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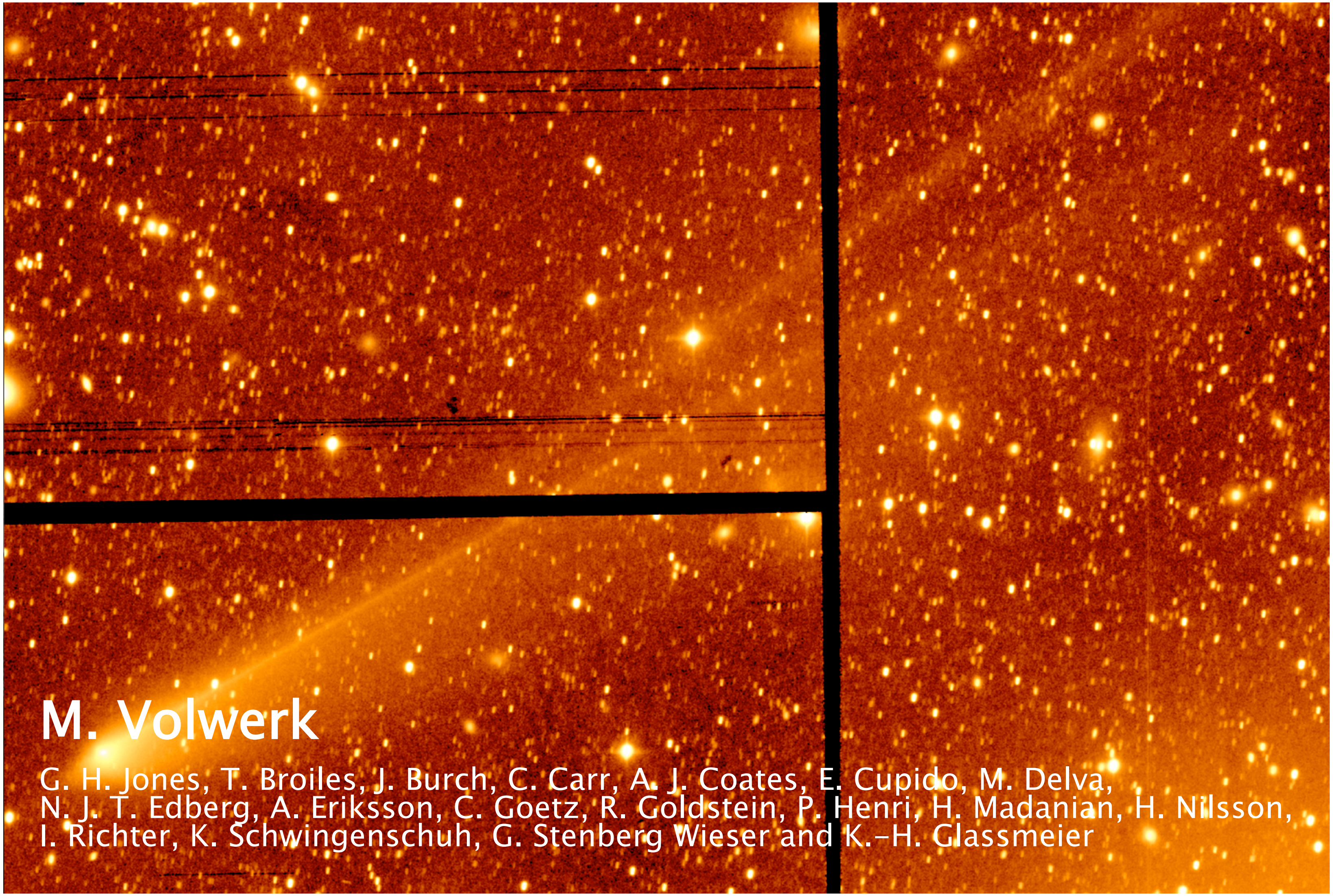
AHEAD AND BEHIND: IMF INTERACTION WITH A WEAKLY OUTGASSING COMET

M. Volwerk

G. H. Jones, T. Broiles, J. Burch, C. Carr, A. J. Coates, E. Cupido, M. Delva, N. J. T. Edberg, A. Eriksson, C. Goetz, R. Goldstein, P. Henri, H. Madanian, H. Nilsson, I. Richter, K. Schwingenschuh, G. Stenberg Wieser and K.-H. Glassmeier

AHEAD



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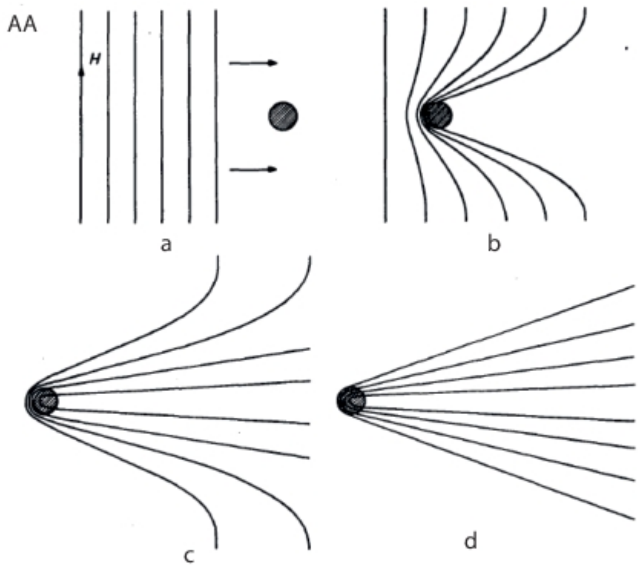
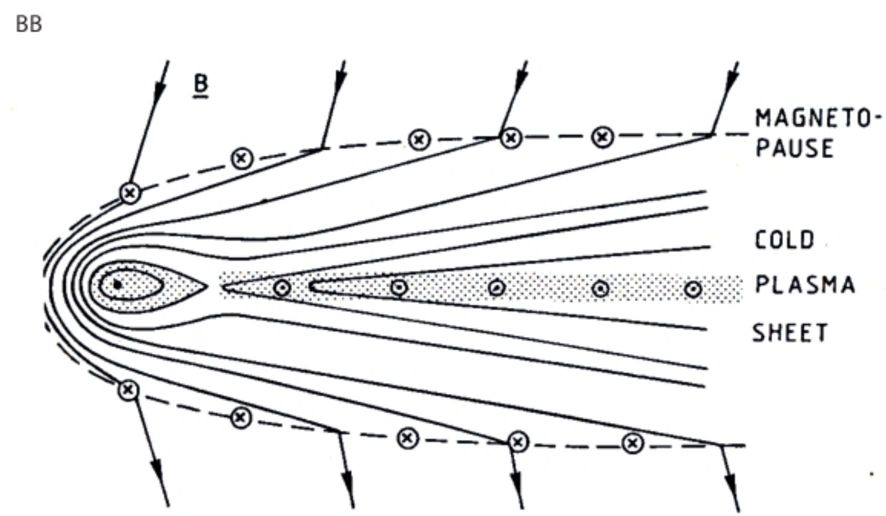
COMETARY COMAE AND TAILS





