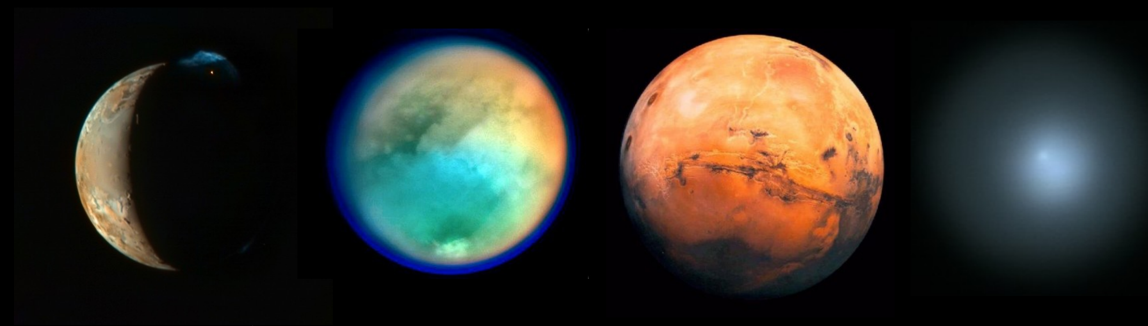

Recent Solar System science with the IRAM Plateau de Bure interferometer

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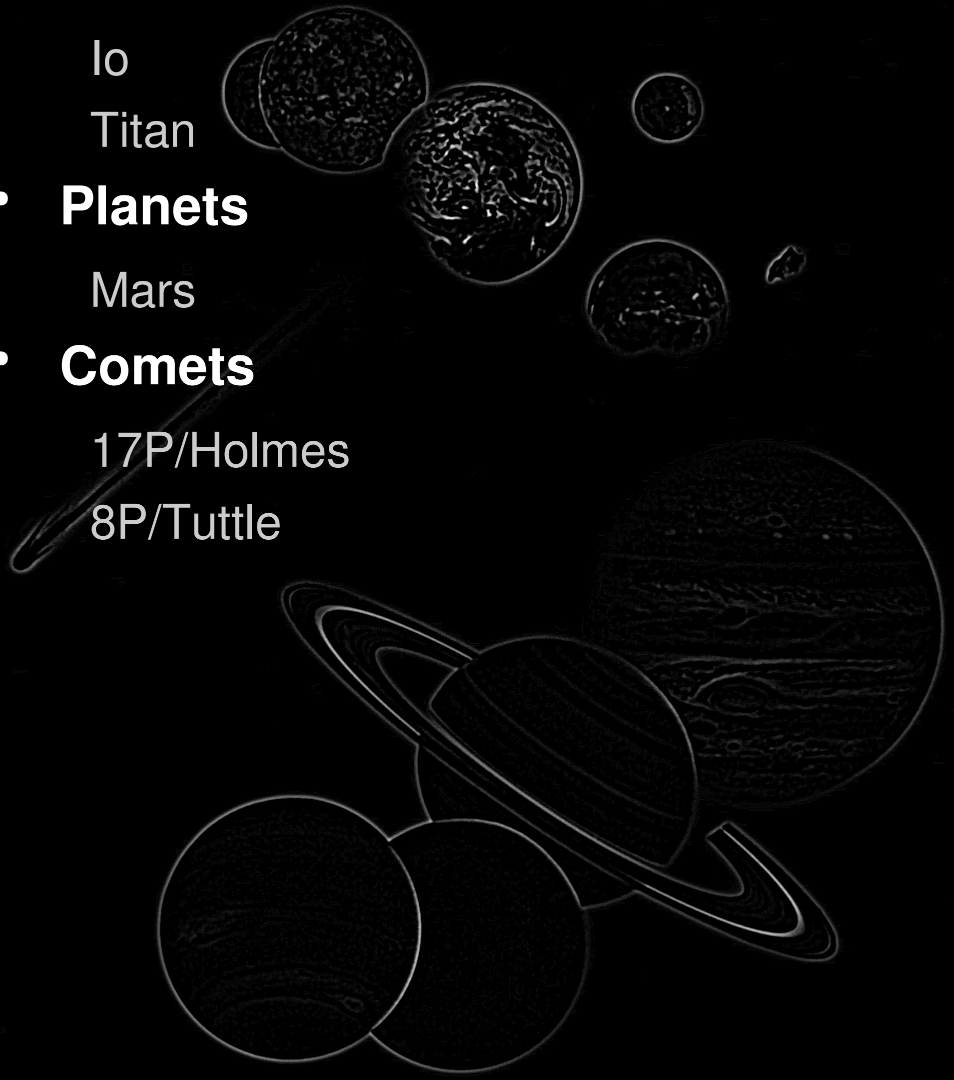
Outline

- **Planet moons**
  - Io
  - Titan
- **Planets**
  - Mars
- **Comets**
  - 17P/Holmes
  - 8P/Tuttle



