

The very slow solar wind

E. Sanchez-Diaz^{1,2}, K. Segura^{1,2}, A. P. Rouillard^{1,2}, B. Lavraud^{1,2}, C. Tao¹

¹ Institute of Research in Astrophysics and Planetology (IRAP)

²Paul Sabatier University (UPS)



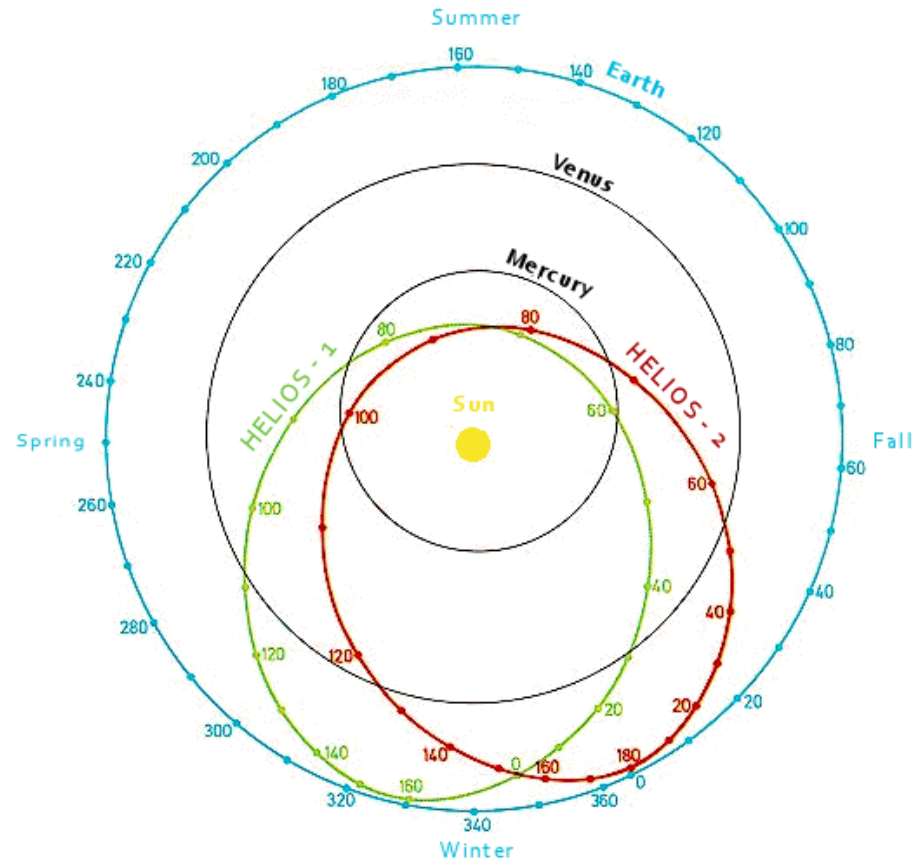
HELIOS



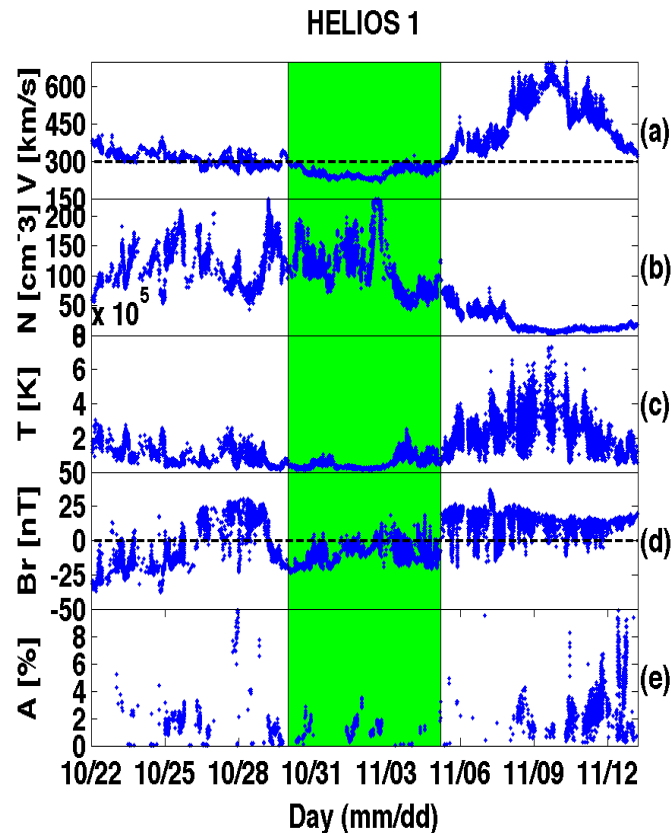
mission time (1974 - 1985)
excluding CMEs.

