

The very slow solar wind: properties, variability and origin



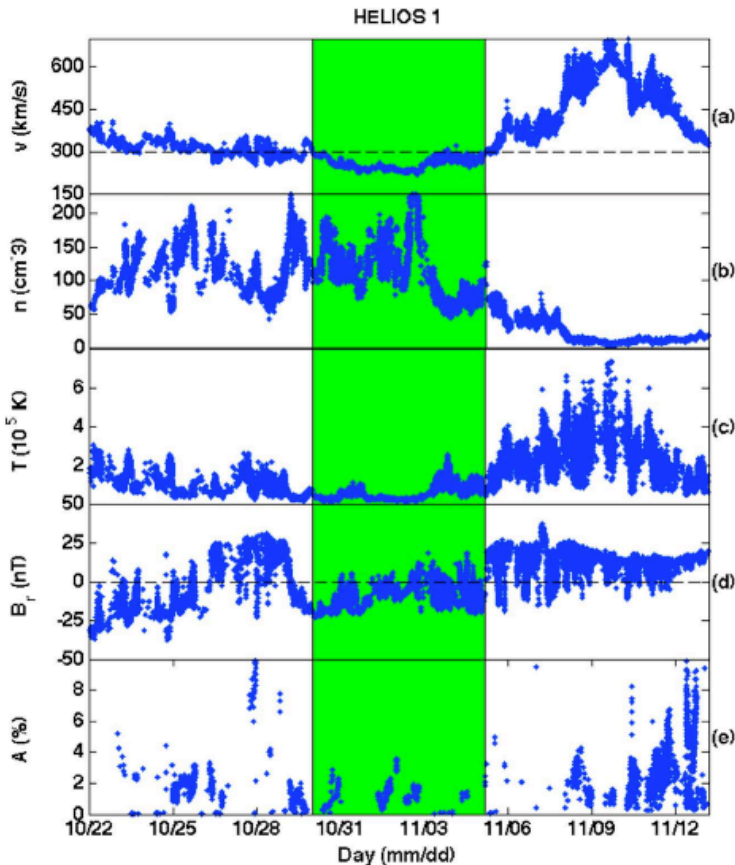
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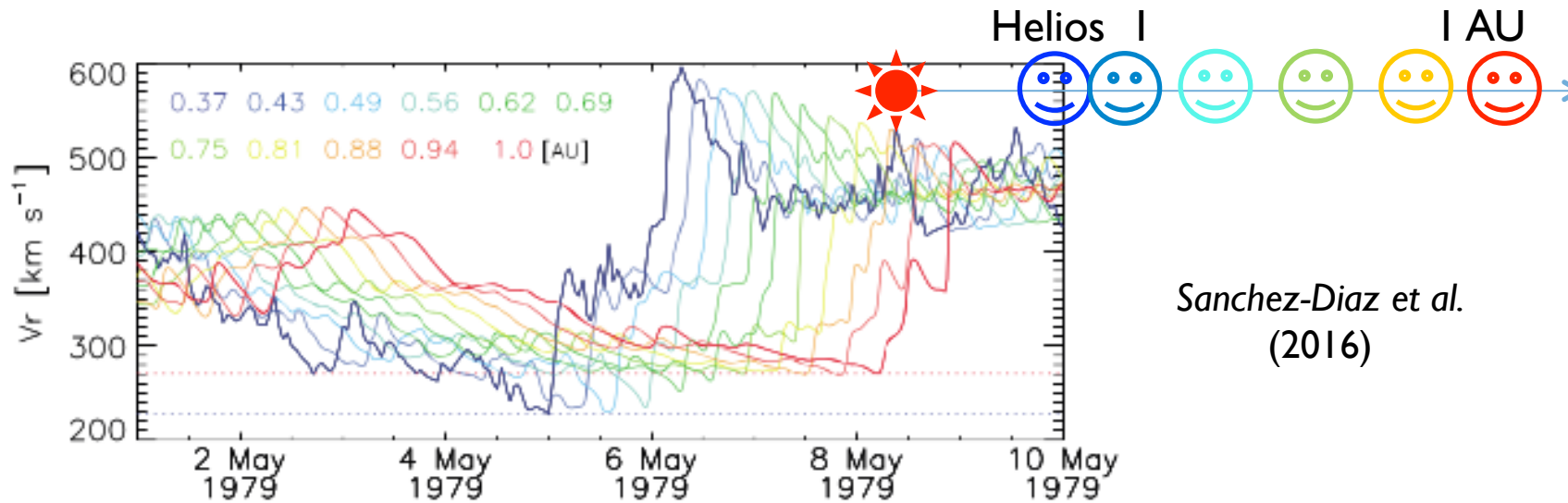
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One example of VSSW



- $V < 300$ km/s
- Remote observations STEREO-HI (Plotnikov et al., 2015)
- In-situ HELIOS

WHY is it not seen at IAU?



