Imperial College, London, UK

The Legacy of the Inner Heliospheric Mission HELIOS: A Review of its data available today and how to best use it in preparation for Solar Probe Plus and Solar Orbiter

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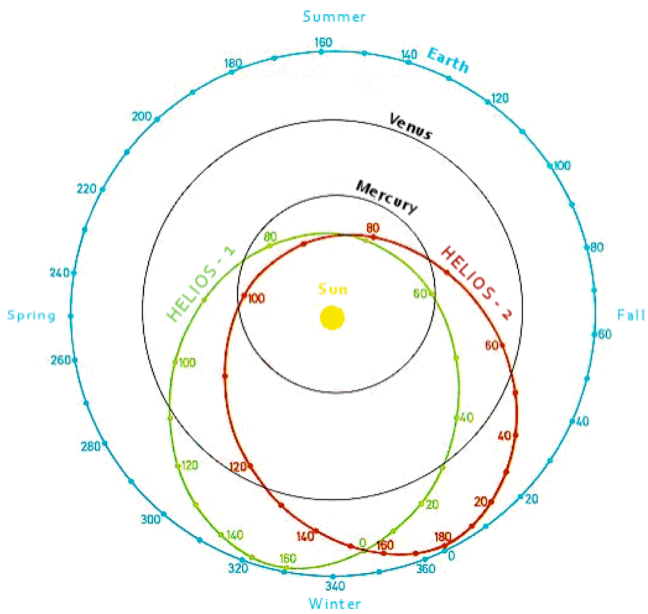
The Helios mission

Aimed at investigating the properties and processes in interplanetary space by approaching the sun to 0.3 AU

- Helios 1: launch on 12/10/1974; orbit with a period of 190 days; perihelion of 0.31 AU and aphelion of 0.99 AU.
- Helios 2: launch on 1/15/1976; orbit with period of 187 days and perihelion of 0.29 AU and aphelion of 0.98 AU.
- Almost identical instrumentation on both s/c. Each was equipped with 2 booms and a 32m electric dipole antenna.
- Both s/c are spin-stabilized with the spin axis perpendicular to the Ecliptic plane and a spin period of 1 sec. Spin of H1 pointing north and that of H2 south.
- Operations ceased for Helios 2 on March 21, 1980 and for Helios 1 on March 1986.
- Plasma measurements: protons (+alphas) and electrons, but slow sampling of VDFs and low phase space resolution.
- No Composition! No Imaging!



Highly elliptical trajectory of the Helios space probes

Instruments and measurements

Investigation	Principal Investigator	Measurements
Flux-Gate Magnetometer	(1) Musmann, Neubauer, (2) Mariani, Ness	Magnetic field strength and direction of low-frequency magnetic fields in the inner heliosphere
Search-Coil Magnetometer	Dehmel, Neubauer	Complement of the Flux-Gate Magnetometer by measuring the magnetic field fluctuations up to 3 kHz
Plasma Particles	Rosenbauer, Schwenn	Velocity distribution functions of solar wind protons, alpha-particles and electrons
Plasma Waves	(1) Gurnett, (2) Kellogg	Electric field of plasma waves in the solar wind from 10 Hz to 3 MHz
Cosmic Rays	Kunow, Trainor	Energetic protons, electrons and x-rays to determine the distribution of cosmic rays
Low-Energy Cosmic Rays	Keppler	Higher energy portion of the crossover region between solar wind particles and cosmic rays.
Zodiacal Light Photometer	Leinert	Scattering of sunlight by interplanetary dust particles
Micrometeoroid Analyser	Grün	Composition, charge, mass, velocity and direction of interplanetary dust particles

Instrumentation: summary

Tabelle 1: Übersicht über die Experimente auf Helios

Nr.	Thema	Experimentatoren	Institut
1	Sonnenwind	H. Rosenbauer, R. Schwenn	MPI für Physik und Astrophysik, Institut für extraterrestrische Physik, Garching
		J. H. Wolfe	NASA Ames Research Center
2/4	Interplanetares	G. Musmann, G. Dehmel, F. M. Neubauer, A. Maier	TU Braunschweig, Institut für Geophysik und Meteorologie
3	Magnetfeld	N. F. Ness, L. F. Burlaga	NASA Goddard Space Flight Center
		F. Mariani	Universität Rom, Istituto di Fisica
5	Elektrische	D. A. Gurnett	Un. of Jowa, Dep. of Physics and Astronomy, Jowa City
	Felder,	P. J. Kellogg	Un. of Minnesota, School of Physics and Astronomy, Minneapolis
	Radiowellen	R. R. Weber	NASA Goddard Space Flight Center
6	Kosmische	H. Kunow, G. Green, R. Müller, G. Wibberenz	Un. Kiel, Institut für Reine und Angewandte Kernphysik
7	Strahlung	J. H. Trainor, K. G. McCracken	NASA Goddard Space Flight Center
		F. B. McDonald	Un. of New Hampshire
		E. C. Roelof, B. J. Teegarden	SCIRO, Melbourne, Australien
8	Strahlung mittlerer Energie	E. Keppler, G. Umlauft, B. Wilken	MPI für Aeronomie, Lindau
		Williams	ESSA, Boulder
9	Zodiakallicht	C. Leinert, H. Link, E. Pitz	MPI für Astronomie, Heidelberg
10	Mikrometeoriten	E. Grün, P. Gammelin, J. Kissel	MPI für Kernphysik, Heidelberg
11	Relativitätstheorie	W. Kundt, O Böhringer	Un. Hamburg, Institut f. Theor. Physik
		W. G. Melbourne, I. D. Anderson	JPL, Pasadena
12	Faraday Rotation	H. Volland, M. Bird	Un. Bonn, Radioastron. Institut
		G. S. Levy	JPL, Pasadena
12 Z	Elektronendichte der Korona	P. Edenhofer, E. Lüneburg	DFVLR Oberpfaffenhofen

1. Plasma Experiment

2 and 3. Flux-gate Magnetometers

4. Search Coil Magnetometer

5. Plasma Wave Experiment

6 and 7 Cosmic Radiation Experiments

8 Low-Energy Electron and Ion Spectrometer

Zodiacal Light Photometer

Micrometeoroid Analyser

Helios: History and Accomplishments

- Helios ranks among the most important missions in Heliophysics and the more than 11 years of data returned by its spacecraft remain of paramount interest to researchers.
- Their unique trajectories, which brought them closer to the Sun than any spacecraft before or since, enabled their diverse suite of in-situ instruments to return measurements of unprecedented richness.
- Analyses of these measurements produced groundbreaking insights into:

  - the large-scale spatial and temporal variations in the inner heliosphere

    [Marsch 1991, Marsch 2006]

  - solar wind turbulence across both MHD and kinetic scales

    [Marsch 1991, Bruno and Carbone, 2005, 2013]

  - the effects of kinetic instabilities

    [Marsch et al. 1982a; Marsch & Livi, 1987, Gurnett 1991]

  - the process of collisional thermalization [Marsch et al. 1982b] and ongoing heating processes [Schwartz and Marsch, 1983]

  - Energetic Particle Acceleration and Transport.

Most of our knowledge of solar wind plasma and magnetic field in the inner Heliosphere comes from the Helios mission

Relevance to SPP/Solar Orbiter

- The importance of Helios to the upcoming SPP and Solar Orbiter (SO) missions is evidenced even in the planned trajectories of these new spacecraft.
- Radial trends produced from the Helios in-situ measurements were invaluable to the SPP and SO instrument teams for making their preliminary designs and continue to be used as they finalize their designs and develop observing plans. This work involved integrating predictions from various theoretical models into a multi-instrument analysis of Helios data, which was extrapolated from the Helios perihelia (0.31 and 0.29 AU) to the SPP perihelion (10 Rs ~ 0.05 AU).
- No comprehensive public repository of all Helios in-situ data is available. Also, very little documentation is available, especially on calibration.
- A careful examination of some of the data raised some questions/concerns. Quantitative analyses of this data set requires overcoming a number of technical and instrumental issues.
- Project of restoration and re-calibration of the Helios data at SSL/UCB.

Current Project with the HELIOS data

Project funded by NASA for 2 years (PI Salem). The goal is:

- To aggregate ALL in-situ Helios 1 and 2 data still available today.
- To look at the data, analyze and make sense of it, identifying and understanding various issues with the data.
- To reprocess and re-calibrate it, if possible.
- To create a single archive of calibrated multi-instrument Helios data.
- To write comprehensive documentation detailing the data available and describing the various issues/uncertainties etc.
- To produce and make available software to download and analyze the data from the Archive.

Current Work with Kiel & Koln

- Helios 1 & 2 E1, E2, E3, E4, E5 and E6 data is being gathered.
- E2 and E3 data are under intense analysis and scrutiny to understand the important magnetic field measurements. A lot of work is being done with the team at the university of Kiel and at Koln university. The raw, original, data sets are lost forever. Only processed & "calibrated" data are available at different resolutions, which show some discrepancies. Therefore a detailed comparison of different data sets from different sources is necessary to understand the processing that has been done to the data. Can we fix the data?
- E1 data is available. "Fluid" moments are somewhat unreliable and need to be reprocessed after a thorough analysis of the proton, alpha and electron distribution functions. This is a large enterprise, and it will be undertaken sometime in the future (new 2016 NASA HDEE proposal).

Current Work with Kiel & Koln - 2

- E4 data seems problematic…
- E5 data has been archived and documented at Univ. of Iowa and I have access to it. It will be added to the full archive.
- E6 (energetic particle data) is available at resolutions down to 15 min at Kiel in a few CDs/DVDs, and will eventually be added to the archive.
- A Wiki document has been started to document all issues with the data for E1/E2/E3/E4 experiments.
- This workshop in Koln was very successful in gathering information from Fritz Neubauer, and get some answers, which will be helpful to develop and complete the wiki with as much information as possible on the state of the data.
- We also talked about applying for an ISSI group on “Reanalysis, Recalibration and Long Term Preservation of Helios 1 & 2 data”.

Current work with Kiel & Koln - 3

- Also, a great effort of gathering ALL possible documentation on all instrument and data sets available are underway, along with the original instrument papers and any other form of documentation (PhD thesis, reports, etc.).

- The most of important ones are the so-called blue books, written in the early to mid 80s, describing the data sets, and in most cases the processing and massaging of the data. These are all in German. Kiel is planning to hire a student to scan them.

- All these documents will be added to the archive.

The particle experiment: E1

- The Helios ***Plasma Detectors*** experiment (E1) [Rosenbauer et al. 1977] employed three plasma analyzers for positive ions (I1A, I1B and I3) and one for electrons (I2). All detectors were mounted normal to the spin axis.
- Positive ions with energy per charge within the range 0.155 to 15.32 keV/Q were measured in 32 energy channels and in two angular dimensions using a combination of a hemispherical, a quadrispherical, and a sinusoidally shaped electrostatic analyzer.
- For ions, we had 9 elevation channels measured simultaneously, 16azimuthal channels resolved during one s/c spin and 32 energy channels swept through one by one with increasing energy, spin by spin, i.e. in 32 sec.
- In HDM (High Data Mode), 7x7x32 VDFs are transmitted. In NDM, 32 energy sweep, but only 5x5x9 VDFs are transmitted (9 channels were chosen around the peak (e.g channels 5 to 13).
- ``energy-per-charge'' ➔ allows protons and alpha-particles to be distinguished.
- "*Good*" measurements of 3D ion distribution functions were obtained at ~40s resolution [Marsch et al. 1982a, 1982b], although the combined protons and alphas need to be carefully separated.

