Science Objectives for a Lunar-Situated UV Spectrograph

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EXEC SUMMARY

This lunar-based instrument can:

- Understand the Heliospheric Boundary Interactions via Spectral Observations of Interplanetary Hydrogen (IPH)

Bonus Science:

- Obtain unique Comet findings
- Support other missions (e.g. IMAP/Carruthers)

…. the case for UV spectrographs ….

UV Observations in Space

- Popular for planetary missions.
- Range of instrumentation (e.g., photometer, **spectrograph**, spectrometer, absorption cell)
- Motivated by characterizing H (water).

Spectrograph Science

- Count emitted photons at λs of interest

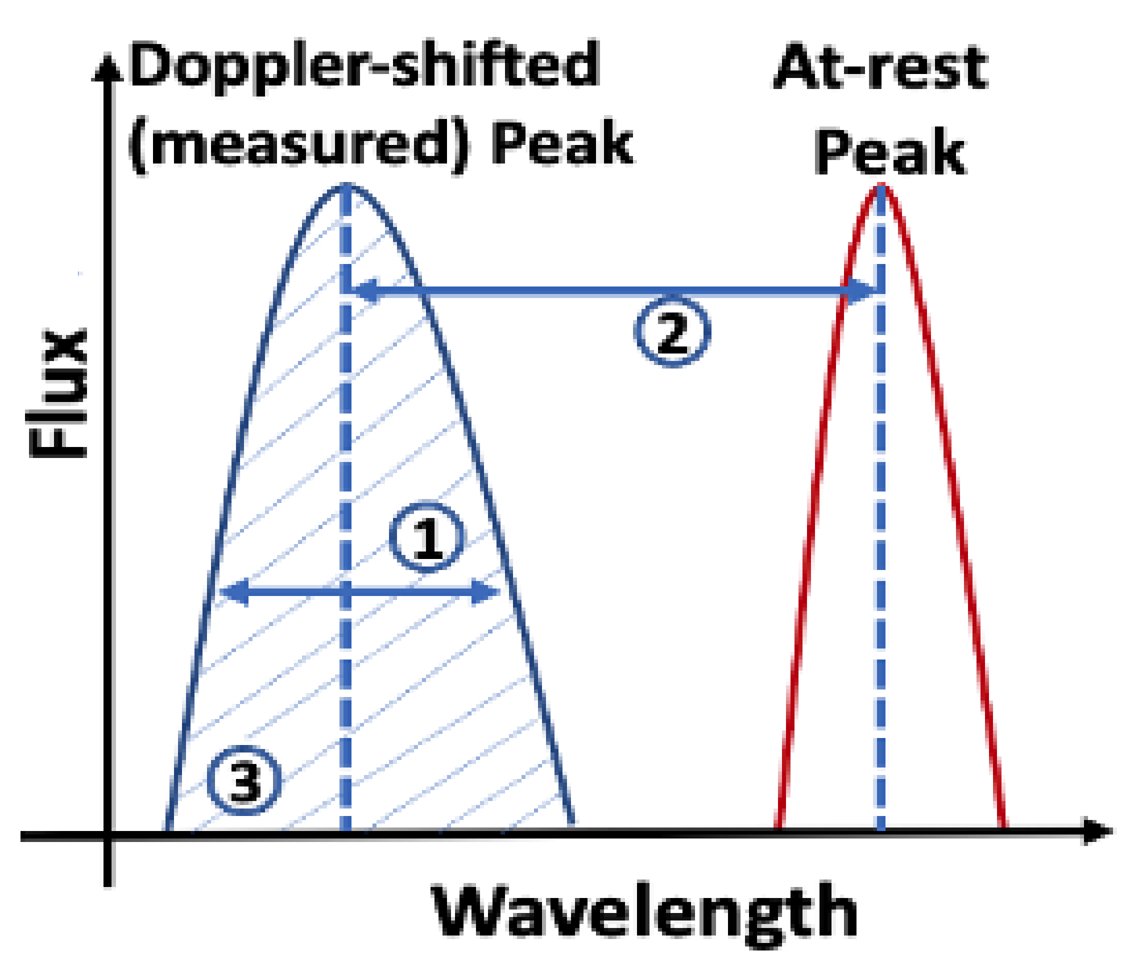
  → Spectrum

- Spectrum analysis

  → B, T, V of emitter

- B, T + Radiative Transfer theory

  → N

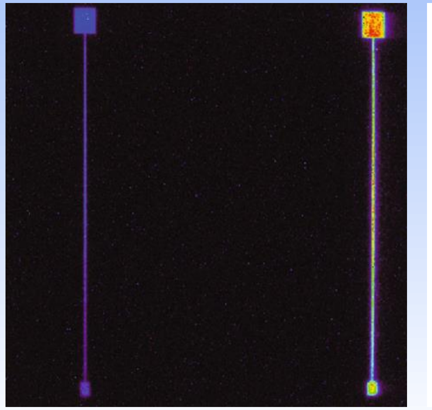


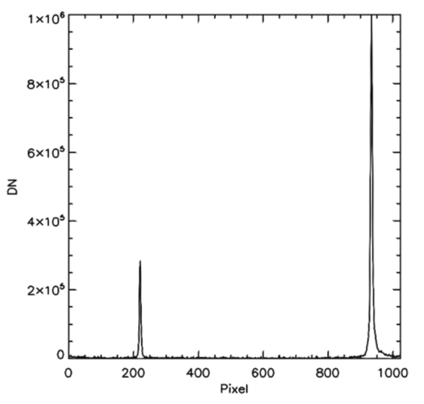
Not all Spectrographs are Created Equal

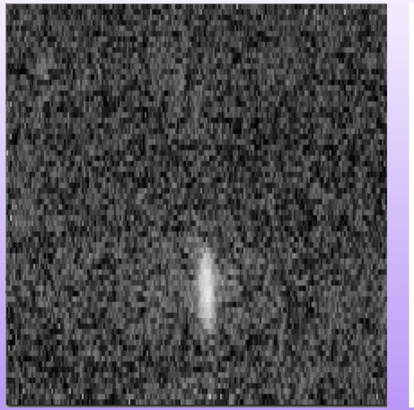
Lo-Rez:

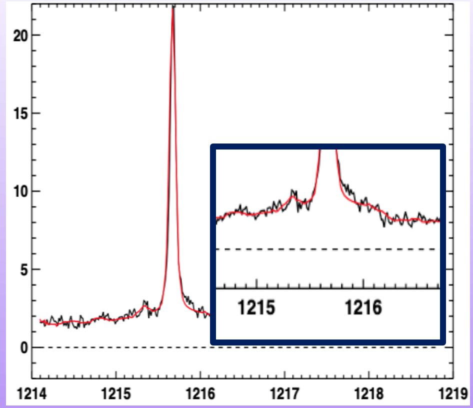
- Good for characterizing wide range of bulk species
- Not great at separating contaminating emissions

