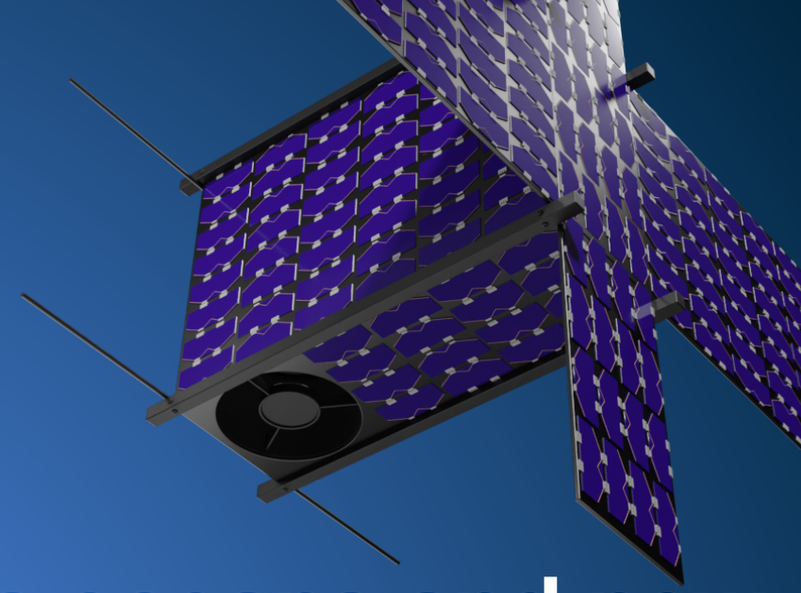
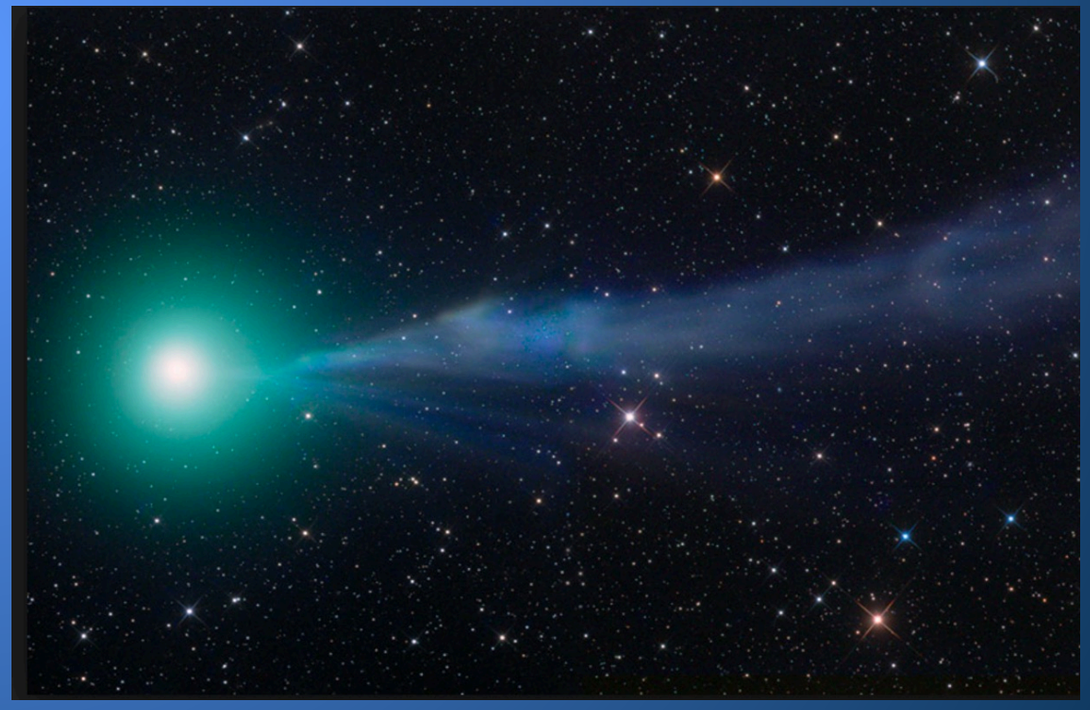
Mission HYADES

(HYdrogen And DEuterium Surveyor)



In search of the cosmic origins of Earth's oceans and new reservoirs of water in our and other planetary systems

Credit: ESO/M.Kornmesser

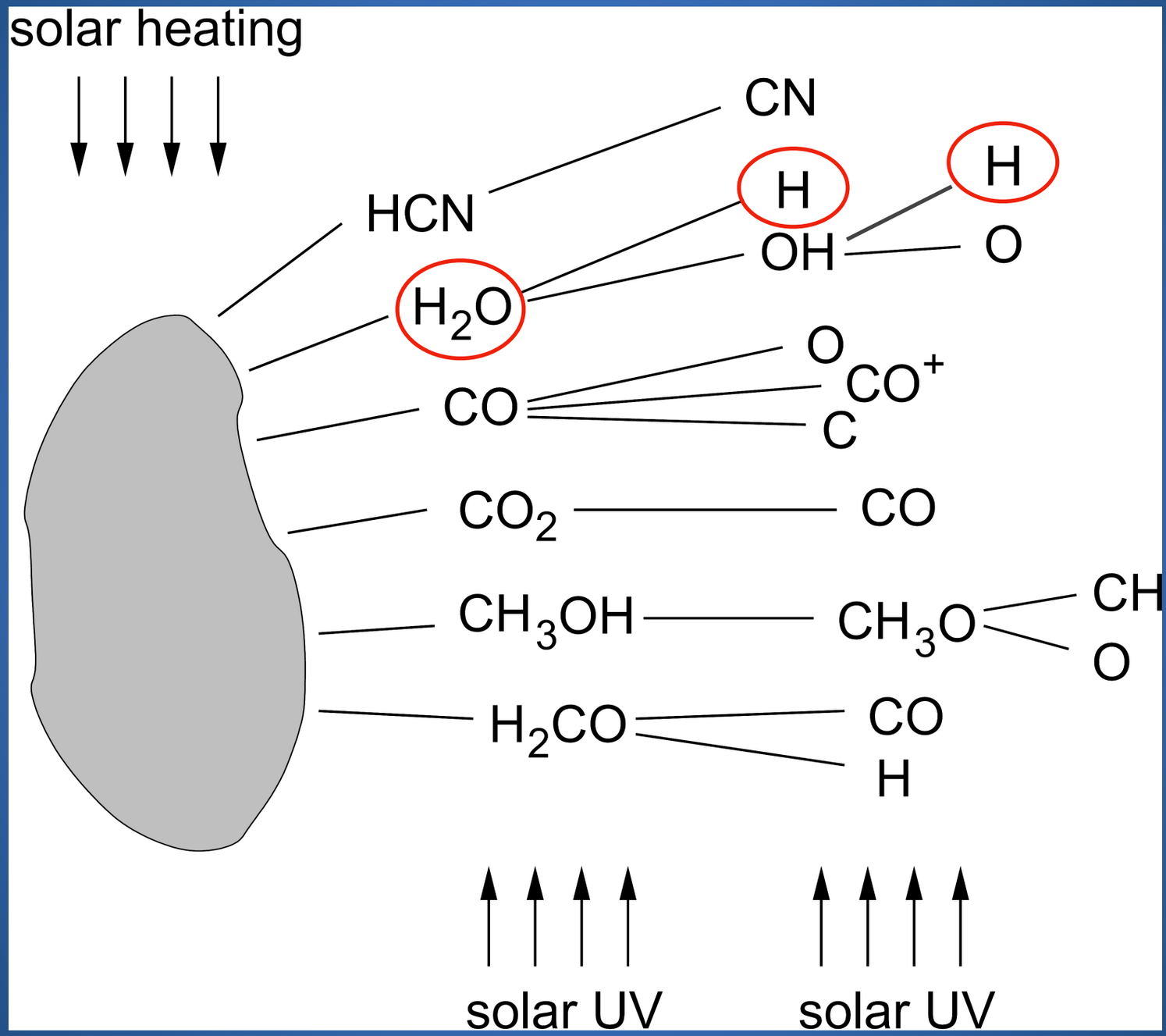


Credit: G. Rhemann

Michał Drahus, Piotr Guzik, Tomasz Kawalec, Mikołaj Sabat

Jagiellonian University in Cracow

Basics of cometary photochemistry



Credit: Christopher Jarchow (MPS)

Driving science questions

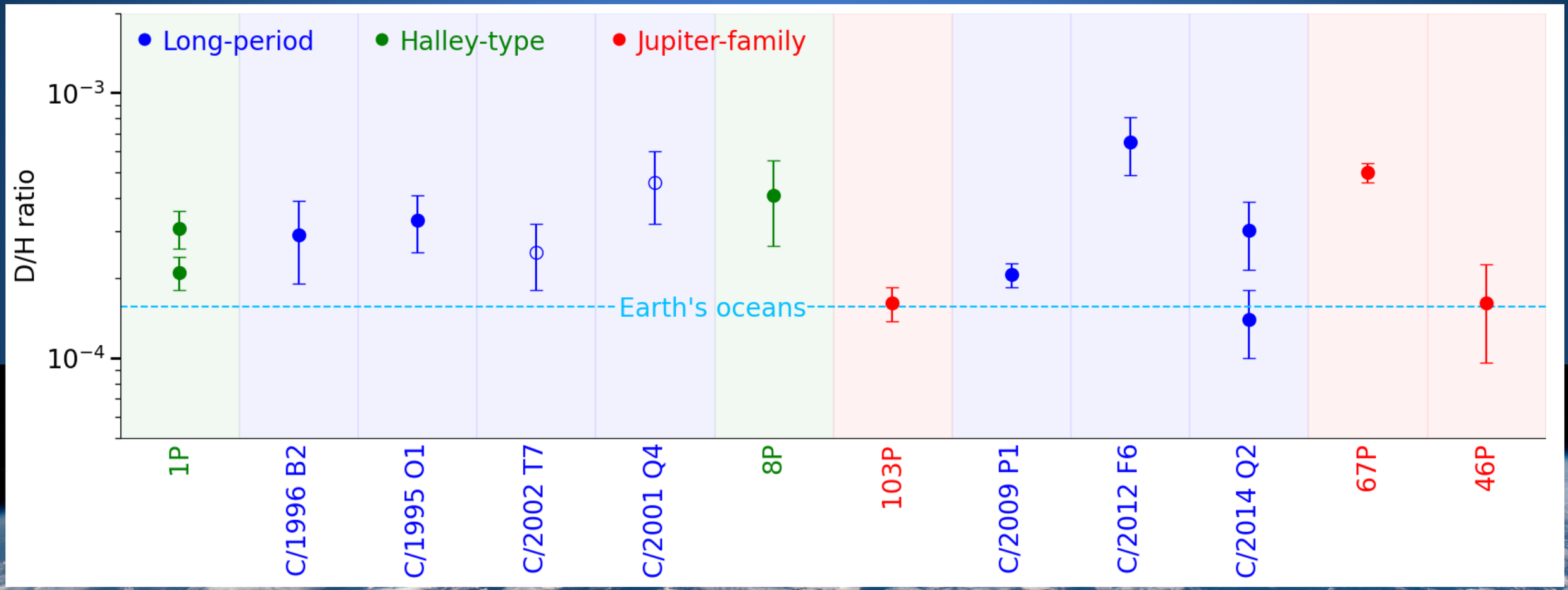
Origin of water on Earth

Late heavy bombardment. Image credit: NASA

Driving science questions

Origin of water on Earth

Numerical data from Müller et al. (2022)



