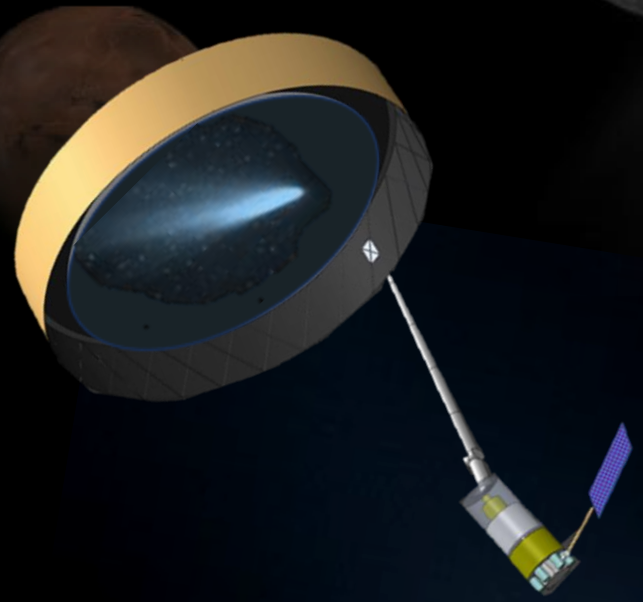

Solar System Science with SALTUS

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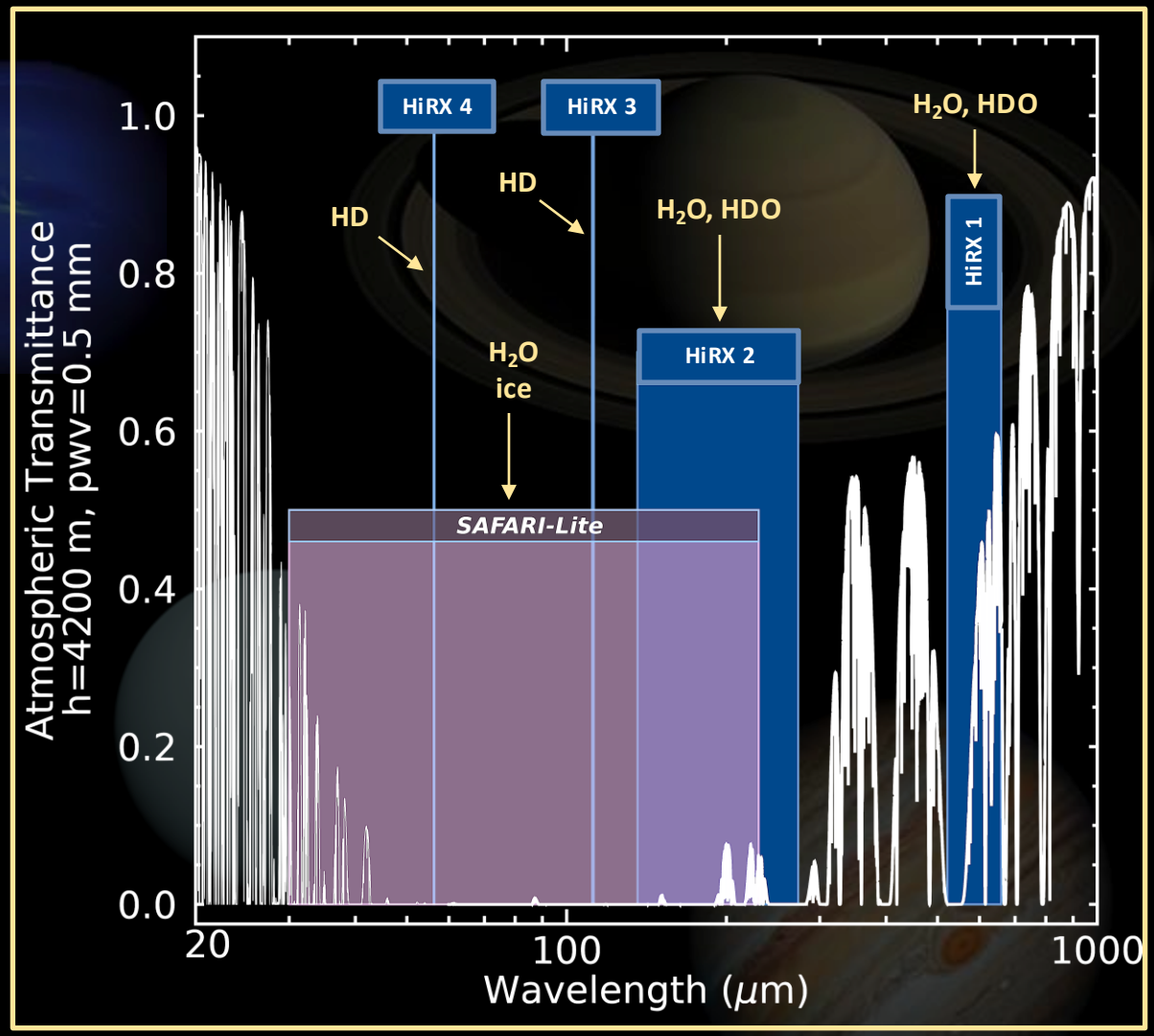
SALTUS has Unique Capabilities

