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VENUS EXPRESS MAGNETOMETER

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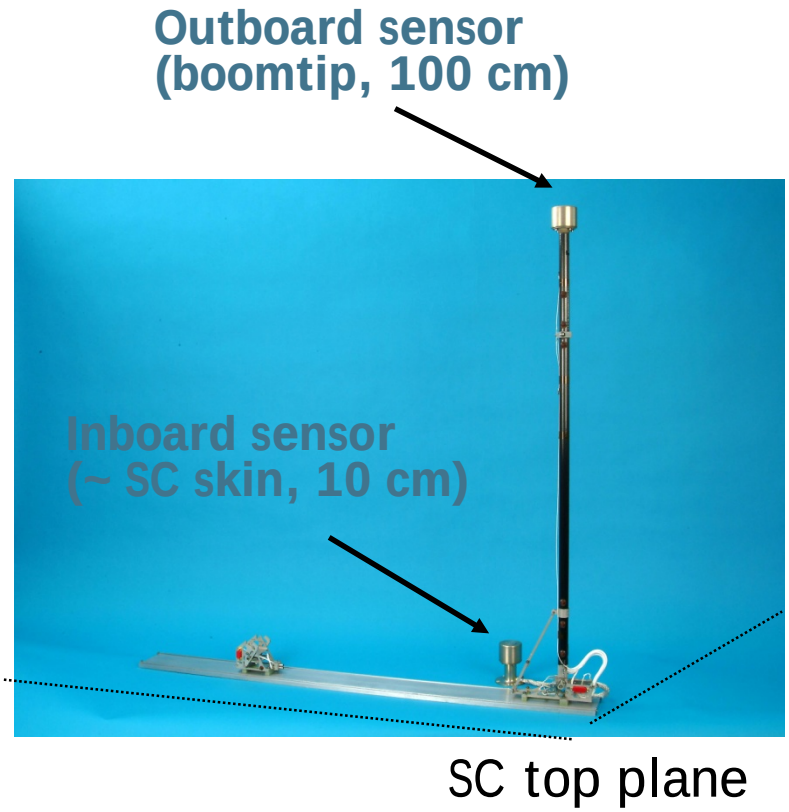
VEXMAG: TWO TRI-AXIAL FLUXGATE SENSORS



MAG-team (PI Tielong Zhang, IWF)

- IGeP, Techn. Univ. Braunschweig (D)
- IWF-ÖAW, Graz (AT)
- Imperial College, London (UK)
- Univ. Sheffield (data cleaning) (UK)

Venus Express

- mainly atmospheric mission
- plasma package: ASPERA, MAG
- spacecraft NOT magnetically clean
- short boom and 2 magnetometers: good compromise ☺

BUT: difficulties to remove influence of SC from MAG data

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BASIC PROPERTIES OF VEXMAG

Two sensors: always operating in same mode

- **B**-vectors: three data-rates: 1 Hz, 32 Hz, 128 Hz

Data-coverage (initially):

- VEXMAG ON: 24 hrs/24 hrs, full orbit coverage
- Near pericenter: 2 hrs of 32 Hz data-rate (pericenter time +/- 1 hr)
- At pericenter: 10 min of 128 Hz data-rate (pericenter time +/- 5 min)

=> combined to 1 Hz data-rate for 24 hrs/24 hrs

Data-coverage later: various for specific times

- Eg. near pericenter: 4 hrs of 32 Hz data-rate (pericenter time +/- 2 hr)
- Some orbits with full 32 Hz data-coverage (few days)
- Eg. longer intervals with 128 Hz data-rate around pericenter:
  40 mins, 2 hrs , …

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MAG DATA CALIBRATION

"Raw" data (= CODMAC level 2 in PDS system)

- 24 hrs of 1 Hz data per day (= per orbit), OB ~ 200 nT, IB ~ 6000 nT

Corrections required for VARIABLE field of SC (= AC field):

- Generated by: switching operations on SC, rotation of solar panels, on/off of heaters etc.
- Up to 1000 (!) events per day
- Correction cumbersome: detection/identification of rapid changes required, from difference (B_outboard – B_inboard)
- Automated approach (neural networks, pattern recognition)

Correction for ~constant or slowly varying background field of SC (= DC field):

