Velocity Distribution Functions of Pickup Ions with Ulysses/SWICS

Master Thesis

Anne Fischer

November 13, 2019

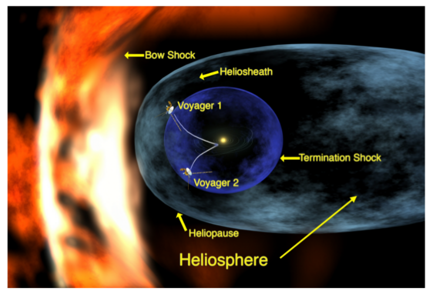
Outline

Pickup Ions Basics

Pickup Ions:
Former neutrals that get ionised within the heliosphere

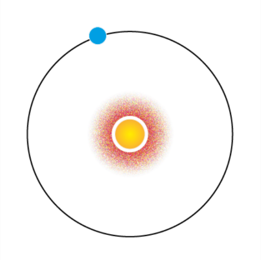
Origin of the neutrals:

- LISM



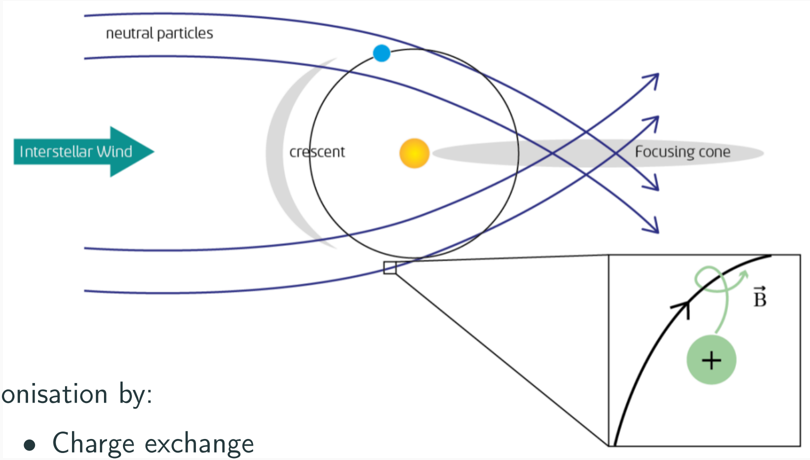
from http://science.nasa.gov

- Inner Source



Taut 2018

The Pickup Process



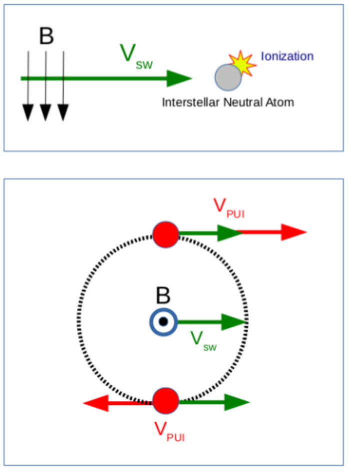
Taut, Drews et al., AGU fall meeting 2014

Ionisation by:

- Charge exchange
- Photoionisation
- Electron impact

→ **Newborn ion is subjected to electromagnetic forces**

The Pickup Process



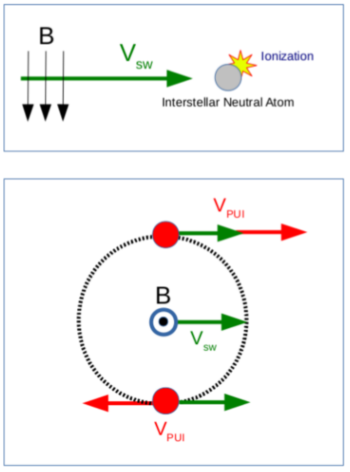
Taut, Drews et al., AGU Fall Meeting 2014

Assumptions:

- particle at rest
- $\vec{B} \perp \vec{v}_{SW}$

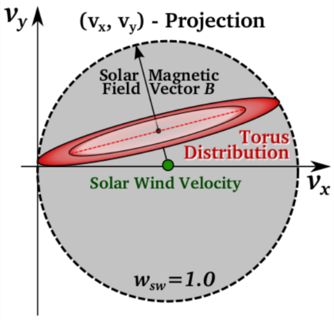
Relative motion
$\rightarrow$ **Gyro-motion**

