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Helicity thinkshop 3, IIS Univ. Tokyo, 19-24 Nov. 2017

Electromotive force measurements in interplanetary space

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Many thanks to:
Phillipe Bourdin & Bernhard Hofer

Acknowledgment: SOHO LASCO

Upcoming in situ interplanetary trio

ESA JAXA BepiColombo
launch planned in Oct. 2018
7.2-year cruise in the inner heliosphere
with magnetic field measurements (down to 0.3 AU)

ESA Solar Orbiter
launch planned in Feb. 2019
simultaneous optical and in situ measurements
heliocentric distance down to about 0.3 AU
inclination about 30 degrees from Earth ecliptic plane

NASA Parker Solar Probe
launch planned in Aug. 2018
in situ measurements as close as 10 solar radii

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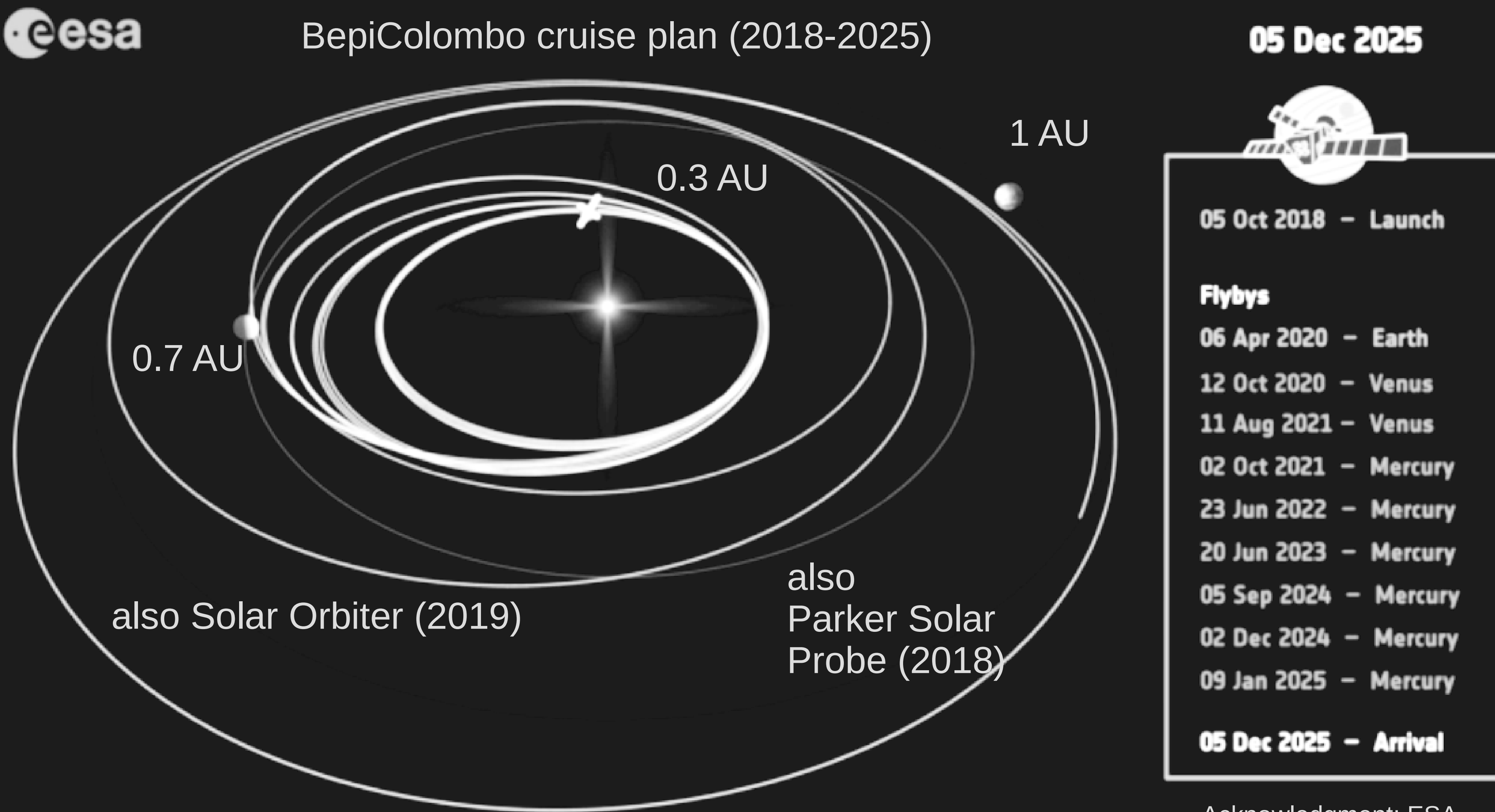
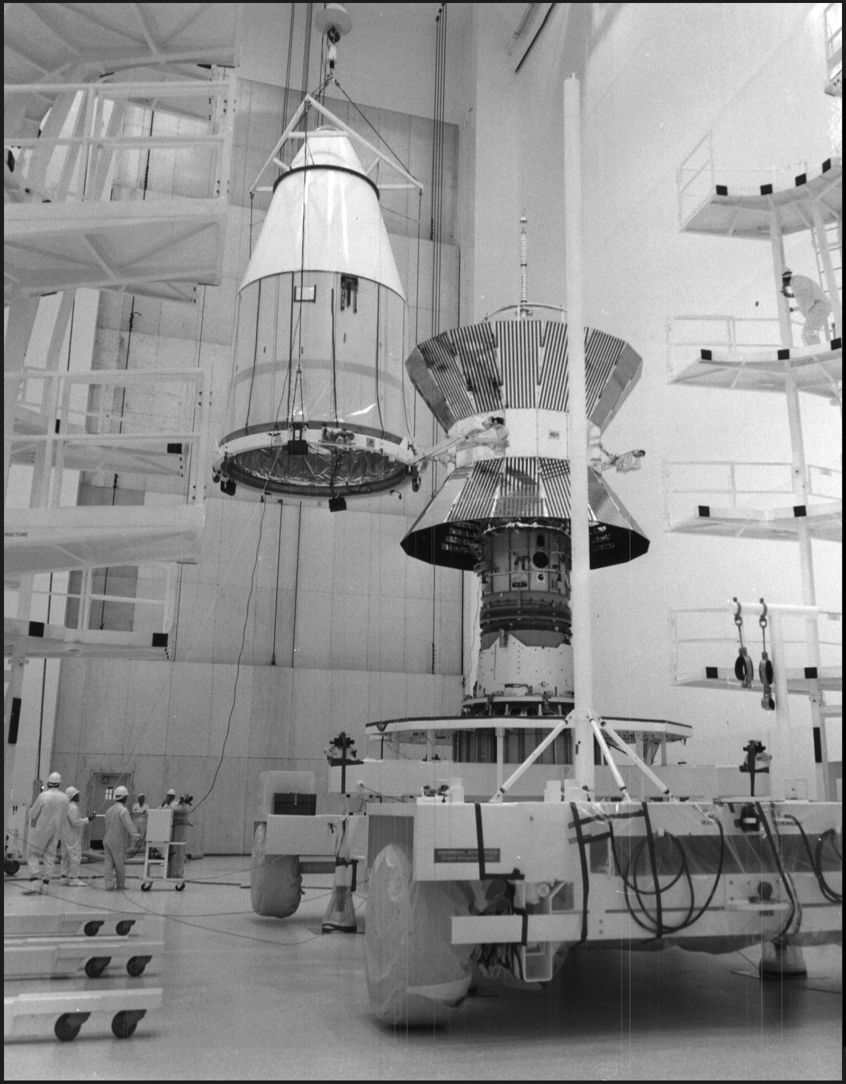
Multi-point measurements!