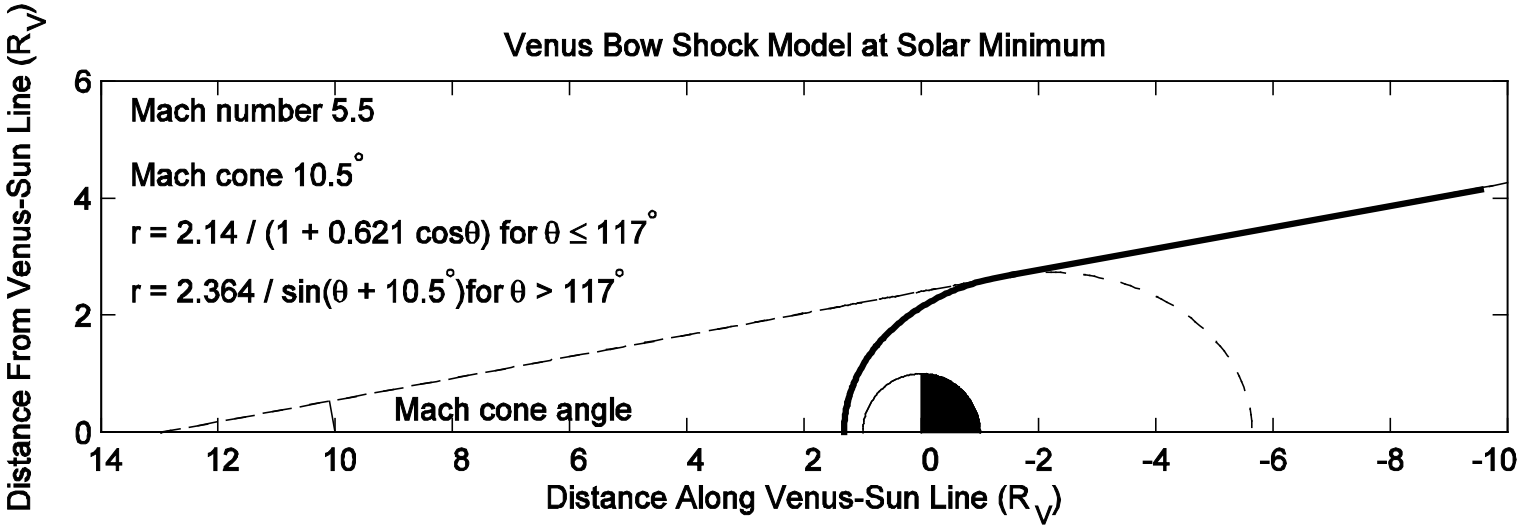
- Using data in quiet SW; based on statistical properties of SW

=> **FINAL accuracy +/- 1 nT of calibrated data (= CODMAC level 3 in PDS)**

MAG MAIN RESULTS (1)

Topics investigated

- Bow shock (BS) shape & model fit
- BS at Solar Minimum: May – August 2006: ~ 140 clearly identified BS crossings



- Bow shock variations & asymmetries

MAG MAIN RESULTS (2)

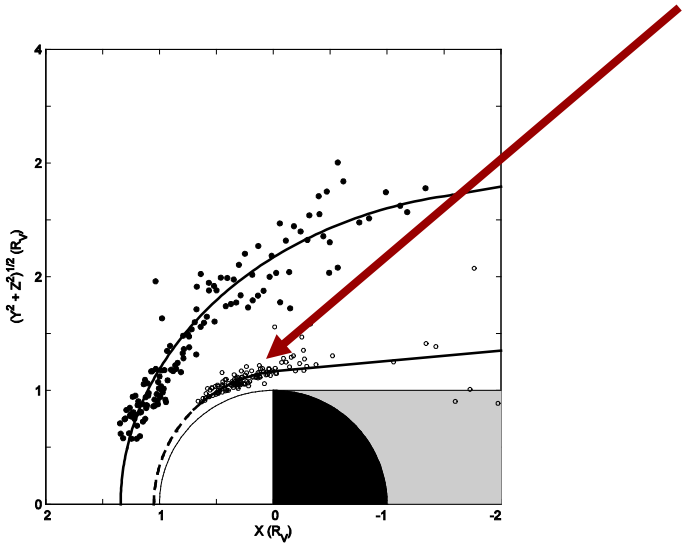
- Induced magnetosphere & magnetic barrier