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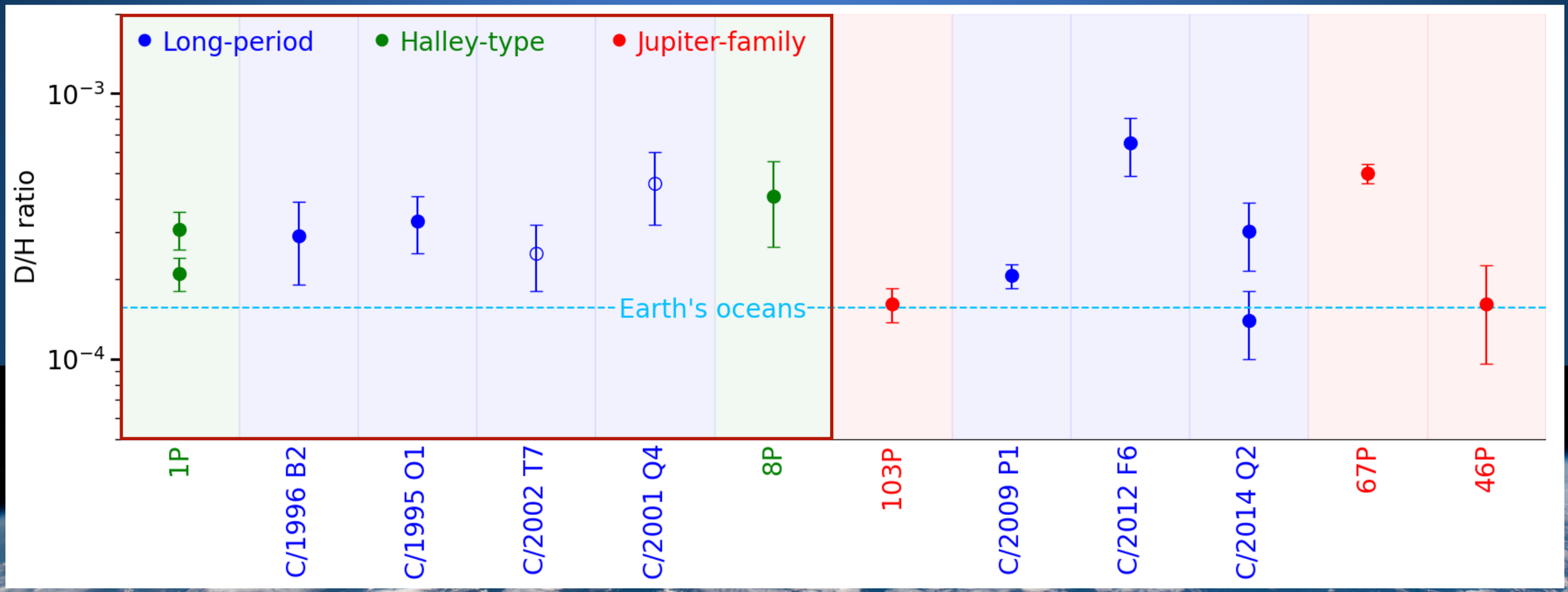

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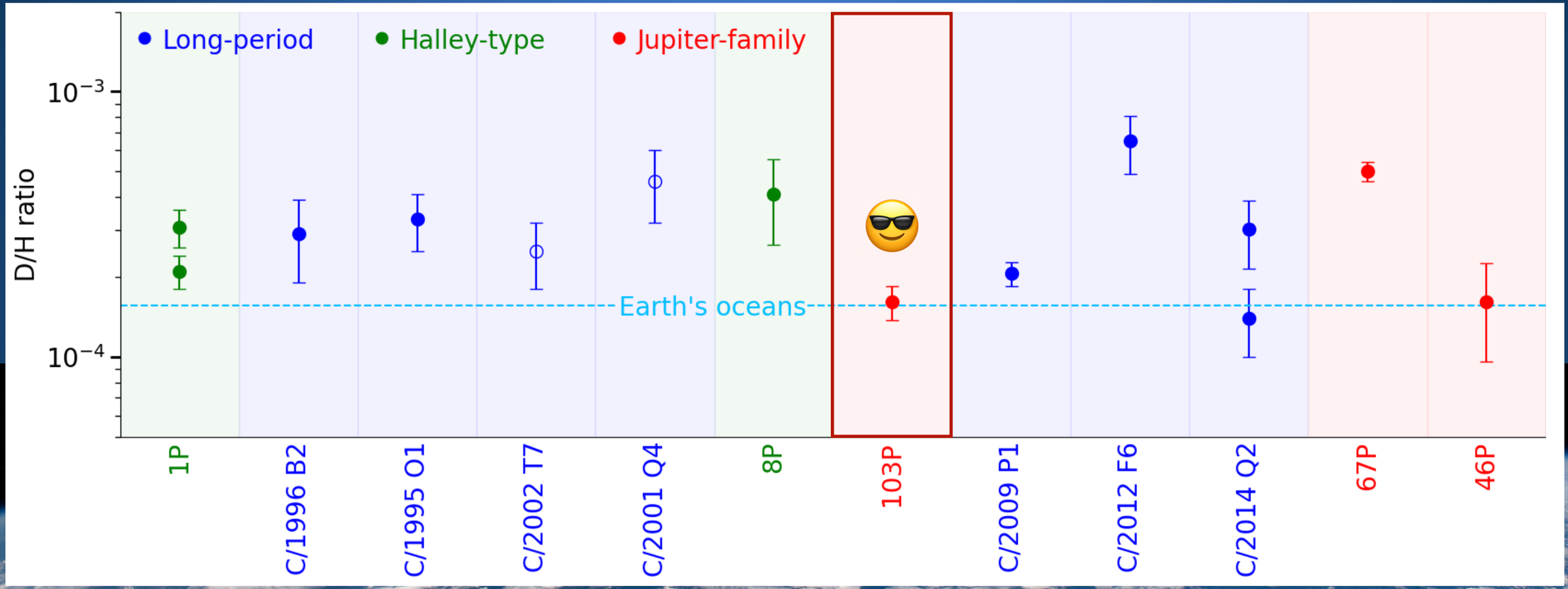

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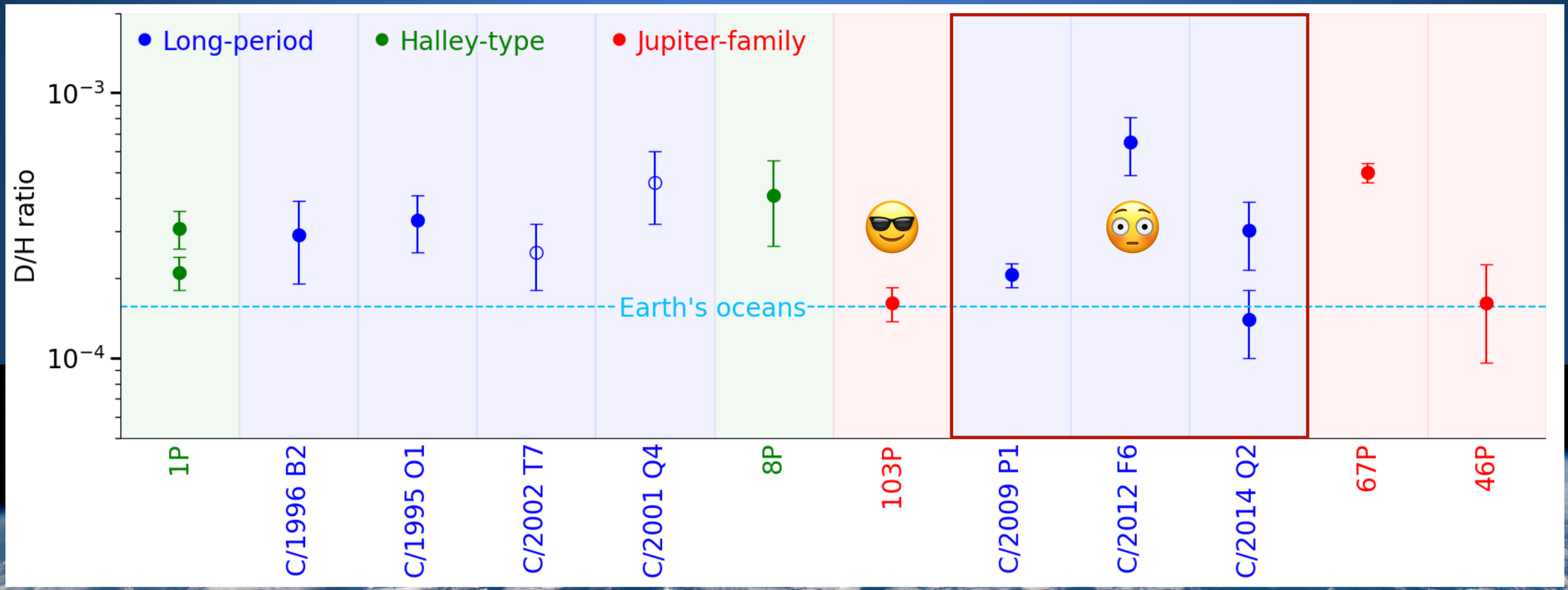

Driving science questions

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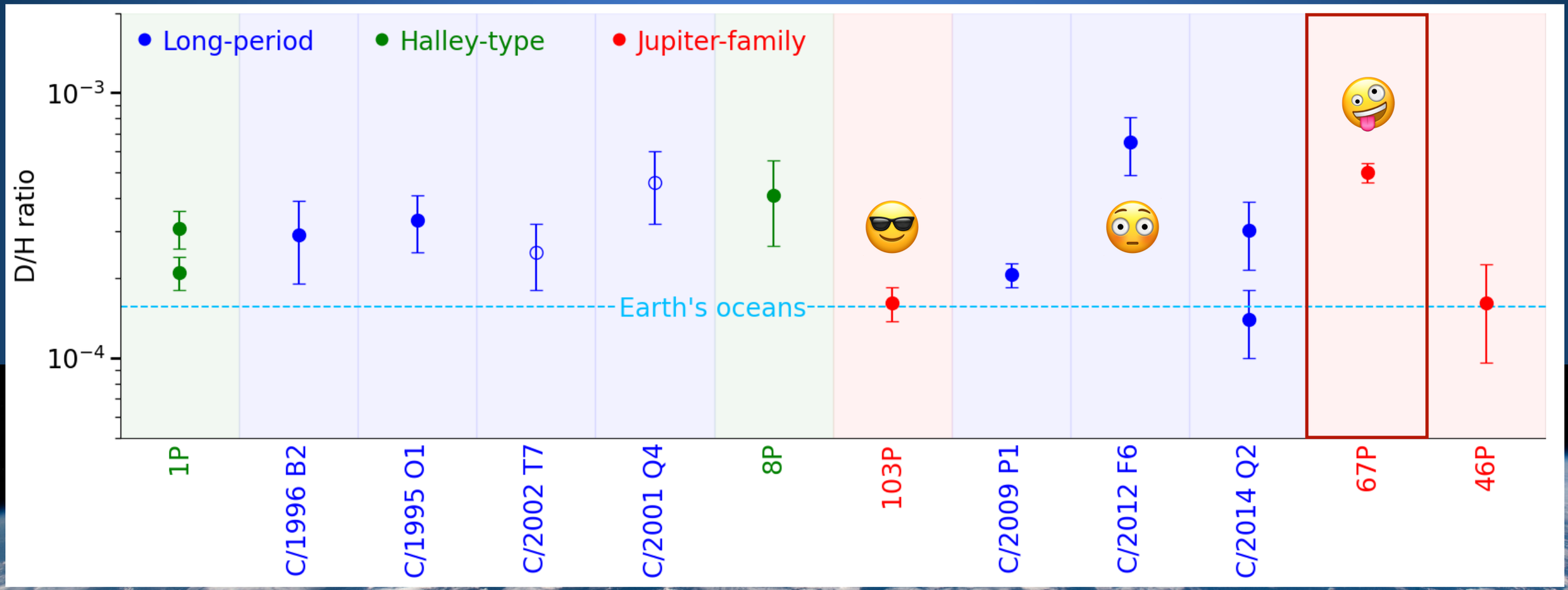

