CHRISTIAN-ALBRECHTS-UNIVERSITÄT ZU KIEL

MASTER THESIS

Thesis Title

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Abstract

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too…

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Chapter 1

Motivation

Chapter 2

Pickup Ions

Pickup ions are created when neutral atoms inside the heliosphere become ionised and are subsequently swept away with the heliospheric magnetic field that is embedded within the solar wind.

2.1 The Heliosphere / Introduction

Oder Überkapitel Solar Physics?

Heliosphere: Grenze zu LISM

Solar Wind: Zusammensetzung, schneller und langsamer, high latitudes: less complex, constant in speed

B-Feldgleichung

Irgendwohin muss unbedingt Motivation, warum PUIs überhaupt interessant sind zu messen

2.2 Pickup Ions

A neutral atom inside the heliosphere is only subjected to the gravitational force and radiation pressure of the sun. It is not sensitive to any electromagnetic forces until it becomes ionised by solar ultra-violet radiation, charge exchange with solar wind protons or electron impact (Q?). After ionisation the particle starts interacting with the solar wind plasma. In particular it is forced onto a gyro orbit about the heliospheric magnetic field that is embedded within the solar wind. As the freshly created ion is swept away with the magnetic field line it is "picked up" from its location of ionisation – a new pickup ion (PUI) has been created.

PUIs were first observed by Möbius et al. (1985) with the SULEICA Instrument on the AMPTE spacecraft. The particles measured at 1 AU were He+ ions of interstellar origin.

Once the particle is ionised, its probability to become ionised another time decreases (Quelle). This characteristic of being only singly charged can help to discriminate PUIs from solar wind ions, that are mostly more often charged (Q?).

PUIs are mostly only single charged. This characteristic can help to distinguish them from solar wind ions of coronal origin which often have been ionized multiple times,

if not completely. (Q?)
VDF non-maxwellian, spatial density pattern

There have been observed several species of PUIs:

2.3 Interstellar Pickup Ions

Heliosheath, relative motion

The neutral part of the LISM can enter the heliosphere as it is not affected by the heliosheath (Todo). Inside the heliosphere the neutrals are guided only by the gravitational force and raOriginofC-Geissdiation pressure of the sun. The neutral particle's species determines how deep it can travel into the heliosphere before it becomes ionized. Species with a higher First Ionization Potential will be able to approach the sun much closer without being ionized. This results in He+ being the dominant PUI species at a solar distance of 1 AU even if in the LISM the abundance of hydrogen is about 10 times the one of helium.

- ionisation process is also dependent on the species
- radiation pressure only important for H (and He?). Kepler orbit...
- Spatial distribution:
  gravitational force and radiation pressure lead to two regions of enhanced density of neutrals (in the ecliptic): Focusing cone and crescent. Focusing cone: For species with high FIP (as the others are ionized before and do not reach the downwind side of the sun)
- variation of He+ with the solar cycle: Rucinski 2003
- H, O and N are depleted in the filtration region (Baranov Malama 1995), Wimmer Skript: even before ioniztion: density is determined by ratio of gravitational force and photon pressure
- neutral density determines PUI production rate

2.4 Inner-source Pickup Ions

The idea of an additional source for the PUI's neutral seed population was born when Geiss, Gloeckler, Fisk, et al. (1995) measured a global distribution of C+ PUIs with the SWICS instrument on Ulysses. Interstellar carbon exists almost exclusively in a single charged state (Frisch et al., 2011) in the LISM. As only neutral atoms can enter the heliosphere it was not expected to find a distinct signature of C+ pickup ions. However, pickup carbon was observed with about the same ratio as oxygen, of which, in contrast, 80% is in a neutral charge state in the interstellar medium. These findings suggested that there must be another source for neutrals that has its origin somewhere inside the heliosphere.
In following studies (e.g. Geiss, Gloeckler, and Steiger, 1995) there were found also other species like O+ and Ne+ of these, so called, inner-source PUIs.
Inner-source PUIs show a composition that is similar to the one of the solar wind (Gloeckler et al., 2000; Allegrini et al., 2005) as well as a velocity distribution function that is centered around $w_{SC} \approx 1$ (Schwadron et al., 2000) and seems to have

thermalized with the solar wind.
Beneath those two characteristics there are other aspects concerning inner-source PUIs, that are still under debate. In particular that is the production mechanism of their neutral seed population. Allegrini et al. (2005) has summarized current candidates for possible scenarios. Two of those give an explanation for the ion's composition as they directly incorporate solar wind ions in the process:

- Solar wind recycling (Gloeckler et al., 2000; Schwadron et al., 2000): Absorption of solar wind ions by heliospheric grains and subsequent reemission of neutral atoms
- Solar wind neutralization (Wimmer-Schweingruber and Bochsler, 2002): Solar wind ions penetrate sub-micron-sized dust grains and undergo (partial) neutralization by charge exchange

(As this work does not focus on inner-source PUIs in particular...)

2.5 VDF

After the particle has been ionised it is forced onto a gyro motion about the local field line of the heliospheric magnetic field due to the Lorentz force.

To examine the velocity distribution of PUIs after they have been ionized we need to consider the initial speed v_{ini} of the neutral particle. For neutrals from the LISM this is mainly given by the inflow speed v_{ISM} of the local interstellar medium with which they enter the heliosphere. As we don't exactly know about the production mechanism of inner-source PUIs, the following considerations mainly relate to interstellar PUIs. Schwadron et al. (2015) obtained $v_{ISM} \approx 25\,\mathrm{km\,s^{-1}}$ with the IBEX satellite for helium. Considering the acceleration by the sun's gravitational force we have a maximum initial speed of $v_ini \approx 50\,\mathrm{km\,s^{-1}}$ at 1 AU. Compared to an average solar wind speed of $v_{sw} \approx 400\,\mathrm{km\,s^{-1}}$ one can neglect this initial speed in a first step.

For simplicity we thus consider a neutral particle at rest that becomes ionized by one of the aforementioned processes. The freshly created ion now is subjected to the electromagnetic forces of the solar wind plasma. In particular, it finds itself at a velocity v_{sw} relative to the magnetic field which is convected outwards by the solar wind that is assumed to flow radially outwards. Due to the Lorentz force the PUI starts to gyrate about the magnetic field line on an orbit that is perpendicular to it.
When we further consider a magnetic field's orientation that is perpendicular to the solar wind flow, $\vec{B} \perp \vec{v}_{sw}$, the ion's gyration speed is v_{sw} while its guiding center moves together with the field line at a speed of v_{sw} as well. Thus, the total speed of the PUI ranges between $0\,\mathrm{v_{sw}}$ and $2\,\mathrm{v_{sw}}$ in a sun frame of reference.
As the heliospheric magnetic field lines are shaped like an Archimedean spiral, the so called *Parker spiral*, the assumption of a perpendicular magnetic field only applies when solar wind speed v_{sw} and solar distance $r_\odot$ follow the relation

$$90^\circ \approx arctan\left(\frac{2\pi}{T_\odot \cdot v_{sw}} r_\odot\right)$$

with sun's sidereal period $T_\odot \approx 25\,d$ (Prölss, 2004). In other cases, e.g. for solar distances about 1 AU, at which the angle between solar wind and magnet field direction is approximately 45°, the maximum speed in a sun frame of reference is decreased.

In general, the gyration speed is given by

todo

with ... .

The velocity space for a pickup situation with a non-radial magnetic field orientation is shown in figure todo on the right. The PUI's total velocity consists of the movement of the guiding center (...) and the gyration velocity (...). We note, that in this case there is a relative velocity between the motion of the solar wind bulk and the PUI's guiding center movement.
However, independent on the magnetic field orientation, every possible velocity space trajectory is part of a sphere with the radius v_{sw} centered around $\vec{v}_{sw}$. That means that, in the frame of the solar wind, the freshly created PUI always moves with a speed that is as fast as the solar wind itself. (todo: Hier w einführen?)

Instead of a single PUI we can consider an ensemble of PUI's that is injected into the solar wind while the magnetic field orientation is not changing much. For that we expect the VDF to form a ring shape in velocity space, commonly called the "PUI torus VDF" (Oka et al., 2002). The expected orientation of this highly anisotropic torus VDF depends on the local magnetic field direction and is sketched in figure todo for three different angles.

...thickness that is related (associated) to the neutral's velocity and is very small compared to the radius...

