

Velocity Distribution Functions of Pickup Ions with Ulysses/SWICS

Master Thesis Results

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October 21, 2020

Outline

Pickup Ions

Motivation

Ulysses SWICS

Methods – The Virtual Detector

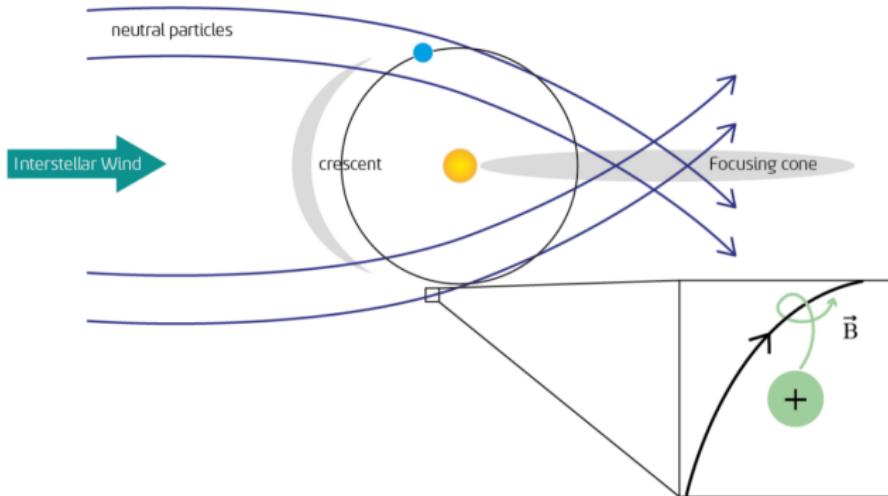
Results – 3D VDF

Outlook & Summary

Pickup Ions

Pickup Ions:

Former neutrals that get ionised within the heliosphere



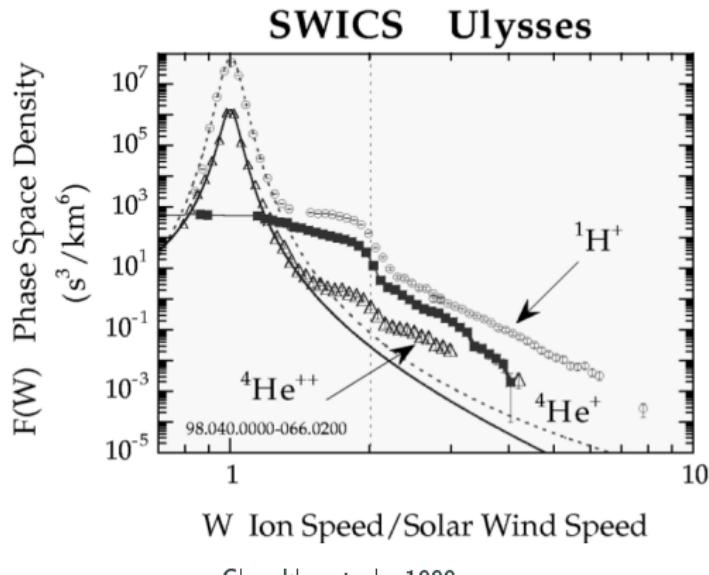
PUI – Measurement

Observed PUIs:

H^{1+} , ${}^3\text{He}^{1+}$, He^{1+} ,
 He^{2+} , C^{1+} , N^{1+} , O^{1+} ,
 Ne^{1+} , Mg^{1+} , Si^{1+} , Fe^{1+}

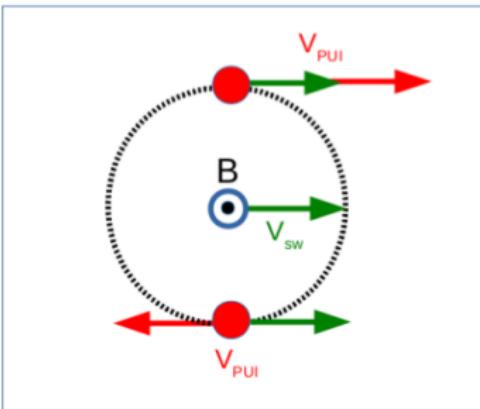
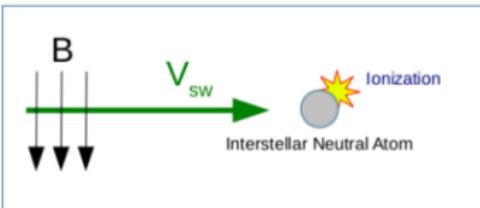
PUI or Solar Wind?

- Charge state
- Velocity distribution function (VDF)

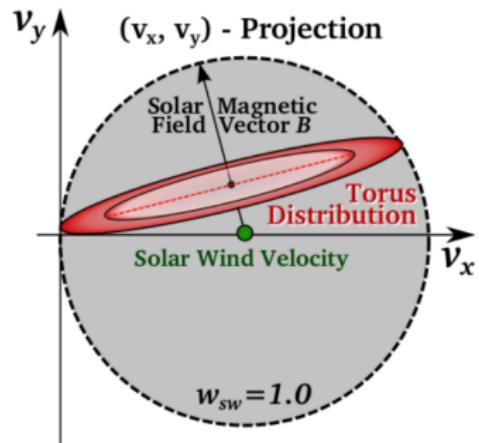


Gloeckler et al., 1999

The Pickup Process



Velocity Space:

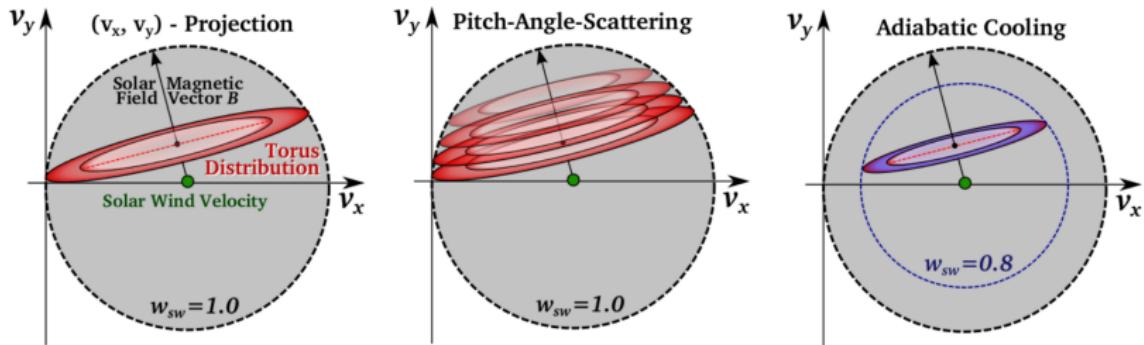


Drews et al., 2016

Taut, Drews et al., AGU Fall Meeting 2014

→ Anisotropic torus VDF

Evolution of the VDF

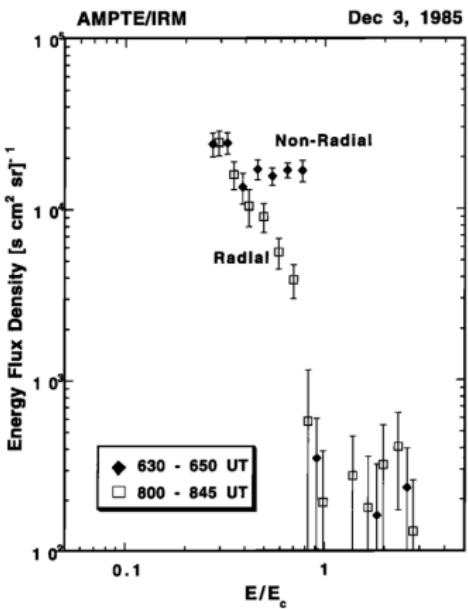


Drews, Berger et al., 2016

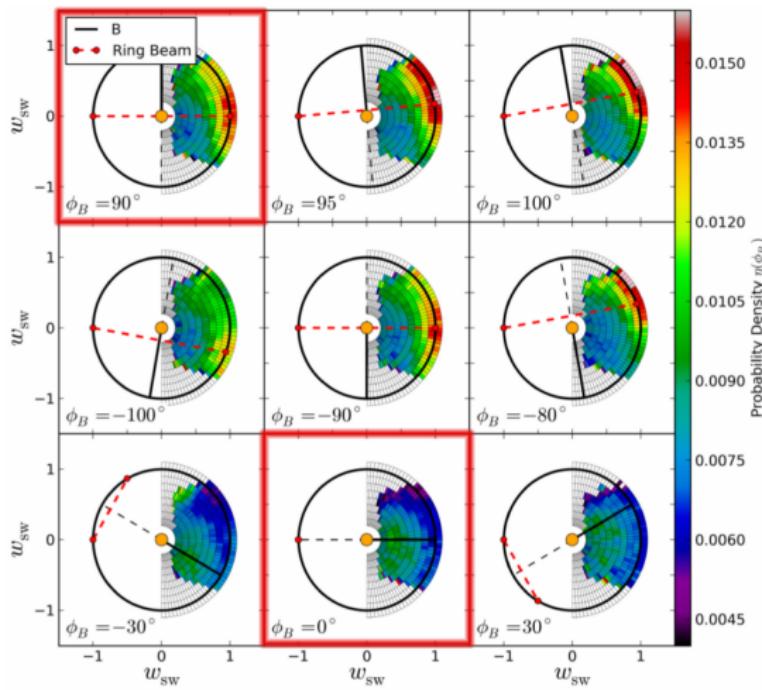
Modification of the
initial torus-shaped VDF
by:

