

# Velocity Distribution Functions of Pickup Ions with Ulysses/SWICS

Master Thesis

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Anne Fischer

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# Outline

Pickup Ions

Basics

Velocity Distribution Function

Ulysses SWICS

Principle of Measurement

Trajectory

Outlook & Conclusion

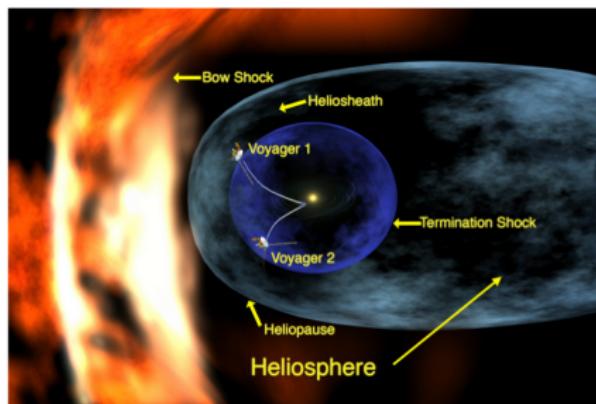
# Pickup Ions Basics

## Pickup Ions:

Former neutrals that get ionised within the heliosphere

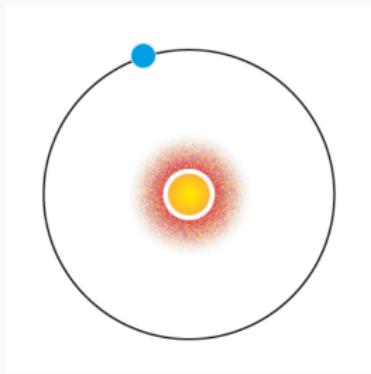
Origin of the neutrals:

- LISM



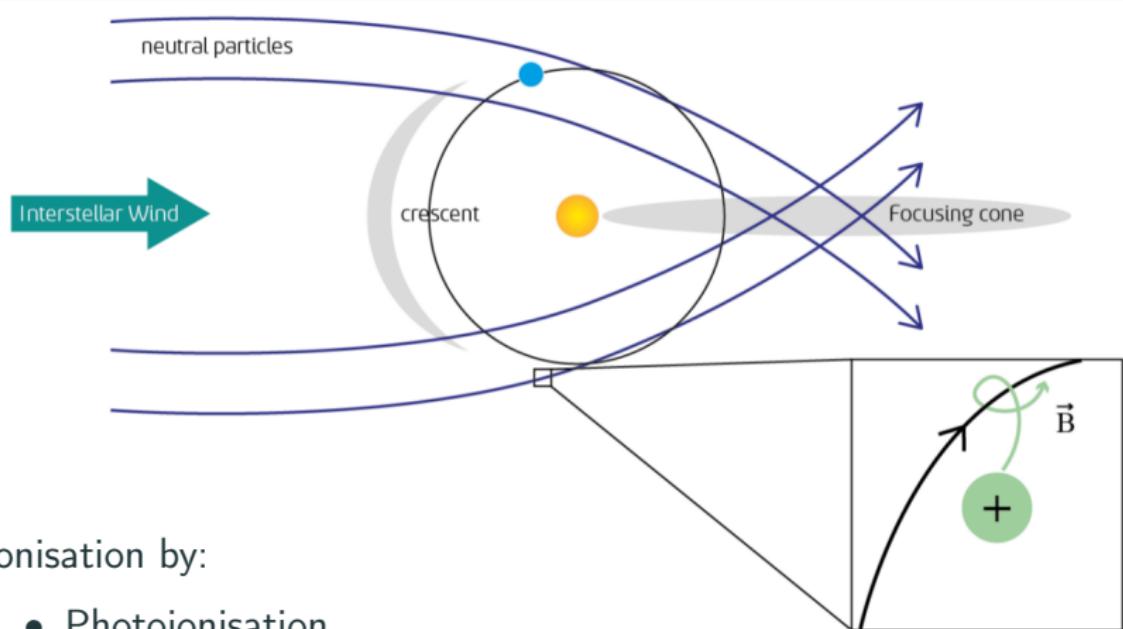
from <http://science.nasa.gov>

- Inner Source



Taut 2018

# The Pickup Process



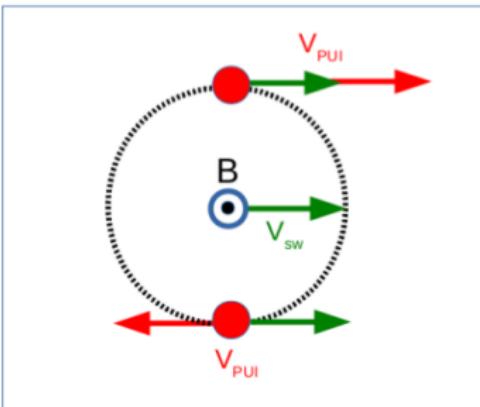
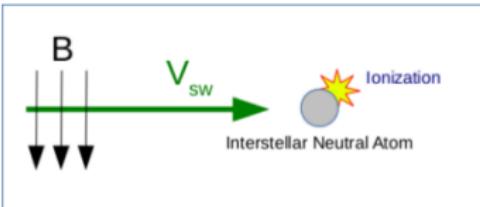
Ionisation by:

- Photoionisation
- Charge exchange
- Electron impact

Taut, Drews et al., AGU fall meeting 2014

→ Newborn ion is subjected to electromagnetic forces

# The Pickup Process

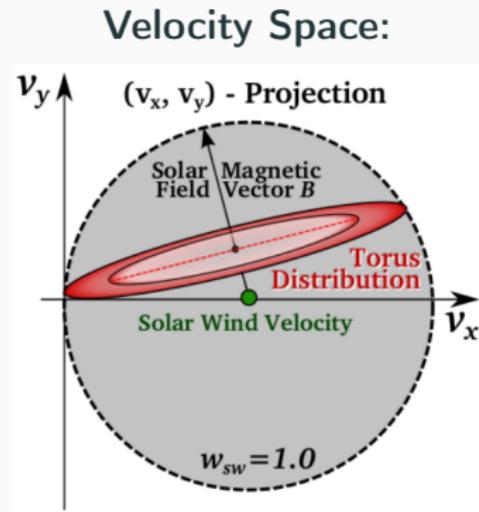
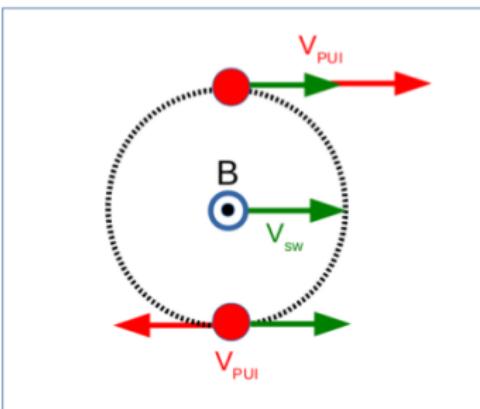
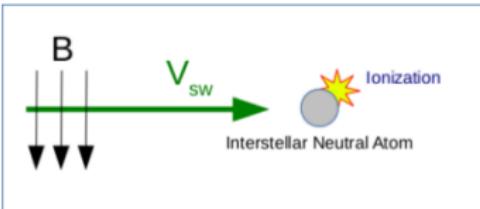


Assumptions:

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

Relative motion  
→ Gyro-motion

# The Pickup Process

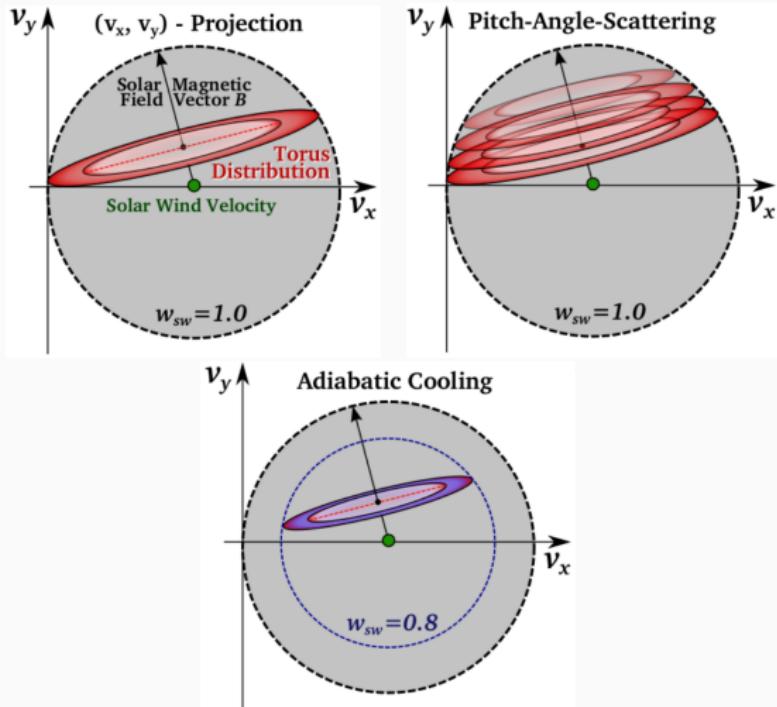


Drews et al., 2016

→ Anisotropic torus VDF

Taut, Drews et al., AGU Fall Meeting 2014

# Evolution of the VDF



Drews, Berger et al., 2016

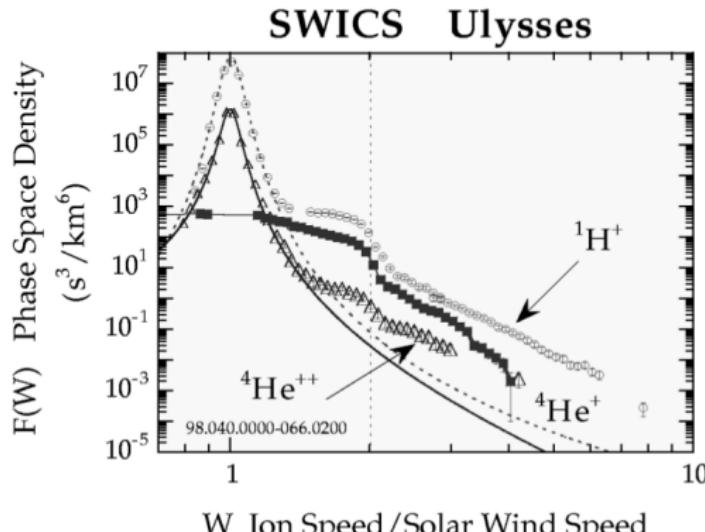
# PUI – Measurement

## Observed PUIs:

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

## PUI or Solar Wind?

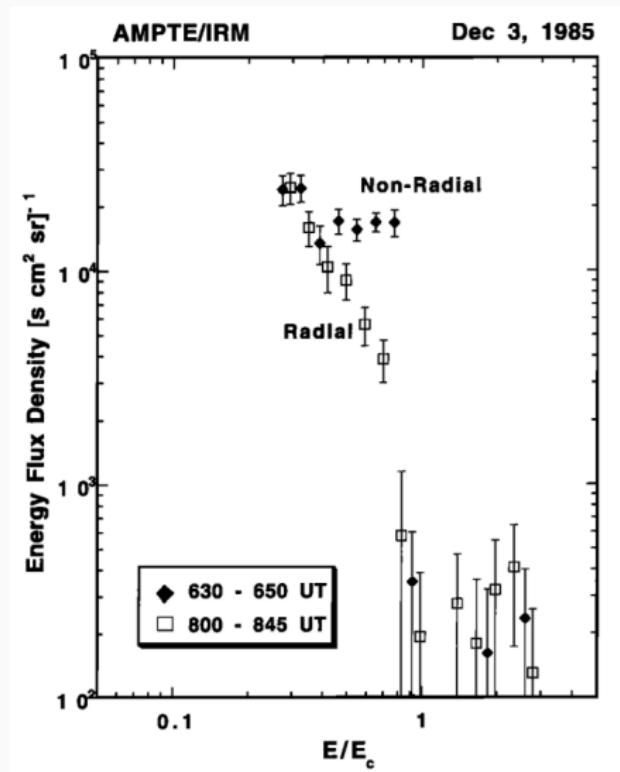
- Charge state
- Velocity distribution function (VDF)