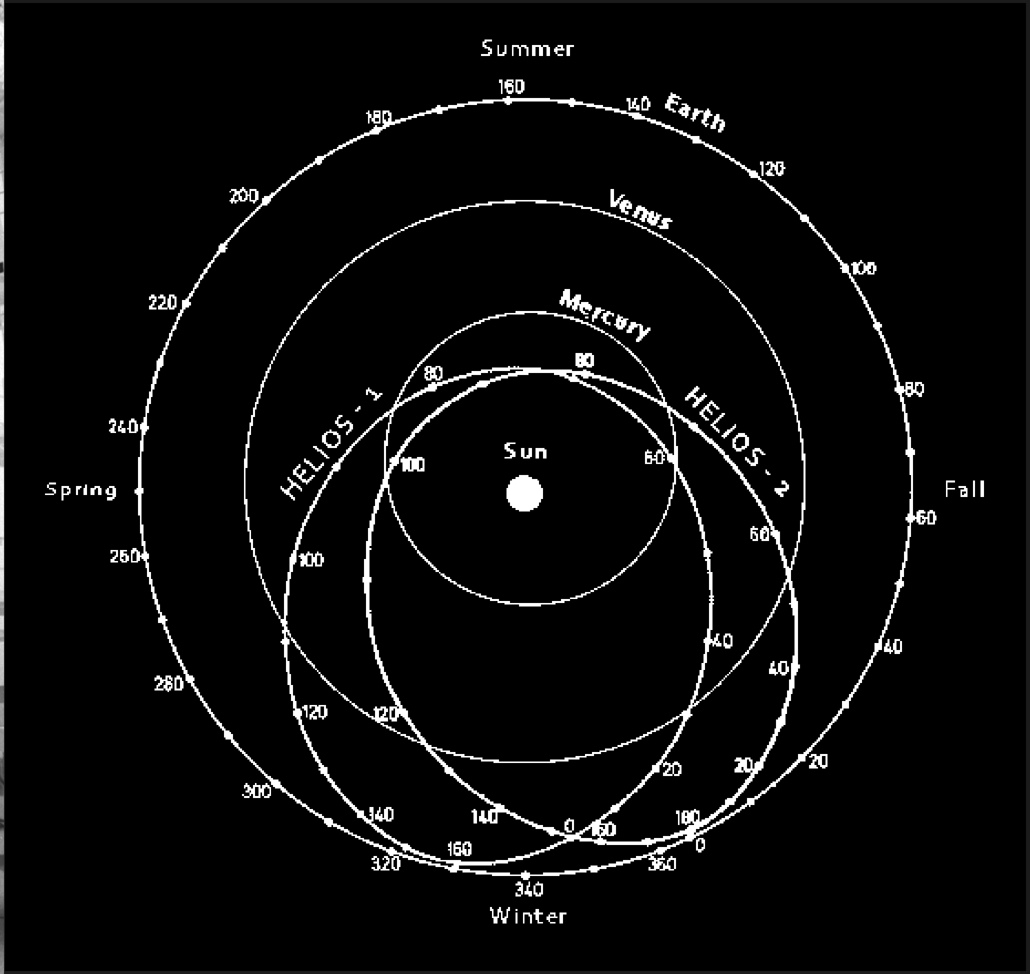


Acknowledgment: ESA

... and ACE, DSCOVR, STEREO spacecraft