Spatial diffusion: chalov Fahr 1998. Signature of plasma parcel in which is was produced doesn't match with the one it is measured in

After the injection, the PUI population is radially carried away with the solar wind. During phase space transport through the heliosphere the PUIs are subjected to multiple processes that are expected to modify the shape of the initial toroidal VDF. However, it is not completely understood how the VDF evolves in detail.

A fast isotropization of the VDF due to pitch-angle scattering was suggested by Vasyliunas and Siscoe (1976) in a theoretical work. However, observations by e.g. Möbius et al. (1998) on $He+$ or Gloeckler et al. (1995) on TODO have shown clear anisotropic features in the measured VDFs. Following studies (todo) explained these findings with the assumption that the ions would be injected into the sunward hemisphere of velocity space more likely. Ineffective pitch-angle scattering into the anti-sunward hemisphere thus would result in an radial anisotropy.

Recent observations have emphasized the influence of the magnetic field direction on the measured anisotropy. Utilising 2D analyses of the velocity space, Oka et al. (2002) and Drews et al. (2015) found that the measured VDF of PUIs is systematically oriented about the direction that is perpendicular to the magnetic field. Thus, it is believed that the VDF's anisotropic features are remnants of the initial toroidal VDF. (and the pa scattering didnt have enough time to isotropize the distribution)

Furthermore, there are different acceleration and deceleration processes that change the PUI's initial VDF and lead to a diffusion in velocity space. Under the assumption of an isotropic VDF the PUI population is often treated as an adiabatic gas that is consequently cooled when expanding with the solar wind. This picture, initially suggested by Vasyliunas and Siscoe (1976), however, must be reviewed due to the doubtful fact of a fully isotropic VDF. Another cooling mechanism, called the *magnetic cooling*, is due to the magnetic field weakening with solar distance. As the PUIs are swept outwards both their ... and their ...invariant have to be conserved which leads to a decrease in both velocity components (parallel and perpendicular to the magnetic field) and thus to a decrease in total velocity (in the frame of the solar wind).

(focusing (adiabatic invariant) & Ginzberg Landau (Fahr2008): "magnetic cooling" (auch gute Erklärung: Fahr&Fichtner2011))

Acceleration of PUIs can be caused by acceleration: first and seconf order fermi (verstehen, gründe): eher außen bzw. ehr innen. Außerdem ein Mechanismus, der nicht an einzelne Events gebunden ist, sondern immer vorhanden: Mechanismus für alle Teilchen, power law -5...
man kann in der 1D Verteilung beobachten, dass 2vsw exceeded wird

PUI He should be measured throughout the mission as they penetrate the heliosphere until 0.5 AU (Gloeckler et al., 1992)

Instrument that is capable of measuring this distribution: large acceptance in absolute velocity, large variation and resolution in angles

2.5.1 1D reduced VDF, aim of this work...?

Chapter 3

Instrumentation

3.1 Ulysses

The Ulysses spacecraft (Wenzel et al., 1992) was launched in 1990 and orbited the sun for nearly 20 years as a joint ESA/NASA project. Ulysses' most remarkable feature is its out-of-ecliptic orbit with an maximum heliographic latitude of $80.1\,^{\circ}$. As the first spacecraft it was hence capable of taking in situ measurements from above the poles of the sun.

Thus, the primary goal of the mission was to study the heliosphere in three dimensions. In detail some of the original main objectives were:

- to study the interplanetary magnetic field and the solar wind, especially its composition, the origin and waves and shocks within the solar wind plasma
- to investigate galactic cosmic rays and energetic particles
- to improve the knowledge about interplanetary dust
- to explore the neutral component of interstellar gas

Some secondary objectives included e.g. the investigation of Jupiter's magnetosphere during the Jupiter flyby and the search for gravitational waves and for gamma-ray burst sources (Wenzel et al., 1992).
For these aims Ulysses was equipped with a wide range of different instruments and antennas. One of the in situ instruments is the Solar Wind Ion Composition Spectrometer, that will be described in the next chapter.