Gloeckler et al., 1999

# Anisotropic features of the VDF

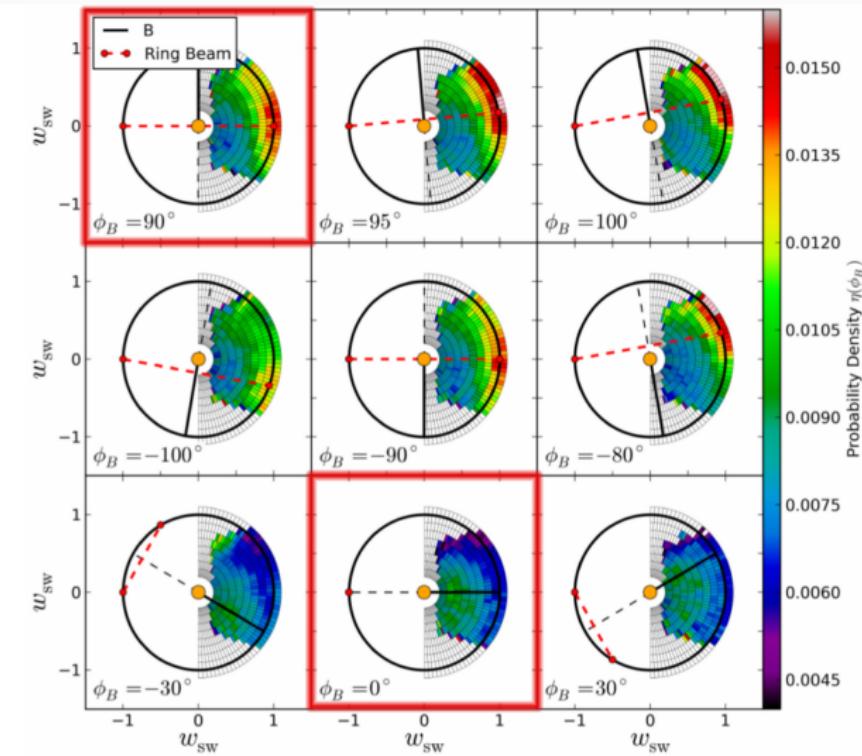
1D measurements  
discover anisotropic  
features of the VDF



Moebius et al., 1998

# Anisotropic features of the VDF

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

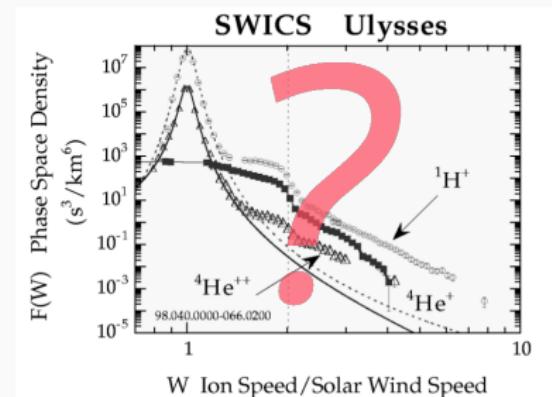


# Motivation

Problem:

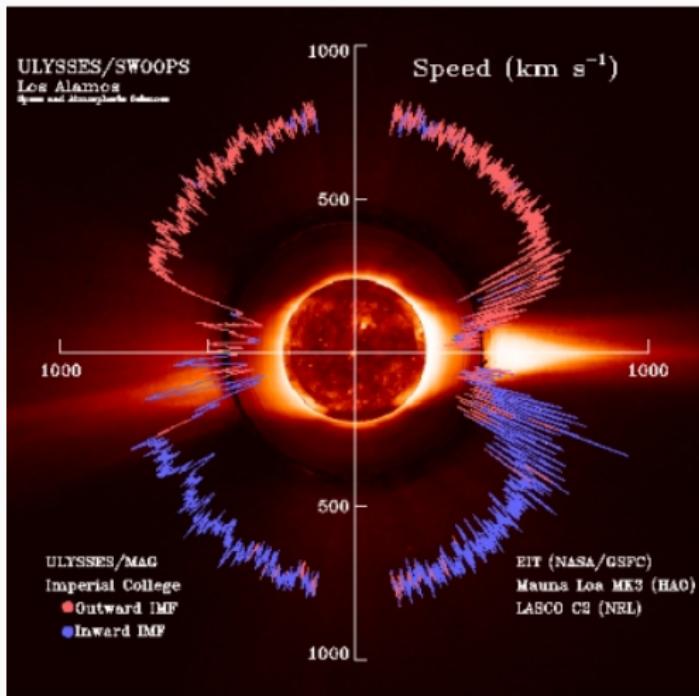
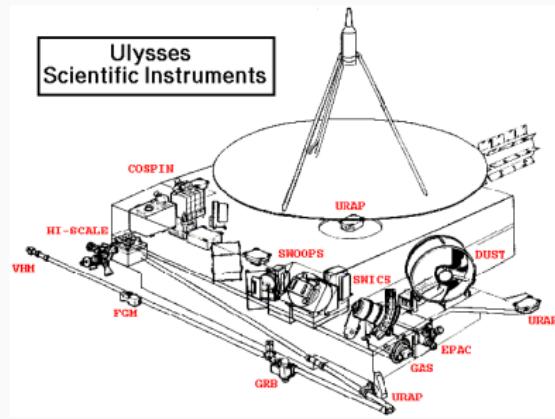
Ambiguity of 1D reduced data

