

The Technical University of Braunschweig (TU-BS)
magnetometer experiment E4 (search-coil)
onboard Helios 1 and 2

by

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Universität zu Köln

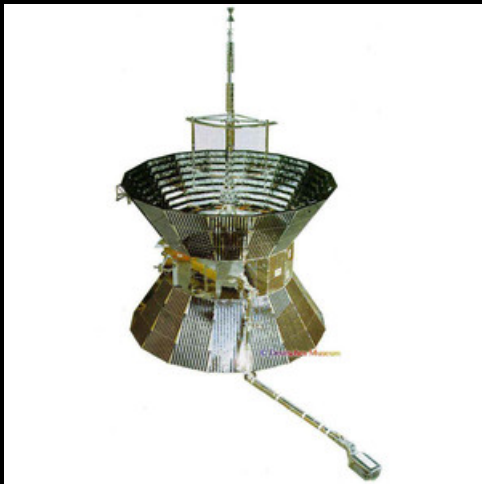
and

G. Dehmel

TU-BS

Helios-mini-Workshop

Köln , June 27- 29 , 2016



Helios search-coil magnetometer E4 (cont'd)

- The objective of this presentation is to provide information for use of Helios search-coil magnetometer E4 data in preparing for the Solar Orbiter (SO) and Solar Probe Plus (SPP) missions.
- No magnetic field measurements up to 2.2 kHz since Helios. However channels #1 and #2 partly covered by MVM73 and MESSENGER magnetometers.
- **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 search-coil magnetometer E4 (cont'd)

Plan of Presentation

- Boundary conditions
- Experiment design
- Experiment performance
- Routine data processing
- Examples of science results
- Final remarks

Helios search-coil magnetometer E4 (cont'd)

Boundary conditions

- Financing of project E4 essentially finished before 1982 when I moved to Cologne to work on new projects.
- Spectral data only were shipped to NSSDC at GSFC in 1981
- Budget application for data saving activities in the nineties was not accepted .
- **Since all the data had to be dumped** ,only the NSSDC-data with relatively low repetition rate are available for this experiment.

Helios search-coil magnetometer E4 (cont'd)

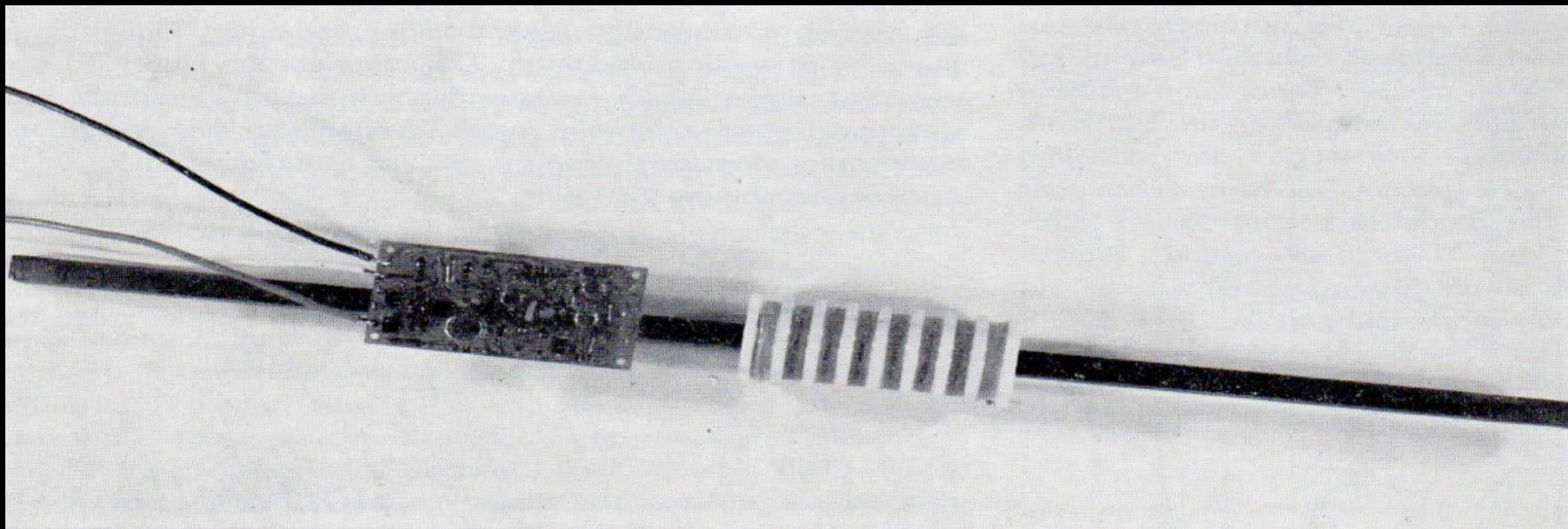
Experiment design:

- The magnetometer consists of a triaxial, orthogonal search-coil sensor triad with two sensors in the spin plane and one parallel to the spin axis mounted on a boom at 4.6 m distance from the axis
 - Sensor type: search-coil like on OGO-5 etc but higher resonance frequency
 - Similar sensors on Galileo atmospheric entry probe lightning detector (1995).
 - Developers started company Metronix in Exploration Geophysics later sold to US company. Selling on all continents in increasing market (“Magnetotellurics” equipment)!

Helios search-coil magnetometer E4 (cont'd)

Experiment design:

Helios E4 sensor and preamplifier



Helios search-coil magnetometer E4 (cont'd)

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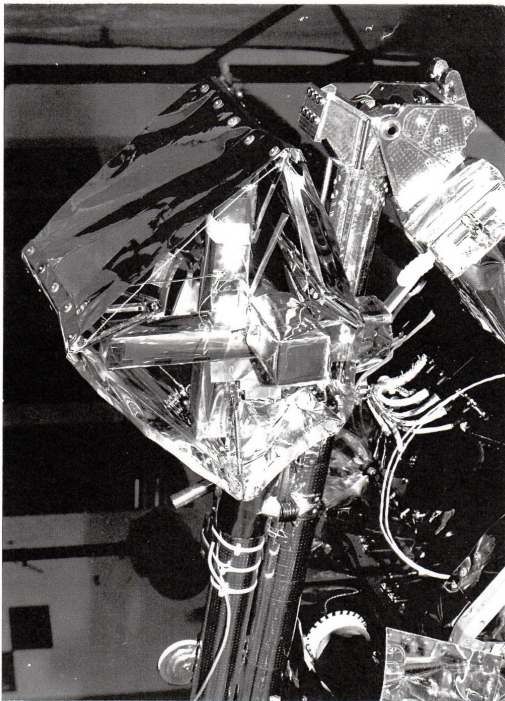


Bild 13 Sensor mit Thermalaustrüstung am Ende des
(zusammengeklappten) Sondenauslegers montiert

Experiment design:

Helios E4 sensor triad

assembly at folded boom

Helios search-coil magnetometer E4 (cont'd)

Experiment design:

- Analog electronics
 - preamplifiers
 - amplifiers for range adjustment, integrators for waveform channels on Helios 1 ,omitted partly on Helios 2
 - active bandpass filters for spectral analyzer
- Digital electronics
 - AD-conversion , nonlinear
 - spectral analyzer mean square value computer yielding mean squares and peak values for averaging interval
- Note that all this hardware was based on late 1960 technology ,i.e. ~ 50 years ago. Development started in 1966.

Helios search-coil magnetometer E4 (cont'd)