A sketch of Ulysses unique orbit is shown in figure 3.1. Ulysses was launched in October 1990 and left earth's gravitational field with 15.4 km/s. Starting with a flyby maneuver around Jupiter Ulysses was sent onto its highly elliptical orbit. With an orbital period of 6.2 years Ulysses completed nearly three orbits around the sun until communication was shut down in June 2009 due to the expiring of the radioisotope thermal generators. Within the mission's long lifetime the Sun's behaviour over its activity cycle of 22 years could be studied.

aspect angle (antenna)– Power: RHU because too far away for solar panels (and radiation belt of Jupiter) – rotation stabilization – mission was extended multiple times

Abbildung Sun Cycles?

spinstabilisiert, Antenna fast Rotationsachse, Antenne zeigt zur Erde, woher Daten (Ulysses, SWICS, Erde)

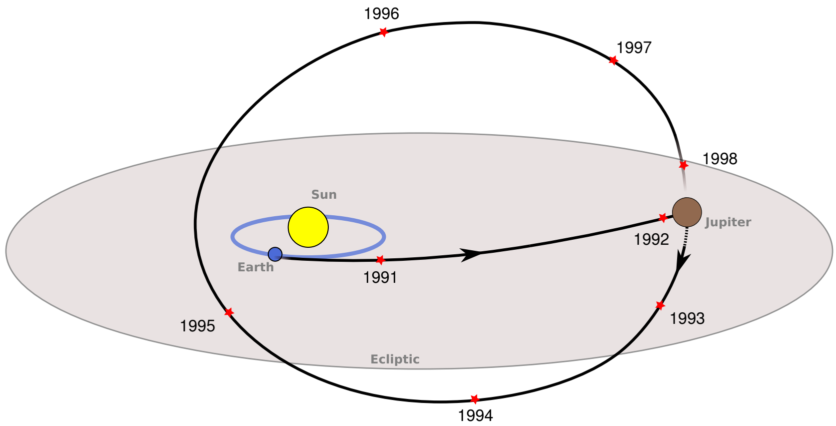

FIGURE 3.1: A sketch of Ulysses' first orbit. After the launch from earth in 1990 the spacecraft was sent to Jupiter from where it left the ecliptic on an elliptical orbit around the sun with perihelion at 1.3 AU and aphelion at 5.4 AU. Due to the orbit's high latitude of $\sim 80^\circ$ Ulysses crosses the Sun's pole regions two times between 1994 and 1996. Figure after European Space Agency (2019).

Rotation

Importance PUIs: ref to PUI-Kapitel und zu objectives

3.2 SWICS

3.2.1 Introduction and Objectives

The Solar Wind Ion Composition Spectrometer (SWICS, Gloeckler et al. (1992)) is a time-of-flight mass spectrometer mounted on the spacecraft Ulysses (s. section 3.1). The instrument is designed to determine the elemental and charge-state composition and the velocity distribution of solar wind ions. With an energy-per-charge range from 0.16 keV/e to 59.6 keV/e SWICS is in principle able to measure every solar wind ion species from protons to iron with any typical charge state. Depending on the individual ion, energies from $E < 1$ keV up to $E > 1$ MeV are covered.

Additionally, the flight spare of SWICS has been mounted on the spacecraft ACE (TODO: ref Stone 1998)

Also capable of measuring PUIs! Erstmals gesehen...?

SWICS measures the mass m, the charge q and the energy E_{SSD} of entering ions by a combination of three separate measurements: The *electrostatic deflection analyzer* within SWICS entrance systems is used for determining the energy per charge of a particle. Within the time-of-flight/energy section the particle's time-of-flight (ToF) and energy (E_{SSD}) are measured.
Todo: Bild von SWICS, neben den beiden sieht man noch die Elektronik...

mounted on the sun-facing side of Ulysses

Opening angles: ± 2 deg perp, 90 deg parallel

In the following section the measurement is described in more detail.