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



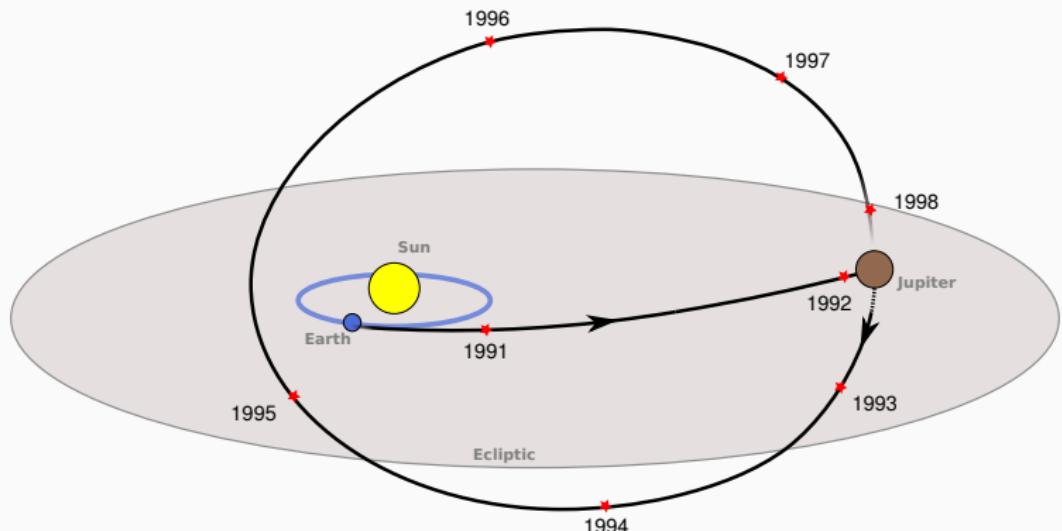
# Ulysses Spacecraft

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



[www.esa.int](http://www.esa.int), 2019

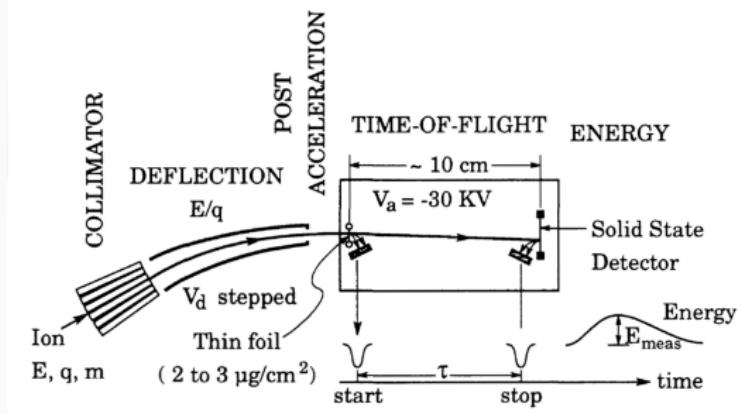
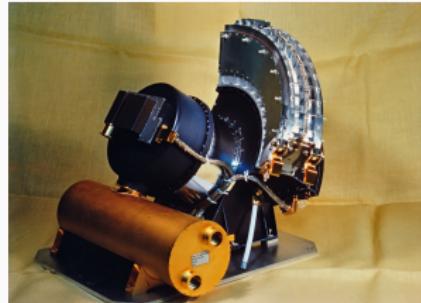
# Ulysses Orbit



*adapted from TODO*

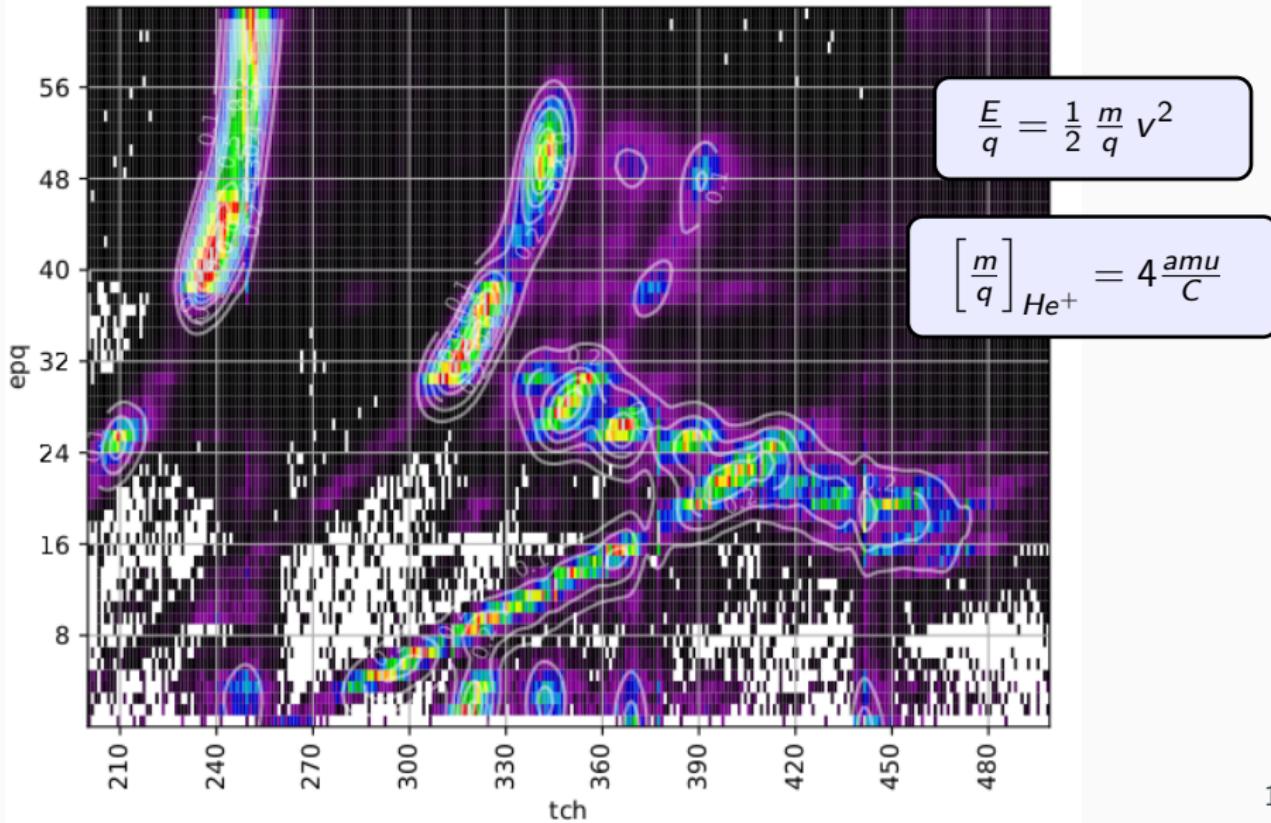
## The Solar Wind Ion Composition Spectrometer