- Pitch-angle scattering
→ isotropisation
- acceleration & deceleration

Anisotropic features of the VDF



Moebius et al., 1998



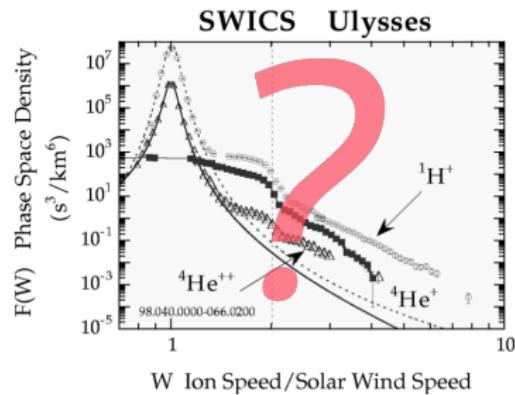
Drews, Berger et al., 2015

Motivation

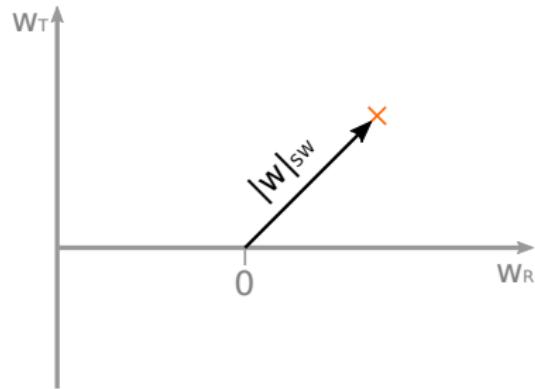
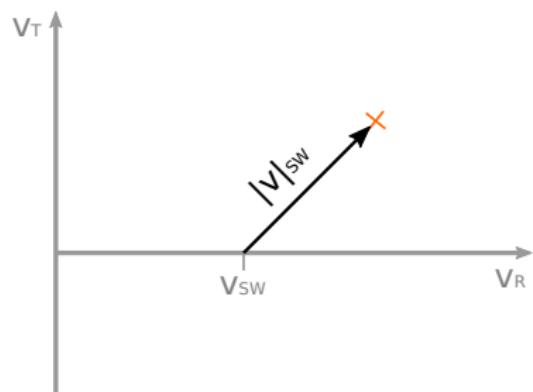
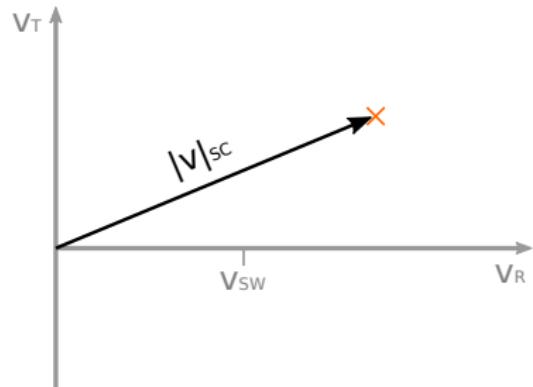
Problem:

Ambiguity of 1D reduced data

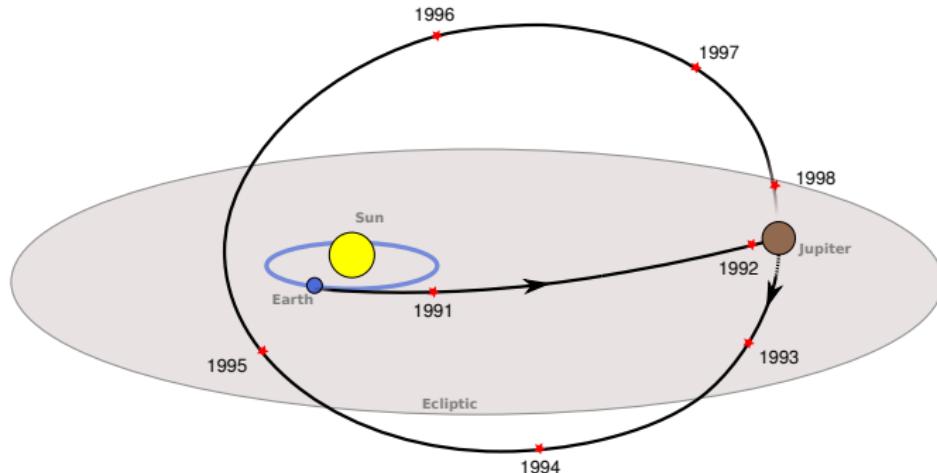
For fully understanding the
PUI transport in phase space
we need to analyse the **3D**
velocity distribution function



Frame of Reference

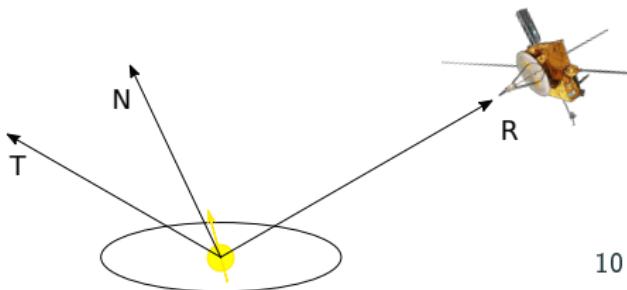


Ulysses Spacecraft (1990 – 2009)



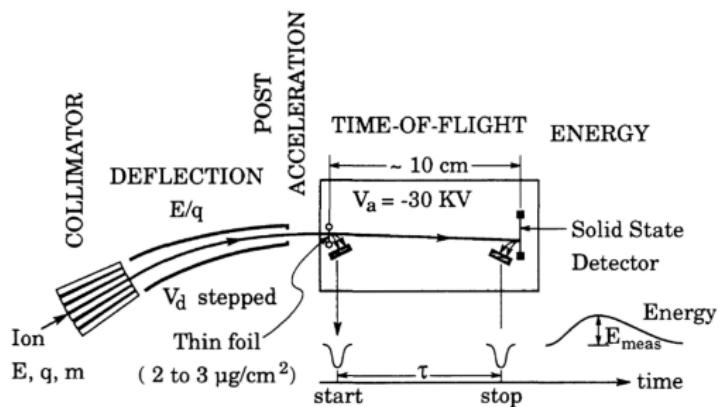
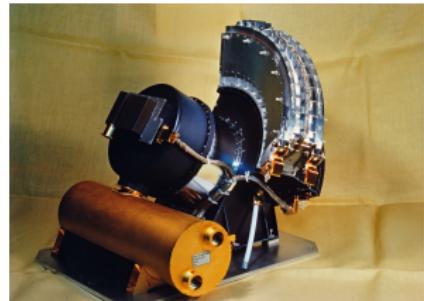
adapted from www.cosmos.esa.int, 2019

- Highly inclined orbit;
orbital period: 6.2 years
- spin-stabilized



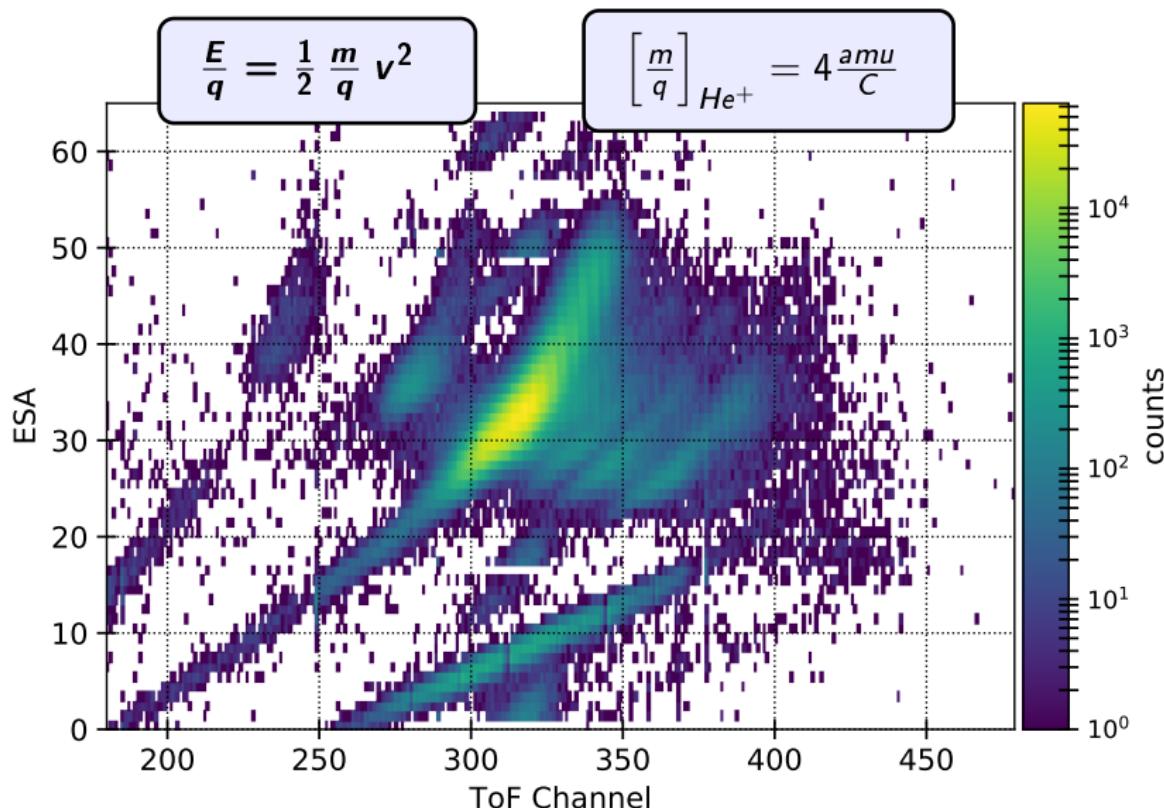
The Solar Wind Ion Composition Spectrometer

