Velocity Distribution Functions of Pickup Ions with Ulysses/SWICS

Master Thesis

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November 18, 2019

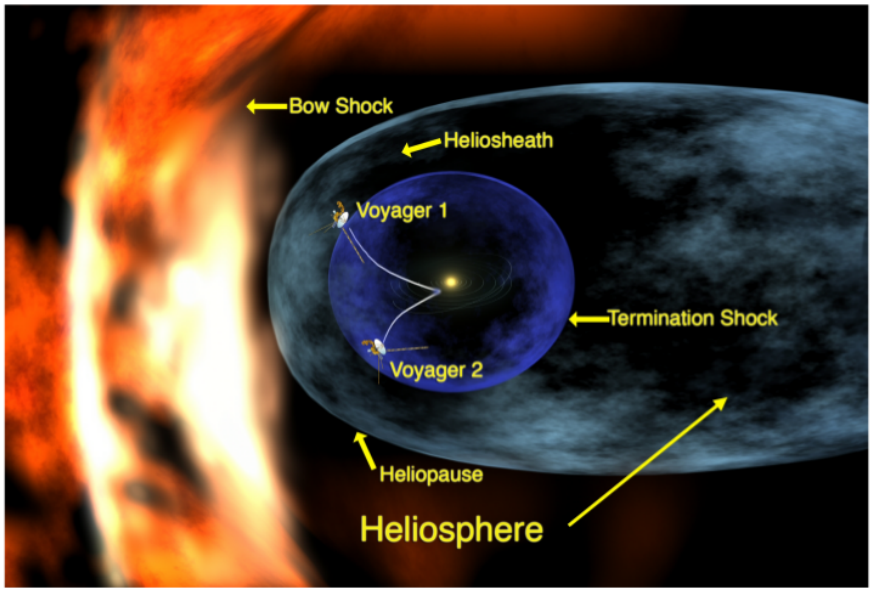
Outline

Pickup Ions Basics

Pickup Ions:
Former neutrals that get ionised within the heliosphere

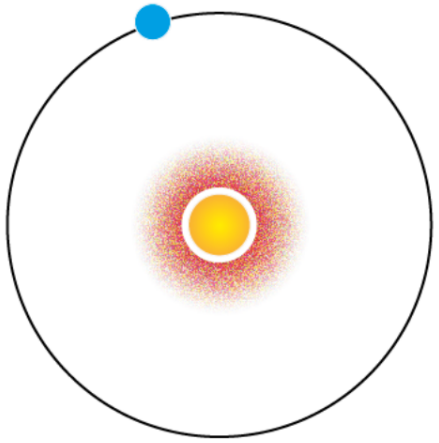
Origin of the neutrals:

- LISM



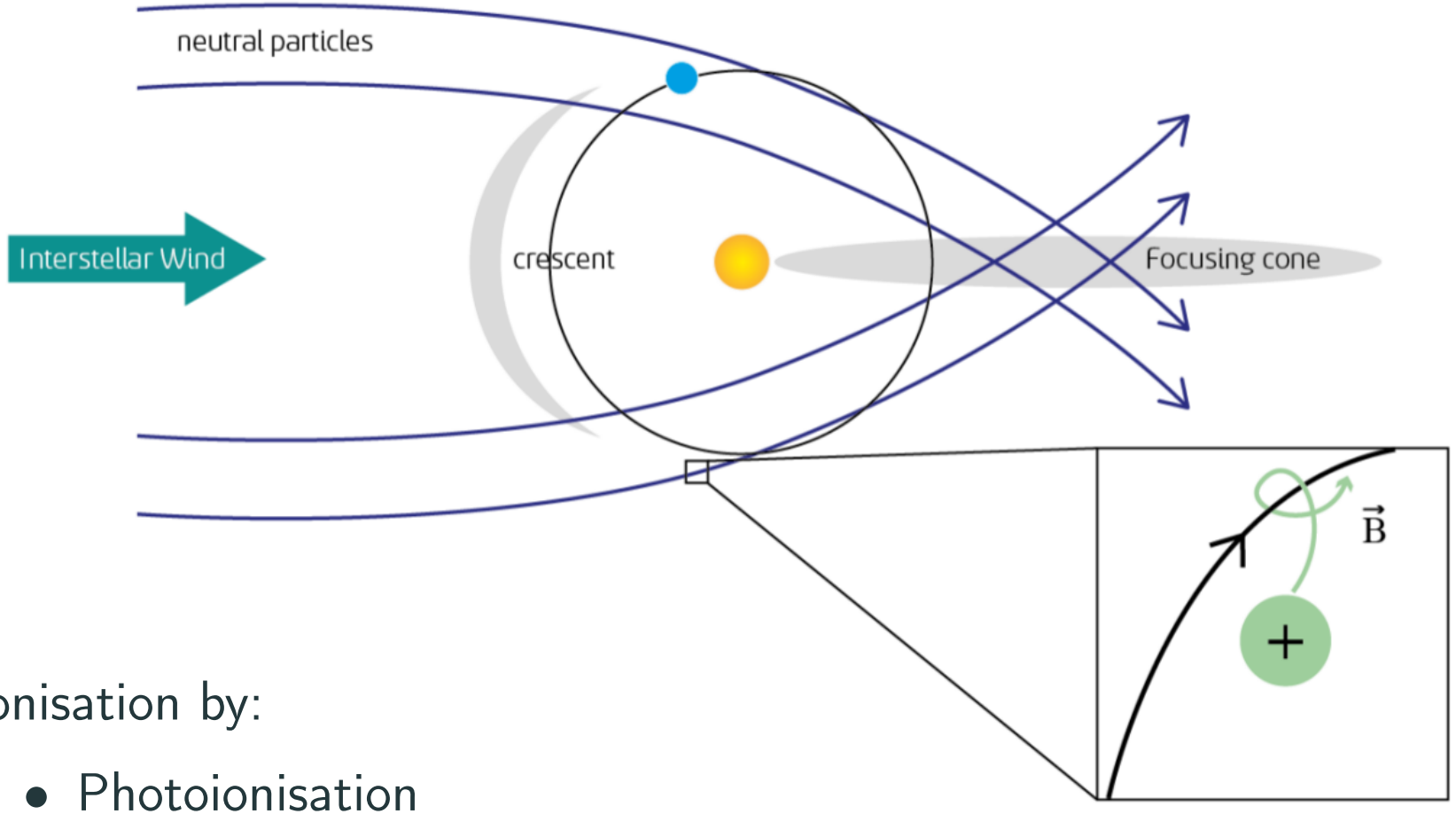
from http://science.nasa.gov

- Inner Source



Taut 2018

The Pickup Process



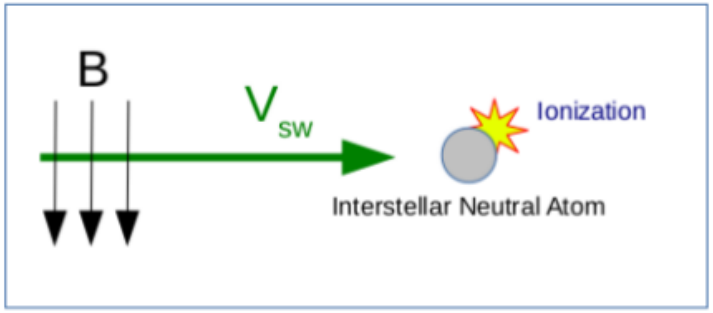
Ionisation by:

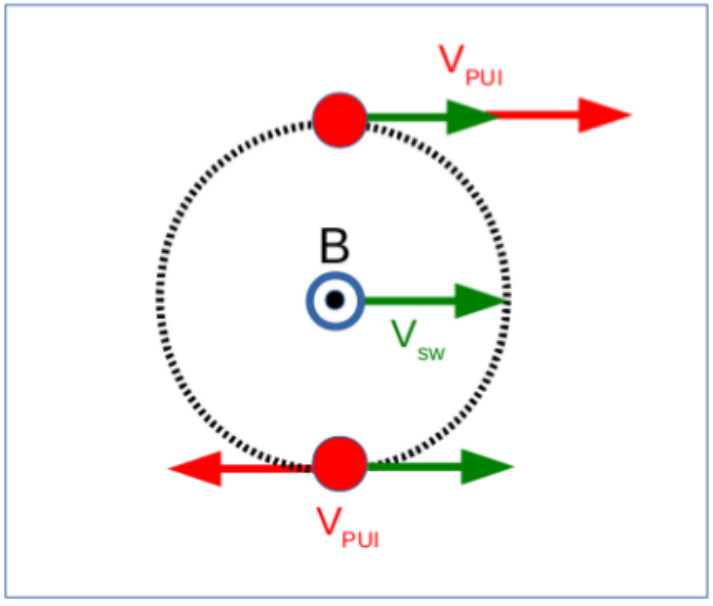
- Photoionisation
- Charge exchange
- Electron impact

Taut, Drews et al., AGU fall meeting 2014

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

The Pickup Process





Taut, Drews et al., AGU Fall Meeting 2014

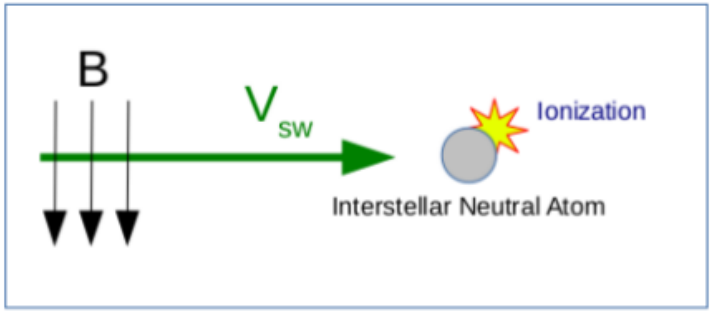
Assumptions:

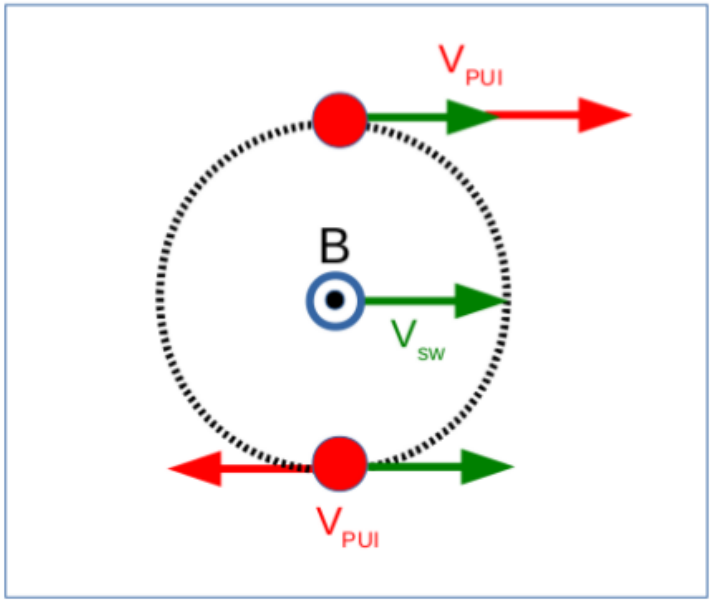
- particle at rest
- $\vec{B} \perp \vec{v}_{SW}$