CME removal:

- Liu, Y. et al., 2005
($A > 8\%$, $T < T_{th}/2$)
- $\text{Beta} < 0.1$



Fast, slow and very slow solar wind



□ Fast solar wind ($V > 500$ km/s)

□ Slow solar wind ($V < 500$ km/s)

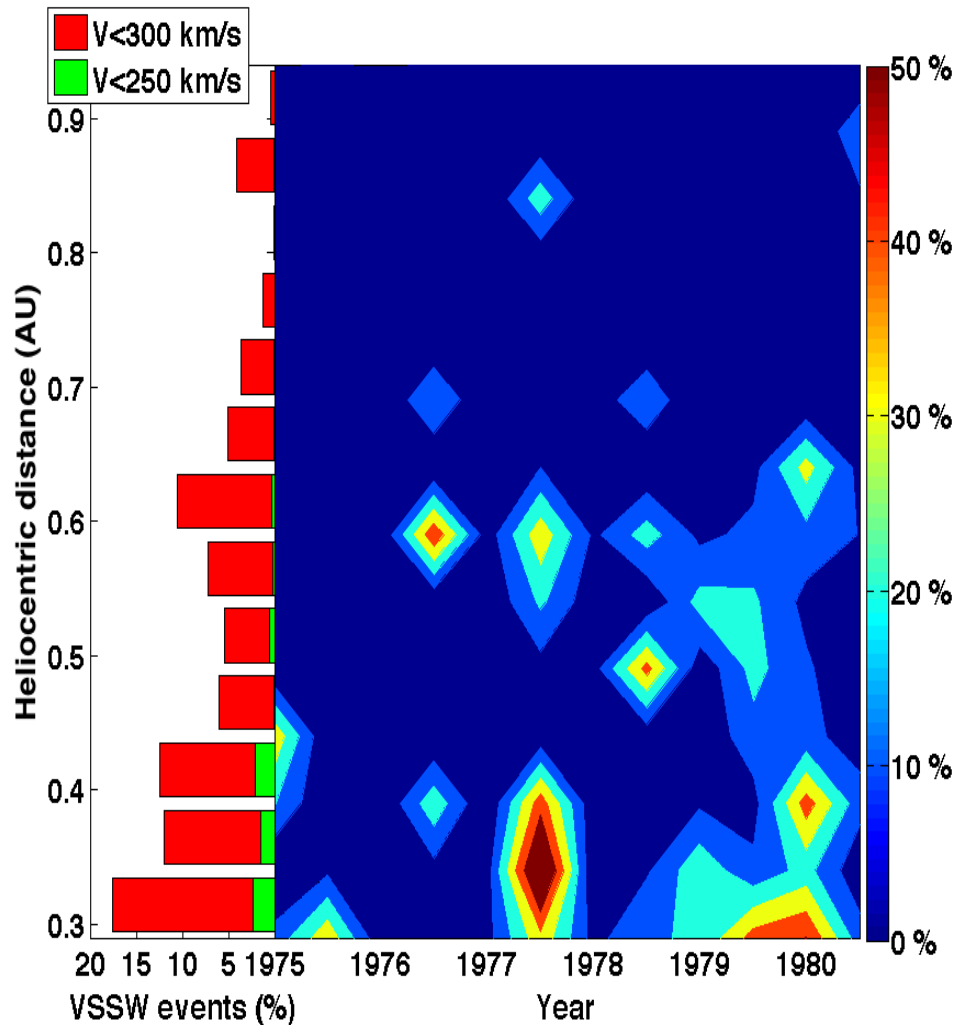
□ Very slow solar wind (200 – 300 km/s)