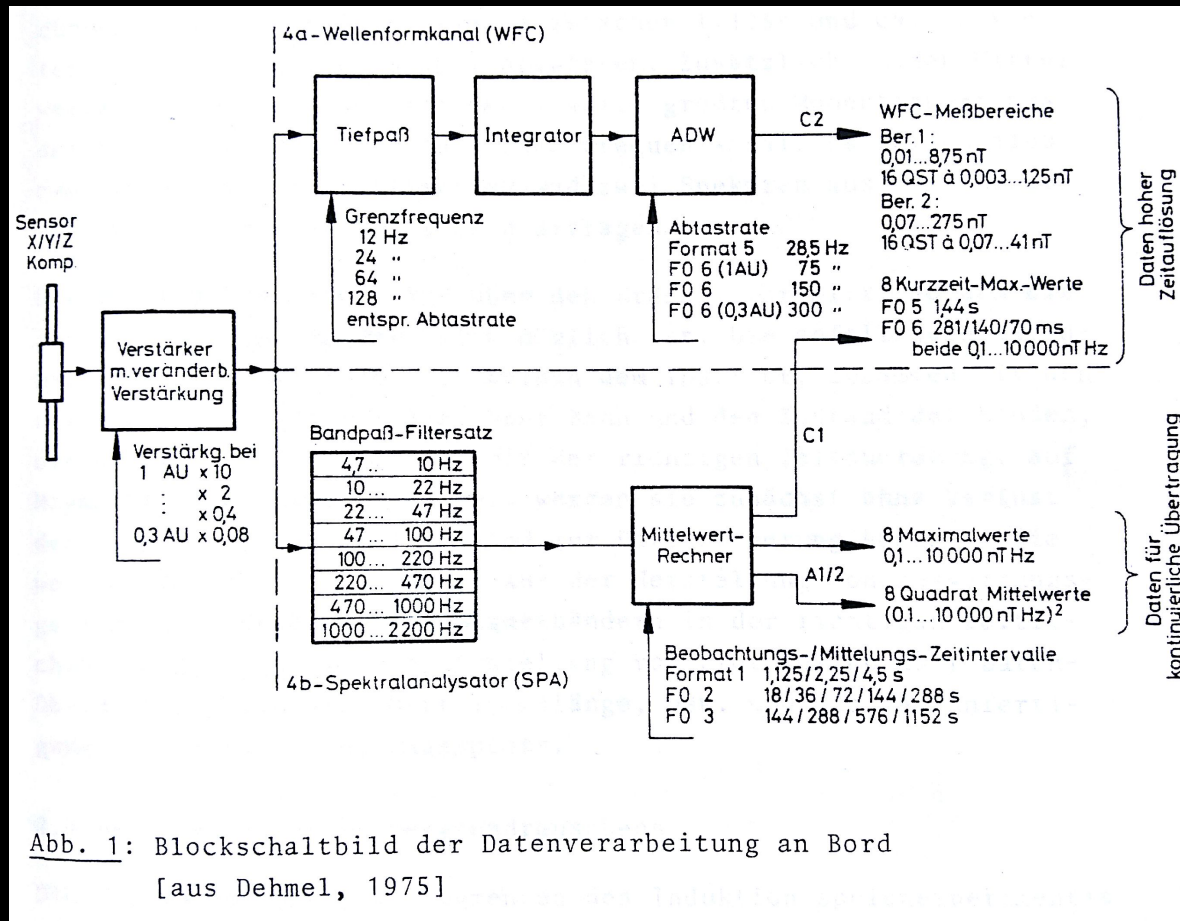


Abb. 1: Blockschaltbild der Datenverarbeitung an Bord
[aus Dehmel, 1975]

Helios search-coil magnetometer E4 (cont'd)

E4a Wave form channel (WFC)

C2 WFC Vector data

X,Y,Z

Adjustable Amplification
10,2,0.4,0.08
1AU → 0.3AU

Low pass filter → Integrator → AnalogDigitalConversion

Corner frequency
12Hz
24Hz
64Hz
128Hz

Sampling frequency
Format 5 28.5 Hz
Format 6 75 Hz
Format 6 150 Hz
Format 6 300 Hz