Sanchez-Diaz et al.
(2016)

Model

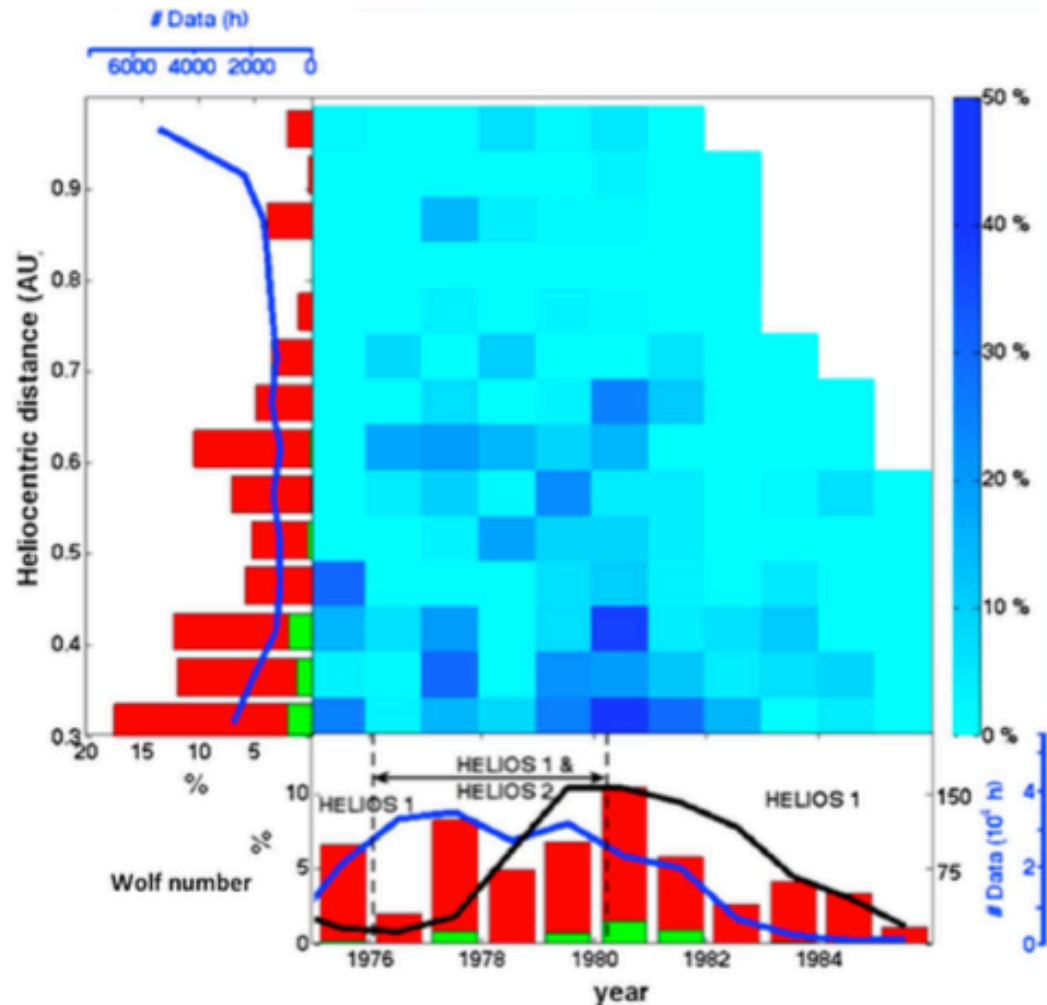
→MHD

→No external heating

Result

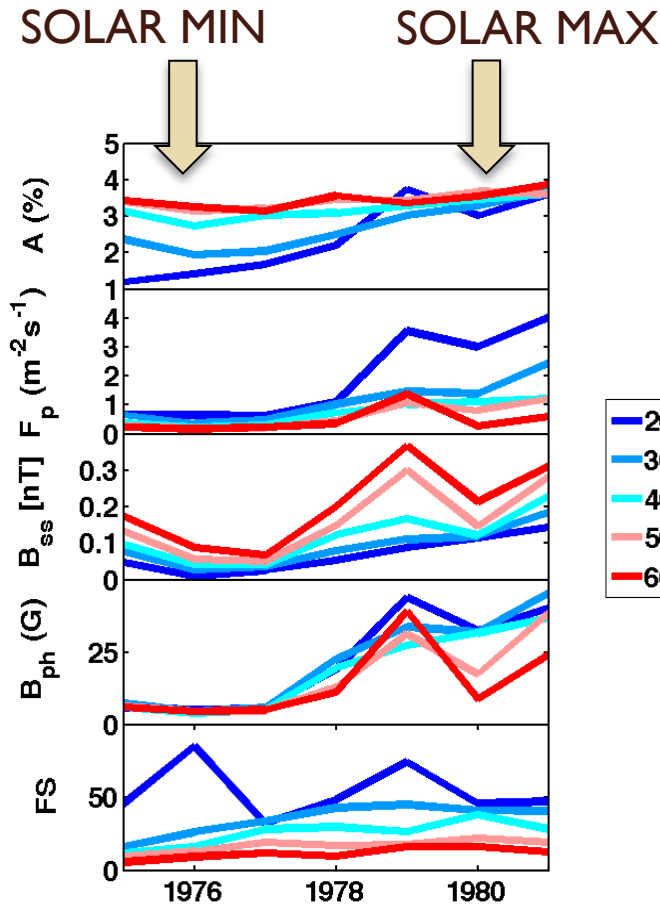
If high pressure gradient
→ acceleration to classical speeds

WHERE and WHEN is it measured?