McComas et al., 2000

Catalogue

Spacecraft	Carrington rot	From	To	HDR	HPS	HCS		
HELIOS 1	1625-1626	29/03/75	06:50	01/04/75	00:29	x	x	x
HELIOS 1	1633	21/09/75	18:00	23/09/75	08:00	✓	✓	✓
HELIOS 2	1647	01/11/76	06:00	04/11/76	13:00	✓	✓	✓
HELIOS 2	1648	26/11/76	10:00	27/11/76	23:00	x	x	✓
HELIOS 2	1653	15/04/77	22:00	17/04/77	09:00	✓	✓	✓
HELIOS 1	1658	25/08/77	19:00	28/08/77	07:00	✓	✓	✓
HELIOS 1	1661	26/10/77	20:00	07/11/77	19:00	✓	✓	✓
HELIOS 2	1661	27/10/77	00:00	05/11/77	21:00	✓	✓	✓
HELIOS 1	1662	19/11/77	18:00	21/11/77	12:00	✓	✓	✓
HELIOS 2	1662	21/11/77	13:00	23/11/77	16:00	✓	✓	✓
HELIOS 2	1663	14/01/78	18:00	15/01/78	23:00	✓	✓	✓
HELIOS 2	1664	19/01/78	20:00	22/01/78	09:00	✓	✓	✓
HELIOS 1	1672	05/09/78	00:00	07/09/78	18:00	x	x	x
HELIOS 2	1672	06/09/78	15:00	09/09/78	10:00	x	x	✓
HELIOS 1	1675	25/11/78	05:00	27/11/78	10:00	✓	✓	✓
HELIOS 1	1678	06/02/79	22:00	08/02/78	09:00	✓	?	no magnetometer
HELIOS 2	1680	17/04/79	13:00	18/04/78	13:00	✓	✓	✓
HELIOS1	1681	03/05/79	10:00	05/05/78	01:00	✓	x	x
HELIOS 1	1681	18/05/79	05:00	22/05/78	16:00	✓	✓	✓
HELIOS 1	1682/1683	06/06/79	06:00	12/06/79	16:00	✓	✓	✓
HELIOS 2	1686	07/10/79	15:00	09/10/79	16:00	x	x	no magnetometer
HELIOS 1	1687	27/10/79	01:00	31/10/79	08:00	✓	✓	✓
HELIOS 2	1688	31/10/79	10:00	02/11/79	03:00	✓	✓	no magnetometer
HELIOS 2	1688	10/11/79	17:00	16/11/79	16:00	✓	?	no magnetometer
HELIOS 2	1688	23/11/79	16:00	24/11/79	22:00	✓	?	no magnetometer
HELIOS 1	1689	22/11/79	17:00	24/11/79	06:00	✓	✓	✓
HELIOS 2	1692	22/02/80	07:00	24/02/80	02:00	✓	?	no magnetometer
HELIOS 1	1695	13/05/80	09:00	19/05/80	01:00	✓	✓	✓
HELIOS 1	1695	25/05/80	15:00	26/05/80	15:00	x	x	x
HELIOS 1	1695	31/05/80	12:00	03/06/80	12:00	✓	✓	x
HELIOS 1	1695	06/06/80	06:00	07/06/80	10:00	x	x	x
HELIOS 1	1696	28/06/80	16:00	30/06/80	22:00	✓	✓	✓
HELIOS 1	1699	27/09/80	10:00	28/09/80	12:00	✓	✓	✓
HELIOS 1	1703	14/12/80	06:00	15/12/80	22:00	x	x	x
HELIOS 1	1709	07/06/81	01:00	10/06/81	12:00	✓	✓	✓
HELIOS 1	1717	28/12/81	01:00	02/01/82	17:00	✓	?	no magnetometer
HELIOS 1	1723	30/06/82	12:00	03/07/82	03:00	✓	?	no magnetometer

Occurrence



- Where/when to find it?
 - Solar maximum
 - Close to the Sun
- How significant is it?:
 - **8%** of the **mission** time
 - **17%** of the **perihelion** time
 - **~40%** of the **perihelion** time during activity **maximum**

