Lyman α emissions from the heliospheric interface

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The Interplanetary Background at Lyman α

- First observations at the end of 1960's OGO-5 mission (Bertaux and Blamont, 1971; Thomas and Krassa, 1971).
- Caused by hydrogen atoms in the interplanetary medium (scattering of solar UV photons H Lyman Alpha at 121.566 nm).
- Used to study distributions of hydrogen atoms in the heliosphere. 4 decades of measurements.

H atoms in the VLISM and solar system

-solar gravitation

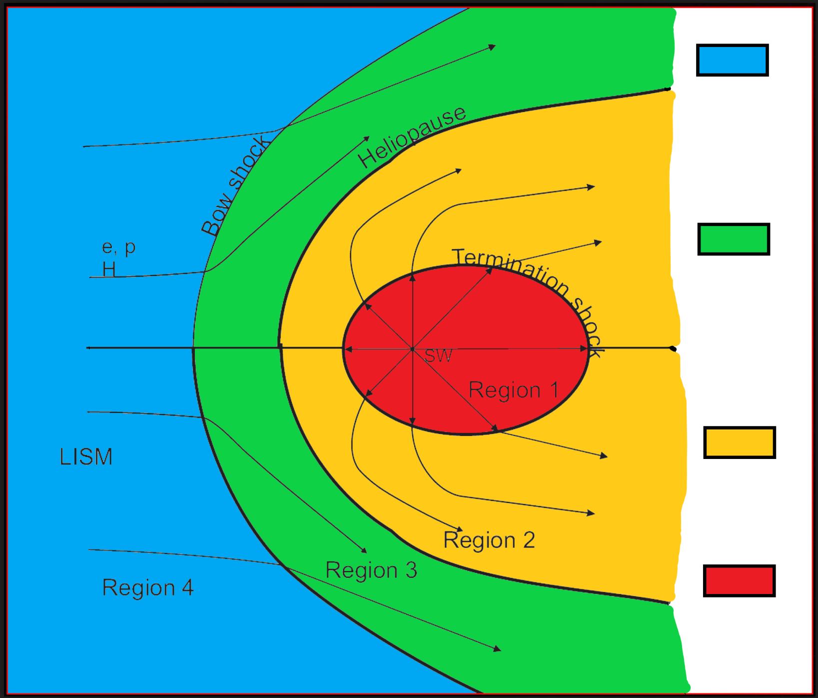
-absorption and resonant scattering of solar Lyman photons => radiation pressure

-LOSSES due to:
- -photoionisation
- -electron impact ionisation
- -CHARGE TRANSFER with solar ions H+, He++

Charge-transfer with H+ is the most efficient process !!!