Relative motion

$\rightarrow$ **Gyro-motion**

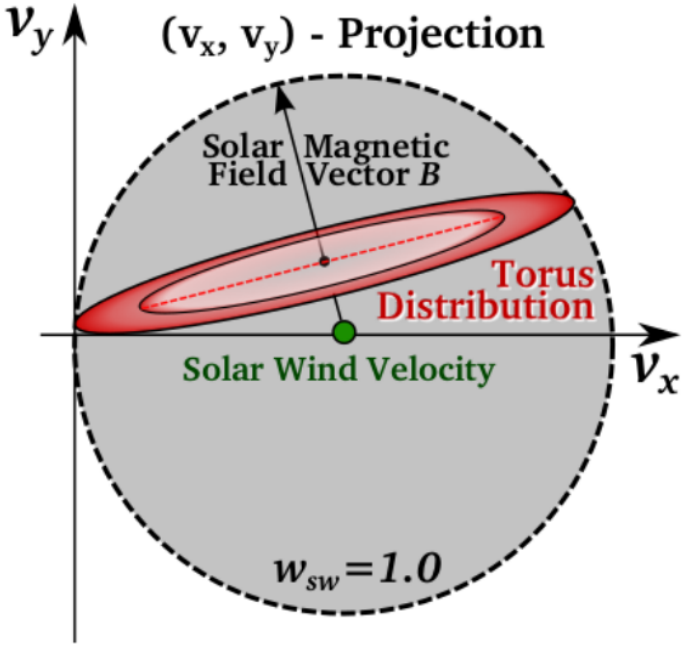
The Pickup Process





Taut, Drews et al., AGU Fall Meeting 2014

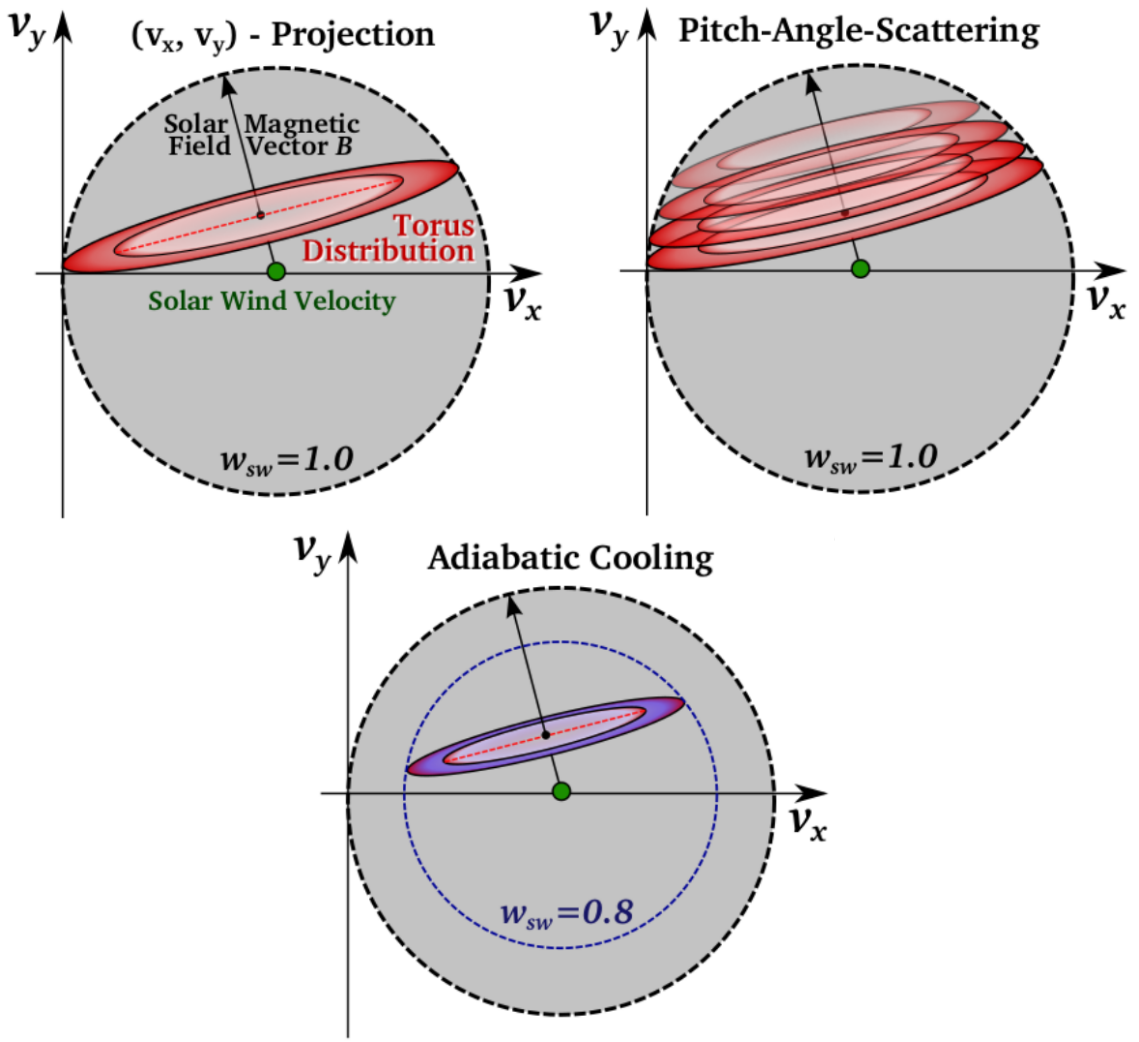
Velocity Space:



Drews et al., 2016

$\rightarrow$ **Anisotropic torus VDF**

Evolution of the VDF



Drews, Berger et al., 2016

Modification of the

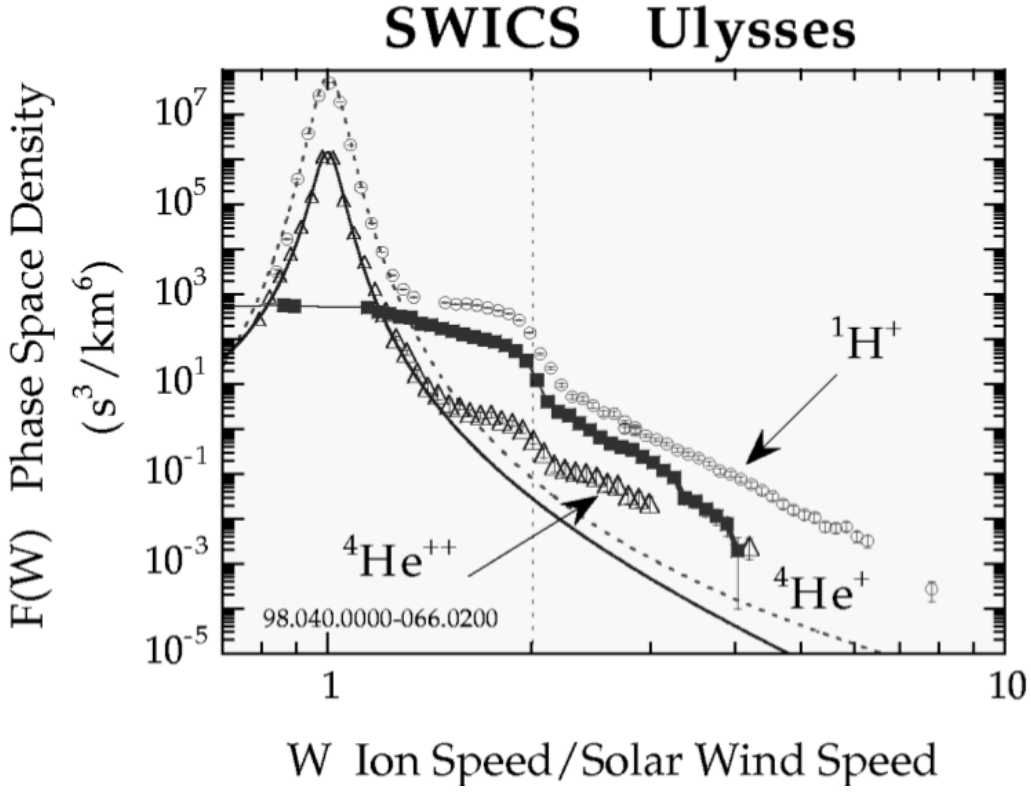
PUI – Measurement

Observed PUIs:

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

PUI or Solar Wind?

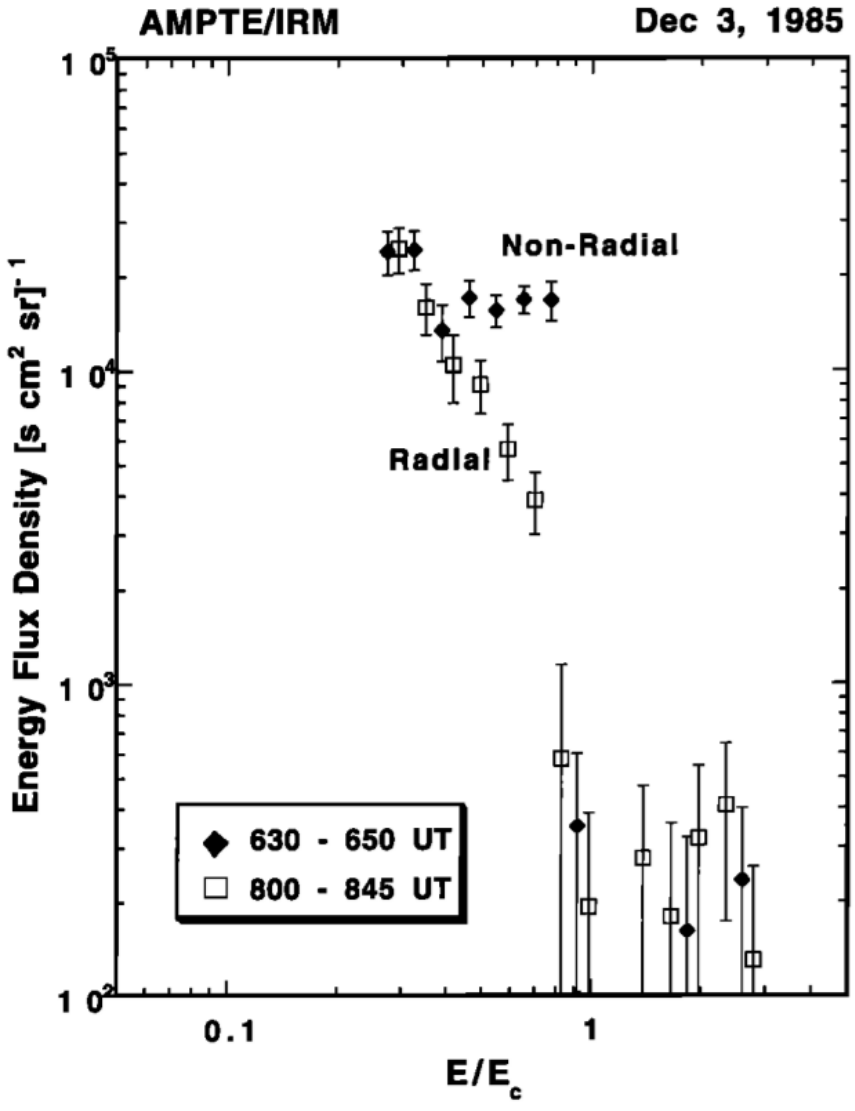
- Charge state
- Velocity distribution function (VDF)