Disparition at 1 AU

MHD propagation (Tao et al., 2001) without external heating predicts acceleration:

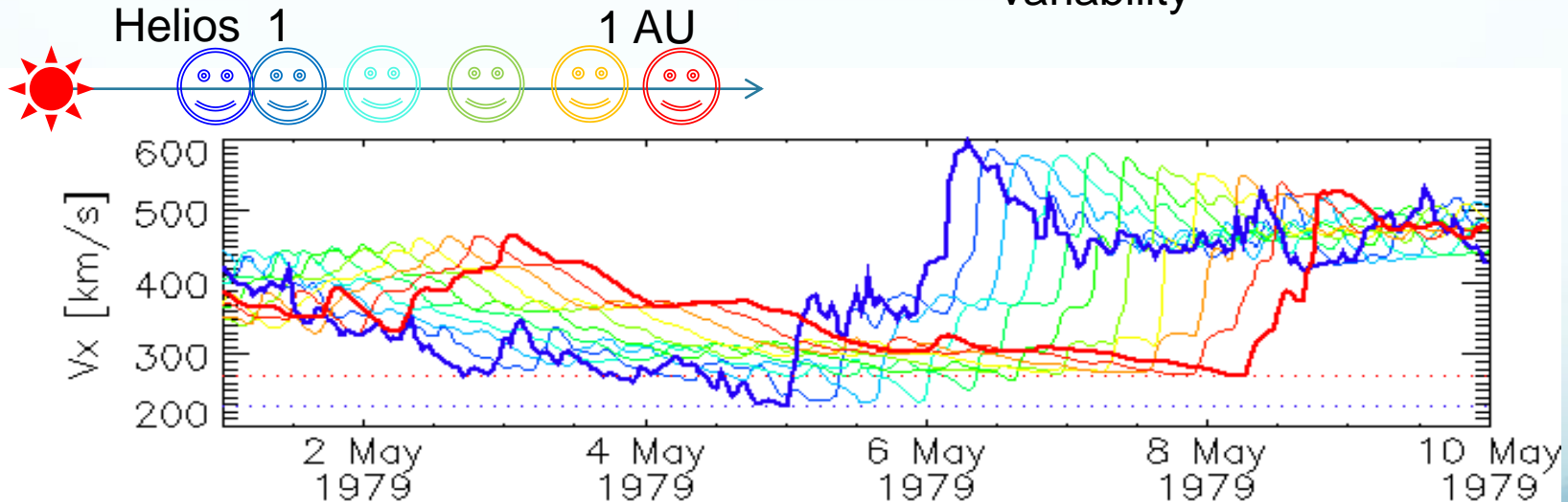
$$\frac{\partial}{\partial t}(\rho v_x S) = - \frac{\partial}{\partial x} \left[\left(\rho v_x^2 + p + \frac{B^2}{8\pi} - \frac{B_x^2}{4\pi} \right) S \right] + \rho \left[g_x + \left(v_y^2 - \frac{B_y^2}{4\pi\rho} \right) \frac{1}{R} \frac{dR}{dx} \right] S + \left(p + \frac{B^2}{8\pi} \right) \frac{dS}{dx}$$