E1 Instrumentation

One Electrostatic deflection analyzer for 3-D measurements of the proton distribution functions.

Special features:

- 0.155 to 15.3 kV
- High sensitivity automatic peak tracing

One Electrostatic deflection analyzer for measuring (current measurement) the positive particles as a function of their energy per charge.

Special features:

- 0.145 to 14.3 kV
- High sensitivity

One Electrostatic deflection analyzer for 2-D measurements of the electron distribution function.

Special features:

- Ability to measure to extremely low energies (0.5 eV to 1.66 eV)
- Insensitive to UV
- Integrates over only ± 5° perpendicular to analysis plane

One Electrodynamic analyzer for separate determination of 3-D proton and α distribution functions.

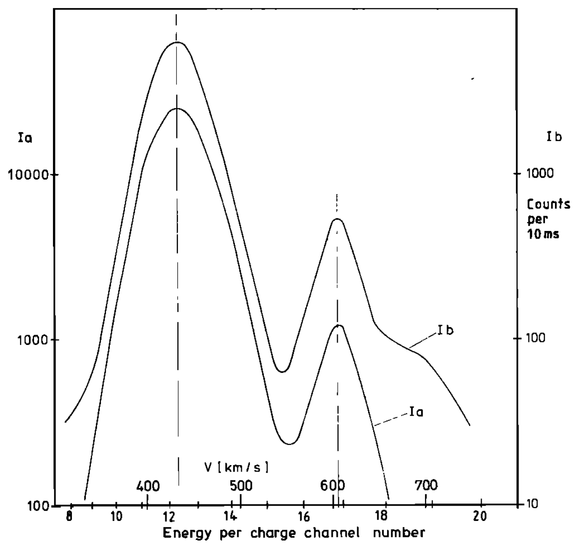
Special features:

- Velocity range 200 to 770 km sec^{-1}
- Wide solid angle of acceptance: 42° x 90°
- Automatic peak tracing

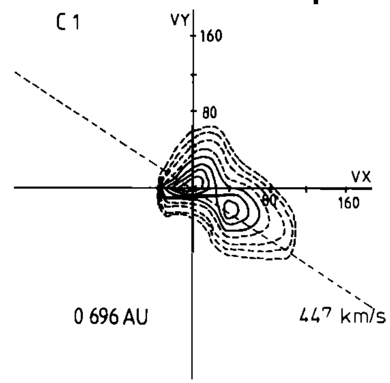
Plasma data available in files

- Several parameters and moments in header, I called, ***metadata***.
- 1D-integrated I1A distribution, I1B 1D distribution.
- 3D transmitted (HDM or NDM) ion I1A distribution.
- 2D transmitted electron I2 distribution.

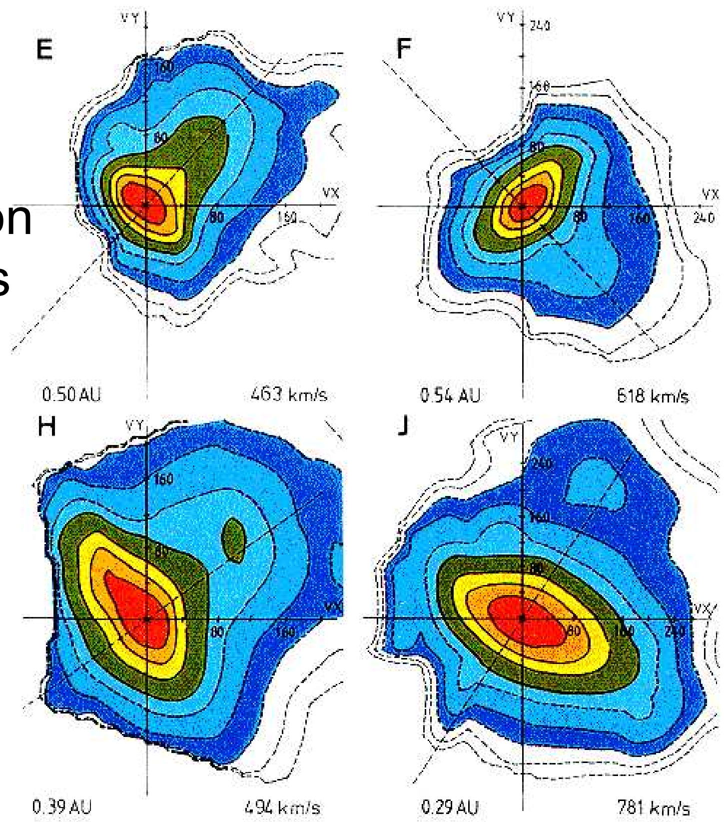
```
           !mode = 0 = NDM; 1 = HDM

Spacecraft parameters:
           ! heliopsheric distance in [AU],
           ! Carrington longitude [degree]
           ! Carrington latitude  [degree]
           ! Carrington rotation number as seen from spacecraft

           ! Sun-Earth  distance in [AU], n.a.
           ! Carrington longitude of Earth [degree]
           ! Carrington latitude  of Earth [degree]
           ! spacecraft-Sun-Earth angle [degree]
           ! Carrington rotation number as seen from Earth
           ! radial and tangential (in eccliptic) velocity of spacecraft in [AU/day]
           ! One fluid proton parameter for i1a
           ! number density [cm^(-3)]
           ! velocity [km/s] or corrected value see above
           ! temperature [K]
           ! azimuth flow angle or corrected value see above
           ! elevation flow angle

!one-fluid alpha parameter for i1a
           ! number density [cm^(-3)]
           ! velocity [km/s]
!one-fluid proton parameter for i1b
           ! number density [cm^(-3)]
           ! velocity [km/s]
           ! temperature [K]

           ! magnetic field components Bx, By, Bz, and standard
           ! deviations sigBx, sigBy, sigBz [Gauss]

 1-D i1a integrated !(cm^-6 s^-3)
 1-D i1a velocities (km / s)

 1-D i1b !(cm^-6 s^-3)
 1-D i1b velocities (km / s)

 3-D protonen+alpha distribution function (cm^-6 s^-3) and x,y,z       velocity components (km /s)
 Maximum of distribution 10 4 11  1.04961904E-19 ! = f(10,4,11) = max(f)

 2-D electron distribution function (cm^-6 s^-3) and       radial velocity (km/s)
 Maximum of distribution 8 1  2.79362517E-25 ! = f_e(8,1) = max(f)
```



Alpha-particle VDF



Proton VDFs

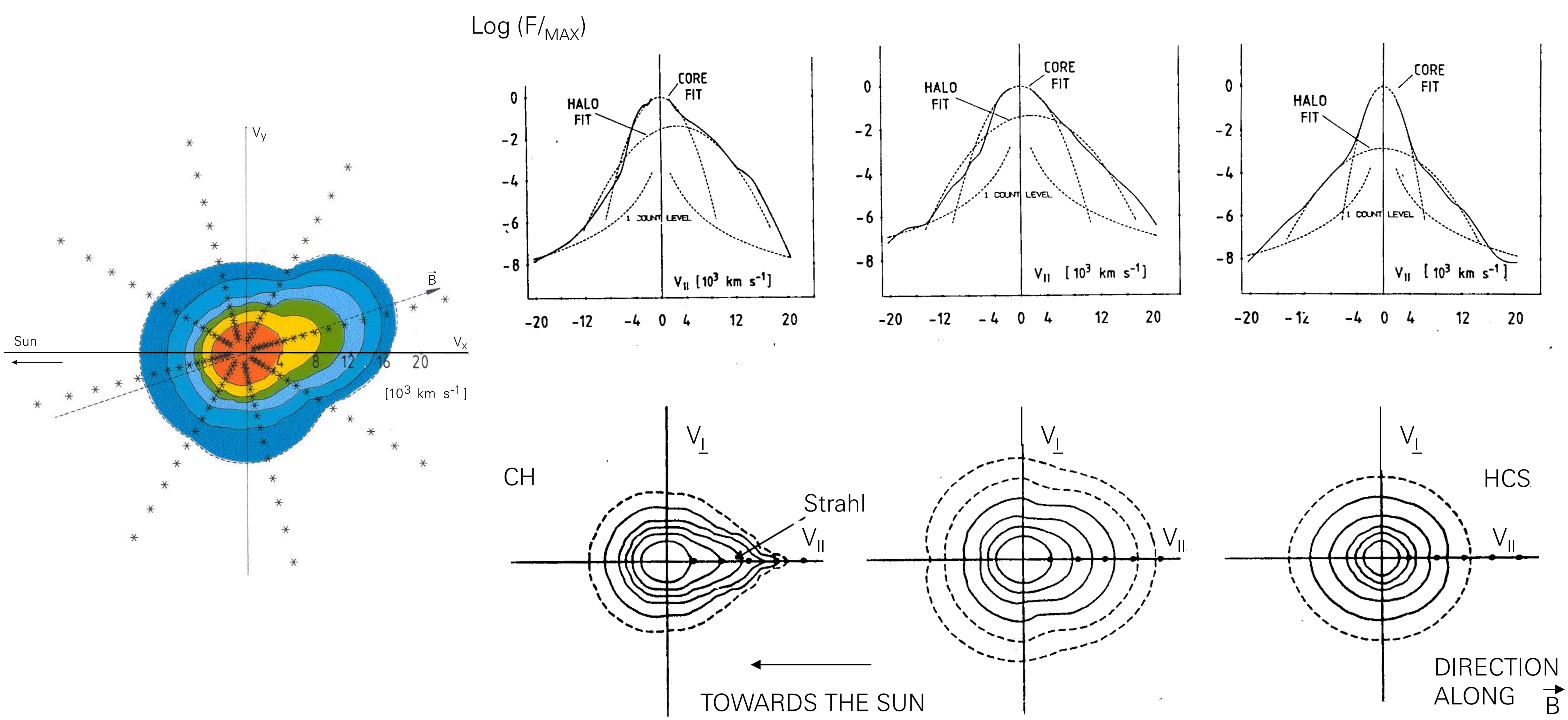


Proton distribution from Helios data in the plane of radial direction and B (dashed line):

- anisotropic core with T_perp>T_para for high-speed winds (right);
- T_perp < T_para but with isotropic core in low-speed winds (left);
- at intermediate speeds (middle), T_para>T_perp;
- double peaks are seen, and the 2nd peak has V ~ Alfven speed;
- values are indicated in the table.