Solar wind imprints on the H distribution

Heliospheric Interface model.
Baranov at al. (1990) and following studies



VLISM H @ ≈ 26 km/s 7000 K

Outer heliosheath mean parameters
H @ ≈ 22 km/s 12000 K

Inner heliosheath mean parameters
H @ ≈ 180000 K

Supersonic SW region mean parameters
H @ ≈ 400 km/s outside of solar H Lya line

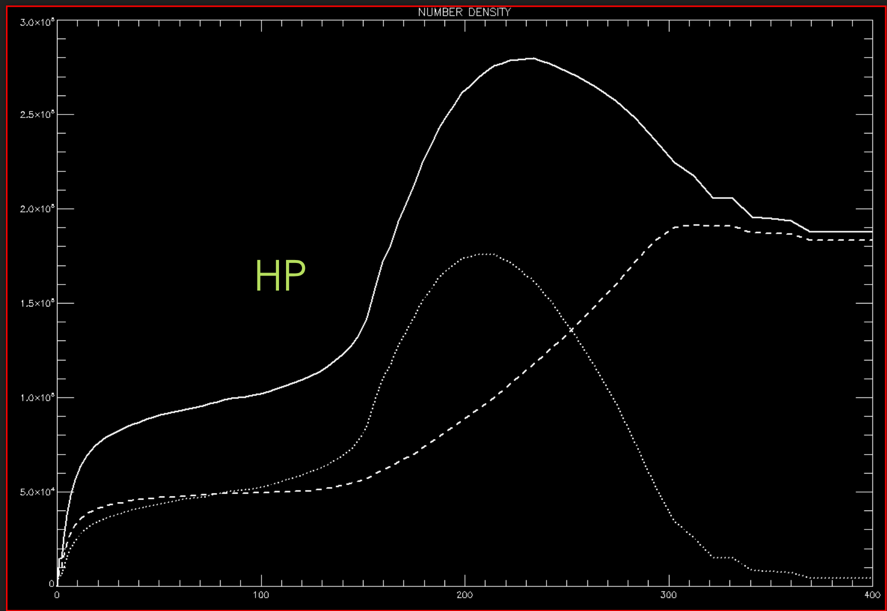
IPH LINE PROFILES ARE VERY IMPORTANT

H density in the Upwind region

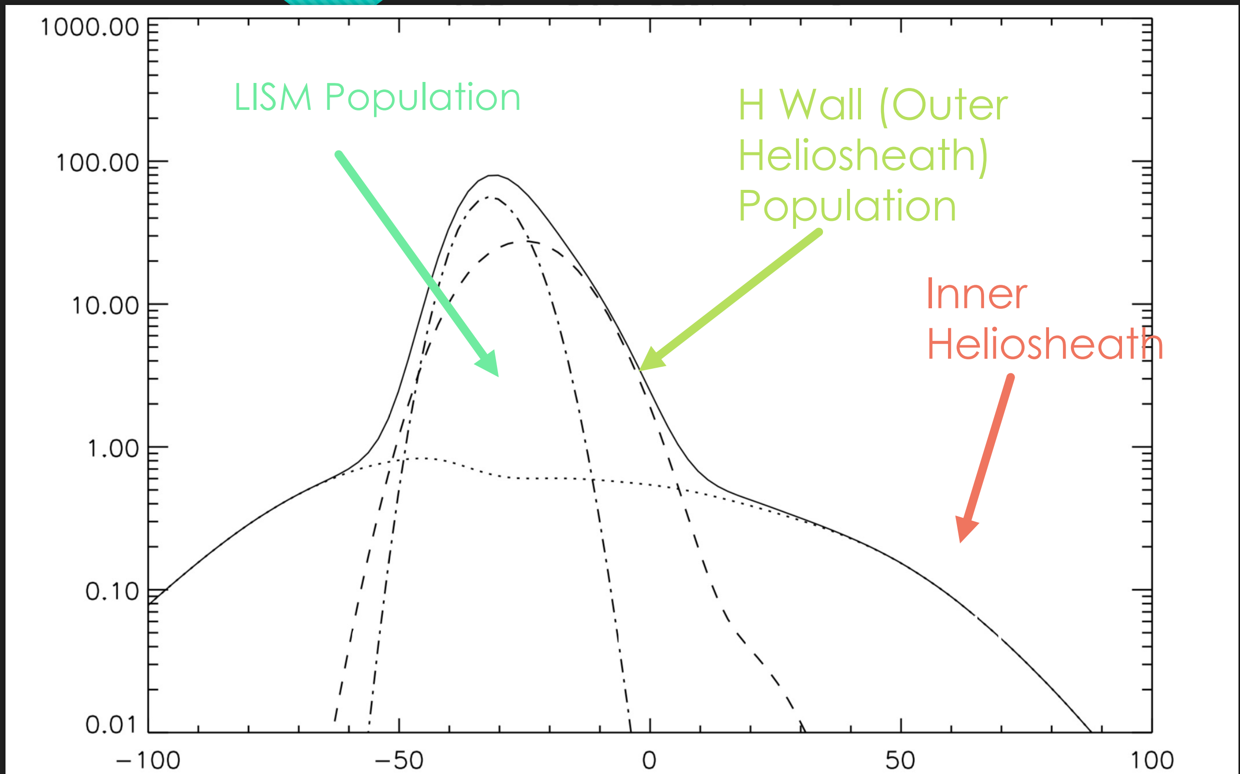
H atoms are coupled to HP through charge exchange

H + H+ -> H+ + H*

H* follows the velocity distribution of local plasma.



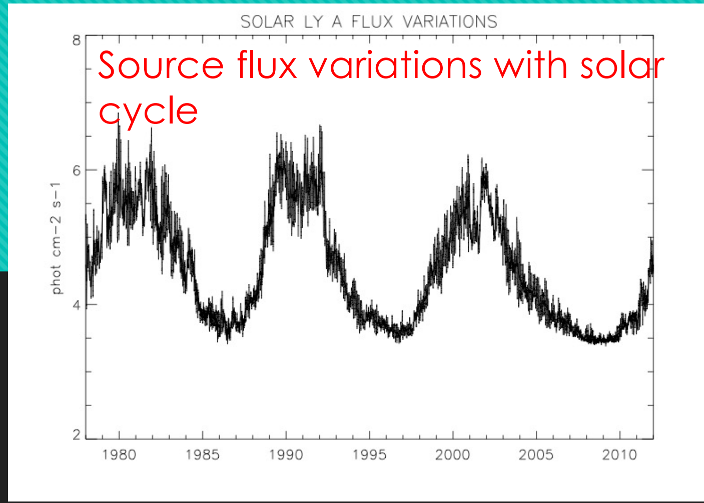
IPH line shape: showing the different populations



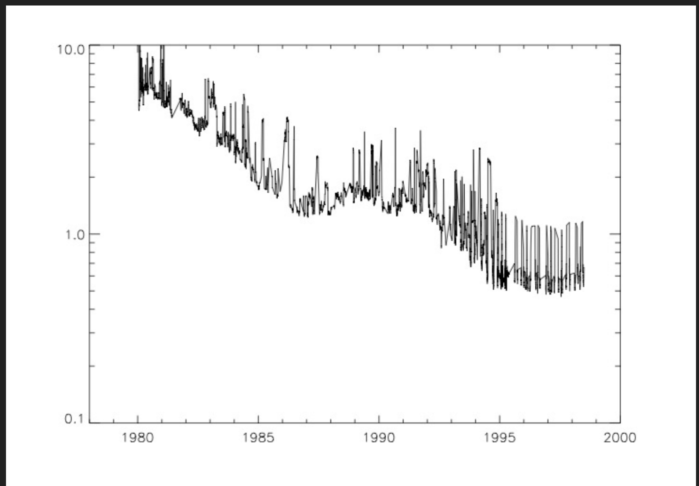
High resolution line profile computed for an observer at 1 AU, in km/s (Quemerais & Izmodenov, 2002).