Sanchez-Diaz et al. (2016)

Solar cycle variability



Sanchez-Diaz et al. (2016)

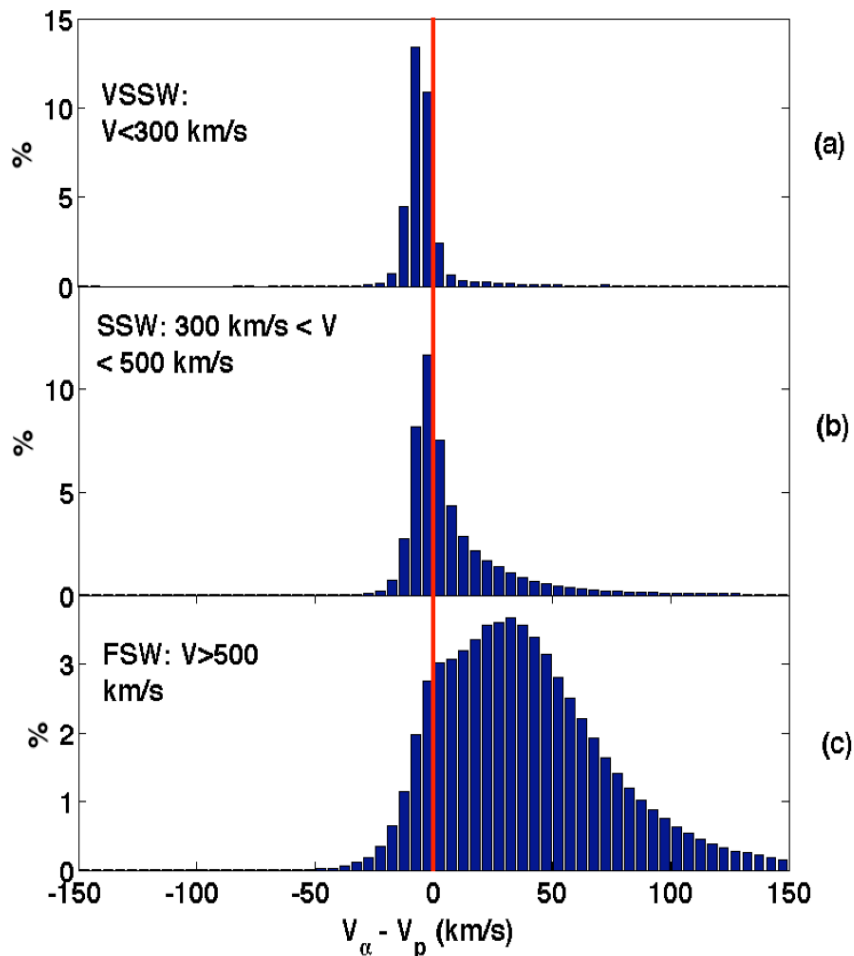
very slow wind (blue),
same trend for:
-He abundance
- $n_p v_p$ (photosphere)
- B (photosphere)