3.2.2 Principle of Measurement / Identification of Particles

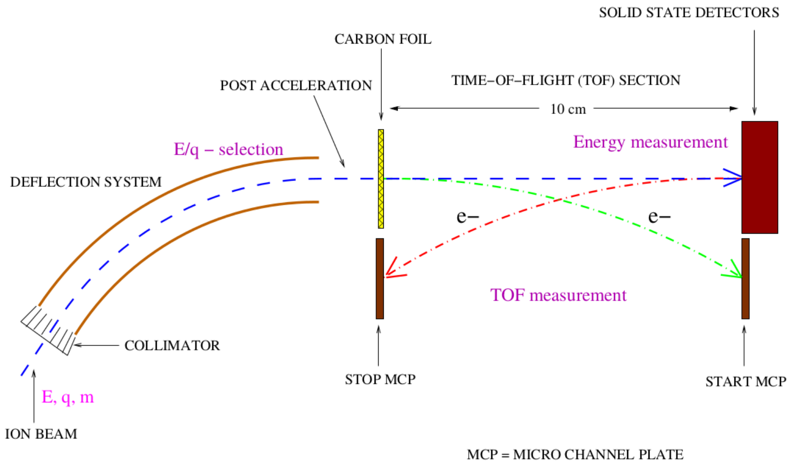

FIGURE 3.2: test

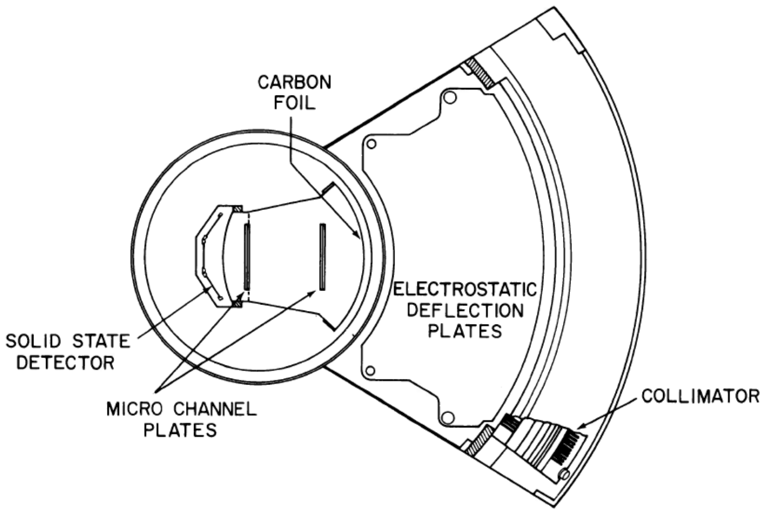

FIGURE 3.3: test

Collimator and Electrostatic Analyzer

Particles enter the instrument through the entrance collimator. It restricts particles to the ones with a trajectory that is parallel to the collimator slits. The geometry of the collimator is curved "fan-shaped"...TODO: Kollimatorgeometrie beschreiben Within the TODO: Two sections After the collimator particles have to pass the electrostatic analyzer. It is split up into two sections – energies from 0.16 to 14 keV/e are covered by the proton/helium channel. Particles within this range of energy will be filtered by their EpQ and after an post-acceleration will be counted by a solid-state detector. As this simple measurement principle is very limiting for our analysis we will focus on the main channel that is suitable for a full m-vs.-mpq analysis. The main channel covers an EpQ range of 0.65 to 60 keV/e. A particle can only pass through the pair of curved deflection plates if its kinetic energy per charge equals a certain ratio that is given by the voltage between the two plates. To measure particles of different EpQ the deflection voltage is stepped through 64 logarithmically spaced values from TODO to TODO. As the voltage steps once per spin of Ulysses (every 12 seconds), a complete voltage cycle lasts $\sim$ 12.8 minutes. Every step has a relative uncertainty of $\Delta E/q \approx 5\%$ that is due to the finite space between the plates. TODO: Plot

Time-of-flight measurement

After passing the electrostatic analyzer ions are post-accelerated by an constant potential drop of 30 kV. They enter the ToF chamber with penetrating through a thin ($\sim 3\,\mu\mathrm{g/cm}^2$) carbon foil where secondary electrons are emitted. These electrons are guided to a microchannel plate detector where a start signal is triggered. The stop signal is triggered after the particles have traversed a distance of 10 cm and hit one of the solid state detectors, where secondary electrons are emitted again. By combining the time stamps of the start and the stop signal the particle's ToF has been measured.

Energy measurement

Furthermore, the particle's energy is measured when they hit one of the three solid state detectors (SSD). The detectors have each an active area of $1.5x1.3\,\mathrm{cm}^2$ and their orientation of the detectors can be seen in TODO. While the central detector is aligned perpendicular to the symmetry axis of SWICS, the other two detectors are slightly tilted with respect to this axis. Particles with different angles of incidence along the width of the collimator can be detected this way.

