# PISSARRO:

## Planetary Instrument for Submillimeter-wave Surface and Atmospheric Reconnaissance and Research in Orbit


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**JPL**


*Technology Workshop for Discovery*

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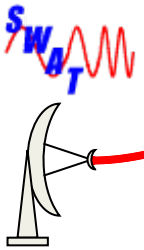


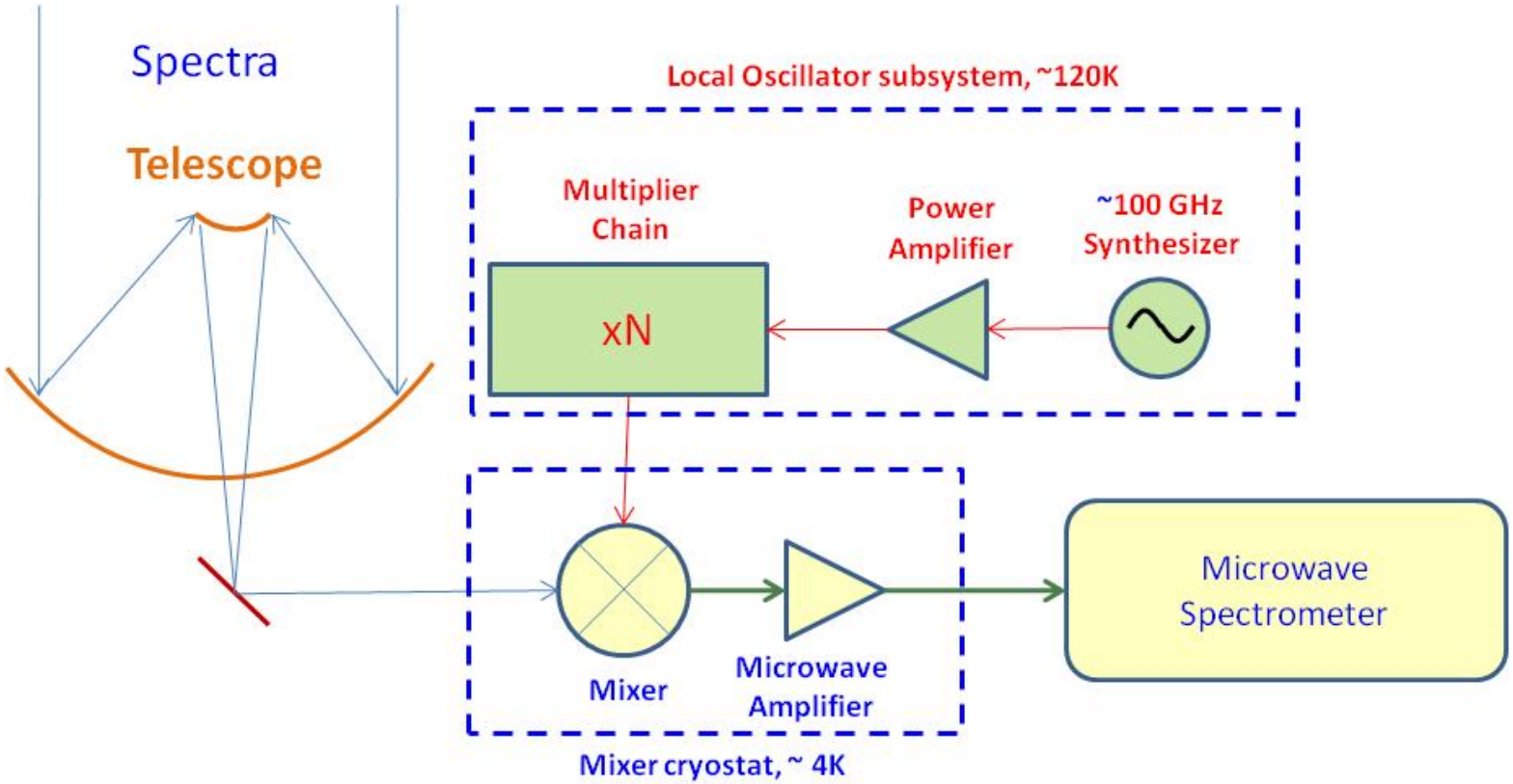
# Outline

- What is PISSARO ?
- What scientific questions can be addressed with PISSARO ?
- PISSARO Technology Readiness

# What is PISSARO?

- Instrument concept funded by the 2012 MatISSE call (currently in the first year of funding)
- PISSARO (Planetary Instrument for Submillimeter-wave Surface and Atmospheric Reconnaissance and Research in Orbit) is a solid-state radiometer and spectrometer in the ~500-600 GHz range
- PISSARO enables unique science investigations for planetary bodies

# Nominal Heterodyne Receiver

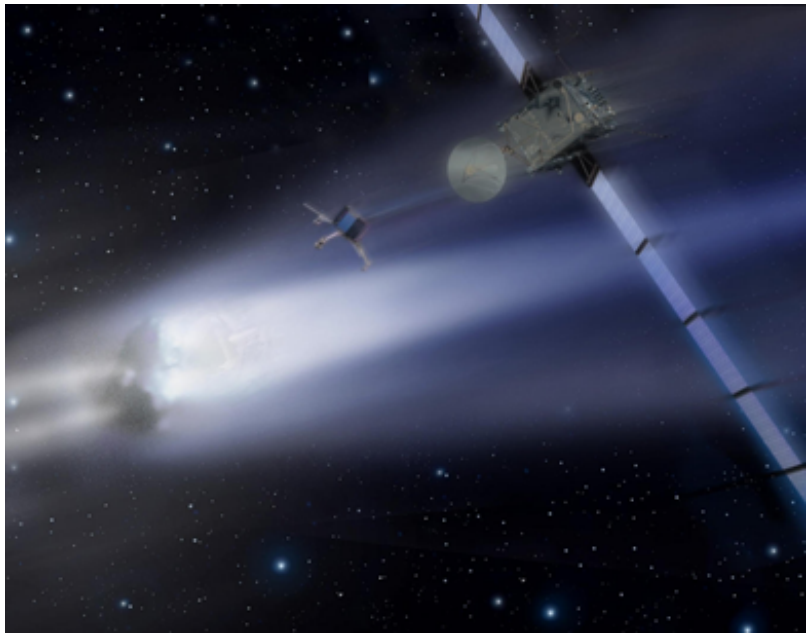


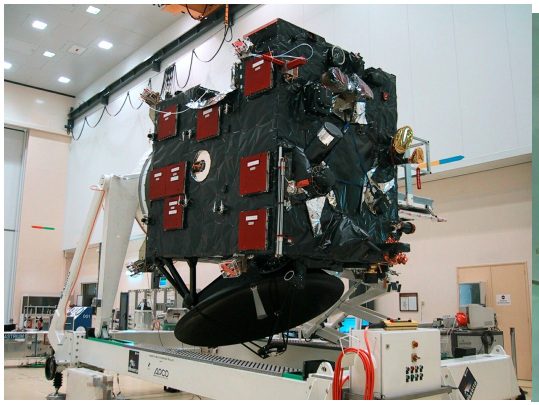

- Tunable
- Extremely high spectral resolution: $\lambda/\Delta\lambda \approx 10{,}000{,}000$
- High sensitivity
- NEDT proportional to sqrt(integration time)