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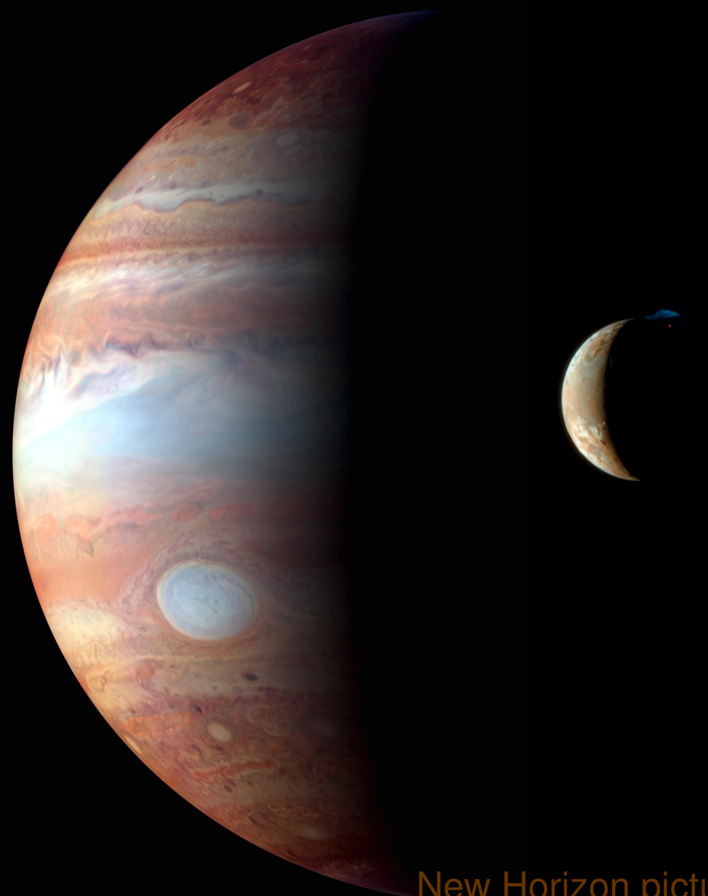
Io (1)

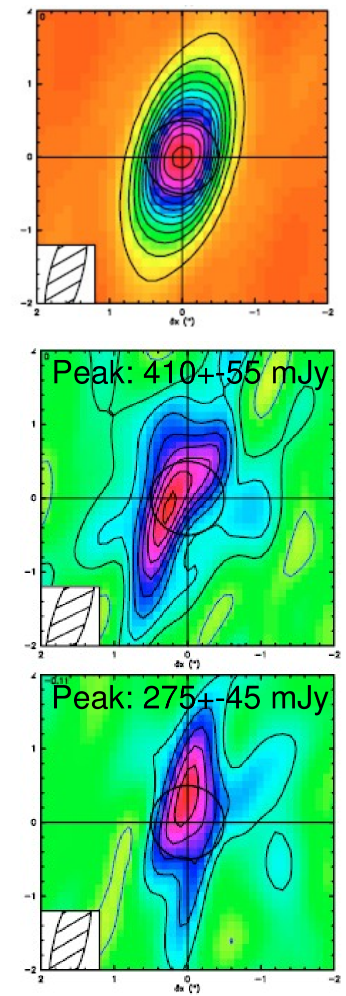
- **Jupiter's moon**
  - Volcanic activity
  - Variable atmosphere
  - Main component: SO_2
- **Remaining questions**
  - Atmosphere extent, temperature
  - SO_2 origin (Plume vs sublimation)
- **Observations at mm wavelengths:**
  - High spectral resolution = gas velocity
  - Interferometry = spatial distribution



New Horizon pictures

Io (2): Moullet et al. 2008

- **Plateau de Bure observations**
  - Jan. and Feb 2005 (Io = 1"): Leading and trailing sides
  - 1.4 mm continuum + SO_2 @ 216 GHz
  - Configuration A (beam = 0.5x1.5")
  - ***1st disk resolved observations***
- **Strong continuum source**
  - Self-calibration
- **Line integrated intensity**
  - Atmosphere extent smaller than the planetary disk
    - 75-100% (45-85%) in the leading (trailing) side