Magnetic field line draping around an active comet – Alfvén [1957]

- Mass loading of IMF by freshly created ions
- Solar wind slows down, fields drape around nucleus

Similar structure as Earth's magnetosphere

Only one direction of IMF

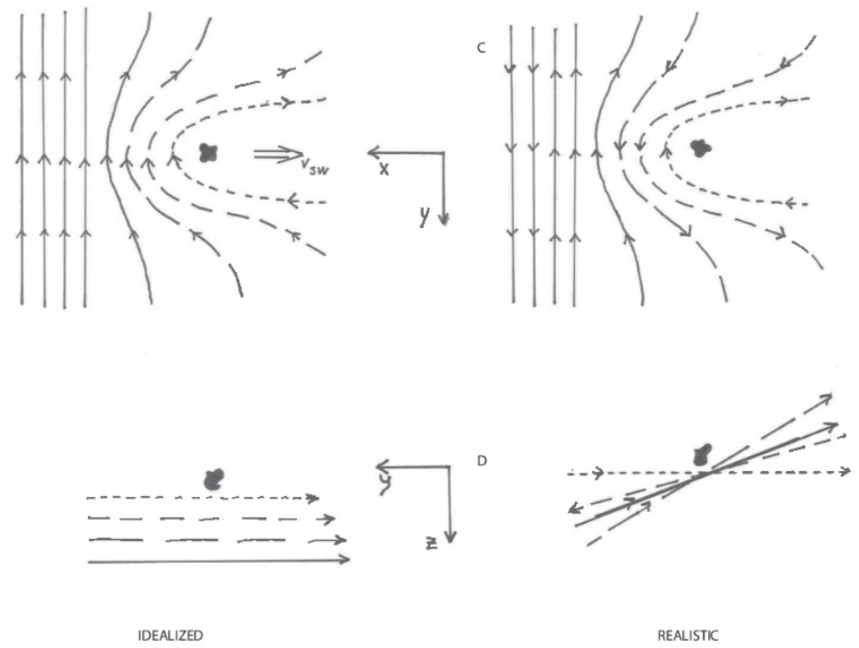
CHANGING IMF DIRECTION

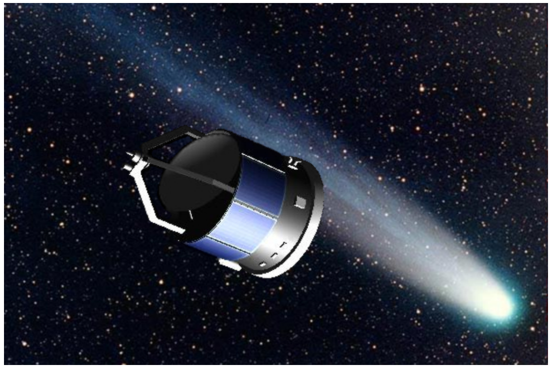
Idealized model vs Realistic model

- Changing IMF direction
- "Nested draping"

A layered structure of the draped magnetic field

- Oppositely directed magnetic field regions
- Clearly observed @ 1P/Halley with Giotto spacecraft





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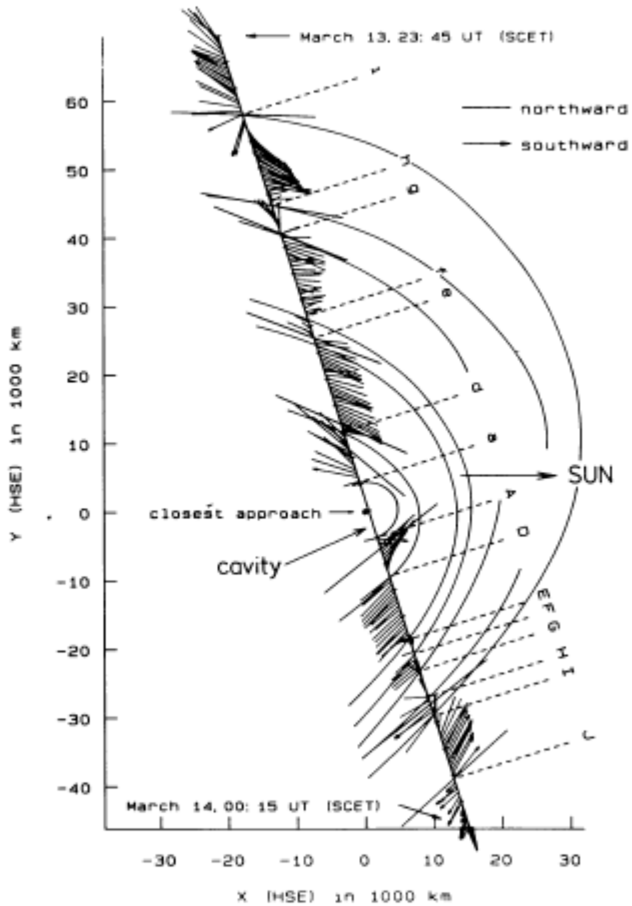
NESTED DRAPING AT 1P/HALLEY



Observations by Riedler et al. [1986, VEGA] and Raeder et al. [1987, Giotto] showed:

- Changing direction of magnetic field
- “Opposite pattern” before and after closest approach

Raeder et al. connected the directions of the field showing

- Nested draping
- Oppositely directed field
- Current sheets separating
- Reconnection (?) [Verigin et al. 1987; Kirsch et al. 1989]

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WHAT’S UP WITH CHURY?