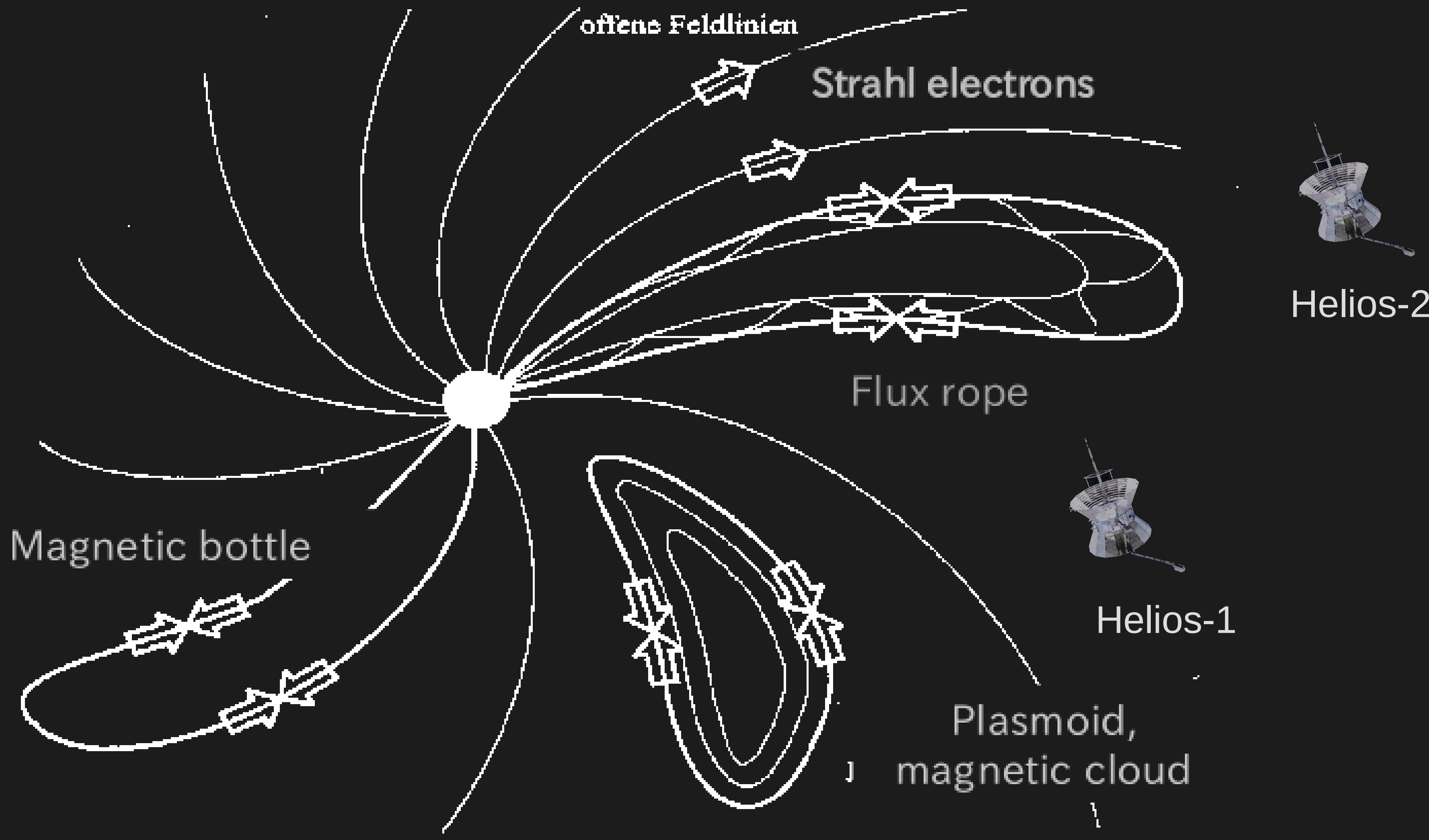
Helios mission (1974-1985, 1976-1979)