- Time-of-flight mass spectrometer
- $\left\{ \frac{E}{q}, \text{ToF}, E_{SSD} \right\}$
 $\Rightarrow \left\{ \frac{M}{q}, M, |v| \right\}$
- identification & energy of the ion

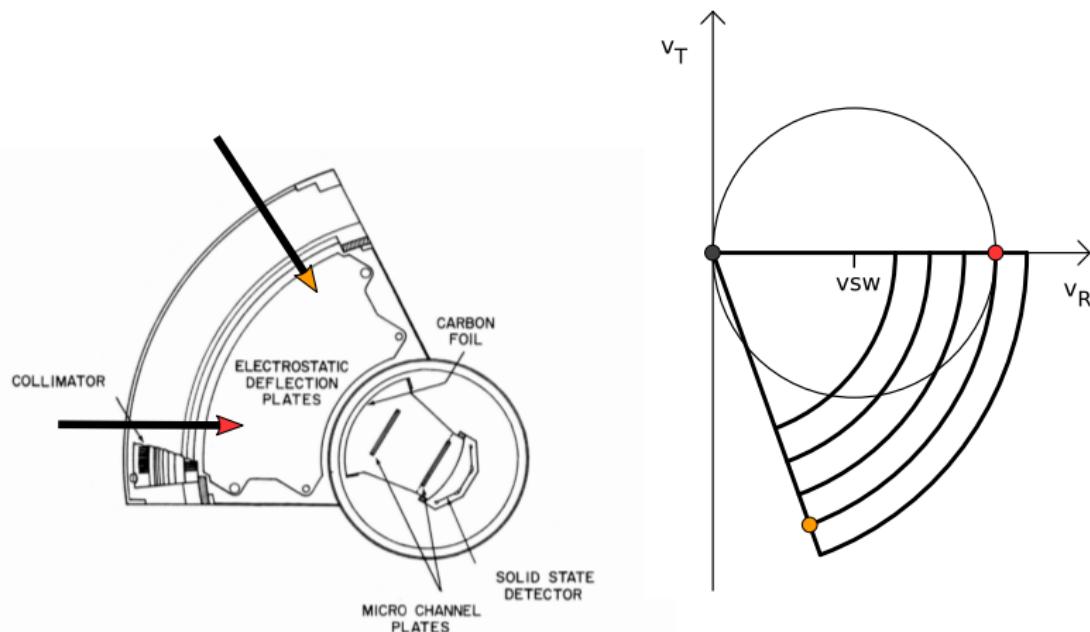


Gloeckler, Geiss et al., 1992

PHA data

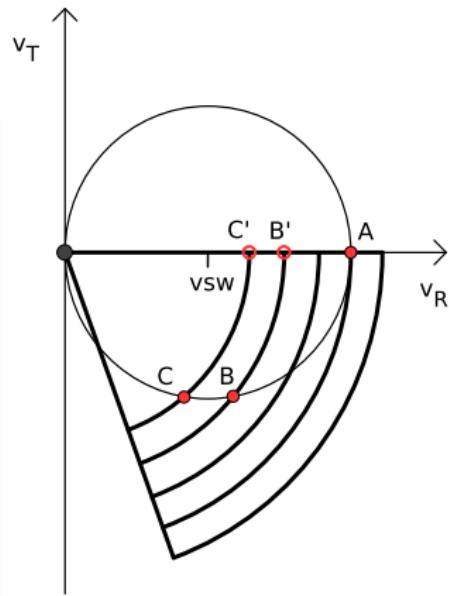
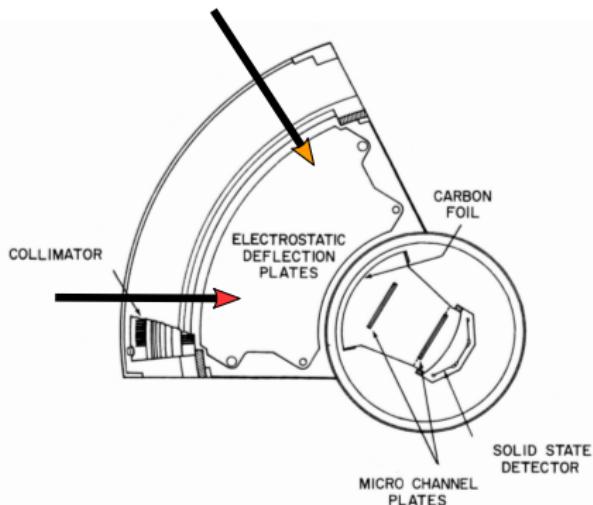


EpQ measurement



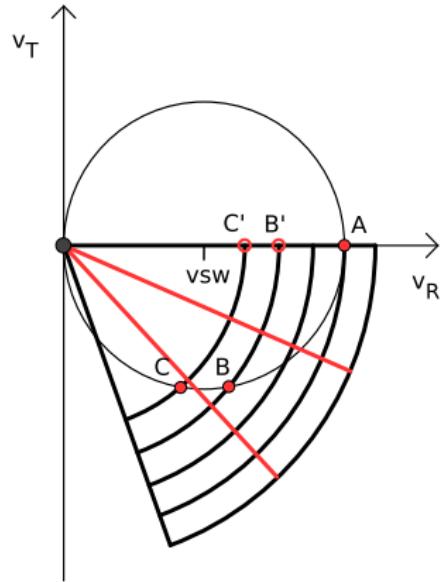
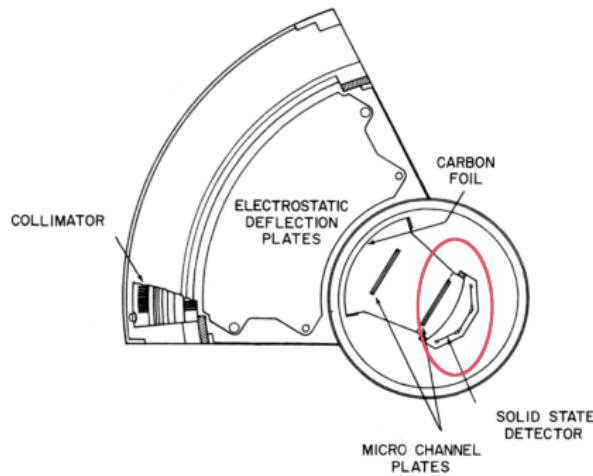
- For constant $\frac{m}{q}$: $\frac{E}{q}$ -step $\hat{=}$ absolute value of velocity

EpQ measurement



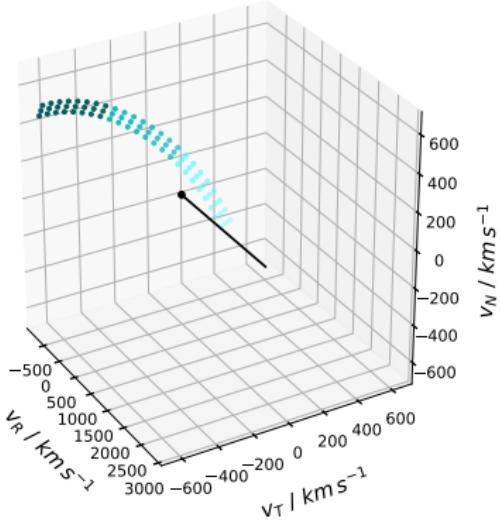
- For constant $\frac{m}{q}$: $\frac{E}{q}$ -step $\hat{=}$ absolute value of velocity
- Integration over EpQ shells \rightarrow loss of information!

