“ at 230 GHz) :
  possible mapping on very large sources , e.g. Jupiter (45“)

- High spectral resolution correlator modes, down to 25 kHz :
  line profile analysis and Dopplershift measurements

- Large instantaneous bandwidth :
  good continuum sensitivity, spectroscopy on wide pressure-broadened lines

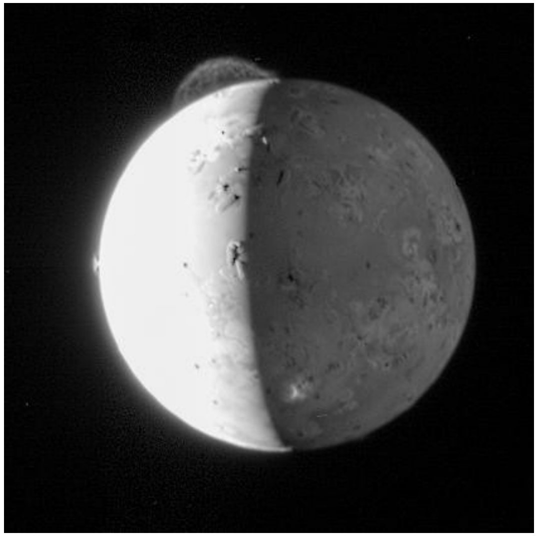

Broadband CO spectroscopy Continuum monitoring
Titan : CO, HCN and nitriles mapping
Callisto and Ganymede continuum rotation curves
Broadband CO spectroscopy Continuum monitoring
Comet Linear : CH3OH and CS mapping


Ceres : rotational lightcurve
Wind mapping in CO(2-1) and CO(3-2)
Wind mapping in CO(2-1)
CS and HCN mapping
Callisto and Ganymede continuum rotation curves, polarimetry
Io : atmosphere mapping (SO2,SO, NaCl)
CO mapping
Titan : CO, HCN and nitriles mapping
E-sma mapping,
Spectral suveys
Broadband CO spectroscopy
Continuum monitoring
CO and HCN mapping
Broadband CO spectroscopy
Continuum monitoring and mapping
Pluto/Charon system mapping
Comet Linear : CH3OH and CS mapping
Comet SW3 : HCN
Comet Holmes : CO, HCN, CS, H2CO mapping

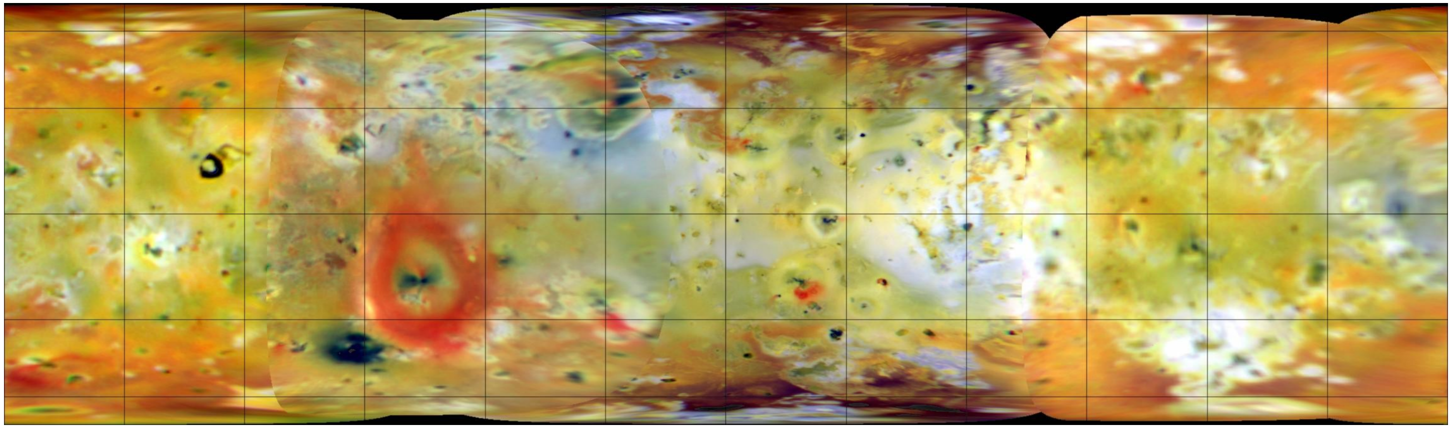
Io's atmosphere

- Composition : $\mathbf{SO_2}$ (90%), SO, NaCl, S_2, ..
- Extremely tenous **~ 1 nanobar**
- **Low lifetime** : thermal escape + plama torus drag + condensation
- Primary origin : volcanic outgassing

What are the sustaining sources/mechanisms ?
Where is it located ? Related to geographic features ?