→ Popular, incremental science





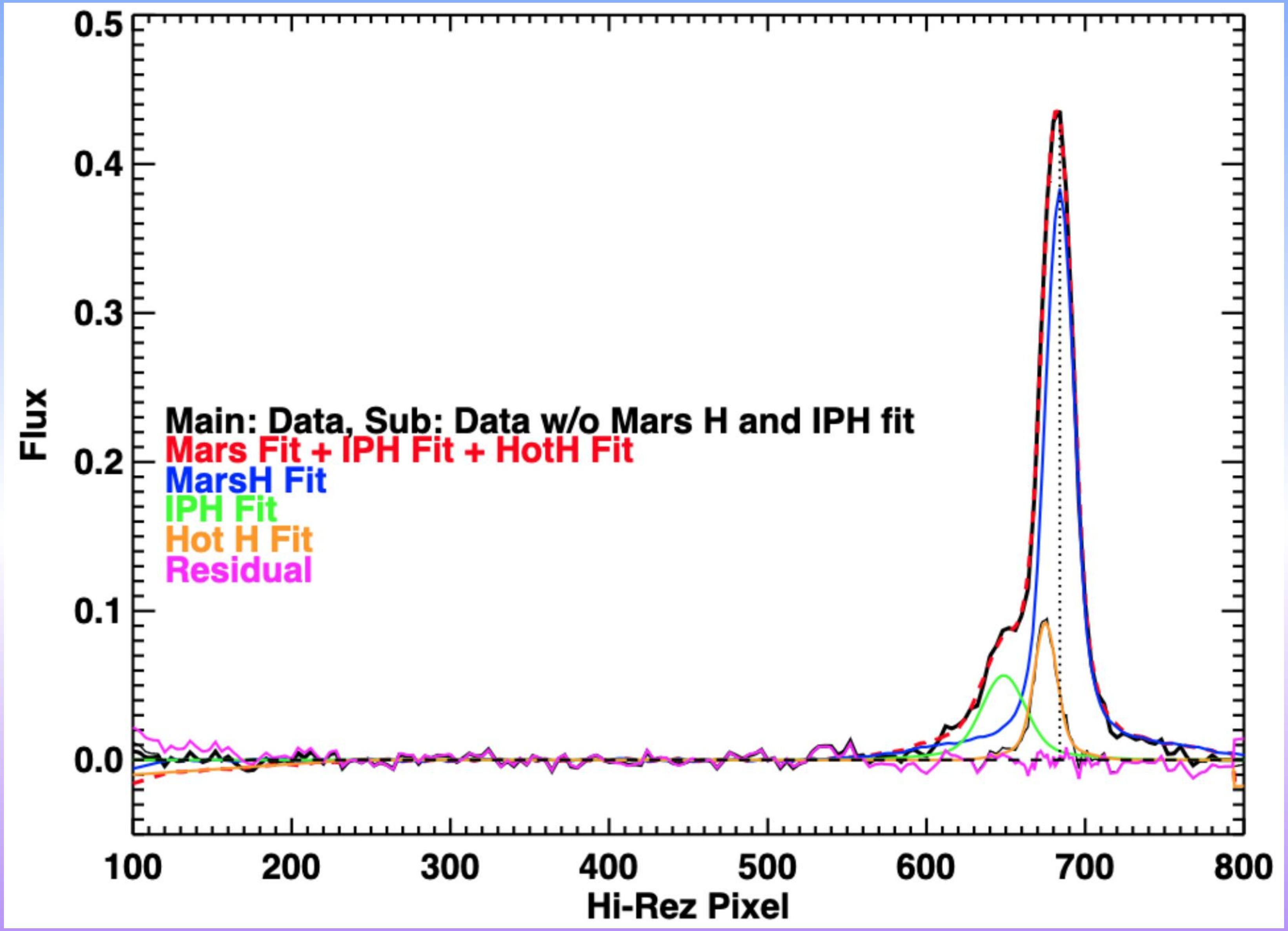




Hi-Rez:

- Uniquely separates close emitters (e.g. D, H, and variants)
- Best for characterizing a few species

→ Rare, ground-breaking science



sample spectrum with multiple Ly-a emissions

…. the case for IPH ….