Angular resolution

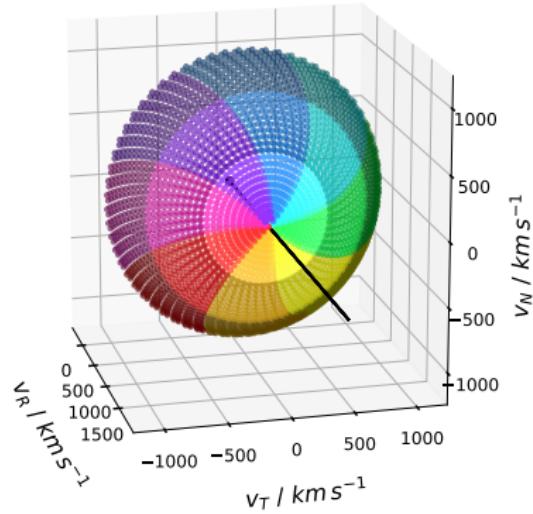


- SWICS: **3 detectors**
Rough distinction between angles of incidence
- 3rd dimension: spin of the SC
Divided into **8 sectors**

The Virtual Detector

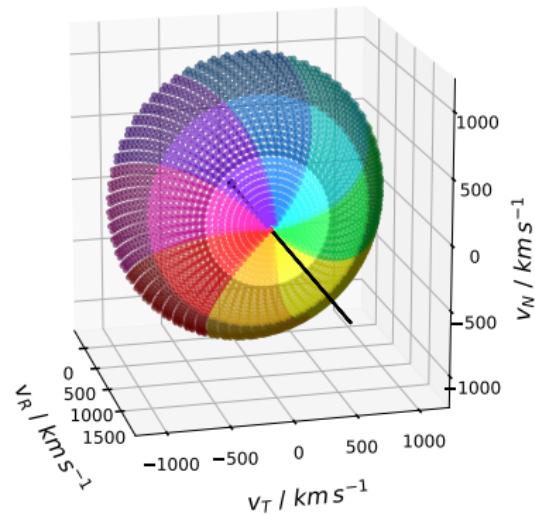
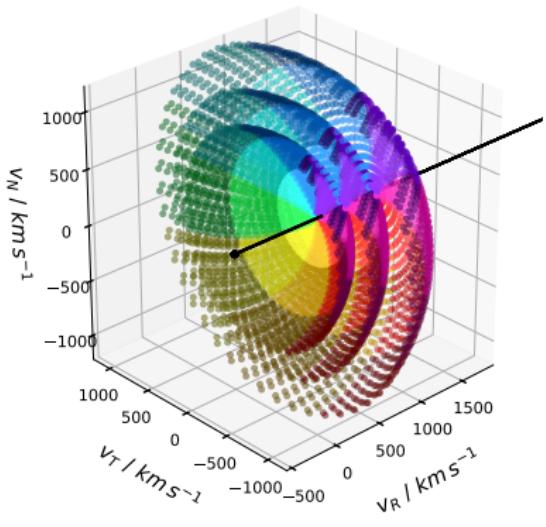


Unrotated collimator acceptance
for one EpQ step

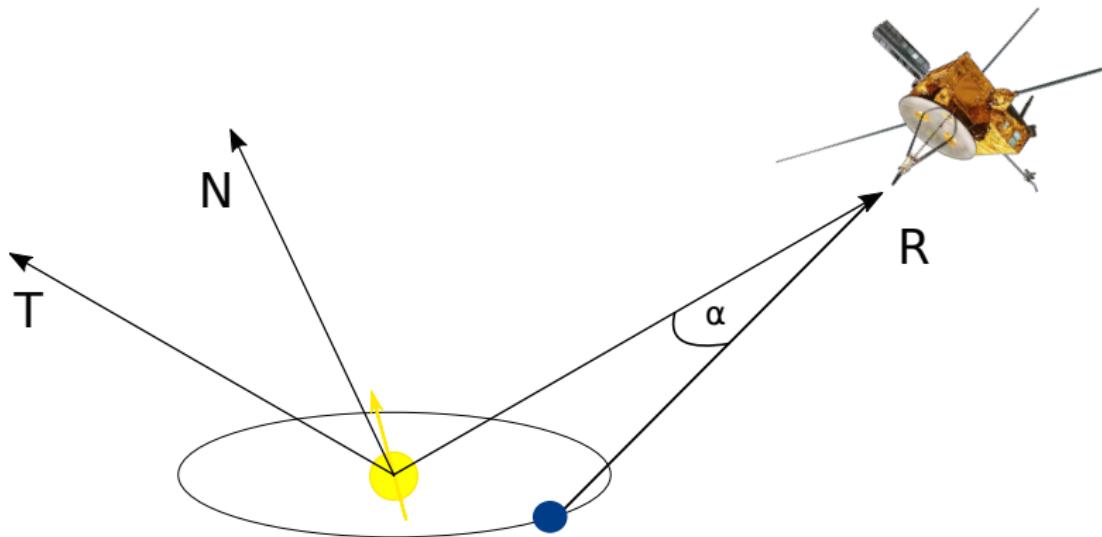


Collimator Acceptance for
one spacecraft spin and one EpQ step

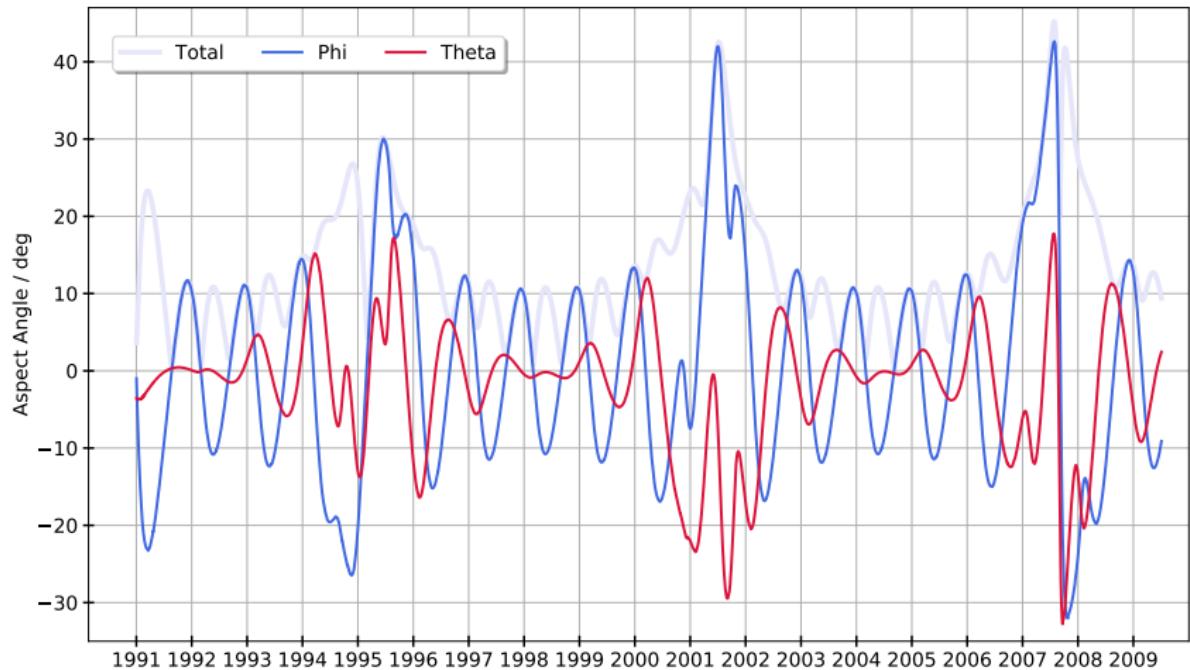
The Virtual Detector



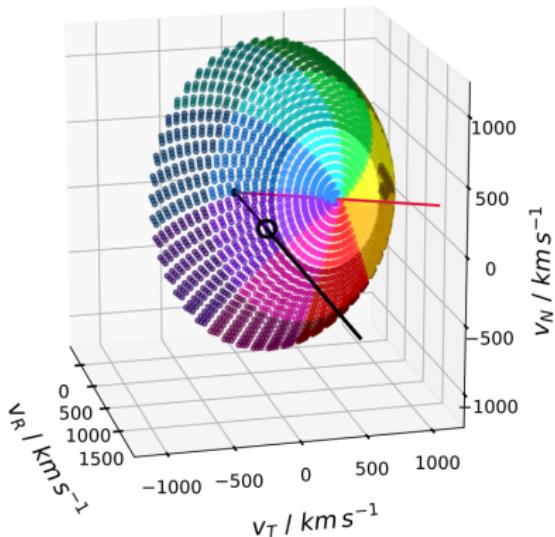
Aspect Angle



Aspect Angle

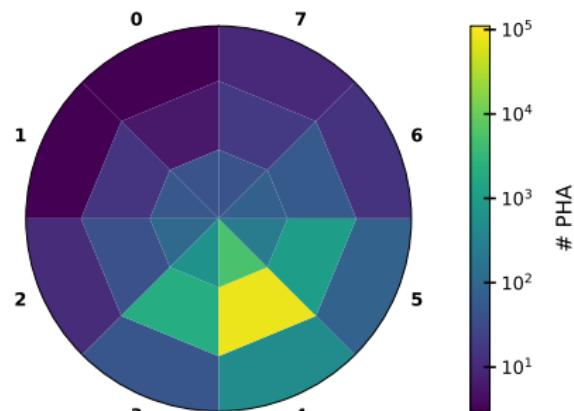


Aspect Angle



Aspect angle:

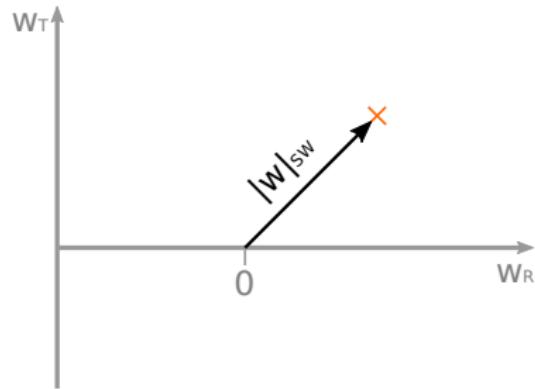
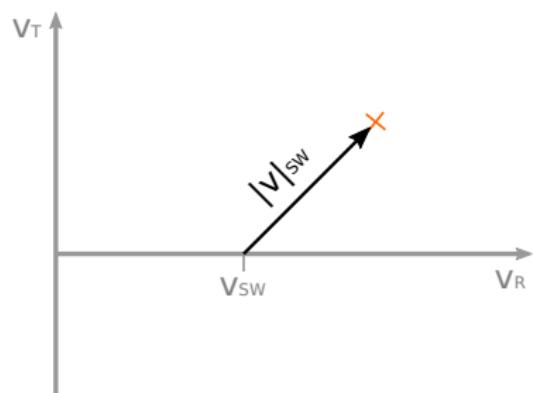
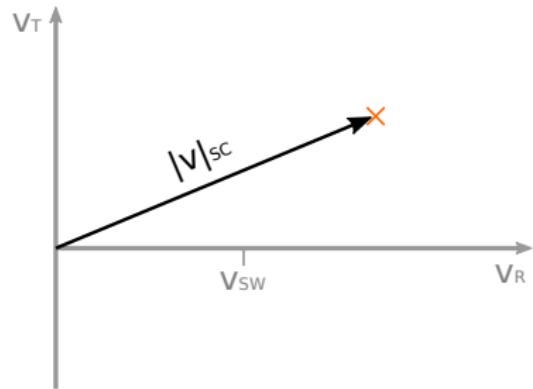
$$\varphi = 25^\circ, \vartheta = -10^\circ$$



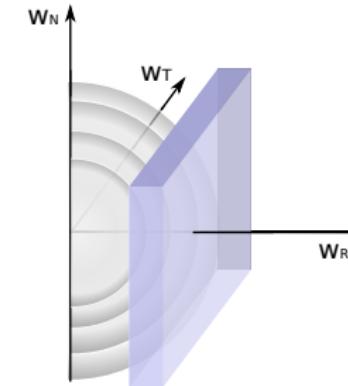
⇒ Plausibility check with
solar wind He²⁺ PHA data

(120 days in 2001)

Frame of Reference



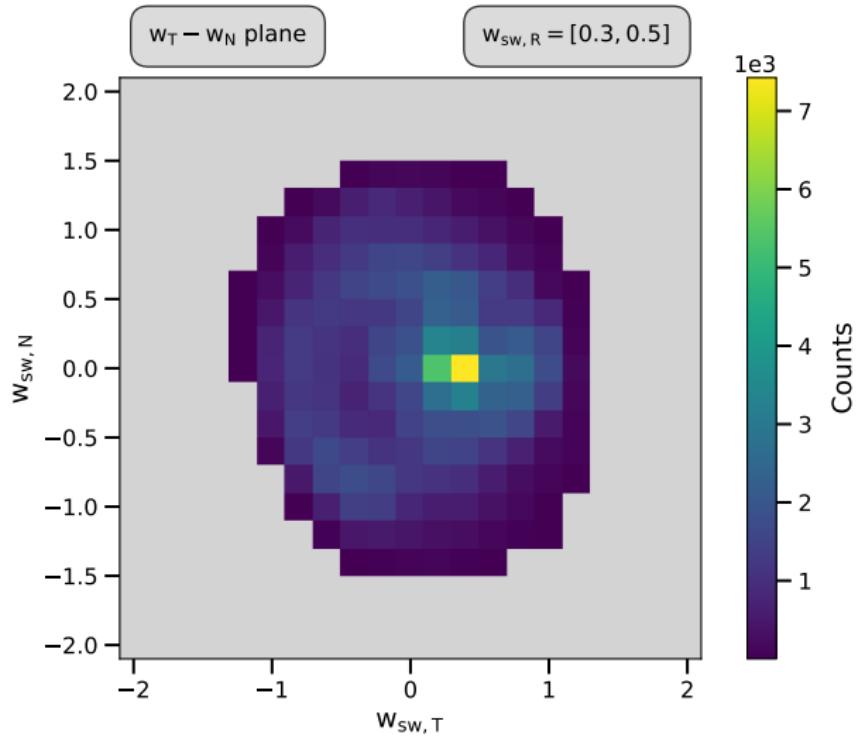
Spherical Cut through VDF



50 days in 1993

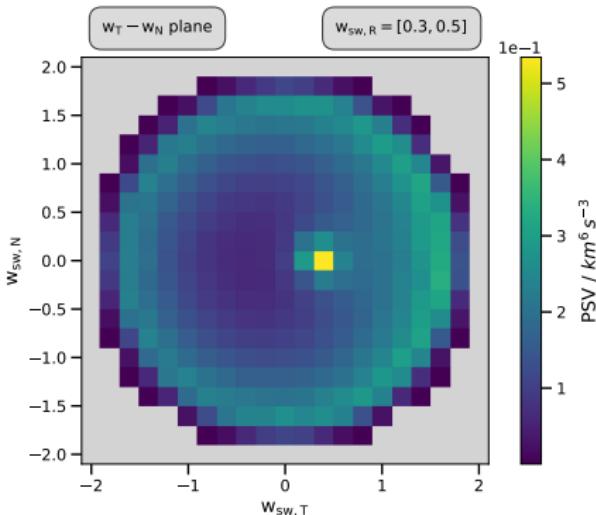
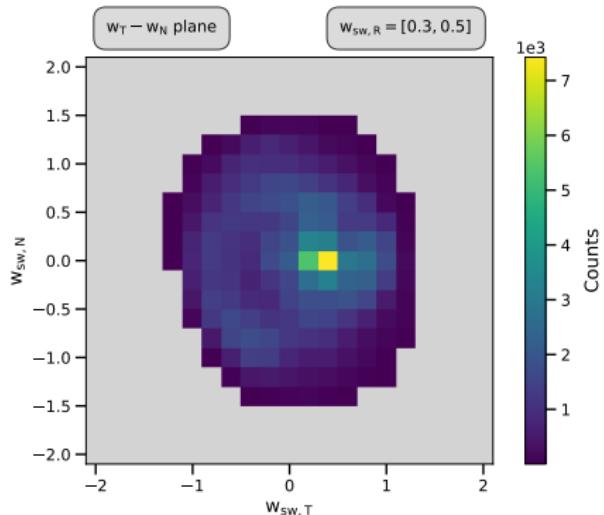
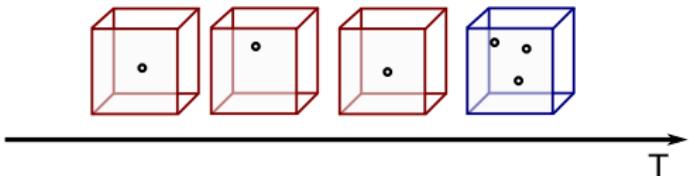
v_{SW} :

760 – 780 km s⁻¹

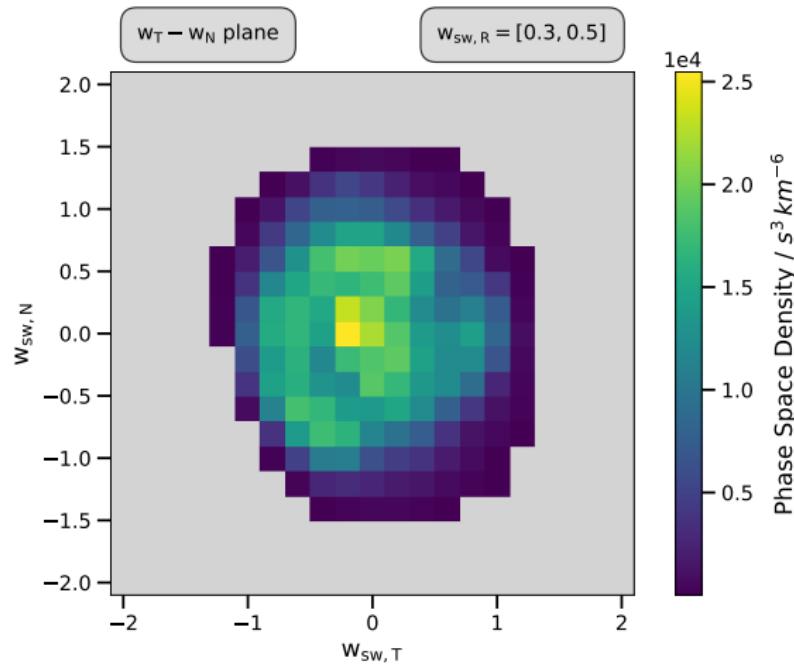
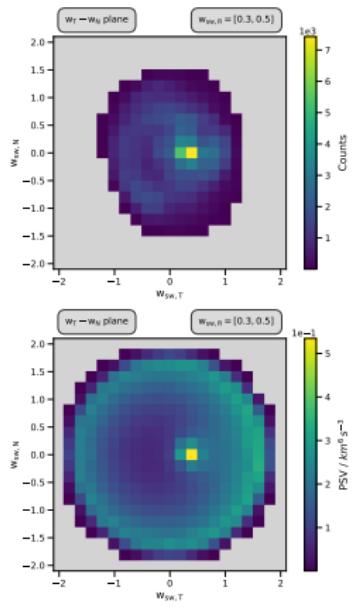