The Pickup Process



Taut, Drews et al., AGU Fall Meeting 2014

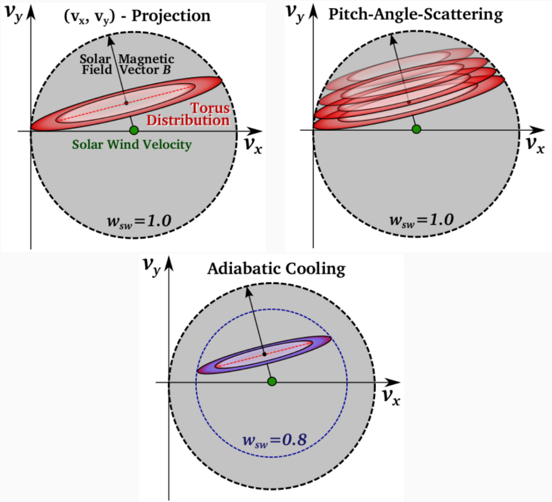
Velocity Space:



Drews et al., 2016

$\rightarrow$ Anisotropic torus VDF

Evolution of the VDF



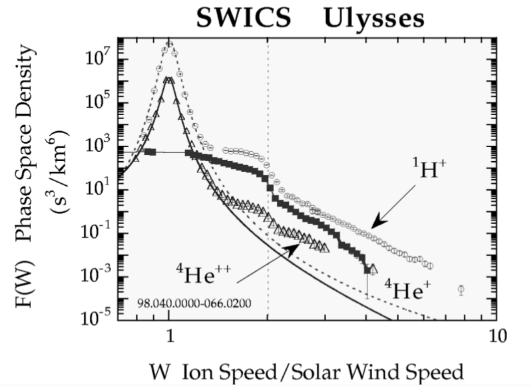
Drews, Berger et al., 2016

PUI – Measurement

Observed PUIs:
H^{1+}, $^{3}He^{1+}$, He^{1+}, He^{2+}, C^{1+}, N^{1+}, O^{1+}, Ne^{1+}, Mg^{1+}, Si^{1+}, Fe^{1+}

PUI or Solar Wind?

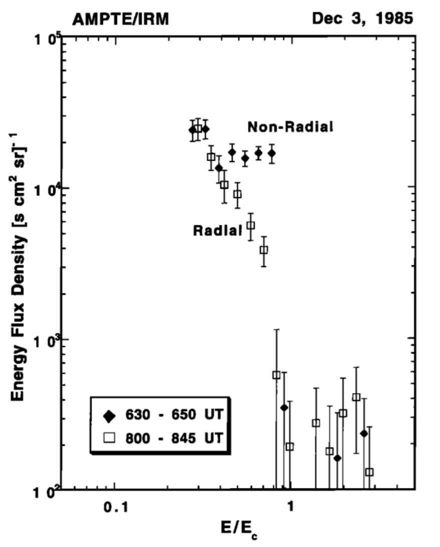
- Charge state
- Velocity distribution function (VDF)



Gloeckler et al., 1999

Anisotropic features of the VDF

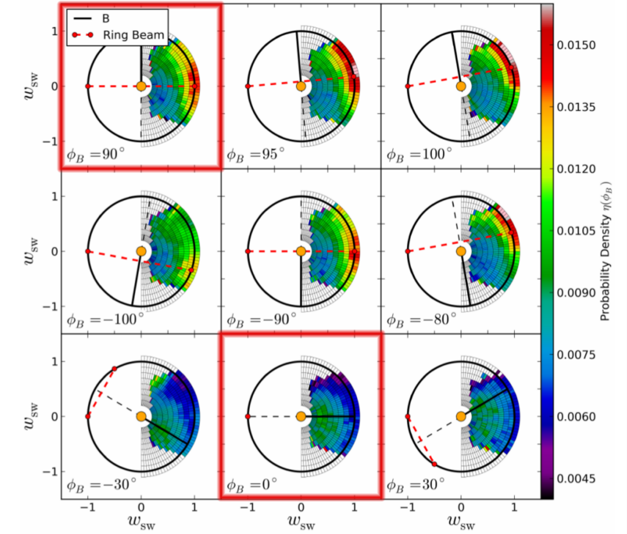
1D measurements discover **anisotropic features** of the VDF



Moebius et al., 1998

Anisotropic features of the VDF

- STEREO / PLASTIC: angular resolution $\rightarrow$ 2D measurement
    - anisotropic feature
    - $\vec{B}$-dependency