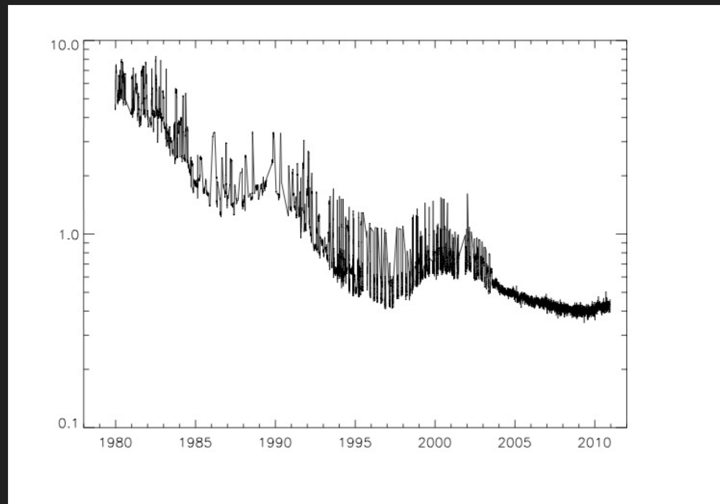
largest set of IPH data

in the outer heliosphere



VOYAGER 2 - UVS





VOYAGER 1 - UVS

What have we learned from V1 & V2 UVS data

Intensity gradient is not compatible with a model without heliospheric interface (after 50-60 AU).

Because of Radiative Transfer effects the H wall does not create a bump (extinction wins over increase of density).

Intensity gives a number density around 0.1 cm-3 (see later)

Excess emission in the Nose Region over Interface Model.

Good agreement between Voyager 1 & 2 at same distance after correction for solar source.

Katushkina et al. (2017):
Plateau from 90 AU to 110 AU explained by emission excess of 20 R
Radial Intensity beyond 110 AU is

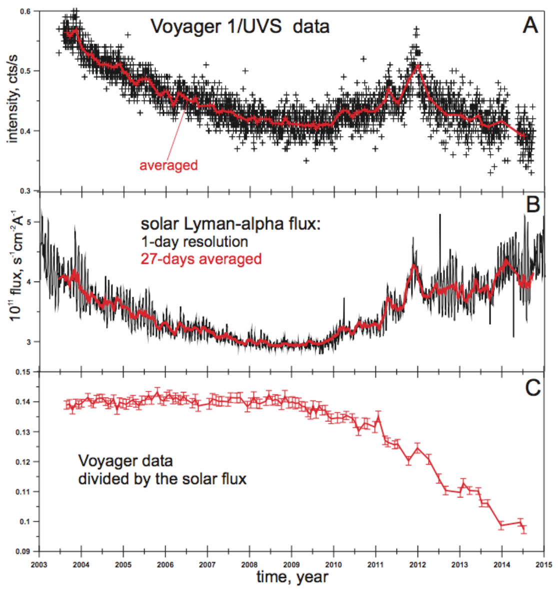


Figure 3. A. Voyager 1/UVS Lyman-alpha intensity measured in 2003-2014. Symbols correspond to original data and red curve corresponds to the data averaged over 27 days. B. Solar Lyman-alpha flux at the line center at the Earth orbit with one-day resolution and averaged over 27 days. C. Voyager intensity divided by the solar flux.

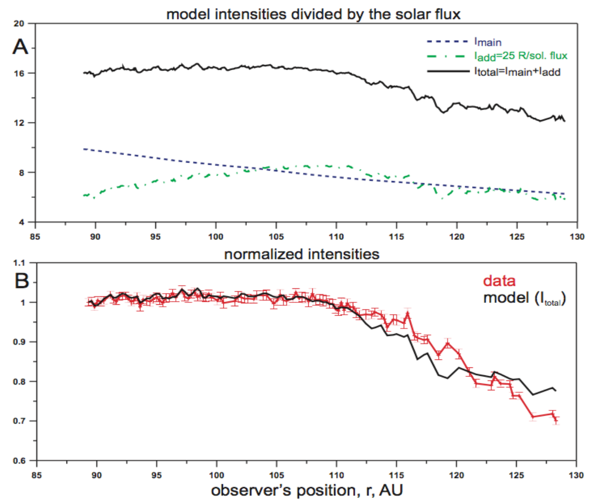


Figure 8. Second artificial scenario with additional 25 R of external (extra-heliospheric) uniform emission. All intensities are divided by the solar flux. A. Three components of the Lyman-alpha intensities are shown. Dashed curve shows the main component of intensity obtain from the base model, dashed-dot curve shows additional intensity that is constant intensity divided by the solar flux, solid curve shows the total intensity that is a sum of two components. B. Comparison of the normalized total intensity with the data is shown.