C1

Bandpass filters

4.7	10Hz
10	22Hz
22	47Hz
47	100Hz
100	220Hz
220	470Hz
470	1000Hz
1000	2200Hz

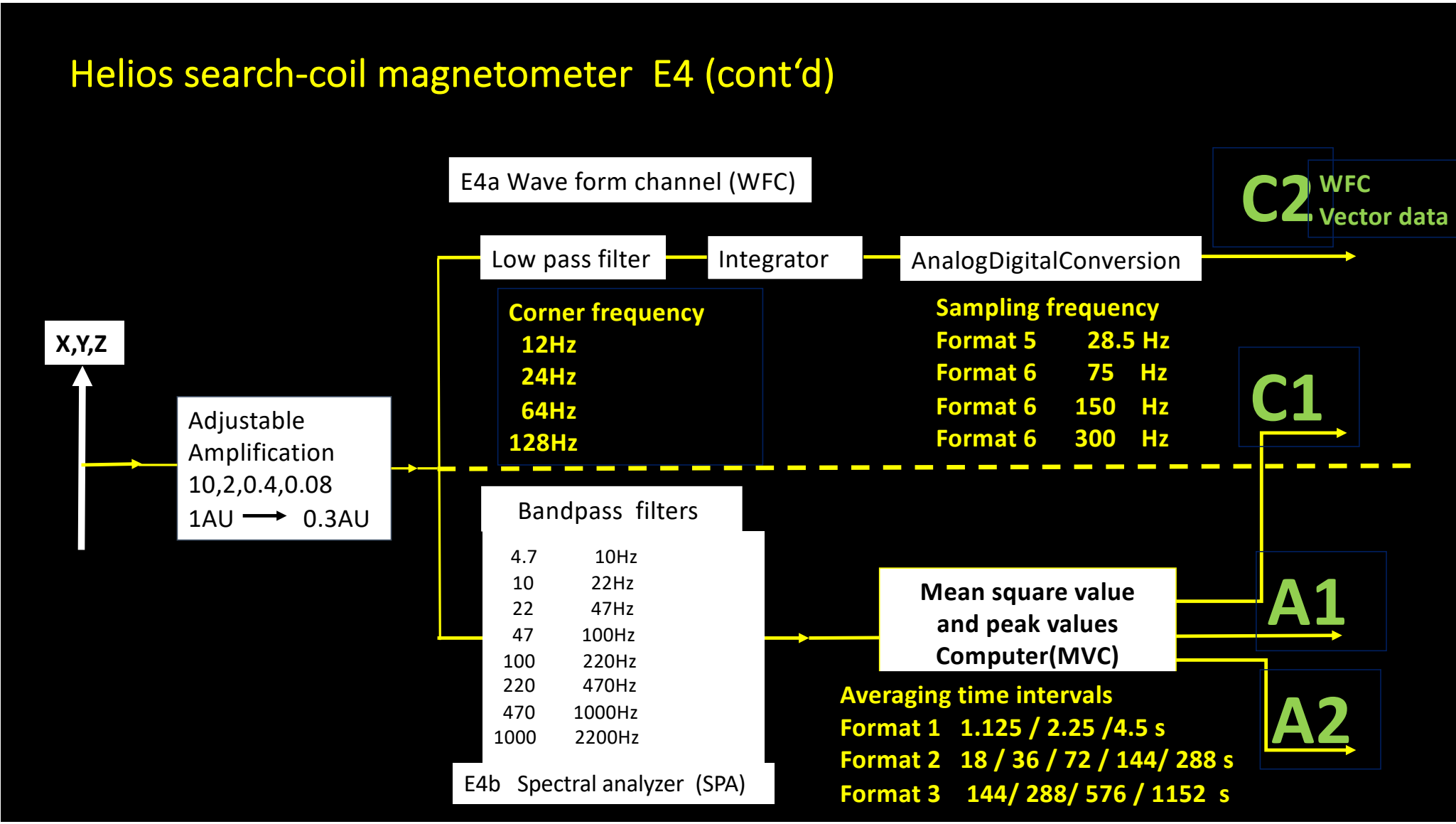
E4b Spectral analyzer (SPA)

Mean square value and peak values Computer(MVC)

A1

Averaging time intervals
Format 1 1.125 / 2.25 / 4.5 s
Format 2 18 / 36 / 72 / 144 / 288 s
Format 3 144 / 288 / 576 / 1152 s

A2



Helios search-coil magnetometer E4 (cont'd)

Experiment performance

- Similar temperature problems as at E2 position. At outer end of the boom only preamplifier could be affected. Inspection of data initially shows no problems.

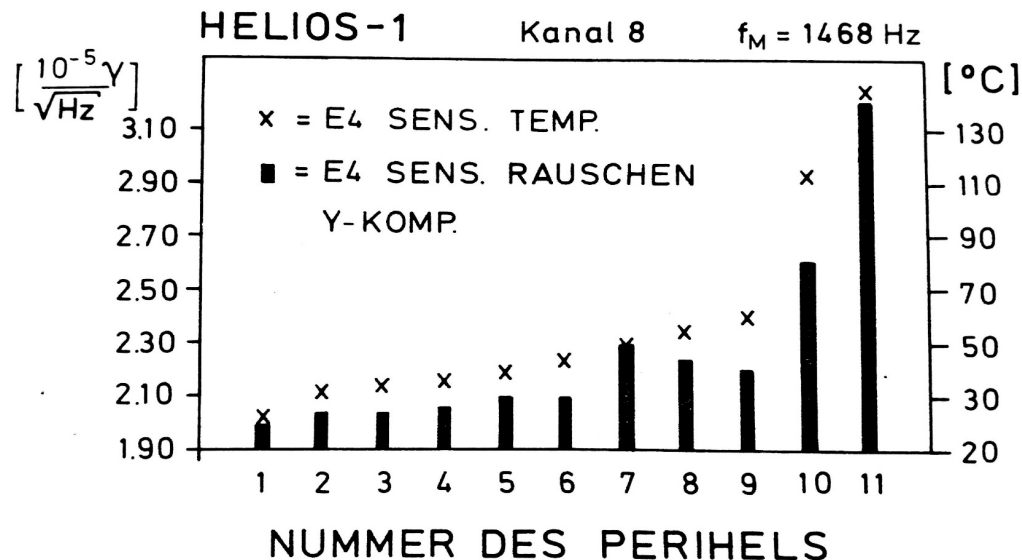


Abb. 3: Sensorrauschen und Sensortemperatur nahe den Perihels von 1975 bis 1980.

However, see noise levels and temperature for channel 8 of

Behavior suggests “healthy” conditions up to end of 1977 .