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

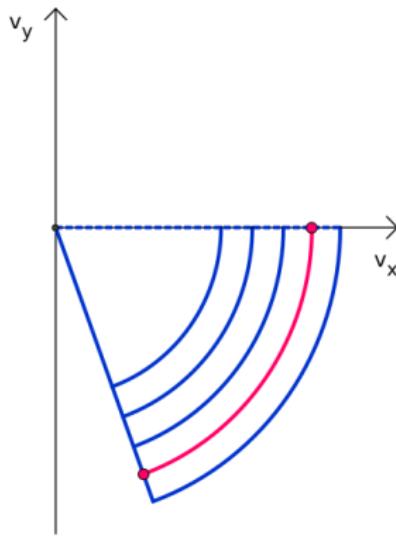
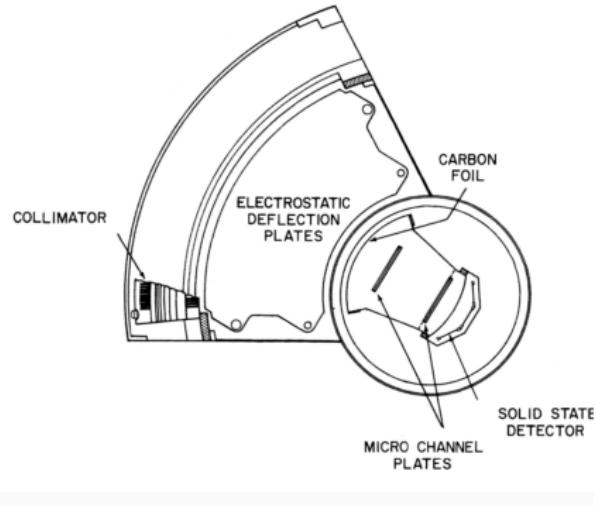


