The Technical University of Braunschweig (TU-BS) magnetometer experiment E2 (fluxgate) onboard Helios 1 and 2

by

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Helios-mini-Workshop

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Helios fluxgate magnetometer E2

- The objective of this presentation is to provide information for reuse of Helios fluxgate magnetometer E2 data in preparing for SO and SPPlus .

MVM 73 (1.0- 0.4 AU) and MESSENGER (0.31-0.47 AU) interplanetary magnetic

field data are of high quality but available for a limited time intervals only.

- Written information unfortunately partly incomplete because of accidental losses of printed documentation . Thus some of the information is available in print and some from memory only:

Space Archaeology problem!

Helios fluxgate magnetometer E2 (cont'd)

Plan of Presentation

- **Political and financial boundary conditions**
- **Experiment design**
  - Mechanical flipper device for calibration purposes
  - Measurement ranges and AD-conversion
  - Digital vector real time data
  - Shock detector and shock mode
- **Experiment performance**
- **Routine data processing and offset problems**
- **Examples of science results**
- **Final remarks**

Helios fluxgate magnetometer E2 (cont‘d)

Boundary conditions

- Financing of project E2 essentially terminated in early eighties when I moved to Cologne (with new commitments in Giotto and continuing Voyager science projects)
- Low time-resolution E2 data were shipped to NSSDC at GSFC in 1981
- Budget application for E2 and E4 data saving activities (hundreds of industrial type tapes with processed data in storage) in the nineties was not successful ! This concerned the full high time-resolution data set , which was available in Cologne only .
- Limited internal funding particularly hurt E4 data.

Helios fluxgate magnetometer E2 (cont‘d)

Experiment design:

- The magnetometer consists of a triaxial, orthogonal fluxgate sensor triad with two sensors in the spin plane and one parallel to the spin axis mounted on a boom at 2.6 m distance from the SC axis

  -Sensor type: "Förstersonde" as on Mariner 2

- Also on boom mechanical flipper device
- Analog electronics

  - to drive the sensors in feedback mode

  - (anti-)aliasing filter (corner frequency 4 Hz)

  - range switching

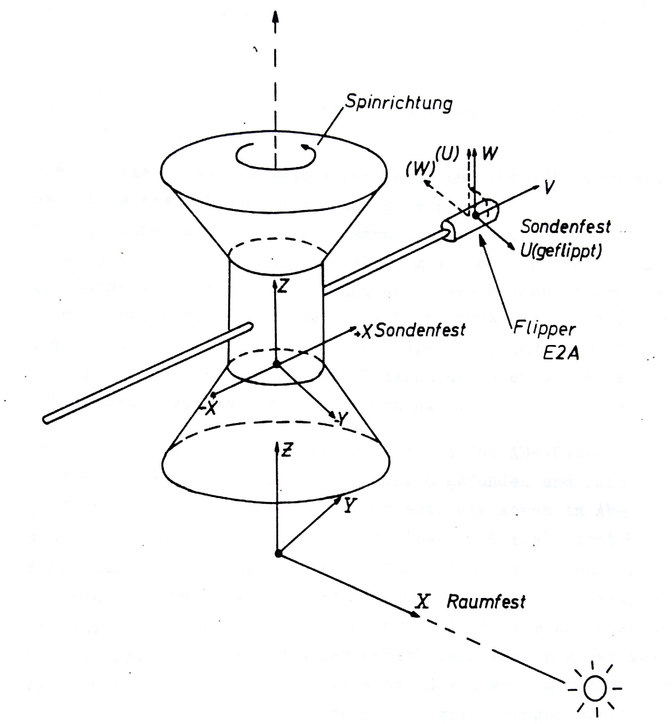


Abb. 9: Anordnung des Förstersondenmagnetometers auf Helios. Aus den mit dem Sondenspin und einer Schiefstellung der Sensorachsen behafteten Daten wird der Feldvektor im raumfesten Koordinatensystem (solar-ekliptisches System) bestimmt.

Helios fluxgate magnetometer E2 (cont‘d)

Experiment design:

- Digital electronics:

  - AD-converter (8bit)

  - Mean-value computer, shock identification

- Note that all the hardware was based on late 1960 – early 1970 technology, i.e. 50 years ago! Design started in 1966!