Other channels and Helios 2 showed similar behavior.

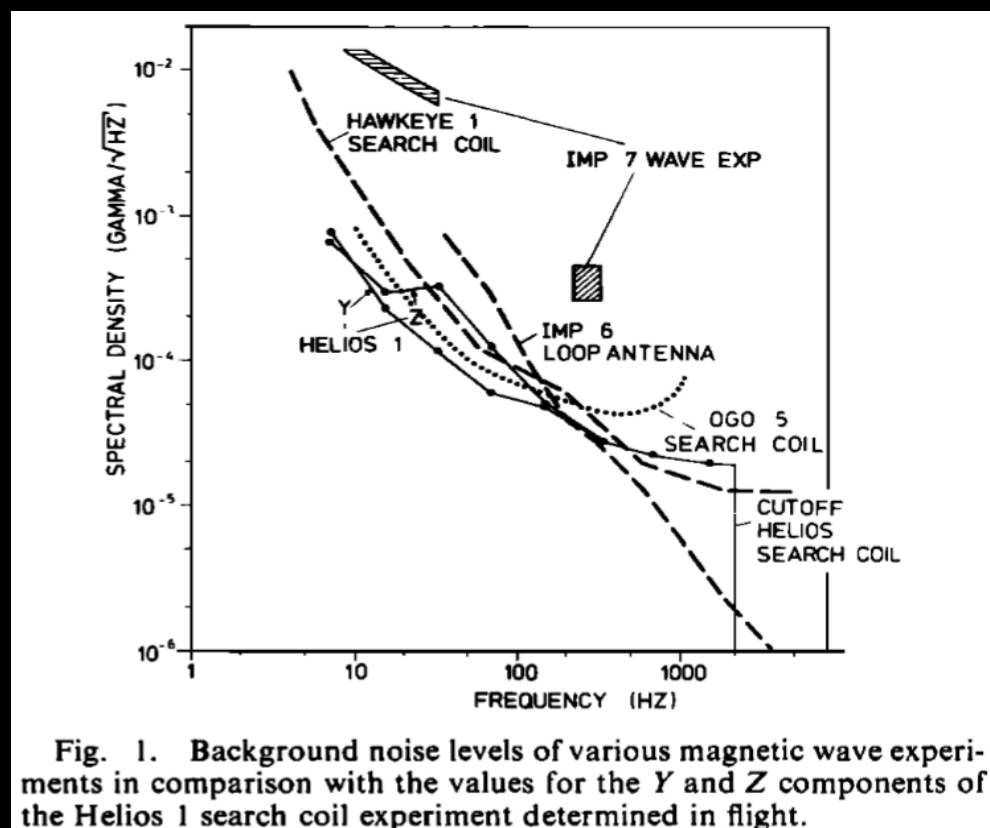
Helios search-coil magnetometer E4 (cont'd)

Experiment performance(cont'd)

- Some smaller interference problems could be solved by reconfigurations of the experiment by command.

Helios search-coil magnetometer E4 (cont'd)

Experiment performance (cont'd)



- Background noise levels for Helios 1 search-coil Y,Z components determined as lower sharp peaks of histograms (near 1 AU):
instrument noise + SC stray field, worked for channels #3 – 8, # 1-2 noise contribution due to spin signal !
- All others mostly instrument noise

Helios search-coil magnetometer E4 (cont'd)

Routine data processing

- Straightforward decalibration
- Digital spectral analyzer data given in $\text{nT}/(\text{Hz})^{1/2}$
for peaks and averages

Helios search-coil magnetometer E4 (cont'd)

3. Selection of scientific results

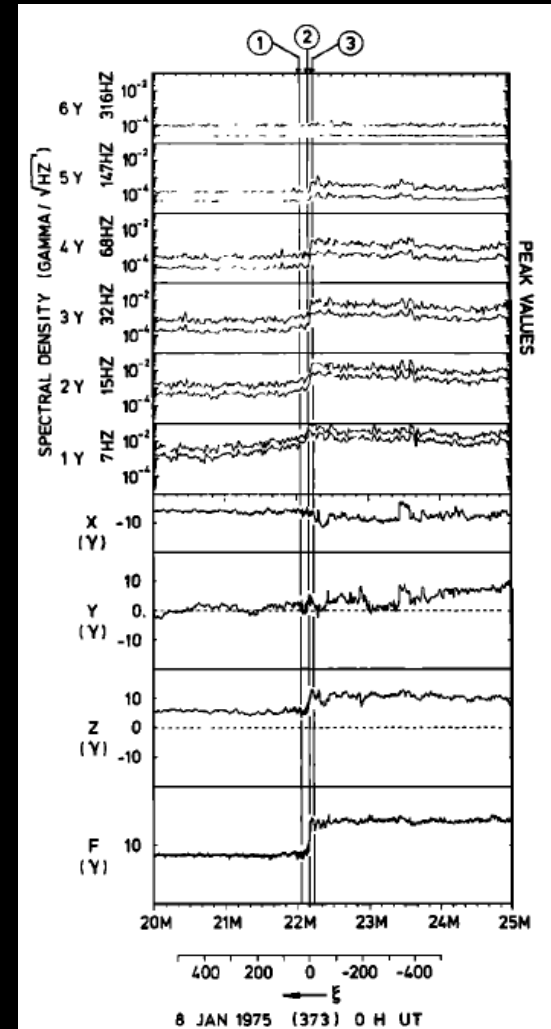
Selection according to usefulness for data validation (E2, E4)