Gloeckler, Geiss et al., 1992

# PHA data



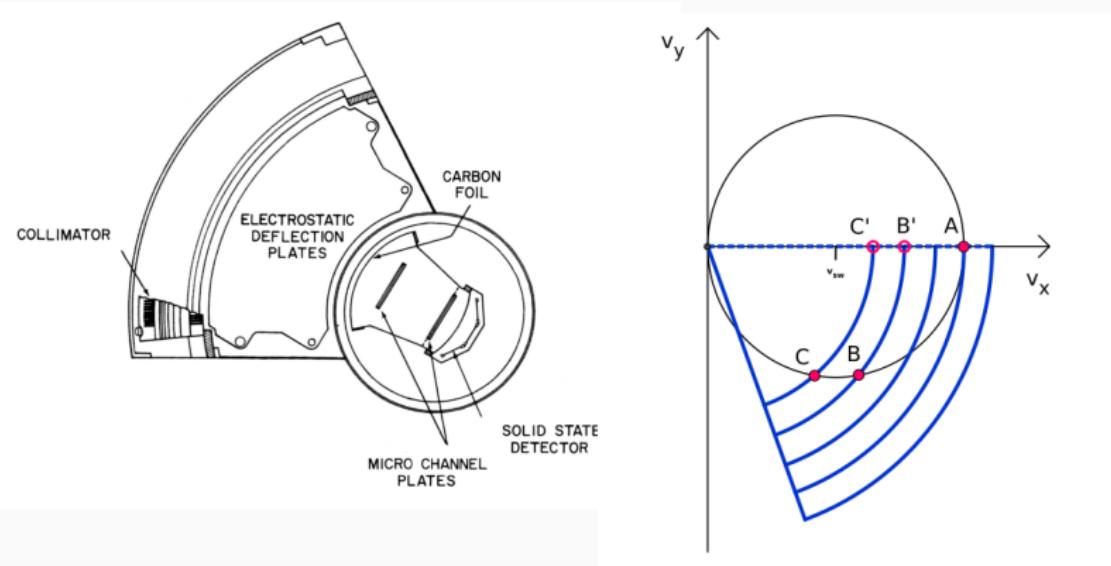
# EpQ measurement



Gloeckler, Geiss et al., 1992

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

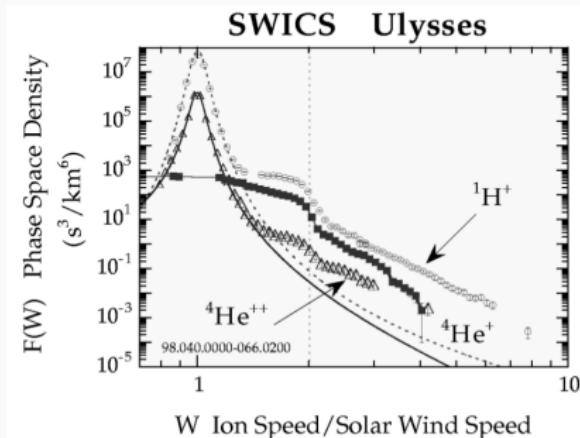
# EpQ measurement



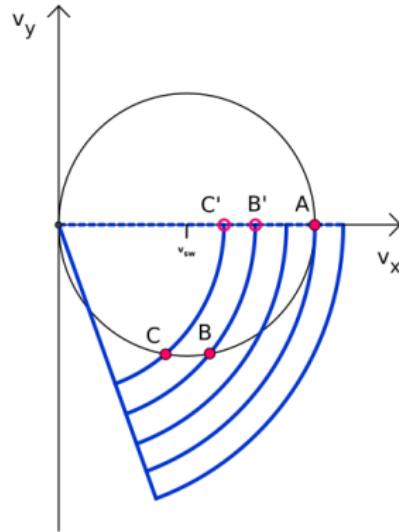
Gloeckler, Geiss et al., 1992

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# EpQ measurement

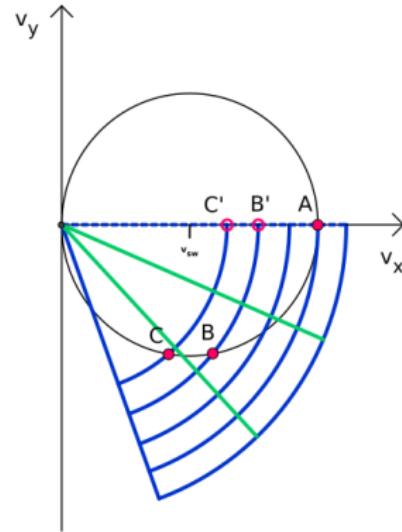
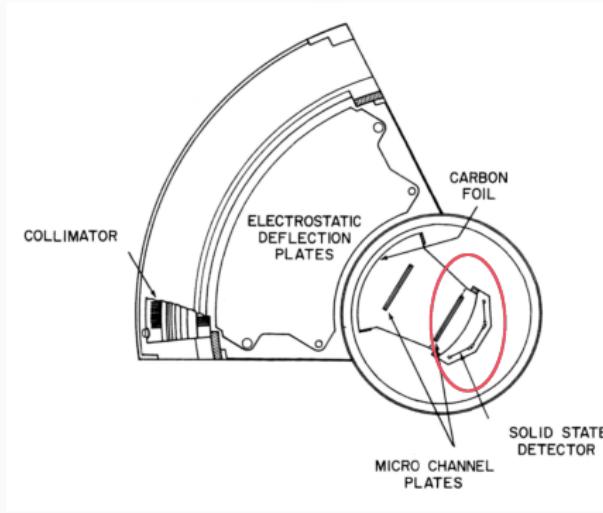


Gloeckler, Geiss et al., 1992



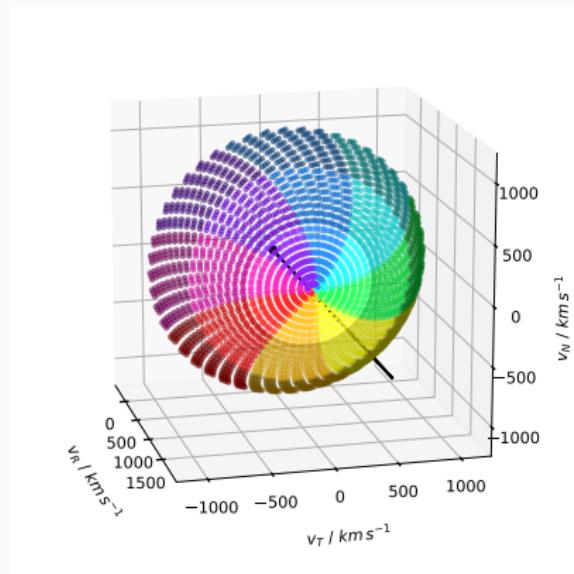
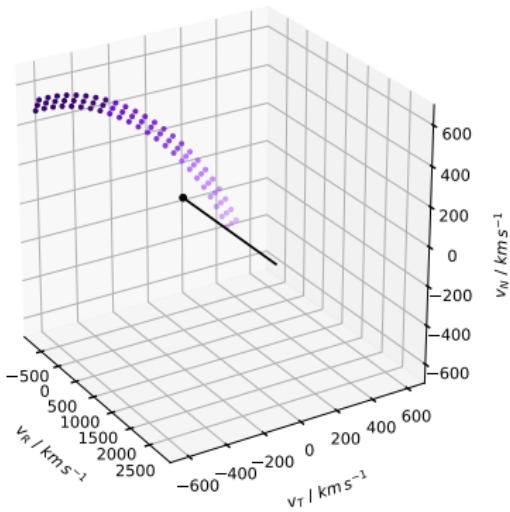
- For constant  $\frac{m}{q}$  :  $\frac{E}{q}$ -step  $\hat{=}$  absolute value of velocity
- Integration over EpQ shells  $\rightarrow$  loss of information!