Dust plume Tvashtar spotted by New Horizons-LORRI (Credits Nasa/ JHUAPL/ SRI)



Io's surface imaged by Galileo-SSI (Nasa Photo Gallery)

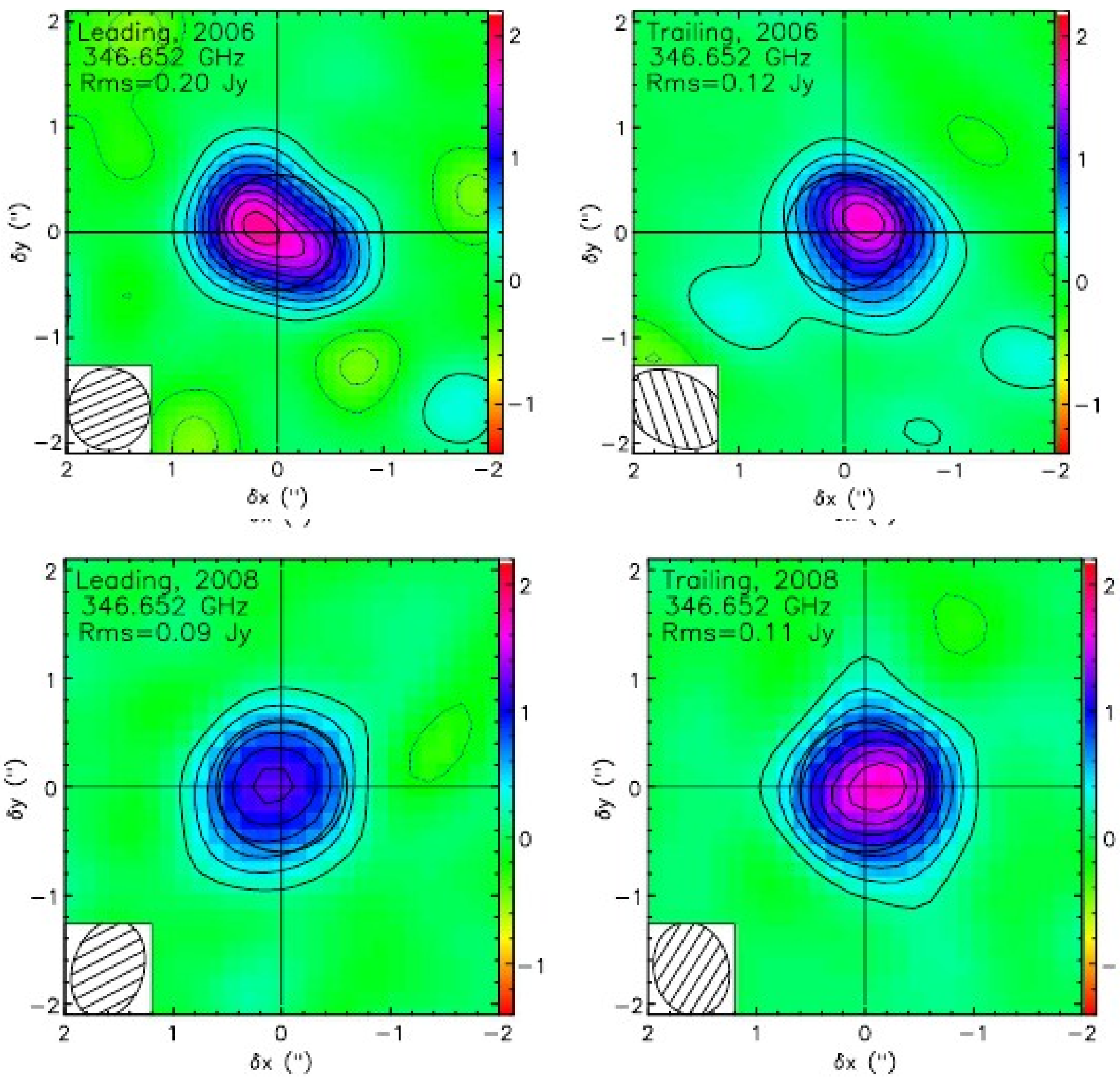
Io's atmosphere : SO2

- 2006 and 2008, extended configuratio
346.652 and 346.528 GHz SO2 lines

- Line-integrated mapping   (1 MHz), **~0.6" resolution** (Io's disk=1.2")

- Emission displacement with respect t
moon's center : SO_2 concentrated on
anti-jovian hemisphere.

- Line emission extent **smaller thar**
continuum.