Dynamic pressure

Tao et al., 2001

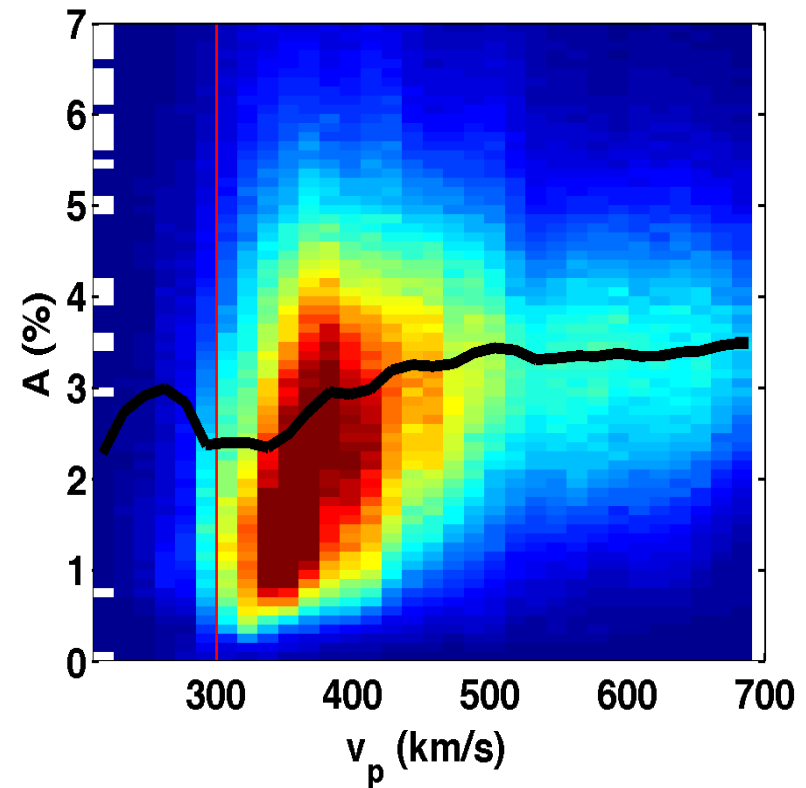
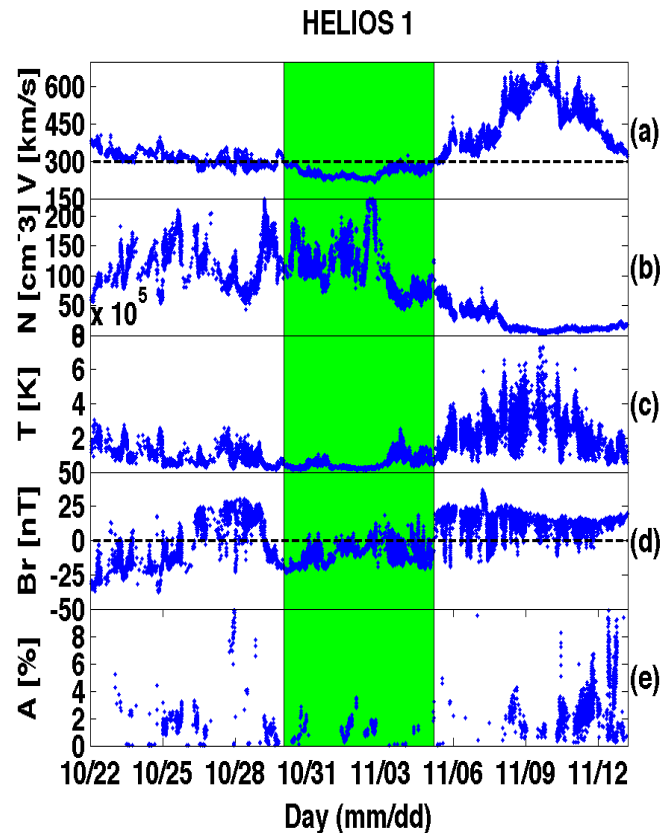
Acceleration at CIRs

Add to the slow wind variability



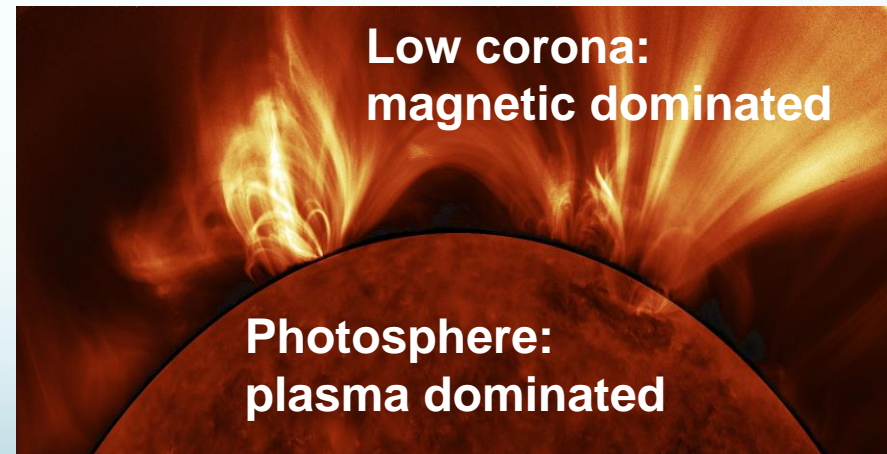
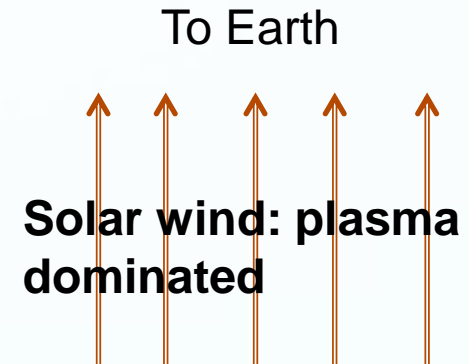
How does the VSSW look like?: in-situ measurements