# PISSARO builds on MIRO heritage

PISSARO is a second generation Submm-wave sounder

1st generation sounder: MIRO on Rosetta





**MIRO**

**Telescope**

30 cm diameter
Fixed Pointing
Boresight along Z-axis of s/c

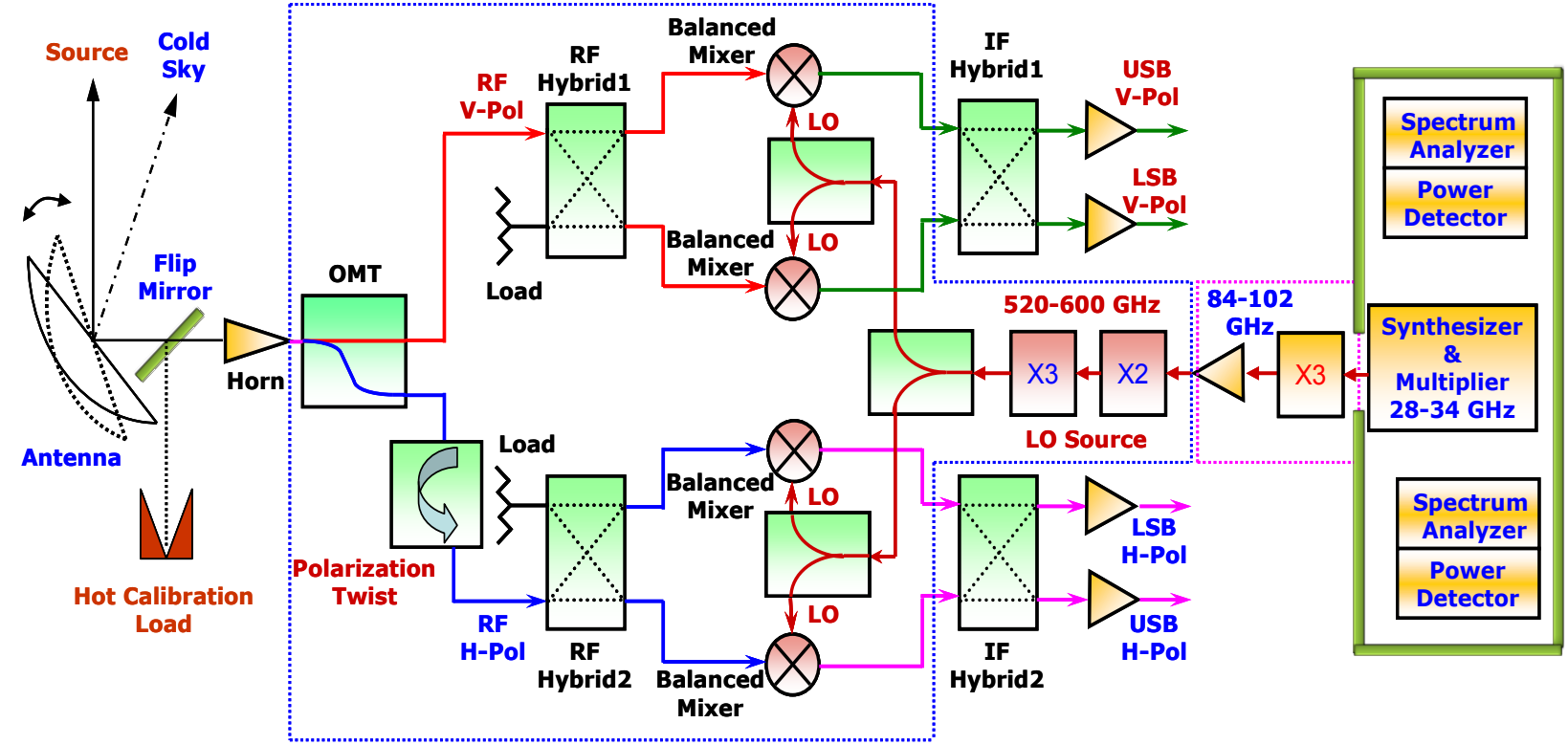
**Receivers (two)**

Two bands
190 GHz (1.6 mm)
563 GHz(0.5 mm)
Continuum - both bands
Spectroscopic (563 GHz only)
Single linear polarization(crossed)
Flip-mirror calibration(warm-cold-sky)

**Half Power Beam Widths**

Submillimeter HPBW- 7.5 arc min
Millimeter HPBW- 23.8 arc min

# PISSARRO: Technology Approach



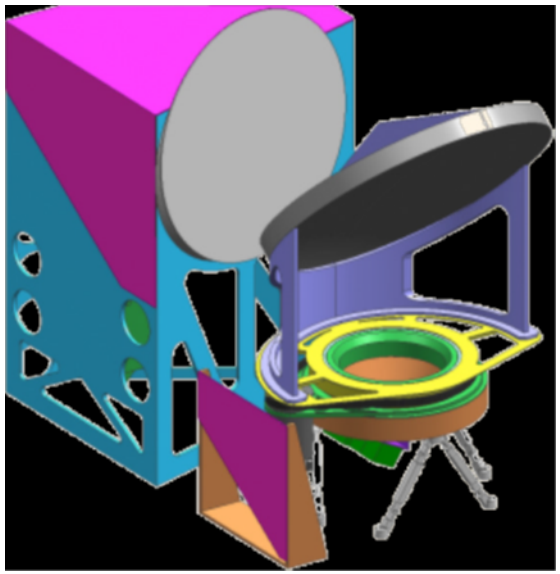

PISSARRO:

- Broadband tunable receiver (MIRO was fix-tuned)
- Sideband separating (MIRO was double side band)
- Both polarizations (MIRO was single polarization)
- Digital backends (MIRO used CTS technology)
- Low-mass and low-power (small as a 1-cubic cm (Micromachining advanced packaging)

# PISSARO Instrument trade space

- **Frequency Band**: 500 to 600 GHz,
  - Optimized for target chemistry
  - Bandwidth
  - Double sideband vs single side band
  - Single vs dual polarization
- **Antenna size**
  - At 550 GHz 30 cm dish gives a 7.5 arcmin beam
  - Higher spatial resolution with higher freq
- **Backend performance**
  - Bandwidth
  - Minimum resolution
  - Power vs. resolution and bandwidth
- ***Power Goal: 20 W  Mass Goal: 10 kg***
- ***Increase of TRL to 6 (by end of FY2015)***

**Conceptual only**

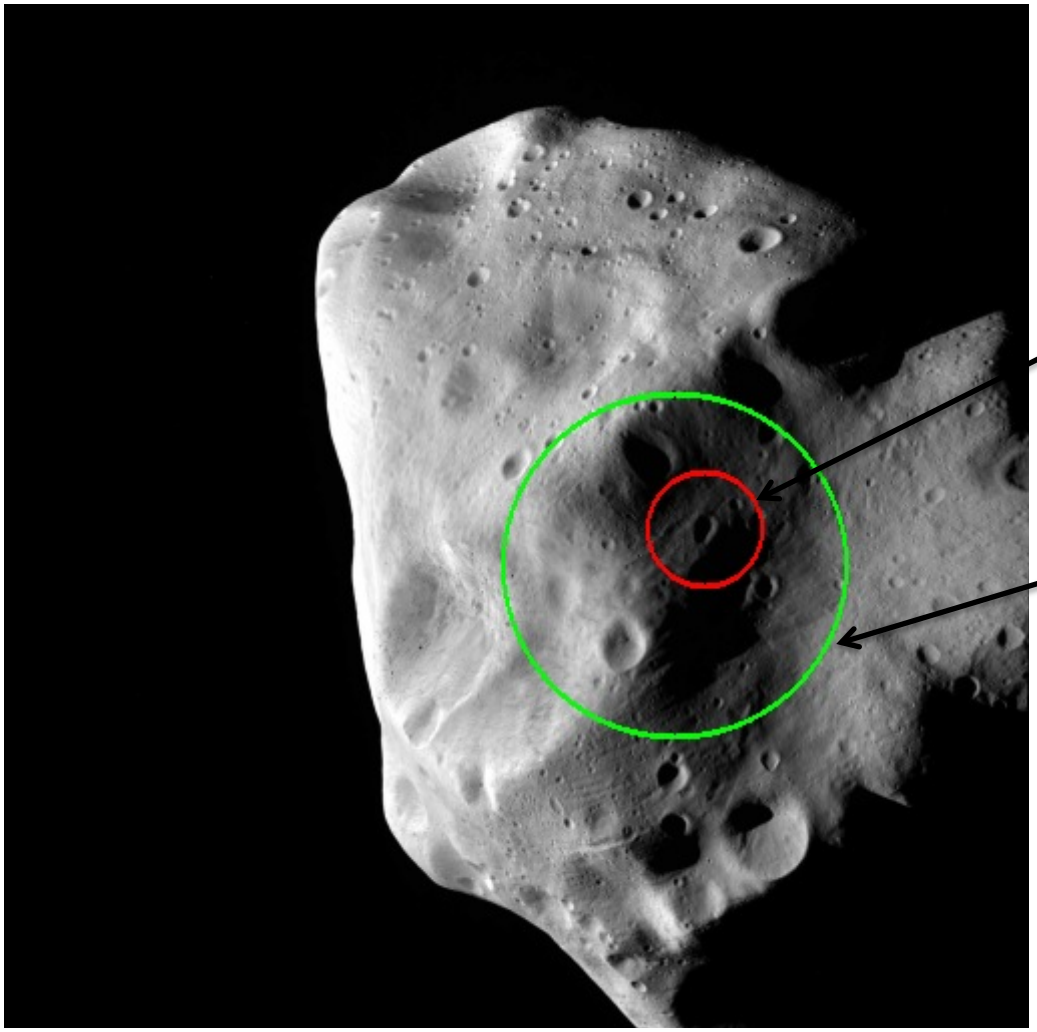


# Science Applications

1. Planetary surface and atmosphere exploration, molecular abundances & mapping (Jupiter, Ganymede, Europa, Titan, Mars, Venus…)
2. Analysis of hydrocarbon and nitrite chemistry (Titan)
3. Water, ice, methane, etc. detection,
4. Plume and volcanic activity localization and characterization (Europa, Enceladeus, Venus, Mars)
5. Wind speed, temperature, pressure profiles with high spatial resolution
6. Comet surface dynamics