Gloeckler et al., 1999

Anisotropic features of the VDF

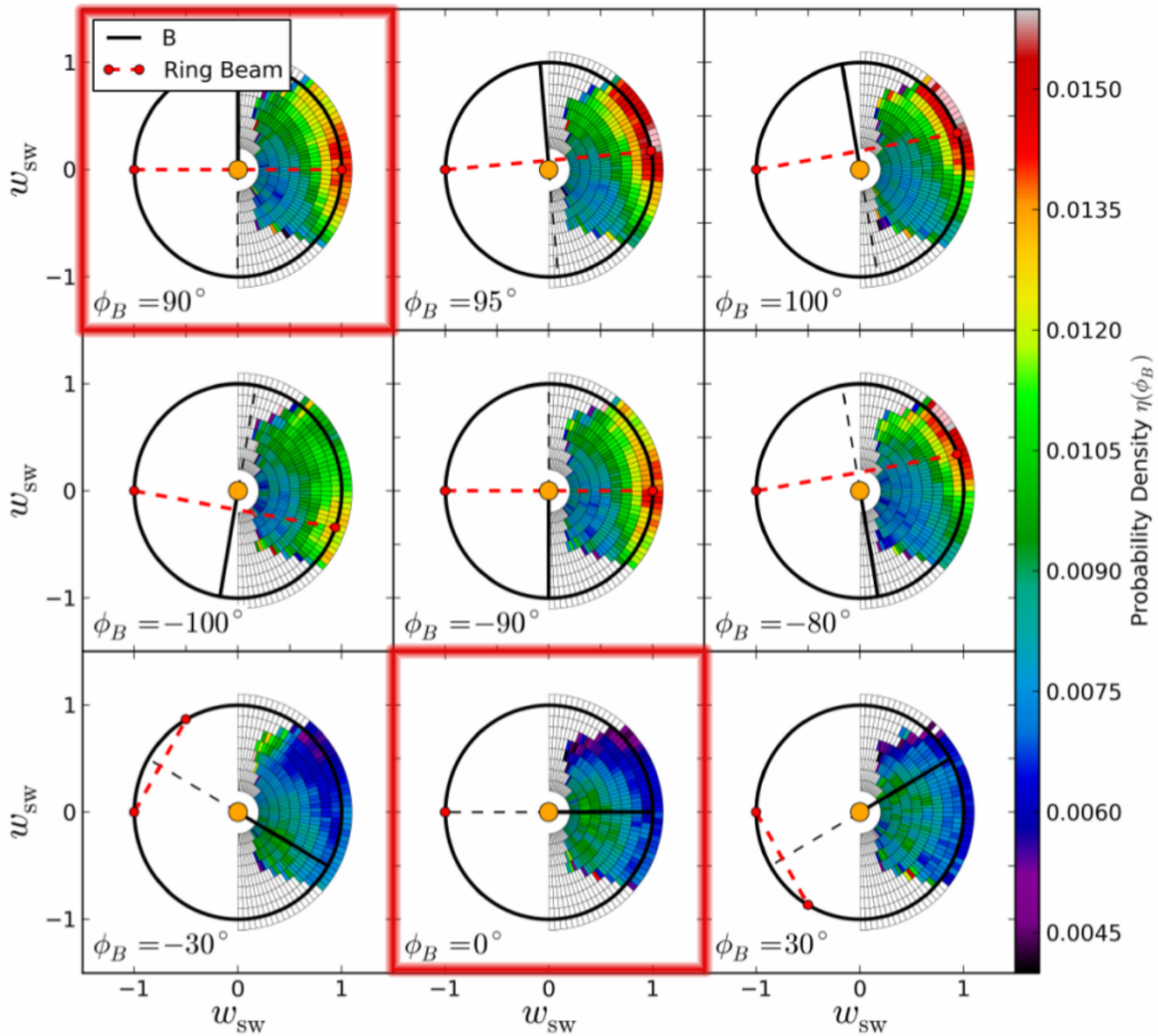
1D measurements discover **anisotropic features** of the VDF