# Angular resolution

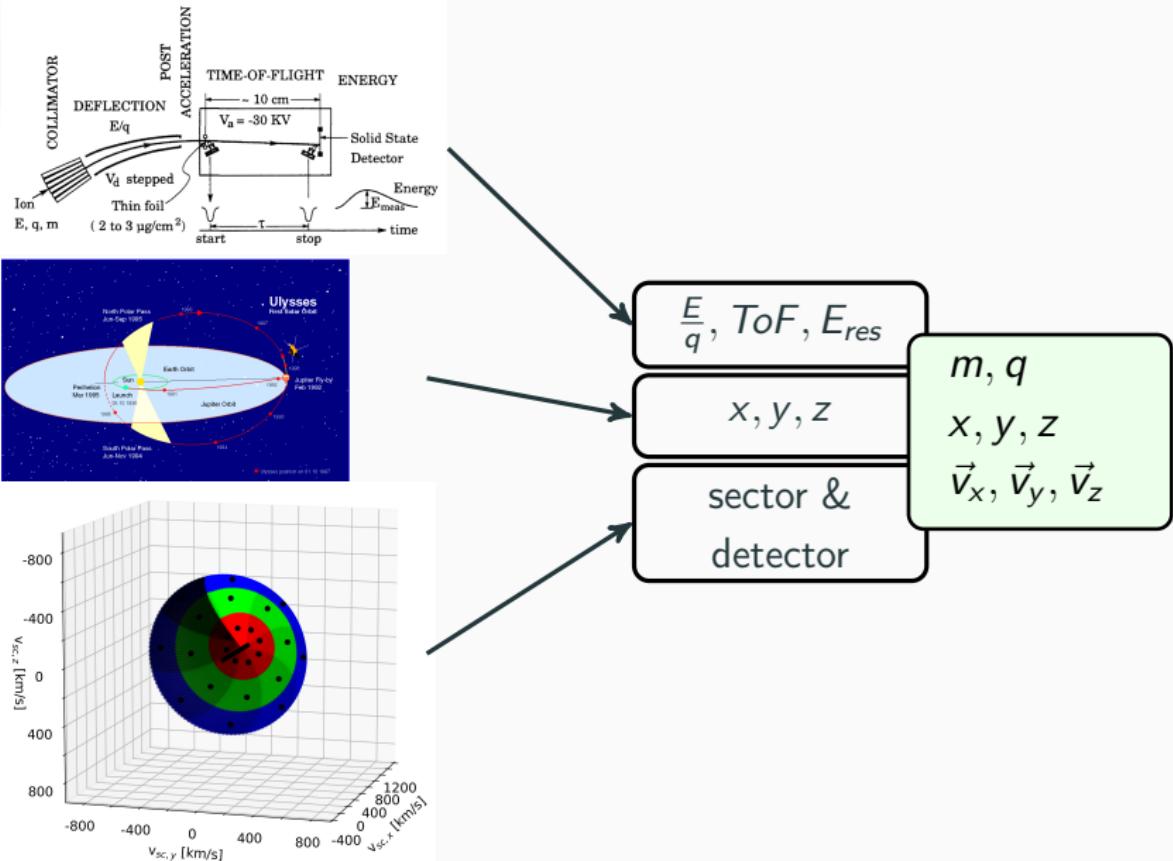


- SWICS: **3 detectors**  
Rough distinction between angles of incidence
- 3rd dimension: spin of the SC  
Divided into **8 sectors**