Levels:
100 mJy for cont.
50 mJy for lines

Io (3): Moullet et al. 2008

- **Spectral maps**

  The line profile depends on the position

  Central position Δv = Doppler shift

  → Mean velocity of the gas

  Limb to limb difference = 330 +/- 100 m.s^{-1}

  Solid rotation = 70 m.s^{-1}

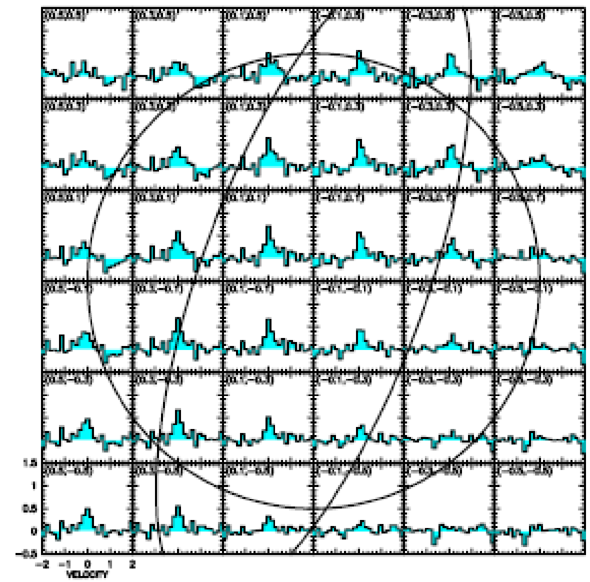
  → Evidence for atmosphere dynamics

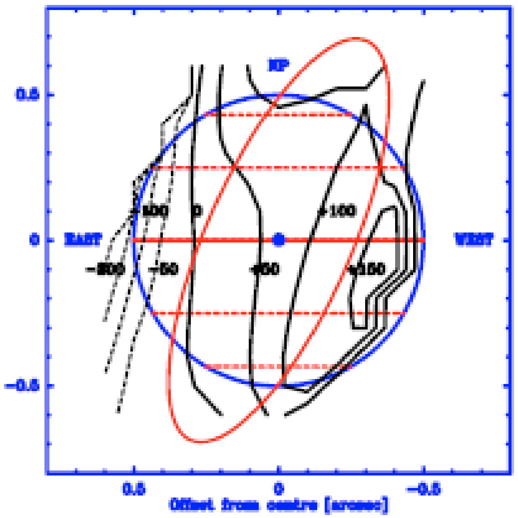
- **Modeling the observations**

  Zonal flow from West to East (~200 m.s^{-1})

  Mean gas temperature 130-180 K

  Low contribution from volcanic plumes





Titan (1): Moreno et al. 2005

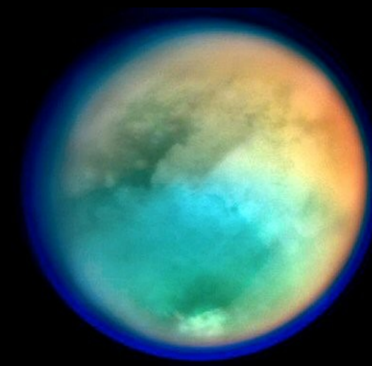
- **Saturn's moon**
- **Global meteorology poorly constrained**
- **Atmosphere at 300-450 km probed at mm wavelengths**
- **PdBI observations in 2003-2004**

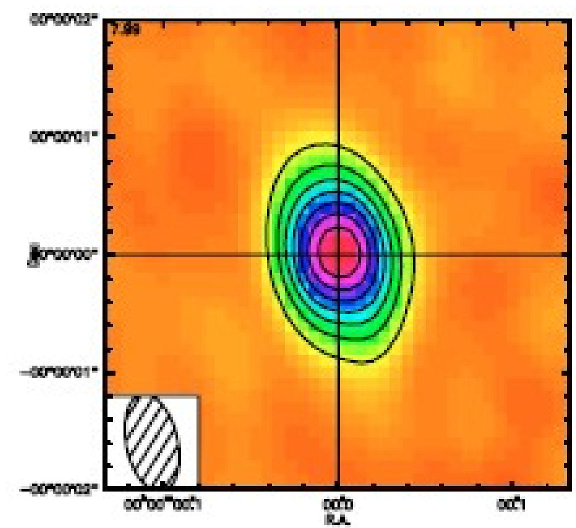
  HC_3N @ 227 GHz

  CH_3CN @ 221 GHz

  Titan ~ 1"

  Beam ~ 0.4"x0.8"