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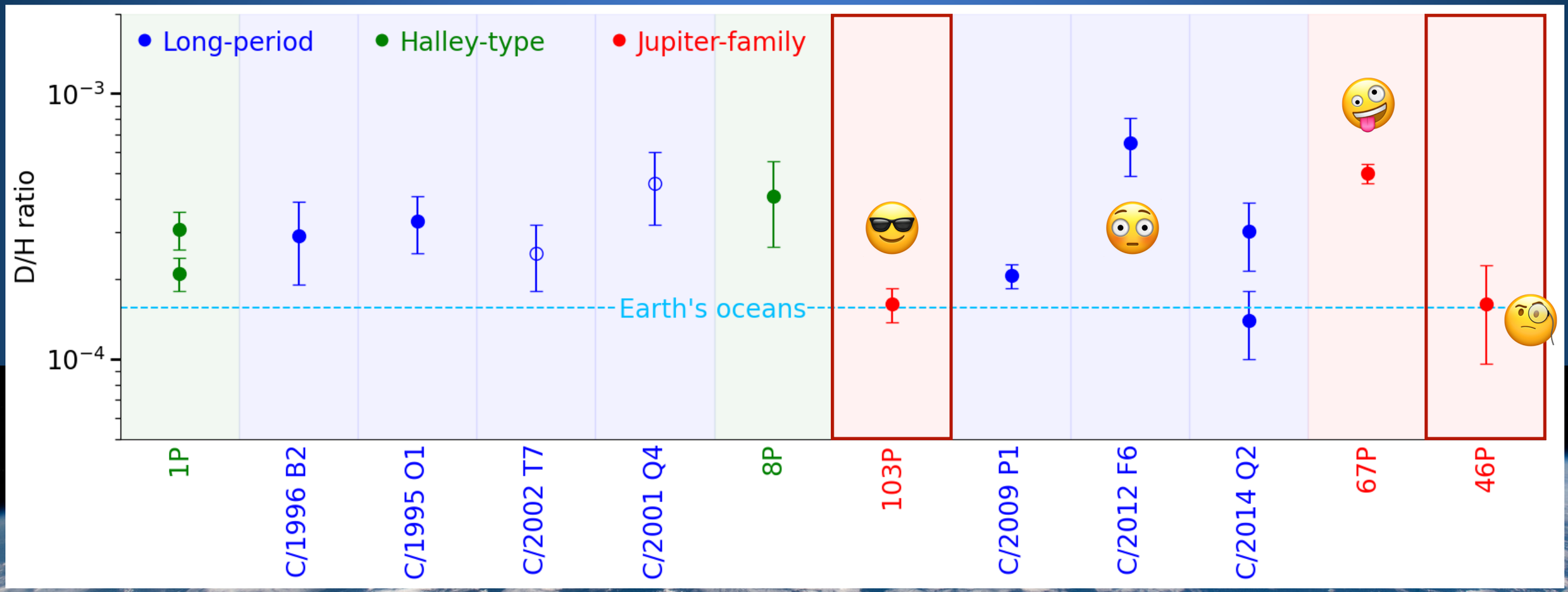
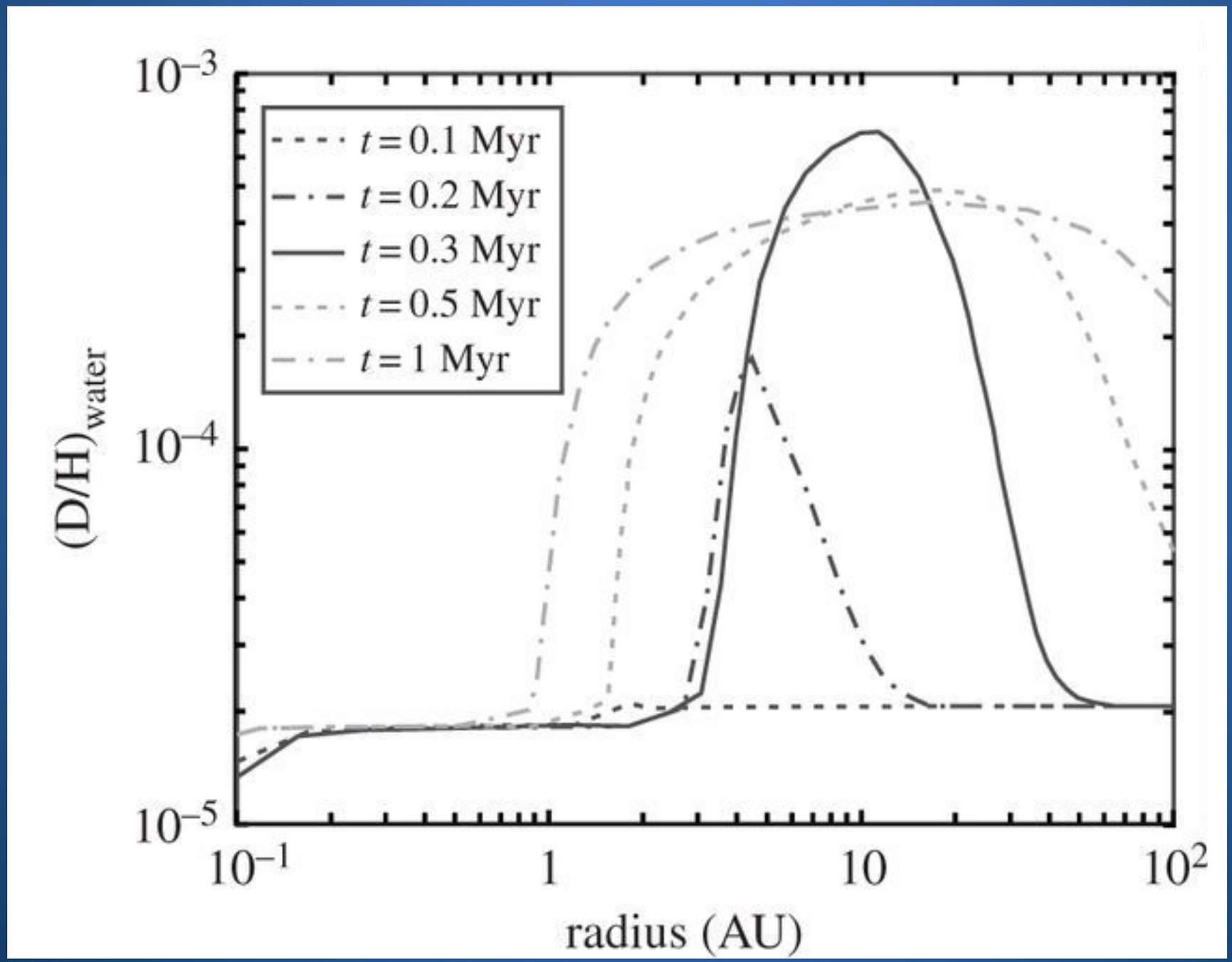


Driving science questions

Origin of water on Earth

From Yang et al. (2013)

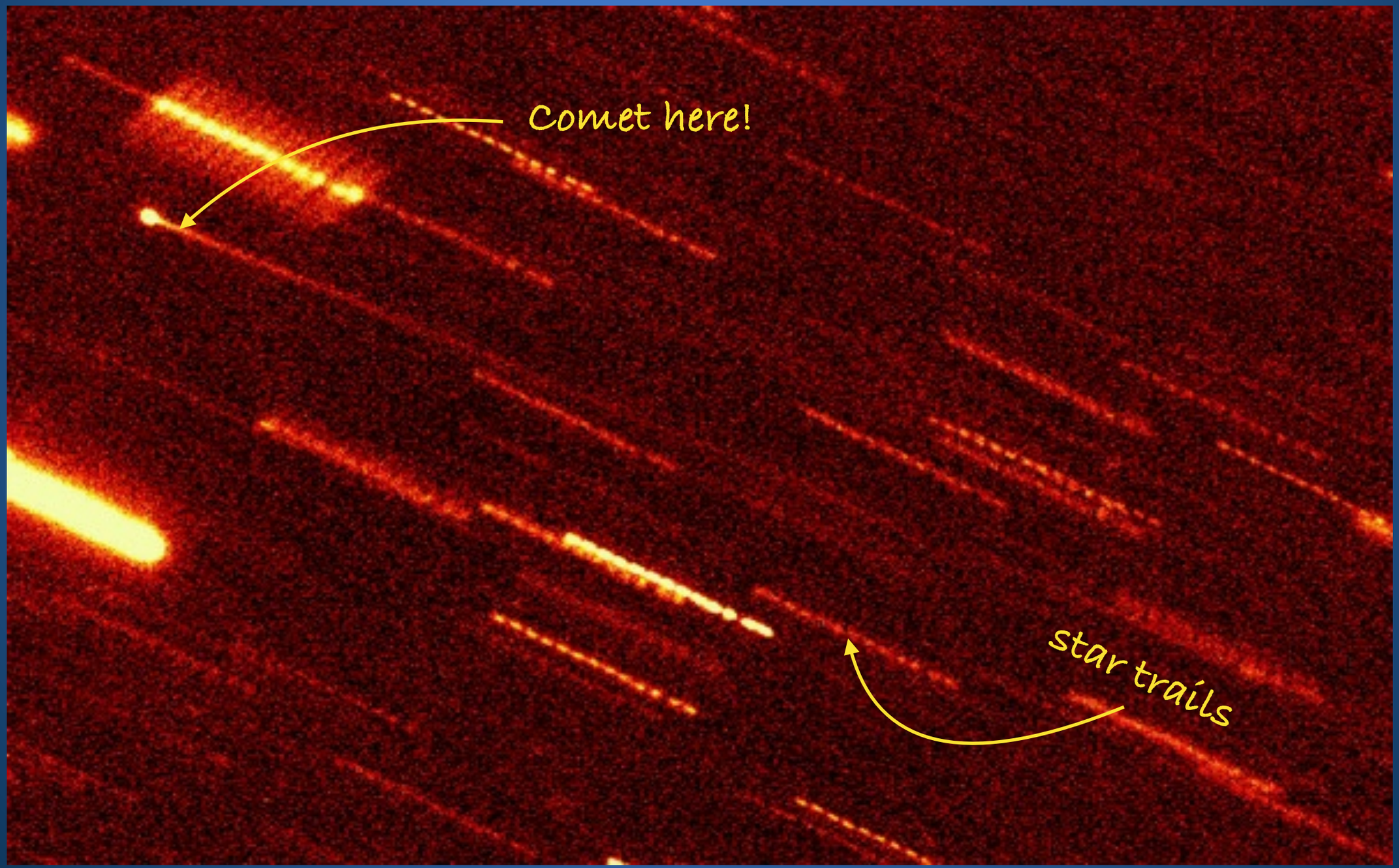


D/H ratio in water in the first Myr after Sun formation

Driving science questions

From Hsieh et al. (2004)

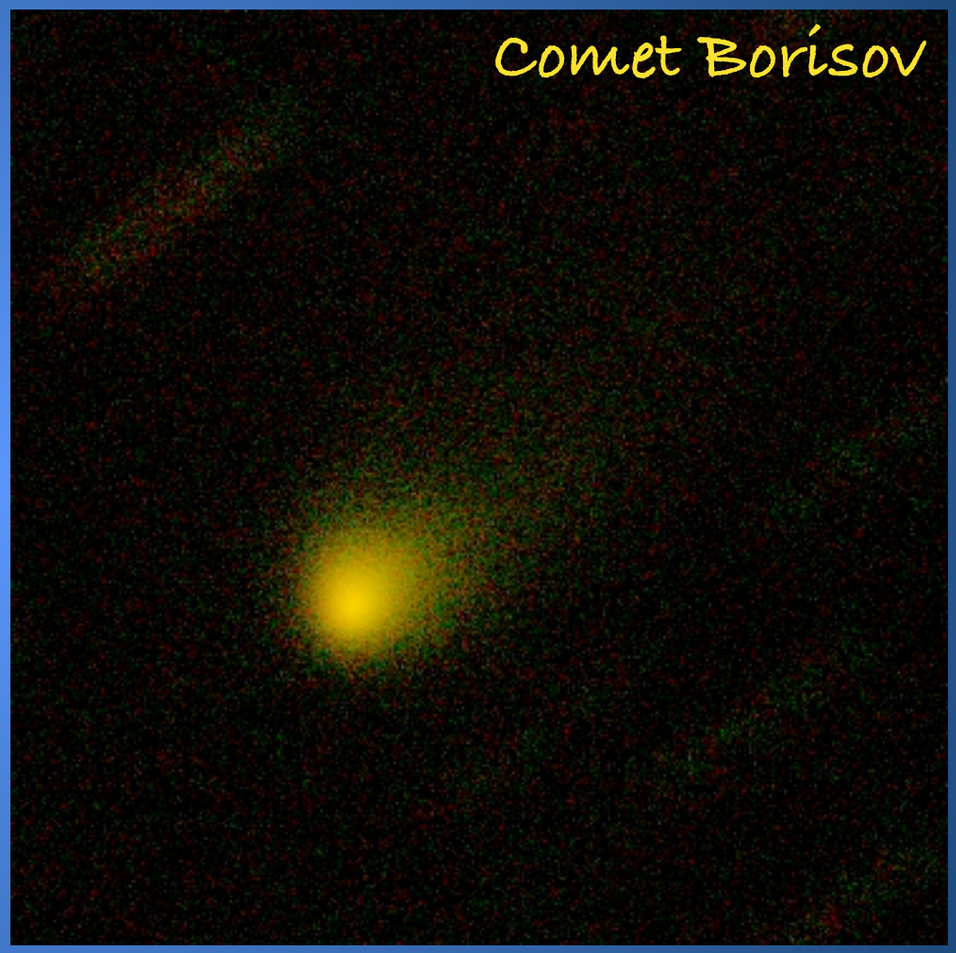
Water reservoir in the Main Belt of asteroids?