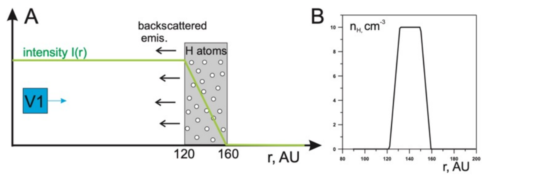
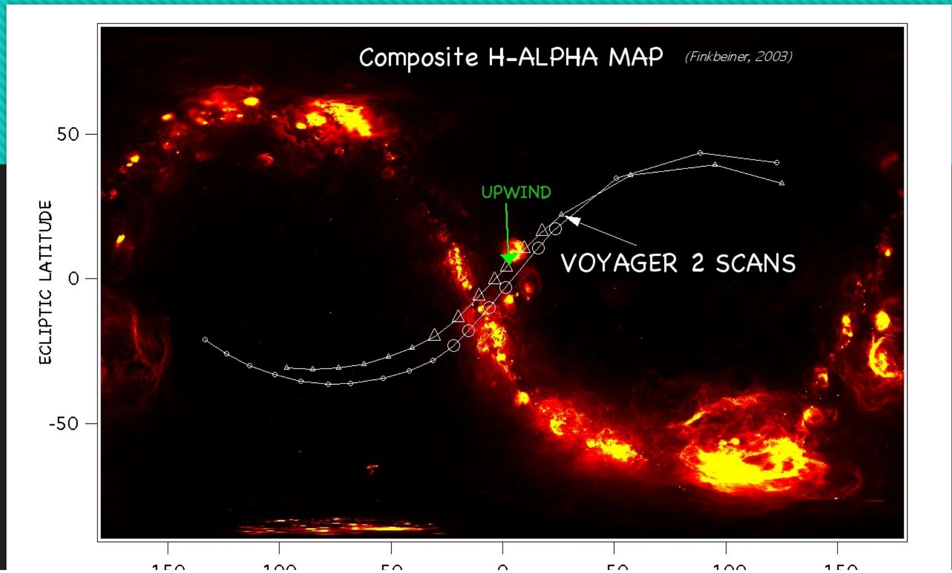
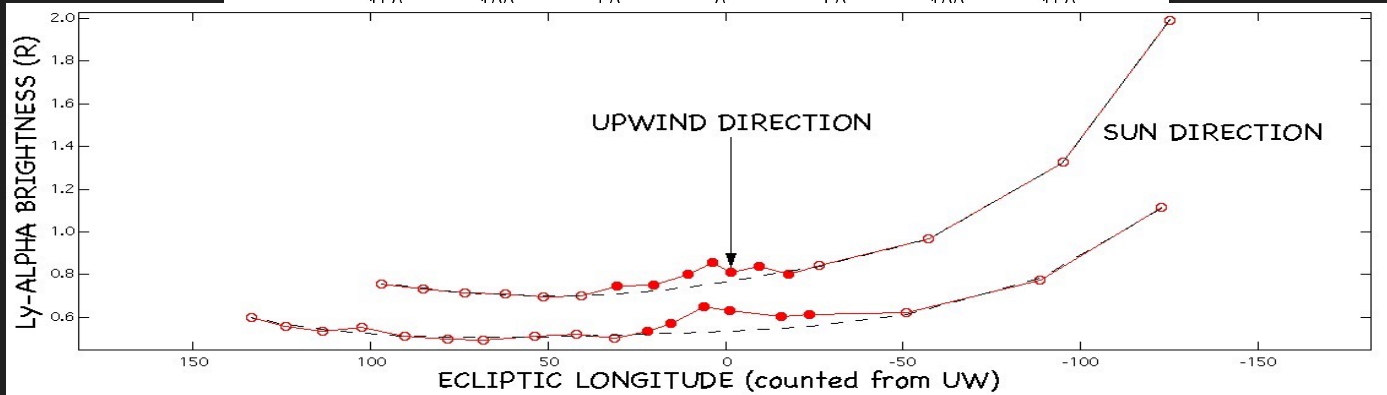


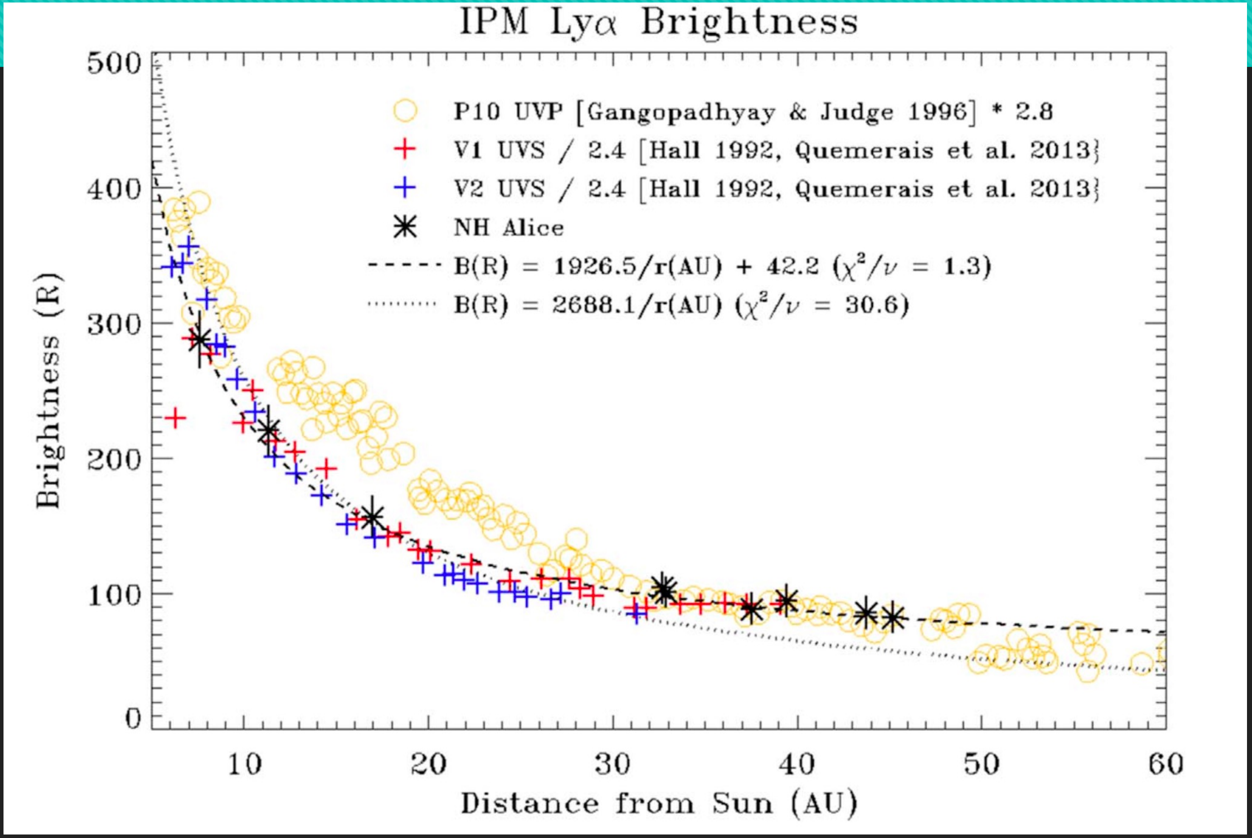
Figure 6. A. Schematic illustration of Lyman-alpha intensity backscattered at the dense layer with significantly doppler shifted H atoms. Green solid curve shows intensity from the layer, which would be observed by spacecraft at different distances from the Sun. B. Hydrogen number density profile at the layer.