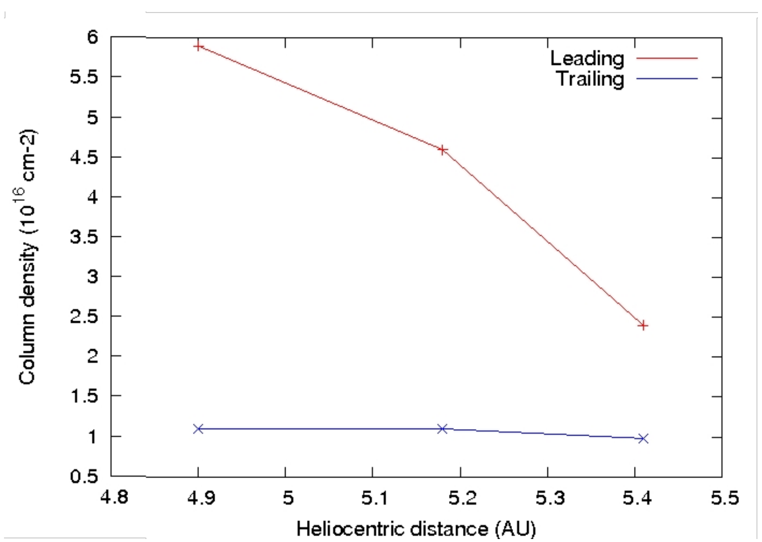


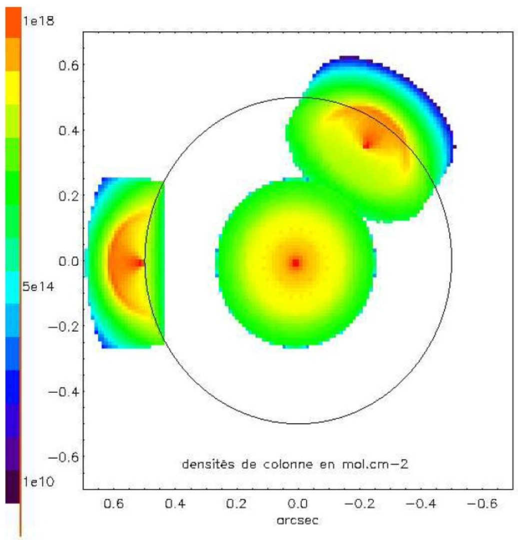
Io's atmosphere : SO2

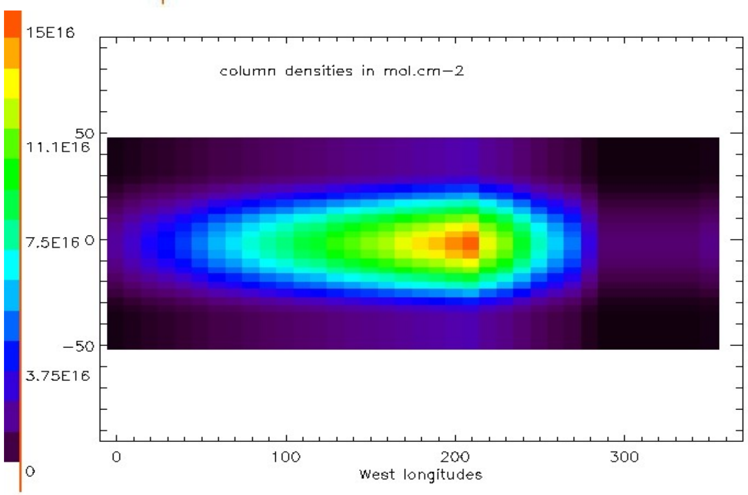
- Comparison to volcanic plumes models : volcanism can only explain <20% of the SO2 content

- Satisfactory comparison to hydrostatic atmospheric models : **sublimation of SO2 ice is probably the main source for SO2**

- Confirmed by dependence of SO2 column density on heliocentric distance :