Helios fluxgate magnetometer E2 (cont‘d)

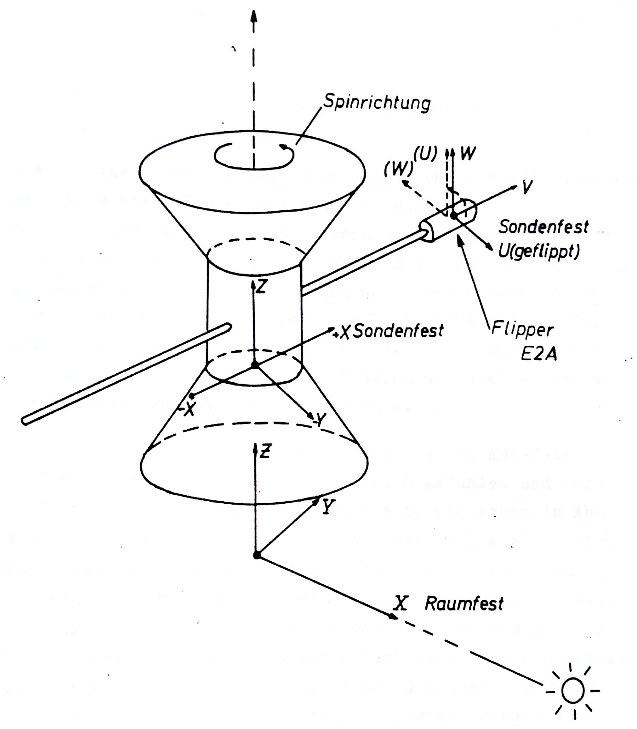
Mechanical flipper device for calibration purposes (see hardware)

- rotation of two sensors by 90°   around boom axis

- helps in determinig the zero offsets of U,W sensors

- Thermal activation of spring through bellows
  (Magnetically ultraclean by HF-heating)

- was of limited use because of failure of thermal
  design for boom mounted systems



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Helios fluxgate magnetometer E2 (cont'd)

Measurement ranges and AD-conversion

The measurement ranges and digitization were chosen after the following considerations:

- space qualified ADC's with up to 8 bits were available only
- observations near 1AU and theory led to
  - sensitive range: -102.0 nT < BX < + 102.0 nT with digitization window 0.4 nT
  - insensitive range: -408.0 nT < BX < + 408.0 nT with digitization window 1.6nT

  to guarantee that even strong disturbances are never missed!
- Range switching with some hysteresis to prevent too frequent range switchings.

Helios fluxgate magnetometer E2 (cont‘d)

Range Switching with hysteresis

- Hysteresis required to avoid excessive switching when magnetic field straddles + -102.0 nT