Lallement et al. (2011). H alpha maps





Gladstone et al. (2023)

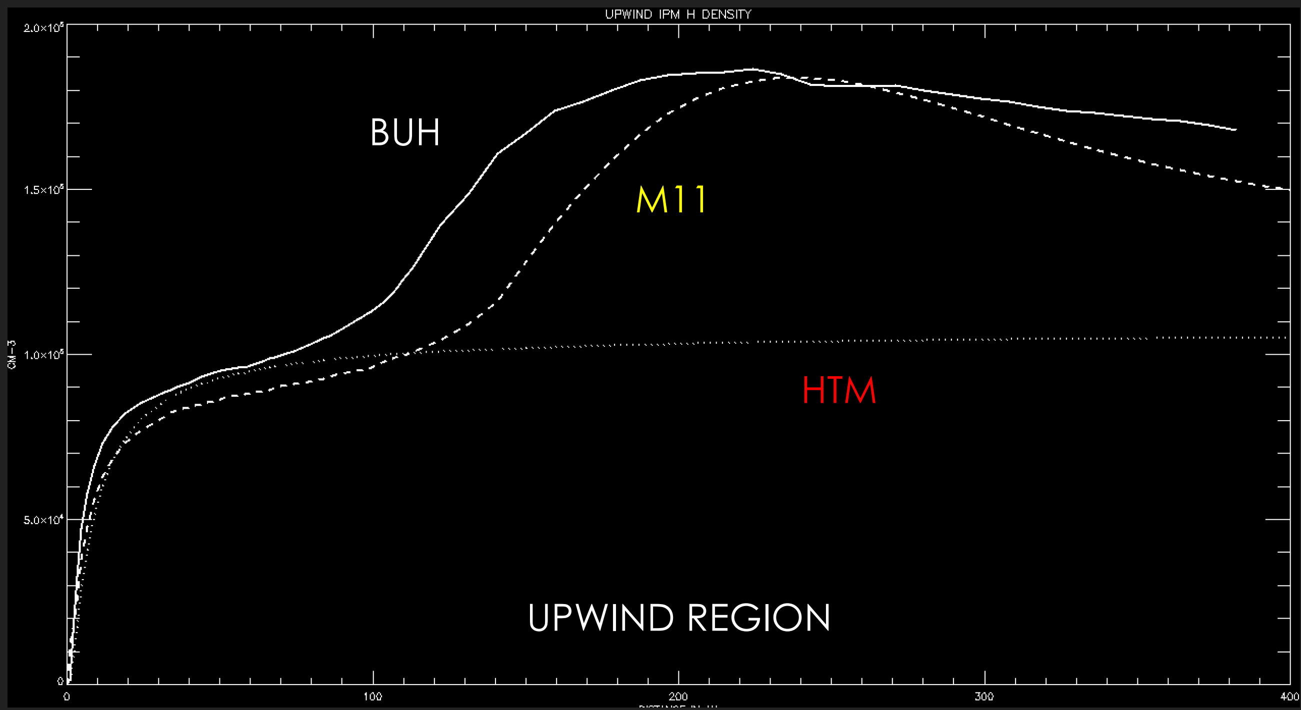


Comparing the Hot model and interface models.

Hot Model (3D) (Lallement et al. 1985)

Izmodenov et al. (2013) (M11)

Boston U model (Powell and Opher 2024)