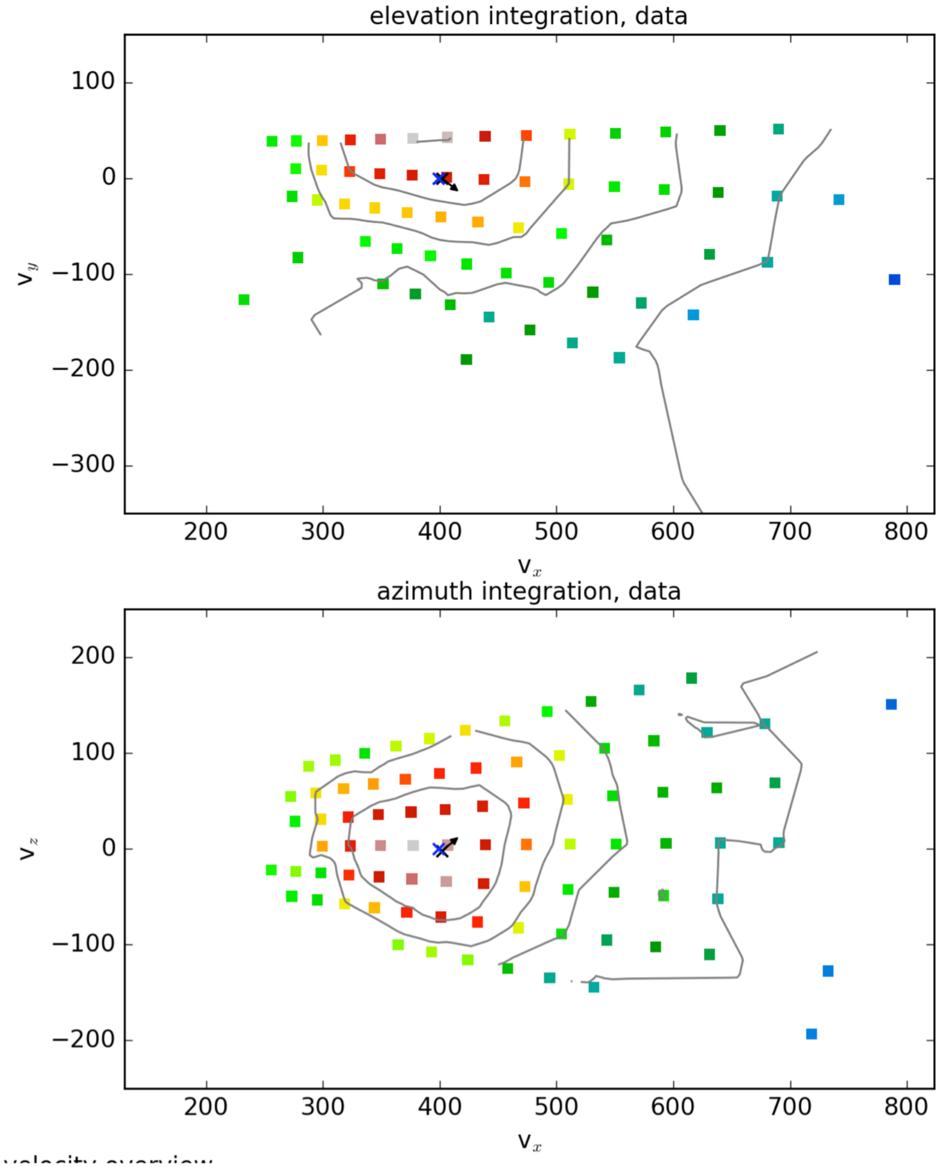
E. Marsch, Chapter 8, Kinetics physics of the solar wind plasma

- Electrons with energy from 0.004 to 1658 eV were measured with a hemispherical electrostatic analyzer in one angular dimension and in 32 energy channels. The field of view of the electron analyzer were perpendicular to the spin axis, i.e. along the ecliptic plane and were narrow in the azimuthal direction (30 deg and 13 deg for Helios 1 and 2 respectively). So, only 2D electron distribution functions were provided [Pilipp et al. 1987] at the same ~40s resolution.



Looking at the ion VDF data

- 3D I1a data.
- On the upper panel, each line represents an azimuthal channel and each point is summed over all 7 elevation angles (in high data mode only). On the x-axis (Vx), each point represents an energy channel.
- On the lower panel, each "line" is an elevation channel, and each point is summed over 7 azimuthal channels (in high data mode only).
- crosses are from the meta data. Blue cross is speed from i1b, and black cross is speed from i1a.



Issues with data?

- How exactly the moments in metadata have been calculated is not clear: from 1D or 3D I1A, or a combination of both (depending on HDM or NDM)?
- Zero counts data are not in the files. No problem for high data mode but it is a problem for normal mode because only 5x5x9 vdts are transmitted.
- Field of view issue: sometimes the bulk of the solar wind is missed by I1A (more Helios 1 than 2, because they fixed it on helios 2 when it was noticed on Helios 1 before Helios 2 launch).
- This could be an issue for calculated moments if 3D I1A distribution data were used, in which case the integrated 1d data should be better (because it would have all the angles).
- Lots of understood issues with proton/alpha particle separation…
- We uncovered the original programs/routines Fortran used to calculate these moments (thousands of lines to take care of every particular case). One can go through these routines to understand how moments were calculated so one can estimate their uncertainties OR start over using modern techniques (VDF fits) like we did for Wind 3DP electrons and SWE protons.

=> A lot more work is needed to understand the moments and their uncertainties or just re-determine them from scratch.

The Fluxgate magnetometers: E2 and E3

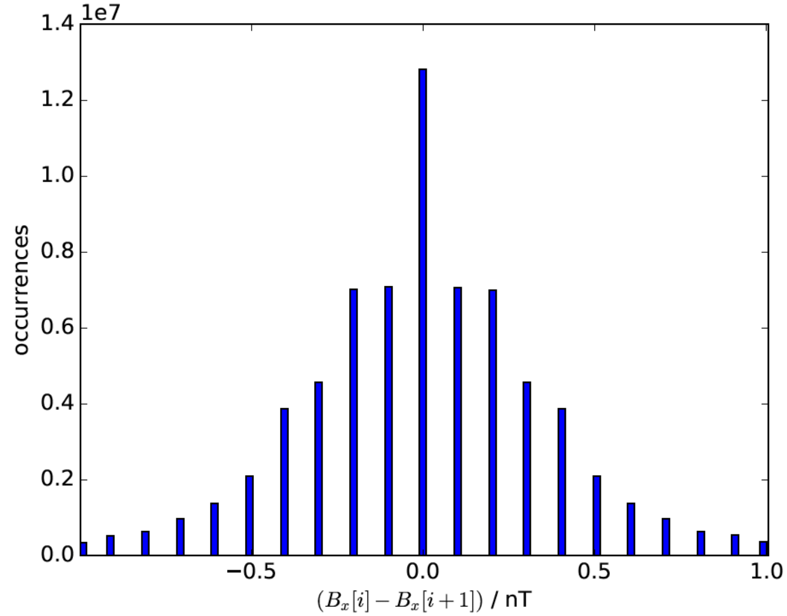
- Helios 1 and 2 were equipped with two different magnetometer experiments: both the Fluxgate Magnetometer for Field Fluctuations experiment (E2) [Musmann et al. 1977, Neubauer et al. 1977] and the Fluxgate Magnetometer for Average Fields experiment (E3) [Mariani et al. 1978] consisted of a boom-mounted, triaxial fluxgate magnetometers.
- E2 made vector measurements of the interplanetary magnetic field at a rate up to 4Hz. There was a “shock” mode (but not understood yet to what it actually did).
- E3 made vector measurements of the interplanetary magnetic field at a rate up to 8 or 16 per sec. The time resolution available, depending on the operation mode, telemetry format, and bit rate, for most cases varied from 0.07 to 1.5 seconds.
- These magnetic field data from E2 and E3 are available at NSSDC and at SSL/UCB: at 40.5 sec and 8 sec for E2 and 6 sec resolution for E3. We recently acquired the 4Hz E2 data from Kiel Germany and in phase of getting the version at Cologne Germany (comparison of these different data sets is important, you’ll see why).
- E2 average mag data at 40.5 sec is also available in the E1 data files (part of the metadata) but this data set was found to be very problematic.

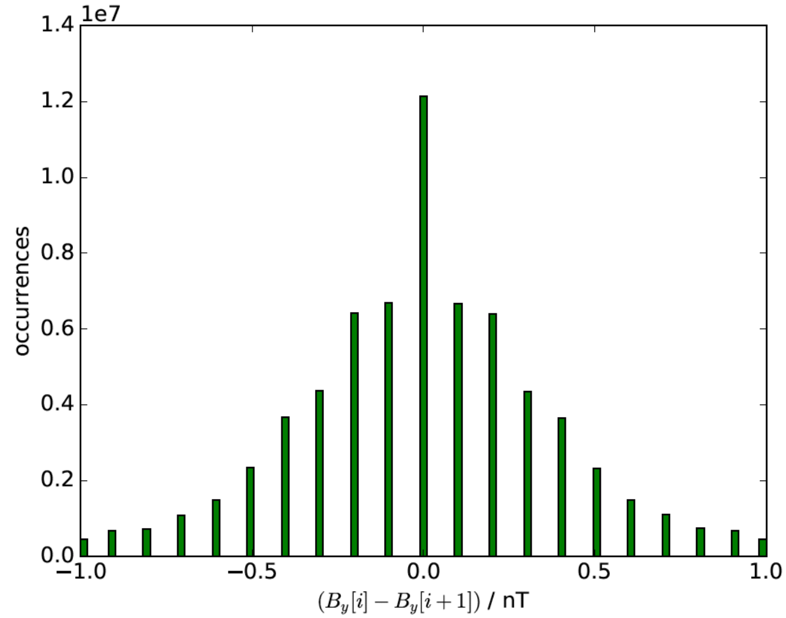
E2 data precision

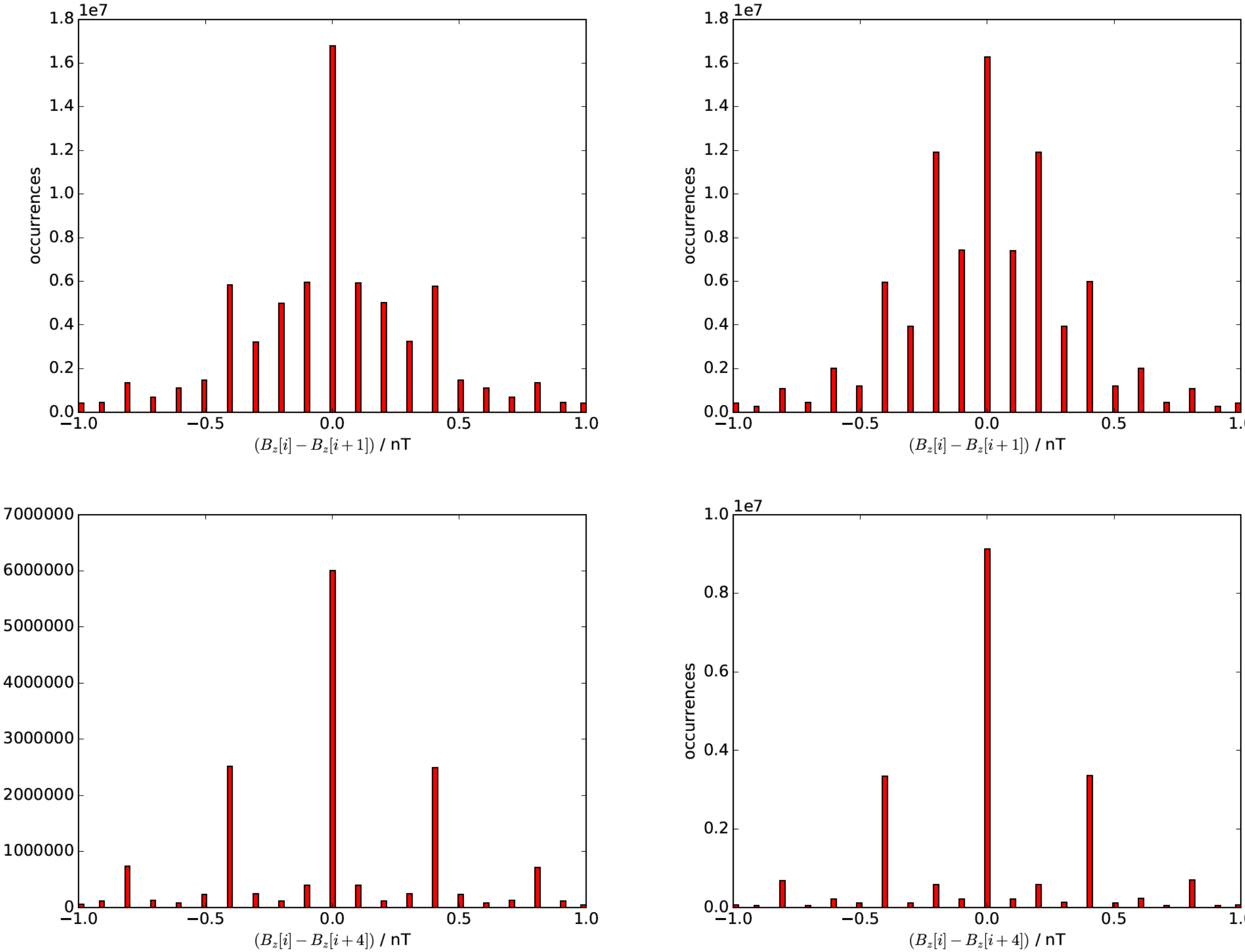
Expected Precision:

- 8 bit and 1 bit sign
- $\pm 100\,\text{nT}$ measurement range

$\rightarrow \frac{200\,\text{nT}}{2^9} \approx 0.4\,\text{nT}$

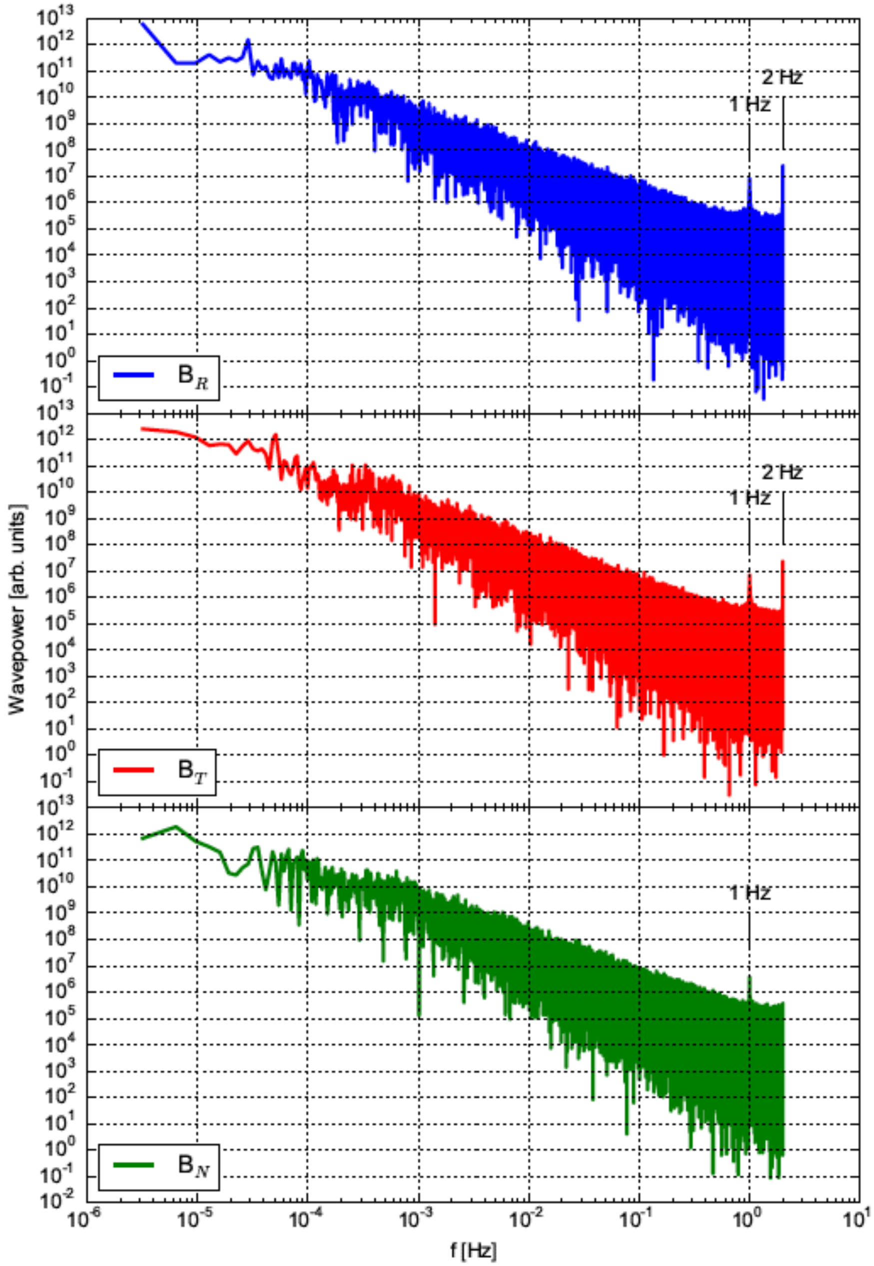






Precision of 0.4 nT probably good, and the 0.1 nT is artificial, caused by the conversion/transformation of the raw data…

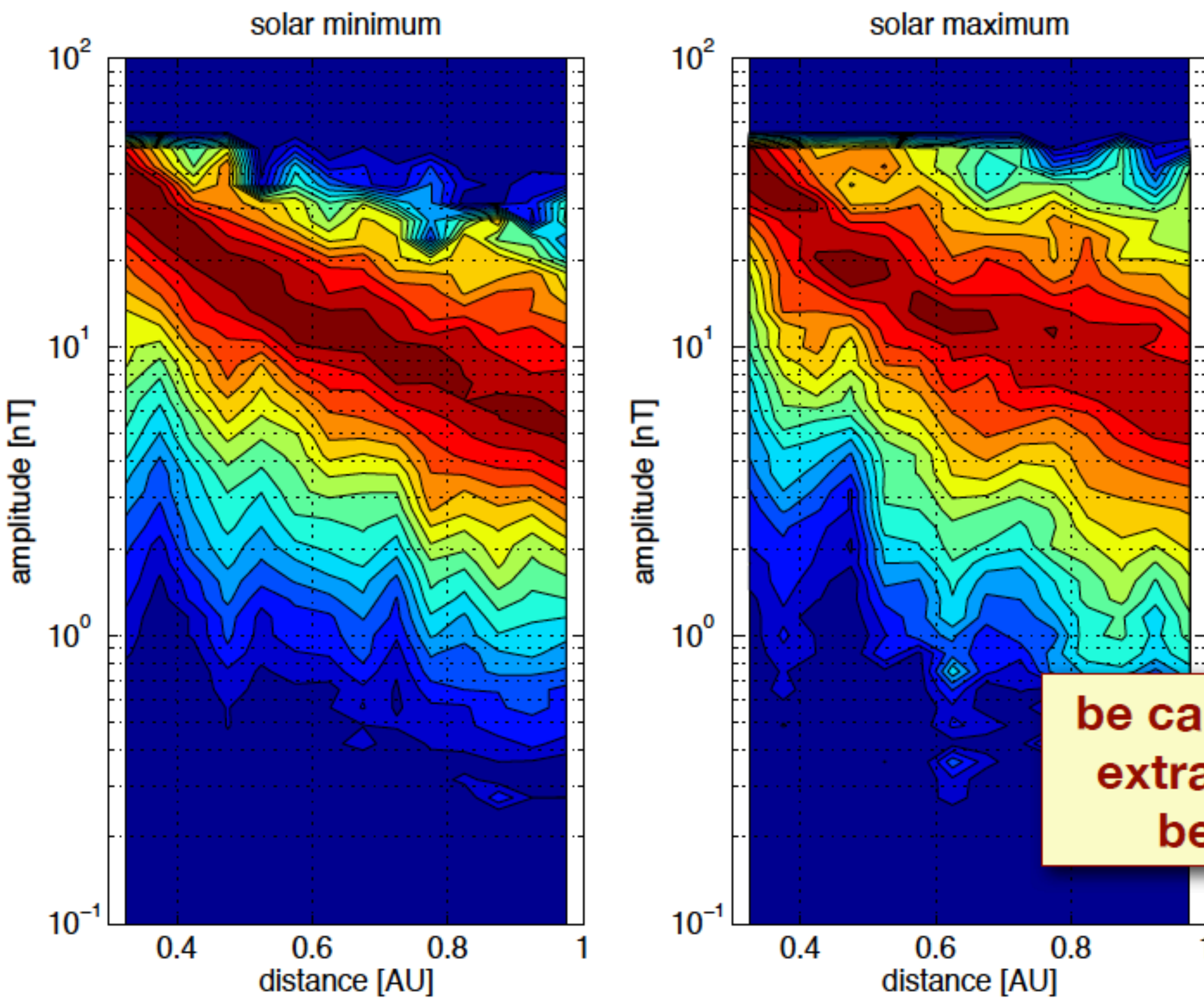
Erroneous zero-point correction?



1 Hz peak results from the spin correction

2Hz peak in B_T and B_R and not in B_N points towards an incorrect zero-point correction in the RT plane. This doesn't mean that the zero-point correction is more precise on B_N.
It is probably quite erroneous as it is shown
when more detailed comparisons between this E2 data set and the data set from the other fluxgate (6 sec res) magnetometer E3.