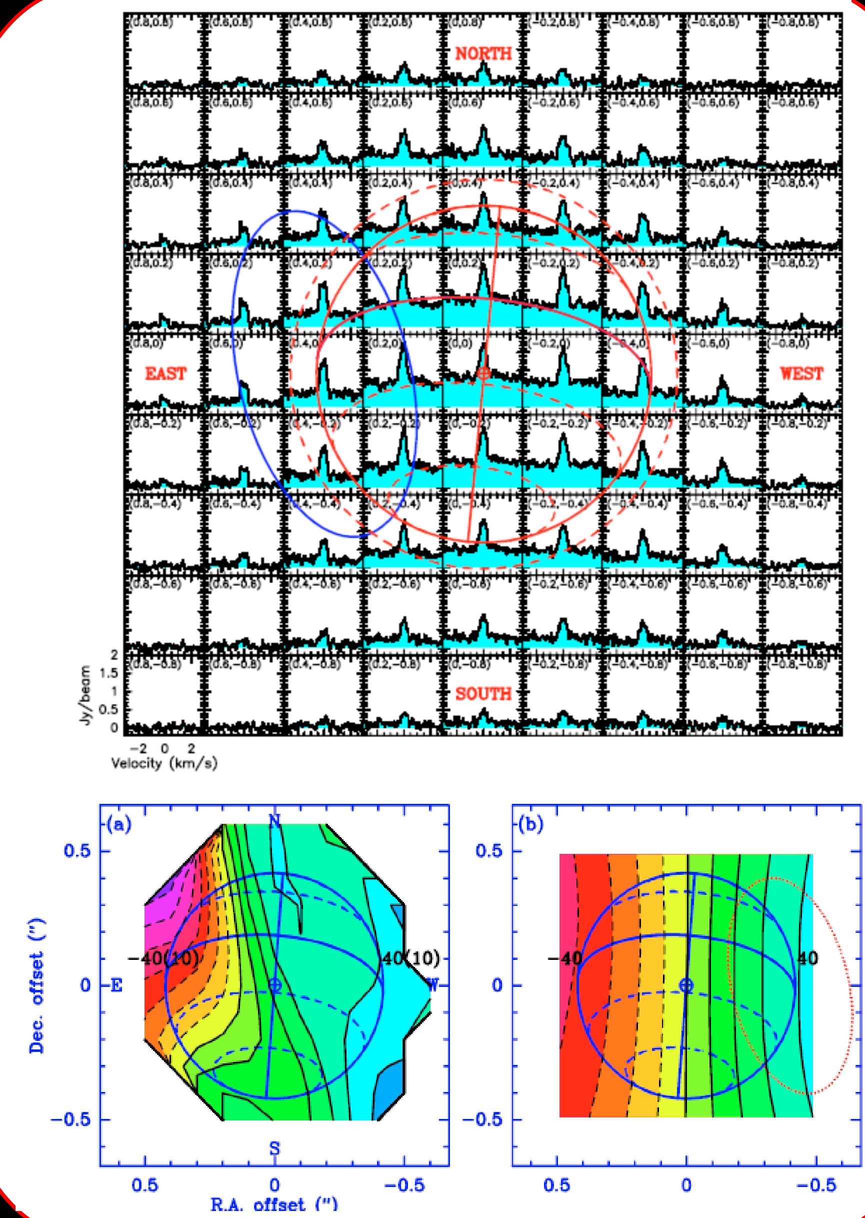




Titan 1.3 mm cont. map
(self calibrated)

Titan (2): Moreno et al. 2005

- **High resolving power**
  - Line Doppler shifts = gas velocity
  - Limb to limb difference
  - → Zonal wind velocities
  - HC_3N @ 227 GHz → 450 km
  - 60 +/- 20 ms^{-1} (prograde)
  - 1st measurement at this altitude
  - CH_3CN @ 221 GHz → 300 km
  - Using 4 lines
  - 160 +/- 60 ms^{-1} (prograde)
  - Superrotation of Titan's atmosphere
  - Velocity decreases with altitude



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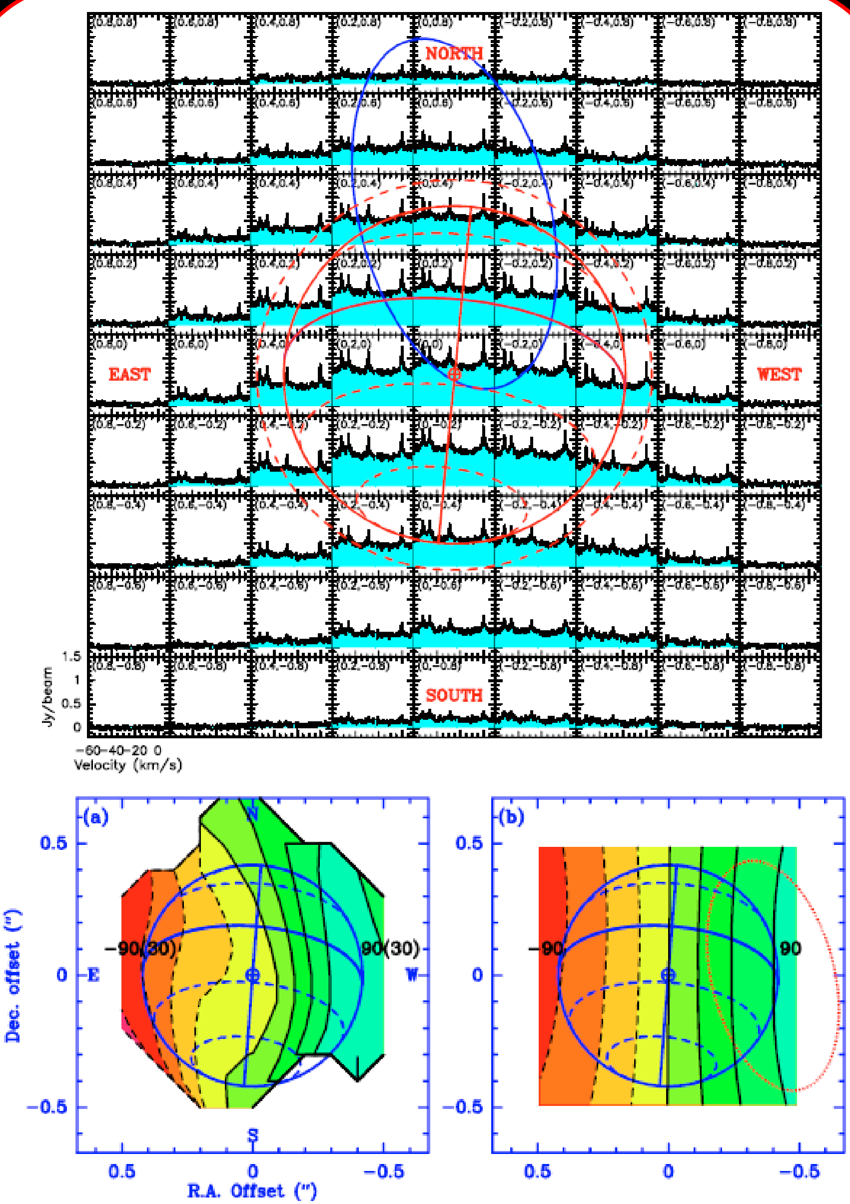
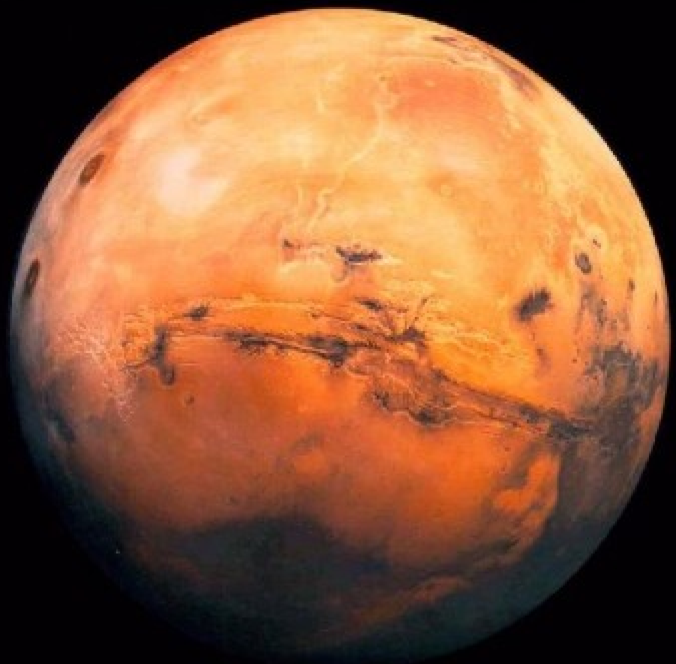