From Counts to Phase Space Density

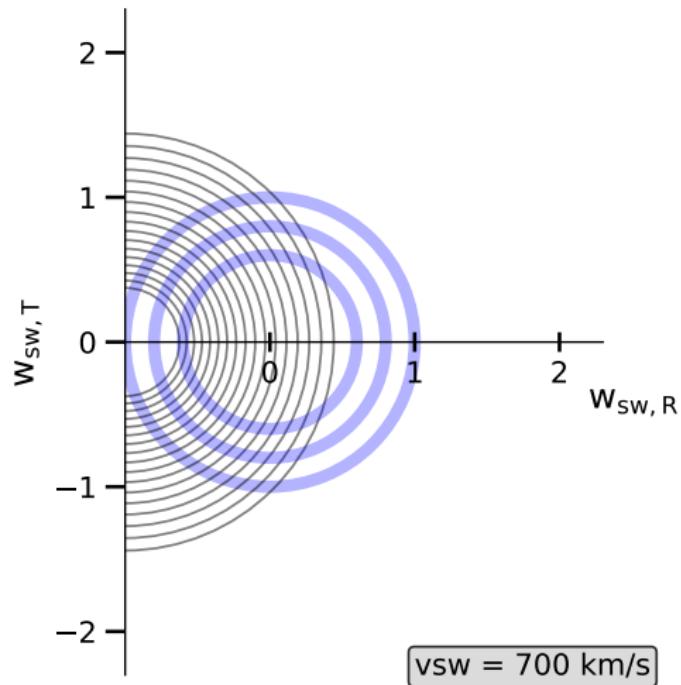
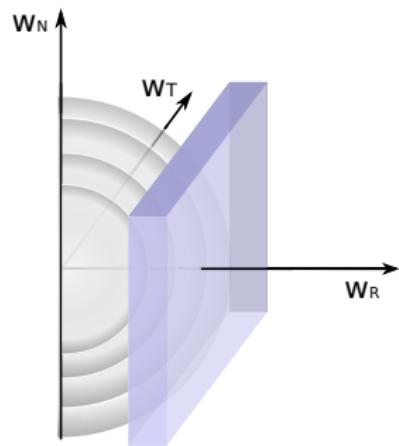
$$PSD = \frac{N}{PSV}$$



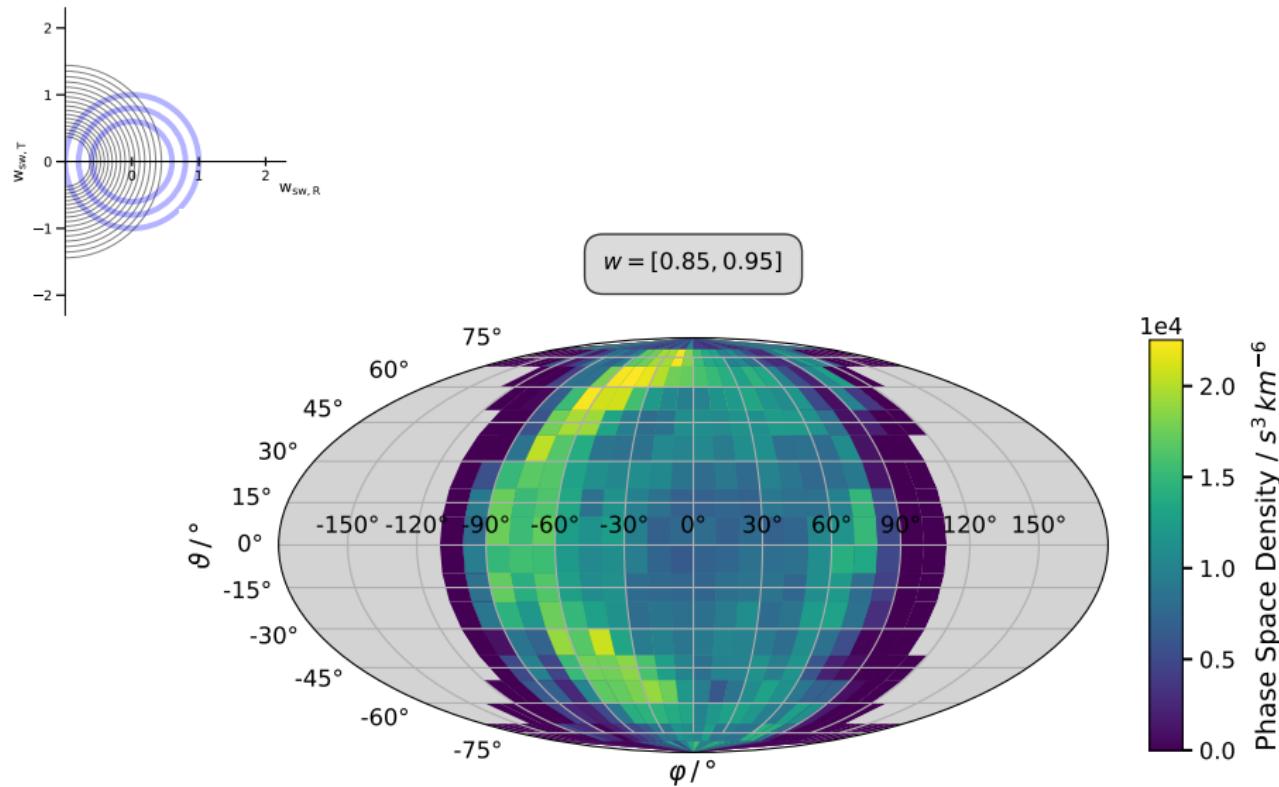
Spherical Cut through VDF



Spherical Surface

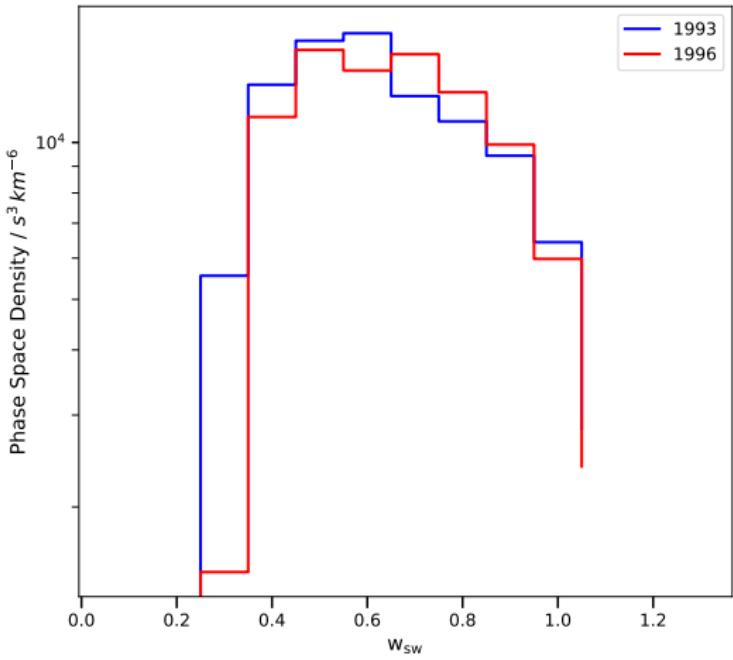
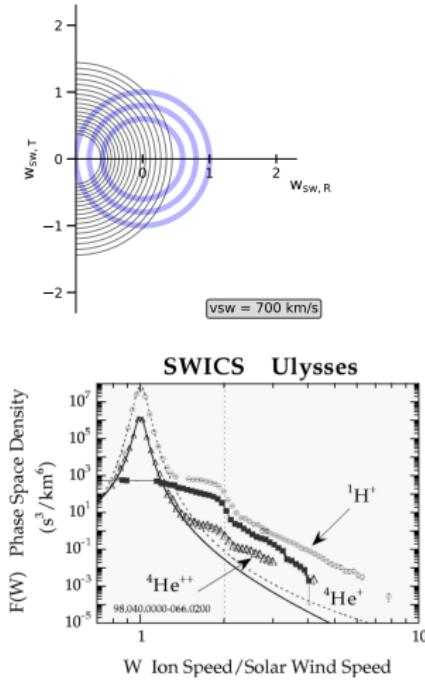