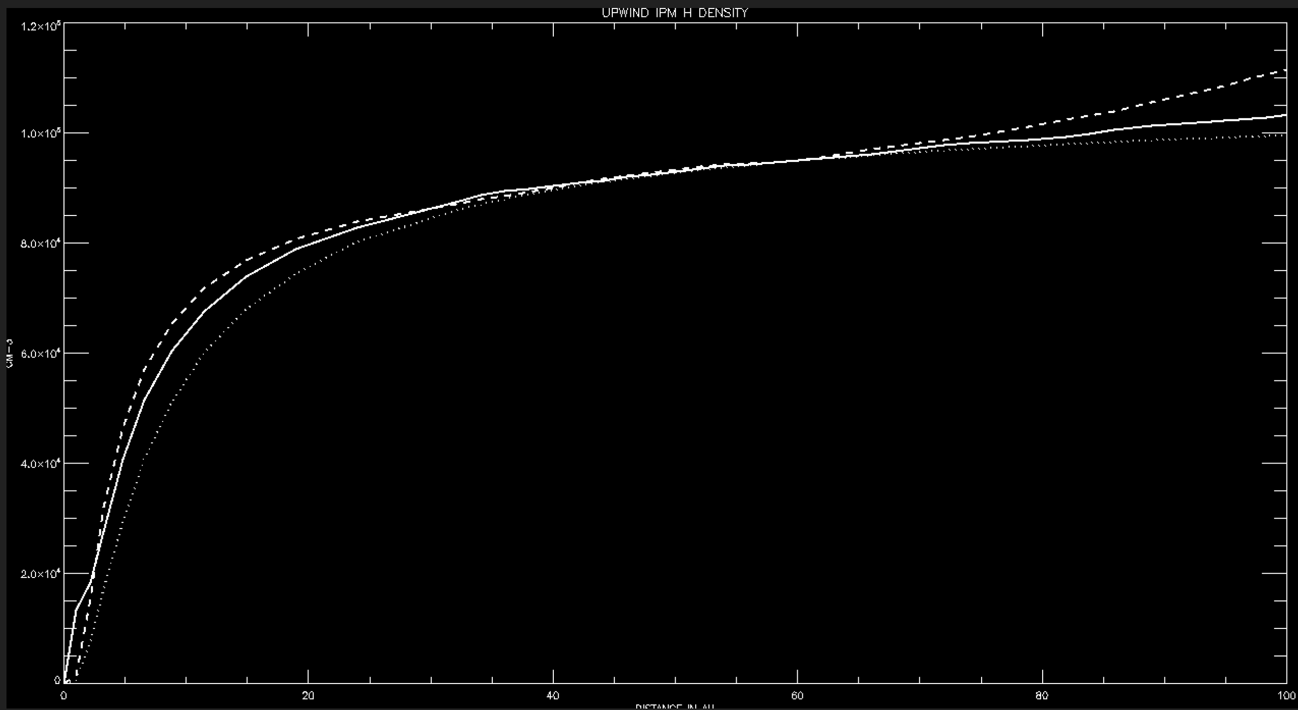


Comparing the Hot model and interface models.

Both Interface models assume a density of 0.14 cm-3 in LISM

At 80 AU the density is 0.1 cm-3 :
40 % filtration at HP

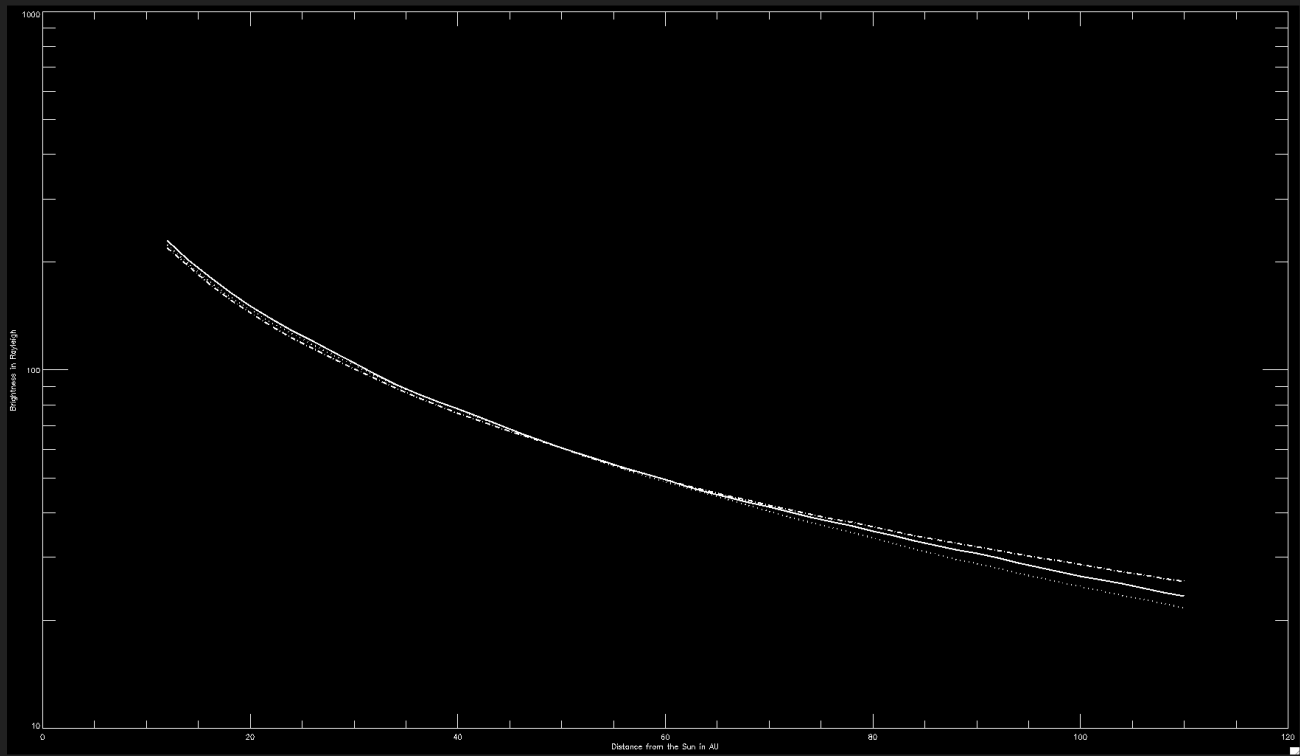
For Hot Model similar density in inner heliosphere is obtained with 0.1 cm-3



Comparing the Hot model and interface models.