$n_p v_p \rightarrow$
collision
rate \rightarrow
He flux

OR

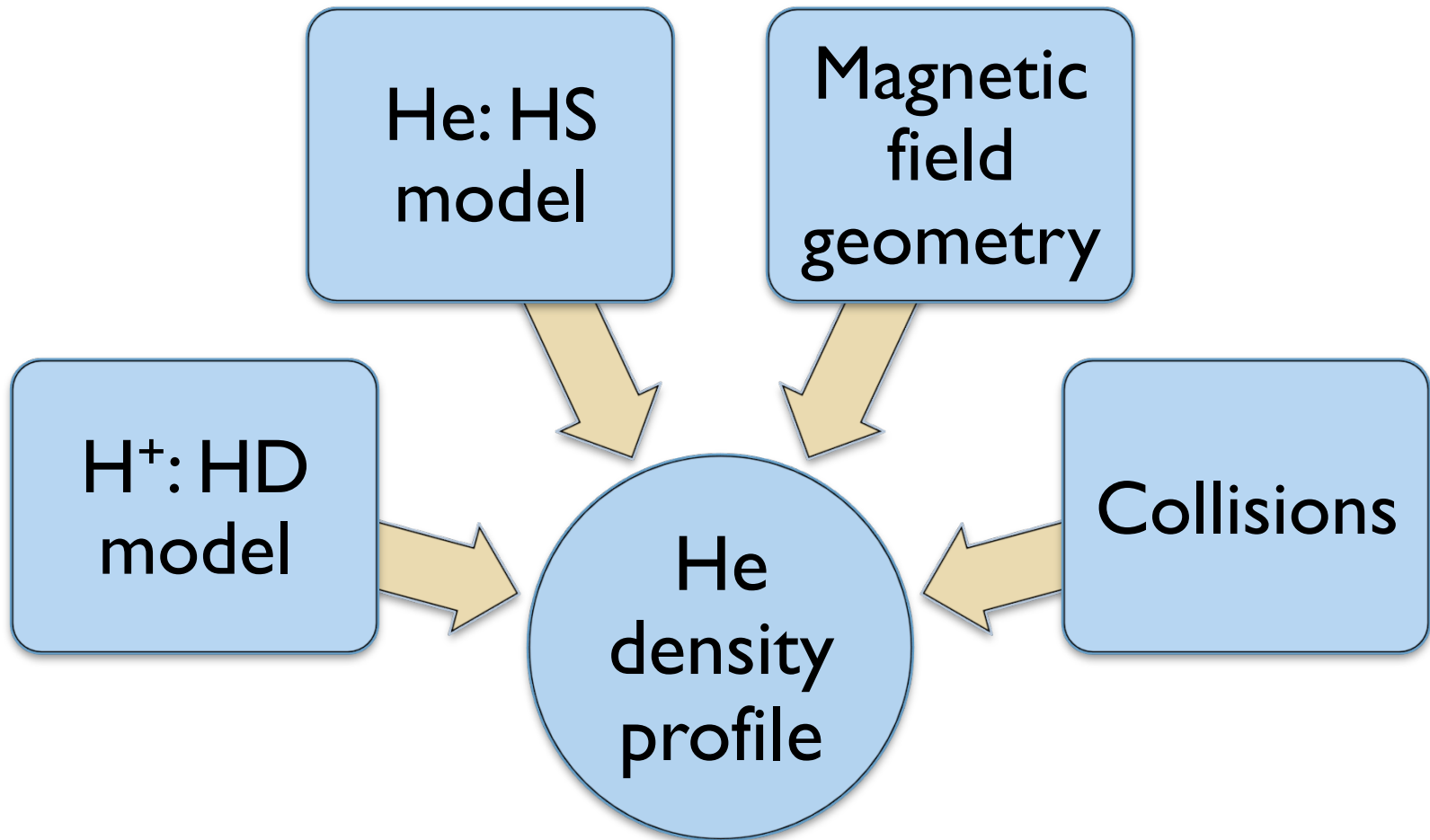
$B(\text{phot.}) \rightarrow n_{\text{He}} v_{\text{He}}$