Moebius et al., 1998

Anisotropic features of the VDF

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

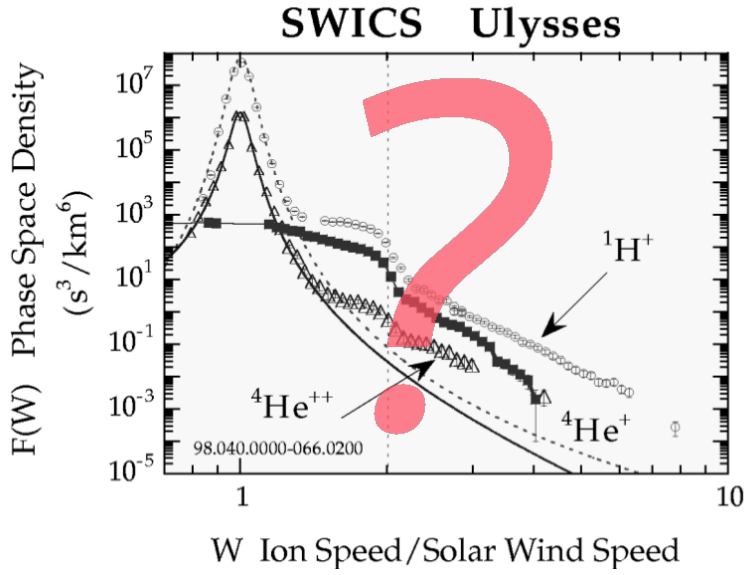


Drews, Berger et al., 2015

Motivation

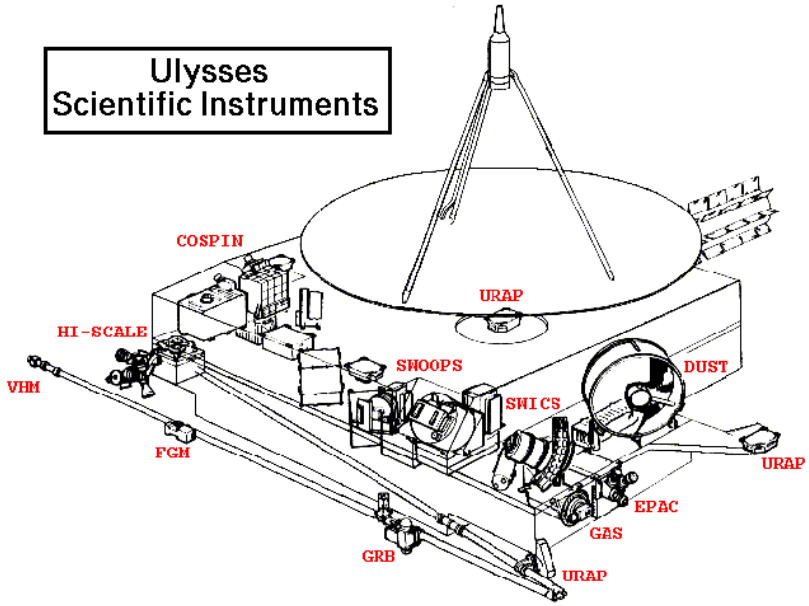
Problem:
Ambiguity of 1D reduced data

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

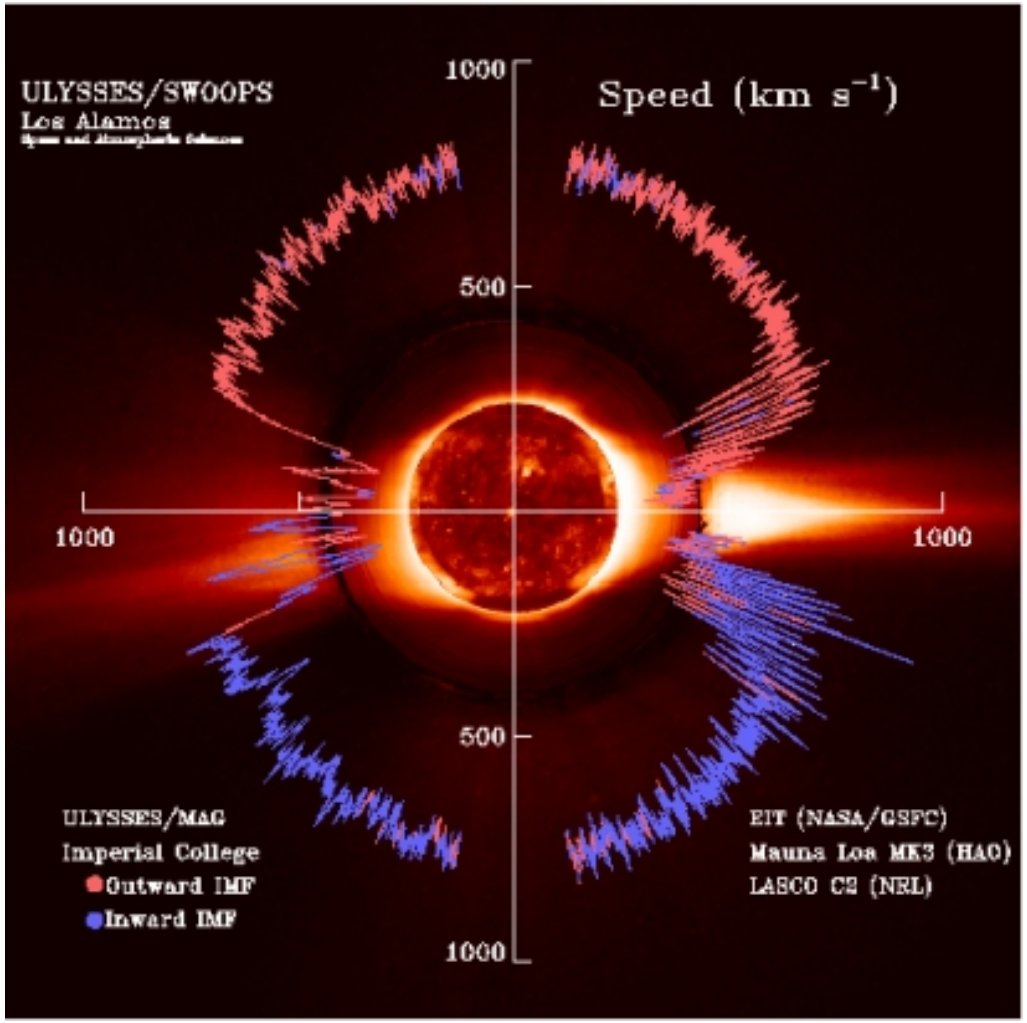


Ulysses Spacecraft

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

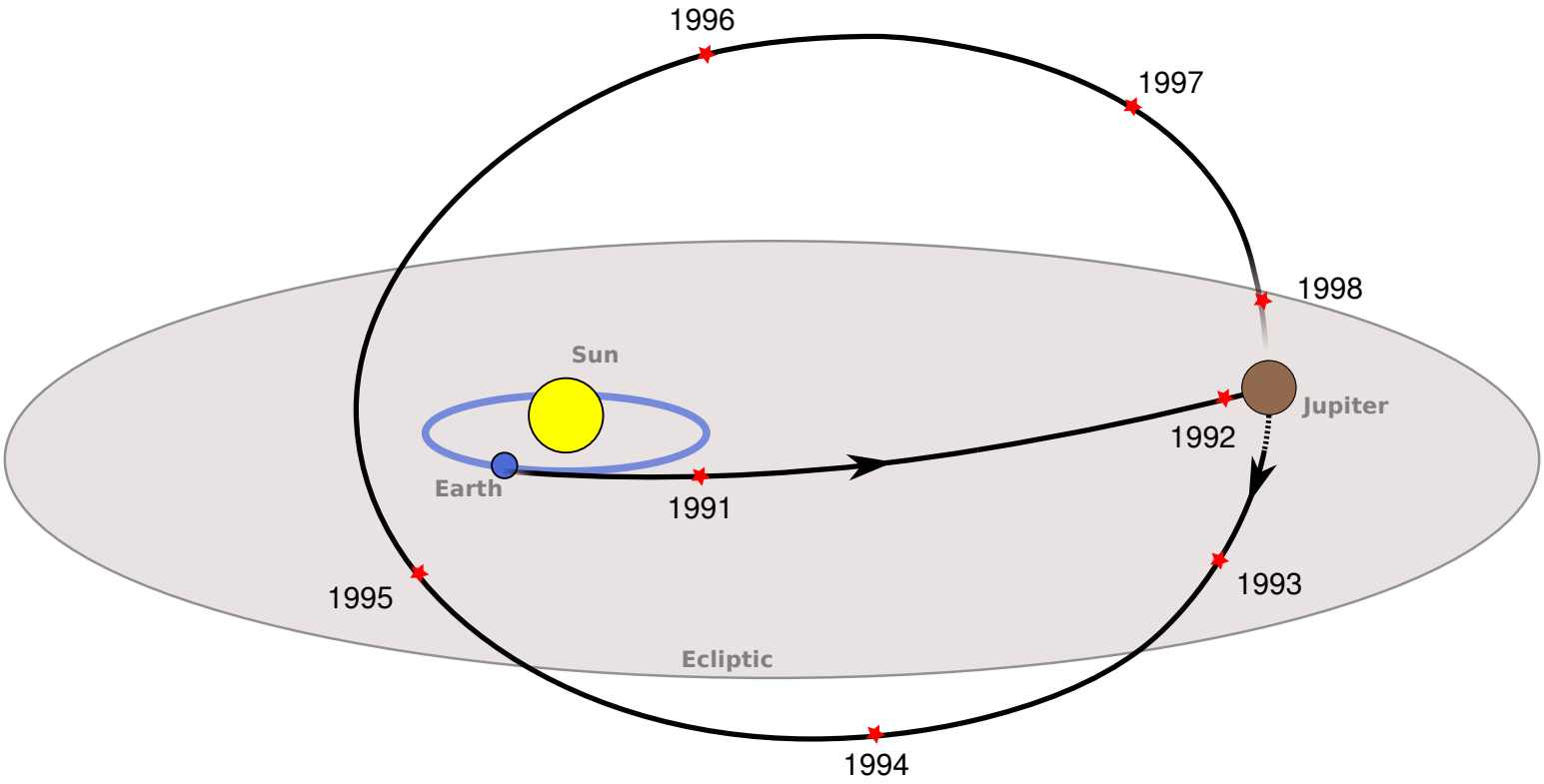


www.cosmos.esa.int, 2019

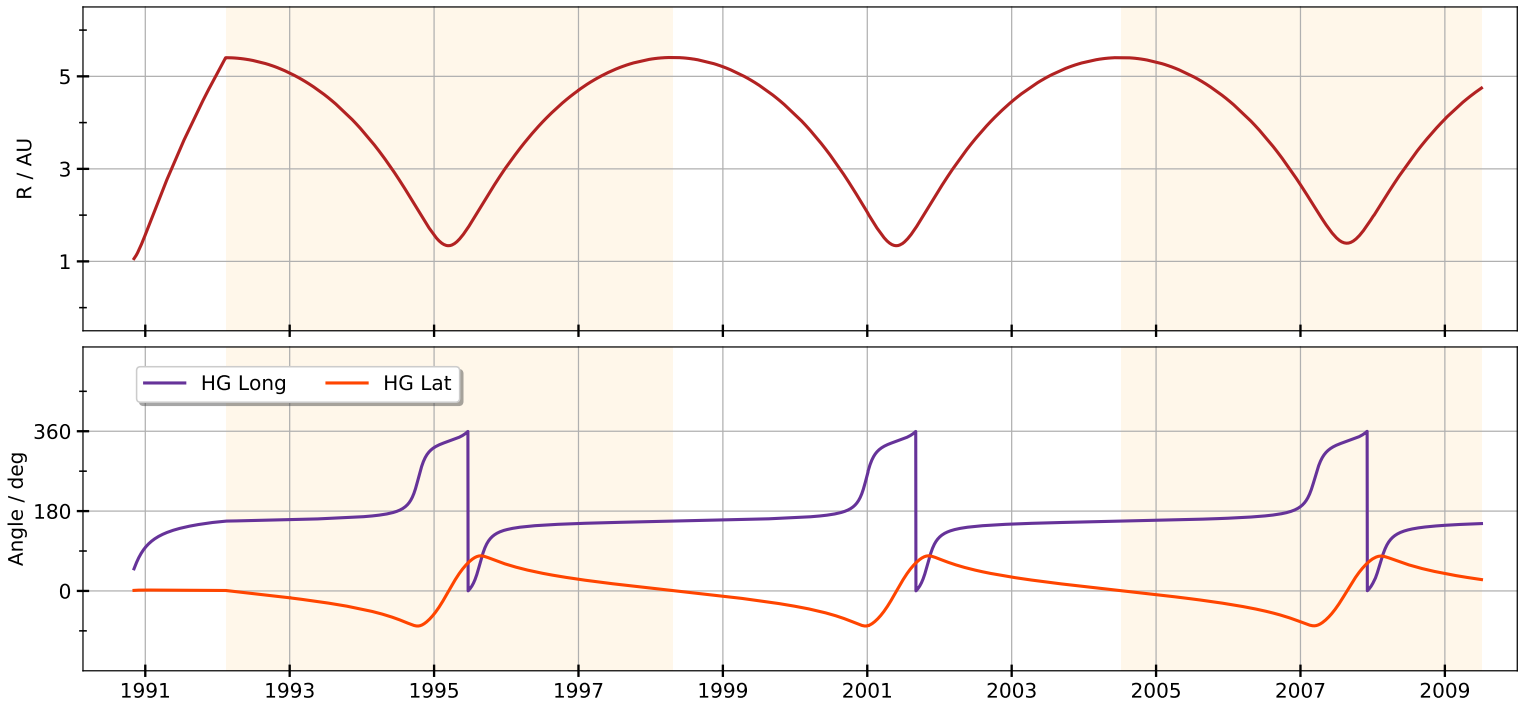


www.sci.esa.int, 2019

Ulysses Orbit



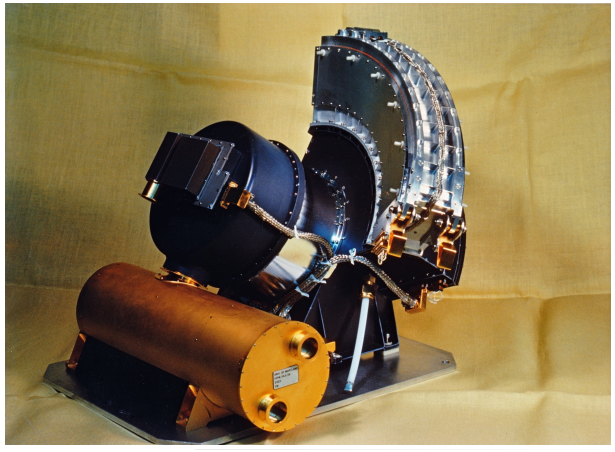
adapted from TODO

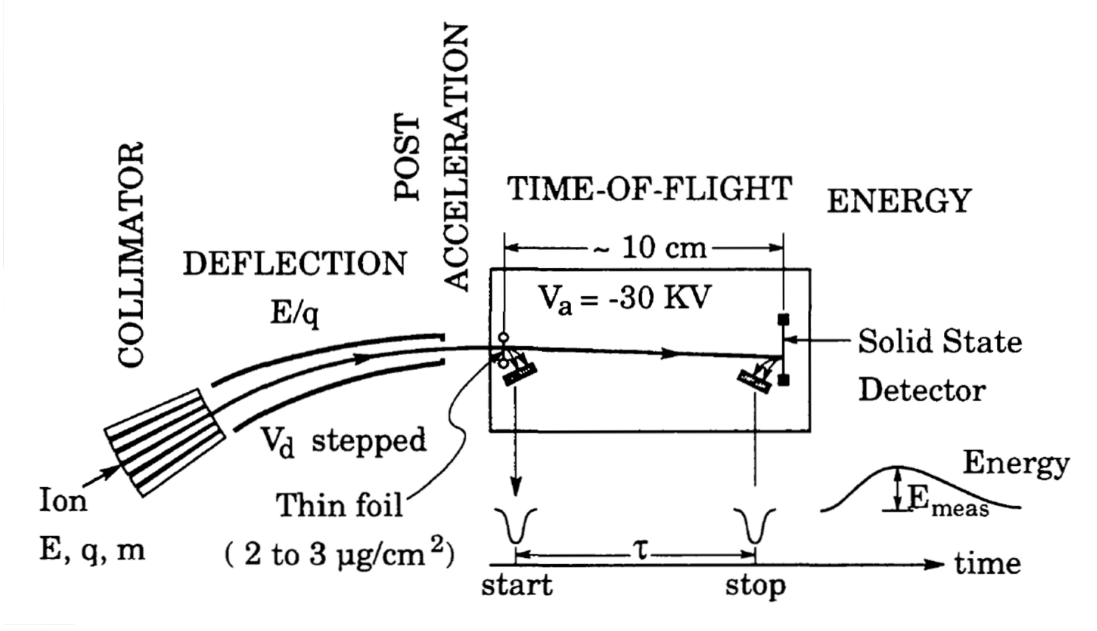

R / AU
5
3
1
HG Long
HG Lat
Angle / deg
360
180
0
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009