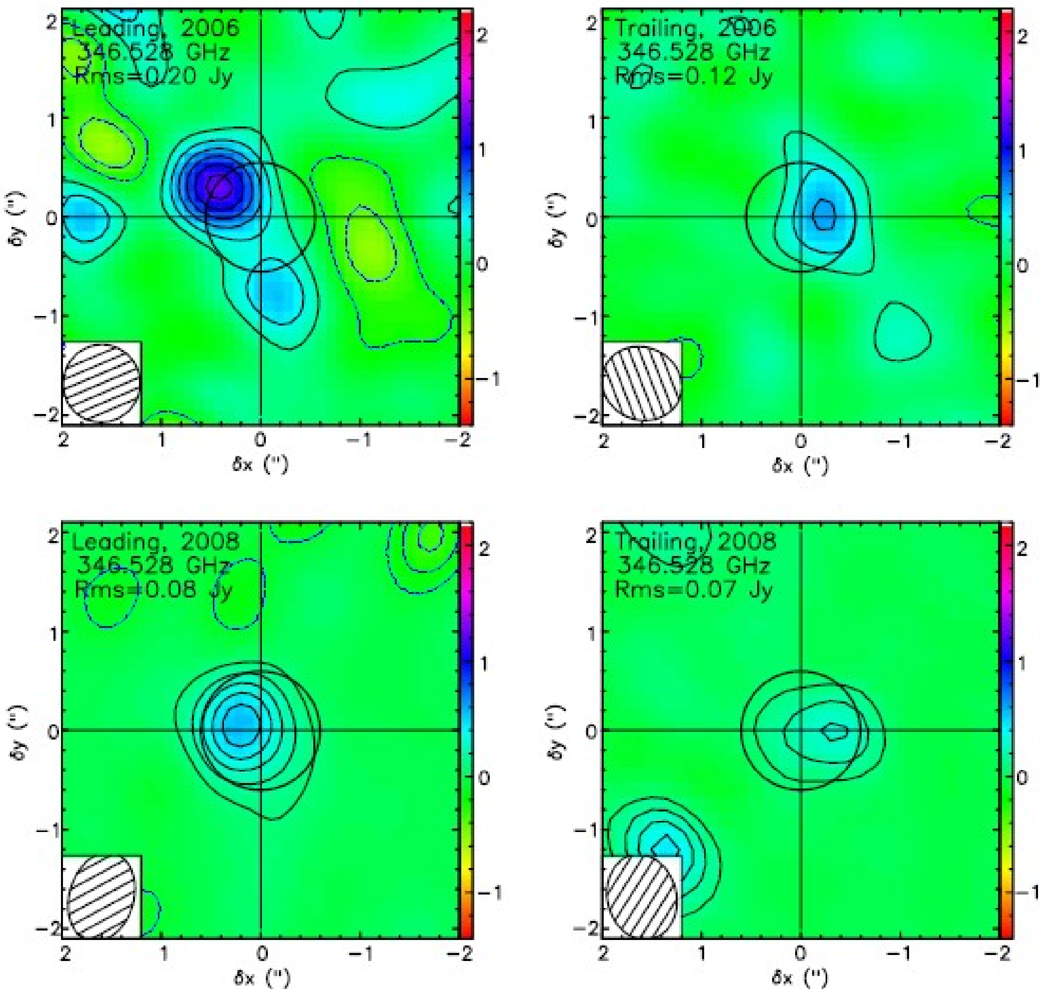






SO2 distribution for volcanic and hydrostatic models. Adapted from Spencer et al. (2005) and Zhang et al. (2000)

Io's atmosphere : SO



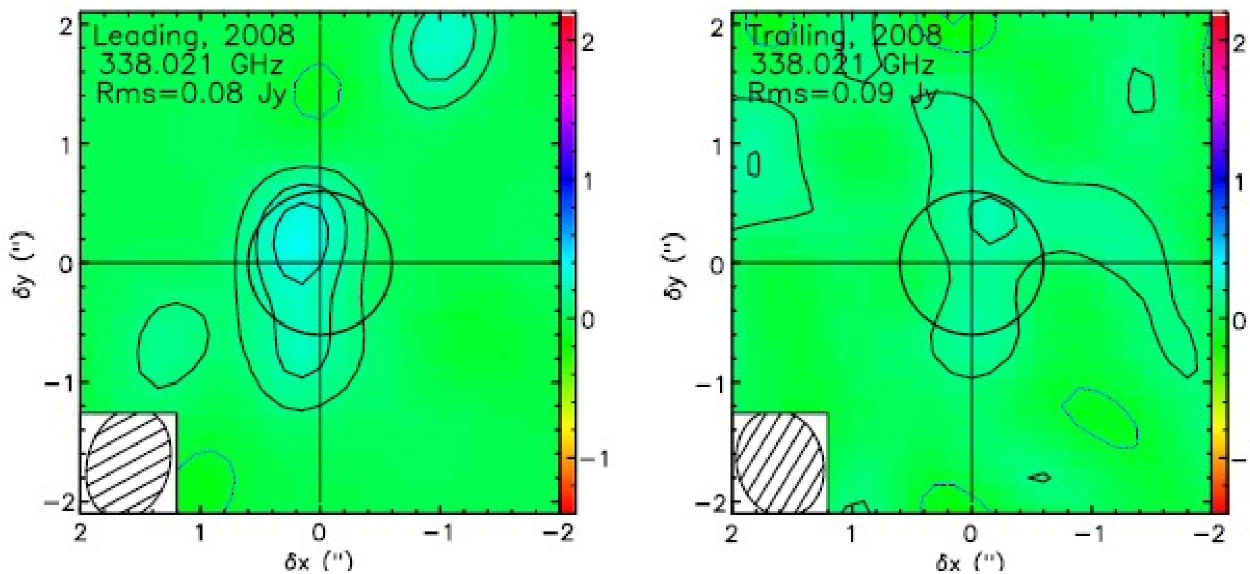
- 346.528 GHz line
- Line-integrated mapping (1 MHz).
- SO concentrated on the **anti-jovian hemisphere.**
- Line emission extent **s**maller than continuum.
- Volcanism can sustain <40% of the atmosphere
- SO2 **photolysis is the best candidate** for SO production