# MIRO observation of Lutetia

S. Gulkis and the MIRO Science Team



# MIRO observation of Lutetia
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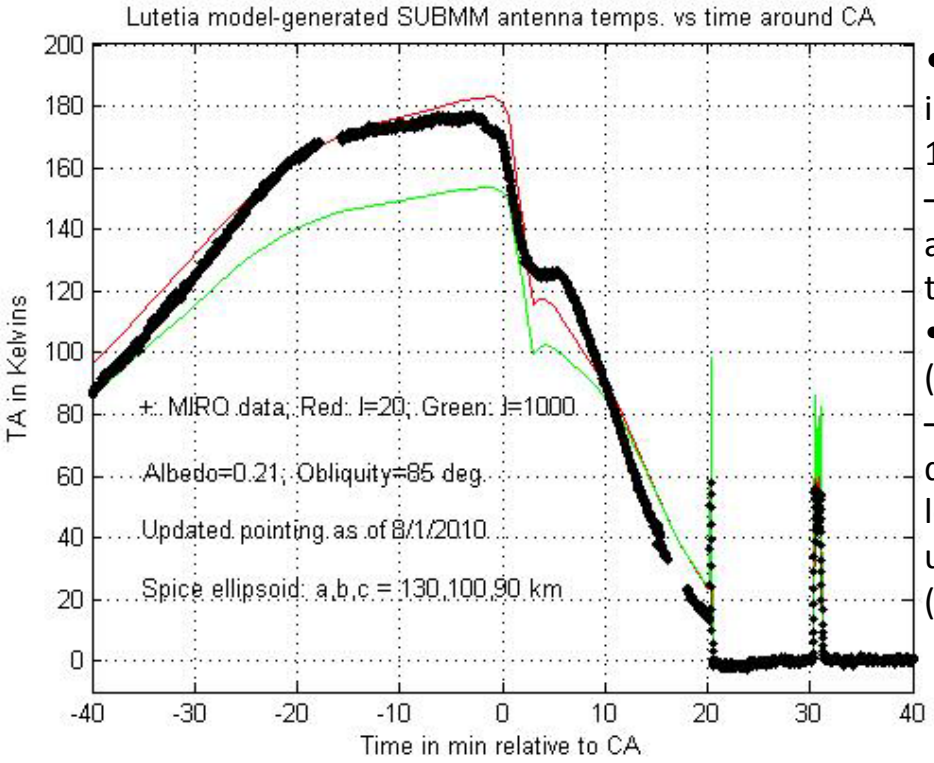



- Best fits to the smm and mm data require a thermal inertia in the range of 10 to 30 (J/K m2 s 0.5)

– Thermal inertia values in the range 10 to 30 (J/K m2 s 0.5) are consistent with values of regolith powder observed on the upper layer of the moon;

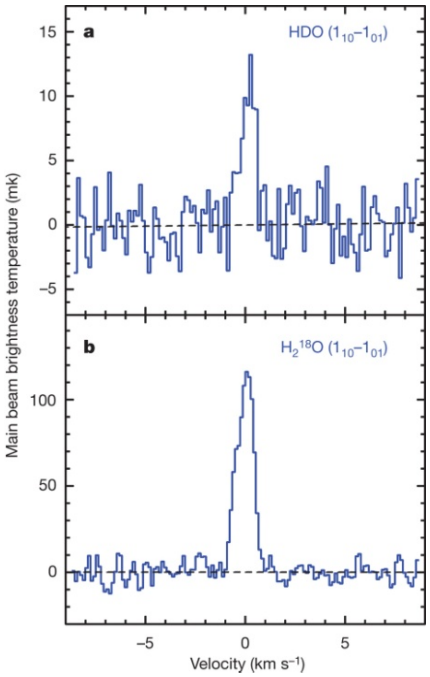
- Best fit of c-axis diameter (night side) is 80 ± 3 km (assumed symmetrical).

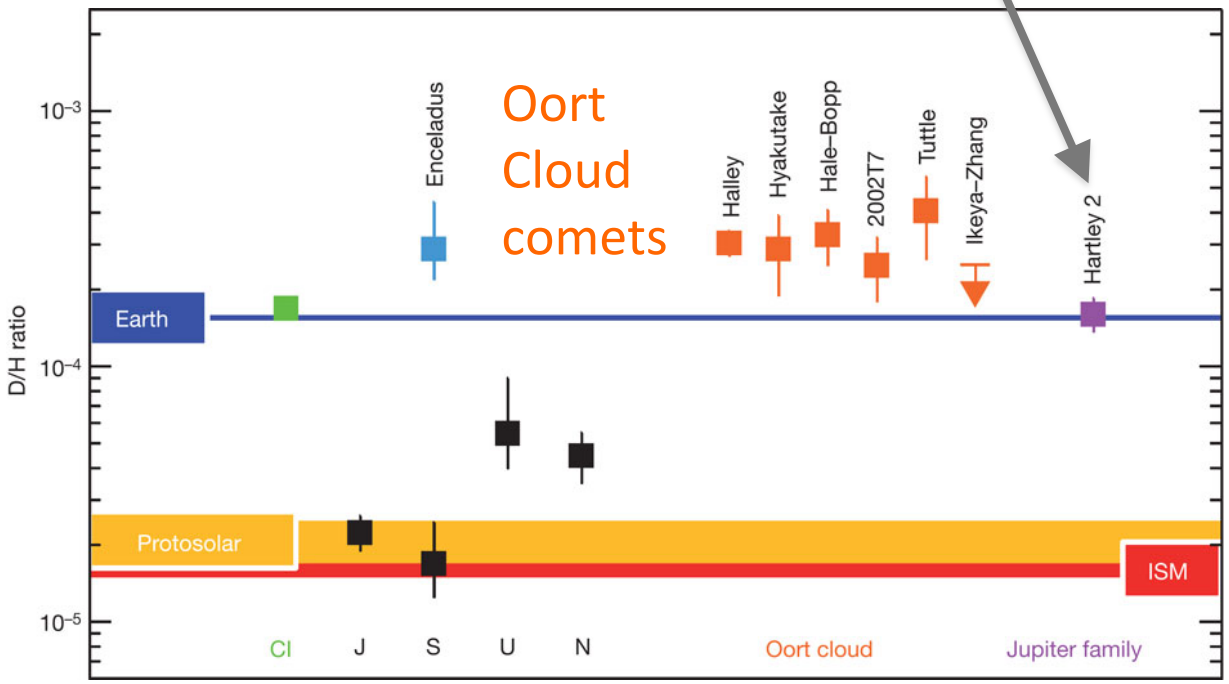
– Based on the Drummond et al. (2010) best triaxial ellipsoid diameters (km) {132± 4 , 101 ± 3 , 93 ±13 }, the MIRO result leads to a volume reduction of 14% and reduces the uncertainty in the c – axis diameter from 13 km to 3 km (14% error vs 4 % error);