- Examples for hysteresis cycles

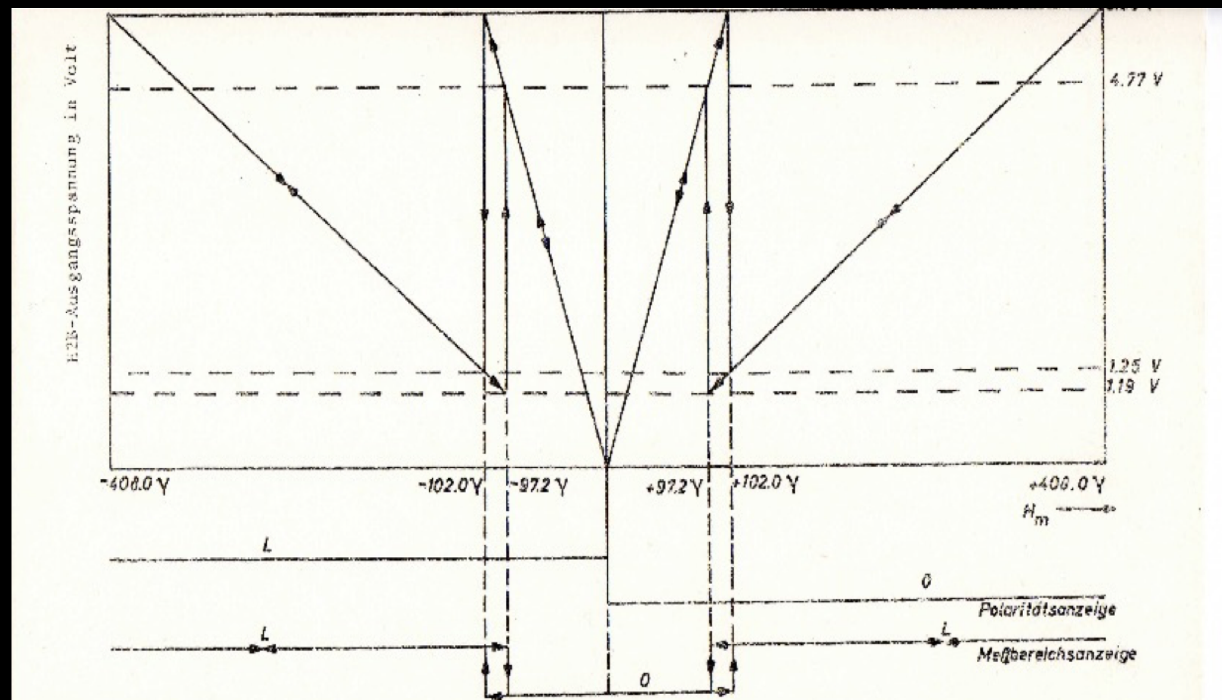

Abb. 2.11

Soll-Ausgangsspannungsverlauf für eine Komponente (Gleichfeld!)

Helios fluxgate magnetometer E2 (cont'd)

- Digital real time vector data

AD-conversion was done spin-synchronously for easier quick-look data evaluation during the mission ,for easier data processing etc

Best sampling rates are > 1 Hz because of resolved spin variation!

Helios fluxgate magnetometer E2 (cont'd)

Spin-synchronous vectors are averaged if available telemetry is too low.

Vectors per spin and mean value averaging periods selected:

formats	total bitrate,bps	#/spin	formats	total bitrate,bps	#/spin
FM1	2048	4	FM5 (Effelsberg)	4096	4
	1024	2		2048	2
	512	1	FM6	16384	8
FM2	512	1	(shock mode)	8192	8
	256	1 / 2*		4096	4
	128	1 / 4*			
	64	1 / 8*			
FM3	64	1 / 8*			
	32	1/16* etc			
FM4	engineering format				

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1 / 2* corresponds to average over two spin periods

1 / 4*   corresponds to average over four spin periods

etc

spin resolved cases in green!

Helios fluxgate magnetometer E2 (cont'd)

- 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!

Helios fluxgate magnetometer E2 (cont'd)

- 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").

Helios fluxgate magnetometer E2 (cont‘d)