Comet 133P photographed by the UH's 2.2-m telescope on Mauna Kea

Driving science questions

Outgassing from interstellar objects

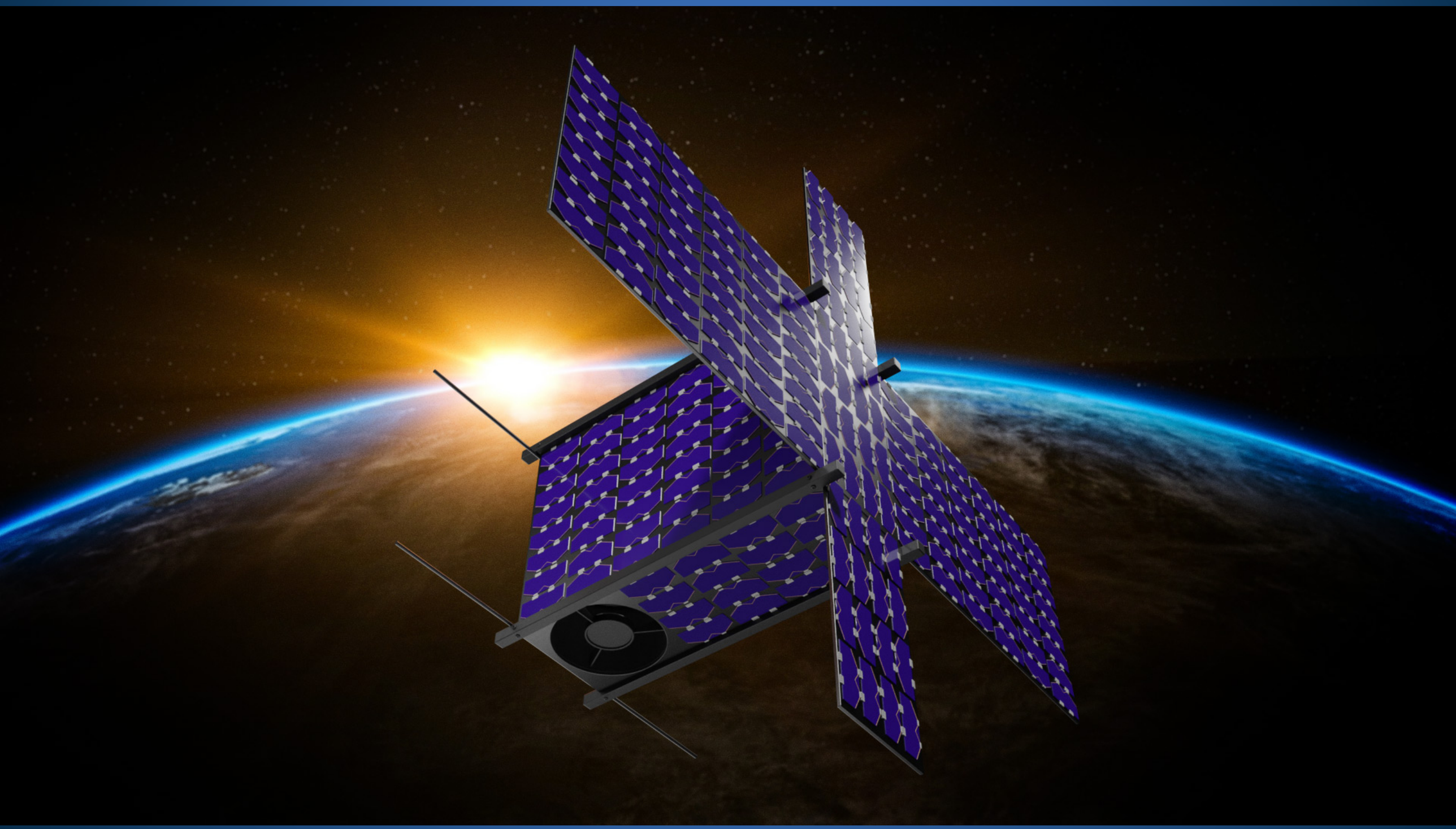


photographed by my team

image size: 1 x 1 arcmin

telescope: 8-m Gemini N

Meet HYADES: HYdrogen And DEuterium Surveyor



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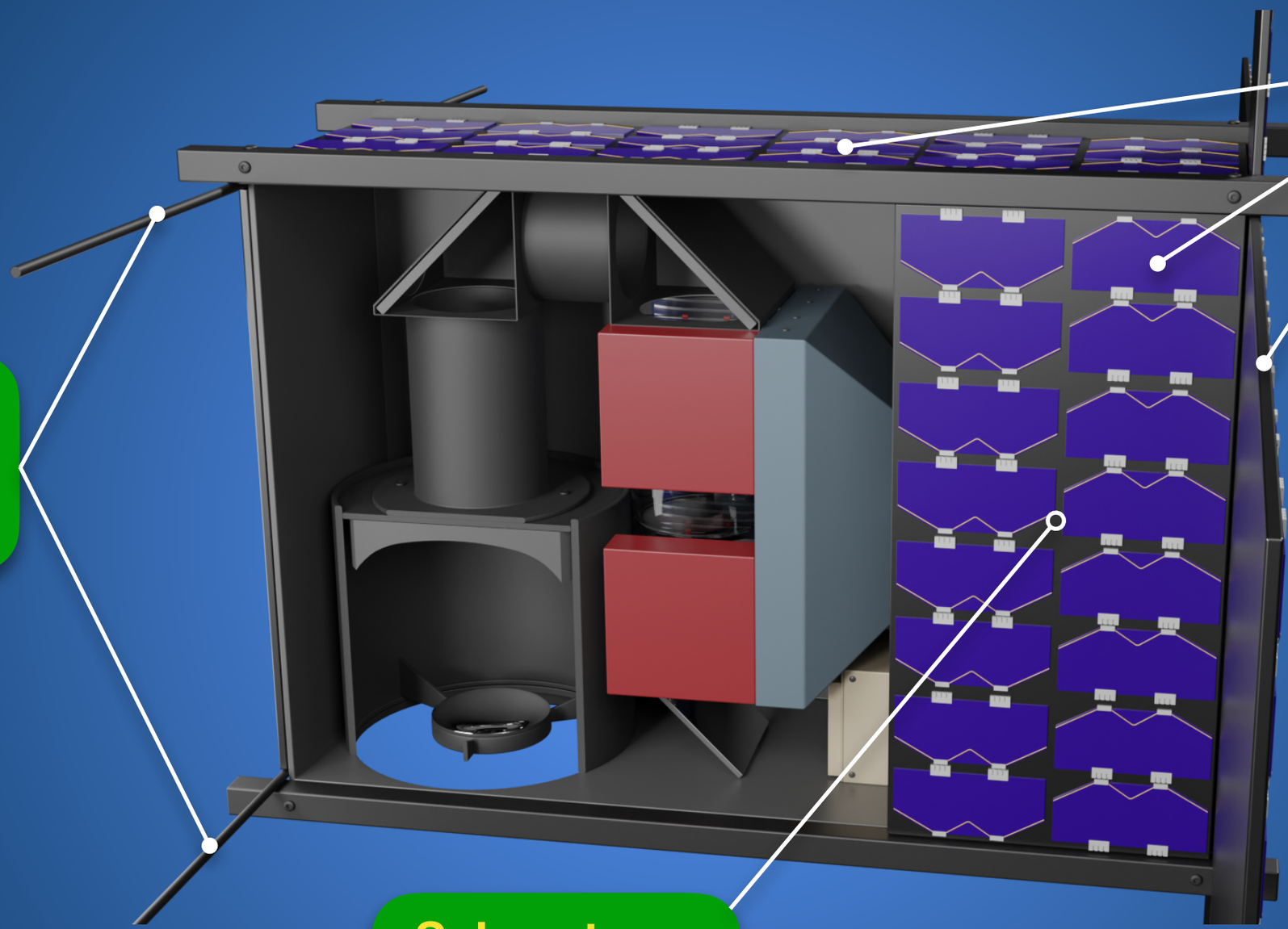