Flybys in May, June and July:

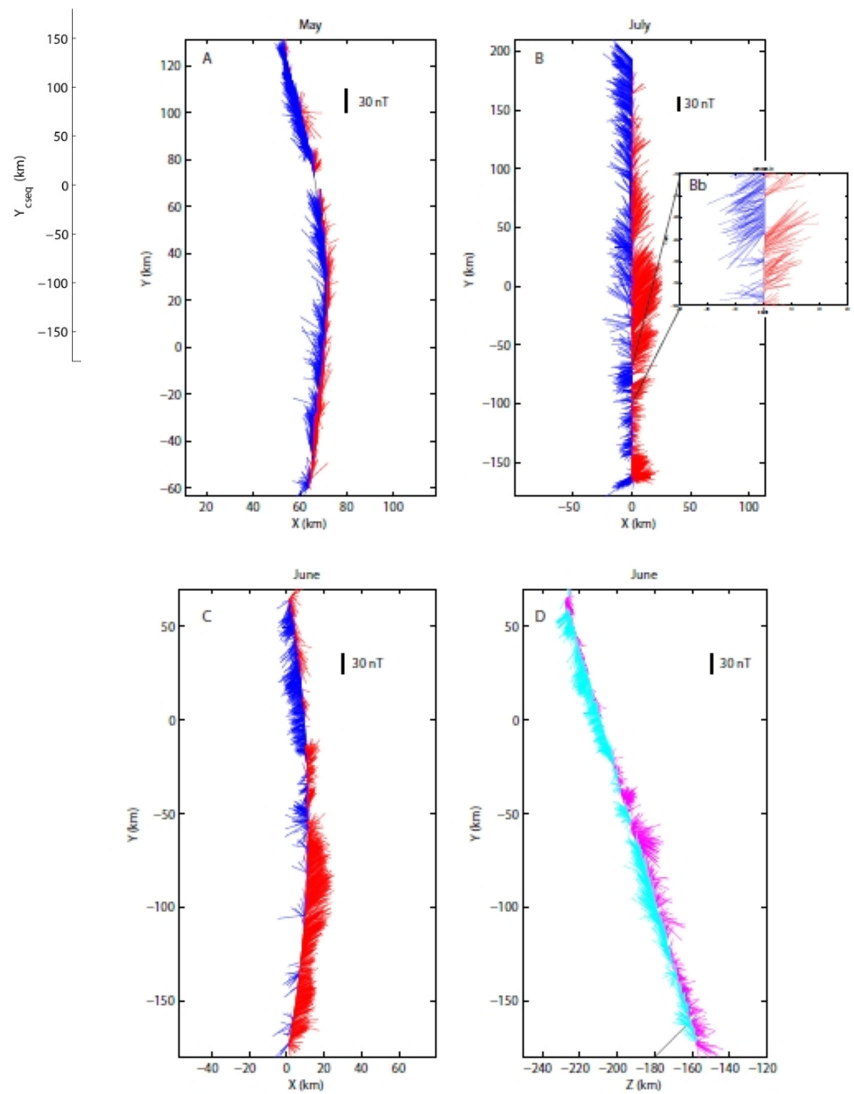
- Orbits that cross y = 0
- Magnetometer data “should” show nested draping

Differences with earlier missions:

- Rosetta moves @$#%& slowly
- 20Hz leads to 💩 of data
- Much more detail

Only plotting every 300 sec 1 vector

- Very messy signatures except for June flyby
- Inset time intervals ~1 hour



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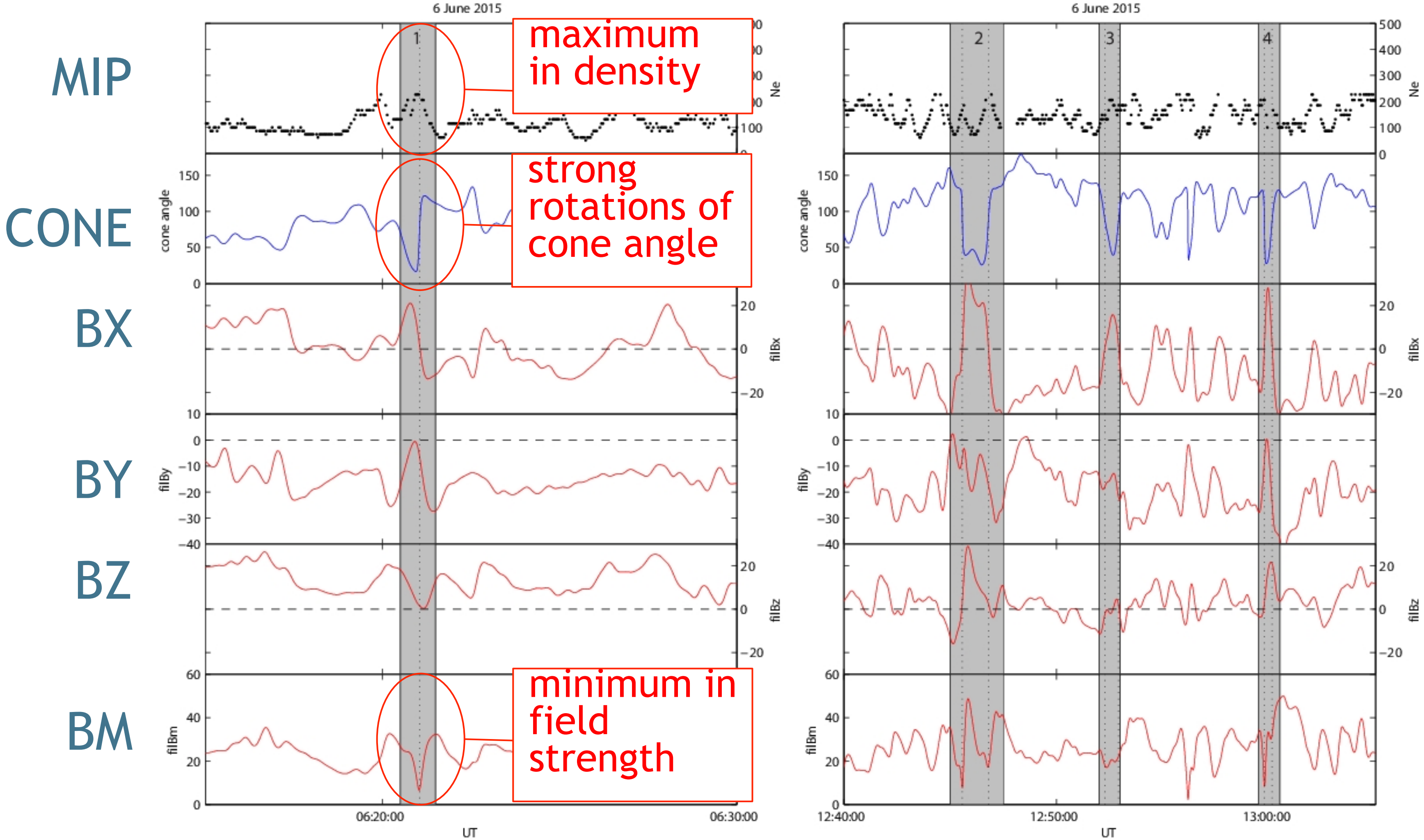
CURRENT SHEETS 5 – 6 JUNE