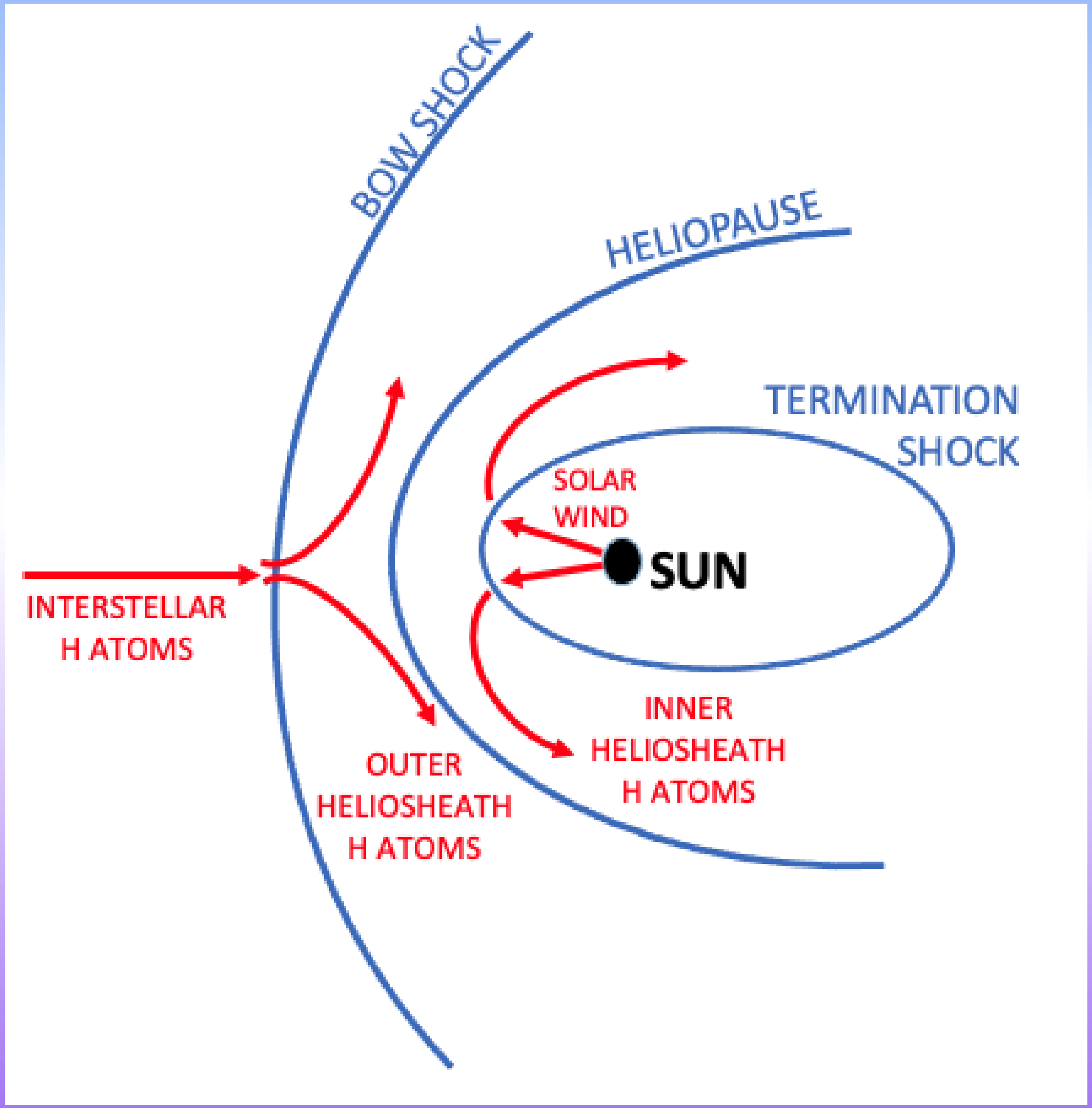
Background

<u>Theory</u>

Interplanetary medium H atoms are from:
1) the unperturbed interstellar medium,
2) outer heliosphere charge exchange R_xs, &
3) inner helioshealth hot charge exchanged component.

<u>Observations</u>

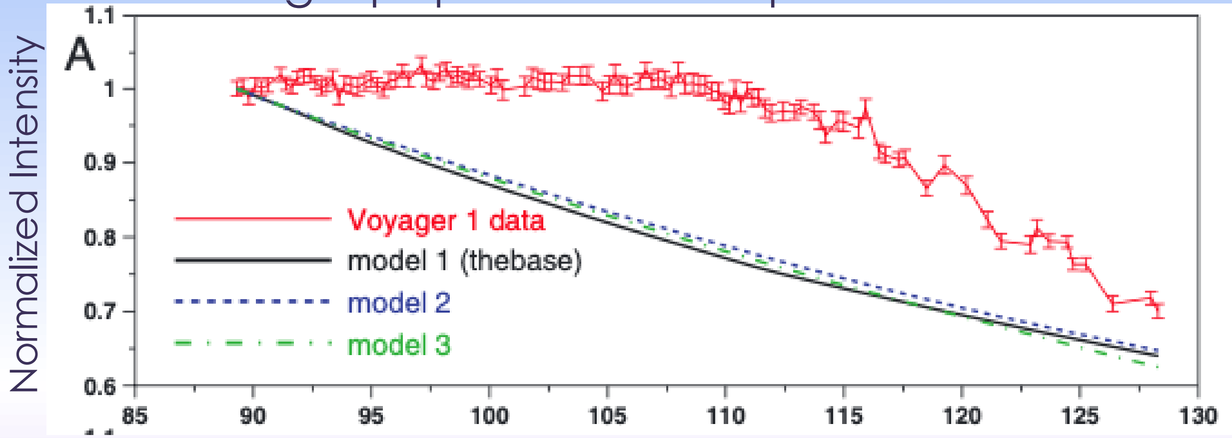