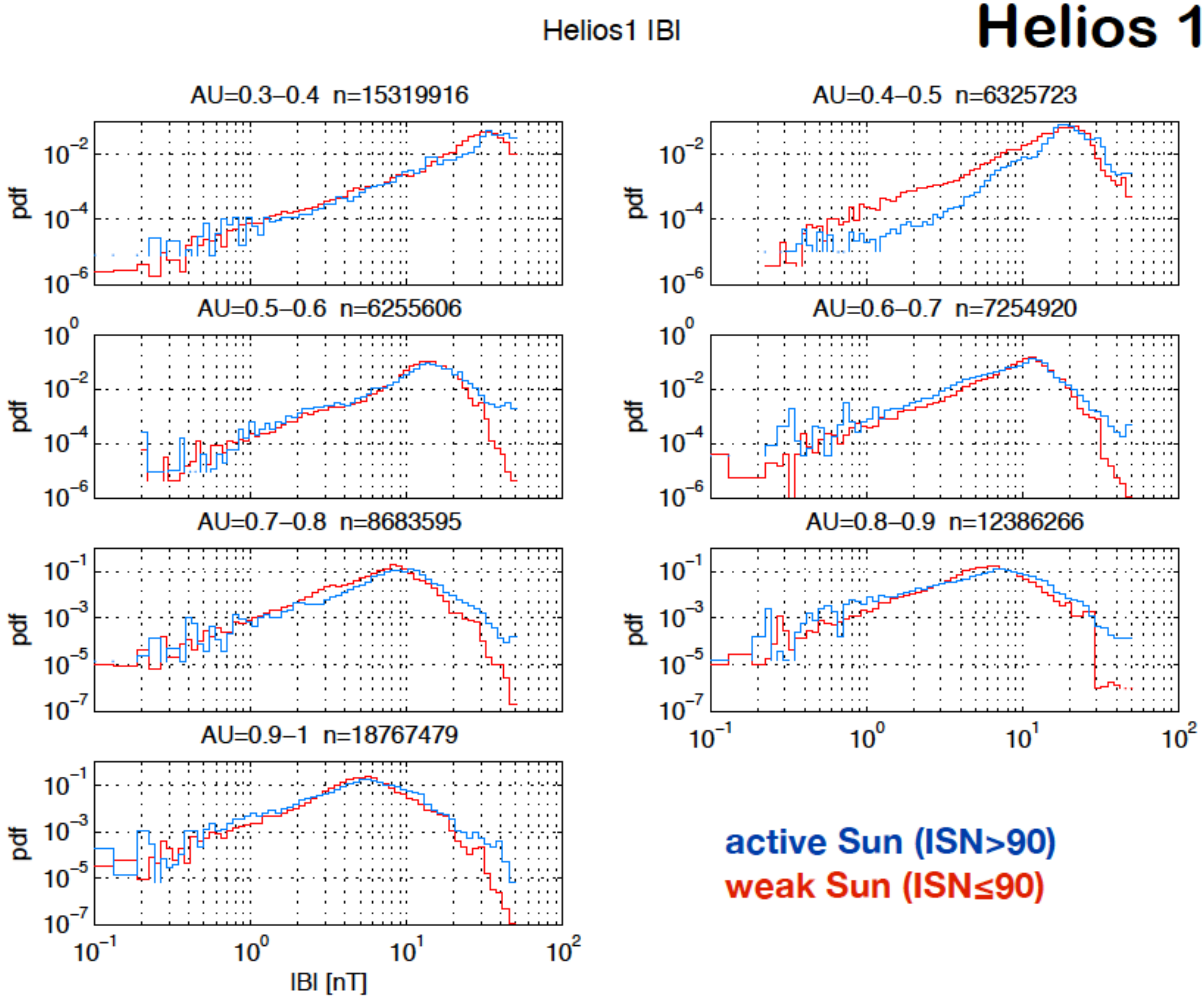
Helios 1 - MAG at 0.3 AU



pdf of |B| versus distance (vertical scale in log)

be careful when you extrapolate values below 0.3 AU

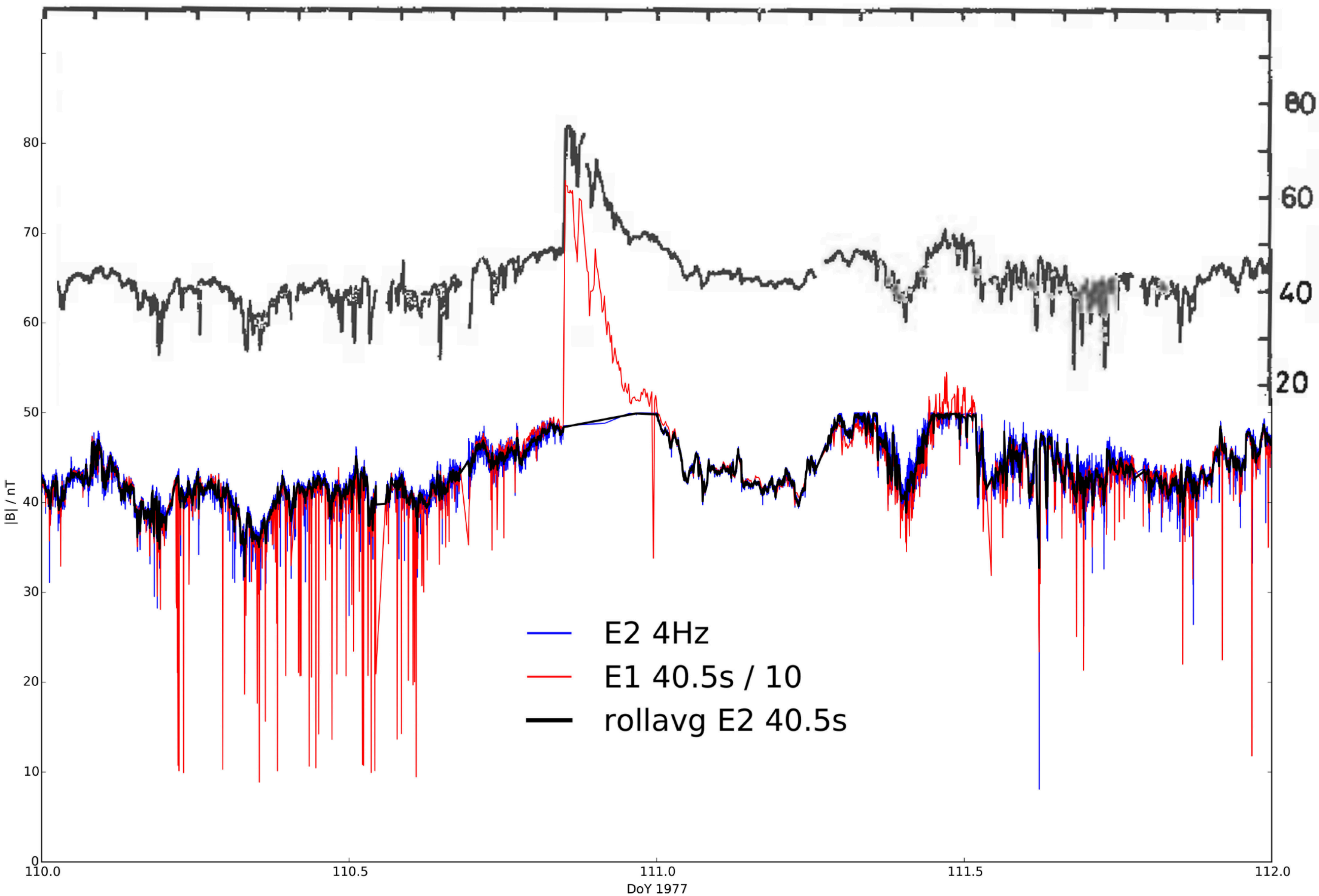
Helios 1 - MAG



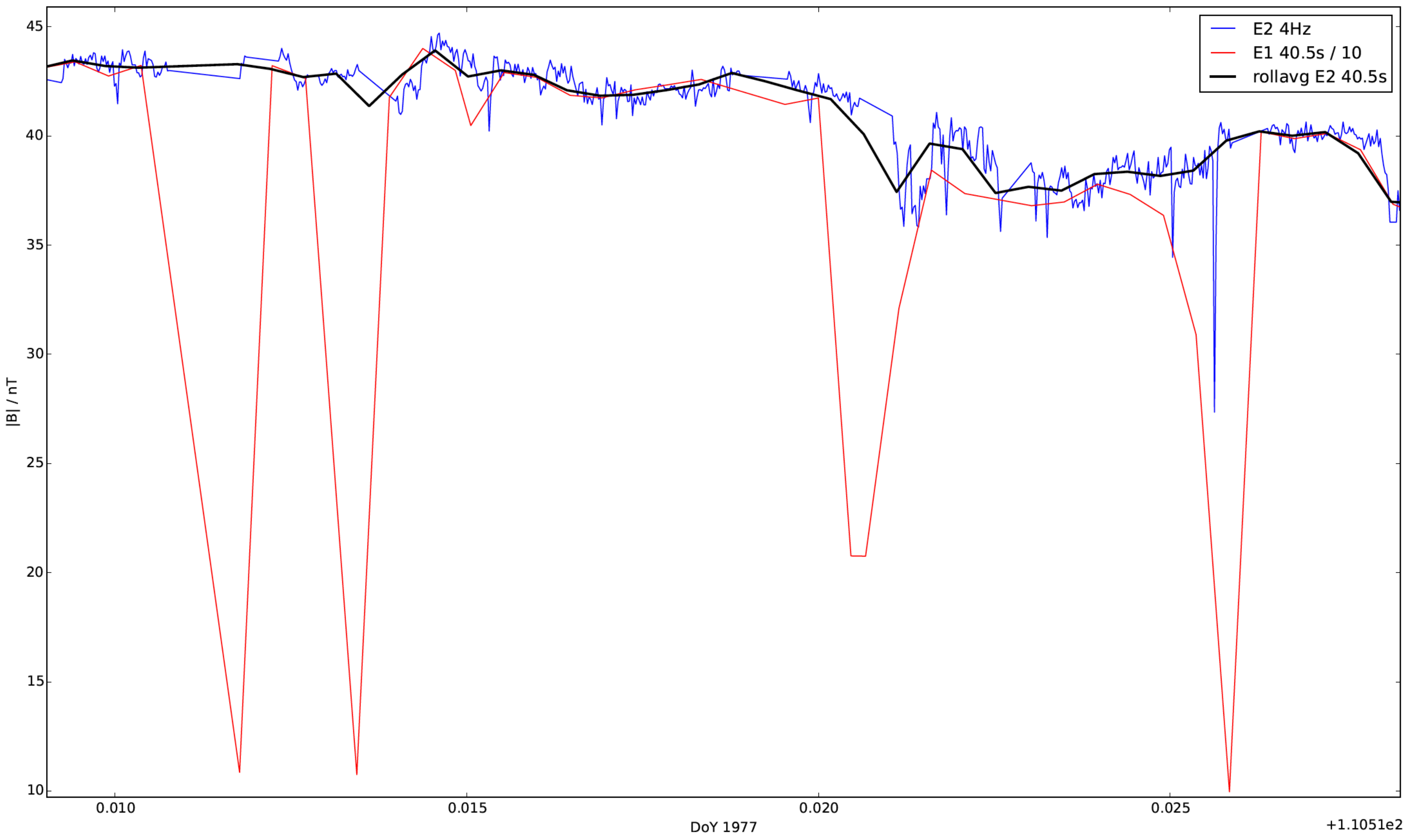
Helios1 IBI
AU=0.3–0.4 n=15319916
AU=0.4–0.5 n=6325723
AU=0.5–0.6 n=6255606
AU=0.6–0.7 n=7254920
AU=0.7–0.8 n=8683595
AU=0.8–0.9 n=12386266
AU=0.9–1 n=18767479
pdf
IBI [nT]

active Sun (ISN>90)
weak Sun (ISN≤90)