Relative alpha to proton velocity



- **Very Slow Solar Wind: narrow distribution. Small relative velocities → Coming from a collisional region?**
- **Fast wind: wide distribution**

Model



H⁺:HD model

Description

→ ID HD solution projected on a field line with any geometry

→ Phenomenological heating flux

Applicability

→ Chromosphere

→ Transition region

→ Corona

Described in *Pinto et al. (2009)*, *Grappin et al. (2010)*, *Verdini et al. (2012)*

He: HS model

$$\left\{ \begin{array}{l} k_B T_\alpha \frac{\partial n_\alpha}{\partial r} + n_\alpha m_\alpha g = -\nu m_\alpha \Phi_\alpha \\ \frac{\partial \Phi_\alpha}{\partial r} + \frac{\beta \phi}{r} = 0 \end{array} \right.$$

Momentum equation

Continuity equation

$$n_\alpha(r) = C_g e^{-\frac{r}{H_g(r)}} + C_d e^{-\frac{r}{H_d(r)}}$$

Local solution for layers of
~constant temperature,
height

$$H_d(r) = \frac{1}{\frac{1}{H_p(T_p(r))} + \frac{\beta}{r}}$$

Diffusive scale height

$$H_g(r) = H_\alpha(T_\alpha(r))$$

Gravitational scale height

Boundary conditions: scale heights

$$C_g + C_d = n_\alpha(r = R_0)$$

$$C_d = \frac{\phi_\alpha(r = R_0)}{D_\alpha} \left(\frac{1}{H_d} - \frac{1}{H_g} \right)$$