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MORE COMPLICATED EXAMPLES

MIP/ LAP

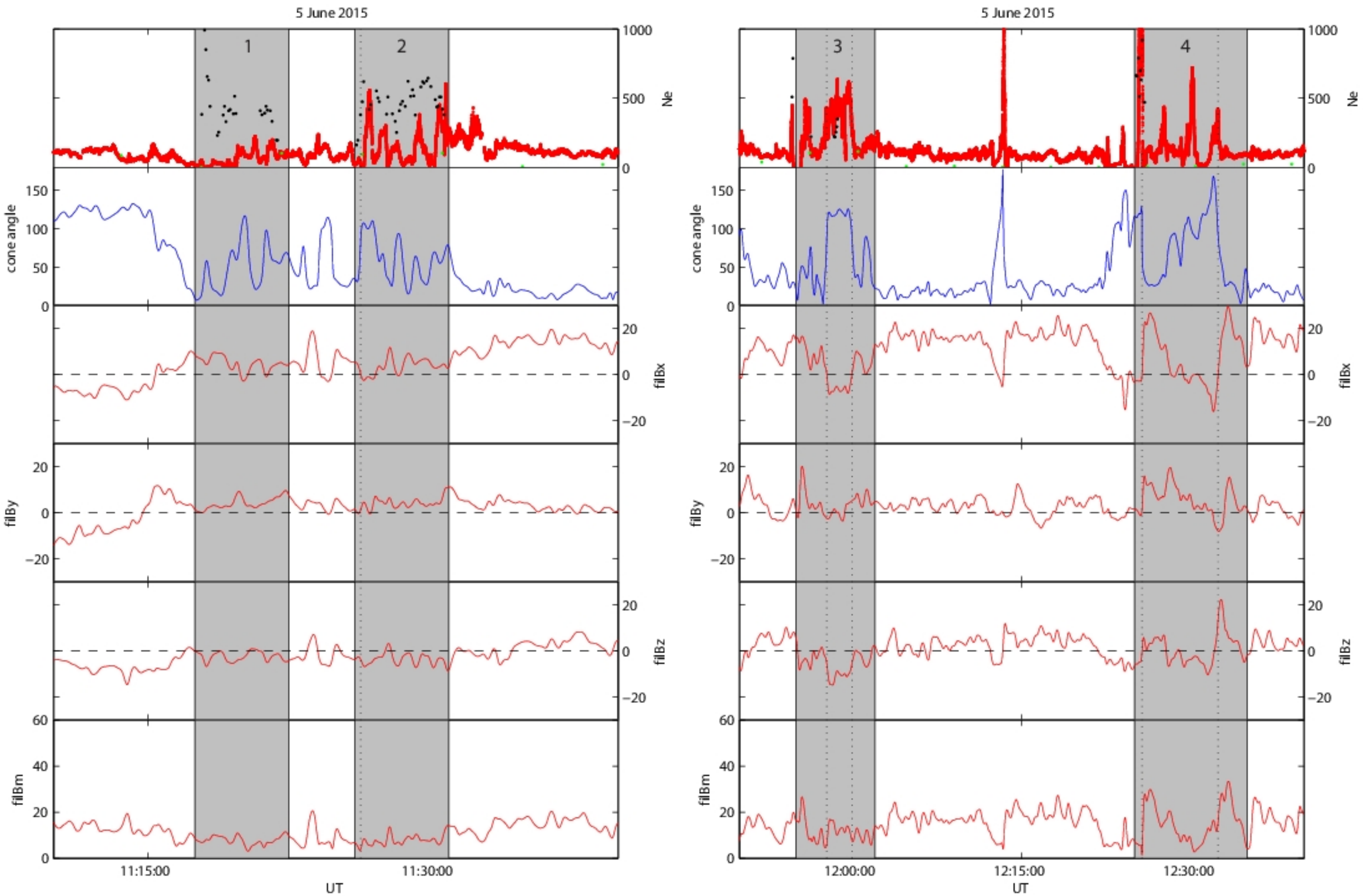
CONE

BX

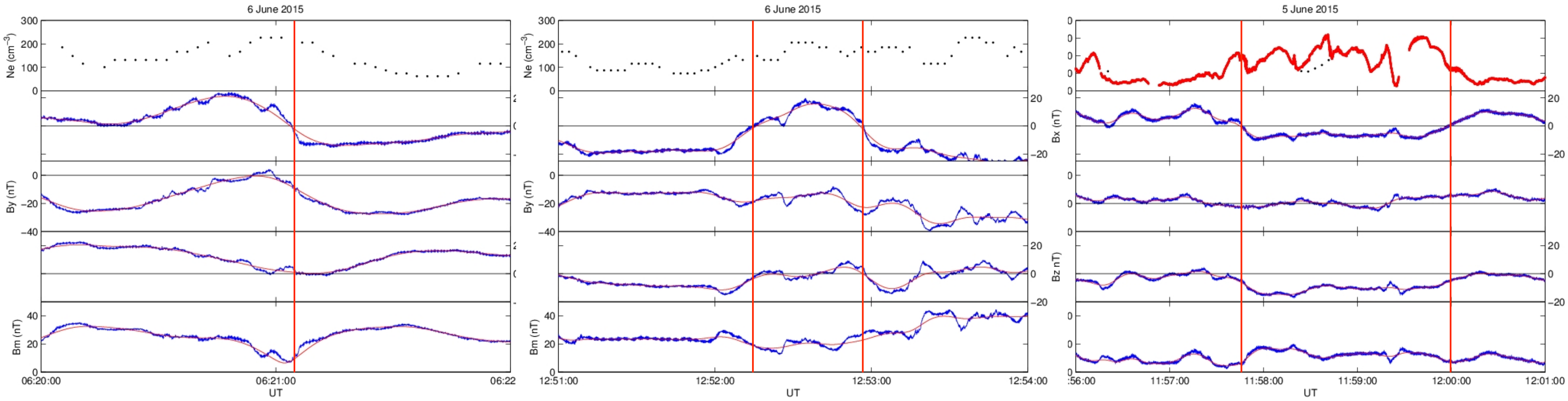
BY

BZ

BM



ZOOM-IN ON THREE DIFFERENT CASES



Three zoom-ins on magnetic field rotations.

Top panels: electron densities from MIP (black) and LAP

Other panels: original (20 Hz, blue) and low-pass filtered (>30 s, red) magnetic field data.

*B*x = 0 crossings are marked by vertical lines. It can be seen that for crossings without (or negligible) *B*y,z-component the electron density peaks at the crossing, in other cases there is no maximum.

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RESULTS

Table 1. Intervals of Strong Magnetic Field Cone Angle, θ_{cone}, Changes[a]

	t1 (UT)	t2 (UT)	ΔB_x (nT)	B_{min} (nT)	J (nA/m^2)	N_e (cm^{-3})
			6 June 2015			
1	06:20:51	06:21:17	28	6	85	290
2a	12:45:19	12:45:40	57	7	216	300
2b	12:46:31	12:47:05	48	17	112	320
3a	12:51:58	12:52:38	28	17	56	160[b]
3b	12:52:38	12:53:03	20	22	64	220[b]
4a	12:59:35	12:59:52	28	8	131	300
4b	12:59:52	13:00:24	39	31	97	N/A
			5 June 2015			
2	11:26:10	11:26:29	6.5	3	27	470[b]
3a	11:57:19	11:58:01	20.5	4	38	430
3b	11:59:40	12:00:14	17.5	7	41	310[b]
4a	12:25:29	12:25:53	25	2	83	920 (1620)
4b	12:32:02	12:33:11	44	11	51	420

[a]Listed are the event time windows, the change in $B_{x,fil}$, and the estimated current density under the assumption that the structure moves over the spacecraft with 10 km/s.

[b]Also listed are the MIP/LAP electron densities, where this is not the local maximum of the density (Usually the MIP and LAP densities agree reasonably well. The number between brackets for 5 June #4a

Nested draping varies on time scales of 1 hour.

Not all discussed current sheets show the characteristic peak in plasma density at the centre of the sheet.

Possibly related to the presence of a guide field (see Figure 2).

There is no evidence for different kinds of plasmas on either side of a current sheet.

No strongly accelerated ions have been observed which could have been an indication of magnetic reconnection in the current sheets.

Volwerk, M. et al. [2017], `Current sheets in comet 67P/Churyumov-Gerasimenko's coma', *J. Geophys. Res. Space Physics, 122, 3308-3321,.*