- **High spectral resolving power**
  - *HiRX: R = 10^6 – 10^7*
- **High spatial resolution**
  - *0.38” at 30 μm to 8.3” at 659 μm*
- **High sensitivity**
  - *20-m primary aperture (25 K)*
  - *4 K SIS and HEB detectors (HiRX)*
  - *0.1 K KID detectors (SAFARI-Lite)*
- **Covers wavelengths obscured from ground-based telescopes**
- **Bridges spectral gap between ALMA and JWST**



What do these unique capabilities bring to Solar System Science?

Solar System Science Themes SS.1 – SS.5

SS.1: Origin and history of water delivered to the solar system via isotopologues in:
- **a)** *Comets and Ocean World atmospheres* (GTO; **HiRX 1,2**)
- **b)** *Atmospheres of Giant Planets, Moon, Ceres, Venus, Mars, Titan, Triton, Pluto* (GO; **HiRX 1,2**)

SS.2: HD abundance in Giant Planet atmospheres (GTO; HiRX 3,4)

SS.3: Ices and other particulates in:
- **a)** *cometary, planetary atmospheres, Enceladus' plumes* (GTO; **SAFARI-Lite**)
- **b)** *surfaces of icy moons, Jupiter Trojans, Centaurs, KBOs* (GO; **SAFARI-Lite**)

SS.4: CHNOPS-containing molecules in Venus, Earth, Mars, comet atmospheres (GO; **HiRX 1,2**)

SS.5: Venus' complex chemistry to help distinguish exo-Venus' from exo-Earths (GO; **HiRX 1,2**)

Note: **GTO**=Guaranteed Time Observing (~30% total time); **GO**=General Observer (~70% total time)

The GO Science themes demonstrate the full science capabilities of SALTUS beyond the GTO agenda. They are by no means all-encompassing and should be taken as *illustrative* science that takes advantage of SALTUS' unique capabilities. There is still time for community feedback to refine them.

Measure HDO, $H_2{}^{16}O$, $H_2{}^{18}O$, and $H_2{}^{17}O$ in Comets

- **Comets help constrain origin/thermal evolution of water in solar nebula**
  - *D/H ratios are critical diagnostics of isotopic fractionation*