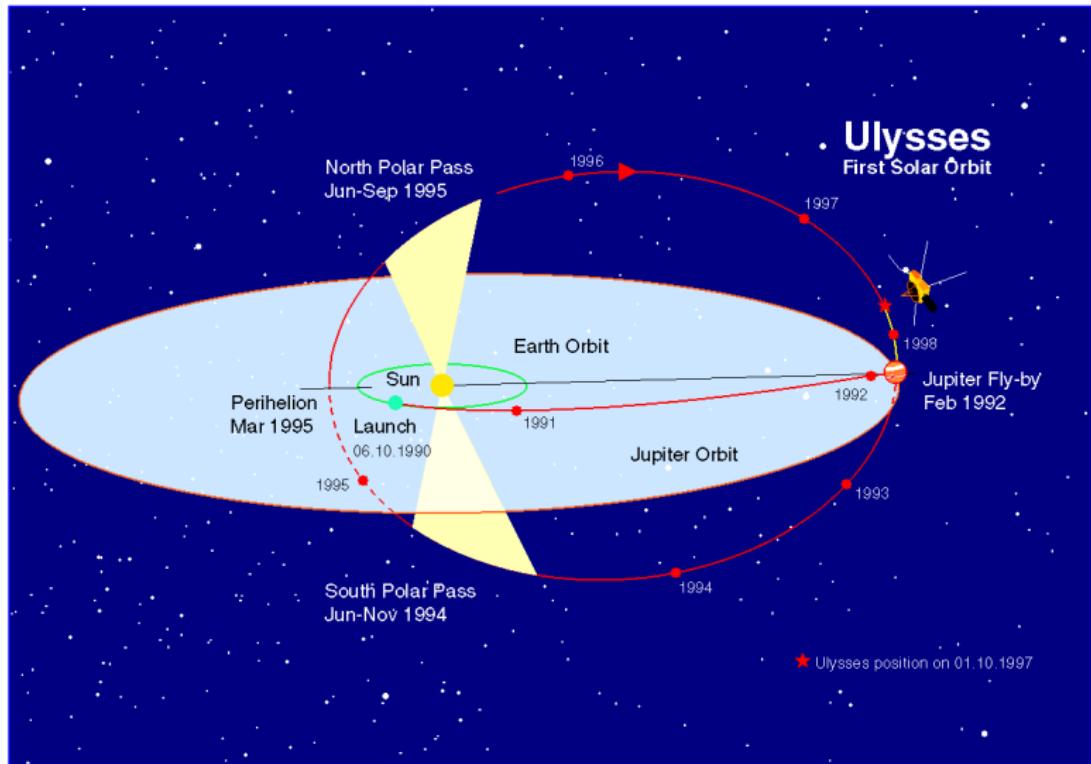
# Virtual Collimator



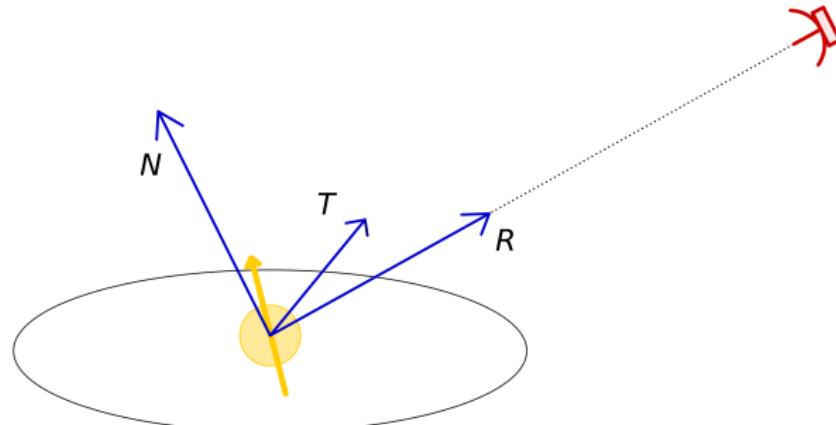
# Conclusion of the Measurement



# Ulysses Trajectory

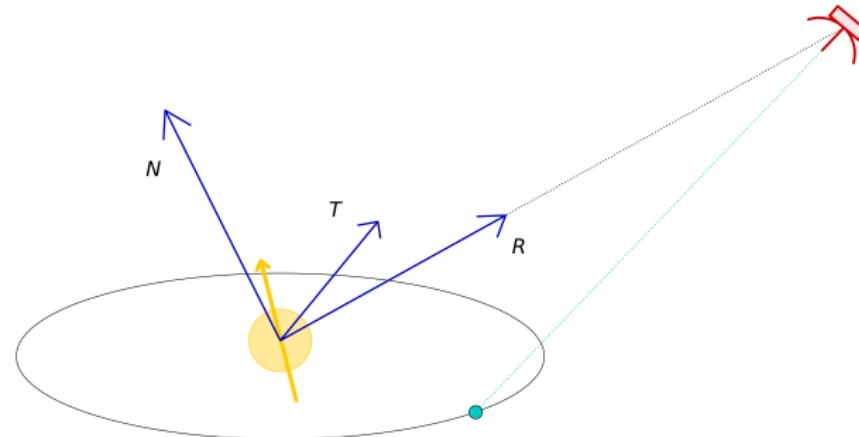


# Ulysses Trajectory – Coordinate System



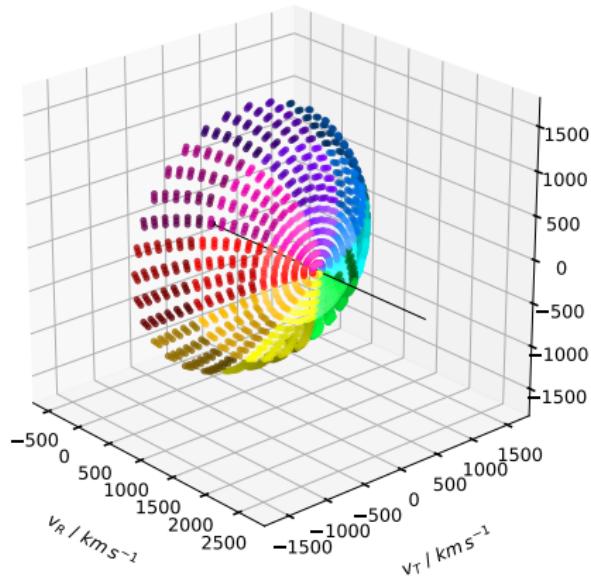
Spacecraft orientated coordinate system:  
Radial Tangential Normal

# Ulysses Trajectory – Aspect Angle

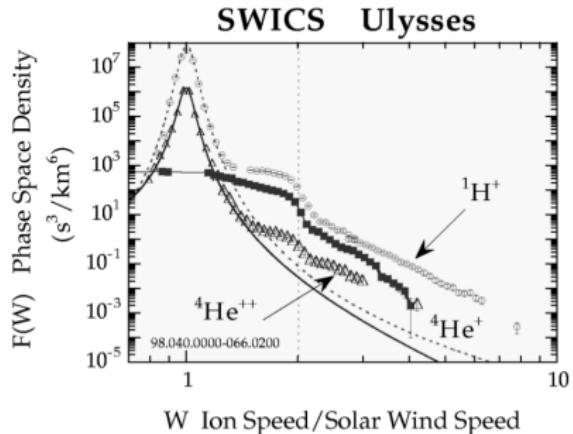
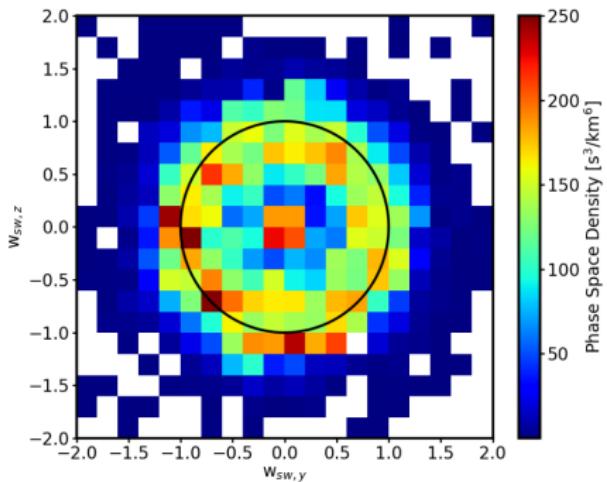


**Aspect Angle:** Angle between Ulysses' antenna ( $\rightarrow$  earth) and  
viewing line Ulysses  $\leftrightarrow$  sun

# VDF – Aspect Angle



# Outlook: ACE SWICS – 3D measurement

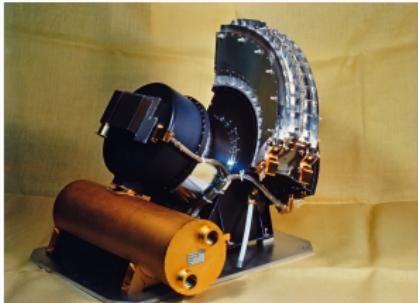


Gloeckler et al., 1999

Berger, AGU Fall Meeting 2018

# Conclusion

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



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Next:

Creating and analysing 3D VDFs based on Ulysses SWICS data