The IPH flow is typically considered a single bulk population (instrument-limited, as observations of total Ly-a brightness are from low-resolution instruments].



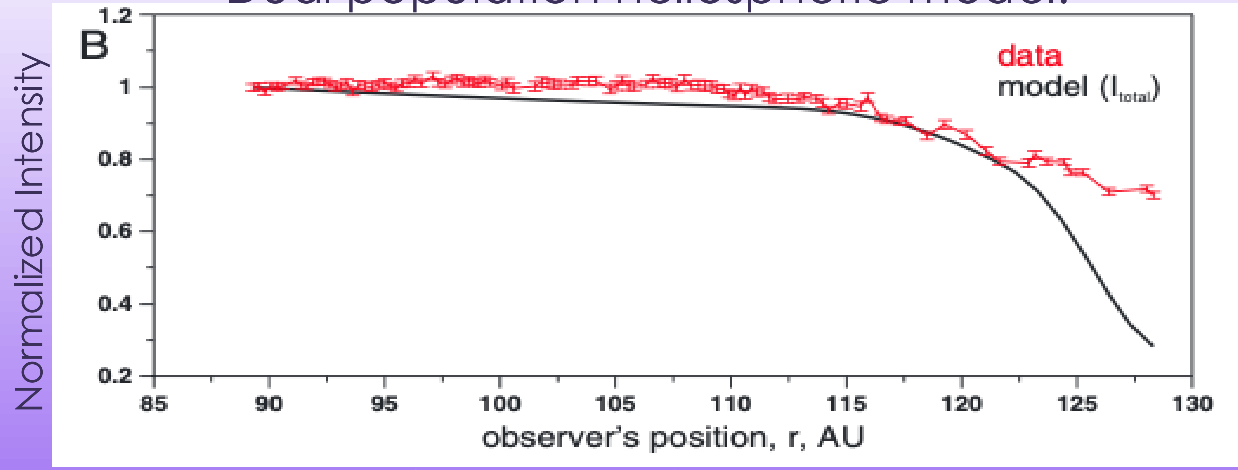
[adapted from Vincent et al., 2011]

Observations ≠ Theory

Single population heliospheric model.