# D/H Ratio in Jupiter-Family Comet 103P/ Hartley2 from Herschel = $(1.61 \pm 0.24) \times 10^{-4}$

## Water in Our Solar System

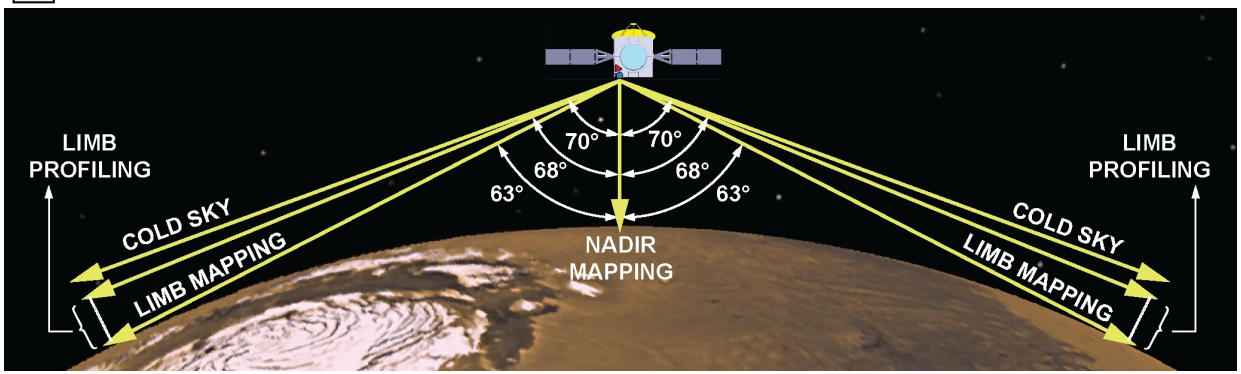
P. Hartogh, D. Lis (Caltech), D. Bocklee-Morvan et al. 2011, Nature 478, 218

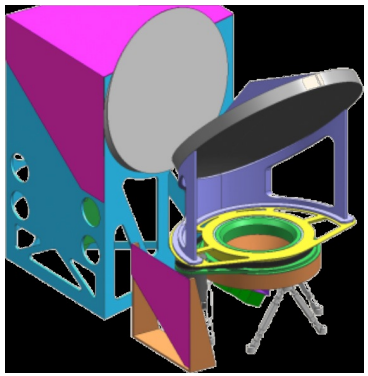



- **Agreement of D/H between Jupiter-Family comet and Earth has revived comets as reservoir for Earth's water**
- Still many issues regarding modeling of early solar system

# Prelim Mars Instrument Concept



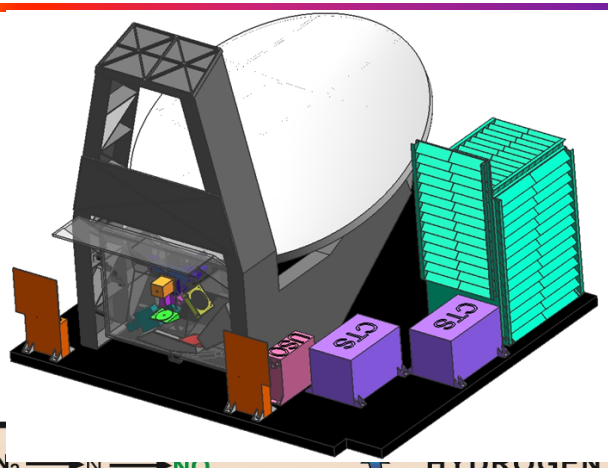
**Submillimeter spectrometry brings unique capability to atmospheric investigations:**

- Atmospheric state (temperature/winds) and composition (H2O, D/H, O3, H2O2, CO): all local times, all atmospheric conditions including dust storms
- *Global coverage including vertical profiling to 100 km*
- *Clear discrimination of lower atmosphere (within 1 scale height of surface)*
- *localized surface source mapping*
- Ultrahigh sensitivity for specific trace gases and isotopologues at parts per trillion for detection and mapping

| Trace Gas | Single 3s limb measurment (pptv) | 15° latitude, 50 sol zonal average (pptv) |
|---|---|---|
| HO2 | 182 | 0.8 |
| NO2 | 5495 | 26 |
| N2O | 3556 | 16 |
| H2CO | 38 | 0.2 |
| HCOOH | 34485 | 159 |
| NH3 | 60 | 0.3 |
| HCN | 11 | 0.1 |
| H2S | 416 | 1.9 |
| H2CS | 97 | 0.4 |
| CH3SH | 1253 | 5.8 |
| OCS | 611 | 2.8 |
| SO2 | 511 | 2.3 |

# Prelim Venus Mission

- 500 km Circular orbit, 1 hour, 27.8 min orbit period




## Key Science Objectives

1. Measurement of vertical profiles of species abundance, temperature, and pressure in the Venus middle atmosphere
2. Measurement of vertical profiles of Doppler shifts of detected molecules, directly yielding wind velocities in the Venus middle atmosphere
3. Measurement of temperature, density, and wind speeds in the important region near the cloud tops where most of the sunlight is absorbed

1. High resolution submillimeter line spectroscopy in two frequency bands with spectral resolution of better than $5x10^5$
2. Limb viewing with <= 5 km (scale height) vertical resolution at periapsis for atmospheric tangent heights ranging from 60-150 km.
3. Nadir direction with <= 50 km horizontal resolution

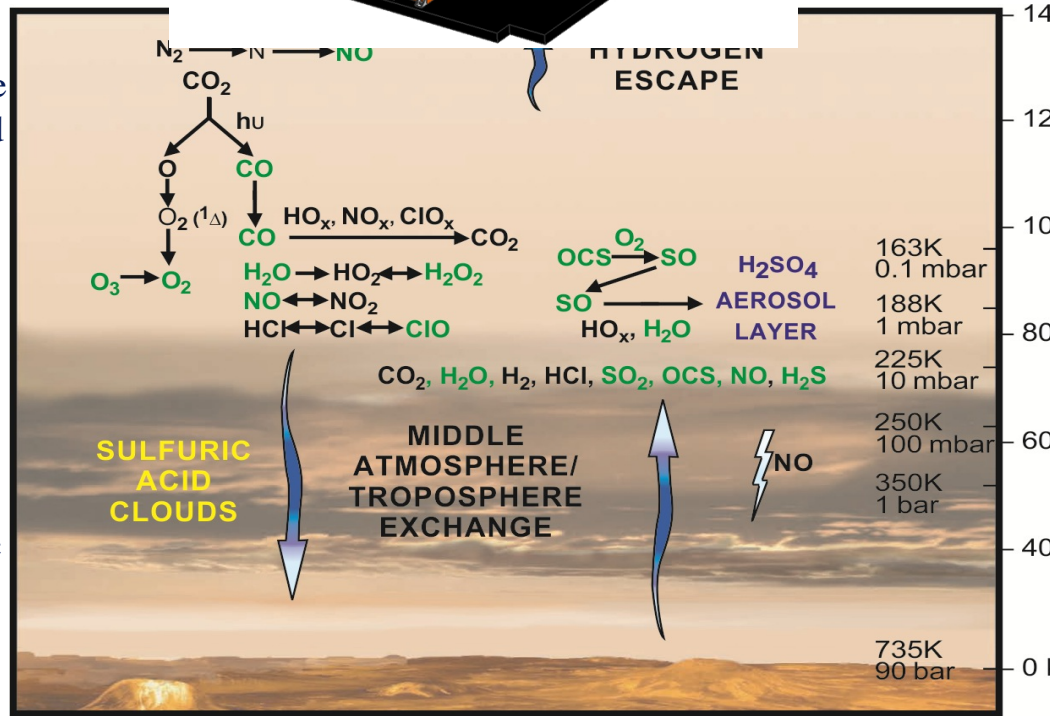



Figure courtesy of Dr. Gordon Chin (GSFC)