Mars (1): Moreno et al. 2008

- **Direct wind measurement in the middle atmosphere at ~50 km**
- **Comparison to Global Circulation Models**
- **4 Plateau de Bure observations at different solar longitudes (1999-2003)**

  → different marsian saisons
- **CO *J*(1-0) line at 115 GHz**

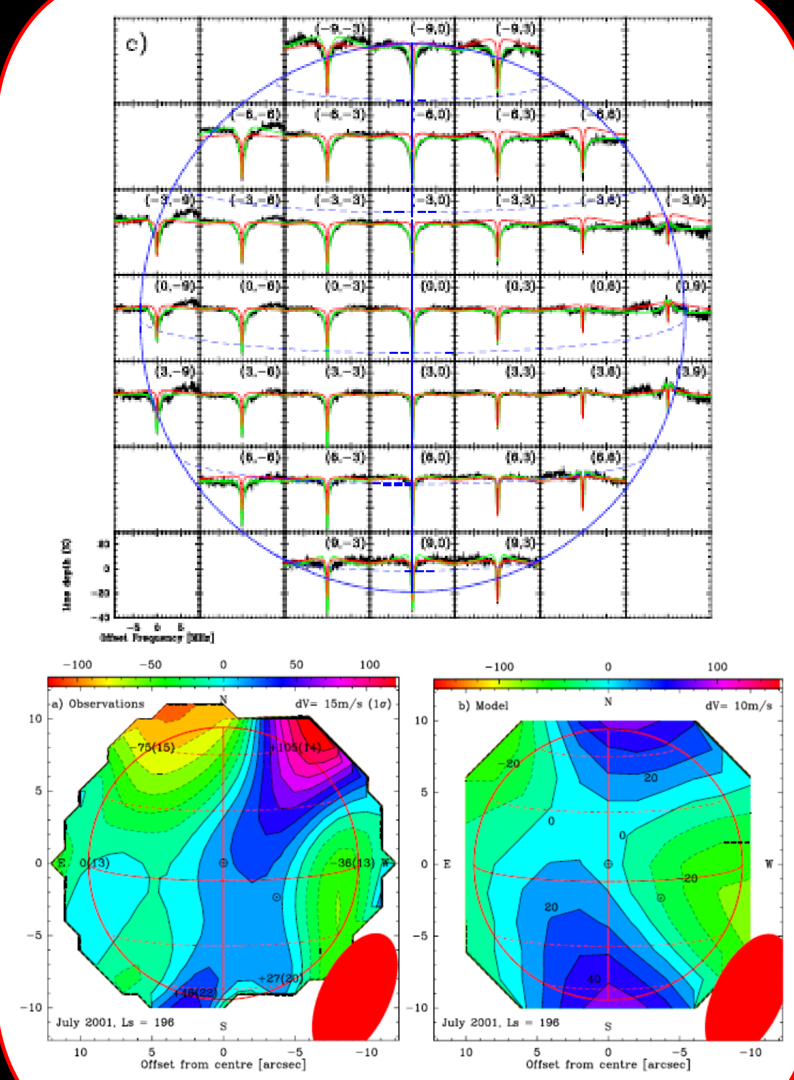
  Mars = 10-20'', resolution ~ 5''