Thus, a wide field-of-view is provided, allowing measurements of particles, die schief reinkommen. Das passt zur Begrenzung vom Kollimator. Man kann auch unterscheiden, welcher getroffen wurde.
Verfälschungen? Folie etc?
The measured energy E_{SSD} is often referred to as *residual energy* in literature. This is potentially misleading as the particles might have more energy due to the post-acceleration

One of SWICS' main objectives is the measurement of the composition of incident particles. An ion and its charge state can be fully identified with the knowledge of its mass m and its mass-per-charge mpq. With the measurement of the ToF, the energy E_{SSD} and the knowledge of the EpQ-step we can calculate the mass, mpq and velocity of an ion i with the following set of equations:

$$m_i = 2\,E_{SSD}\left(\frac{Tof}{d}\right)^2 \tag{3.1}$$

$$\frac{m_i}{q_i} = 2\,(EpQ + V_{PAC}) * \left(\frac{Tof}{d}\right)^2 \tag{3.2}$$

$$v_i = \sqrt{2\,EpQ\,\frac{q_i}{m_i}}, \tag{3.3}$$

where d is the length of the time-of-flight section and V_{PAC} is the post-acceleration voltage. v denotes the ion's initial velocity when entering the instrument and is not to be confused with its velocity during the time-of-flight measurement, that is altered particularly by the post-acceleration.

3.2.3 Velocity Space Coverage

3.2.4 The Section

von den Rohdaten zur 3D VDF:

Datenfilterung: ET Matrix – woher Daten – welche Datenprodukte – warum He und He2 – He und He2 identifizieren – Prioritätsschema hier?
andere Daten: B, vsw (Swoops)

Kollimatormodell – warum eigentlich – wie umgesetzt?
Das Ziel ist, einem gemessenen Teilchen einen v-Vektor zuzuordnen. Eine Sek-Det-Kombi ist aber nicht eindeutig. Ihre Bedeutung hängt davon ab, wohin das Instrument guckt (FoV), von der Eigengeschwindigkeit des SC und davon, wie das SC gerade gedreht ist. Zusätzlich hat der Kollimator eine komplizierte Geometrie, sodass eine analytische Lösung schwierig ist: Also numerische Lösung.
Was macht das Modell? – Ich will das FoV zu jedem Zeitpunkt bestimmen. Ich nehme dafür einzelne Messpunkte auf der originalen Geometrie. Dann gebe ich noch ins Modell, wie das gerade ausgerichtet ist. Übergang vspace: Dann weiß ich, welche v-Vektoren möglich gewesen sein können, damit dieses PHA-Wort entstanden ist.
Kalibrierung: He2+, Det-Sec-Histogramme – Suche nach Sek 0

vom FoV zum Vspace

Zweifache Beschränkung im w-Space: Bei kleinem w: keine hohen Steps (kleine Geschwindigkeiten) durch das unter-den-Threshold-Rutschen. Bei hohem w: ende der Schalen (Step 0: 1708.5 km/s)

Chapter 4

Data Analysis and Methods

wohin damit?

PHA pro Spin... Ideal / mit Fehlern alpha, beta
SWICS provides two types of data products from the analogue signals Tof, ESSD and the EPQ-Step. 24-bit

4.1 Data products

PHA words, data transmission

4.1.1 Priority weighting

SWICS performs an on-board mass and mass-per-charge-classification. For every ion with valid measurements the m and mpq are calculated based on the measurements of ESSD, Tof and the particle's EPQ-step using a look-up-table technique.
On the one hand these values are used for sorting the ions into predefined boxes in the m-mpq-space which yield in the so-called matrix rate, a second data product that is provided by SWICS.
Secondly, and more important for our analysis, the m and mpq information is used to sort every measured ion into one of three priority ranges.
Range, BRW

Range 0	$m < 8.7; m_0 : mpq < 3.3$	H, He^+, He^{2+}; Doubles
Range 1	$m > 8.7$	Heavier ions
Range 2	$m_0 : mpq > 3.3$	Doubles

4.1.2 Detection efficiencies

Threshold, Doubles...