Spherical Surface



vsw : $760 - 780 \text{ km s}^{-1}$ – 50 days in 1993 25

1D Spectrum

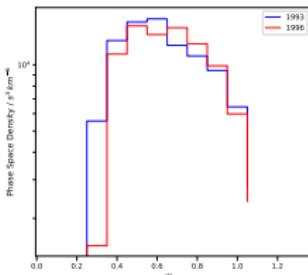
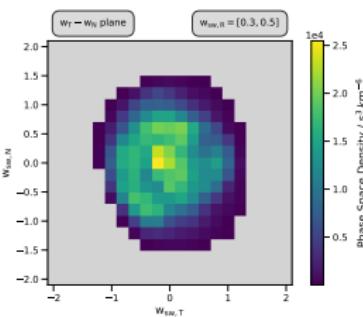
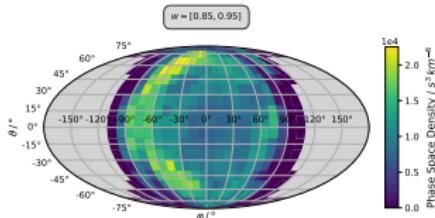


$v_{SW} : 760 - 770 \text{ km s}^{-1} - 100 \text{ days each in 1994, 1996}$

Summary & Outlook

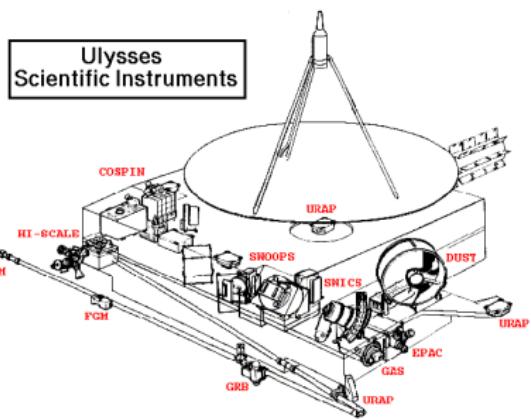
- He⁺ data from Ulysses SWICS
- Virtual Detector
- Geometrical Effects
- Phase Space Normalisation

⇒ 3D measurement of PUI VDF

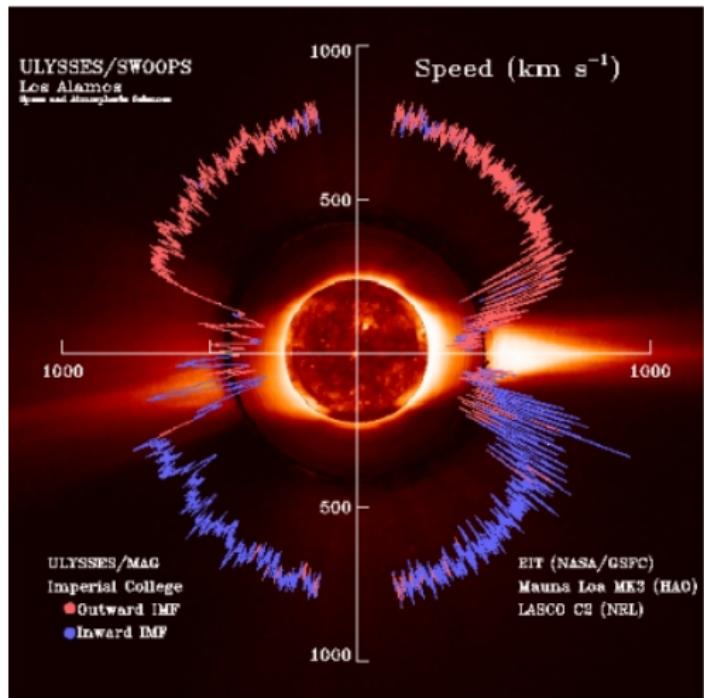


- PUI torus distribution with the IMF
- PUI energy diffusion processes

BACKUP

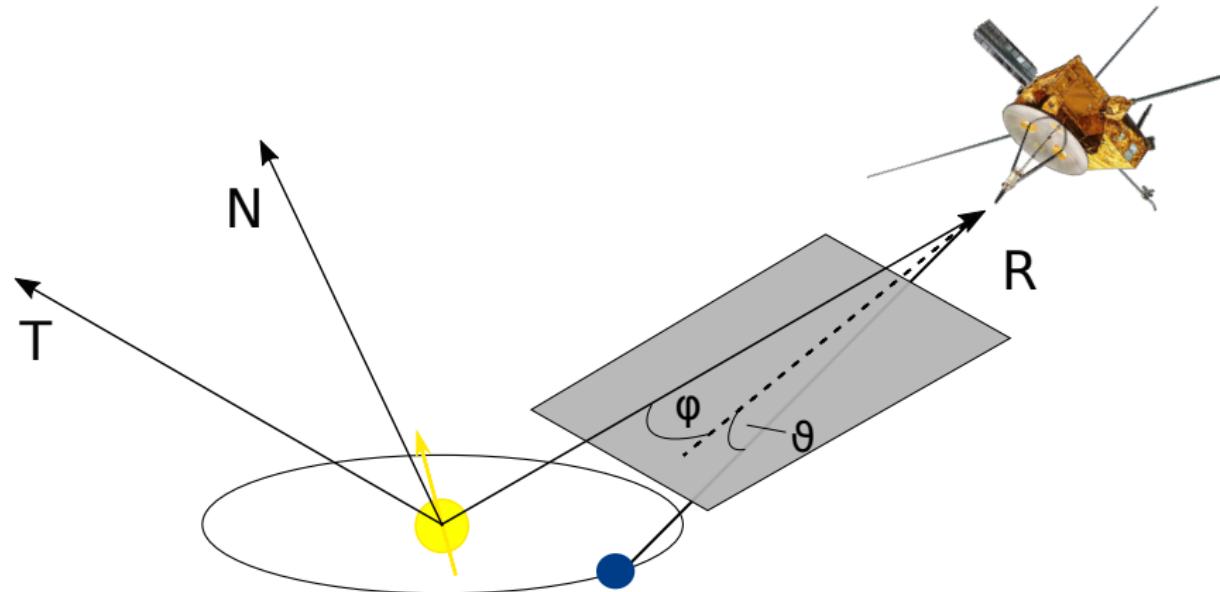


www.cosmos.esa.int, 2019

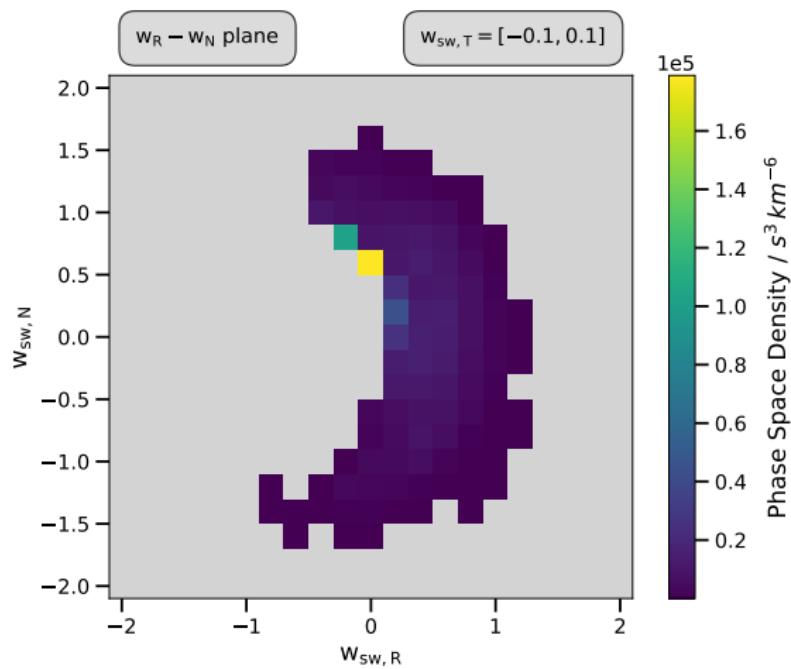
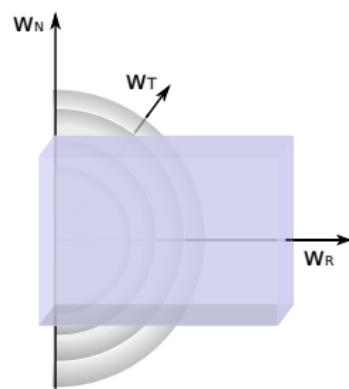


McComas et al., 2000

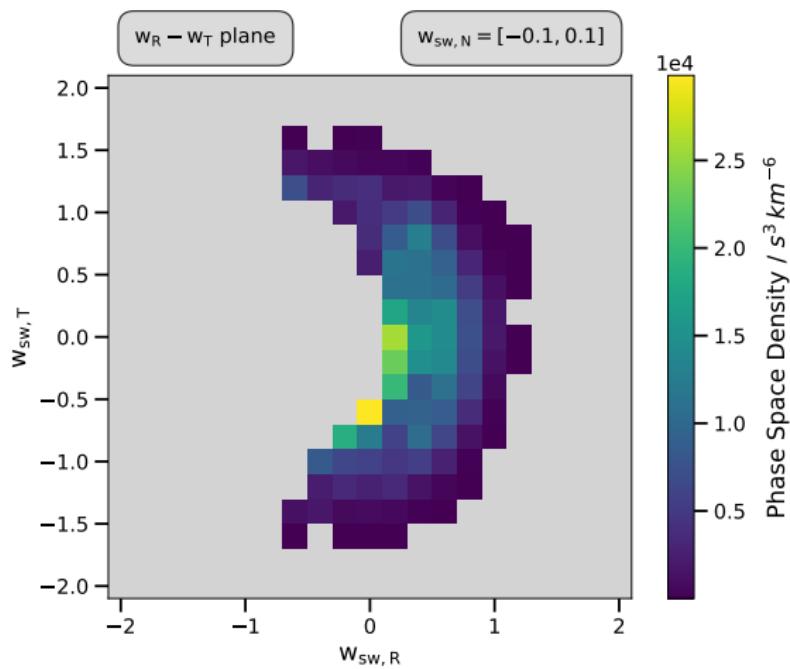
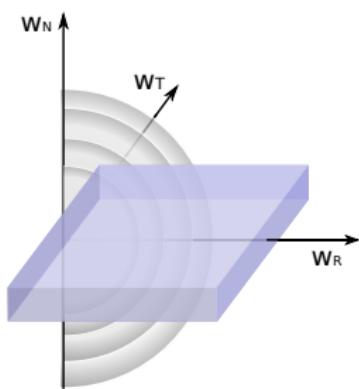
Aspect Angle