$$C_d < 0 \quad (H_g < H_d)$$

→ Momentum transfer $H \leftarrow He$

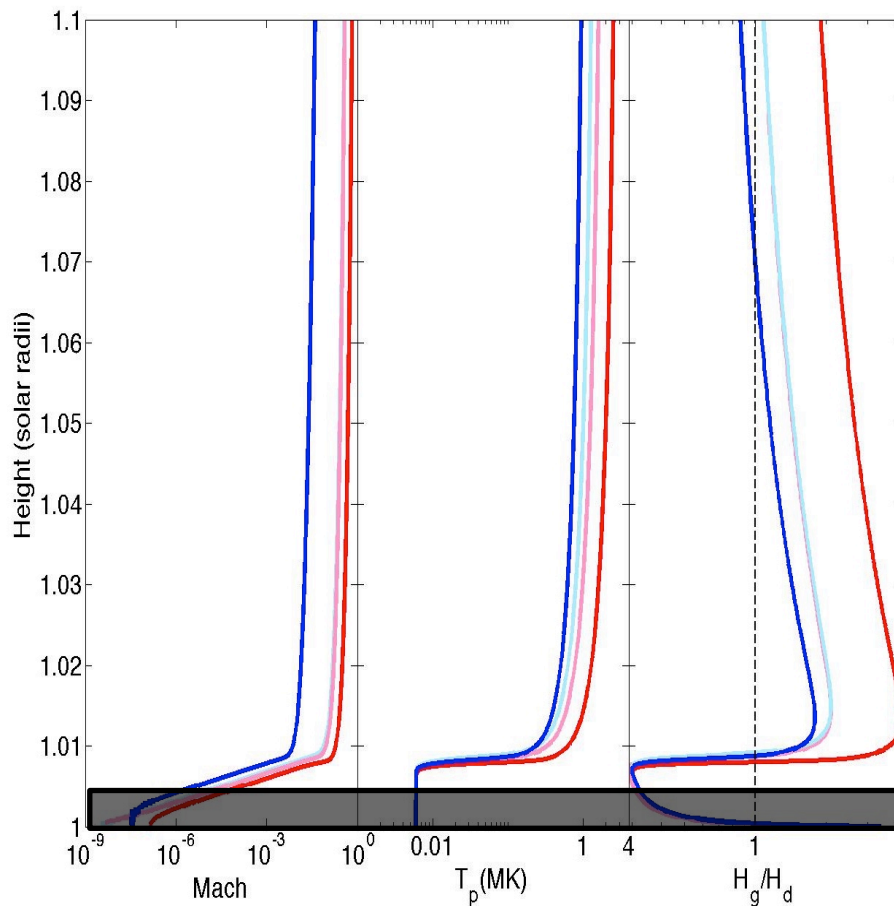
→ collisions slow He down

$$C_d > 0 \quad (H_g > H_d)$$

→ Momentum transfer $H \rightarrow He$

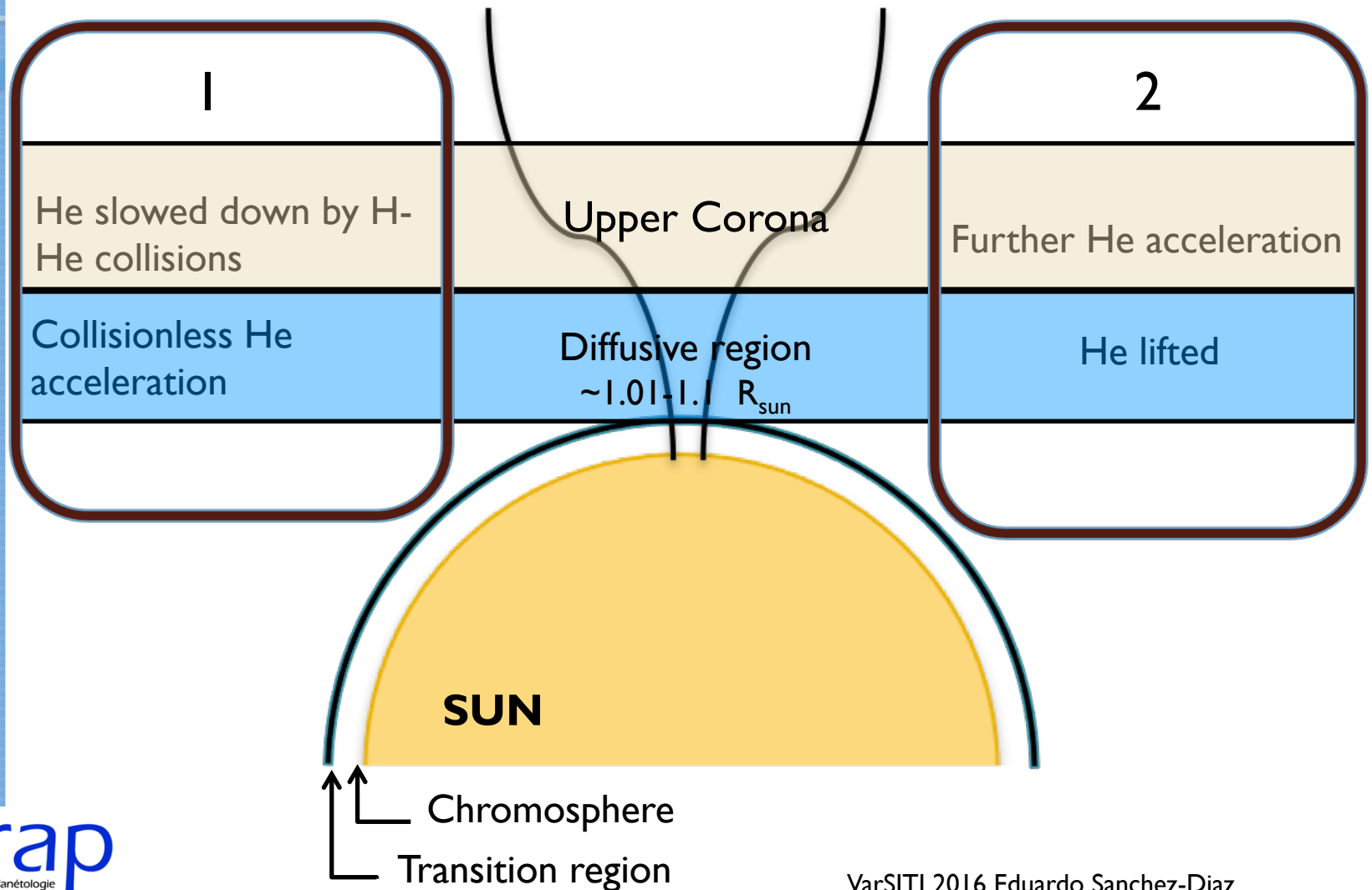
→ collisions accelerate He

Profiles of relative scale heights

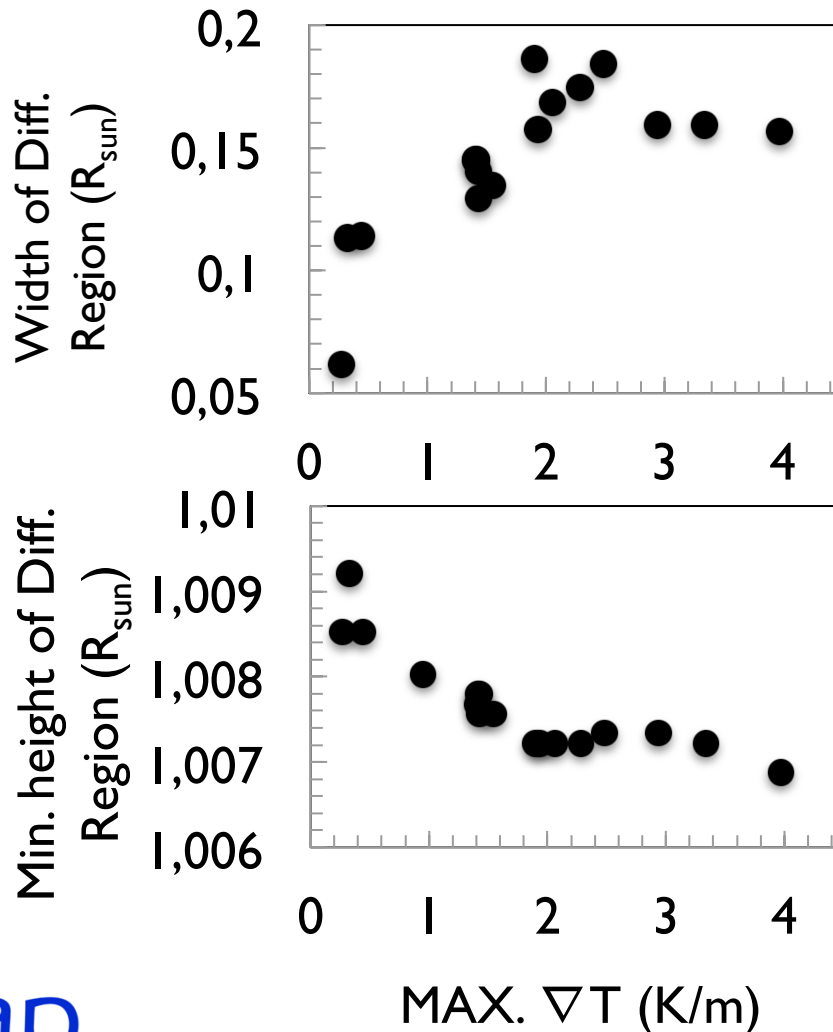


- **Above Transition Region: diffusion region with $H_g > H_d \rightarrow$ He lifting by diffusion is possible**
- **Higher up in the corona $H_g < H_d$: He^{++} might be slowed down by collisions with H^+**

Two possible scenarios



Diffusive region: dependence with heating rate



Higher ∇T (= higher B_{ph}) \rightarrow The He diffusion region is the:

- Lower down (denser \rightarrow more collisional)
- Wider

Summary

Properties

- SW Speed extends down to 200 km/s inside 0.7 AU
- VSSW disappears in SIR
 - Composition, density, etc., adding to slow wind variability
- Signature of HPS crossings

Origin

Diffusive region
~1.01-1.1 R_{sun} :

- Momentum transfer
H → He
- Wider & lower for higher heating rate (solar max) → Scenario 2 (He uplifting) more likely

Above ~1.1 R_{sun} :

- He slowed down if collisions enough