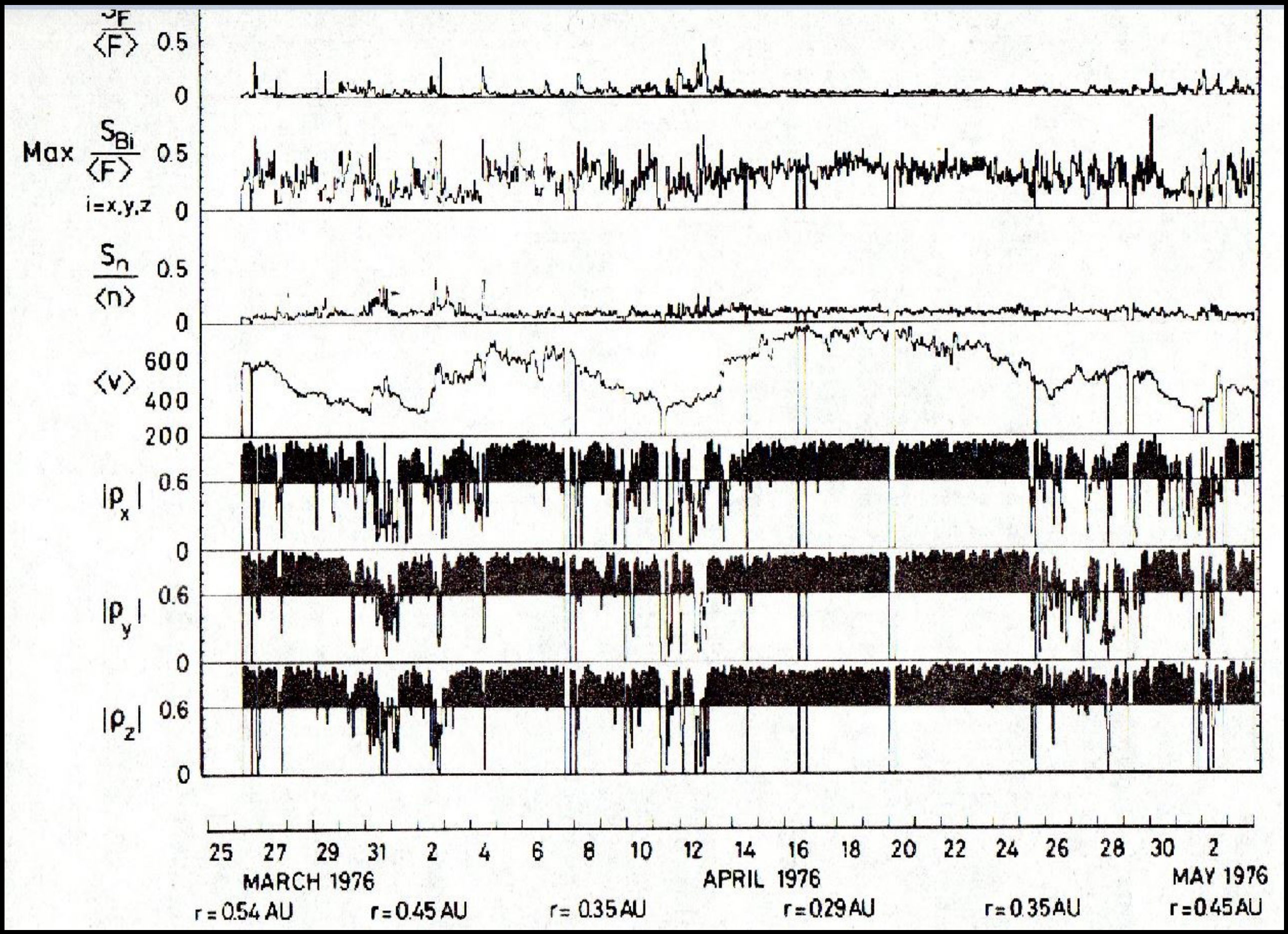
- Experiment performance(cont'd)

- 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.)

Helios fluxgate magnetometer E2 (cont'd)

- Experiment performance(cont'd)



Data based approach:

Alfvénic fluctuations in the solar wind:

The large values of the correlation coefficients indicate the high quality of ***both*** the participating experiments E1 (plasma analyzer) ***and*** the fluxgate magnetometer E2.

Note that the measurements and the data analysis of both experiments are completely independent!

Helios fluxgate magnetometer E2 (cont‘d)

- 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 .

Helios fluxgate magnetometer E2 (cont'd)

- Routine data processing and offset problems (cont'd)

- 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.