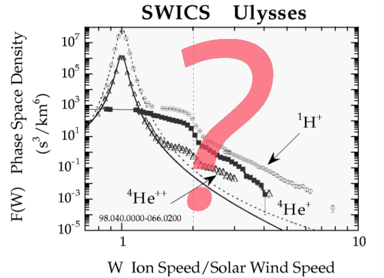


Drews, Berger et al., 2015

Motivation

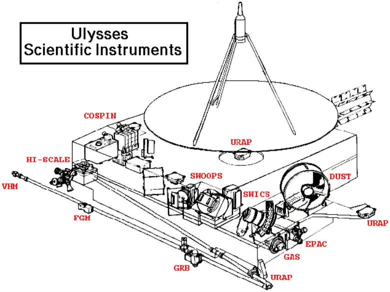
Problem:
Ambiguity of 1D reduced data

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

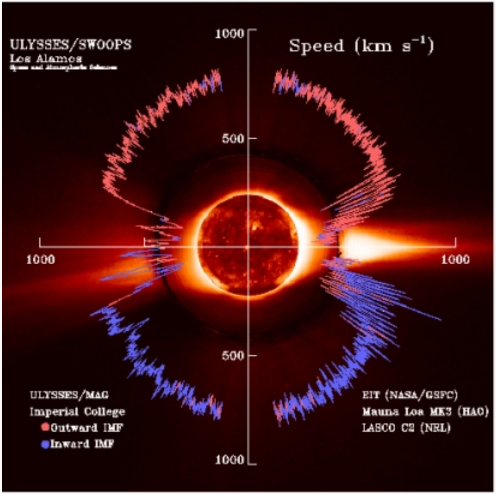


ULYSSES Spacecraft

- Launched 1990 (– 2009)
- Highly inclined orbits above the solar poles $\rightarrow$ unique data!



www.cosmos.esa.int, 2019

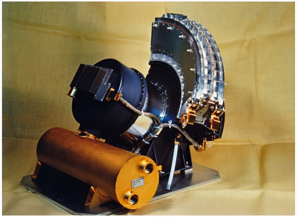


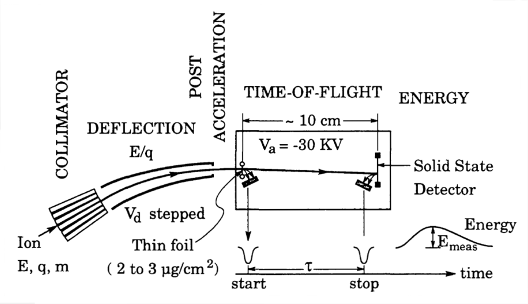
www.sci.esa.int, 2019

SWICS

The **S**olar **W**ind **I**on **C**omposition **S**pectrometer

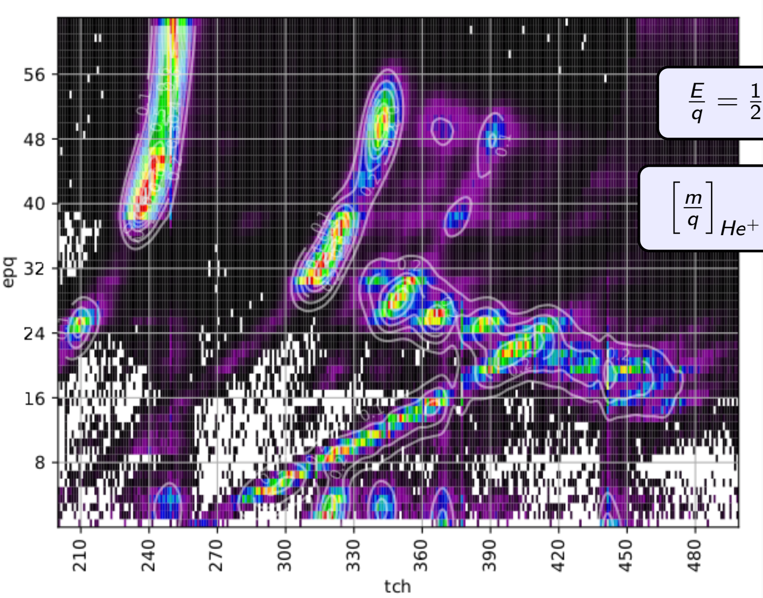
- Time-of-flight mass spectrometer
- $\left\{\frac{E}{q}, ToF, E_{SSD}\right\} \Rightarrow \left\{\frac{M}{q}, M, |v|\right\}$
- identification & energy of the ion