... But not for He

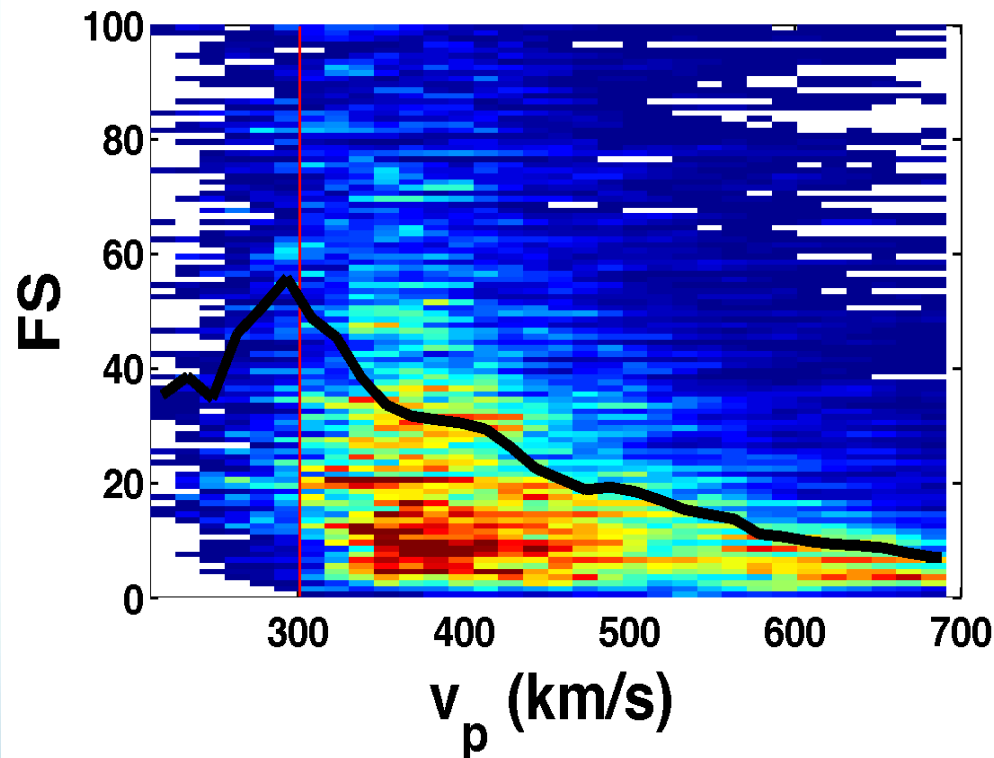


Tracing the solar wind back to the Sun: PFSS model

- Two steps:
 - SW: ballistic tracing back
 - Low corona: PFSS. Plasma follows field lines