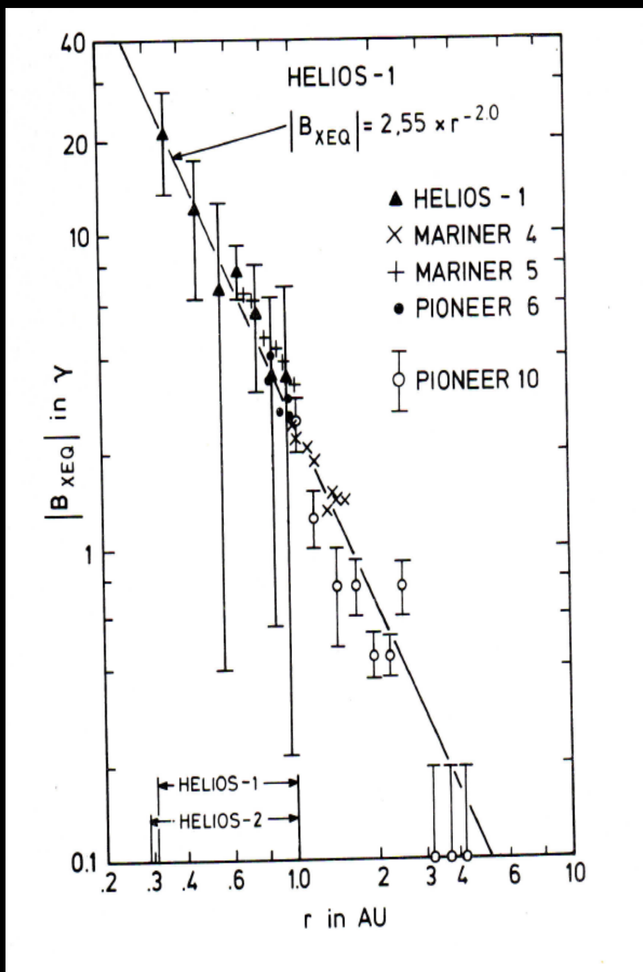
Helios fluxgate magnetometer E2 (cont‘d)

Selection of scientific results (mainly 1974- 1982)

Some may also be useful for validation of E2 data

1. Radial variation of interplanetary magnetic field (E2)
2. Macroscopic picture of shock interactions (E2)
3. Alfvén waves in the solar wind (E2)
4. EM-waves from 4.7 Hz to 2.2 kHz and their radial variation (E4)
5. Shock structure (E2,E4)
6. Directional discontinuity structure (E2, E4)

Helios fluxgate magnetometer E2 (cont'd)