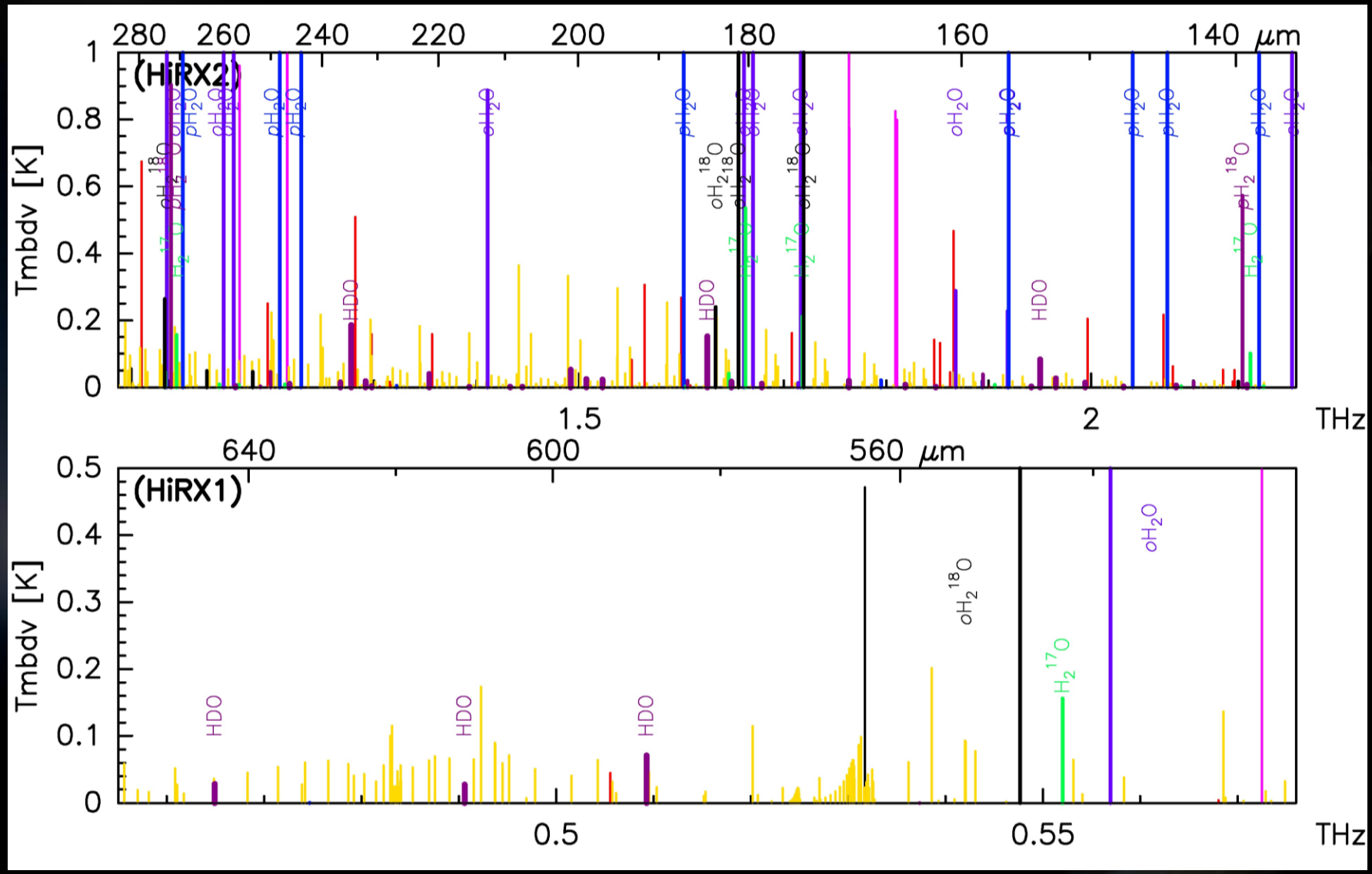
- **Accurate D/H ratios reported in 2 comets from remote investigations**
  - *high accuracy requires near-simultaneous H_2O with multiple HDO lines*
  - *D/H ratios reported in 14 other comets with an intrinsic dispersion (range) of ~1 – 3× that of Earth's oceans (VSMOW)*
  - *few simultaneous measurements of HDO with other water isotopes exist*

- **SALTUS HiRX will significantly increase the sample size and accuracy of D/H by observing HDO and H_2O in 30 – 40 comets with a single instrument**

- **HiRX will measure at least 5 HDO transitions between 112 and 645 μm in <12 hours**
  - *simultaneously retrieve $H_2{}^{16}O$, $H_2{}^{18}O$, and $H_2{}^{17}O$*