Solar panels

Up to 100 W of average power

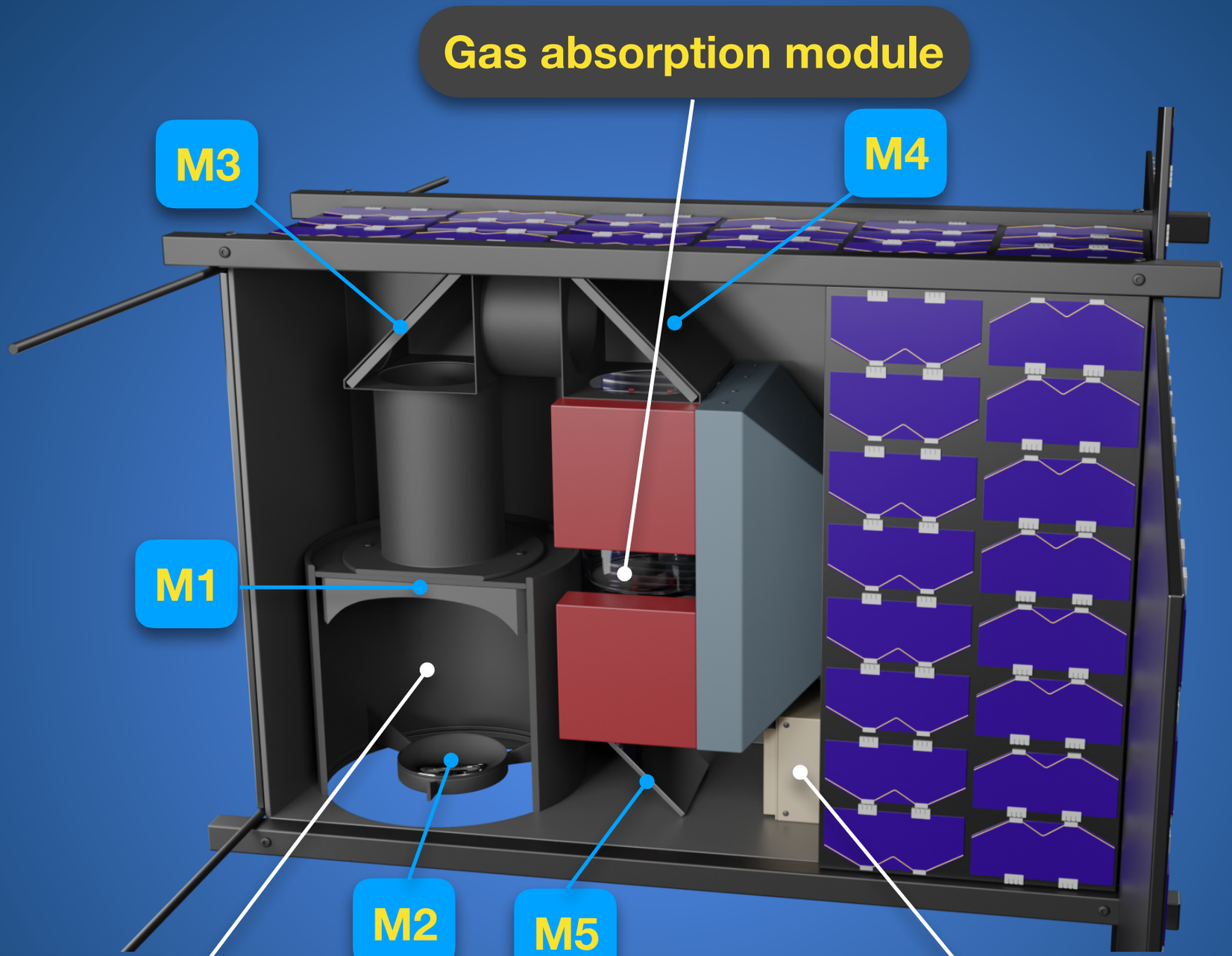
Antennas

Downlink rate ~100 MB/day

Subsystems

Reaction wheels
Star trackers
Power, battery
Communication
Board computer

Meet HYADES: HYdrogen And DEuterium Surveyor



Telescope

M1 = 9.5 cm
SiC optics
MgF_2 coatings (85% at Ly α)
Produces parallel beam

Detector

Type: MCP
KBr photocathode
2.5 cm imaging dia

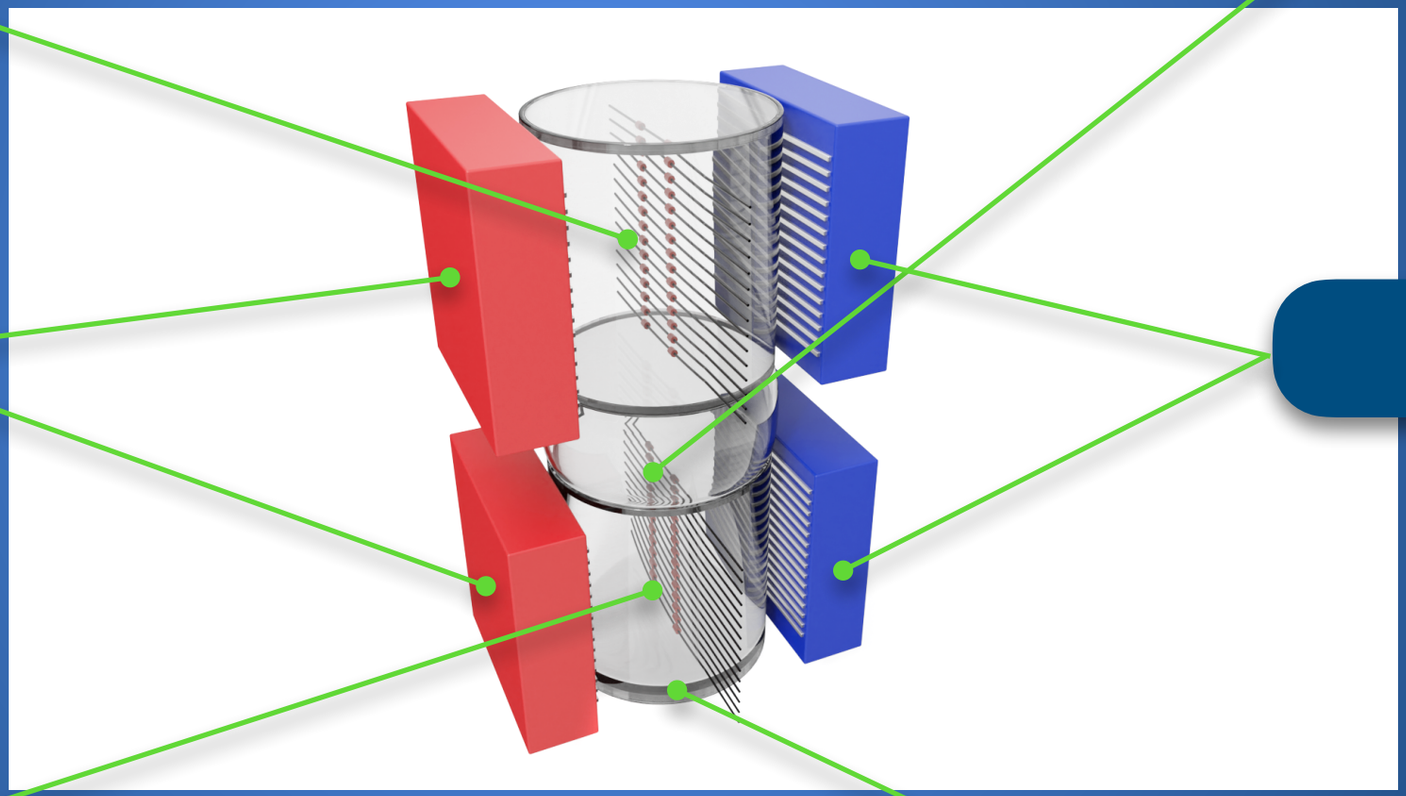
HYADES: gas absorption module

Hydrogen cell

Length: 6.5 cm
Pressure: 0.3 mbar
Temperature: ~300 K
H / H_2 ratio: 2.3%

Oxygen cell

Length: 3 cm
Pressure: 200 mbar
Temperature: ~200 K



Cathodes

Anodes

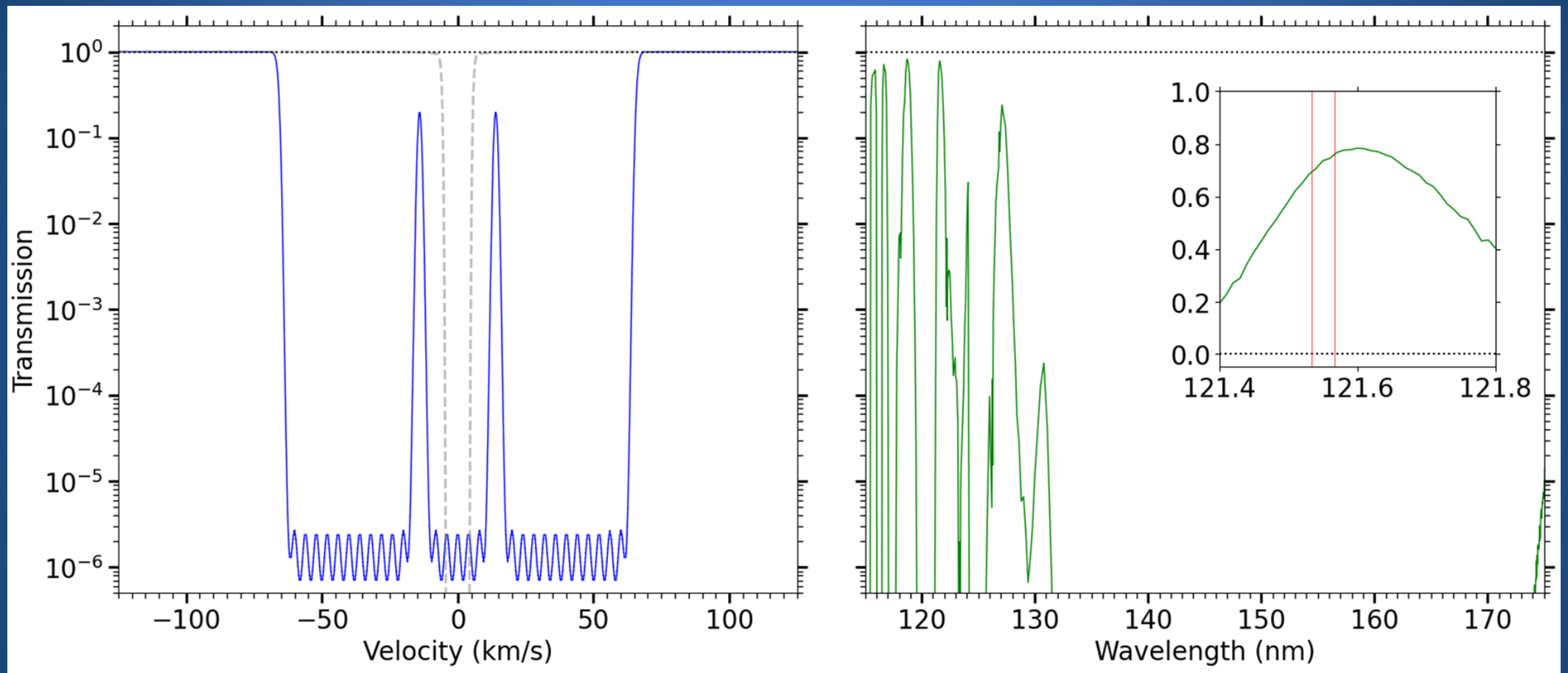
Deuterium cell

Length: 6.5 cm
Pressure: 0.3 mbar
Temperature: ~300 K
D / D_2 ratio: 2.3%

Lens

Shape: bi-aspheric
Material: LiF

HYADES: gas absorption module



HYADES: sensitivity

5 sigma outgassing limits (1 au from Sun and Earth)

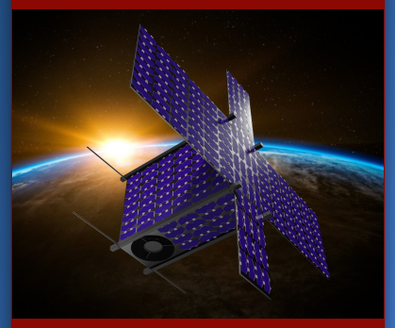
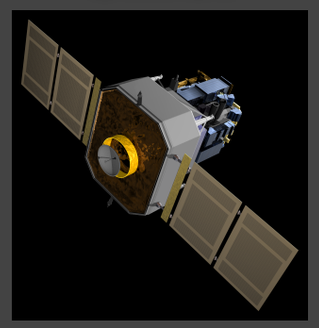
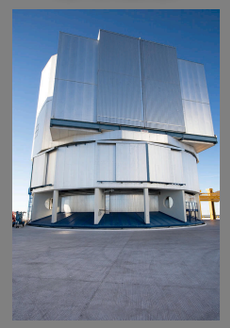
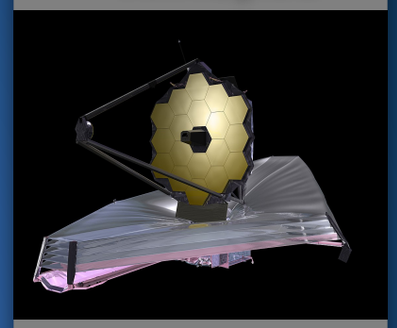
50 grams/second of H_2O

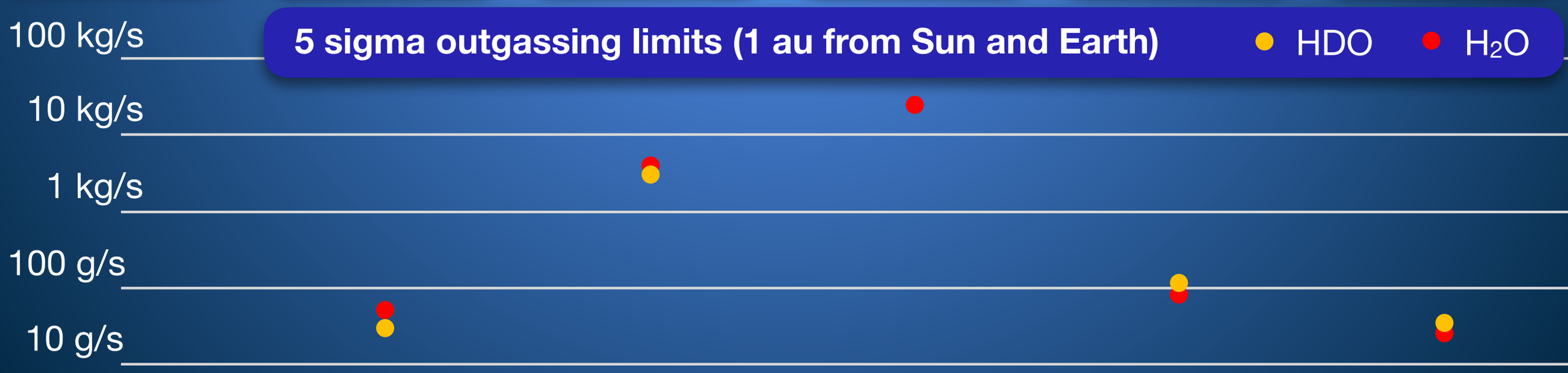
30 grams/second of HDO

What makes HYADES so sensitive?