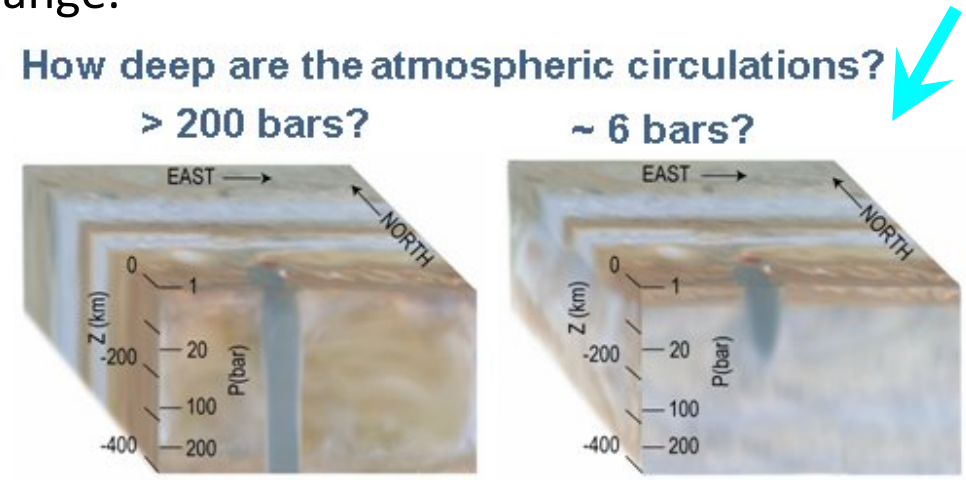
# Plume hunting & surface sputtering

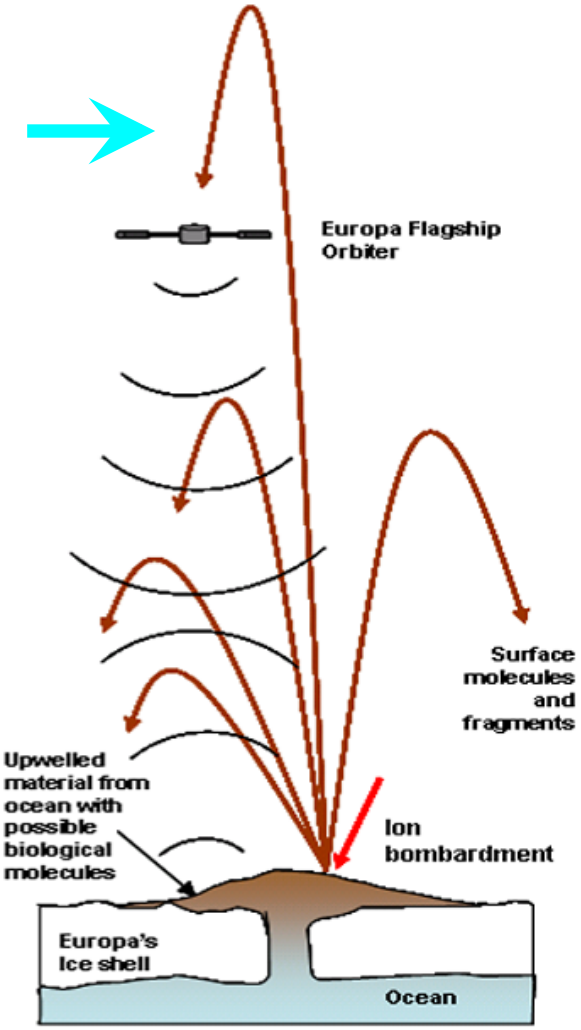
***Ganymede:***

Characterize the physical properties of the Ganymede atmospheric components and interaction with the Jovian system environment.

***Jupiter:***

Wind speed, temperature, pressure and constituent profiles with high spatial resolution
to study atmospheric dynamics at scales down to less than one scale height at pressures of 0.5 to 2 bars over planetary scales in the 0.5 to 2 um wavelength range.



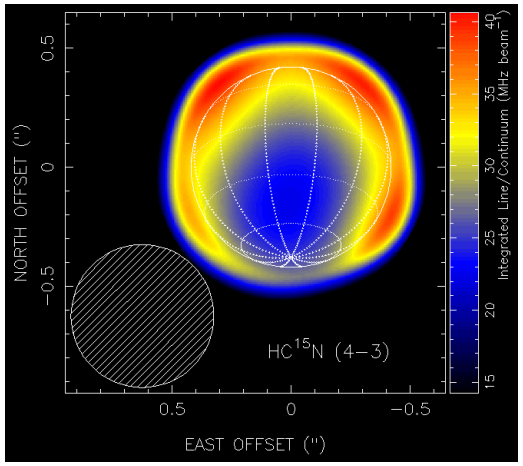

Courtesy John Pearson

# Science Goals at Titan

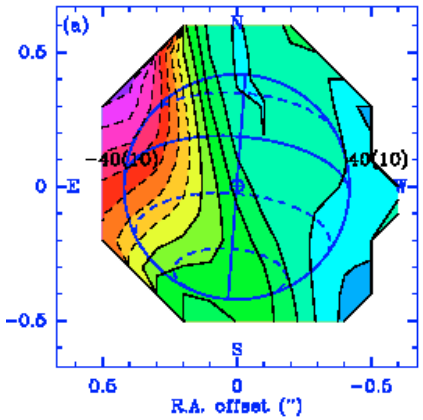
Determine the 3-D distribution of temperature, wind velocities, pressure, and composition in the stratosphere, mesosphere and lower thermosphere of Titan

Species to be detected include organic precursors including (but not limited to!):

$CO$, $CH_4$, $HCN$, $CH_2N_4$, $NH_3$, $DCN$, $H_3CN$, $CH_3CN$, $HC_3N$, $H_2O$, $C_2H_3CN$, $CH_3CCH$, $CH_2NH$




HC$^{15}$N Distribution @Titan
From Gurwell/SMA



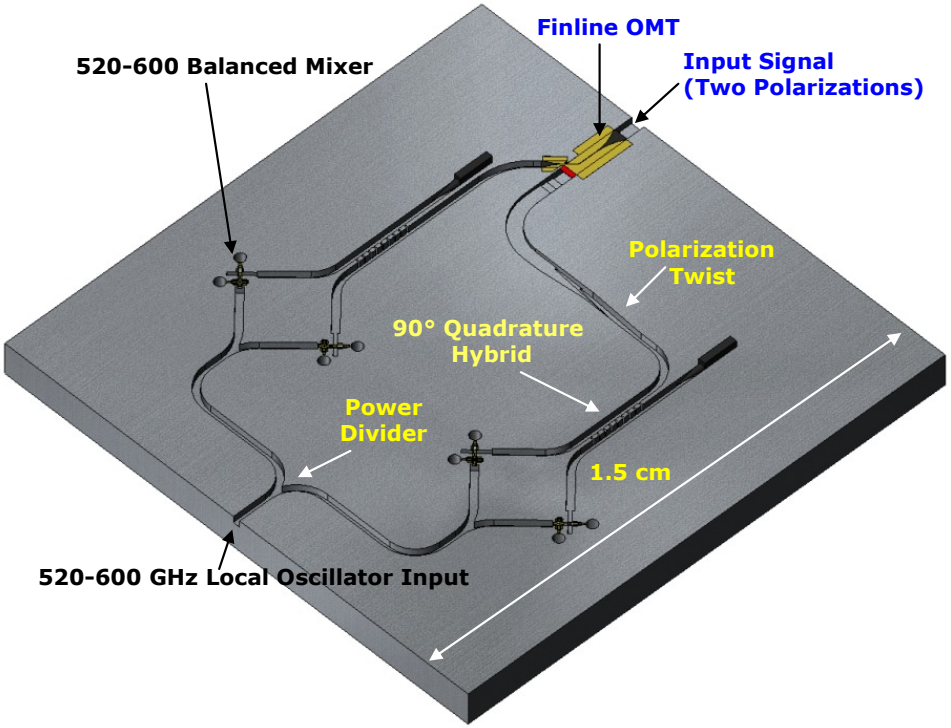

Winds in HC3N
Moreno, A&A 437, 319–328 (2005)

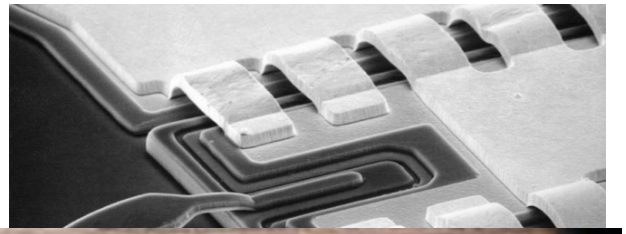
At Enceladus:
Composition, density, temperature and dynamics of gas plume