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)
7. Broadband spectrum of magnetic field variations(E2, E4)

Helios fluxgate magnetometer E4 (cont'd)

3.5.Shock Structure

- Search-coil magnetometer E4:
spectral densities and peak values for
channels 1 – 6
- Fluxgate magnetometer E2
X, Y, Z solar-ecliptic components
- ξ = coordinate in shock normal direction
in ion penetration lengths

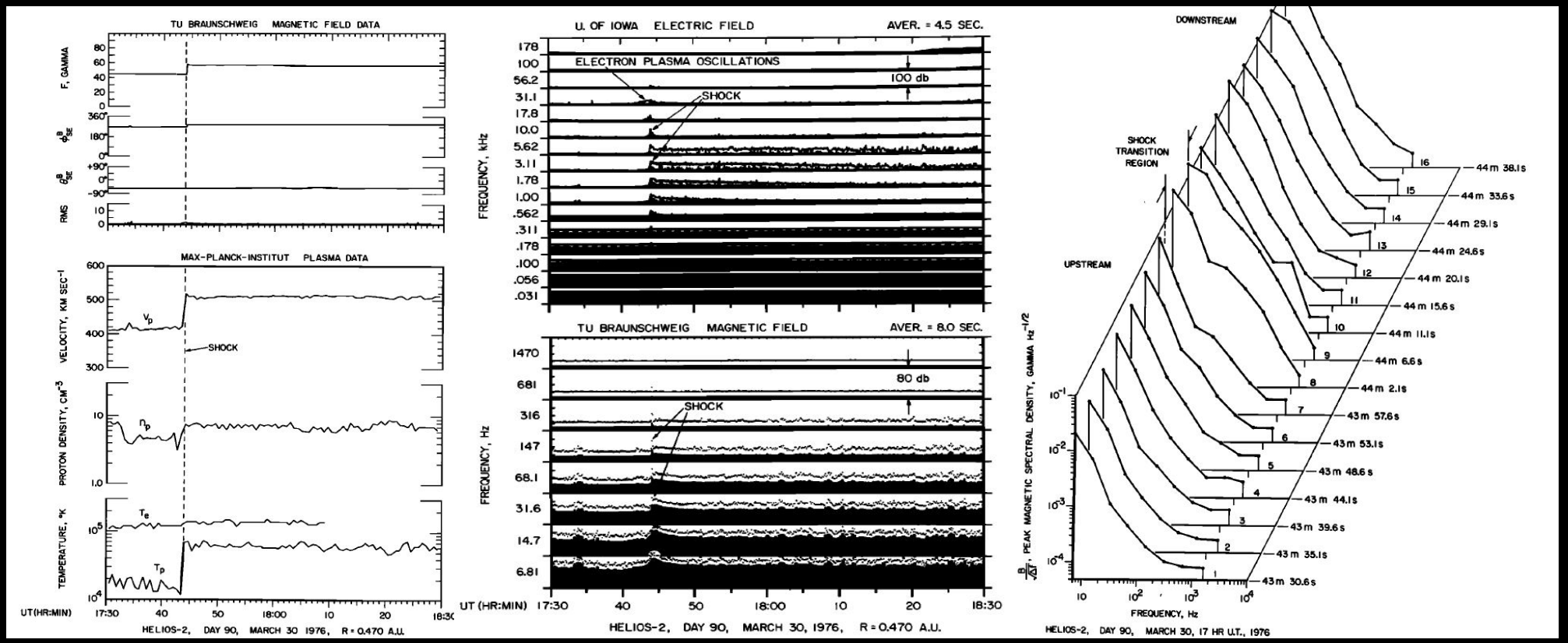


Bad print