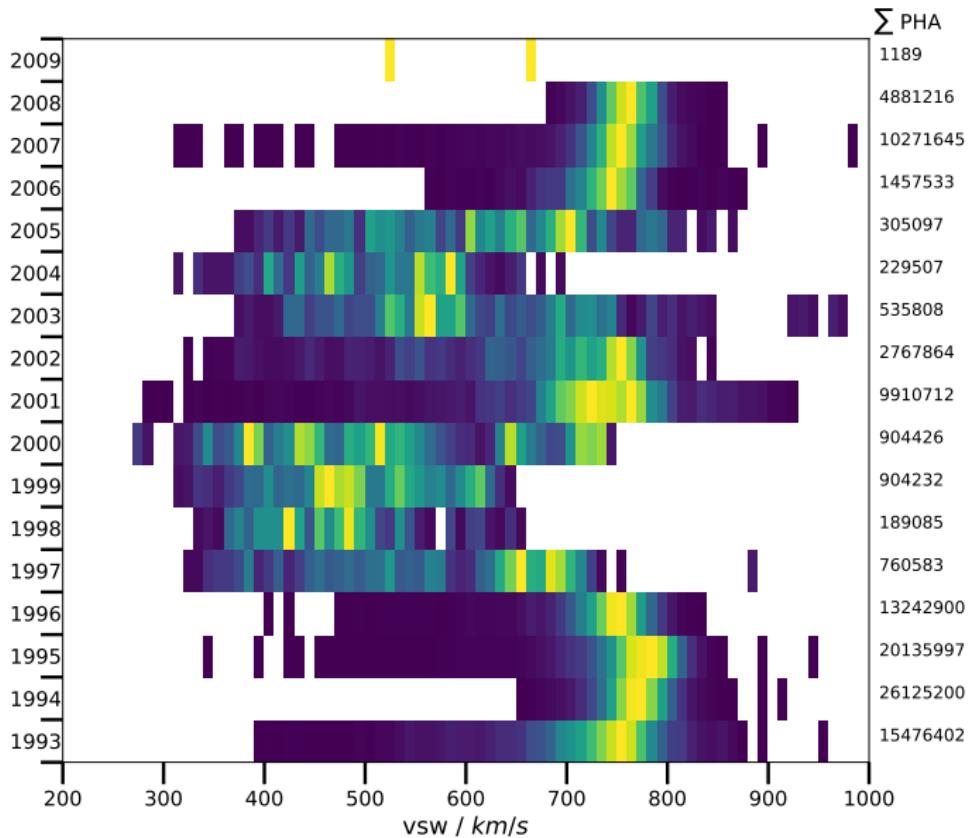
Cartesian Cut: T

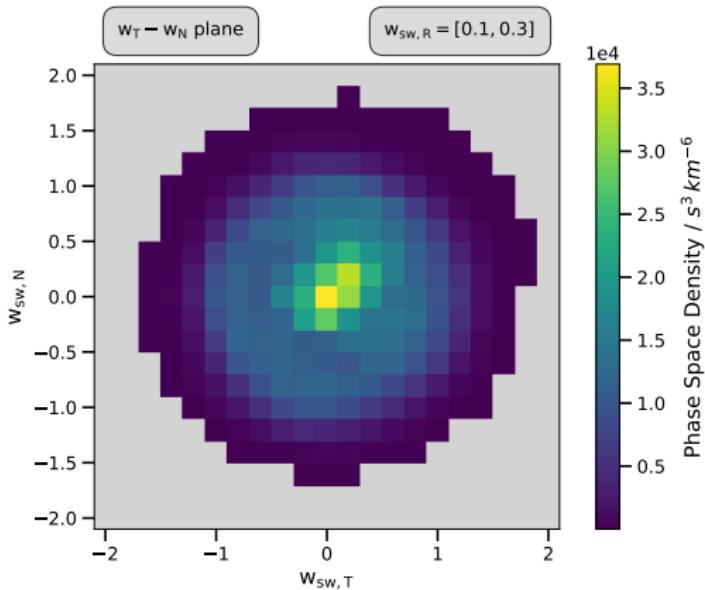
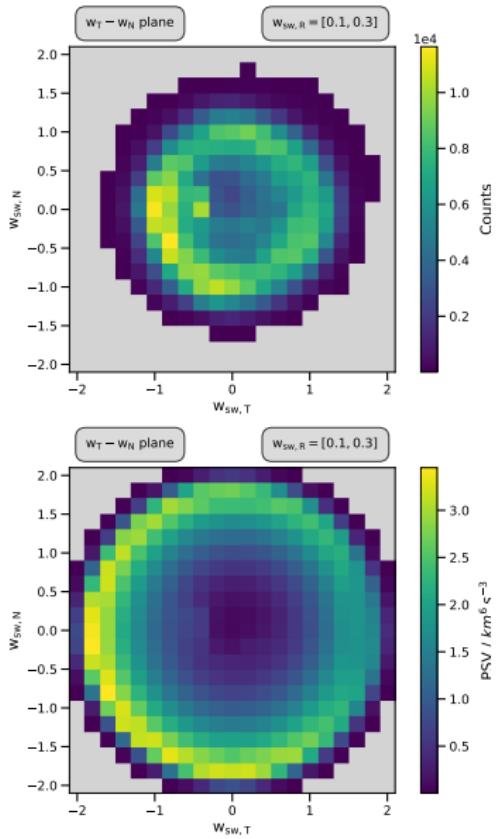


Cartesian Cut: N



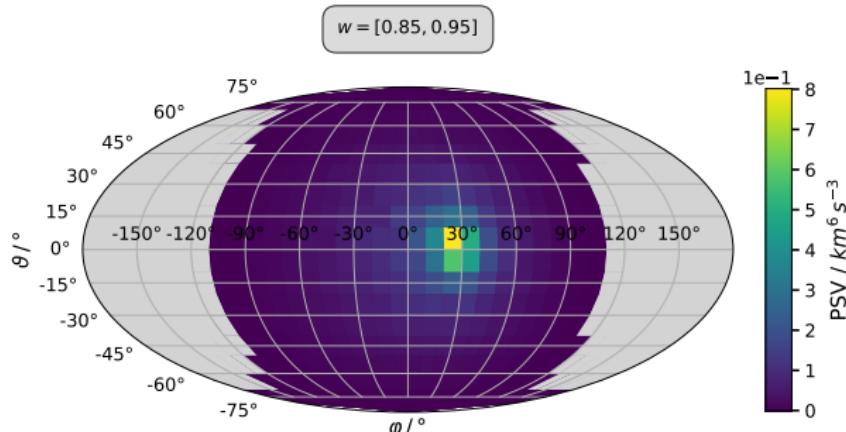
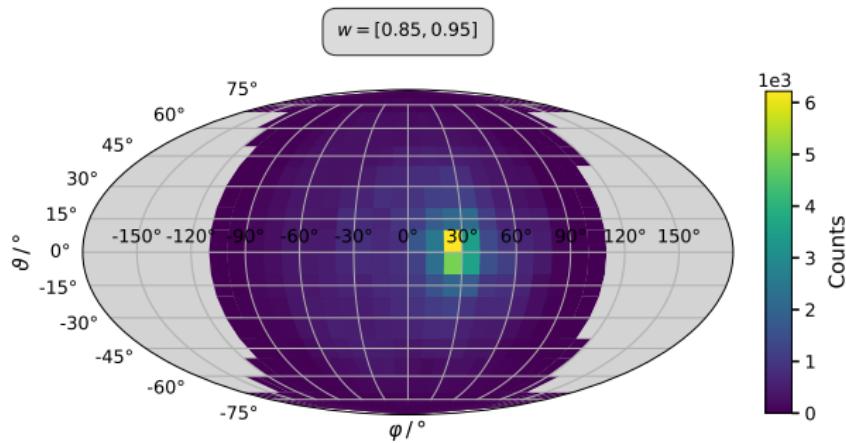
He^+ Data: vsw





$v_{SW} : 740 - 780 \text{ km s}^{-1}$

250 days in 1994



vsw : $760 - 780 \text{ km s}^{-1}$

50 days in 1993