BEHIND

M. Volwerk

C. Goetz, I. Richter, M. Delva, K. Ostaszewski, K. Schwingenschuh and K.H. Glassmeier

TAIL EXCURSION WITH B-FIELD VECTORS

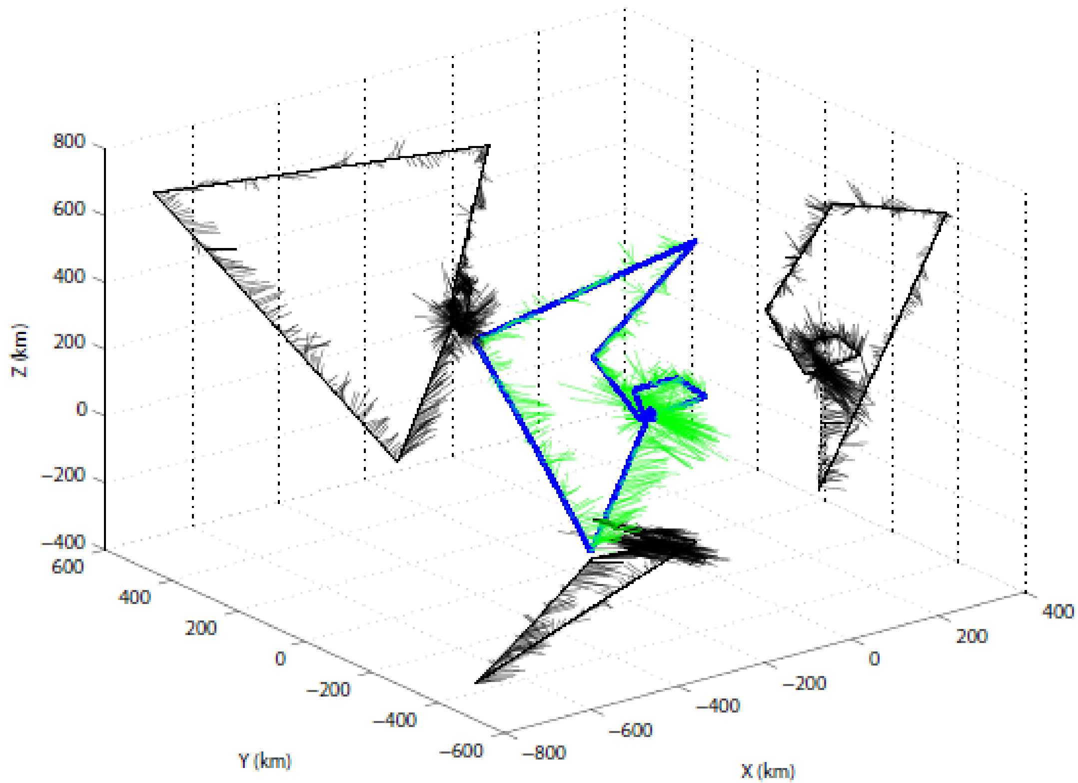
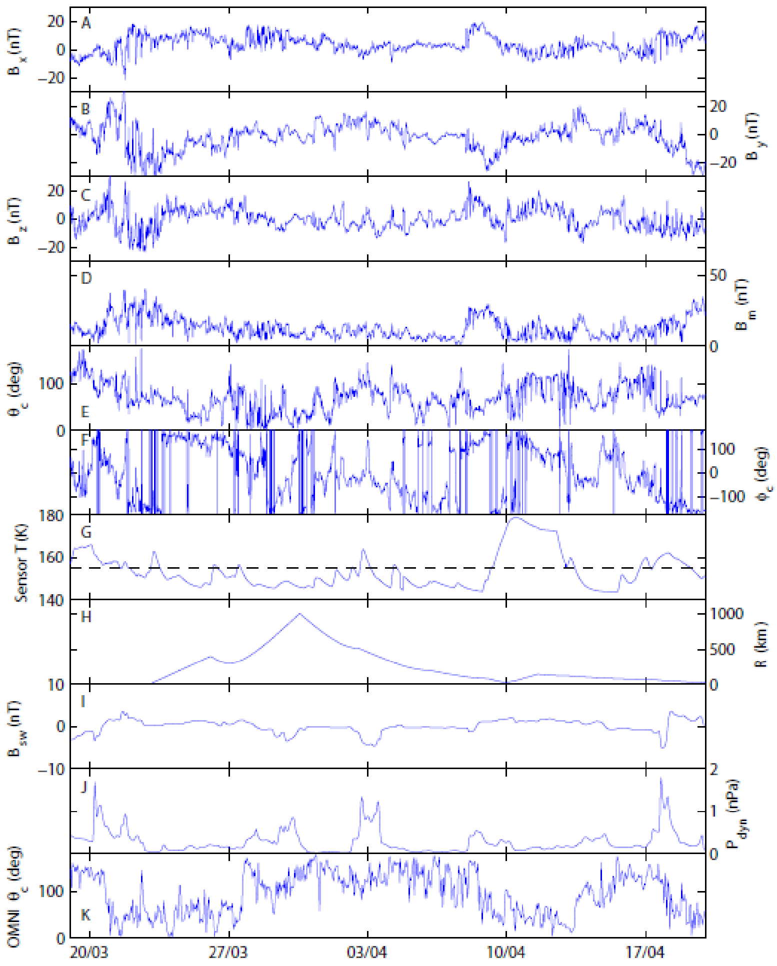


Fig. 1. A 3D view of the magnetic field (green, one vector per hour) along orbit of Rosetta (blue) in the CSEQ coordinate system. The black parts are projections onto the three different planes.

MAG OBSERVATIONS



A-D: Magnetic field

E-F: Cone and clock angle

G: Sensor Temperature

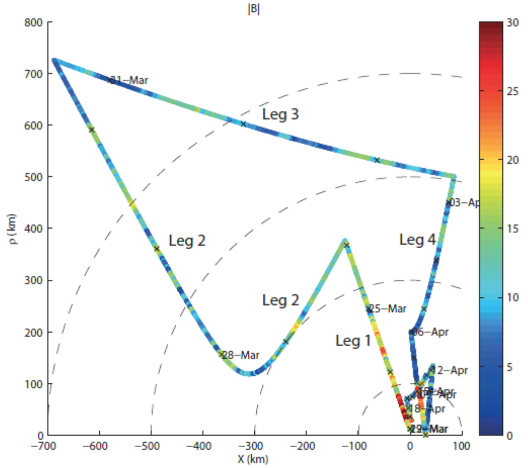
H: Radial distance

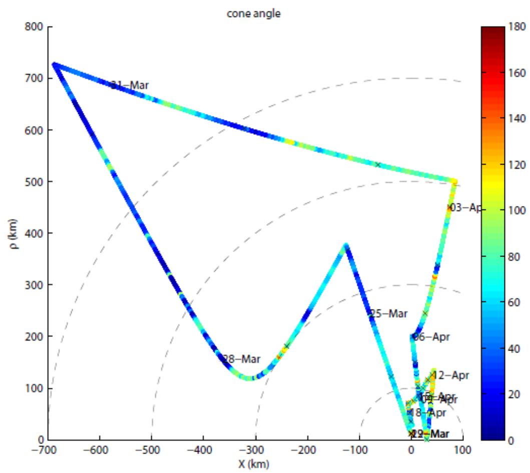
I: Bt,sw (Tao model)

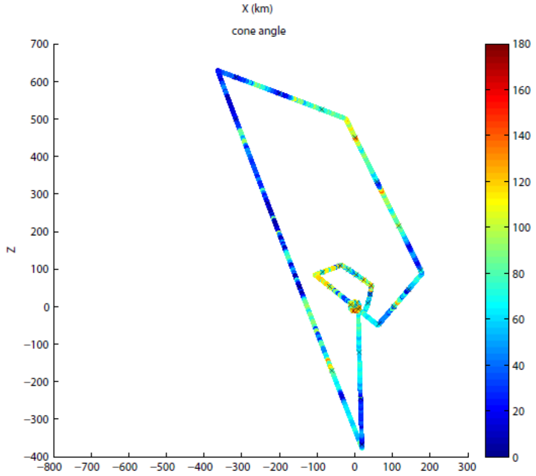
J: SW ram pressure (Tao model)