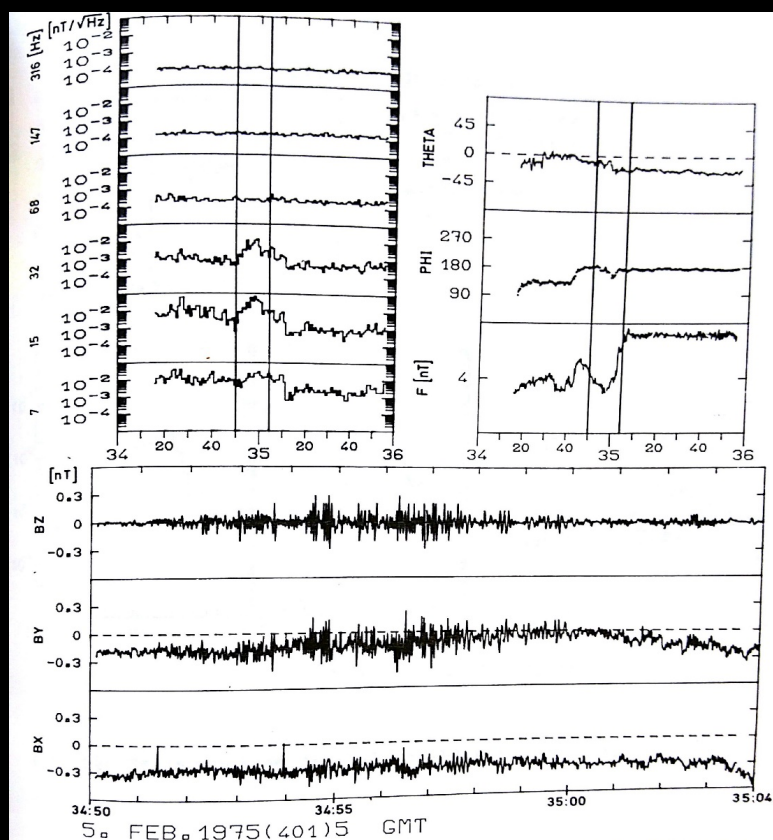
Helios search-coil magnetometer E4 (cont'd)

3.5. Shock structure

Low Mach number, very low beta, high alpha-particle contribution shock -- Gurnett et al. (1979)



Helios search-coil magnetometer E4 (cont'd)



3.6. Discontinuity structure

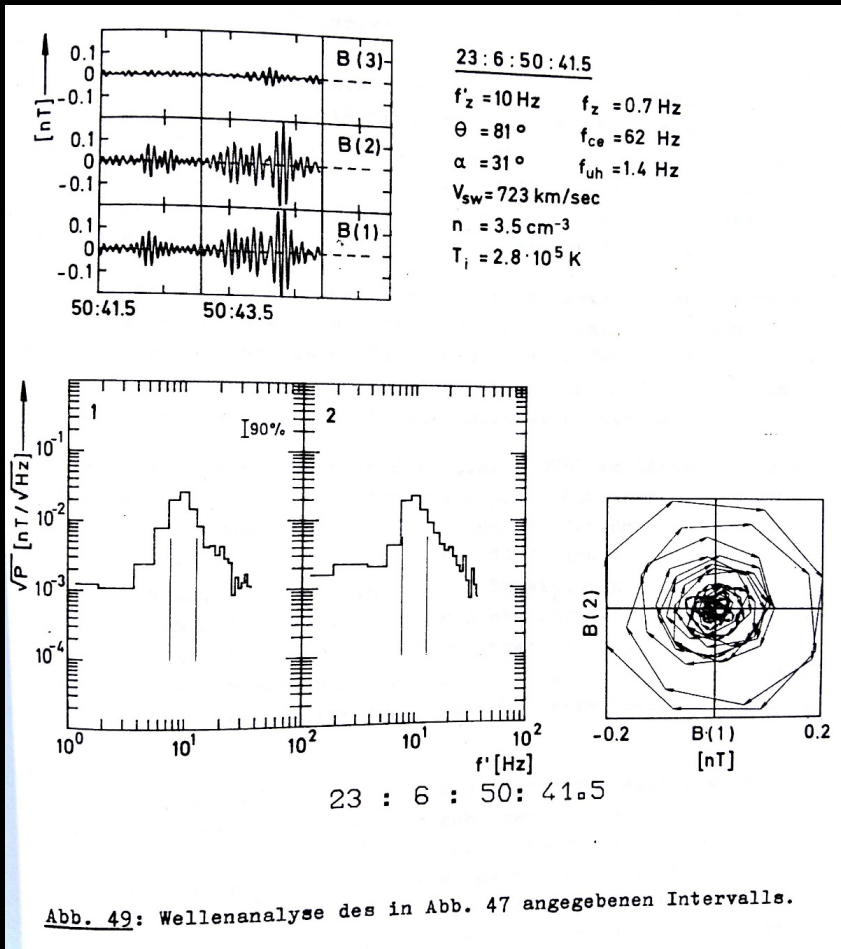
Discontinuity structure with

superposed waves

centered on magnetic field minimum

with frequencies up to 50 Hz

Helios search-coil magnetometer E4 (cont'd)