Gloeckler, Geiss et al., 1992

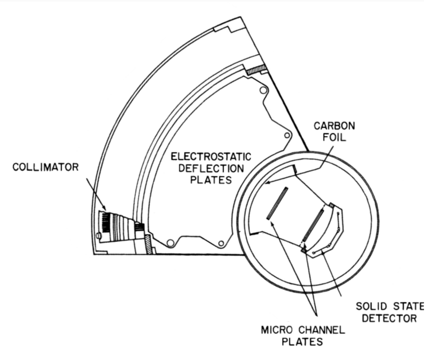
PHA data

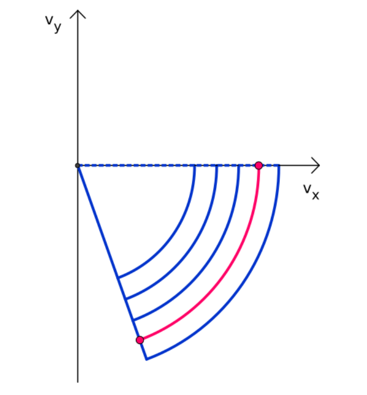


$$\frac{E}{q} = \frac{1}{2}\,\frac{m}{q}\,v^2$$

$$\left[\frac{m}{q}\right]_{He^+} = 4\,\frac{amu}{C}$$

EpQ measurement

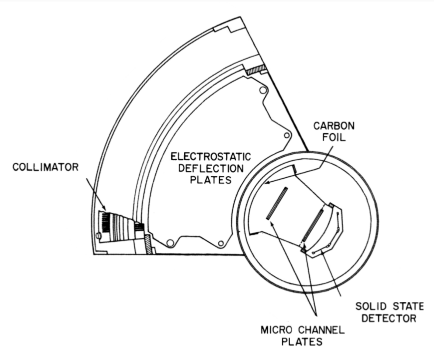


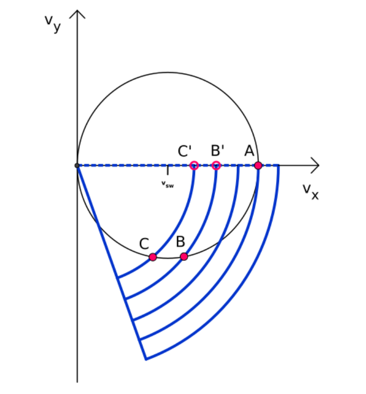


Gloeckler, Geiss et al., 1992

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

EpQ measurement

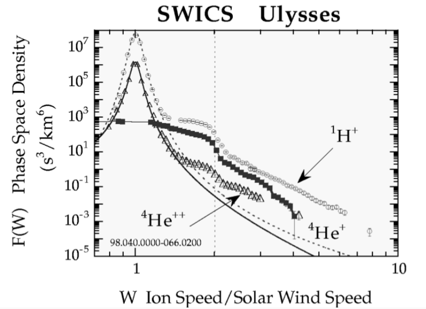




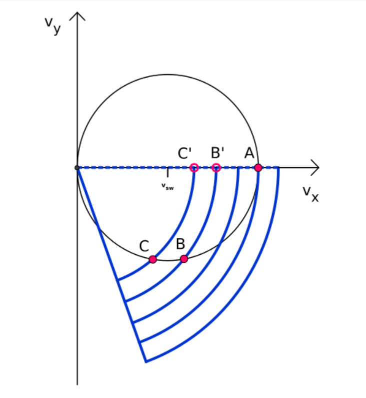
Gloeckler, Geiss et al., 1992

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

EpQ measurement

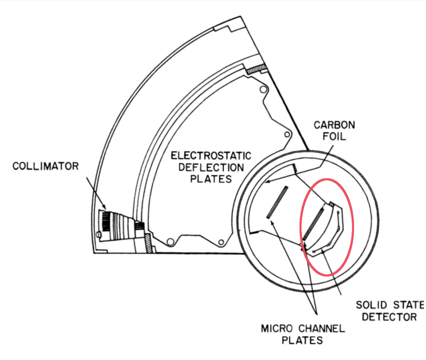


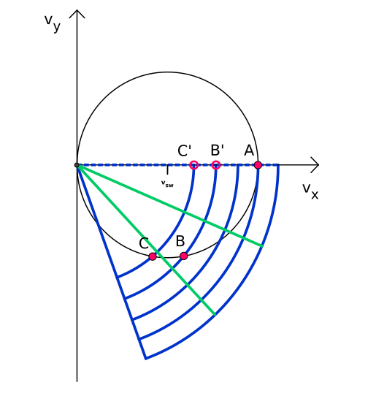
Gloeckler, Geiss et al., 1992



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

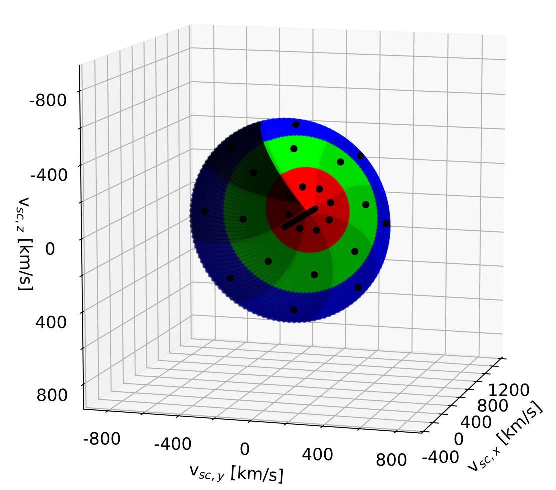
Angular resolution





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

Virtual Collimator

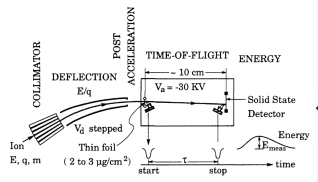


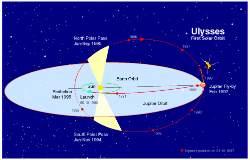
Velocity Space acceptance

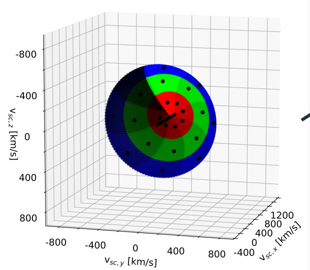
- for one species
- for one $\frac{E}{q}$-step