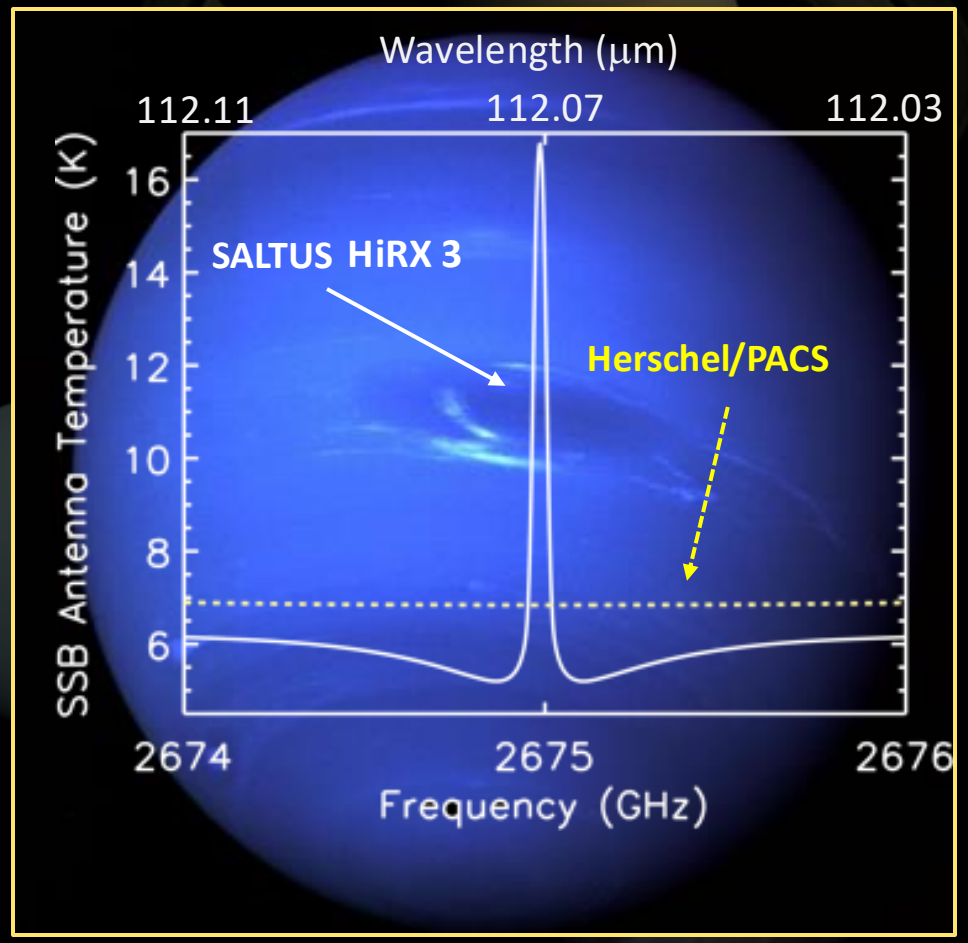
HiRX 1 and 2 Comet Simulation

- $QH_2O = 5x10^{28}$ at 1 AU
- $H_2{}^{16}O$ (blue)
- HDO (thick maroon)
- $H_2{}^{18}O$ (light maroon)
- $H_2{}^{17}O$ (green)
- CH_3OH (yellow)
- H_2S (red)
- NH_3 (pink)
- HCN, CO (thin black)