Acknowledgment: NASA

Natural laboratory of helicity



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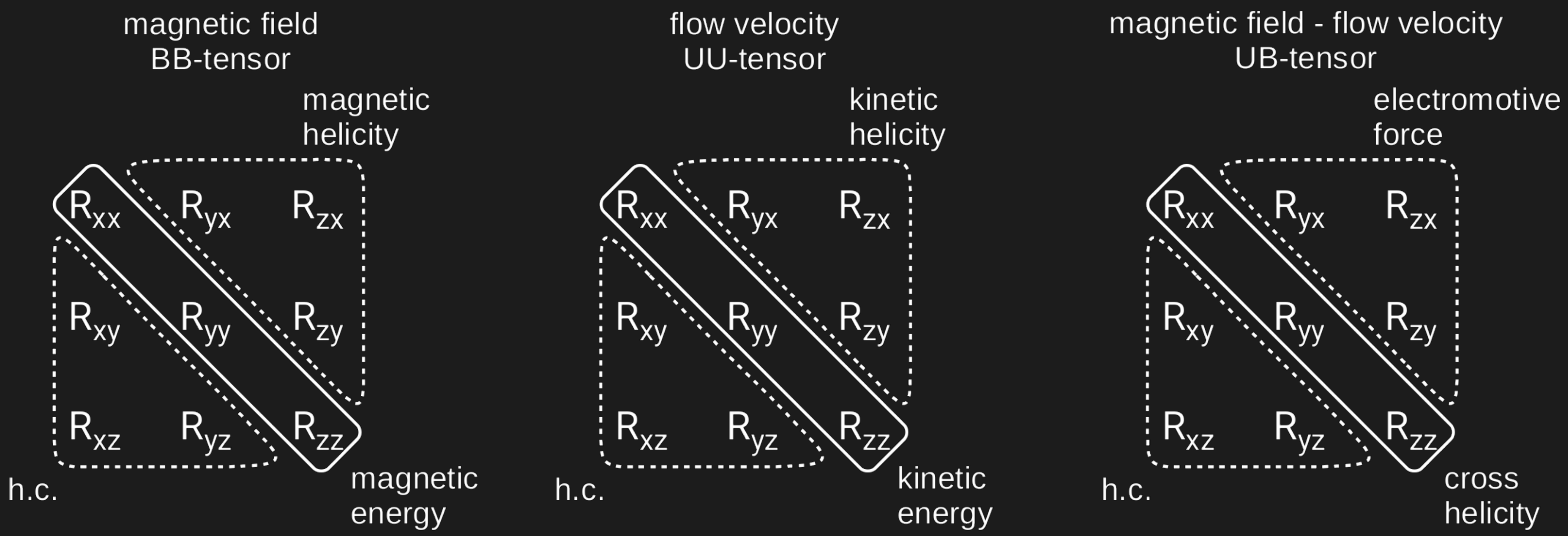
Why do we care electromotive force?