Dual population heliospheric model.

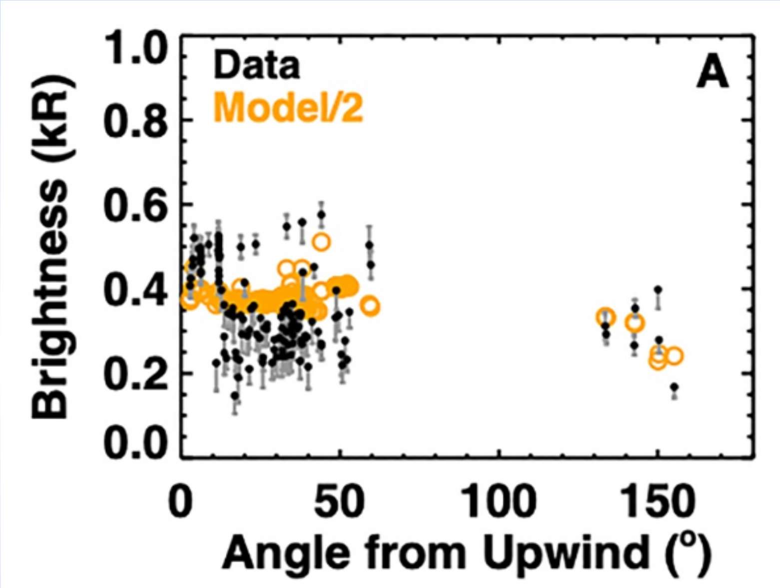


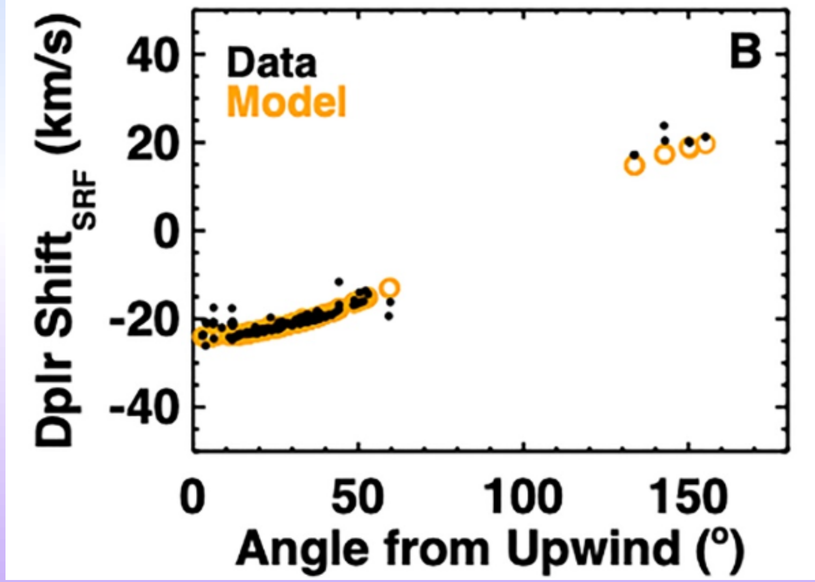
[adapted from Katushkina et al., 2017]

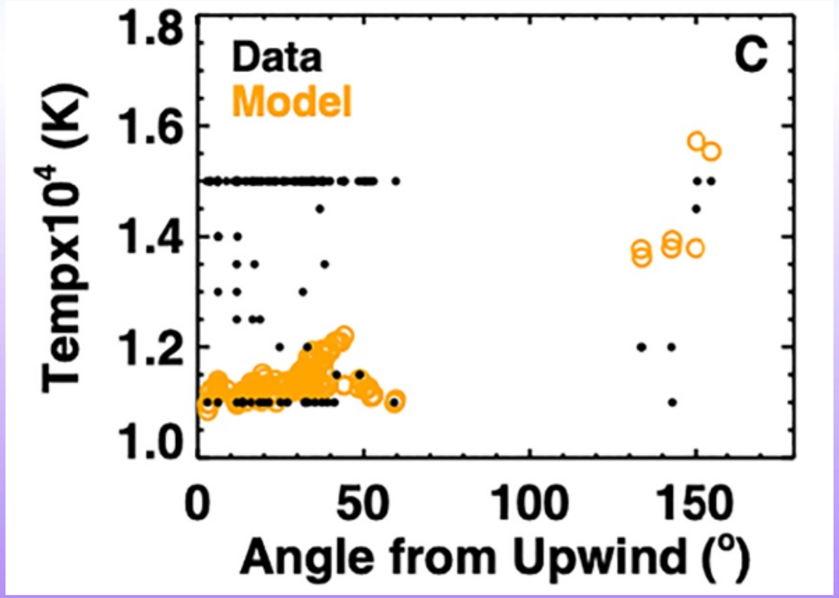
The spectral profile of the backscattered solar Ly-a reveals the velocity distribution and thus the interaction of the solar wind with the ISM

→ What can state-of-the-art instruments find?