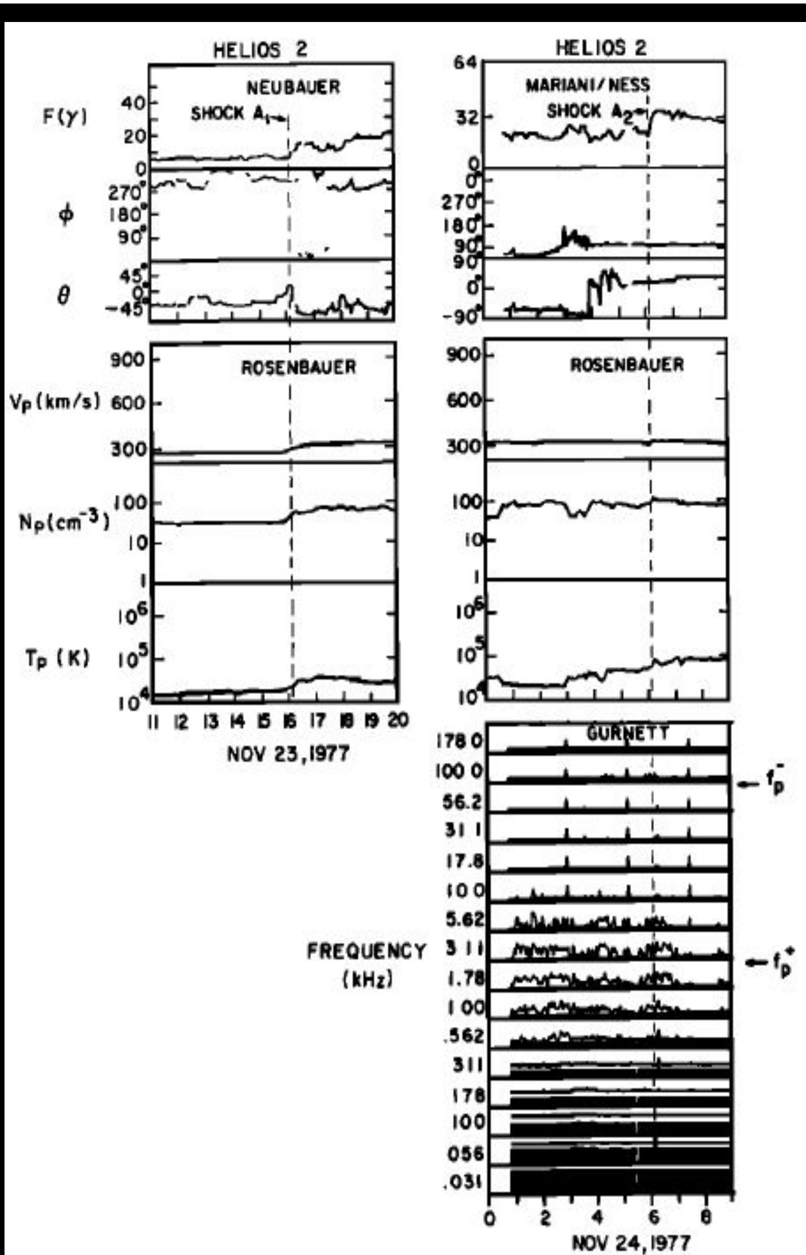
Radial variation of radial

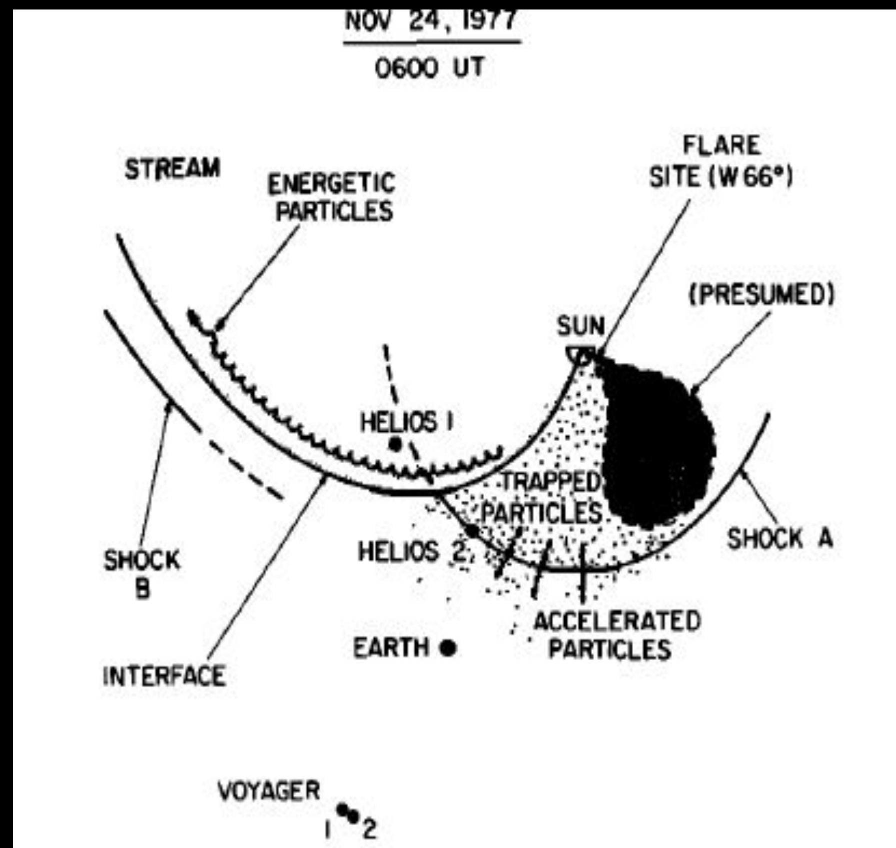
IMF-component B_{XEQ}

(Data until 1977)

Helios fluxgate magnetometer E2 (cont'd)

Merging shocks A1 and A2 in the inner heliosphere
Nov 23-24 after Burlaga et al.(1980)





Helios fluxgate magnetometer E2 (cont'd)

Final Remarks

- We have described the Helios TU-BS fluxgate magnetometer investigation E2 (1974-1982) particularly in support of the scientific preparation of the SO and SPPlus-missions.
- Because of temperature problems and partial flipper failure

  zero-offsets may be affected particularly at low time-resolution

- ***To avoid difficulties it is recommended to use mainly the high time-resolution data with more than 1 vector per spin period.***

Helios fluxgate magnetometer E2 (cont‘d)