SWICS

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

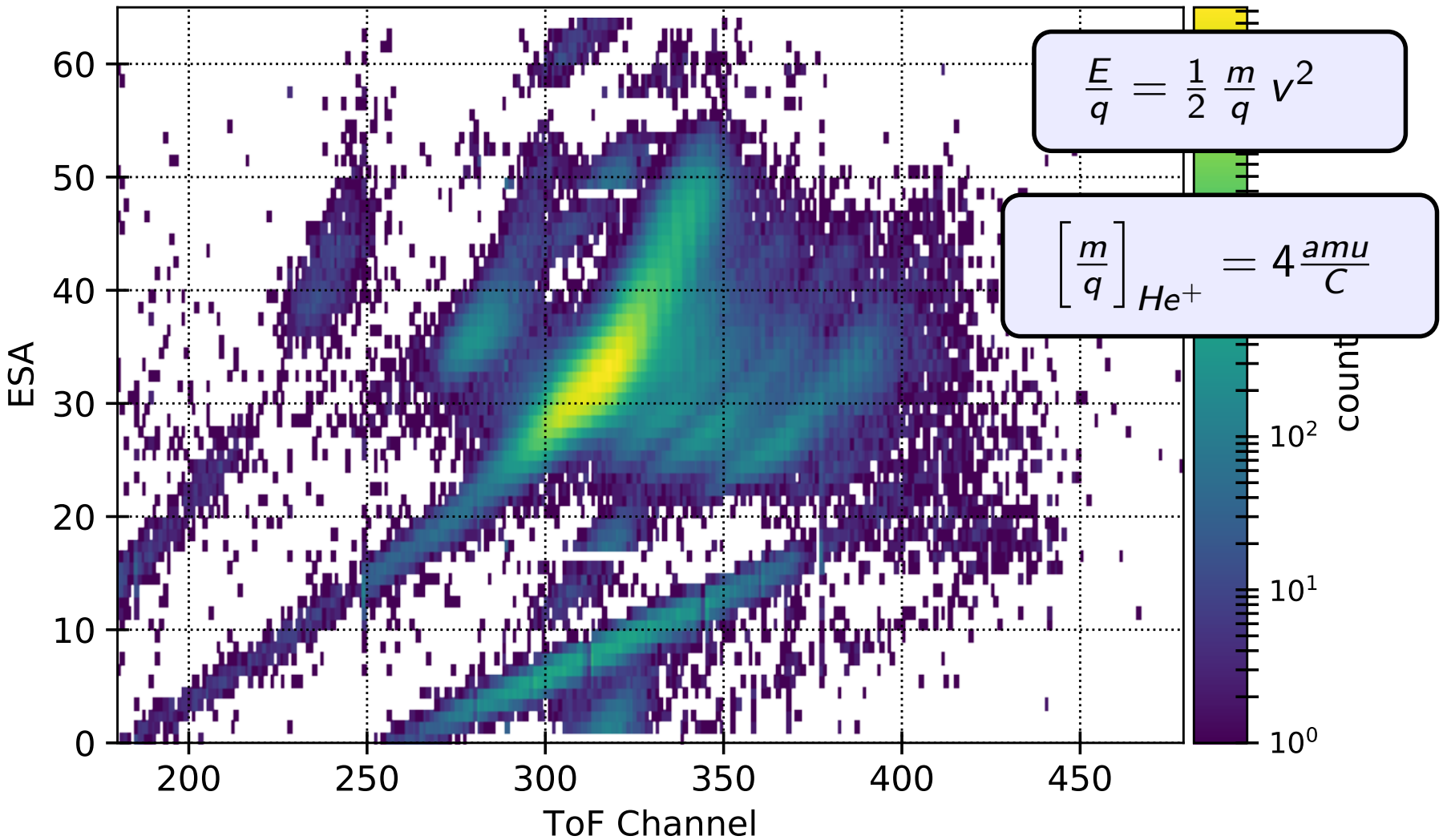
- Time-of-flight mass spectrometer
- $\left\{\frac{E}{q}, ToF, E_{SSD}\right\}$ $\Rightarrow \left\{\frac{M}{q}, M, |v|\right\}$
- identification & energy of the ion



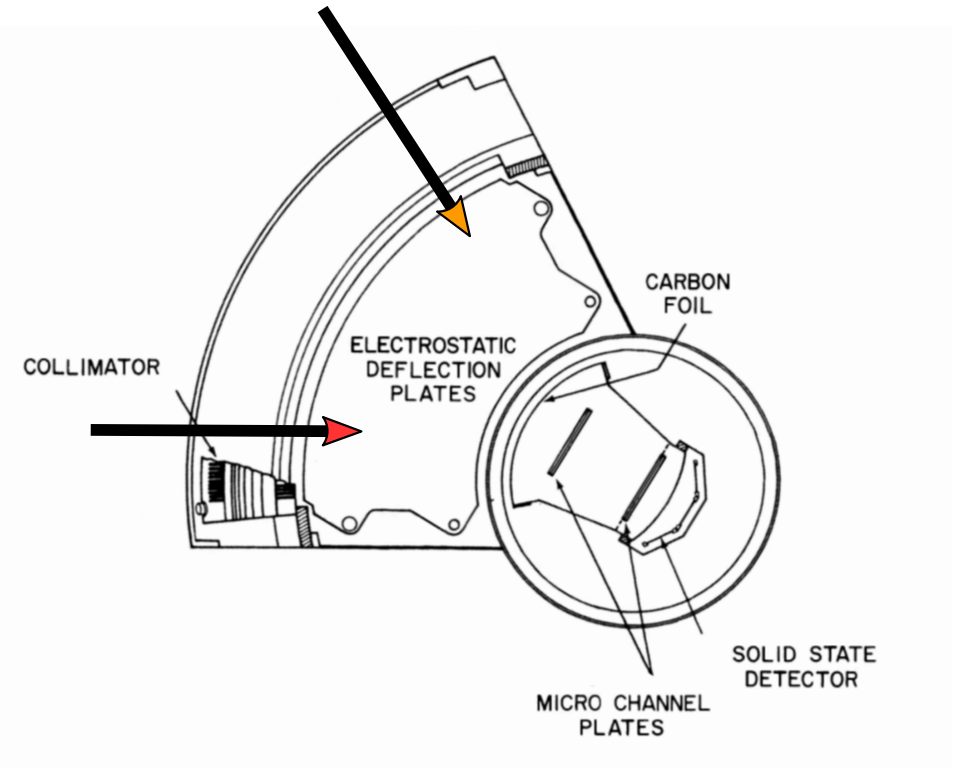


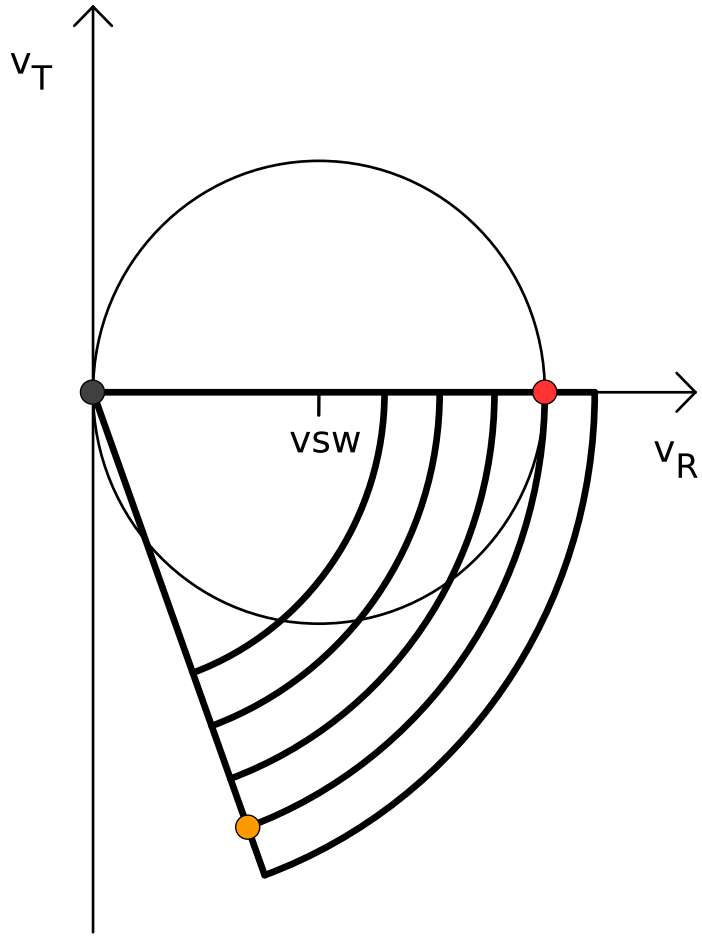
Gloeckler, Geiss et al., 1992

PHA data


$\frac{E}{q} = \frac{1}{2}\frac{m}{q}v^2$
$\left[\frac{m}{q}\right]_{He^+} = 4\frac{amu}{C}$
ESA
ToF Channel
count
0
10
20
30
40
50
60
200
250
300
350
400
450
10^0
10^1
10^2