Some IPH Findings from 1.5 AU





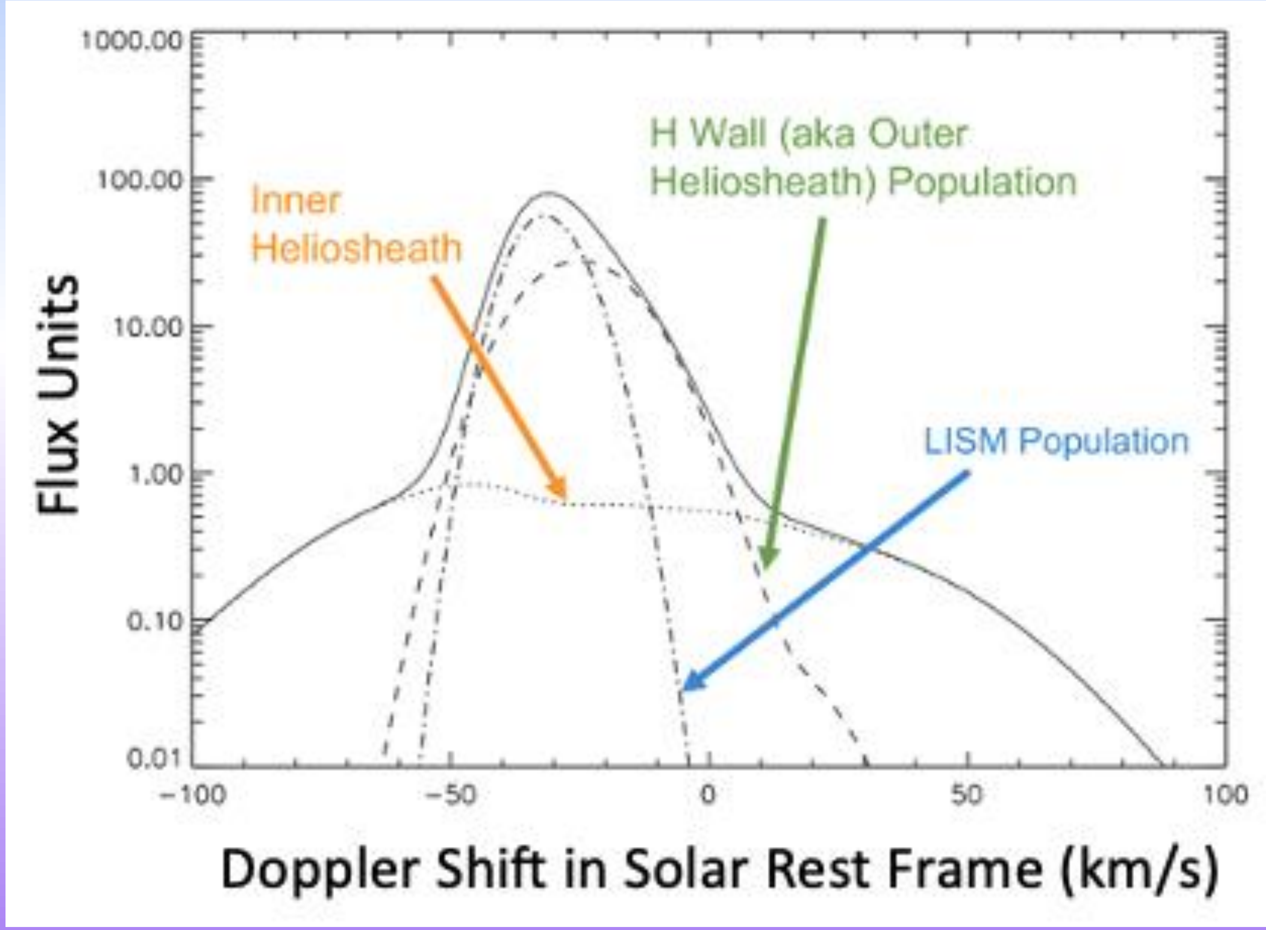


Interplanetary Hydrogen Properties Observed From Mars

M. Mayyasi[1], E. Quémerais[2], D. Koutroumpa[2], I. Baliukin[3,4,5], A. Titova[3,5], V. Izmodenov[3,4], J. Clarke[6], J. Deighan[7], N. Schneider[7], and S. Curry[8]

Spectral resolution still unable to address resolving IPH populations

How to Address this Science?