Example of a shock in the E2/E4 blue book



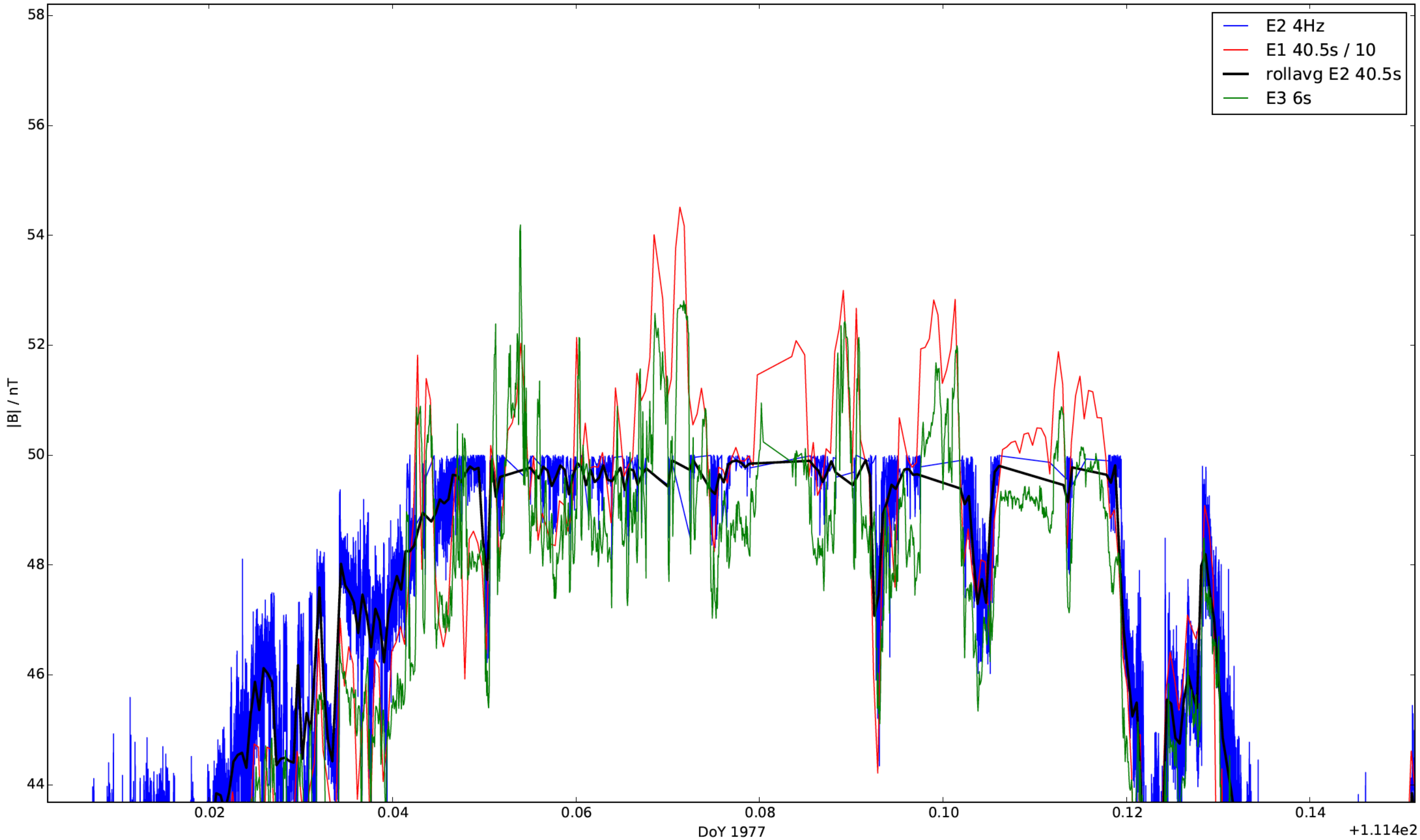
E2 data: comparing data sets at different resolutions



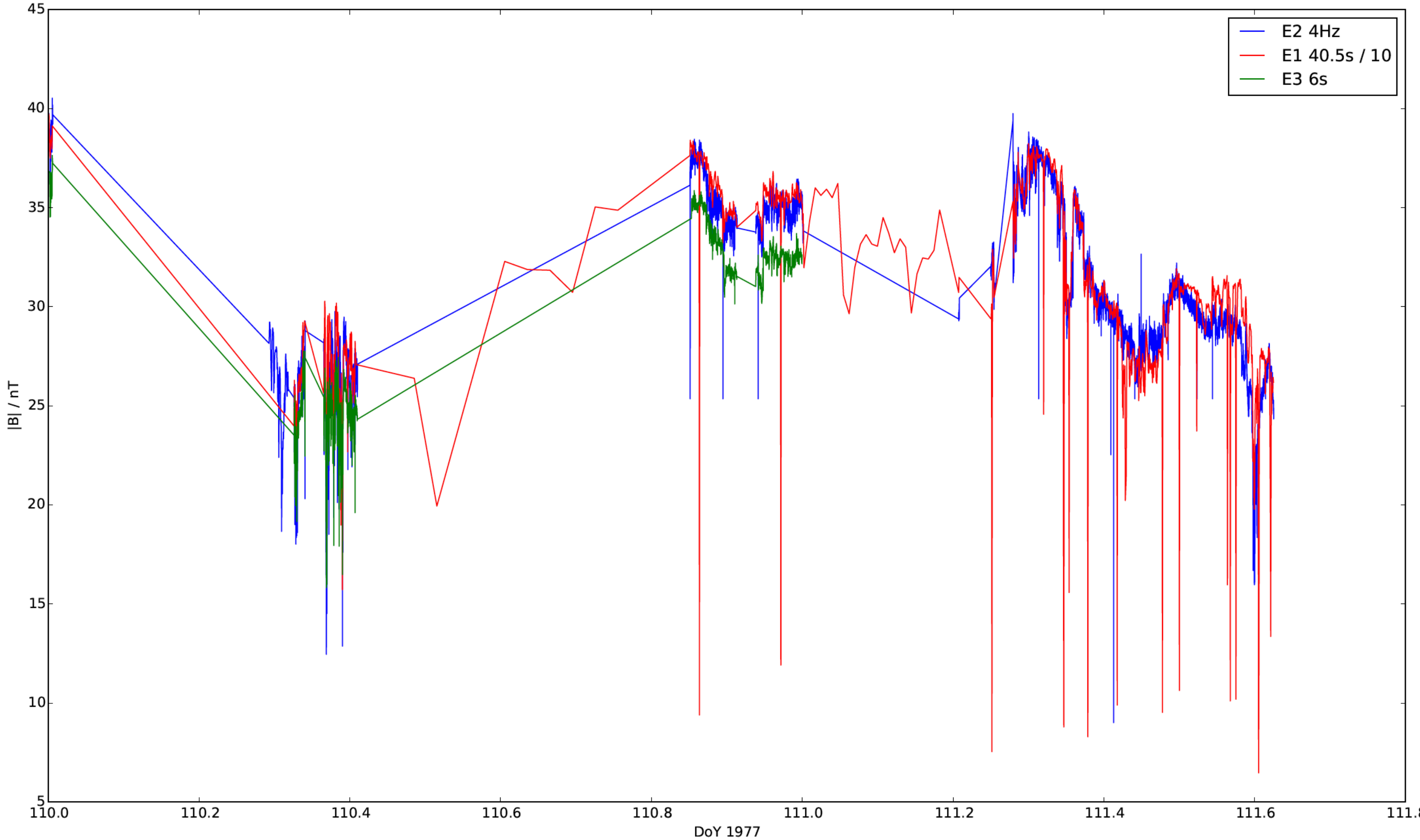
Magnetic field data from E3

- The high resolution (8Hz, and bursts of 100-300 Hz?) are gone forever. Magnetic tapes with this data set degraded with time and were discarded!
- The only data set left from this E3 instrument consist of 6 sec resolution averages.
- This Ness/Mariani et al. data set was used a lot in publications by Bavassano etc. in the 80s.
- Comparisons with the E2 4Hz or the 40.5 sec data show significant differences.

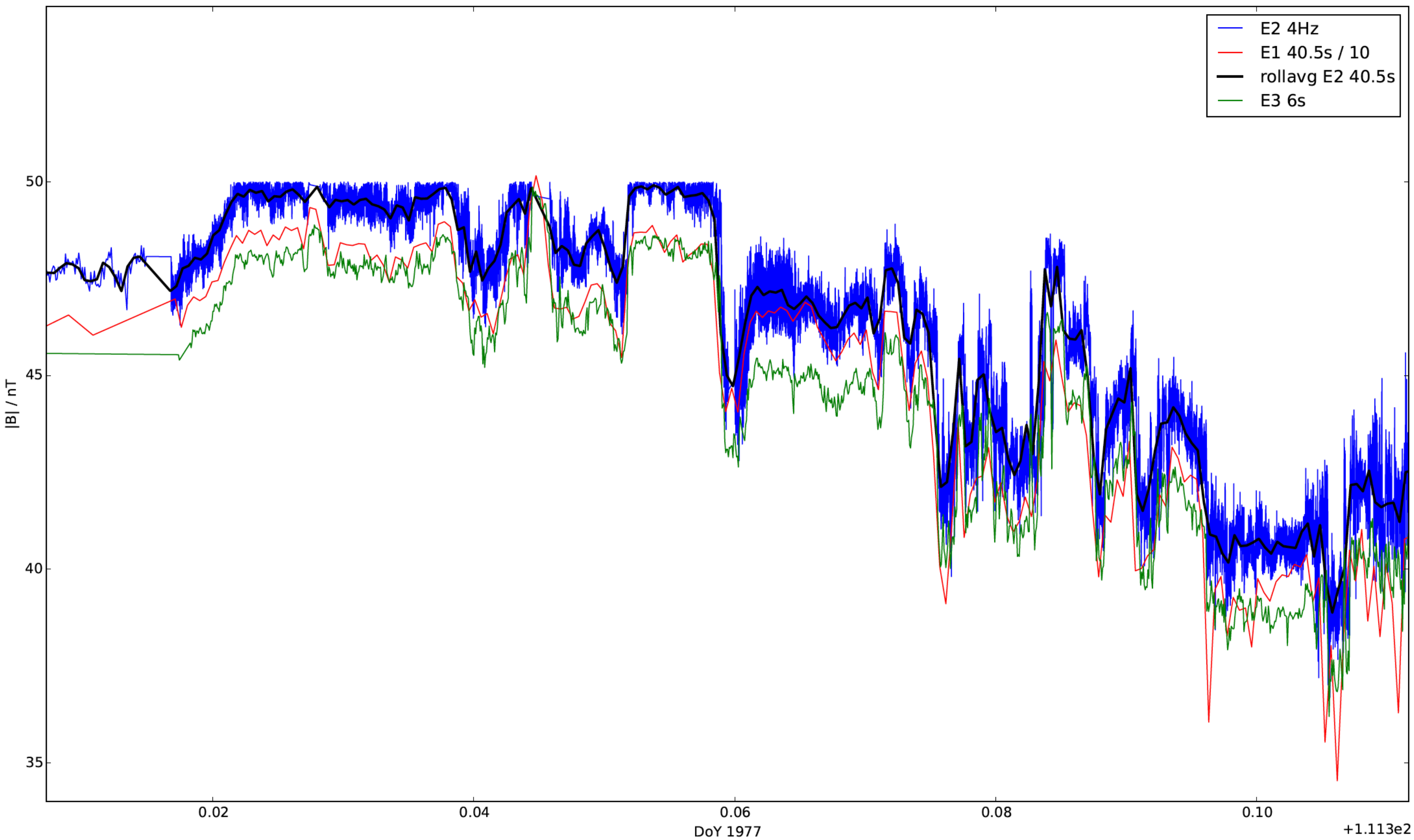
Comparing E2 and E3 data



E3 has data gaps that E2 do not have! E2 and E3 show an offset!