Mars (2): Moreno et al. 2008

- **Ls = 140**
  - Clear atmosphere
  - Retrograde zonal wind ~100 ms^{-1}
  - OK at equator, not at lat 45 deg
- **Ls = 197**
  - Major dust storm
  - Mid-latitude prograde wind

Ls = 263
  - Clear atmosphere
  - Prograde wind at equator
  - Good agreement with GCM at equator
- **Ls = 317/322**
  - Strong retrograde wind (-200 ms^{-1}) in the west
  - Latitudinal winds in the east
  - Different from GCM: regional dust storms



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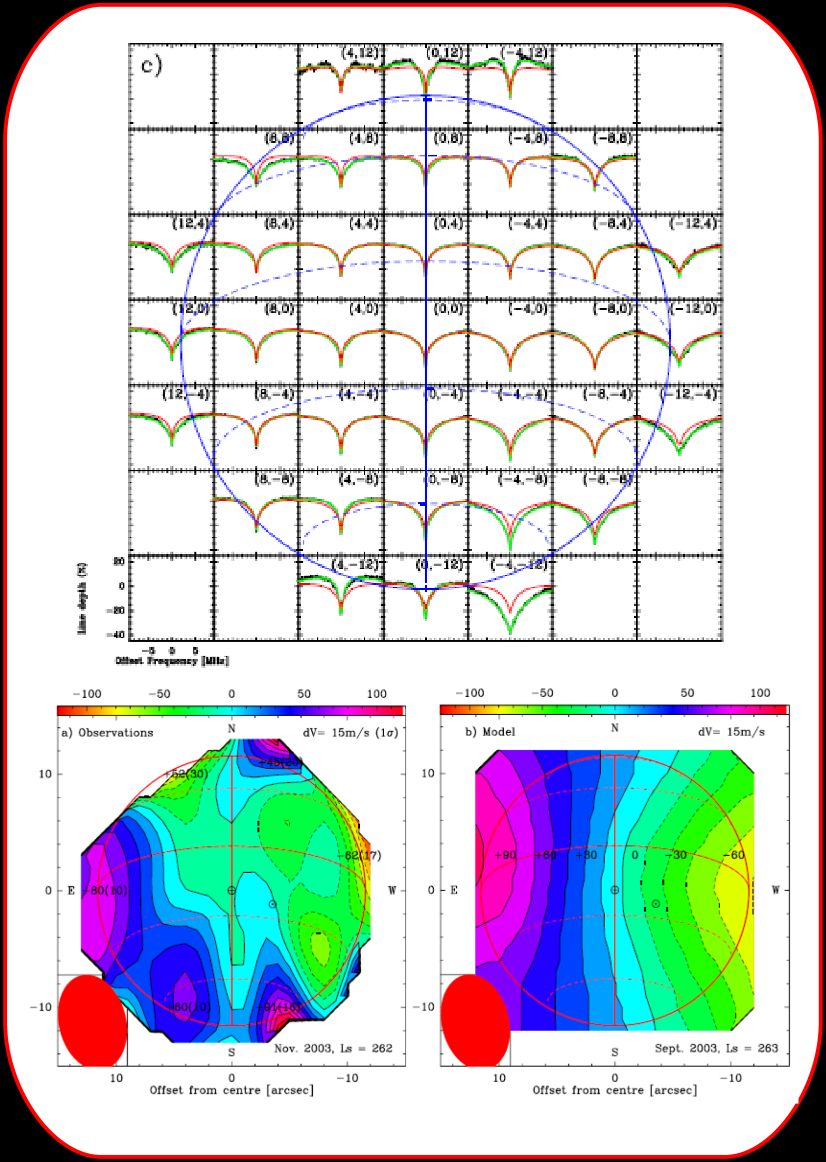
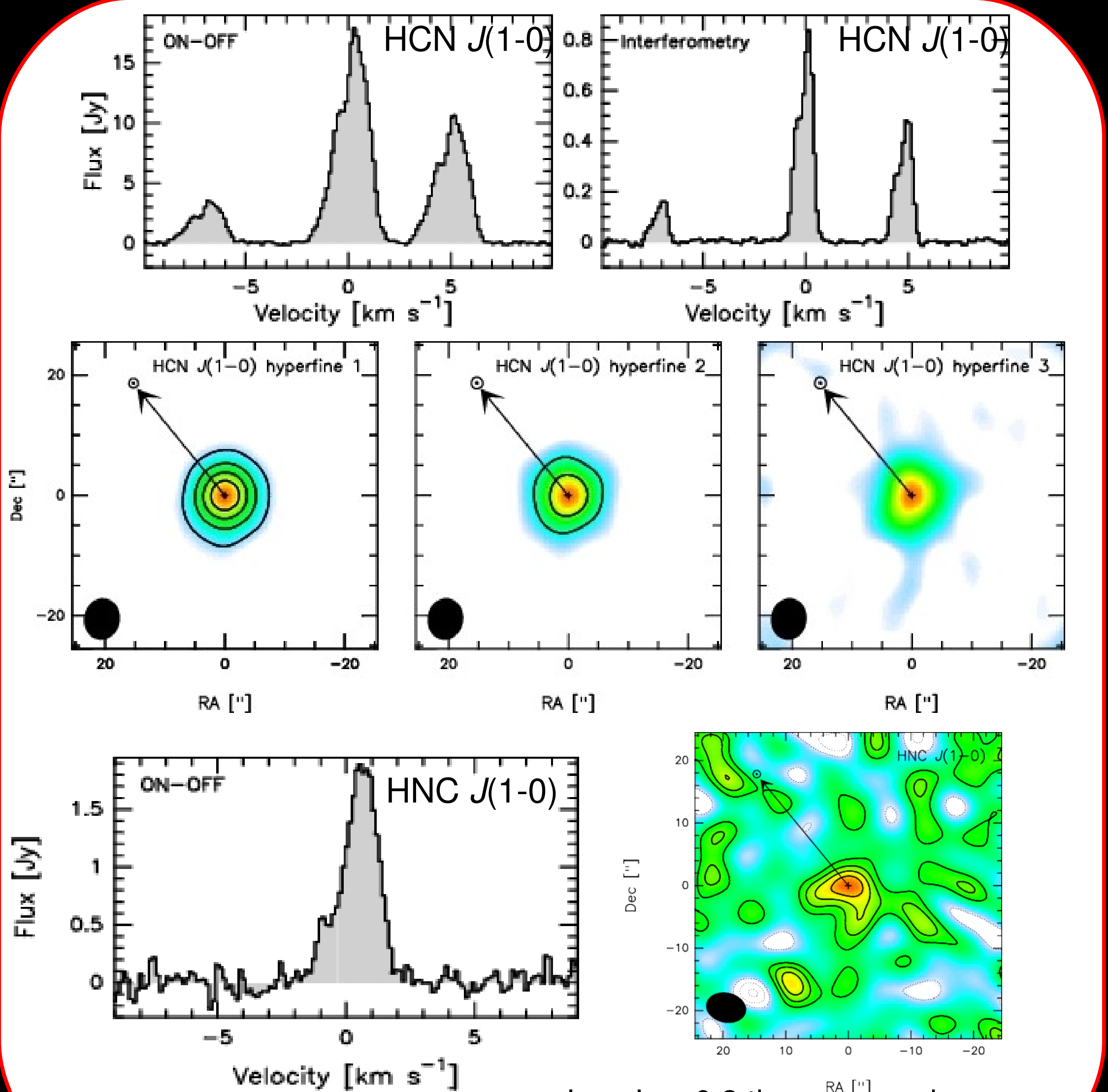