EpQ measurement

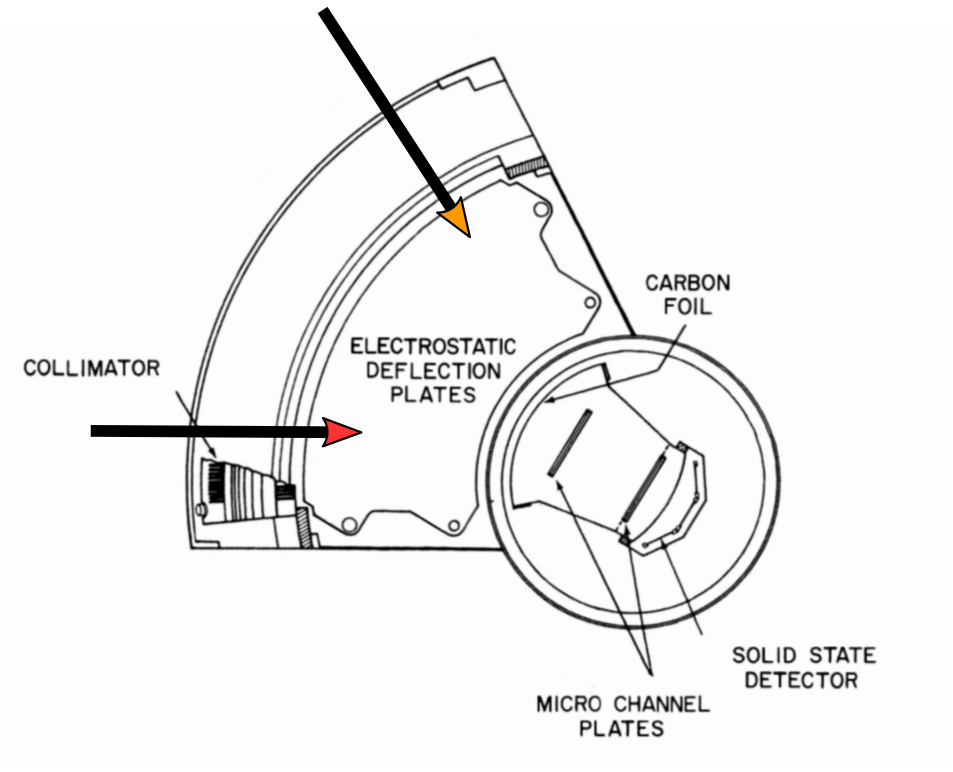




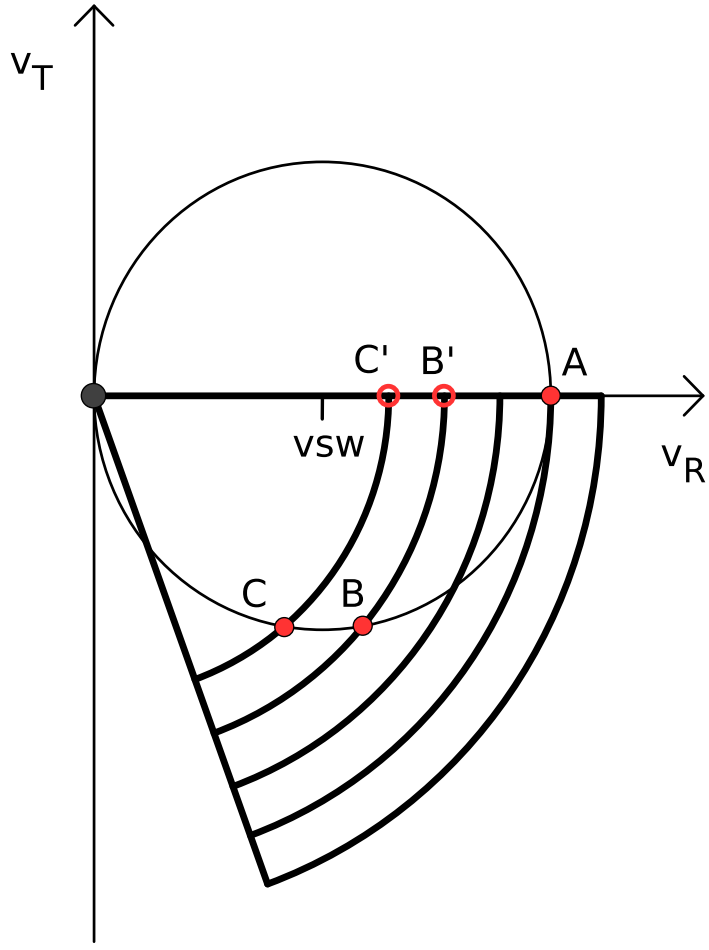
Gloeckler, Geiss et al., 1992

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

EpQ measurement

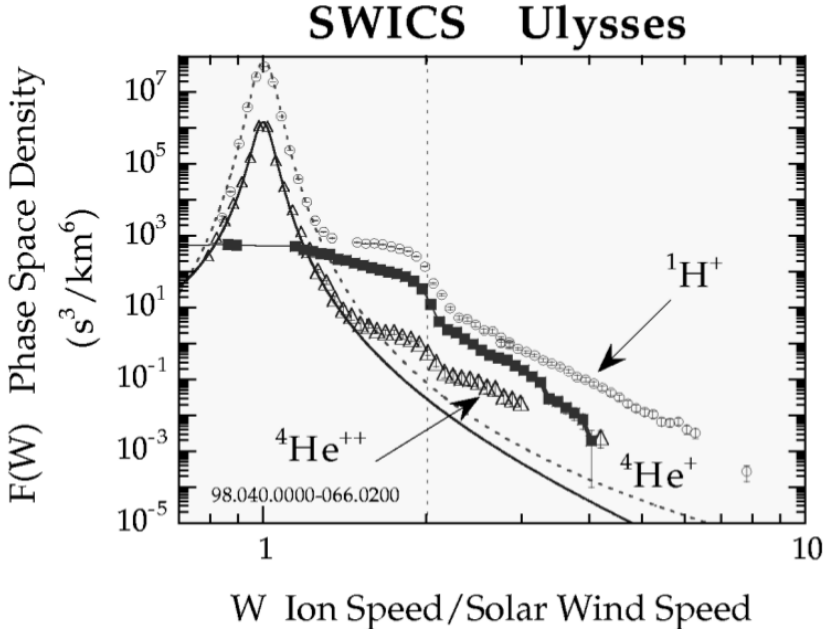


Gloeckler, Geiss et al., 1992

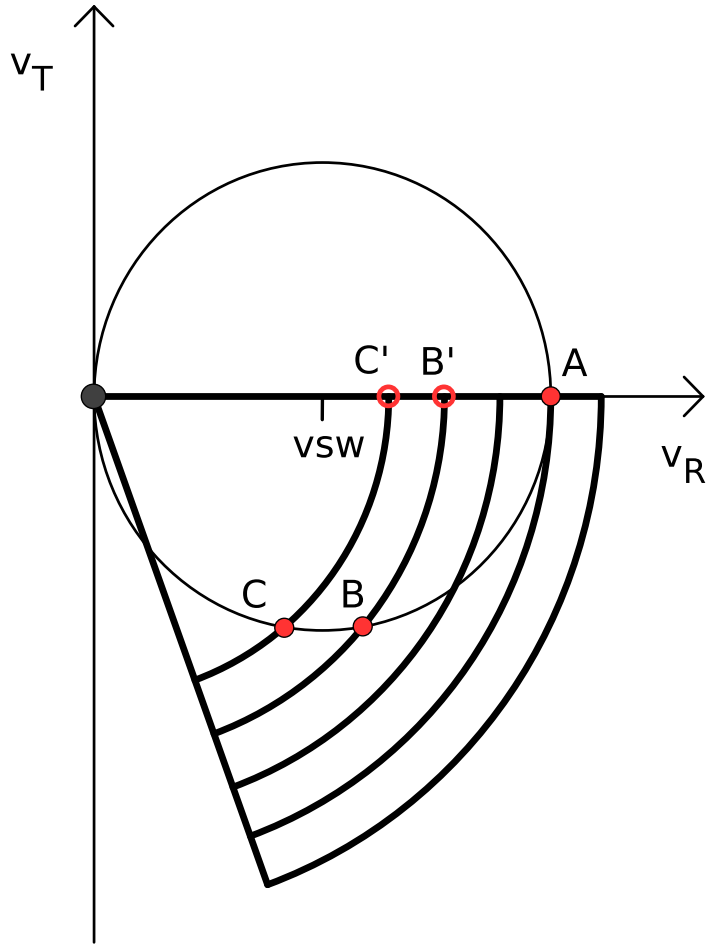


- For constant $\frac{m}{q}$: $\frac{E}{q}$-step $\widehat{=}$ absolute value of velocity