Model of the radial variation of the upwind brightness (computed for the trajectory of NH) between 12 AU and 110 AU for the 3 models

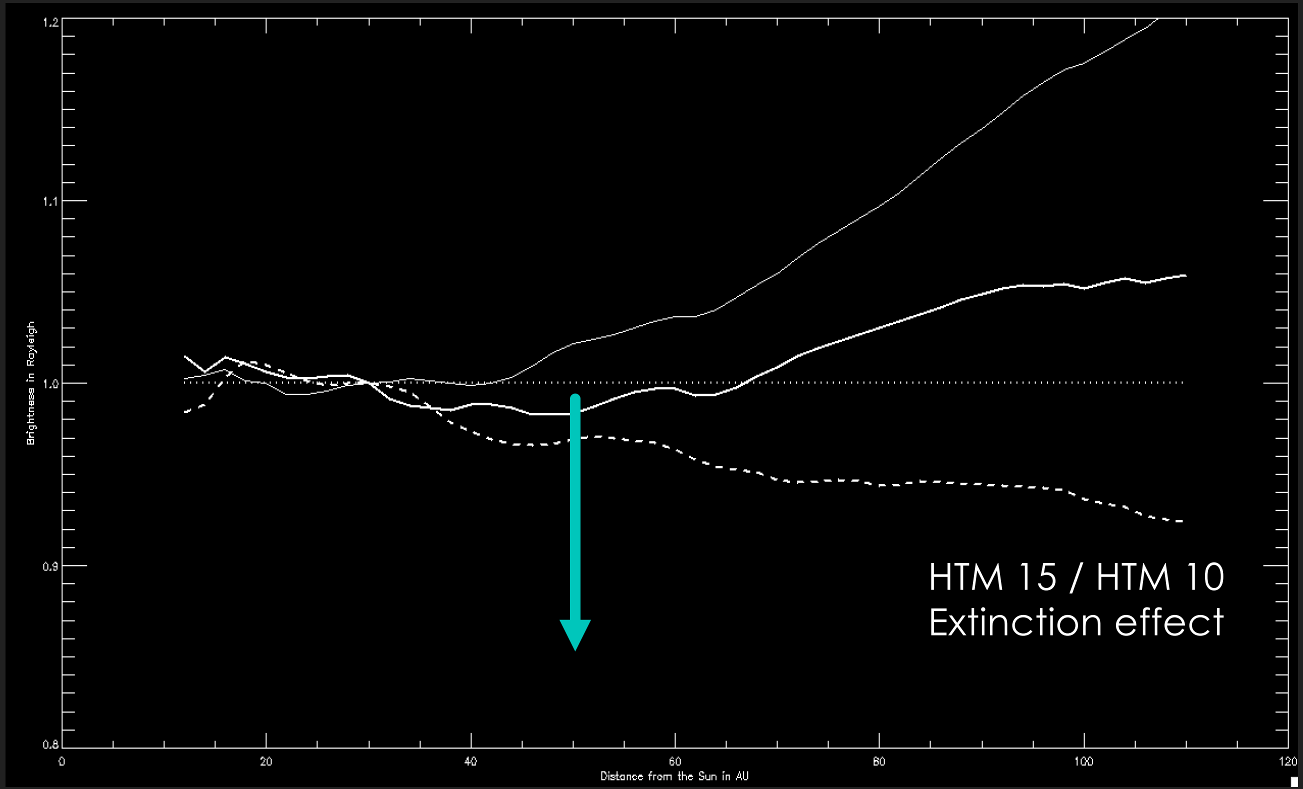
All 3 models give similar values (normalized at 50 AU). The decrease is slightly faster fr the Hot Model



Comparing the Hot model and interface models.

To give better perspective, we can divide each model by the reference *HOT MODEL*