- ★ Extreme brightness of the Lyman alpha line
- ★ Very long ionization lifetime of H and D (~ 2 months at 1 au)
- ★ Large field of view (~ 2 deg)
- ★ Very low sky background (~ 200 R in H and ~ 20 R in D)

HYADES vs competitors

	HYADES	Hubble STIS	SOHO SWAN	VLT UVES	JWST NIRSpec
					
Diameter	9.5 cm	2.4 m	2.7 cm	8.2 m	6.5 m
Throughput	4%	4%	1%	0.35%	30%
Sky area	1° x 1°	0.2″ x 6″	5° x 5°	1.8″ x 10″	0.4″ x 3.8″
Exp time	100 hrs	100 hrs	45 sec	100 hrs	100 hrs
HDO tracer	D	D	—	OD	HDO
H_2O tracer	H	H	H	OH	H_2O



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	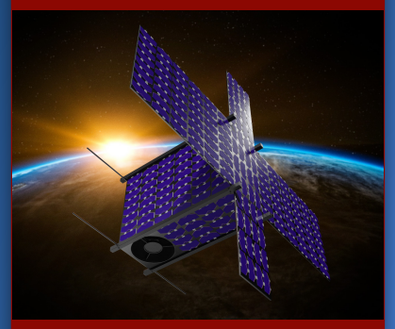		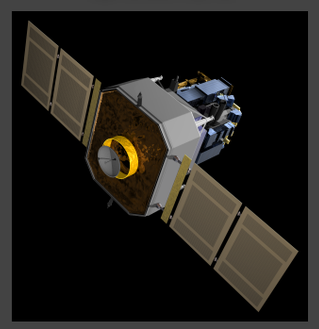		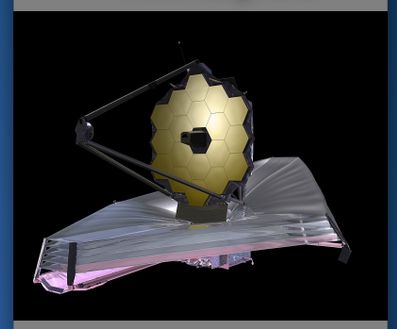
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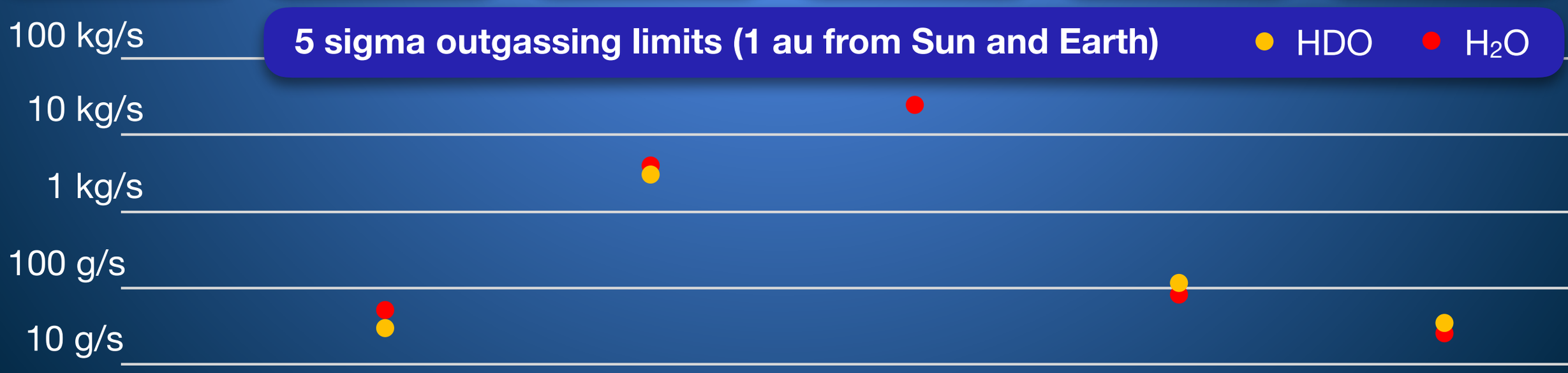

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	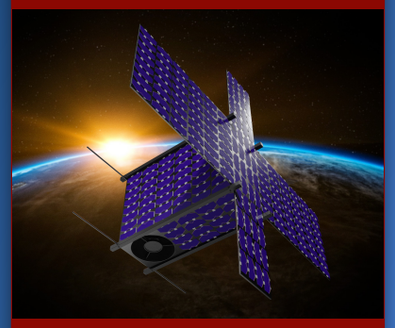		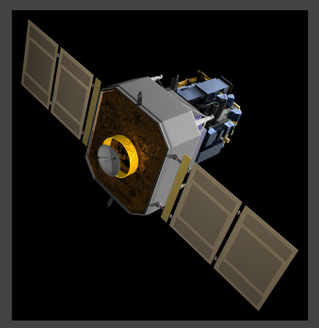	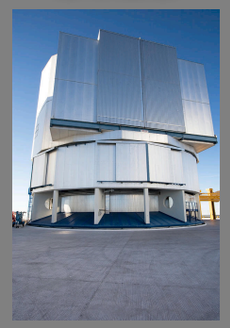	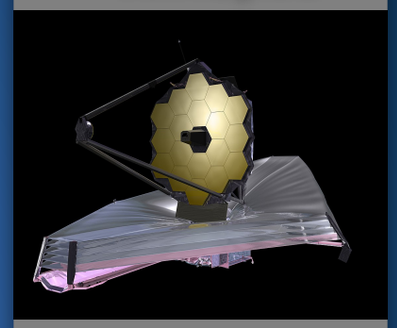
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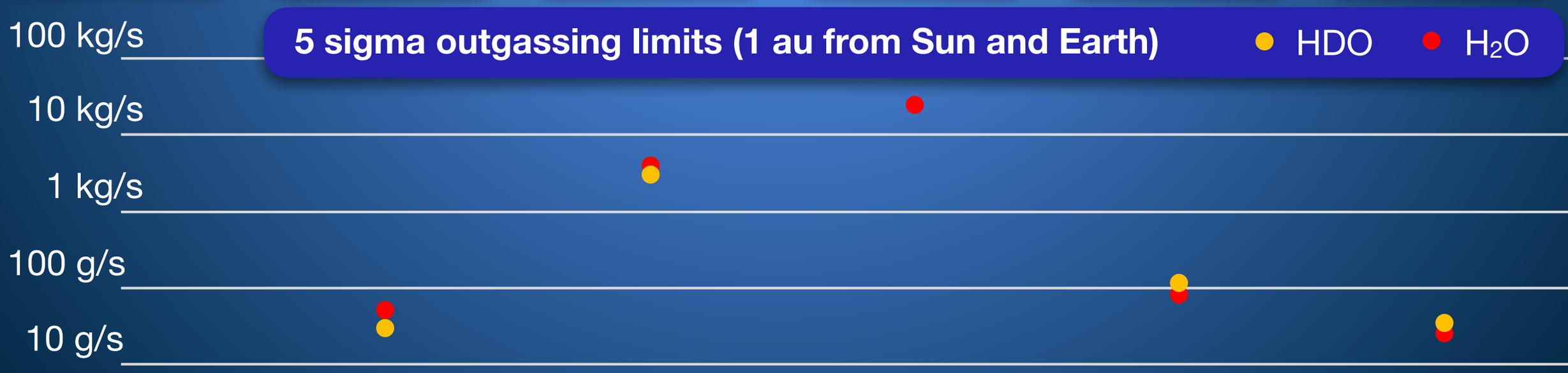

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	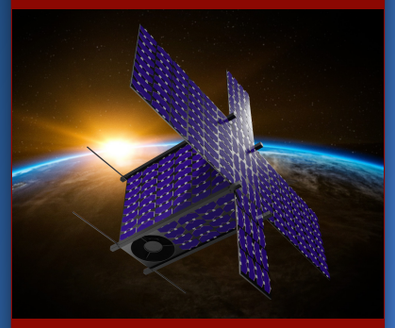		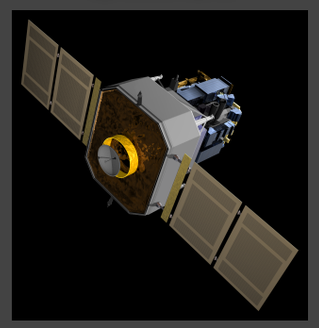	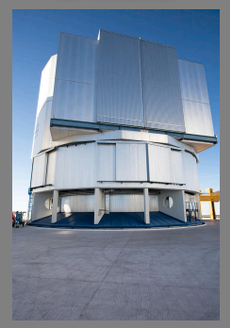	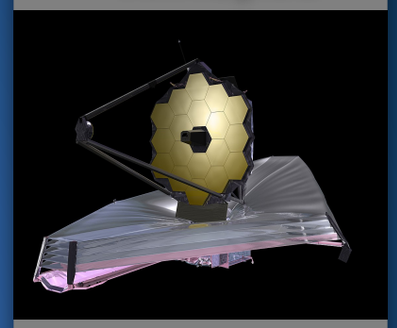
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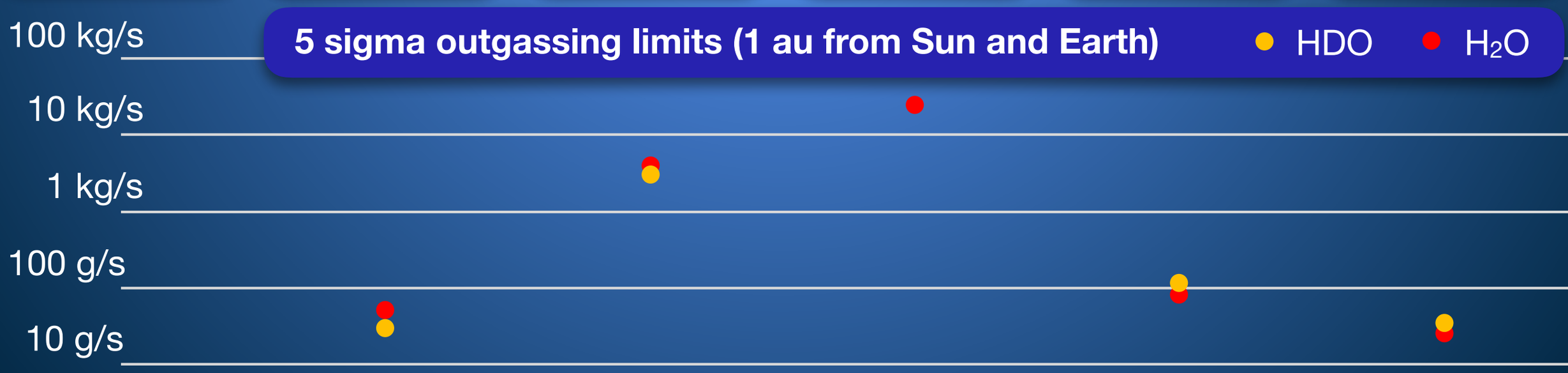