EpQ measurement

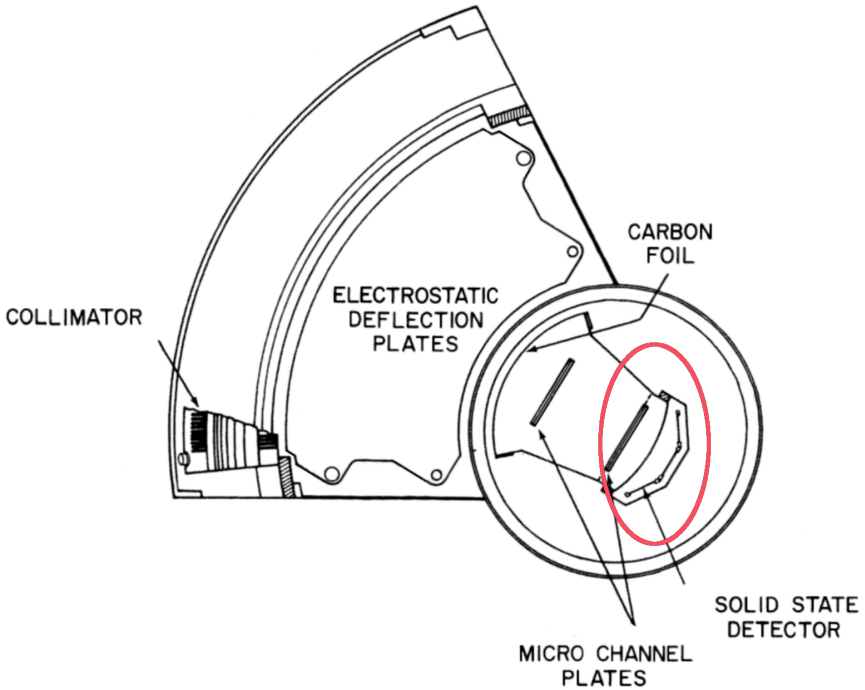


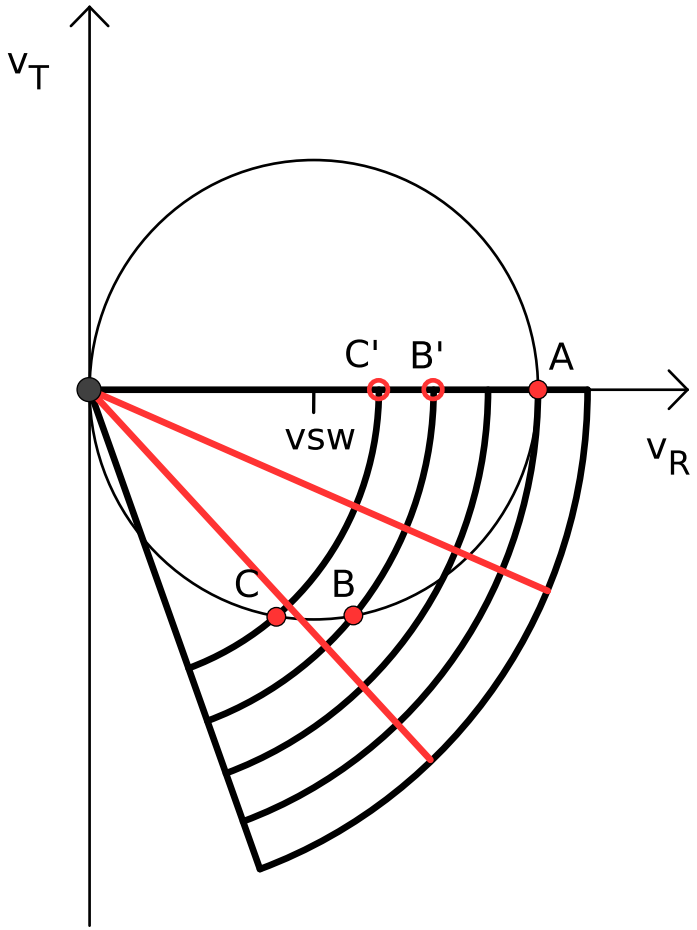
Gloeckler, Geiss et al., 1992



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

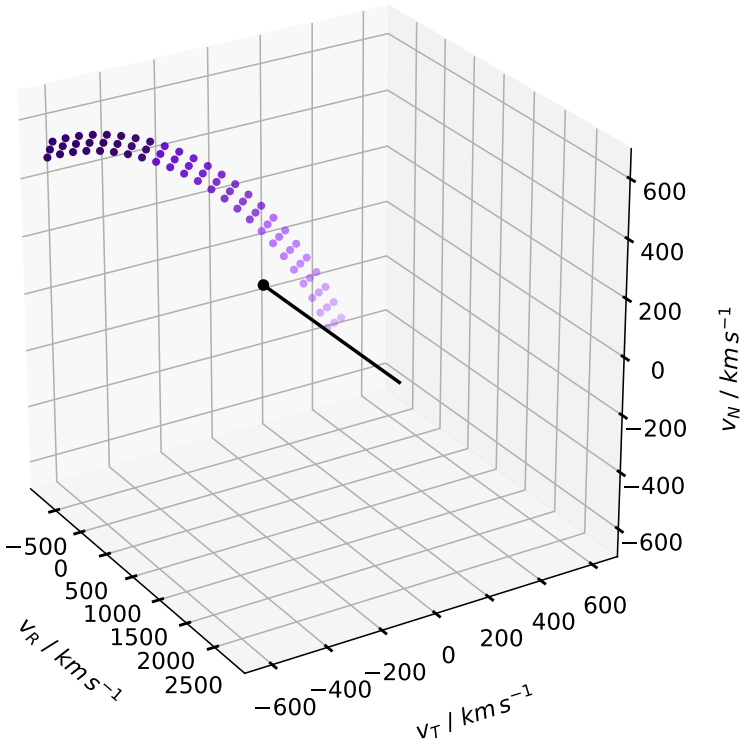
Angular resolution

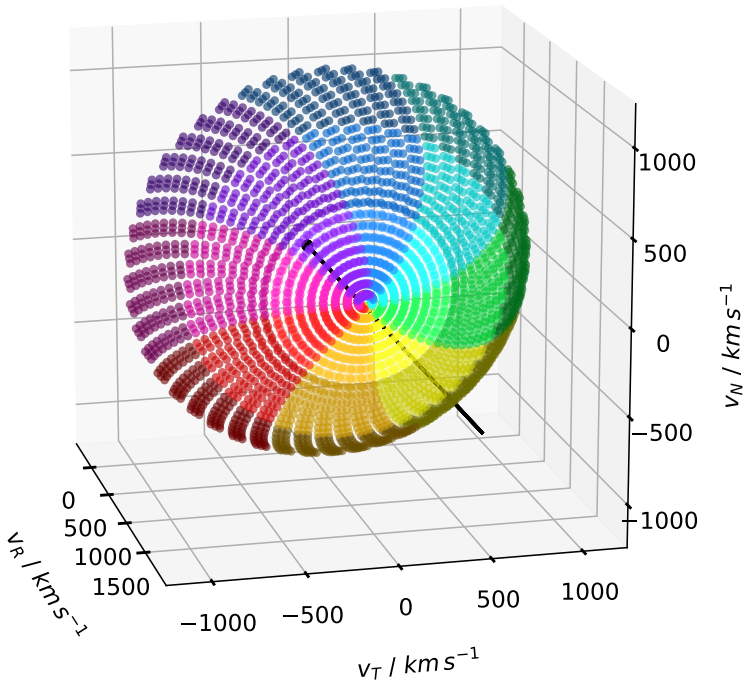


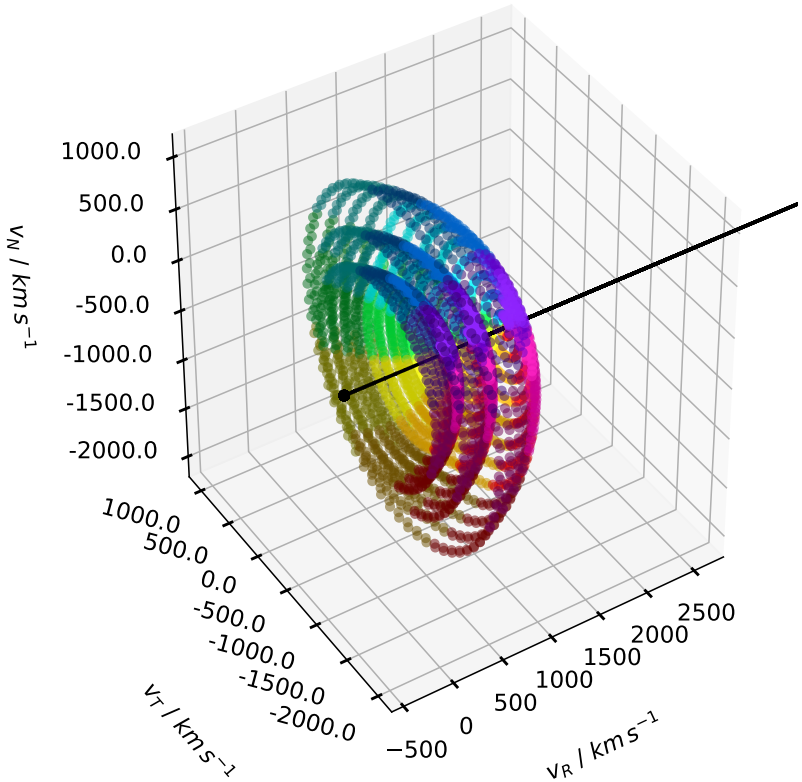


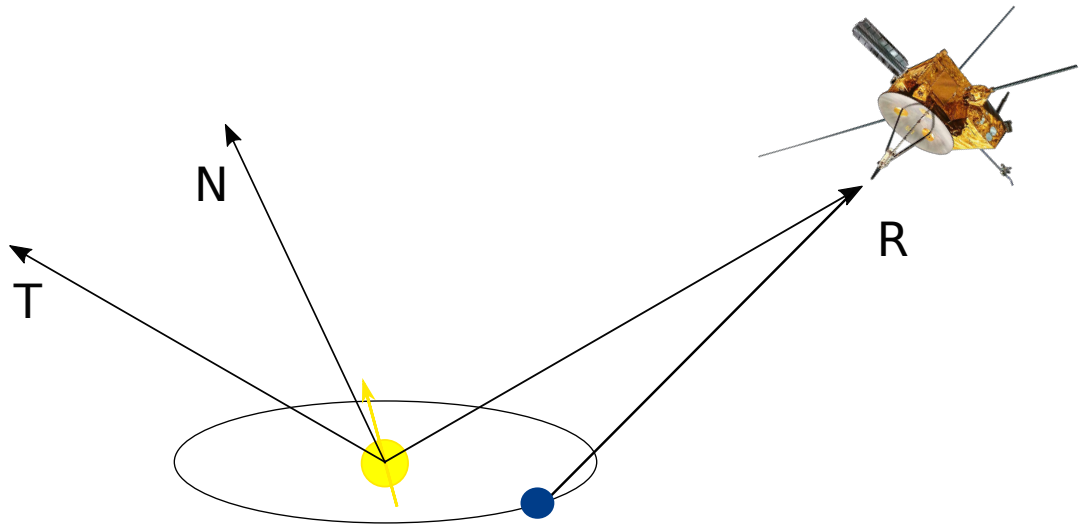
- SWICS: **3 detectors**
  Rough distinction between angles of incidence
- 3rd dimension: spin of the SC
  Divided into **8 sectors**