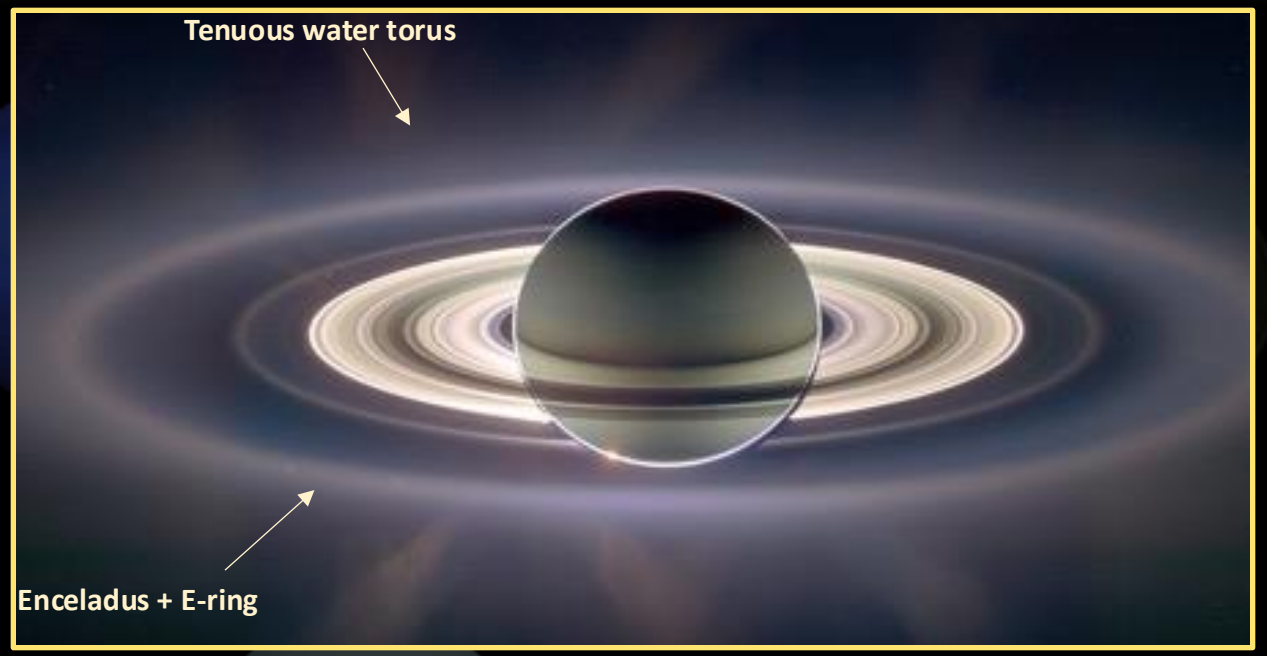
Measure HD in the Giant Planets

- **Accurate D/H measurements needed to constrain origin models**
  - *HD can only be measured from stratospheric- and space-borne platforms*
- **HD measured by *Herschel*, *ISO*, and *Cassini***
  - *stratospheric and tropospheric contributions could not be separated*
  - *limited accuracy in deriving HD*
- **SALTUS HiRX will independently measure HD in the upper troposphere and stratosphere**
  - *spectrally resolve emission line core to derive stratospheric HD*
  - *test the expectation that HD is well mixed*
- **SALTUS will measure both the HD 1-0 (112 μm; HiRX 3) and HD 2-1 (56 μm; HiRX 4) lines**



Measure H_2O in Enceladus' Torus

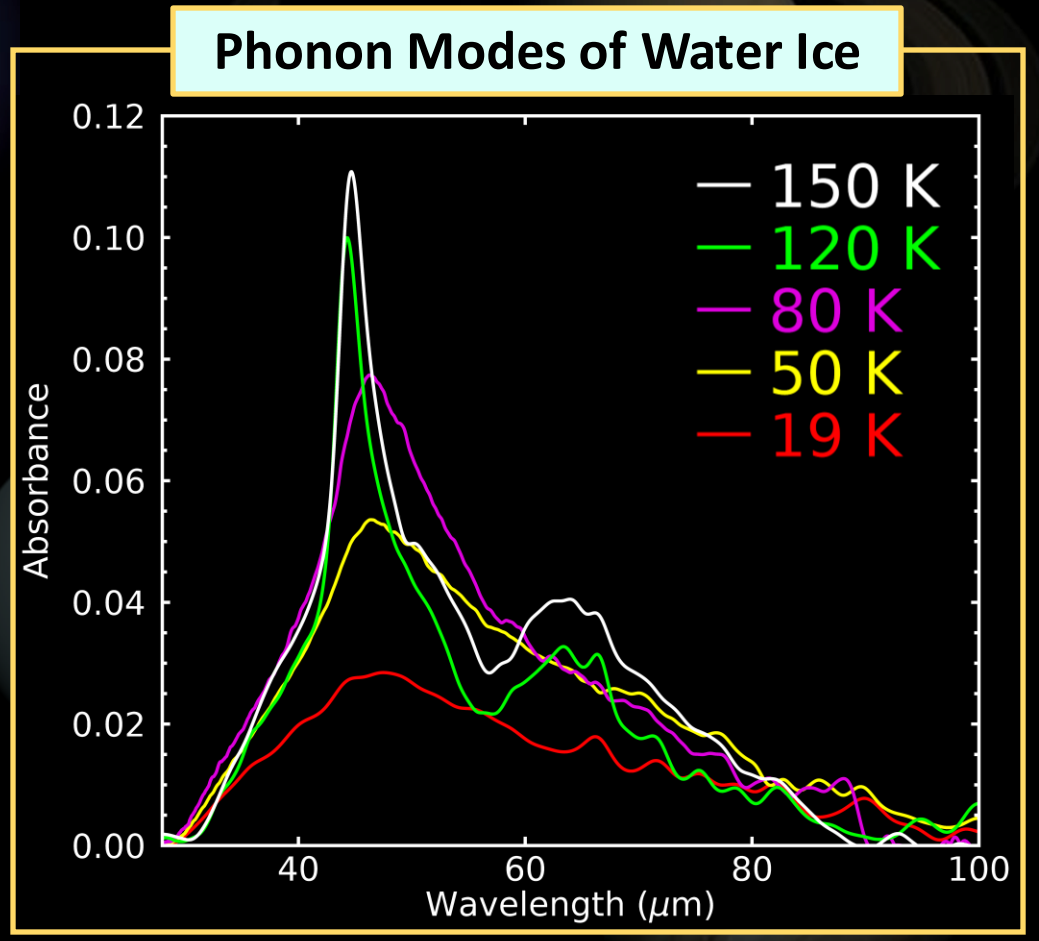
- **Investigate habitability of an Ocean World**
  - *100s of kg/s of water vapor jet into space*
  - *torus extends 10s of thousands of km*
  - *large spatial extent allows for water isotopic measurements*