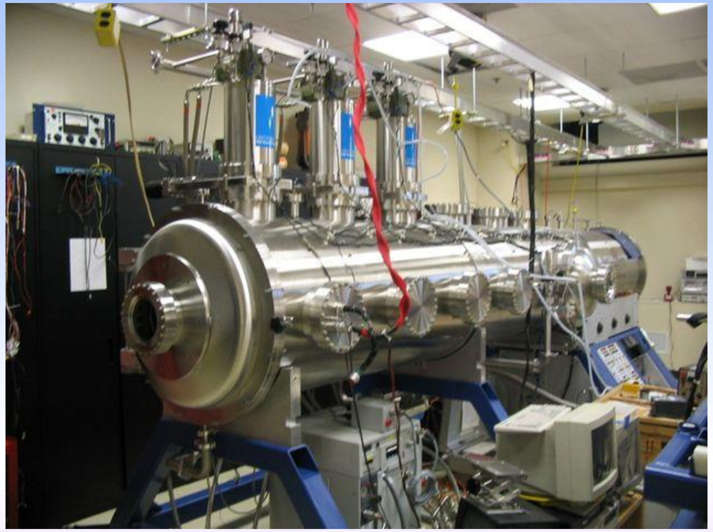
[modeled profile from Quémerais and Izmodenov, 2002]

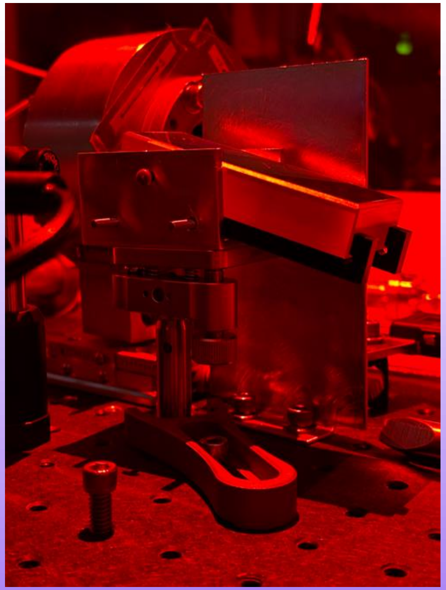
- Desing an instrument with spectral resolution ~3.5 km/s
  (H & D ~85 km/s)
  (Mars & IPH bulk ~42 km/s)
- Find a funding opportunity for development (TRL→ 5)
- Find a rideshare (TRL → 6)
- Find a mission to fly it on.