Courtesy, E. Lellouch

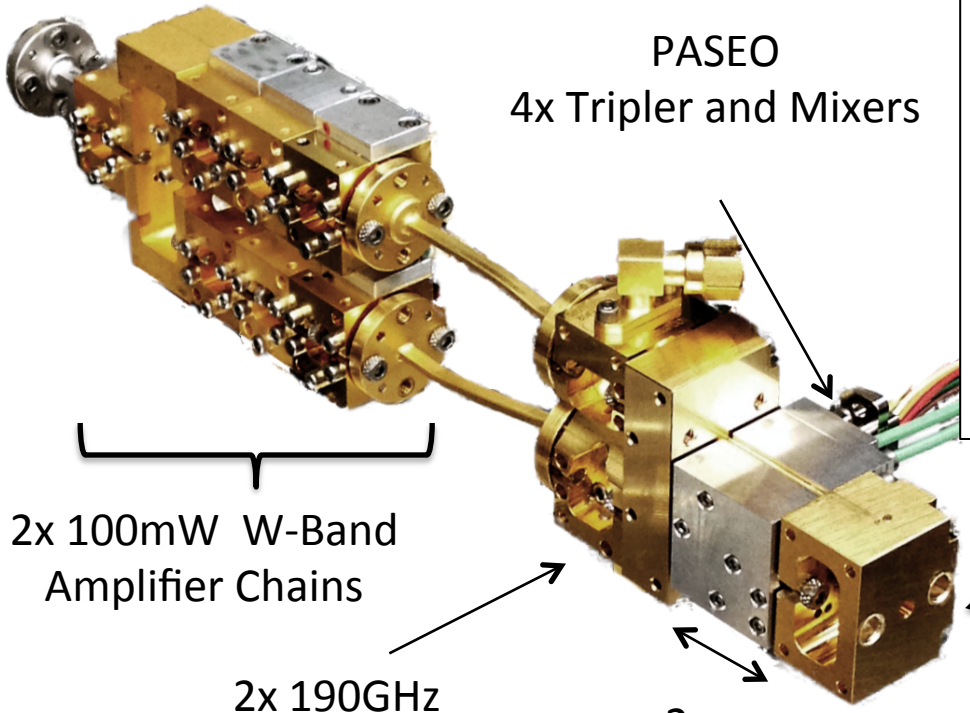
# Technology Readiness

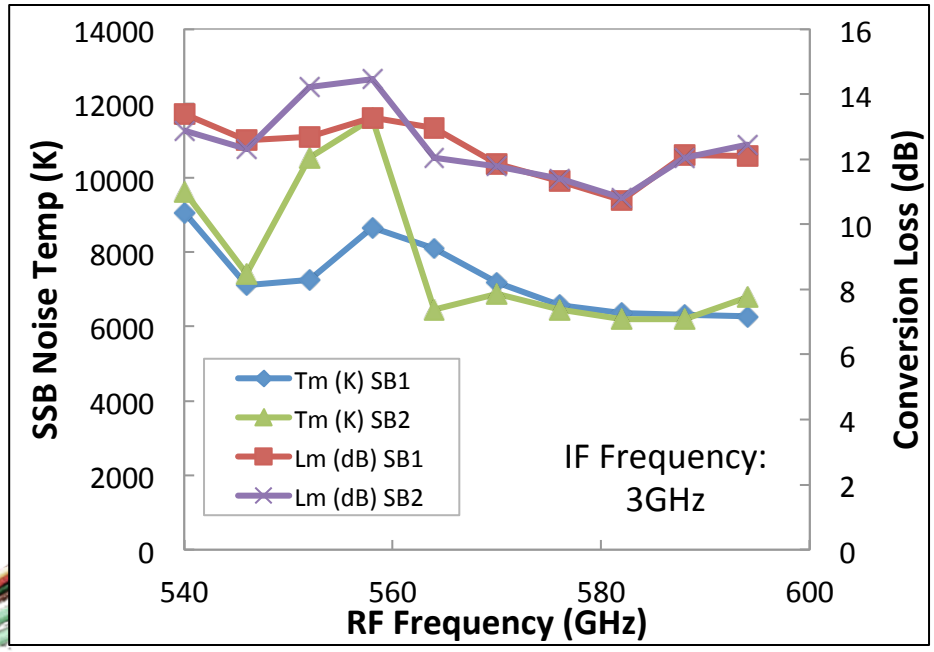
- Mixers: Based on JPL membrane planar diodes
- Multipliers: Based on successful design of HIFI LO to 1.9 THz
- For dual-polarization: OMT has been demo'ed
- For sideband separating: Hybird couplers
- Silicon micromaching



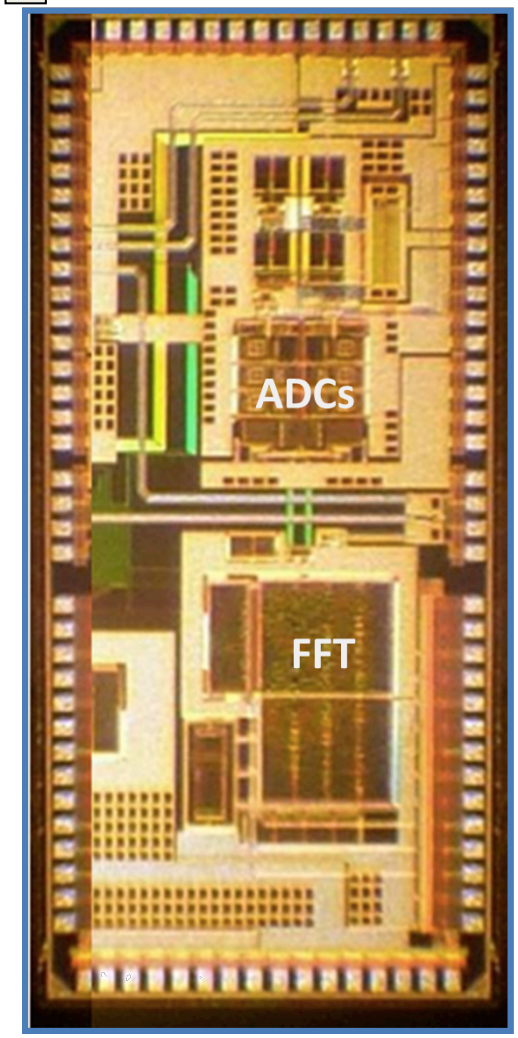



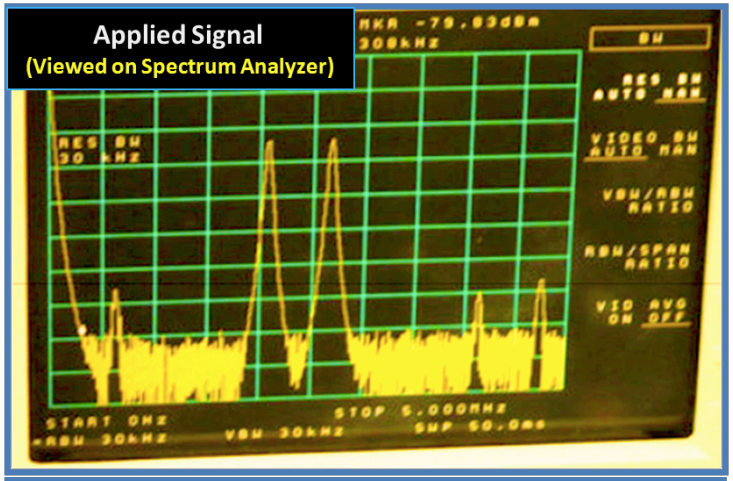
# Prototype Testing

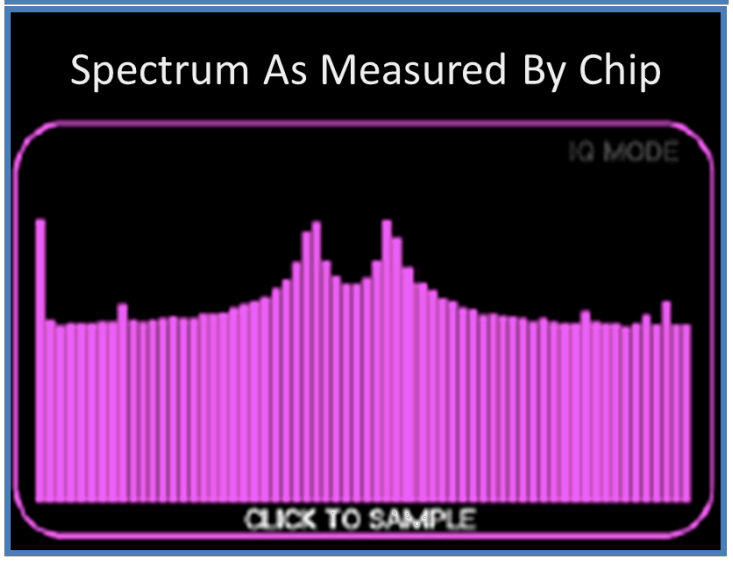


# Back-End Processor Detail




| | 65nm Demonstration |
|---|---|
| Bandwidth | 10 MHz |
| Dynamic Range SNDR (dB) | 30 dB |
| Num Channels | 128 |
| Power Consumption (W) | 130 mW |
| Size | 16 $cm^3$ |
| Weight | 31 g |