Io's atmosphere : NaCl

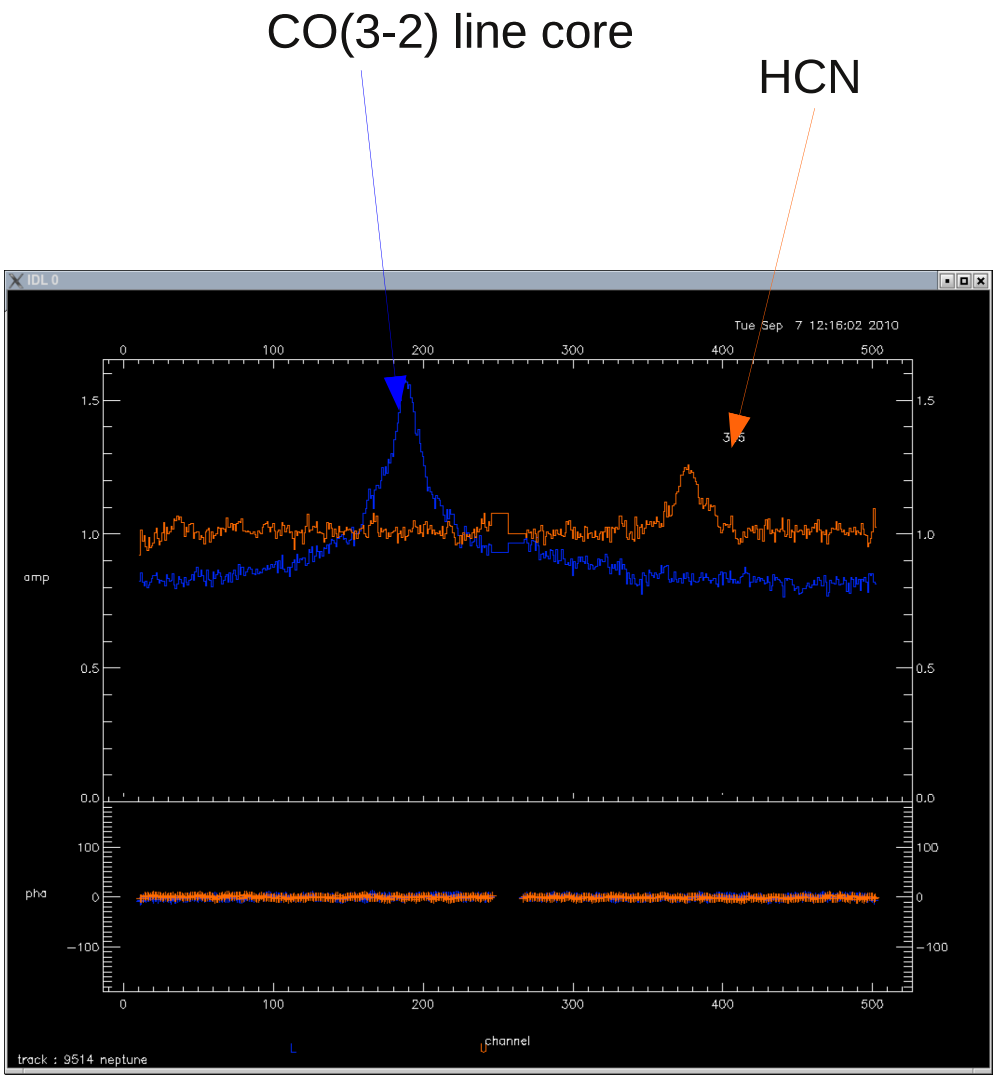
• Line at 338.021 GHz

• Low S/N : cannot interpret emission shape, concentrated on the anti-jovian hemisphere.