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	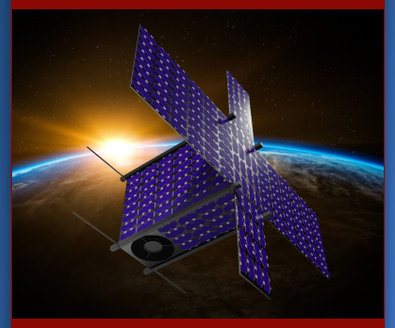		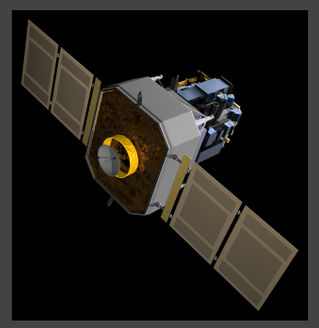	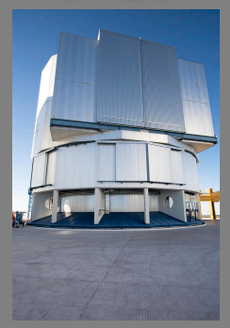	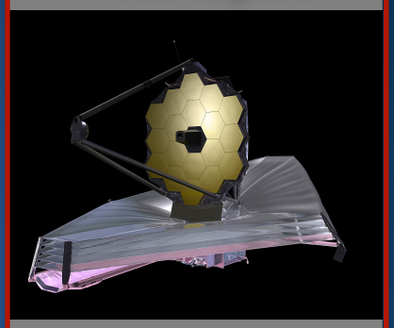
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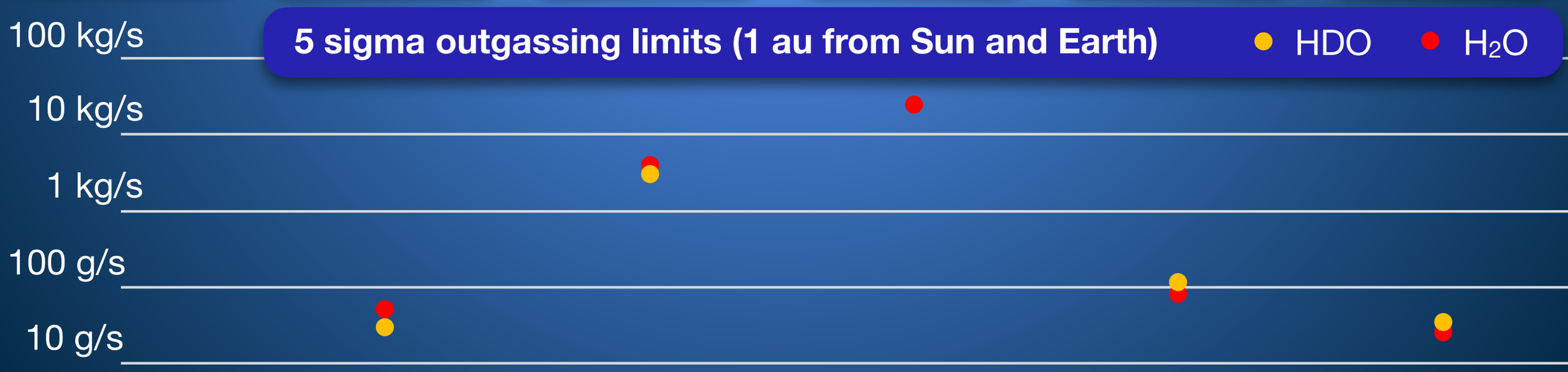
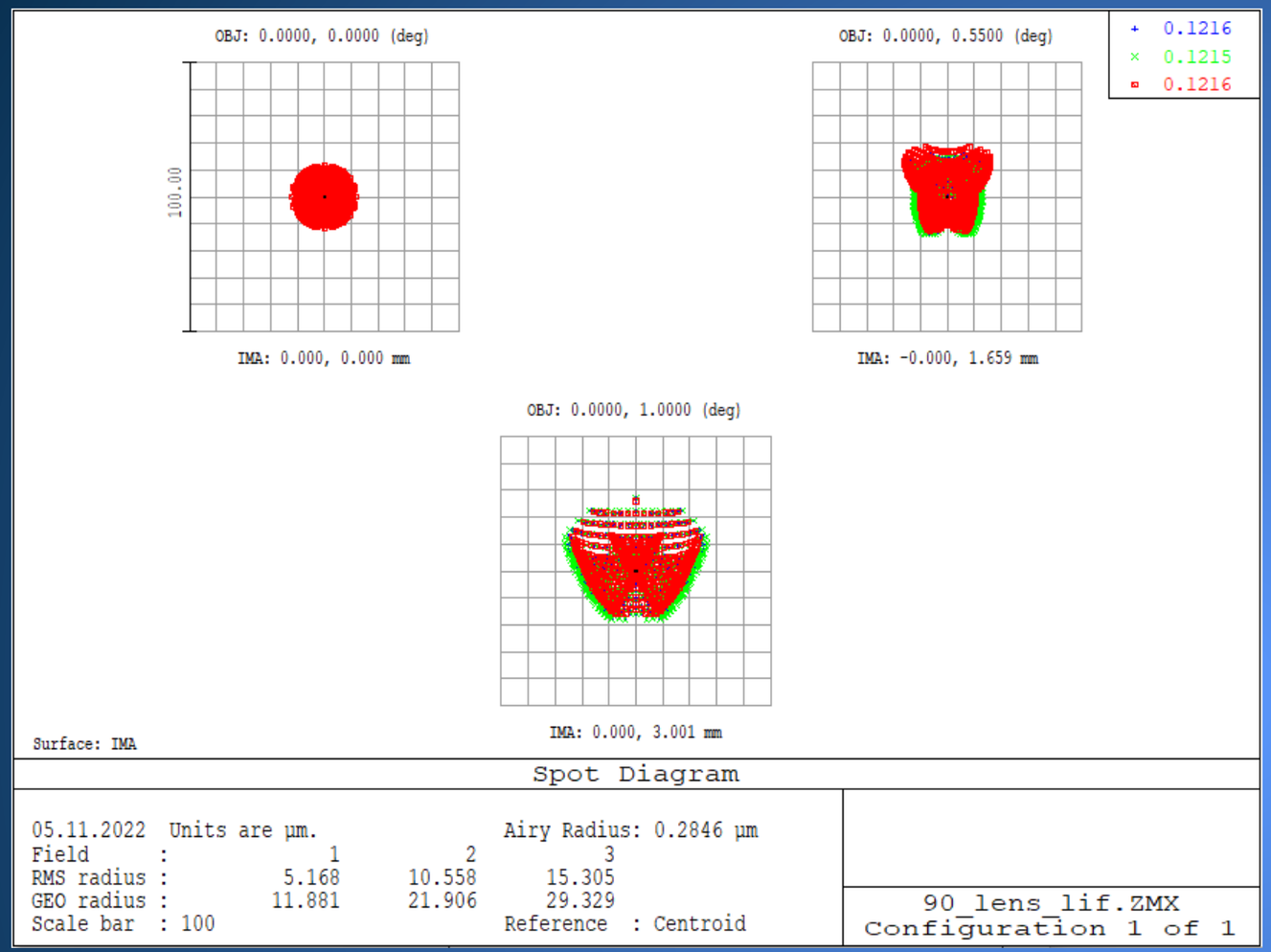
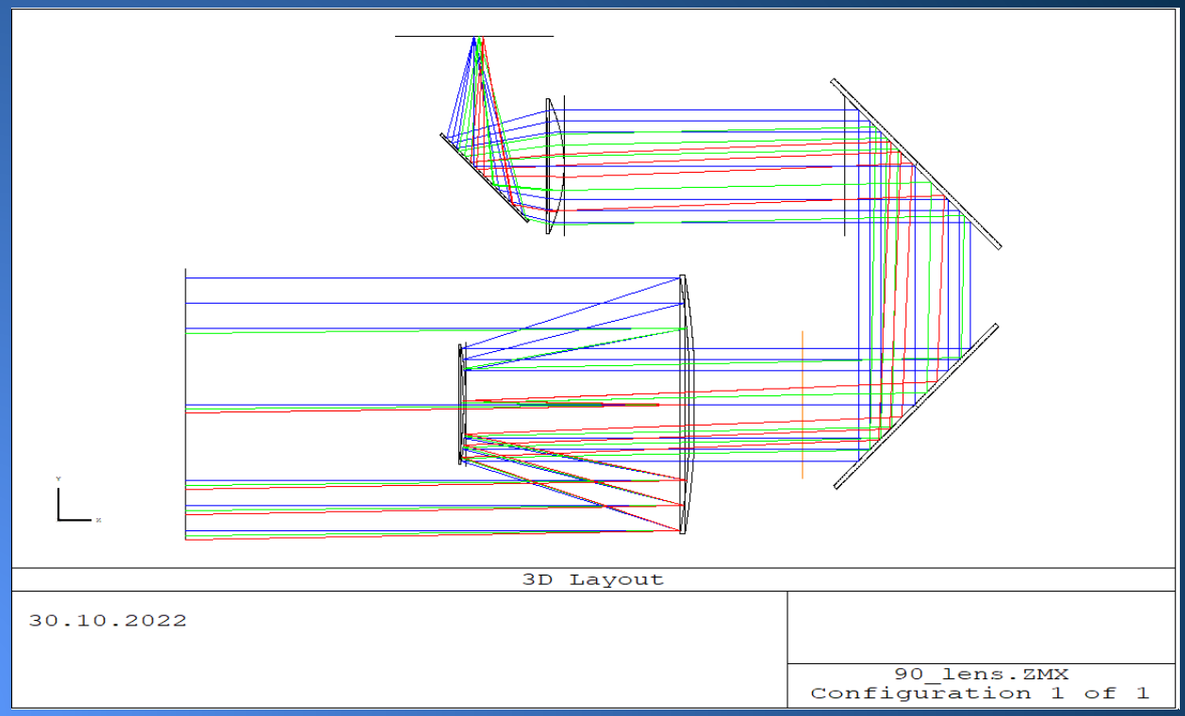
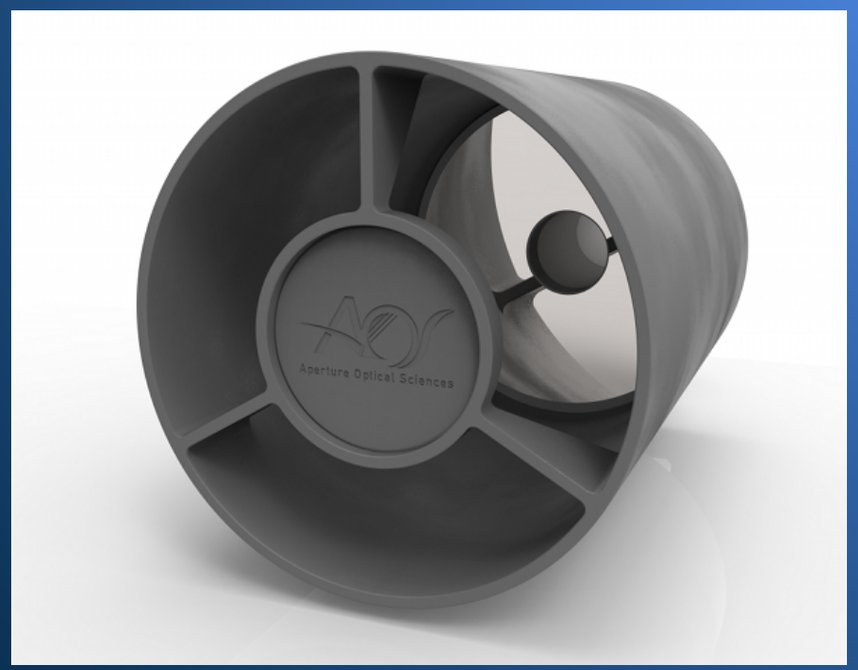
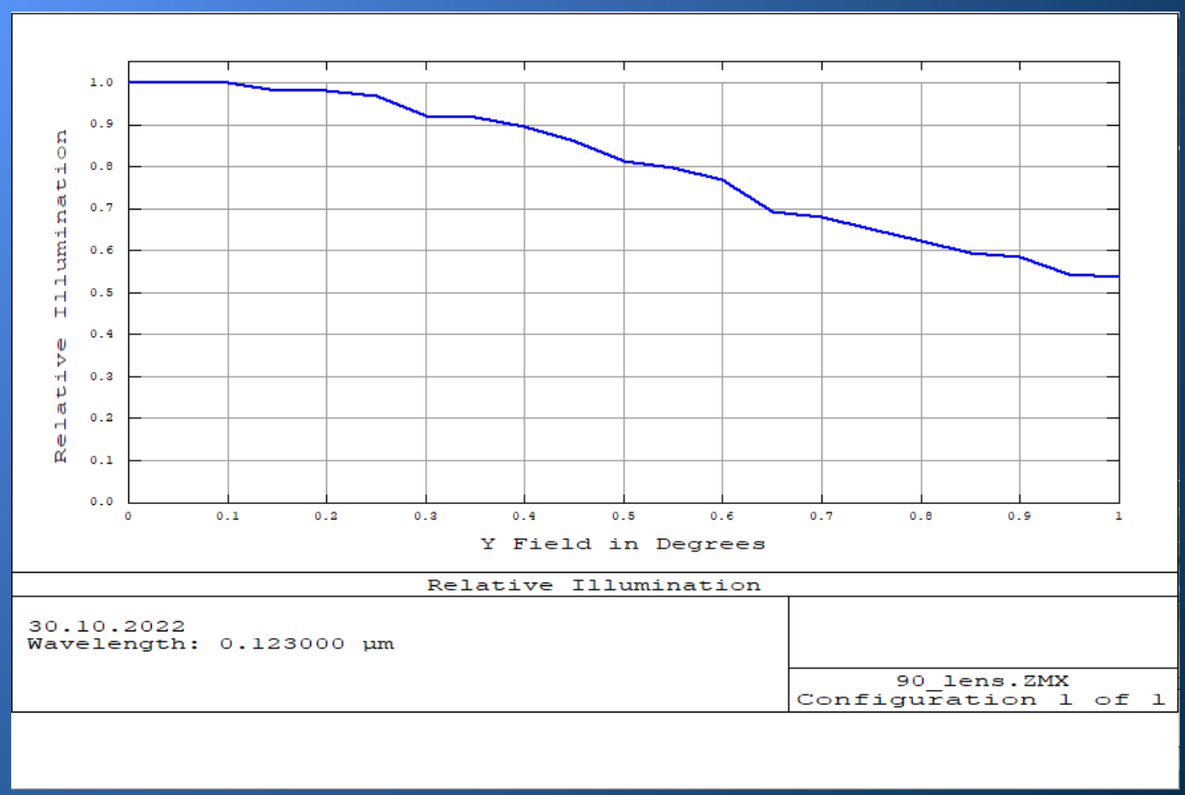