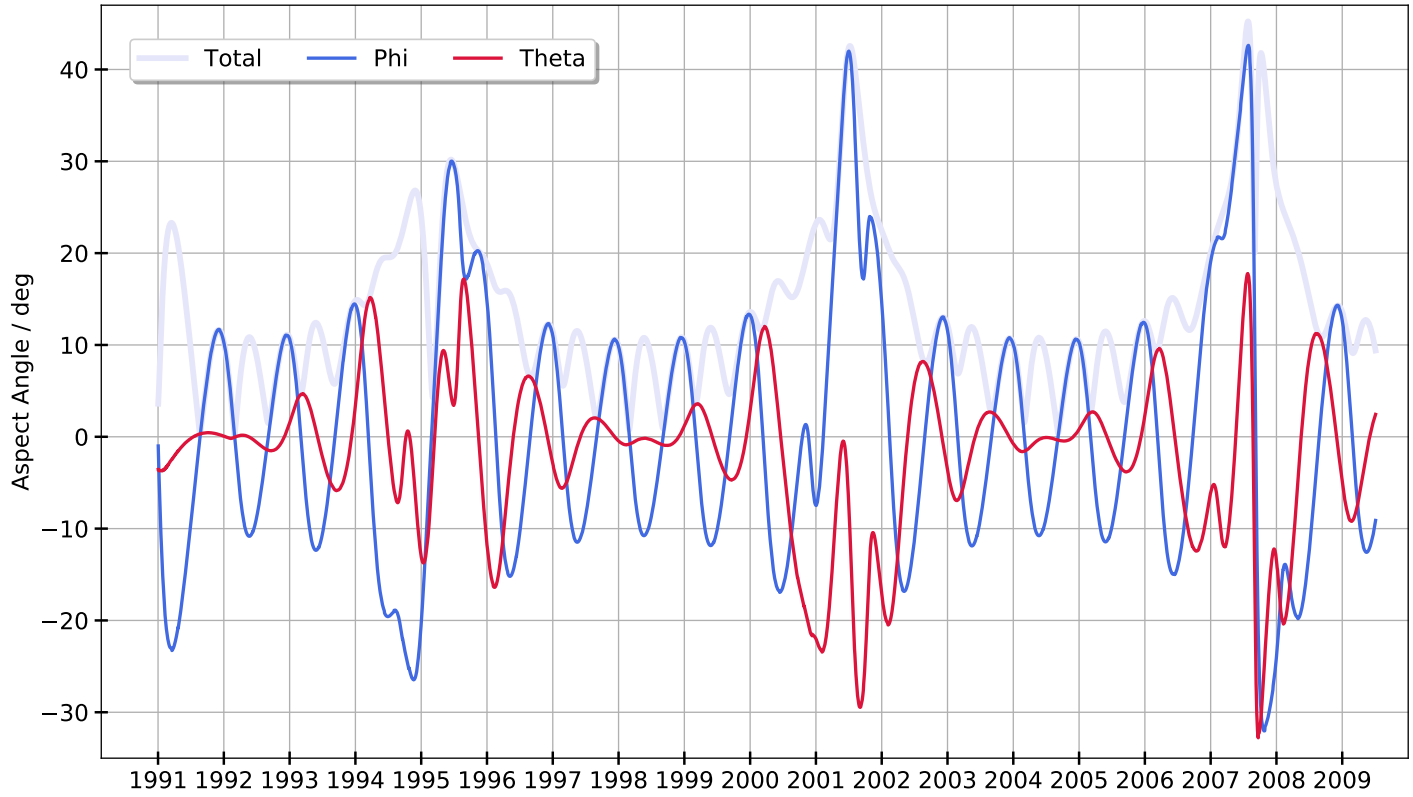
Virtual Collimator

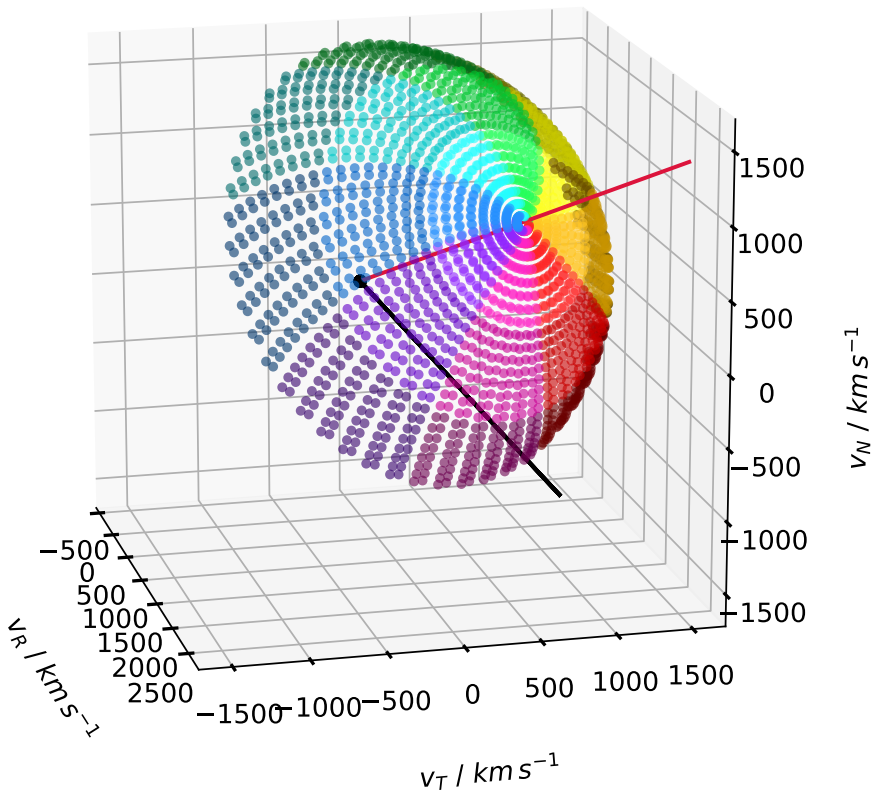


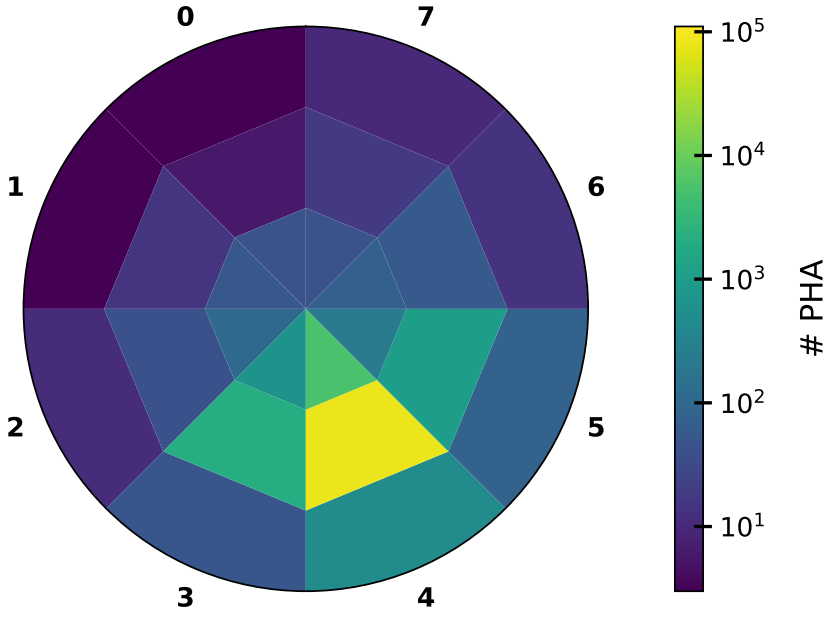



1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
-2000.0
v_N / km s^{-1}
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
-2000.0
v_T / km s^{-1}
−500
0
500
1000
1500
2000
2500
v_R / km s^{-1}

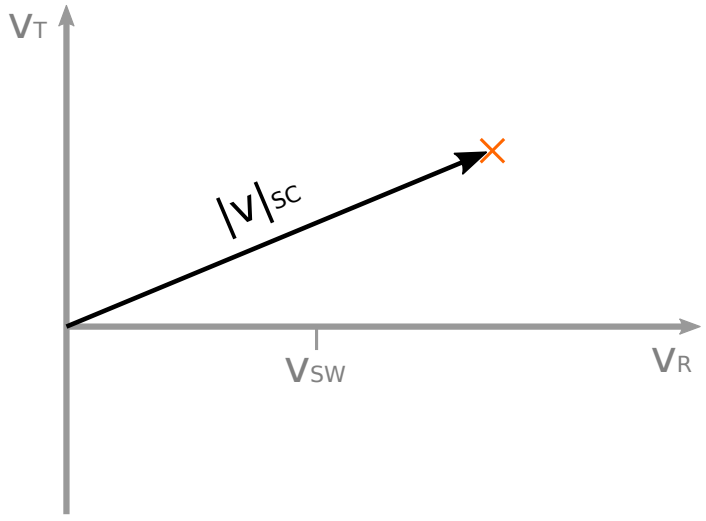

N
T
R

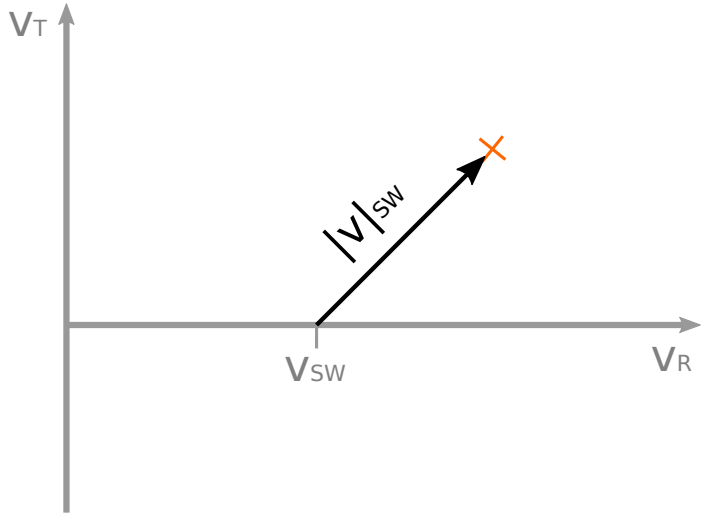

Total
Phi
Theta
Aspect Angle / deg
40
30
20
10
0
−10
−20
−30
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009

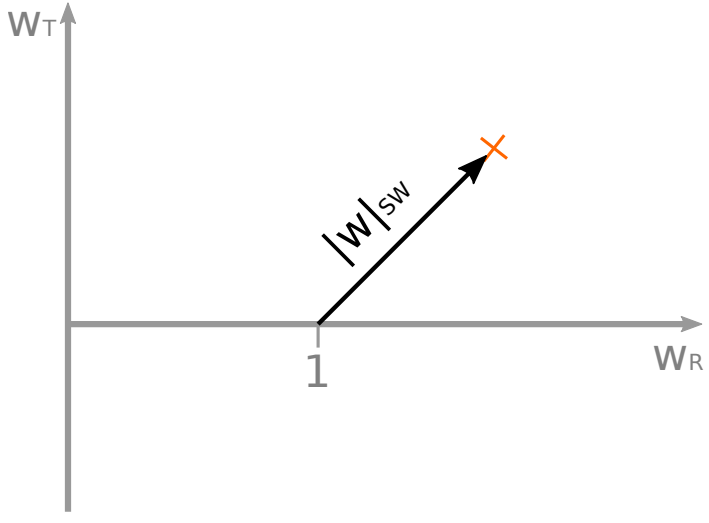

1500
1000
500
0
−500
−1000
−1500
v_N / $km\,s^{-1}$
−500
0
500
1000
1500
2000
2500
v_R / $km\,s^{-1}$
−1500 −1000 −500 0 500 1000 1500
v_T / $km\,s^{-1}$


0
7
1
6
2
5
3
4
10^5
10^4
10^3
10^2
10^1
PHA

Transition

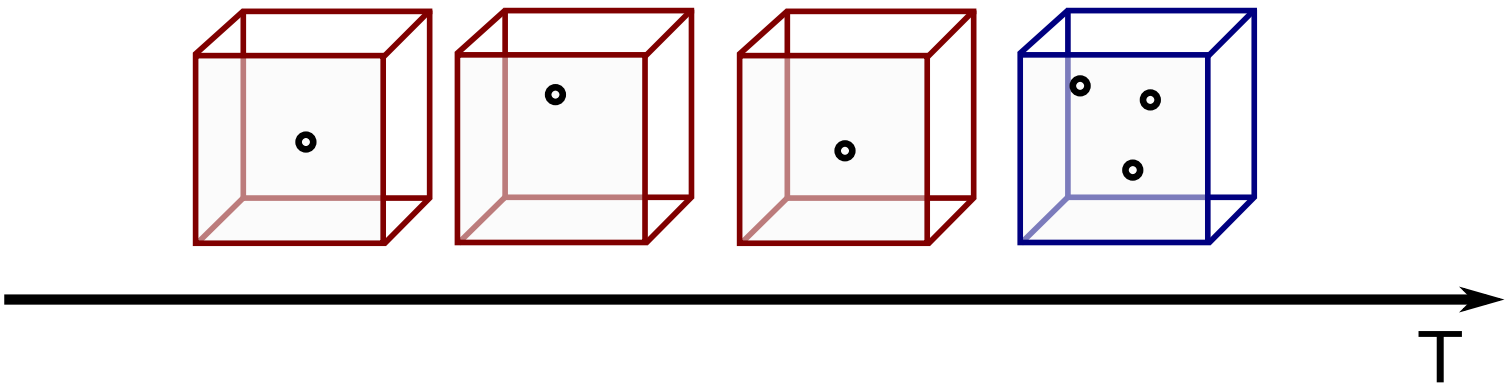






Slice Counts

Einschub: Counts zu PSD



Slice PSD

Skymap

1D

Conclusion