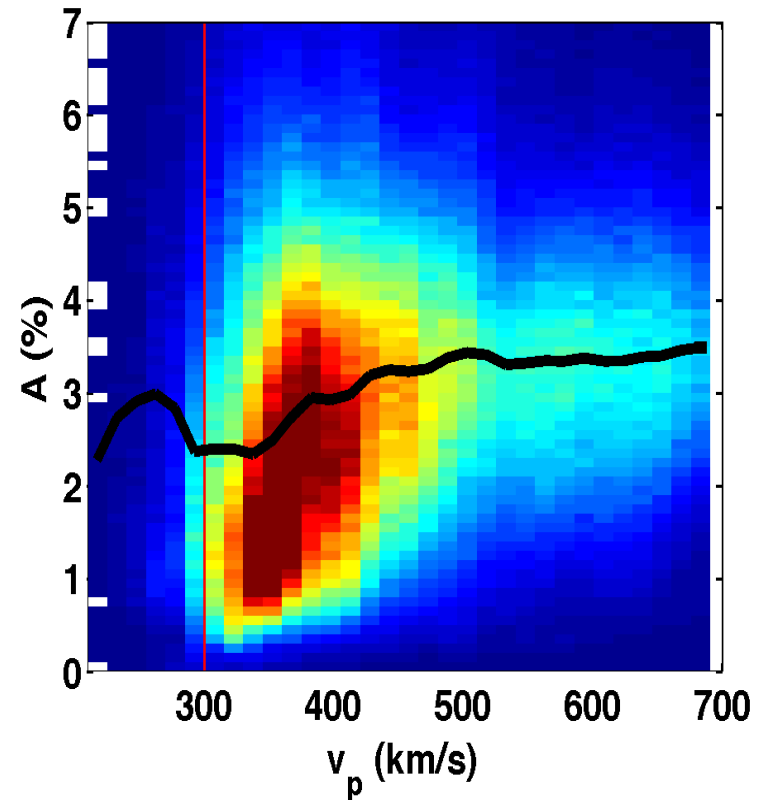
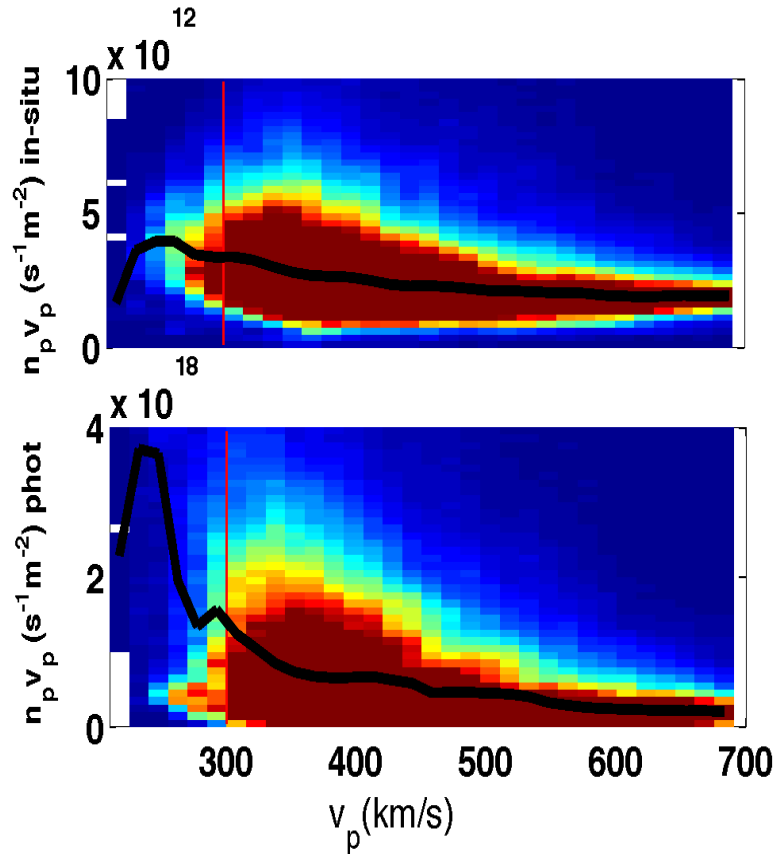
What are the properties of the VSSW source regions?