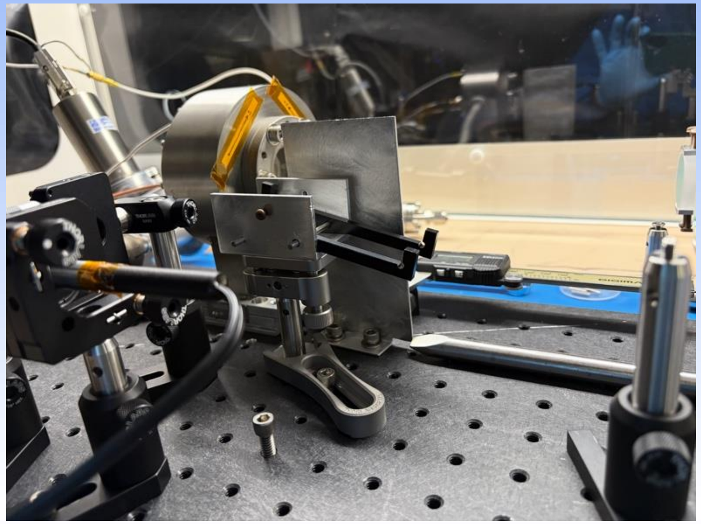
Design Requirements

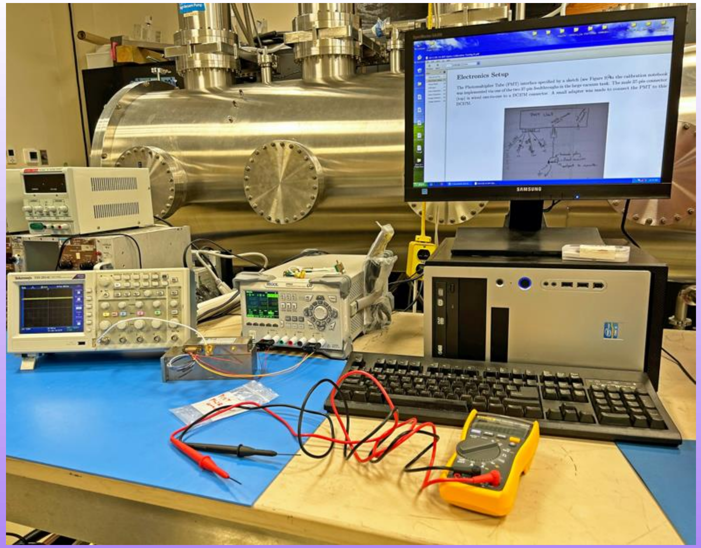
Requirement	Design Goal	Means
▶ Spectral Resolution ▶ Sensitivity	Utilize heritage technology, then upgrade design for improved measurements	• Echelle grating • >f/15
▶ Mapping FOV ▶ Longevity	Prepare for an articulating or spinning spacecraft platform	No deployable / movable components
▶ Mission Opportunity	Minimize SWaP to be ISP-friendly	• TRL > 6 • low noise MCP

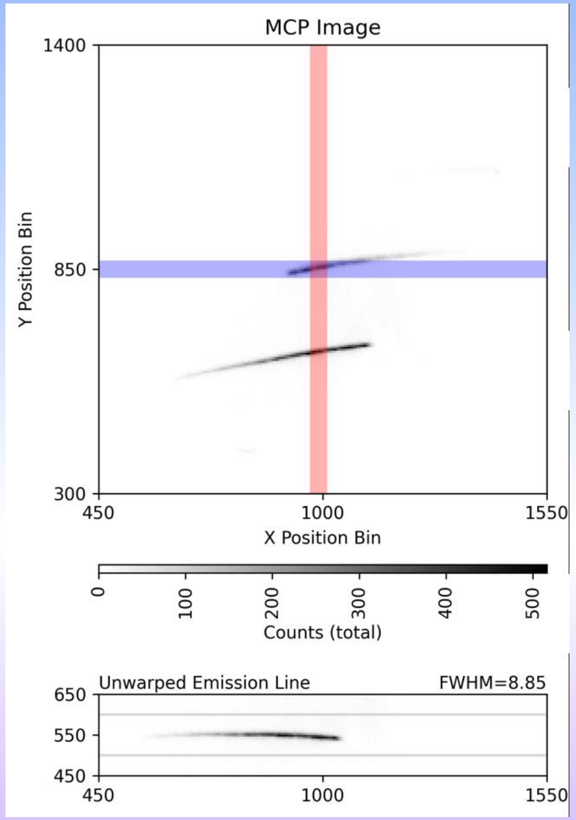
In the Lab

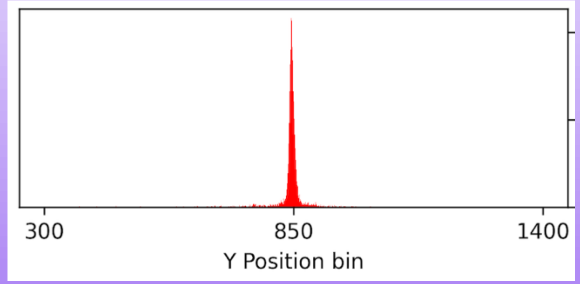












Vacuum Chamber, MCP housing & Software, PHIRSL, component testing → Functional output!

.... the case for the Moon ....

Dis/Advantages to Being on the Moon

- Better sensitivity than ISP-situated due to RTGs.
- Could characterize effects of dust on H Ly-α absorption.
- Dust accumulation on the instrument window would require an astronaut to physically clean.
- If pointing gear does not exist, manually pointing by an astronaut would be required to point at the body of interest.

Putting HIRSL on the Moon – dark side

- Non-polar dark-side of the Moon, looking zenith-ward facilitates IPH mapping through rotation of the moon [upwind – downwind].
- Doppler shifts between instrument line of sight (Moon), Earth's geocorona, and IPH can separate the emissions.
- Bonus science 1: Support IMAP/Carruthers during Earth-Moon-L1 alignment to get column of H, to be used as proxy for space weather stripping of water from Earth.
- Bonus science 2: Observe D & H on comets and planets while in FOV.

Putting HIRSL on the Moon – Facing Earth

- Earth-facing FOV would provide a subset of IPH mapping.
- Same doppler shifts as with dark-side.
- Added observations of terrestrial D, H, O, N
- Bonus Science 1 and 2 apply.
- Bonus Science 3: characterize water escape from Earth

Lookahead

- Promising design being developed as prototype bread/brass board (→ TRL 5).
- Instrument can provide unique measurement capabilities for IPH Ly-a, Planetary (including terrestrial) D, H, & O, as well as for Cometary D, H, & O
- Looking for multiple rideshare opportunities (→ TRL 6).
    - Dosimeter (to account for RTGs)
    - [HIRSL + Dosimeter] System