• Emission coherent with **purely volcanic origin**



Neptune's atmosphere : CO and HCN



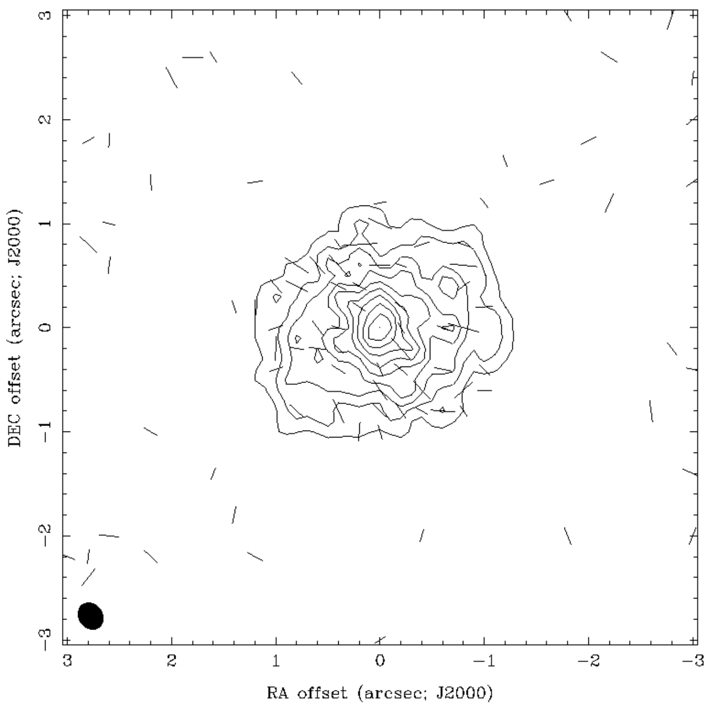
. CO and HCN unstable in Neptune' stratosphere, but detected : **exogenic** (comets/satellite) or **internal origin** (vigourous convection from the deep layers) ?

. mm-CO lines give access to both tropospheric (broad wings) and stratospheric (core) abundances.

. **CO never mapped** : distribution would give clues on the source

- August/September 2010 :
3 tracks in extended configuration for CO(3-2) / HCN (4-3). Resolution 0.8“ (Neptune 2.3“)

Polarimetry on Galilean moons



Continuum and polarization ratio and orientation on Ganymede , July 2009

- The **thermal emission from a surface should be polarized (Fresnel law).** Polarization increases with emission angle and dielectric constant.

- Retrieving the soil **dielectric constant** with polarization measurements → **emissivity, limb darkening** analysis (temperature distribution)

- Polarization mapping on Callisto and Ganymede at 347 GHz in very extended mode tempted in July 2009

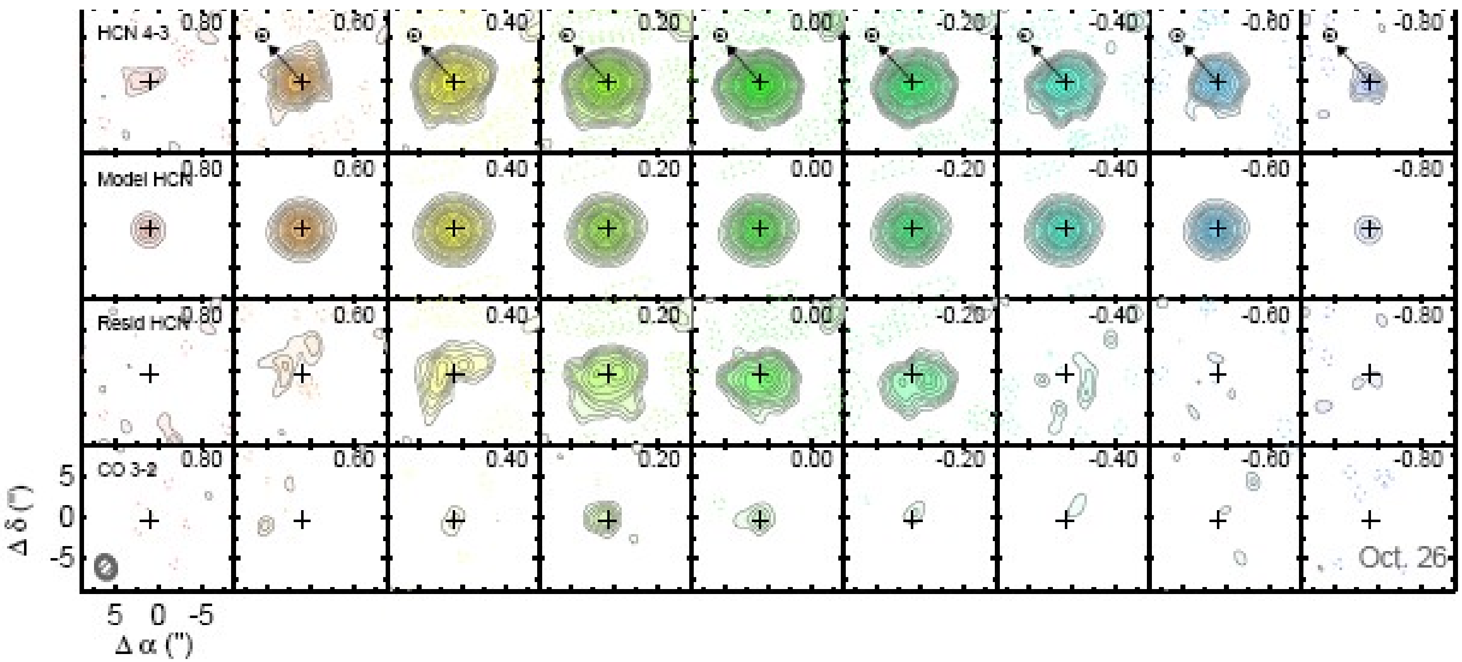
- Results not satisfactory : more S/N needed , self-calibration techniques