HYADES: optical performance

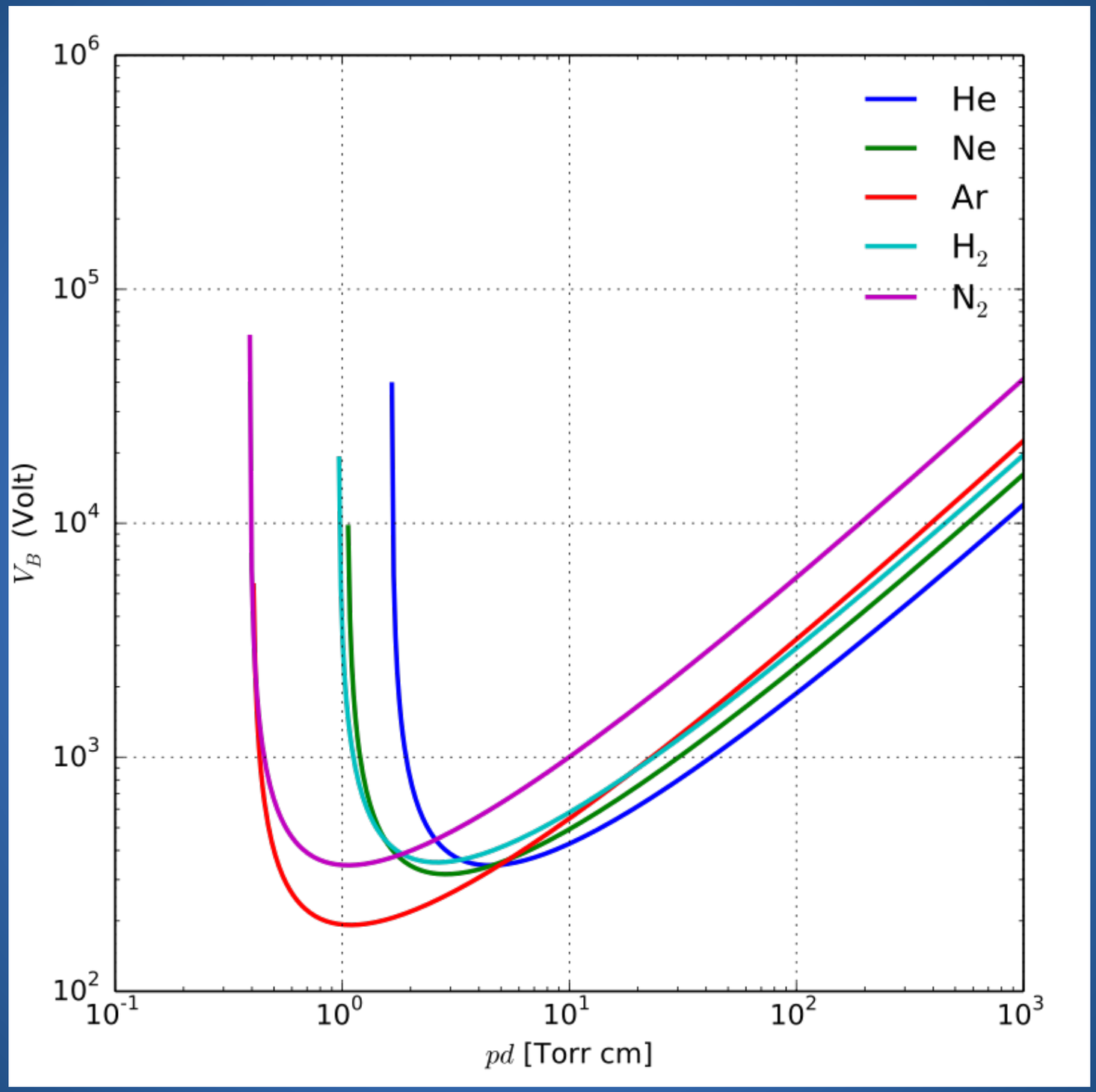








HYADES: gas absorption module



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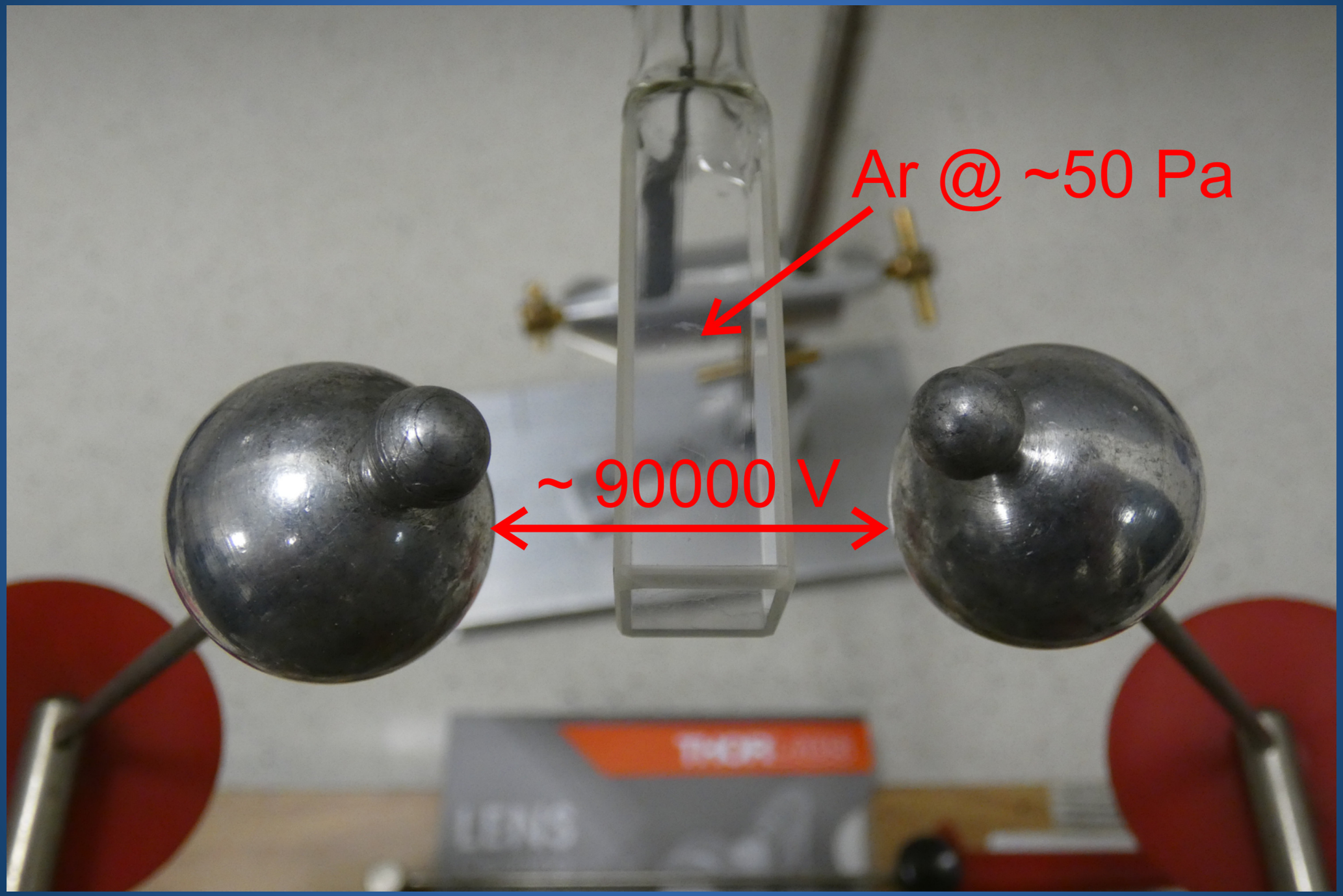


HYADES: gas absorption module

Gas absorption unit manufacturing process:

1. Glass body shaping (Hamamatsu)
2. Welding the filaments unit to cell body (Hamamatsu)
3. Attachment of the pressure valve (Hamamatsu)
3. Attachment of MgF2 windows to cell body (Hamamatsu)
5. Obtaining vacuum conditions inside the cell (University)
6. H/D gas introduction and valve sealing (University)

HYADES: components summary

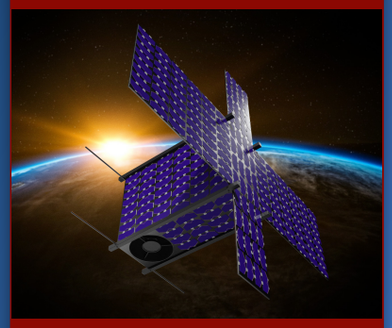
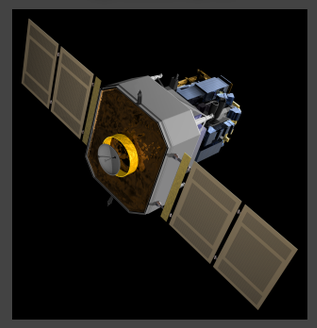
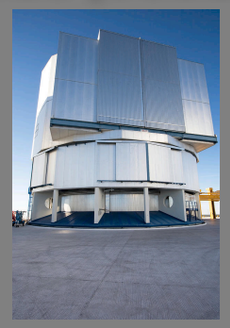
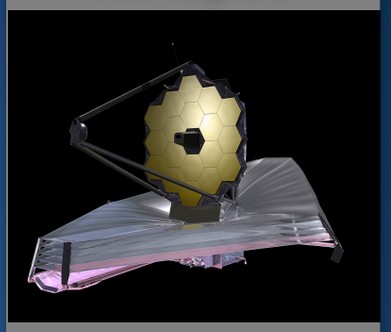
	Mass [kg]	Peak power [W]	Est. cost [EUR]
Telescope optics and subsystems	1.5	-	75000
MCP detector	1.25	6 / 0	75000
Gas absorption unit	3	28 / 0	150000
High-voltage generator	2	0 / 30	100000
Science instruments	7.75	34	400000
Critical mission services	-	-	100000
Launch	-	-	300000
6U CubeSat bus in ready to fly package	4.2	-	800000
Satellite total cost	**-**	**-**	**1600000**

HYADES: commissioning plan

In-flight commissioning and testing:

1. Communication tests, establishing the actual data transfer
2. Point source observations to:
   - determine pointing and guiding stability
   - characterize PSF over the FoV
   - determine photometric stability
   - test detector linearity
3. Calibration with spectrophotometric standards (CALSPEC):
   - cold star to account for Lyman-alpha emission
   - hot star to establish continuum component effect on cold star observation
4. Background observations to determine the gas-cell performance for the expected electrical configurations
5. Determining the overall optical performance on extended objects (comets)

HYADES vs competitors

	HYADES	Hubble STIS	SOHO SWAN	VLT UVES (CUBES)	JWST NIRSpec
					
Diameter	9.5 cm	2.4 m	2.7 cm	8.2 m	6.5 m
Throughput	4%	4%	1%	5% (50%) x 7%	30%
Sky area	1° x 1°	0.2″ x 6″	5° x 5°	1.8″ (1.5″) x 10″	0.4″ x 3.8″
Exp time	100 hrs	100 hrs	45 sec	100 hrs	100 hrs
HDO tracer	D	D	—	OD	HDO
H_2O tracer	H	H	H	OH	H_2O