4.2 ET matrices, identification

Fig. 4.1 shows longterm PHA data collected with Ulysses SWICS over two years for EPQ Step 25 (= Energy per charge TODO). For every particle with valid measurements the E_{SSD} channel is plotted over the ToF channel. As a particle's mass and mass-per-charge is connected to the measured values EpQ, τ and E_{SSD} by equations 3.1 – 3.3, every ion species occupies a distinct position in the so-called *ET-Matrix*.

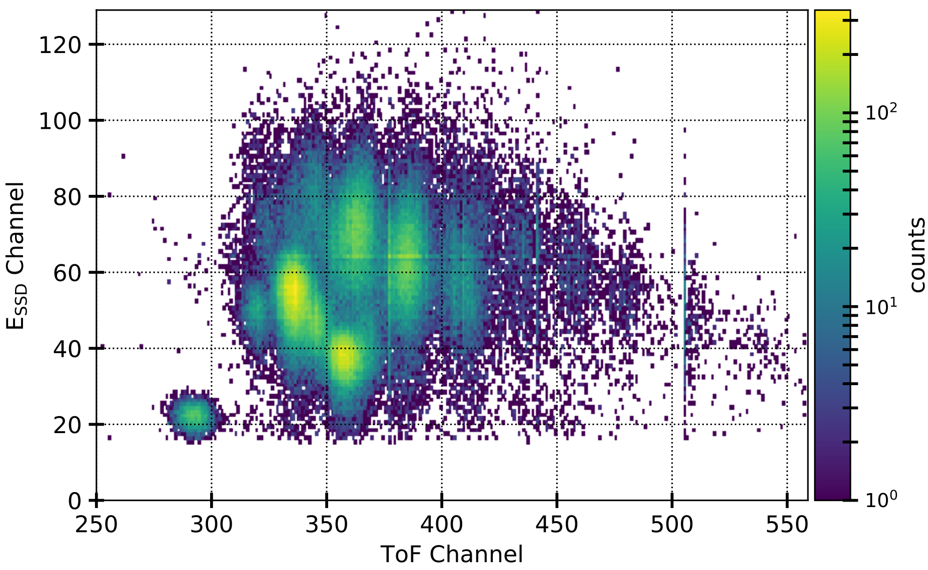

FIGURE 4.1: test

4.3 Filter He+

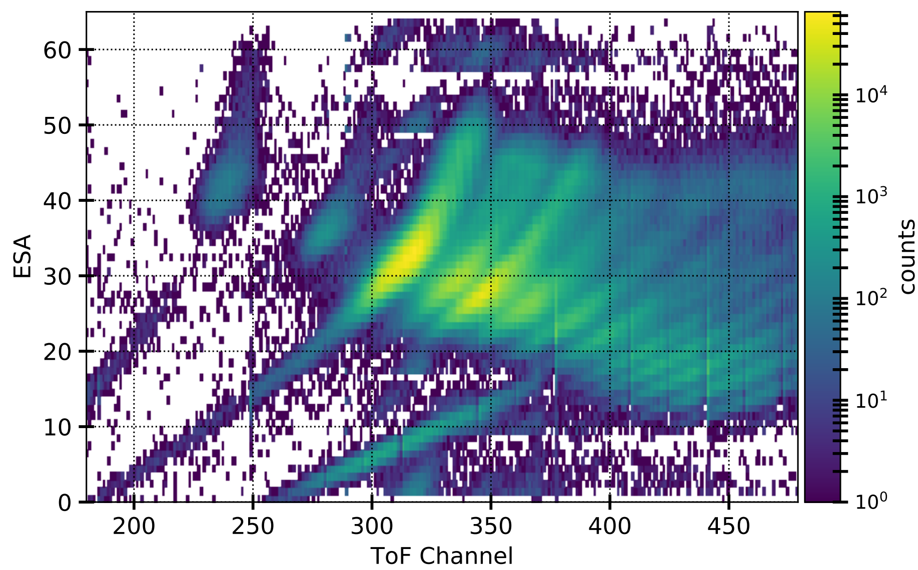

FIGURE 4.2: test

For extracting only the He^{+} events from the PHA data we plot the events' energy-per-charge over their measured ToF. Teilchen derselben mpq werden auf Kurven *todo* geortet. Spezies höherer Mpq finden sich auf Kurven mit größeren ToF-Werten. Man kann so z.B. todo, todo und todo identifizieren. Unten ist He gut zu erkennen weil suprathermal. An die suprathermalen *He*-Teilchen schließen sich zu höheren ToF andere Teilchen mit derselben mpq auf der gleichen Kurve an. Weil die Kurven dort enger liegen, kann man He in dem Bereich auch nicht von anderen mit