$\rightarrow$ **Spherical dome**

Conclusion of the Measurement







$\frac{E}{q}, ToF, E_{res}$

x, y, z

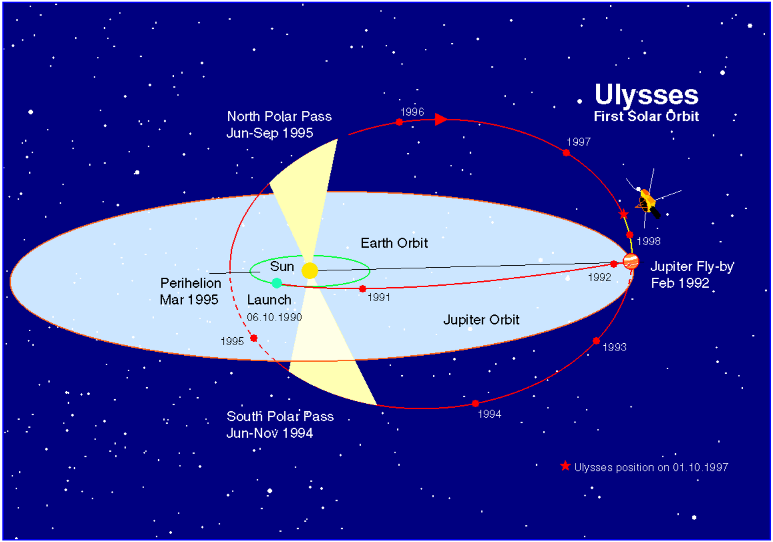
sector & detector

m, q

x, y, z

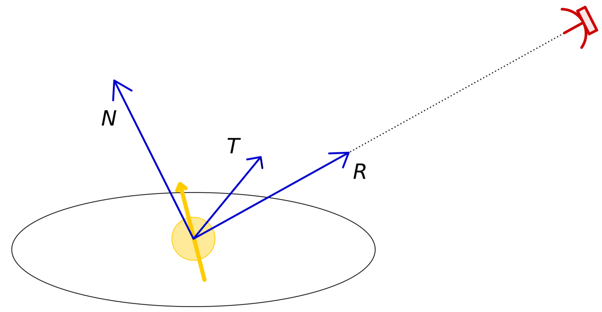
$\vec{v}_x, \vec{v}_y, \vec{v}_z$

Ulysses Trajectory



www.cosmos.esa.int, 2019

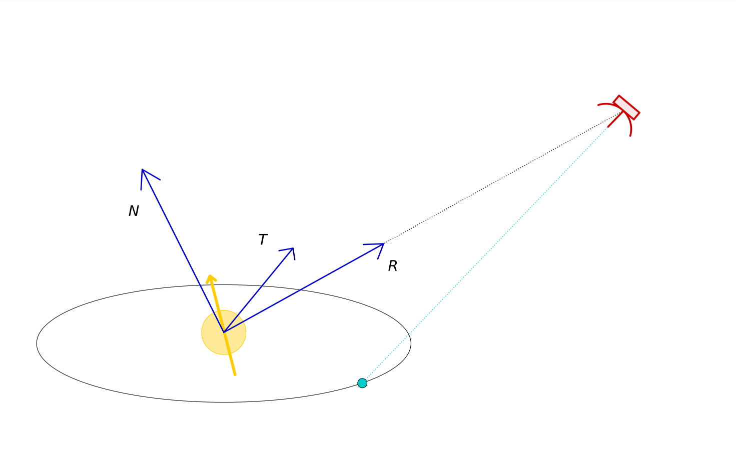
Ulysses Trajectory – Coordinate System



Spacecraft orientated coordinate system:

Radial Tangential Normal

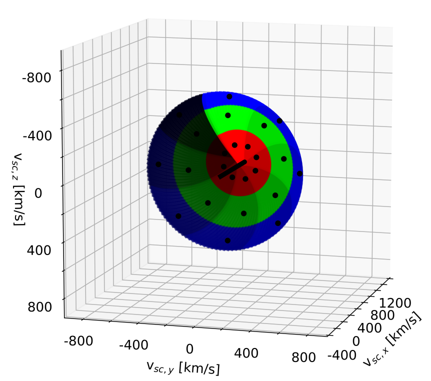
Ulysses Trajectory – Aspect Angle

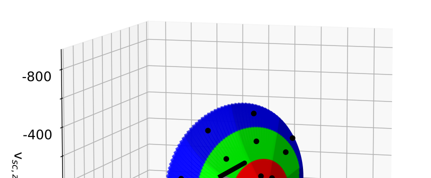