Systematic differences between E2 and E3 in mag data

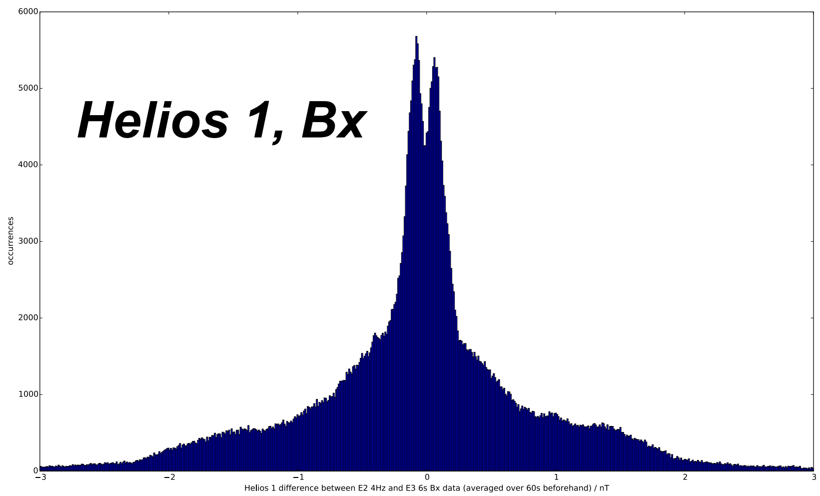


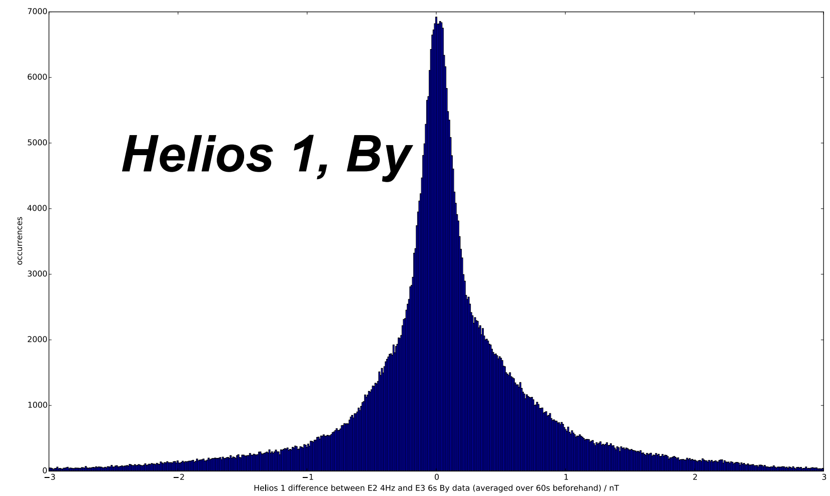
50 nT Cutoff in E2 4Hz data

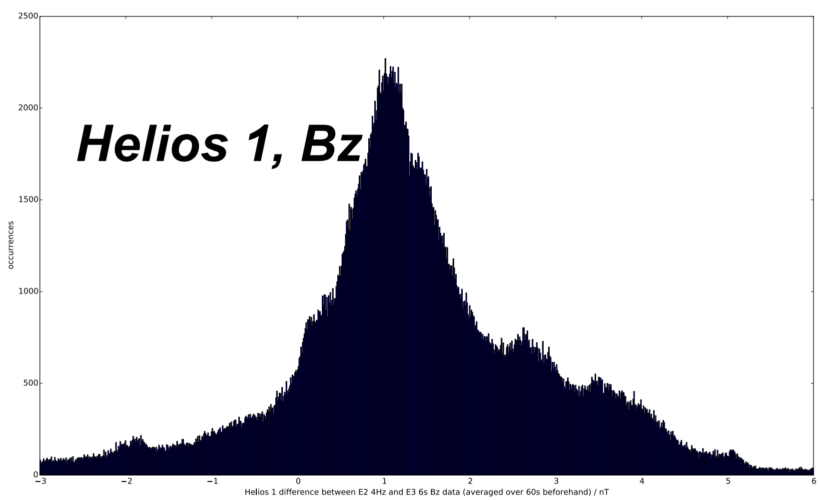
- What is the origin of the 50nT cutoff.   Is it from missing E2 data from a different mode of operation?

- Similarly E2 4Hz data shows gaps well below the 50nT limit when E2 40,5 sec data shows no gaps. Is that linked to the missing data above 50nT? data missing from different mode of operation?

E2 4Hz versus E3 6s mag data: comparing 1 min averages



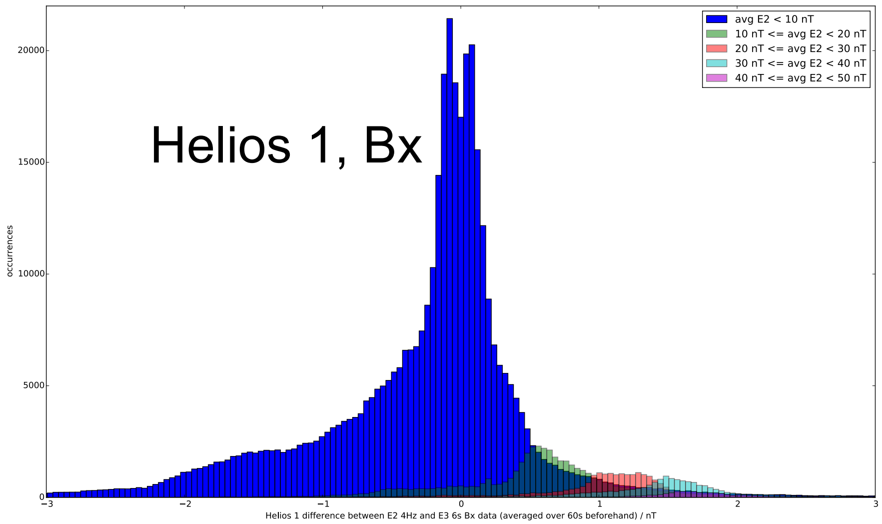




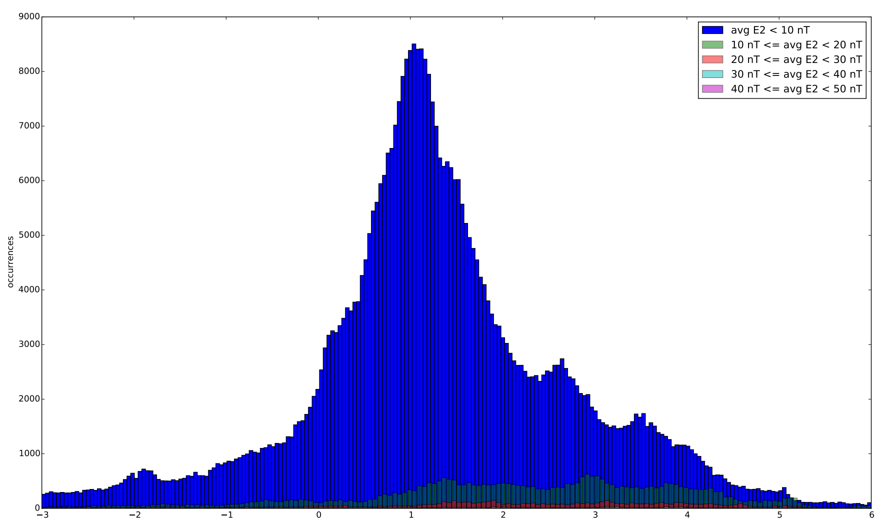
If only measurements uncertainties were responsible for the differences between E2 and E3 then the histograms should be normally distributed around zero.

Differences for Bx an By data from E2 and E3 show a histogram nicely centered in 0 but with high tails.
Not for Bz …

E2/E3 comparisons: comparing 1 min averages



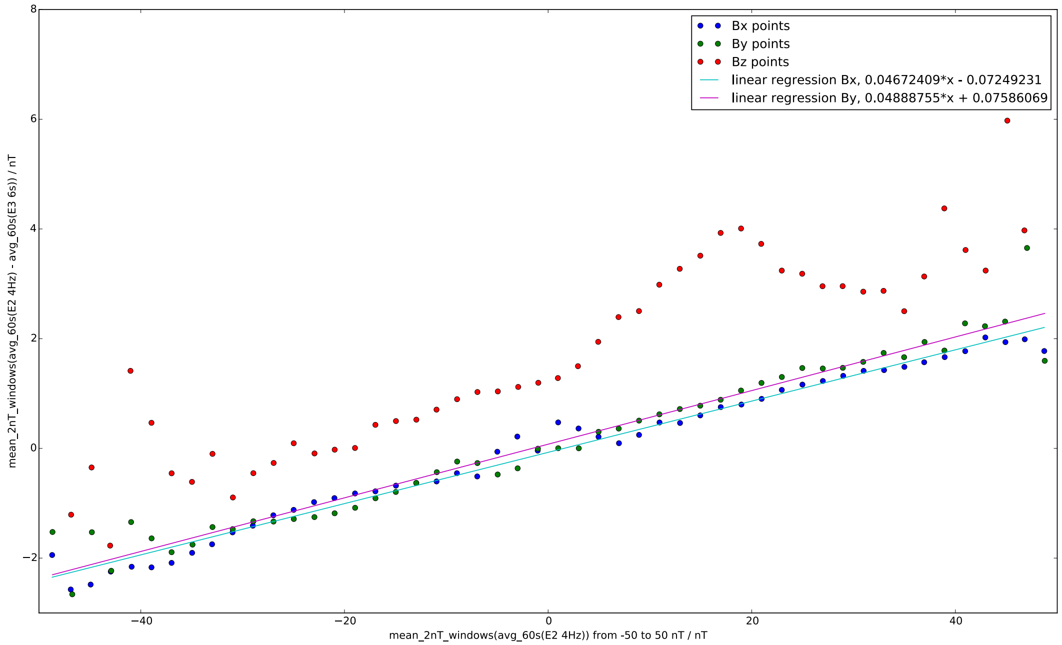
The higher the Bx or By the higher the differences between E2 and E3.



The comparison of B_z is more messy!

This suggests that the B_z component is less precise …

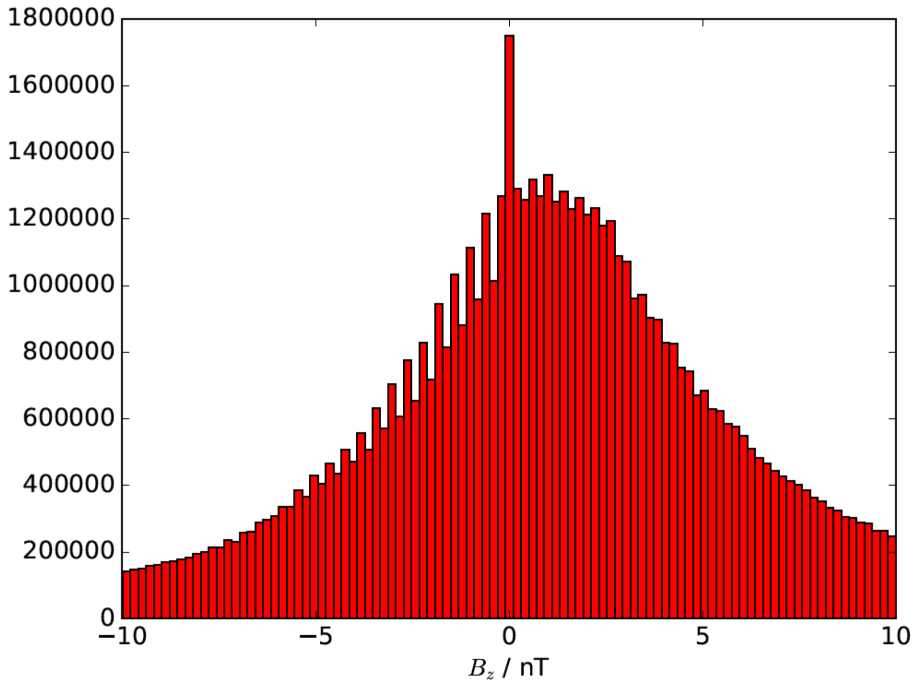
Averages of B components in bins of B between -50 and 50 nT: E2 versus E3