Acknowledgements

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- Hardware phase TU Braunschweig: F.Gliem, R.P.Kugel, A.Maier, B.Stoll

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- Data processing Cologne: W.Heibey, H.Marschall, A.Söding, K.Sperveslage, R.v.Stein, A.Wennmacher

End

Helios fluxgate magnetometer E2 (cont‘d)

- Experiment performance(cont'd)

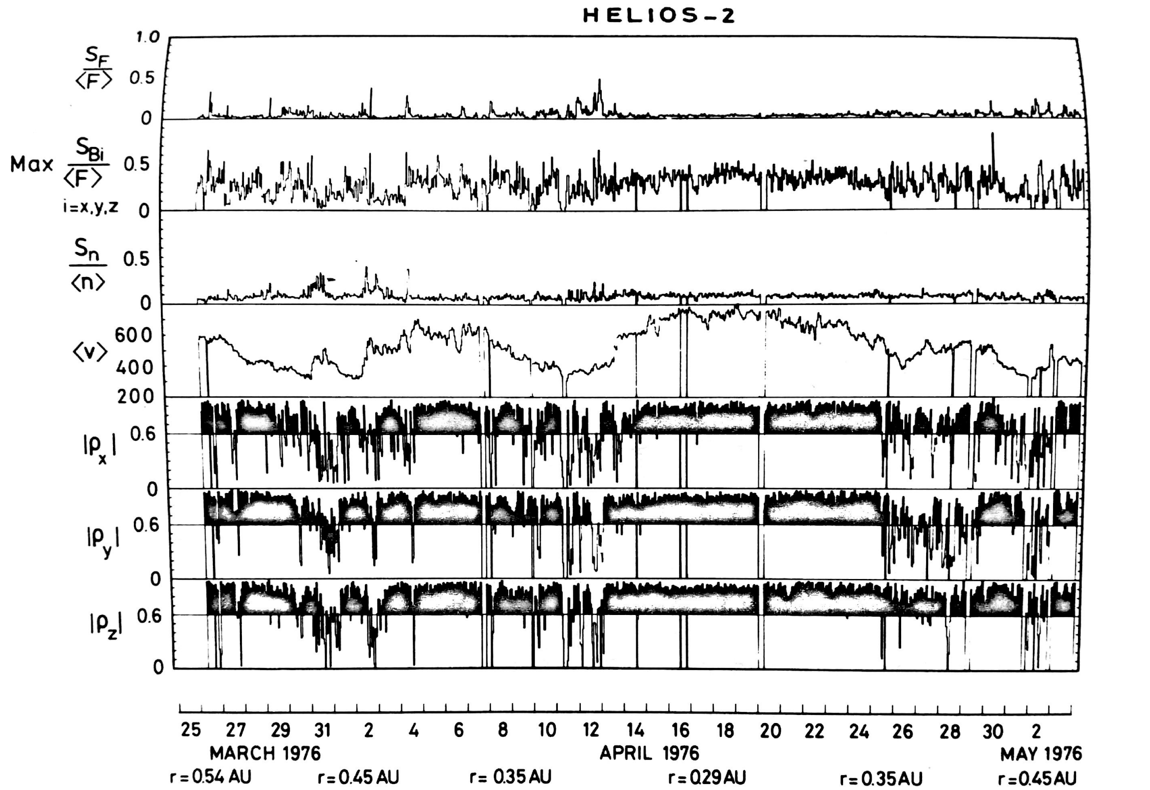

Abb. 11: Allgemeine Eigenschaften der von Helios-2 gemessenen MHD-Fluktuationen in Verbindung mit dem Geschwindigkeitsprofil des Sonnenwindes bei Sonnenentfernungen zwischen 0.98 AE und 0.91 AE. Die sieben Kästen beinhalten (von oben nach unten) jeweils berechnet für eine Stunde die normierten Standardabweichungen des Magnetfeldbetrages, der Magnetfeldkomponenten, der Dichte, sowie die Mittelwerte der Sonnenwindgeschwindigkeit und die Absolutwerte der Korrelationskoeffizienten zwischen δv und δb für die drei Vektorkomponenten.

Data based approach:
Alfvénic fluctuations in the solar wind:
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