Second-order quantities: energy, heliciy, and <u>electromotive force</u>



Narita, Nonlin. Processes Geophys. 2017

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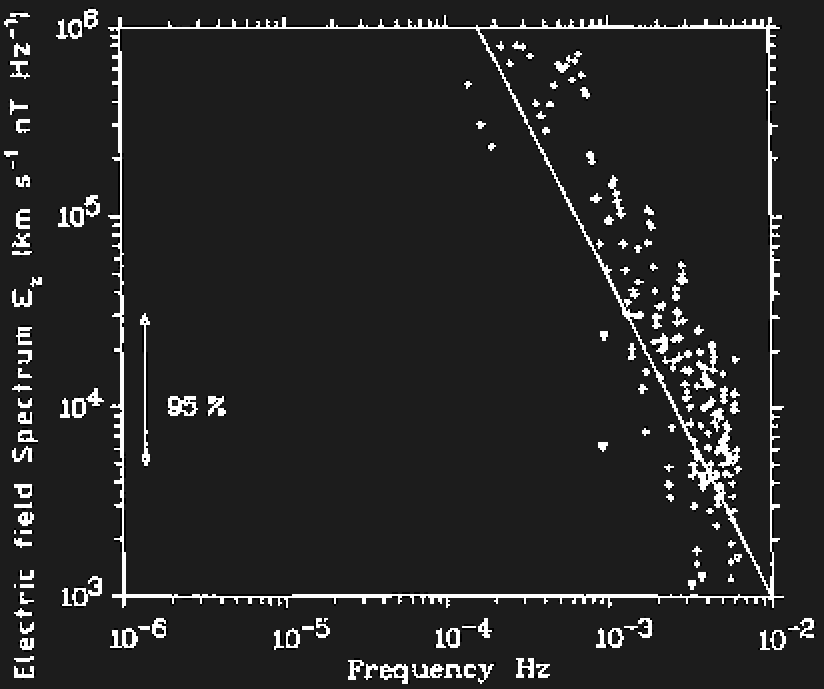
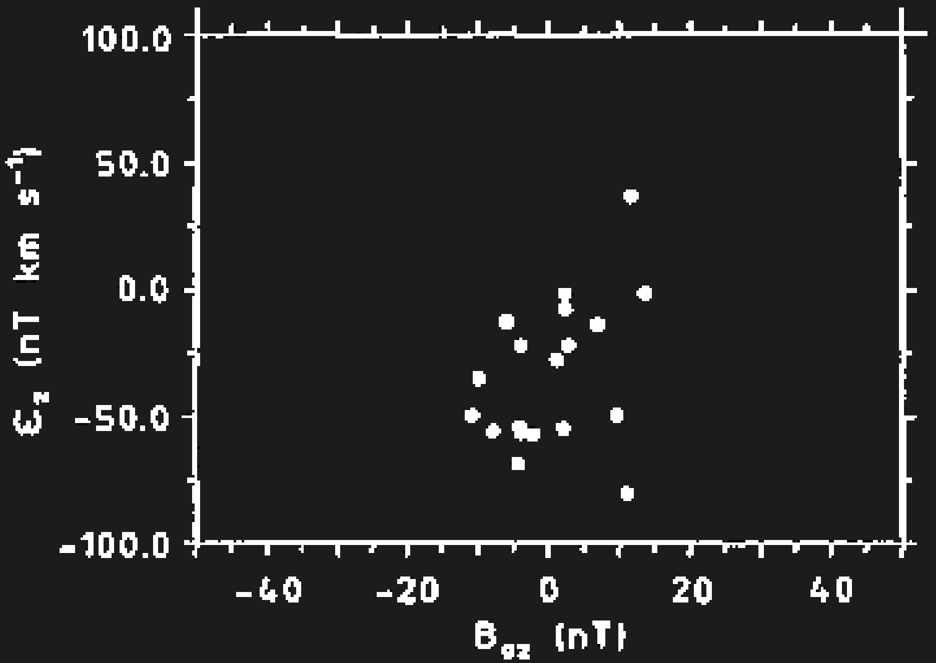
Pioneering work by Marsch & Tu

Frequency spectrum of electromotive force



Electromotive force vs. mean magnetic field



Marsch & Tu, Solar Wind Seven Conf. 1991

Electromotive force looks in a turbulent state (power-law spectrum) but does not show a clear dependence on the mean magnetic field.

Coefficients alpha and beta

a simplified model of electromotive force (no cross helicity term yet)

$$\boldsymbol{\mathcal{E}}_{\mathrm{em}} = \alpha \boldsymbol{B}_0 - \beta \nabla \times \boldsymbol{B}_0$$

coefficient beta ... eliminate alpha term by cross product with B_0

$$\beta_{\mathrm{obs}} = -\frac{1}{H^2} \boldsymbol{H} \cdot (\boldsymbol{B}_0 \times \boldsymbol{\mathcal{E}}_{\mathrm{em}})$$

$$\boldsymbol{H} = \boldsymbol{B}_0 \times (\nabla \times \boldsymbol{B}_0)$$

coefficient alpha ... scalar product with B_0 and use beta_obs

$$\alpha_{\mathrm{obs}} = \frac{1}{B_0^2} \boldsymbol{B}_0 \cdot \boldsymbol{\mathcal{E}}_{\mathrm{em}} + \frac{\beta}{B_0^2} \boldsymbol{B}_0 \cdot (\nabla \times \boldsymbol{B}_0)$$