Comet 17P/Holmes outburst

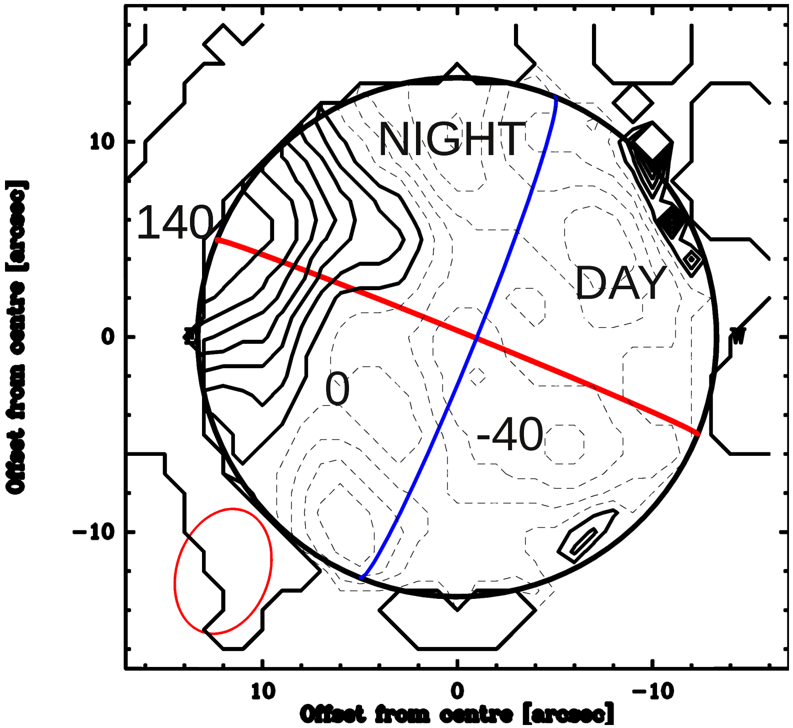
- Monitoring of the **outburst in October 2007**, through continuum, CO, HCN, H2CO and CS lines mapping

- **Two structures : isotropic outgassing + jet**

- CO/HCN much higher in the jets : CO outgassing could be related to the onset of the outburst



Venus' mesospheric winds



- The mesosphere (65-120 km altitude) usually exhibits both subsolar to antisolar flows and zonal retrograde flows, highly temporally variable
- Dopplershifts mapping on CO(2-1) and CO(3-2) lines in subcompact configuration give **access to winds in the 90-100 km range** (PI. H. Sagawa, January 2009)
- CO(2-1) : Detection of **retrograde zonal winds on the night-side ~ 140 m/s**

Dopplershift map on the CO(2-1) line core in m/s.
Dashed contours correspond to approaching winds (blue-shift), full contours to receeding winds (red-shift). Countour step=20 m/s.

Imaging Pluto's system

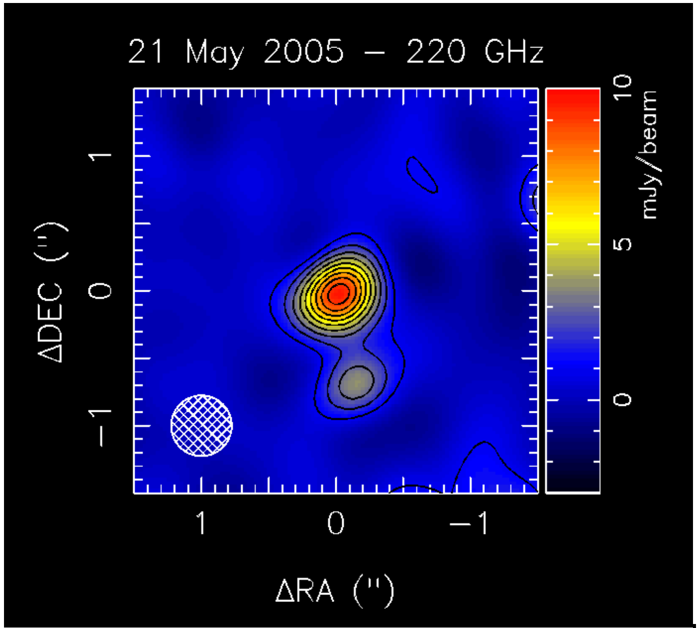
- **First thermal resolved imaging of the Pluto/Charon system**