Comets

- **Preserved remnants of the Solar System formation**
- **Millimeter spectroscopy:**
  - Rotational emission of molecules in the inner coma
- **Single dish (~10-50"):**
  - Composition
  - Expansion velocity
  - Temperature
- **Interferometry = Imaging (~1-10")**
  - Structure of the inner coma
  - Simultaneous continuum observations:
    - Nucleus and/or Dust
- **Constraints**
  - Recent and reliable ephemeris required
  - Short delays (discovery - observations)

The coma of 17P/Holmes (1): Gas

- **Outburst on 24 Oct. 2007**
  PdBI on 27 Oct.
- **Single dish and Interferometry**
  HCN *J*(1-0) at 88.6 GHz
  HNC *J*(1-0) at 90.6 GHz
  ~50'' and ~7'' beams (1''=1200 km)
- **HCN compact source isolated**
  Icy particles cloud (~750 km)
- **HCN line width = gas velocity**
  Acceleration in the coma
- **HNC origin unknown**
  3 σ detection in interferometric data
  New constraints on its origin ?



Levels = 0.2 the map maximum
σ = 0.3 the map maximum

The coma of 17P/Holmes (2): Dust

- **Imaging the big (mm) particles coma surrounding the nucleus**
- **Modeling the flux radial extent (27 and 28)**