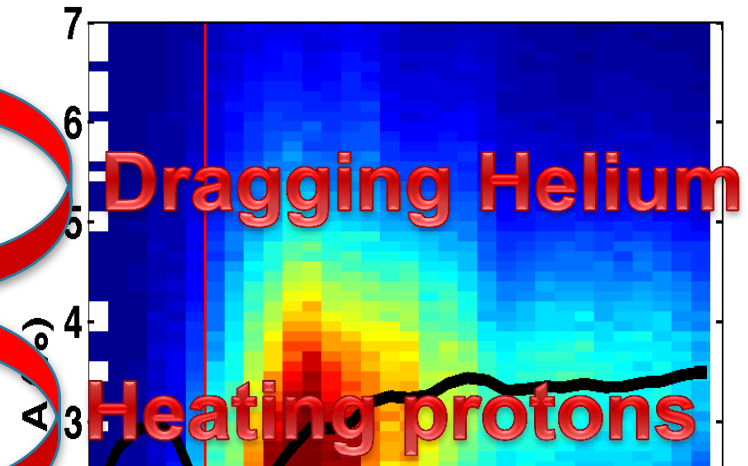
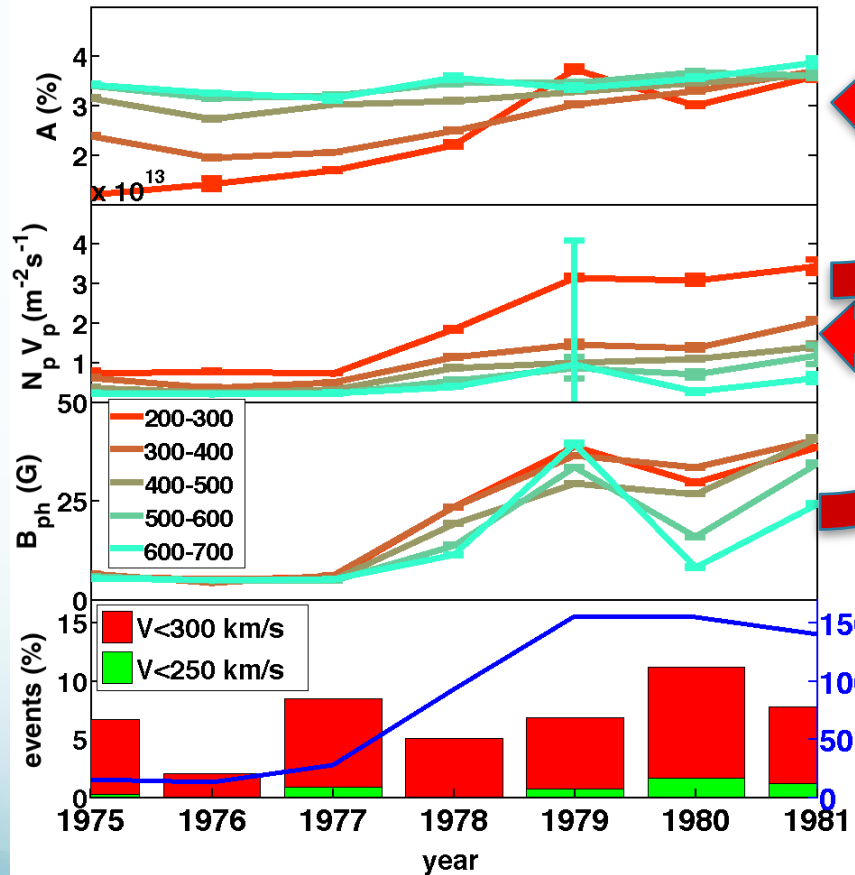
Expansion factor:

- $V > 300$ km/s: known scaling law (anticorrelated to speed)
- $V < 300$ km/s: expansion factor correlated to speed

How does the VSSW look like?: solar origin



Variability



1D solar wind model
(Pinto et al., 2009)

2 fluids collisional model
(Blelly et al., 2005)

Frictional force
Between H and
He

Conclusions

- Close to the Sun, solar wind speed extends down to 200 km/s, specially at solar maximum
- Very low speeds disappear in SIR
 - Composition, density remain → Add to slow wind variability.

Future work

- Model acceleration of VSSW: Is He drag efficient?
- Combination with images of blobs: are they as slow as the VSSW at 0.3 AU?
 - STEREO: catalogue of blobs with their speeds
 - SolarOrbiter/SolarProbePlus: in-situ+remote VSSW