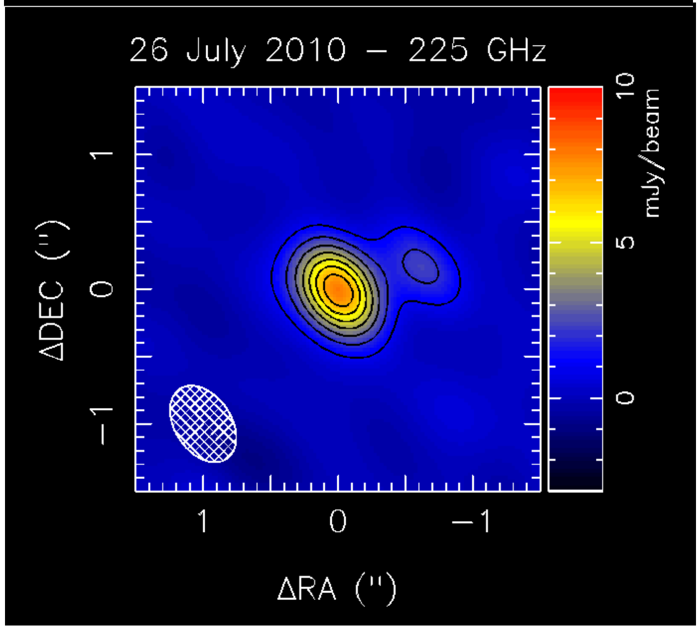
- SMA observations at 230 and 270 GHz in very extended configuration (2005 and 2010) : 0.4-0.5“ beam to separate Pluto from Charon (0.9“ separation)

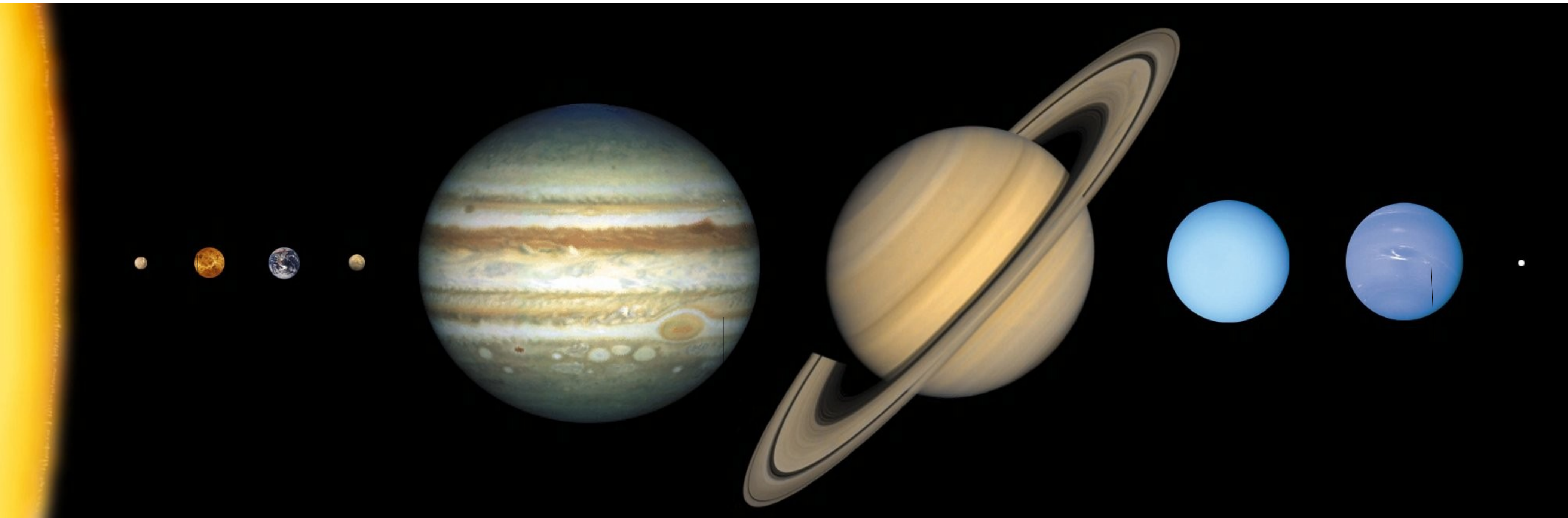
- Determination of each temperature (assuming the emissivity)

  Pluto: 41±5 K   Charon: 54±11 K (in 2005)

- Consistent with Charon in equilibrium with solar radiation, **Pluto could be in vapor pressure equilibrium with N2 atmosphere.**







Mapping of minor species (SO2)

Mapping of minor species

Ganymede/ Callisto : surface polarimetry with expanded bandwidth

Wideband spectroscopy (PH3)

Wideband spectroscopy (CO)