4 GHz Bandwidth
8192 channels

# Conclusions

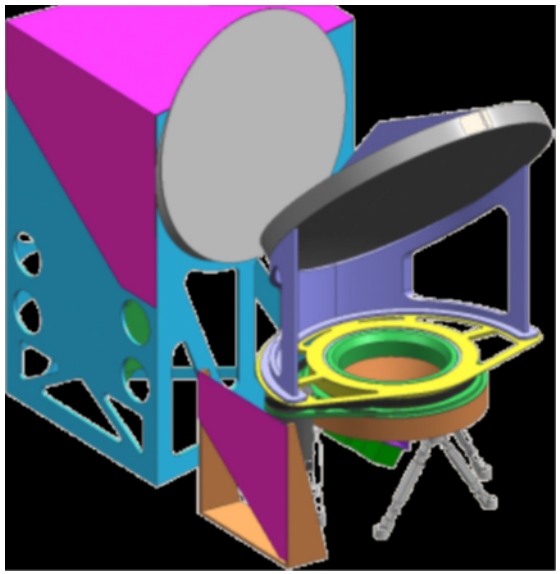
- PISSARO is a unique and enabling instrument that can provide:
  - quantitative measurement of water (comets, planets, asteroids…)
  - unprecedented sensitivity and provide temperature/pressure profiles
  - precise constituent concentration localized in latitude, longitude, and altitude.
  - localization of geothermal hot spots and volcanism,
  - measured wind velocities (down to m/s)
  - analysis of wind and pressure dynamics to improve the accuracy of models for entry descent and landing (EDL) purposes and improve atmospheric evolution models
  - confirmation and characterization of plume activity
  - measured dielectric coefficients for planetary bodies
- PISSARO is currently at TRL 3-4 though a submm-wave sounder based on relatively mature technology (metal machining, DSB etc) can be classified at a much higher TRL

ROOM 1: 4:30-5:00
5:00-5:30

# PISSARO Instrument Concept

- **Submillimeter heterodyne** passive remote radiometer/spectrometer instrument for high spectral resolution investigation of atmospheric molecular lines.
- **Band operation**: 500 to 600 GHz, integrated dual-polarization and side-band separating operations. Increases sensitivity of spectrometer/radiometer by a factor of 2, and provide high calibration accuracy due to sideband separation.
- **Wideband Tunable local oscillator** to look at many lines with single broadband radiometer. **Maximum sensitivity with minimal system complexity** using balanced fundamental mixer requiring minimum LO power.
- **Wideband digital polyphase backend spectrometer** will greatly reduce the power and mass compared to prior units.
- ***Power Goal: 20 W  Mass Goal: 10 kg***
- ***Increase of TRL to 6 (by end of task)***

**Conceptual only**



# Science Applications

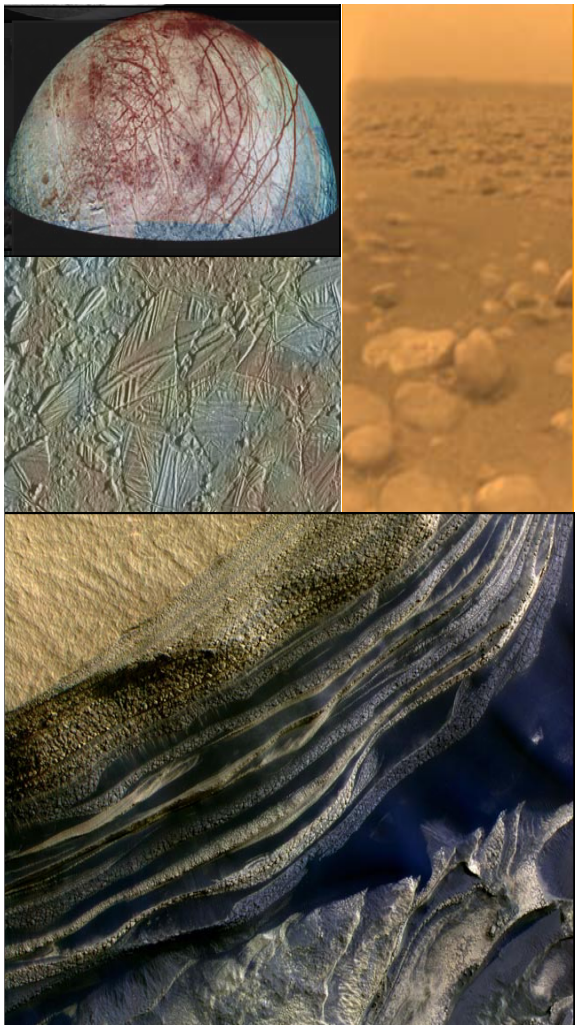
## Spectrometer:

The sideband separating dual-polarized high-resolution spectrometer will offer unprecedented sensitivity and give temperature/pressure profiles and precise constituent concentration localized in latitude, longitude, and altitude. These data will allow the chemistry and dynamics of planetary atmospheres to be mapped for a wide range of purposes, including localization of geothermal hot spots and volcanism, identification and analysis of out-gassing from possible "oases of life" environments or as the result of other processes, analysis of wind and pressure dynamics for both scientific research and to improve the accuracy of models for entry descent and landing (EDL) purposes, and to improve modeling of atmospheric evolution.

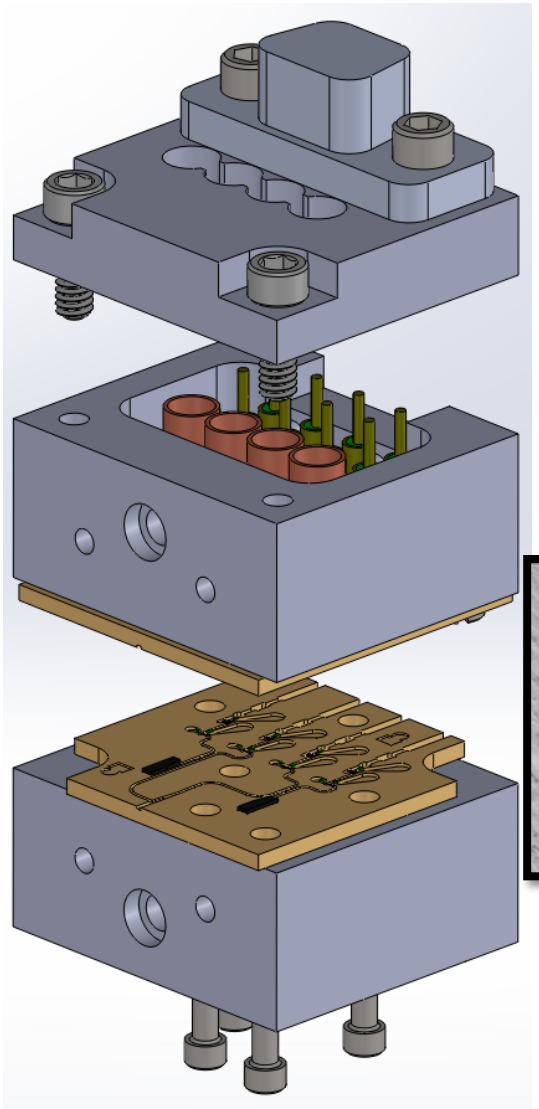
## Radiometer:

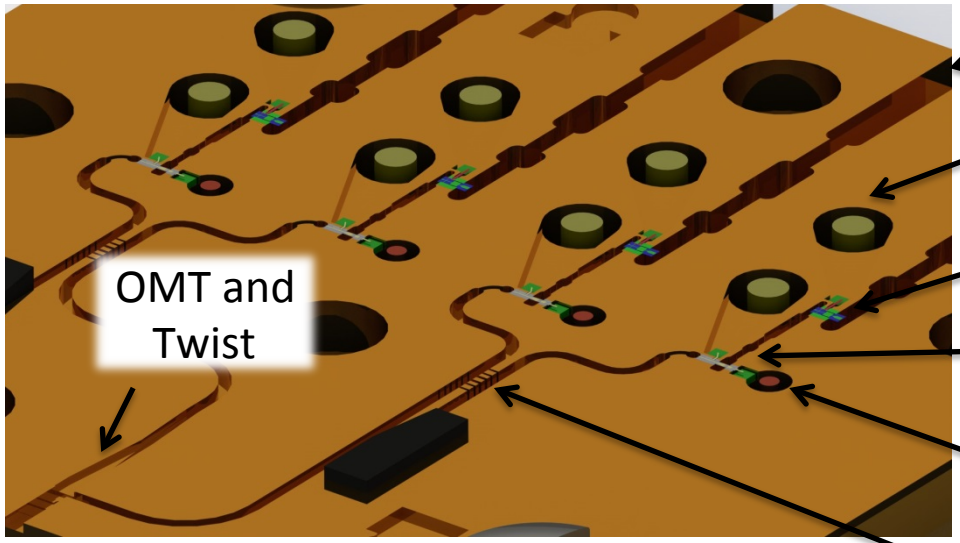
An integrated polarization discrimination radiometer without the need of any reorientation of the spacecraft or any polarization grids will be invaluable for analyzing the materials and dielectric properties of planetary surfaces such as those of Titan, Europa, Mars, and Ganymede. Availability of both the sidebands simultaneously will increase the radiometer sensitivity.

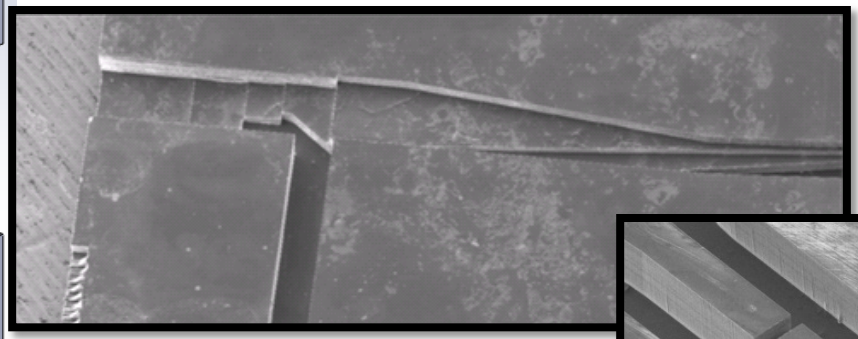
No such instrument exists today. All the current spectrometer/ radiometers at these frequencies either use wire grid polarizers or re-orient the space-craft to get the data required to make the surface property measurements.

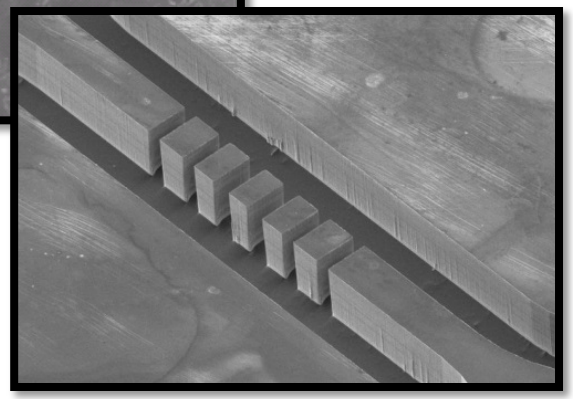


# Dual-Polarization SSB Receiver



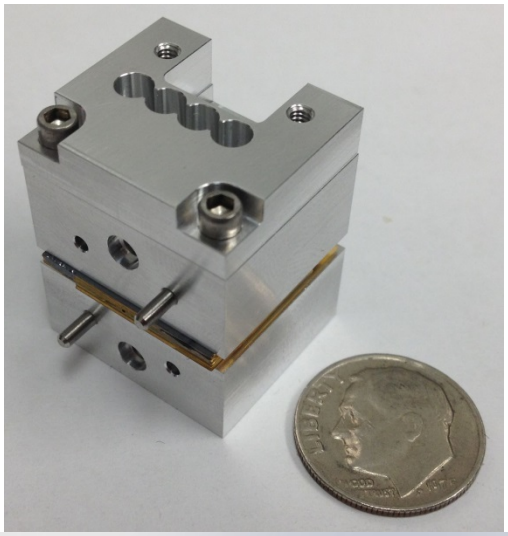


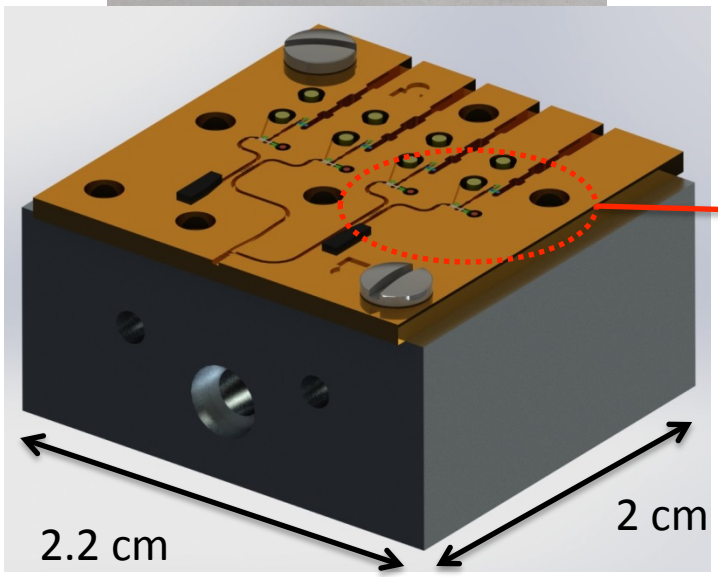



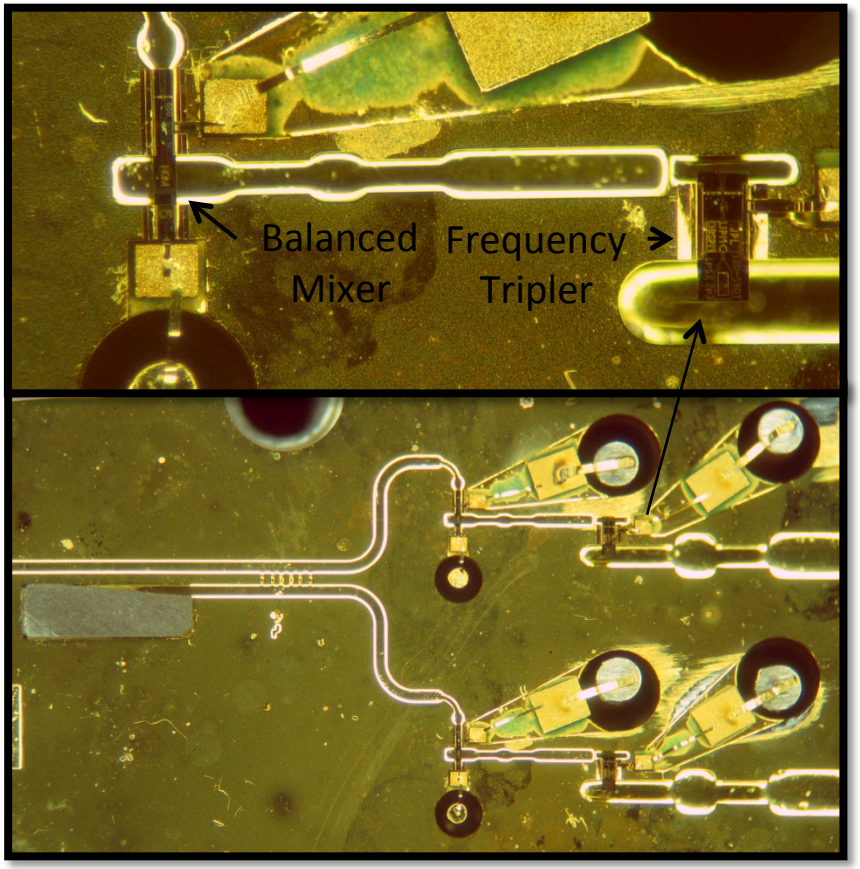


Waveguide
Hybrid

# Assembly and Test Setup





# Sideband Separation