K: Cone angle OMNI solar wind

ALONG THE ORBIT: NO SYMMETRIES







Total magnetic field along the orbit in X-R cooridinates

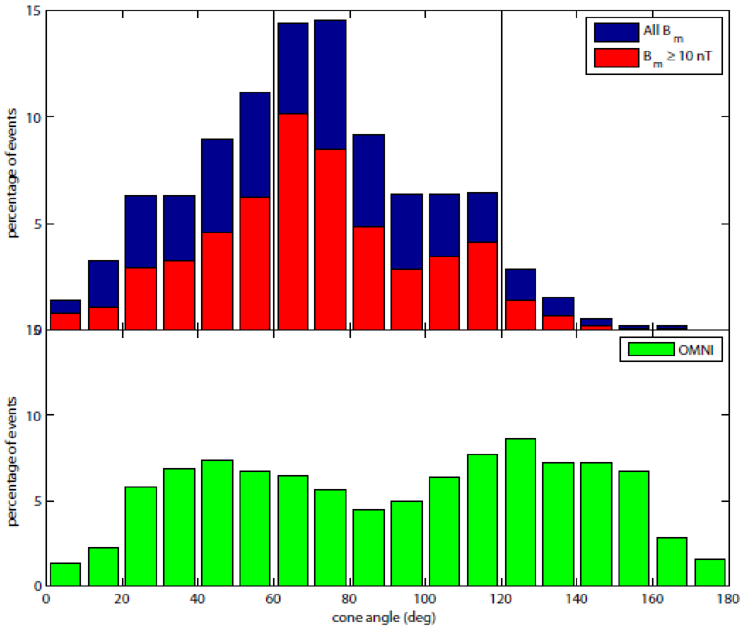
Cone angle along the orbit in X-R coordinates

Cone angle along the orbit in Y-Z plane

If there is a “regular” tail, then one would like to see a change in cone angle from sunward to tailward

This does not happen!

DISTRIBUTION OF CONE ANGLES



The cone angles along the tail excursion:

Blue – all data

Red – stronger than 10 nT

Green – OMNI distribution

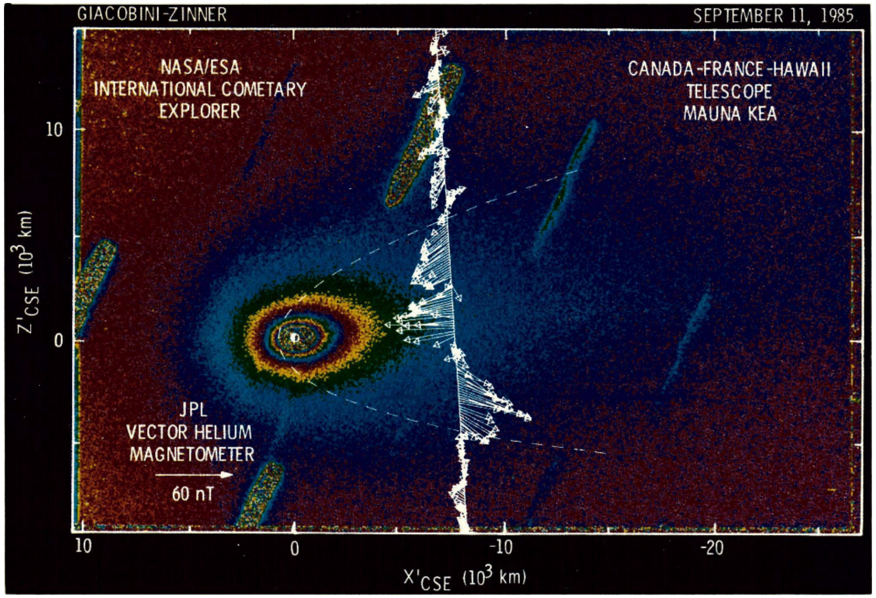
Clearly, at 67P/CG

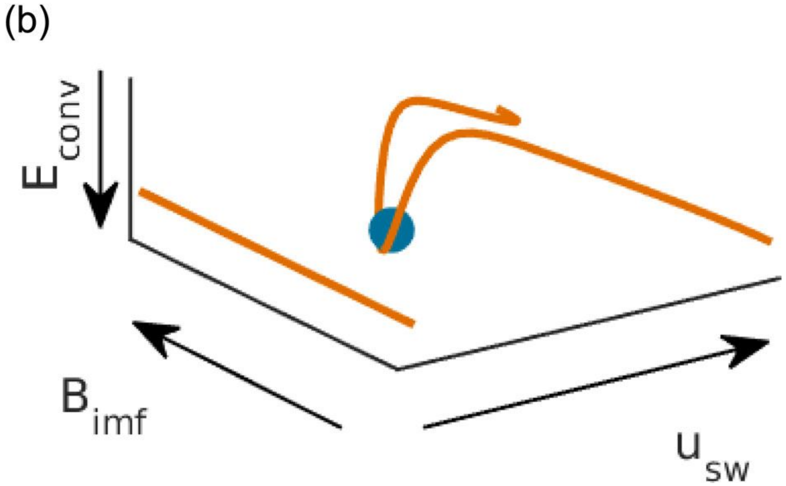
Cone angle peaks around 70 – 80 degrees

Most of the time field is "vertical" in the tail

Deflection of the field through ion pickup

„WEIRD“ DRAPING





In the case of „normal“ comets

- Strong mass loading dominating
- Alfvén‘s model holds
- But comet 27P/Giacobini-Zinner!