3.6. "Magnetic hole" structure

„magnetic hole“ structure associated waves in MVA-coordinate system centered on magnetic field minimum, spectra, hodograph with frequencies up to 50 Hz

Helios search-coil magnetometer E4 (cont'd)

3.7. Broadband spectrum of magnetic field variations

Broadband magnetic field spectra in $\text{nT}^{**2}/\text{Hz}$ from E2 and E4 measurements around first perihelion of Helios 2

11 h averages of macroscopic magnetoplasma properties

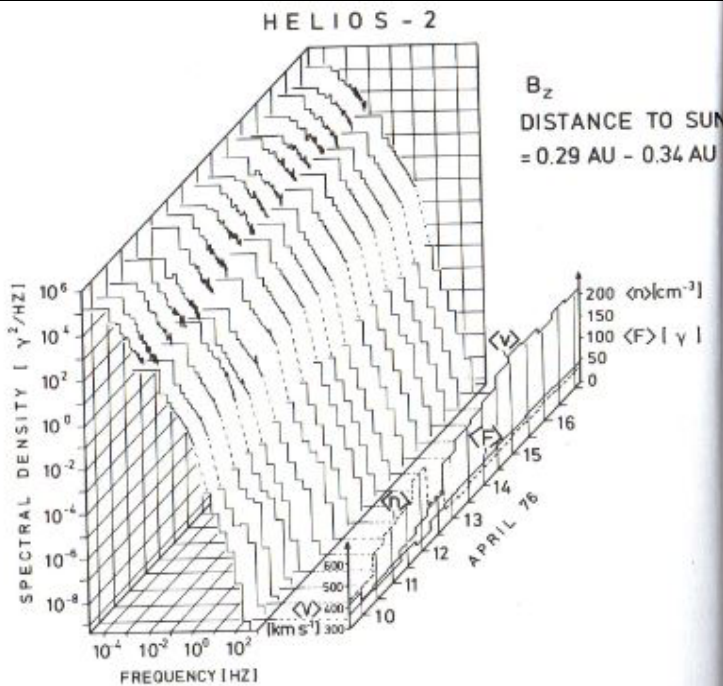


Abb. 31: Zeitliche Folge von jeweils elf Stunden auseinanderliegenden Spektraldichteschätzwerten der z_{5g} -Komponente des interplanetaren Magnetfeldes zwischen 0.29 AE und 0.34 AE. Spektraldichteschätzwerte unterhalb von 2 Hz wurden aus Daten des Förstersondenmagnetometers berechnet, wobei für die tiefen Frequenzen bis zu $1,2 \times 10^{-3}$ Hz 40,5 Sekunden - Mittelwerte und für die höheren Frequenzen bis zu 2 Hz die hochauflösenden Daten benutzt wurden. Die aus letzteren Daten berechneten Spektraldichteschätzwerte wurden jeweils über 170 Einzelspektren segmentgemittelt. Die Spektraldichten oberhalb von 4,7 Hz wurden mit dem Induktionsspulenmagnetometer gemessen und entsprechend gemittelt. Damit wird insgesamt ein Frequenzbereich von $2,4 \times 10^{-5}$ Hz bis 470 Hz erfaßt. In der Abbildung rechts sind elfstündige Mittelwerte der Strömungsgeschwindigkeit, der Protonendichte und der Magnetfeldstärke gezeigt.

Helios search-coil magnetometer E4 (cont'd)

Final Remarks

- Helios search-coil magnetometer E4 provided magnetic field data at frequencies as high as 2.2kHz under good magnetic cleanliness conditions
- Data were provided as waveform data and spectral analyzer data (8 logarithmically spaced spectral channels) in real-time modes and memory modes including an event mode referred to as shock mode
- The experiment provided data from launch until the early eighties on Helios 1 and until 1980 on Helios 2
- Because of increasing severe thermal problems at the sensor location data were considered reliable until end of 1977 at least.
- Because of archiving problems spectral data only are available for the first nine months of each mission including also the 2.perihelion for each!

Helios search-coil magnetometer E4 (cont'd)

Acknowledgements

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