  Thermal emission model

  Dust density distribution model

  - Isotropic ouflow (1D)
  - Q = Q(t) Gaussian decrease after outburst

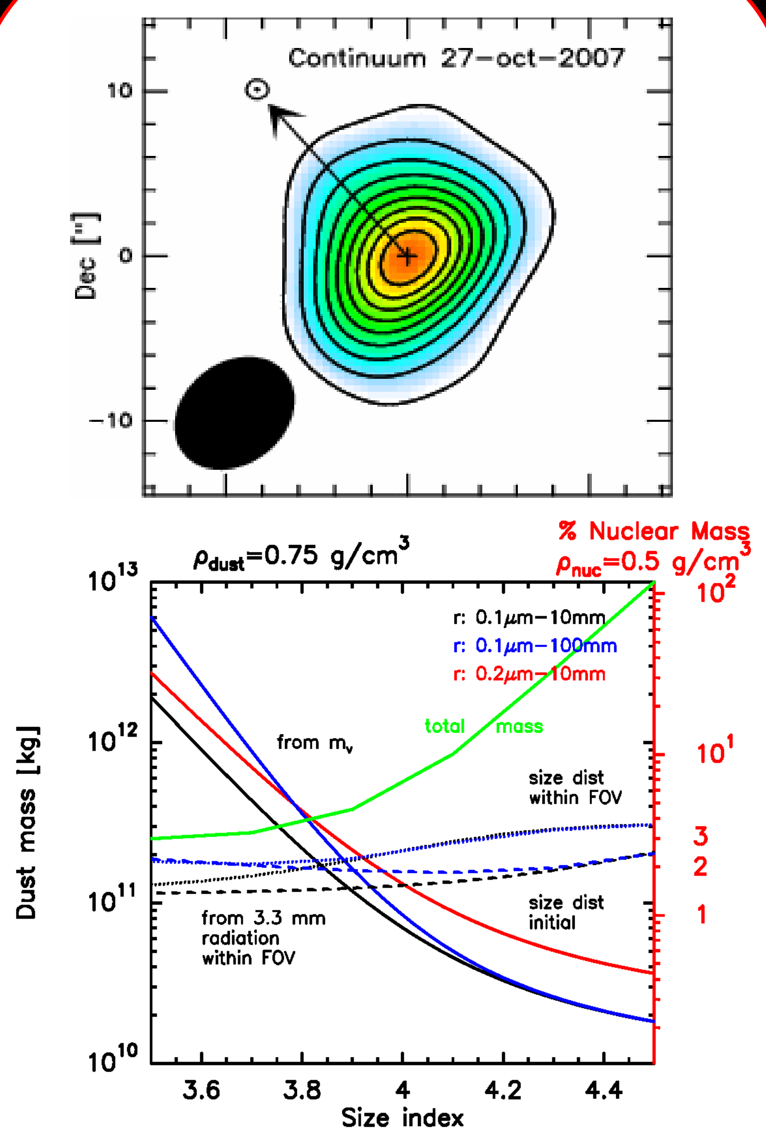
  Slow decrease of the dust production rate:

  Grain fragmentation
- **Released dust mass estimate**

  Few % the nucleus mass

  Gas to dust ratio ~ 25%

  Boissier et al. 2008 (to be submitted)



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The nucleus of 8P/Tuttle

- **Favorable situation of the comet:**

  Size estimation 15 km (Licandro et al. 2000)

  Low activity (no contamination of the nucleus flux by dust)

  Δ = 0.25 AU

  47 mJy expected at 1 mm

  PdBI sensitivity ~ 1mJy

- **Observations in Jan 2008**

  Flux ~ 6 +/- 2 mJy @ 240 GHz

- ***Mean diameter ~ 5 km***

  In agreement with some observations

  - Spitzer Space Telescope (Groussin et al., ACM 2008)

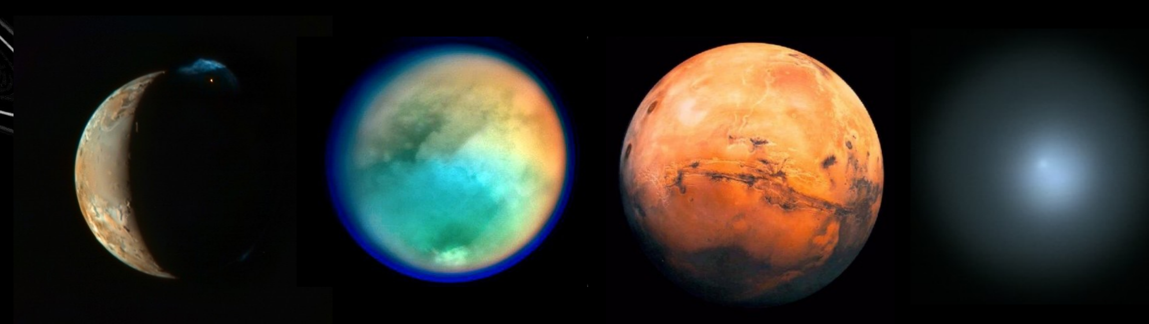
  In disagreement with others

  - Isaac Newton 2.5 m Telescope (Snodgrass et al. 2008)
  - Arecibo radar observations (contact binary ?, Harmon et al, ACM 2008)

  ...to be investigated...

Summary

- **Solar System science is possible with the PdBI**
- **It requires some specific cares**
  - Tight observing windows
  - Ephemeris and velocity corrections
- **Characterization of atmosphere dynamics for planets and moons**
  - Mars, Io, Titan
- **Various interests in cometary science**
  - Gas coma, Dust coma, Nucleus
  - The science depends on the situation
    - Distance
    - Array configuration
    - Comet properties



The (not so recent) case of Hale-Bopp

- **March 1997: 5 days, 9 molecules**
- **Altenhoff et al. 1999**
  - Nucleus size estimation ~40 km
- **Bockelée-Morvan et al. 2000**
  - New molecules found (SO_2,...)
- **Henry et al. 2002**
  - CO jet near the nucleus equator
  - Further study based on physical modelling to be published: Boissier et al. 2008
- **Boissier et al. 2007**
  - CS, H_2S, SO observations
  - Constraint on CS life time
  - Nuclear origin of H_2S
  - Extended source of SO (SO_2 + ??)
  - Evidences for nucleus heterogeneity