- **SALTUS HiRX measurements will provide a rare opportunity to probe conditions in the interior of Enceladus**
  - *first to spatially-map out water emitting directly from the torus*
  - *measure isotopic ratios through HDO and $H_2{}^{18}O$ transitions*
- **Building on the Herschel HIFI legacy but with higher spatial resolution and sensitivity**
- **SAFARI-Lite will characterize the water ice near Enceladus and in the E-ring**

Measure far-IR ice signatures with SAFARI-Lite

- **Far-IR comprises low energy lattice vibrational modes of ices**
  - *unique views into composition, structure, porosity, thermal evolution*
  - *evolutionary history imprints into spectral dependence*
- **Easily distinguish between amorphous and crystalline phases**
  - *phase transition temperatures*
  - *informs on ice thermal evolution*
- **Extend our understanding of near-IR detected ices through their far-IR characterization**
- **Spectral signatures of solid N_2 and O_2 ice in outer solar system objects and comets**
- **Spectral signatures of mineral compositions of silicates in asteroids and comets**
  - *e.g., Fe in olivine at 69-μm*



C. M. Anderson and M. S. Ugelow (2023, in preparation)

More High-Impact Measurements with the GO Program

- **H_2O delivery to Gas Giant stratospheres**
  - *planetary rings, icy moons, interplanetary dust particles, comet impacts*
- **Gases in Venus' middle atmosphere**
  - *H_2O and HDO; numerous sulfur compounds; confirm/refute PH_3 detection*
- **H_2O in Titan's stratosphere**
  - *constrain its external source*
- **CH_3D and CH_4 on Titan**
  - *retrieve deuterium inventory; methane cycle*
- **H_2O on Ceres**
  - *source and spatial distribution*
  - *cryo-volcanism/ice sublimation from localized regions*
- **Lunar exospheric H_2O**
  - *density/spatial variations; pure science and resource utilization*
- **N_2 ice on Triton's surface**
  - *Mixed or pure?*

SALTUS is truly a community resource!

Molecules Galore!

There are a profusion of molecules available for Solar System Science with SALTUS GO.