ähnlicher mpq unterscheiden. We can take advantage of SWICS' on-board priority weighting. We only plot the Range0-events. This roughly cuts out events with $m > 8.7$. Nur H, He2+, He+ bleiben übrig als prominente Ionen. Man sieht, dass auch einige schwerere in die Box reinlecken, aber das betrifft nicht die ESA-Steps, in denen Helium auftritt.
Man kann jetzt prima per Auge eine Maske legen. Zusätzlich w filtern um eventullen Hintergrund zu unterdrücken...? Man sieht, dass wir nur Helium-PHAs bis EpQ-Step todo auswerten. Der Grund ist, dass He1+ aufgrund der geringen Masse nicht genug Energie hat, die Triggerschwelle des SSDs zu überschreiten. Somit liegen He1+-Ionen bei höheren ESA-Steps (kleineren Energien pro Ladung) als Double Coincidences vor und taugen nicht für unsere Analyse.
Für alle Jahre. Anzahl: todo

4.4 Filter He2+

für die spätere Kalibrierung (todo: Verweis) brauchen wir eine Spezies, bei der wir davon ausgehen, dass sie sich mit dem SW-Bulk bewegt und die als Triple Coinzidences vorliegt (für die Richtungsinformation). We choose He2+ wegen guter Statistik und auch in Range0. Im Gegensatz zu He1+ auch bei höheren ESA-Steps anzutreffen, weil mehr Nachbeschleunigung durch die höhere Ladung. Dadurch nicht so schnell unter SSD-Threshold. Gleiches Verfahren, einfach ausschneiden. Hier ist es nicht so wichtig, alles mitzubekommen, weil wir anhand von He2+ keine Analyse der VDF durchführen wollen.
Für alle Jahre. Anzahl: todo

Weitere Daten: vsw von SWOOPS, B-Feld

4.5 Collimator

Geometrie, Aspect Angle: Ausrichtung zu jedem Zeitpunkt bekannt (FoV) (hierher die Kalibration! Nur damit funktioniert die Ausrichtung) Wir füllen die einzelnen Bereiche mit verschiedenen möglichen Messpunkten

Übergang FoV -> vSpace: Richtungsinfo aus FoV Betrag aus EpQ-Steps außerdem: Eigengeschwindigkeit Ulysses

Dann nehmen wir PHA-Worte und können jedem ein gemessenes Volumen im Phasenraum zuordnen (?).

4.6 Phasenraumbla

Mittlere Phasenraumdichte in einem Bin, in den zwei Instrumentenbins A und B reingehen: (differential PSD)

$$\bar{\rho} = \frac{N_A + N_B}{\frac{N_A}{N_{A,ges}} V_A + \frac{N_B}{N_{B,ges}} V_B} \tag{4.1}$$

Dabei ist N_i die Anzahl der Hits, die im Messbin gelandet sind und $N_{i,ges}$ die gesamte Anzahl an Bins. Hits heißt GEsamtcounts durch Detektoranzahl. Eigentlich gebe ich statt N_i $N_i \cdot Detektoranzahl$ rein, aber das kürzt sich ja raus.

Effizienz und Sektorgewichte dazu:
Allg.:

$$\rho = \frac{N \cdot brw}{V \cdot Eff}$$

Und dann

$$\bar{\rho} = \frac{N_A + N_B}{\frac{N_A}{N_{A,ges}} \frac{V_A \cdot eff_A}{brw_A} + \frac{N_B}{N_{B,ges}} \frac{V_B \cdot eff_B}{brw_B}} \tag{4.2}$$

4.7 Outlook

- Efficiency müsste genau bestimmt werden: Dabei berücksichtigen, welcher Anteil unter den Threshold wandert. Evtl. überschätzen wir die Eff., wenn wir die interpolierten Werte von ACE/SWICS nehmen.

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I, Anne Fischer, declare that this thesis titled, and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
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