A magnetic cloud event of Helios-2

magnetic field

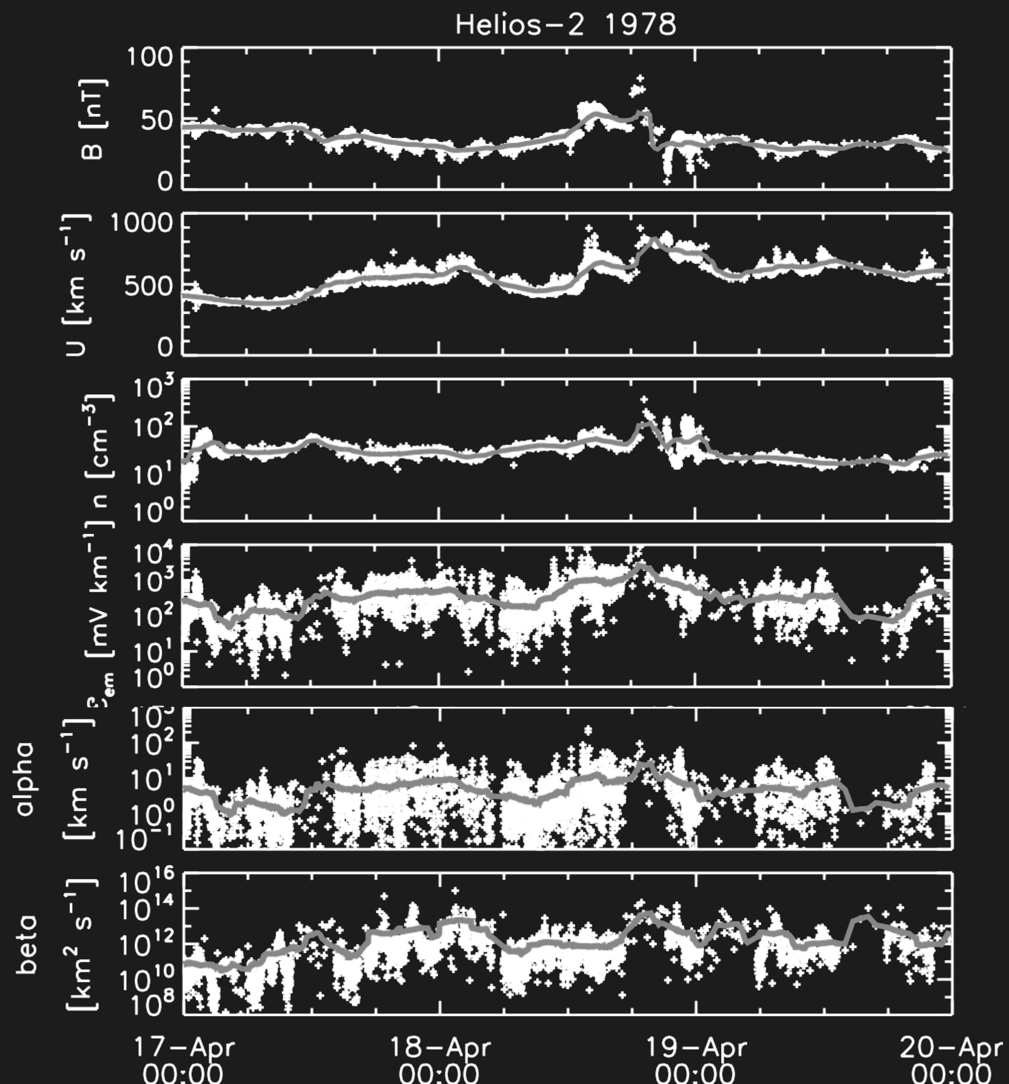
flow velocity

plasma density

electromotive force

coefficient alpha

coefficient beta



Narita & Vörös, submitted to AnGeo

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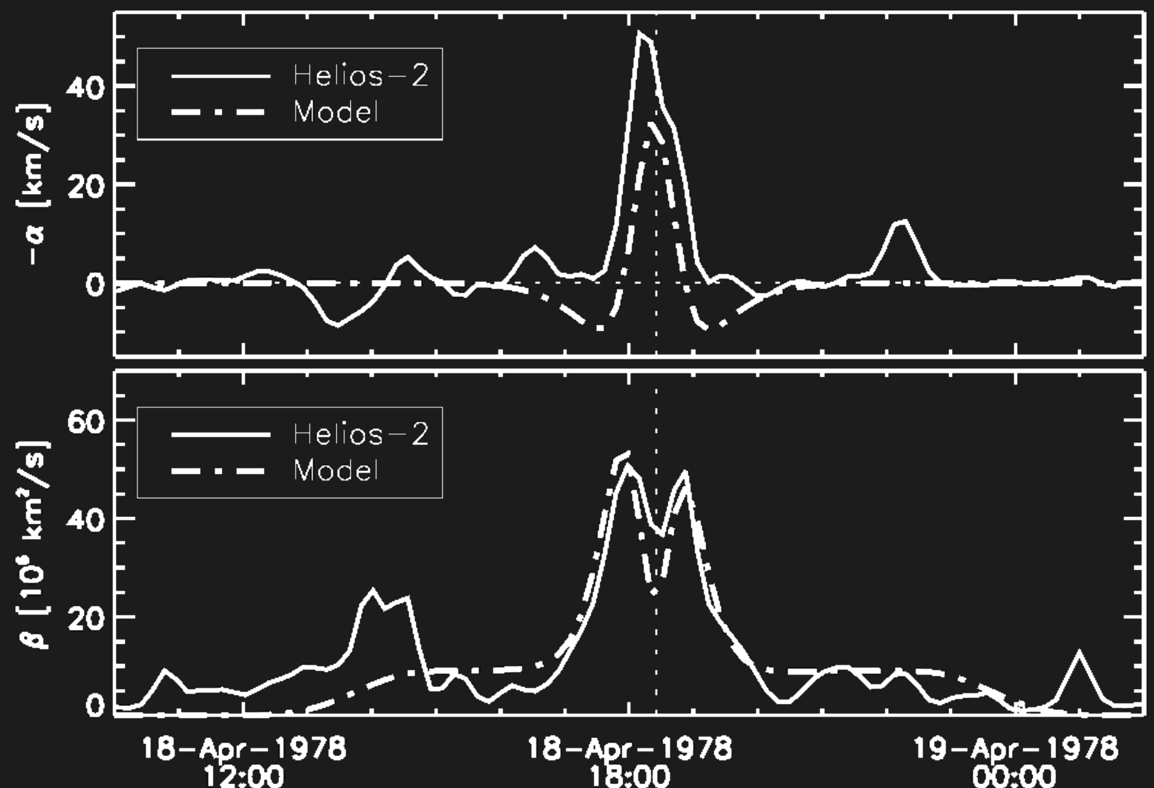
Another approach using a vortex model

An analytic expression for the flow velocity.

Fitting of the time series data in the parameter space.

Reconstruction of the Helios measurements of alpha and beta



Hofer, Bourdin, and Narita, submitted to ApJ

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Discussion & conclusions

- Follow-up of the first-time test (Marsch & Tu 1991) for the electromotive force against the solar wind data
- Enhancement of alpha and beta terms confirmed during a magnetic cloud event in the Helios-2 data
- Short-period magnetic field amplification possible locally in interplanetary space, but unlikely to grow on a long time scale due to the transient phenomenon nature
- We have a problem... What do we mean by “mean” of the mean field B_0? Is it a smoothing, a low-pass filter, or some fitting methods?