In the case of weakly outgassing comets

- Intermediate mass loading
- Leading to deflection of solar wind by momentum conservation
- Draping goes „up“

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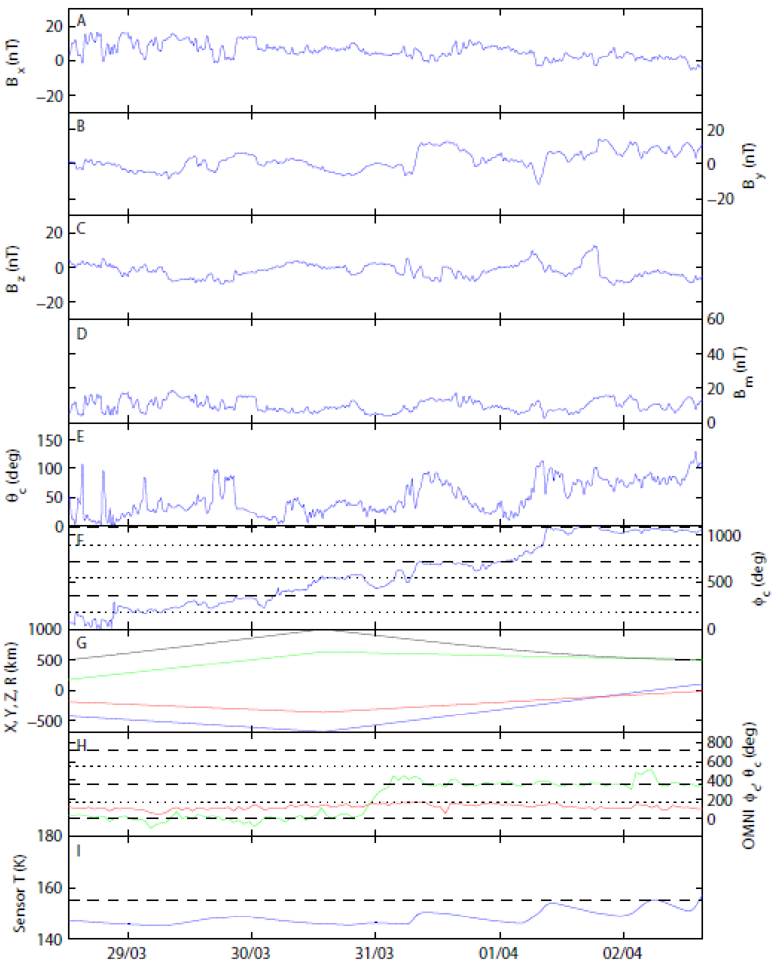
WHAT ABOUT THE CLOCK ANGLE?



"Far away" from 67P/CG

R > 500 km

Interesting feature, the "unwound" clock angle (i.e. taking care of 2π jumps)

Always increasing clock angle as Rosetta moves away and comes back again (PANEL E)

This does not happen in the OMNI data (PANEL H)

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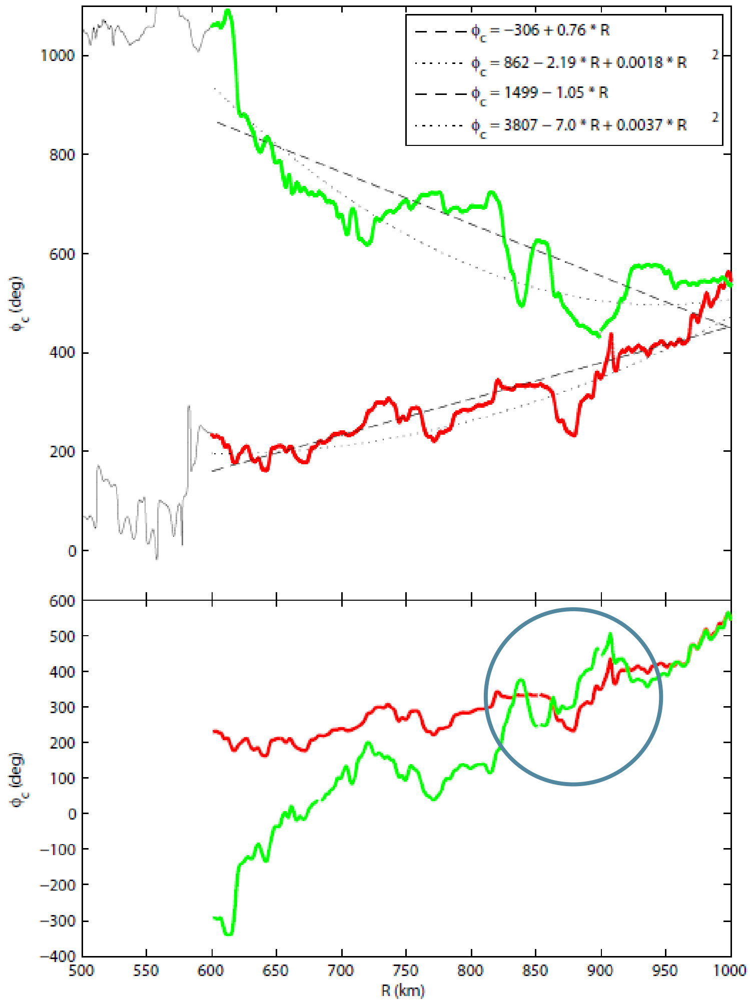
"REWINDING" CLOCK ANGLE



Clock angle always increases

Angular velocity
outbound – 5.65° /hr (red)
inbound – 5.83° /hr (green)

Assuming Doppler shift:
Rotational wave moving tailward at v ~ 136 m/s

"Rewinding" clock angle shows that similar structural features are seen in both paths

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CONCLUSIONS

Comet 76P/Churyumov-Gerasimenko brought us to an unknown plasma environment

- In the weakly outgassing phase usual conceptions, like traditional draping, do not occur
- But „nested draping“ is observed, i.e. regions of alternating B-field direction
- Deflection of the solar wind makes the field „vertical“ in the near tail region
- In the „far“ tail
  - the field is always pointing sunward
  - A helical wave travels down the tail

Volwerk, M. et al. [2017], `A tail like no other: RPC-MAG's view of Rosetta's tail excursion at comet 67P/CG, to be submitted to A&A.