At 100 AU, the difference is within 20%



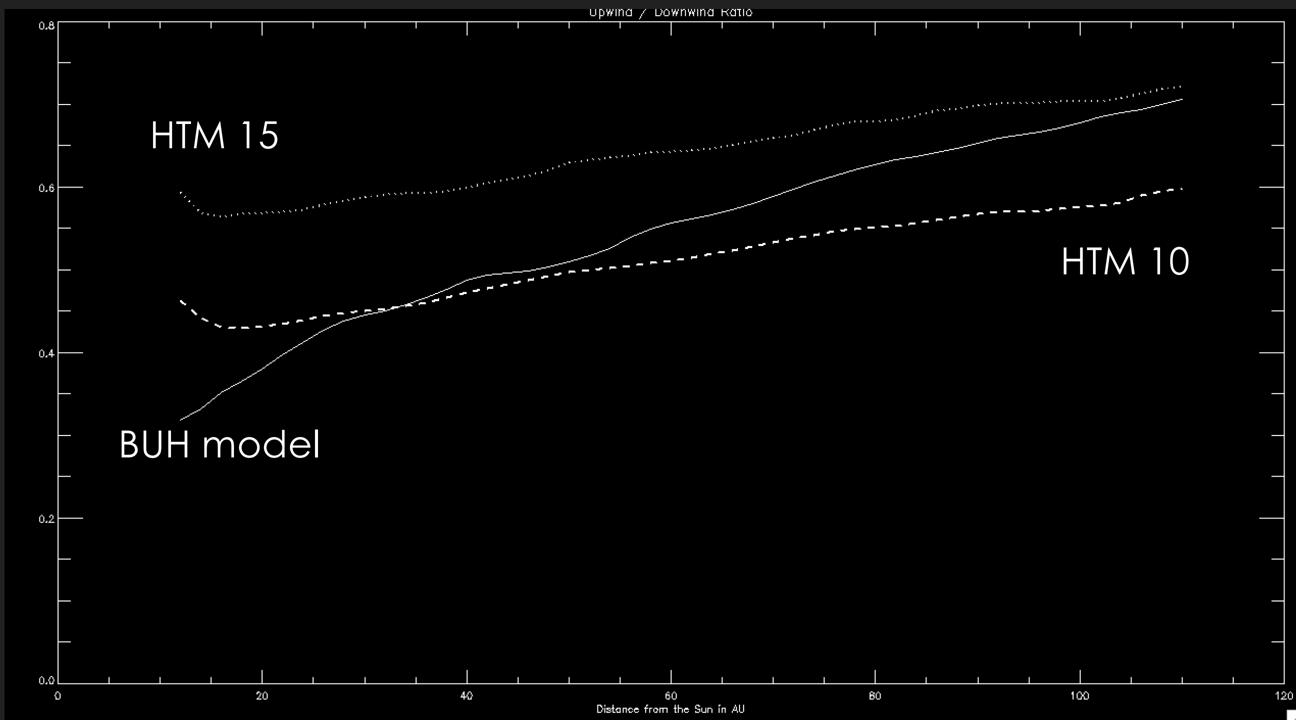
Comparing the Hot model and interface models.

Upwind/Downwind brightness ratio is an interesting test.

The ratio is getting toward 1 with increasing density.

No solar flux or calibration correction needed;

Reflects the H density gradient (combined with total opacity).

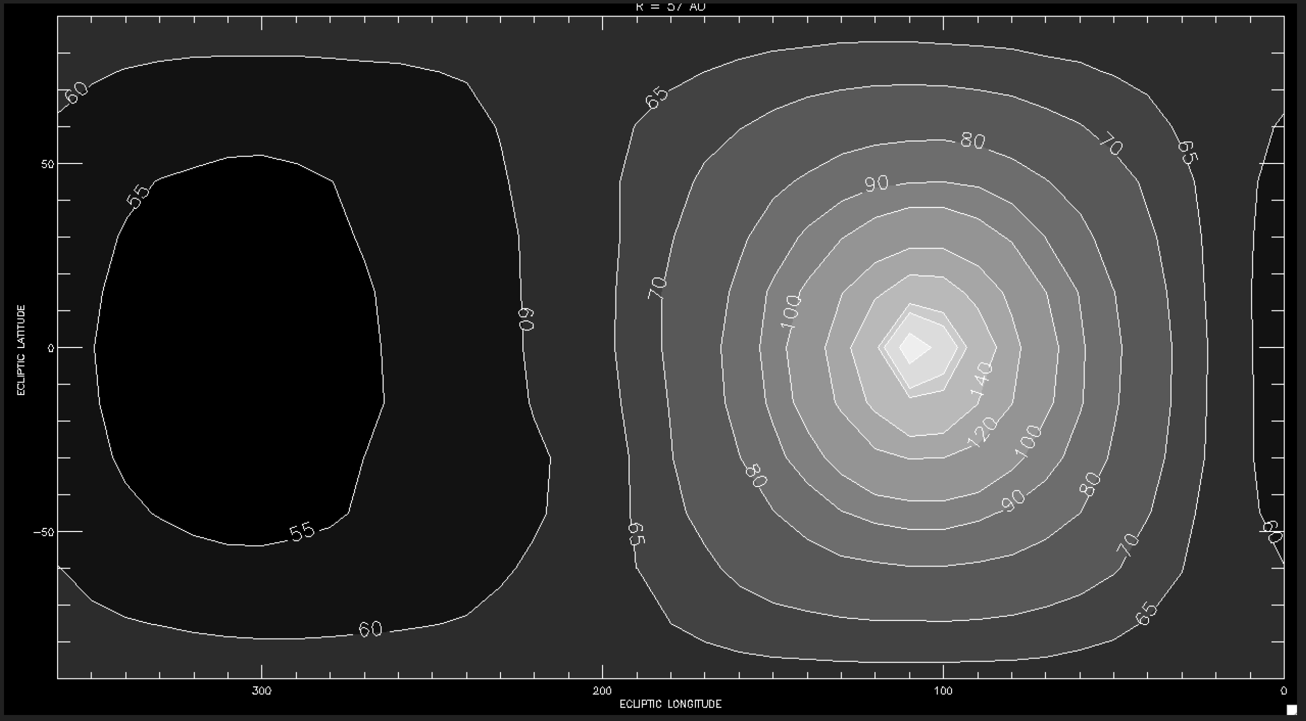


Comparing the Hot model and interface models.

Full Sky Map of IPH Brightness at 57 AU

Computed for BUH model.

Possible to test the 3D distributions



Conclusion

The difference between the Hot Models and the Interface Models should be visible after 50-60 AU. Similar radial dependance before.

Voyager 1 data beyond 80 AU need to be confirmed.
-Plateau from 80 to 110 AU
-Fall-Off after 110 AU

- Upwind/Downwind ratio variation with distance is a good test of the models.
Potentially, this could allow to characterize the H wall strength and the strength and orientation of the interstellar B field.