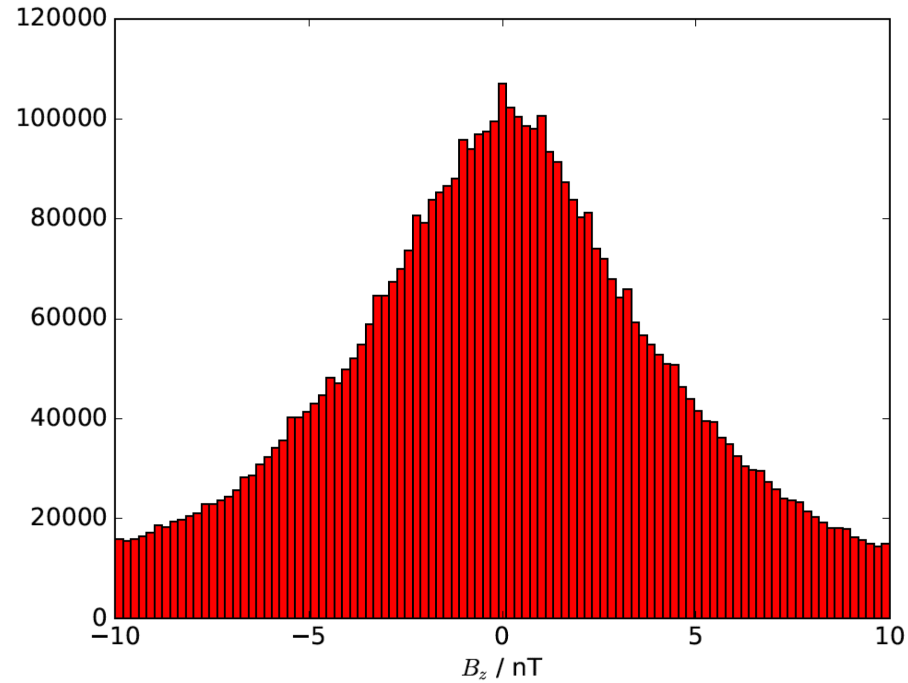
- 2nT bins from -50 to 50nT
- Average of the differences between E2 and E3 for each bin

Are these large differences in Bz due to a bad calibration of E2 Bz or E3 Bz? Which one is right?

Bz histogram: E2 versus E3



E2 Bz



E3 Bz

E2/E3 Recap

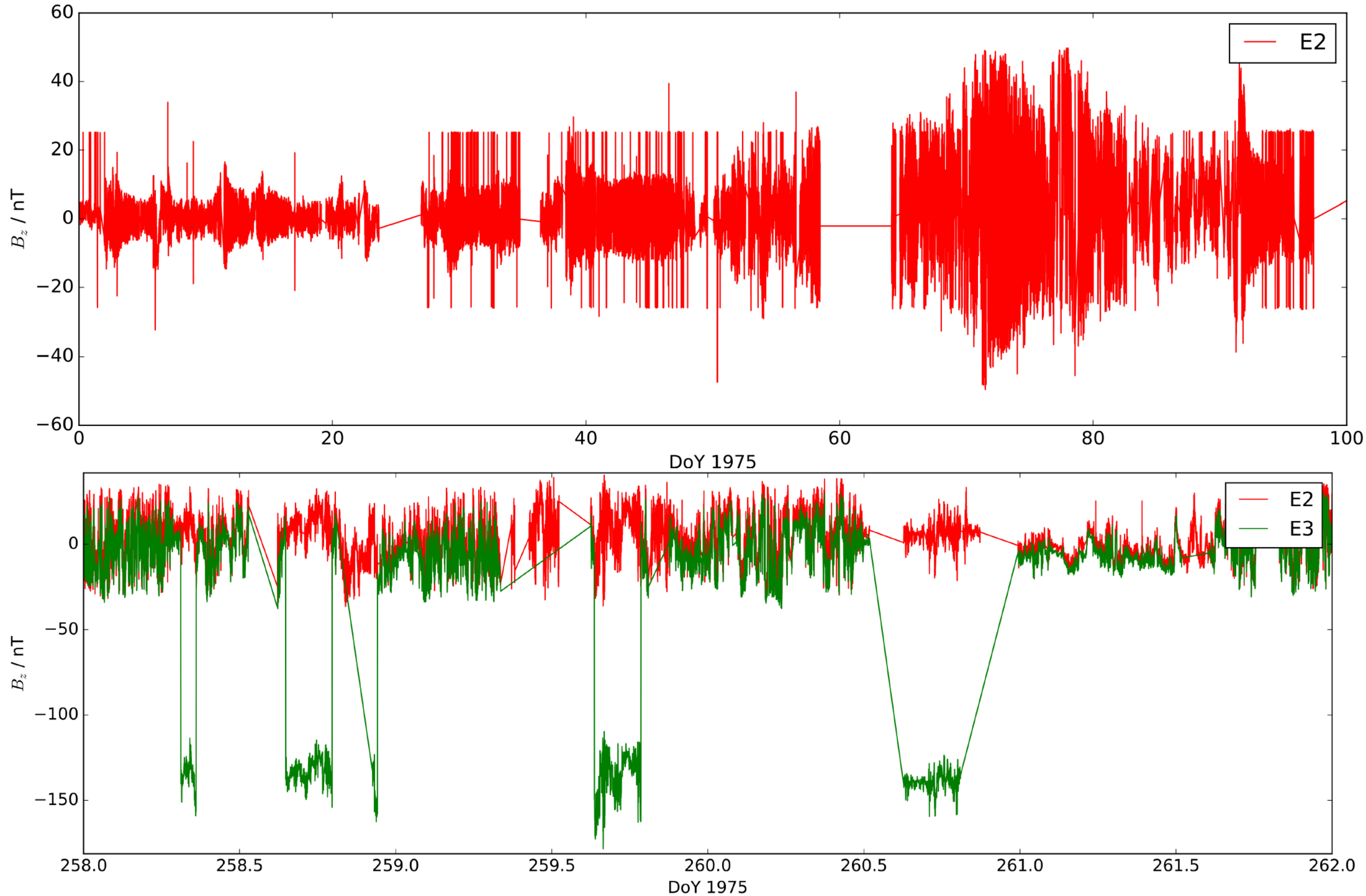
All datasets are pre-processed - this states the main problem. 40 years after HELIOS was launched, we cannot do anything about it.

E1 The 40.5 sec magnetic field metadata was averaged with a fixed number of points, not considering data gaps.

E2 The dataset is capped hard at 50 nT, but shows other unexpected data gaps too. The reason remains unclear; it might be that the shock mode data is missing.
The B_z-component looks compromised due to a wrong zero-point correction.

E3 The dataset is already averaged to a 6 sec resolution and has significantly more data gaps than E2.

E2/E3: More problems …



Recap on E2/E3 mag data

- The 40.5 sec averages (NSSDC and E1 metadata) were calculated with a different dataset, most probably a more complete E2 dataset.
- The NSSDC data may be helpful to recover more correct 40.5 sec averages, at least for HELIOS 1. It doesn't show the averaging problem, but there are small differences that still need to be determined.
- Alfen speeds calculated with the E1 metadata are erroneous, at least to some percentage.
- Recalculating the averages for E1 is challenging. The additional data gaps that were not present at the time of the first calculation and the 50 nT cap limit this effort. If one considers the zero-point correction issues as a minor problem, it should nevertheless be possible in many cases.
- The 6 sec E3 data may serve as a benchmark and as a substition for the 4 Hz data in some cases, although the time resolution is comparibly poor.
- All datasets combined offer the chance to bypass the problems of the individual ones. Nevertheless this requires a case-to-case analysis; automation to some degree looks possible but difficult.

Information on E2 by F. Neubauer (1)

- **Shock detector and shock mode**

In the commandable shock mode a shock detector selected the best event in the sense of the largest relative jump in magnetic field magnitude for a given commanded time interval: E.g. best 120s interval out of 4 hours!

"Event" data were shifted through the memory like through a big shift register and the best selected in this way !

The onboard determination of zero offsets was not always reliable because of the temperature problems.Thus the shock mode proper could only rarely be used.

Without shock ID the high-resolution time event could be selected by command.

"Event" data or "shock" data consisted of high time-resolution E2 data,E4 waveform and spectral data and selected E5 electric field data.

This data is not available any more because of limited archiving!

Information on E2 by F. Neubauer (2)

- **Experiment performance**

  The experiment performance was excellent except for the consequences of the poor thermal design of the boom mounted sensor boxes of E2 and E4 (responsibility of the Helios project!).

- On Helios 1 sensor temperatures were much too high with 75° at 1.perihelion increasing to 89° at 12.perihelion.Hence the flipper mechanism failed fatally before 1.perihelion making zero-offset determinations impossible. Also for reasons not completely understood the sensitivity sometimes changed abruptly with subsequent abrupt changes back. Various techniques were successfully used to identify and correct for these events including a final visual inspection ("eyeballing").
- The thermal design was changed subsequently leading to too low temperatures on Helios 2 near 1 AU ! This led to “creeping“ instead of abrupt flipping of the sensor rotation angles and led to the requirement of no flips at sensor temperatures below 20° C after the “creeping“ interval i.e. after April 7,1976.
- In addition after the 1.perihelion of Helios 2 slowly varying SC-field variations with several hours period and a few nT amplitude were observed .
- E2 on Helios 1 operated although at much too high temperatures into 1986!
- The Helios 2 mission ended abruptly on March 3, 1980 because of transmitter failure (long after the contractual lifetime of 18 months.)

Information on E2 by F. Neubauer (3)

- **Routine data processing and offset problems**

- During routine data processing the raw data were corrected for sensor misalignment (including the ”creeping” effect) , the transfer function of the aliasing-filter and the zero-offsets due to sensor zero-offsets plus spacecraft fields. The sensor zero-offsets were greater than anticipated mainly because of the excessive temperatures on Helios 1 aggravated by the flipper problems .

- The best zero-offset determinations are possible when spin variations are resolved and frequent flippings are available. Zero-offsets were also determined by inflight techniques like the so-called Hedgecock technique (Hedgecock,1975) developed at Imperial College for Heos.

- Hence to be on the safe side one could mainly use data intervals with 4 vectors per spin or at least 2 vectors per spin.

The Search Coil Magnetometer (SCM): E4

- The Search Coil Magnetometer experiment (E4) was designed to observe the high-frequency component of magnetic fluctuations using three search-coil sensors mounted perpendicular to each other (two in the spin plane and one parallel to the spin axis).

- They measure the three components of the magnetic field from 4.7 to 2200 Hz, in eight logarithmically-spaced frequency channels [Neubauer et al. 1977, Beinroth & Neubaeur 1981, Denskat et al. 1983]. This frequency range has been chosen such as to allow observations up to the maximum expected electron gyrofrequency f_{ce} on the orbit of Helios.

- Filter outputs are squared and averaged by a digital "mean-value-computer" over successive time intervals of length τ_{ave}. In general, τ_{ave}~1.125s (but depends on bit rate, i.e. ~20min for the lowest bit rate). In addition to the mean square value M_n, the peak value in the same time interval is obtained and transmitted.

- Through a collaboration between Dr. Thierry Dudok de Wit in Orléans (and myself and Stuart Bale at SSL to a lower extent), the search coil magnetometer data was read from 9-track tapes to CD and a decommutation program was written to restore the data to ASCII files. But only 35% of the data seemed uncorrupted.