Aspect Angle: Angle between Ulysses' antenna ($\rightarrow$ earth) and

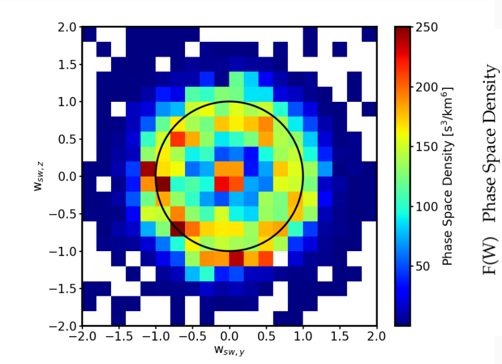
viewing line Ulysses $\leftrightarrow$ sun

VDF – Aspect Angle

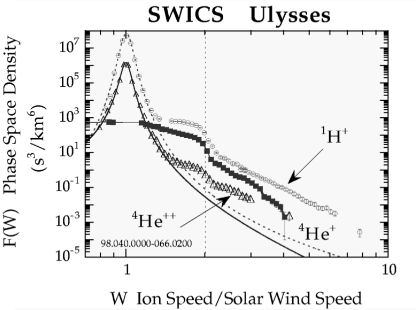




Outlook: ACE SWICS – 3D measurement



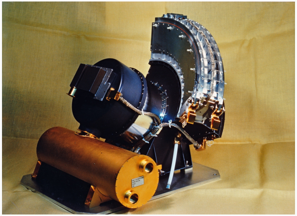
Berger, AGU Fall Meeting 2018



Gloeckler et al., 1999

Conclusion

- Pickup Ions basic concepts
- Ulysses SWICS
  - Principle of measurement
  - Data & Software
  - Coordinate Systems



Next:

Creating and analysing 3D VDFs based on Ulysses SWICS data