Comets

$H_2{}^{33}S$
$H_2{}^{16}O$
OCS
HDO
$O^{13}CS$
$H_2{}^{18}O$
$OC^{34}S$
$H_2{}^{17}O$
$OC^{33}S$
CO
SO
^{13}CO
SO_2
$C^{18}O$
$^{34}SO_2$
H_2CO
H_2O_2
$H_2{}^{13}CO$
NH_3
$H_2C^{18}O$
$^{15}NH_3$
HCOOH
HCN
CH_3OH
$H^{13}CN$
O_2
$HC^{15}N$
$O^{18}O$
HNC
$O^{17}O$
HF
H_2S
HCl
$H_2{}^{34}S$
CH_3CN

Venus

$H_2{}^{16}O$
H_2S
$H_2{}^{18}O$
$H_2{}^{34}S$
$H_2{}^{17}O$
$H_2{}^{33}S$
HDO
H_2SO_4
$CO^{18}O$
ClO
$CO^{17}O$
^{37}ClO
$^{13}CO^{18}O$
H_2O_2
$^{13}CO^{17}O$
SO
CO
SO_2
^{13}CO
$^{34}SO_2$
$C^{18}O$
OCS
O_2
$O^{13}CS$
$O^{18}O$
$OC^{34}S$
$O^{17}O$
$OC^{33}S$
O_3
NO
$OO^{18}O$
NO_2
$OO^{17}O$
PH_3

Ocean Worlds

$H_2{}^{16}O$
H_2O_2
HDO
O_3
$H_2{}^{18}O$
$OO^{18}O$
$H_2{}^{17}O$
$O^{18}OO$
CO
$OO^{17}O$
$C^{18}O$
$O^{17}OO$
^{13}CO
CH_3OH
NaCl
NH_3
SO_2
$^{15}NH_3$
$^{34}SO_2$
HCN
H_2S
$H^{13}CN$
$H_2{}^{34}S$
$HC^{15}N$
$H_2{}^{33}S$
HNC

Titan

$H_2{}^{16}O$
$H_2{}^{16}OCO^{17}O$
HDO
$^{13}CO^{18}O$
$H_2{}^{18}O$
$^{13}CO^{17}O$
$H_2{}^{17}O$
HCN
CH_4
DCN
$^{13}CH_4$
$H^{13}CN$
CH_3D
$HC^{15}N$
CO
$H^{13}C^{15}N$
^{13}CO
HC_3N
$C^{18}O$
CH_3CN
$^{13}C^{18}O$
C_2H_5CN
$CO^{18}O$
C_2H_3CN

Giant Planets

HD
PH_3
CH_4
H_2S
$^{13}CH_4$
$H_2{}^{34}S$
CH_3D
$H_2{}^{33}S$
CO
NH_3
^{13}CO
$^{15}NH_3$
$C^{18}O$
HCN
$H_2{}^{16}O$
$H^{13}CN$
$H_2{}^{18}O$
$HC^{15}N$
$H_2{}^{17}O$
GeH_4
HDO
AsH_3

Moon/CERES

$H_2{}^{16}O$
HDO
$H_2{}^{18}O$
$H_2{}^{17}O$
OH

Pluto

H_2O
HDO
$H_2{}^{18}O$
$H_2{}^{17}O$
NaCl
CO
^{13}CO
$C^{18}O$
HCN
$H^{13}CN$
$HC^{15}N$
HNC
CH_4
$^{13}CH_4$
CH_3D

Mars

$H_2{}^{16}O$
HDO
$H_2{}^{18}O$
$H_2{}^{17}O$
CO
^{13}CO
$C^{18}O$
$CO^{18}O$
$CO^{17}O$
$^{13}CO^{18}O$
$^{13}CO^{17}O$
O_2
O_3
H_2O_2
H_2CO
$H_2{}^{13}CO$
$H_2C^{18}O$
HCOOH
CH_4

Solar System Science Logistics

- **SALTUS operational efficiency is currently 60%**
  - *~6600 hrs over 5 yrs for Solar System Science*
  - ***GTO** occupies 30% of this time, while **GO** program comprises 70%*

- **Threshold Science**
  - *Year 1; Phase-E will commence ~2032*
  - *observe ~80 objects, 6 – 10 combined JFCs and OCCs*
  - *science includes initial detection/discovery of astrochemically-relevant compounds*

- **Baseline Science**
  - *Years 2 – 5*
  - *an additional ~220 objects, 24 – 30 more combined JFCs and OCCs*
  - *broadens Threshold Science impact by expanding measurements to include i) additional transitions, ii) more spatial and time coverage on target, iii) spectral surveys.*

All GTO and GO data will be made public as soon as practical through a NASA-managed astrophysics data archive.

Thank you for your time.

Questions?

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