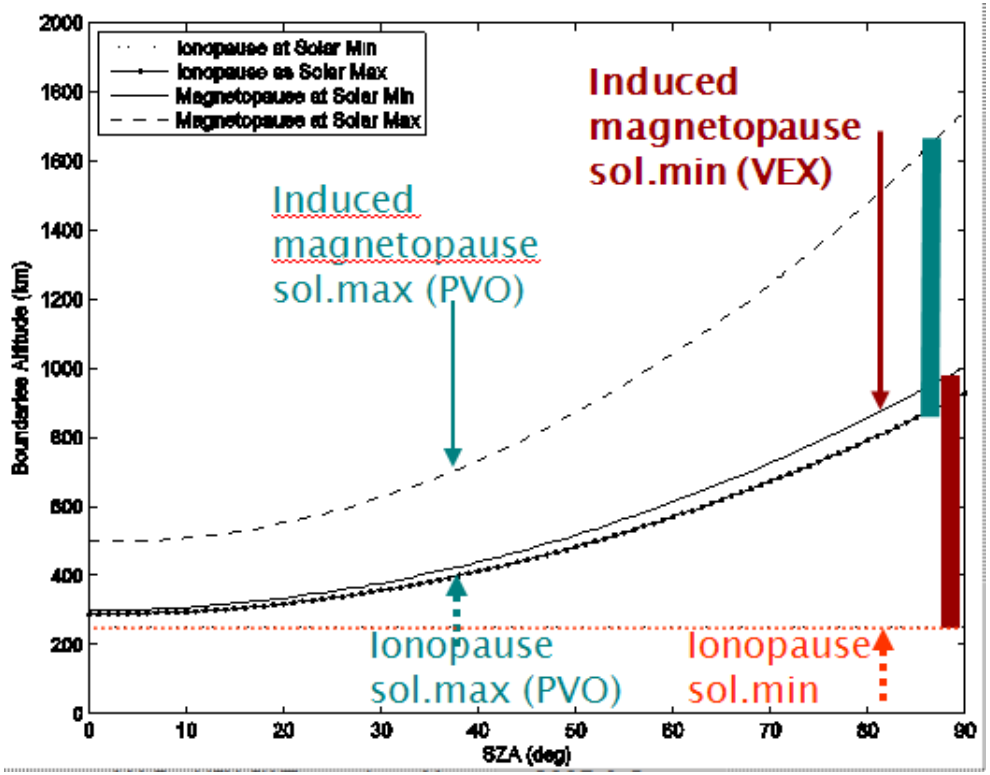
  Induced magnetopause altitude: 300 km @ nose, 1013 km @ terminator

  Magnetic barrier thickness:

  same for solar max and solar min at terminator (750-900km);

  at nose the magnetic barrier is pushed into ionosphere during solar min, ionosphere appears to be magnetized





MAG MAIN RESULTS (3)

- Nature of induced field at Venus: **Dubinin et al., PSS 2013**
  toroidal due to motional electric field $\mathbf{E} = -\mathbf{V}_{sw} \times \mathbf{B}_{imf}$ (= 0 for $\mathbf{V}_{sw} \parallel \mathbf{B}_{imf}$) ?
  induced dipole due to Faraday induction rot $\mathbf{E} = -\partial\mathbf{B}/\partial t$?

  => at Venus: both mechanisms occur !

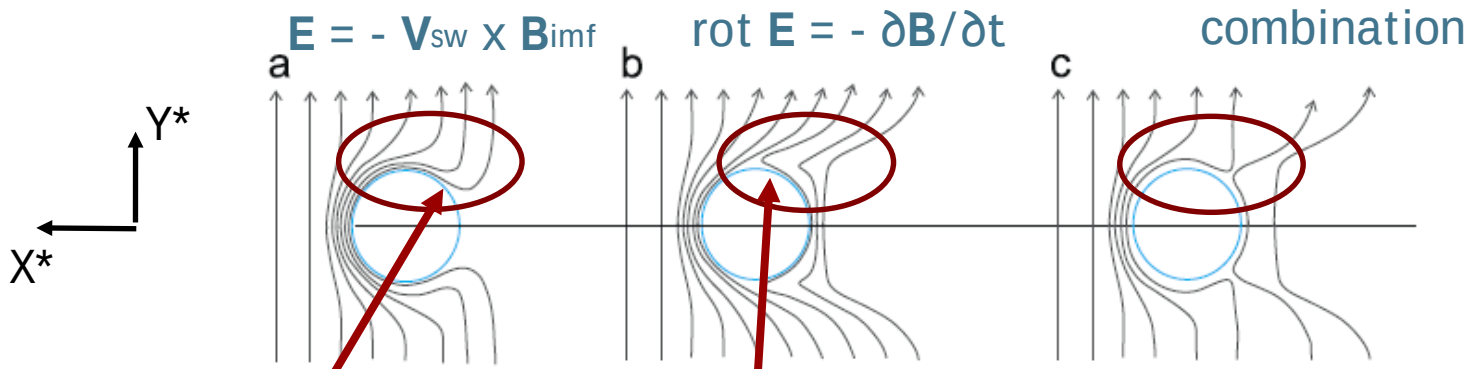


Fig. 1. Sketch of possible field configurations for the induced currents driven by the motional electric field (a), Faraday electric field (b) and by both mechanisms. (c), in the (Vsw, BIMF) plane.

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MAG MAIN RESULTS (4)

- Reconnection in tail (case studies)

Zhang et al., Science 2012

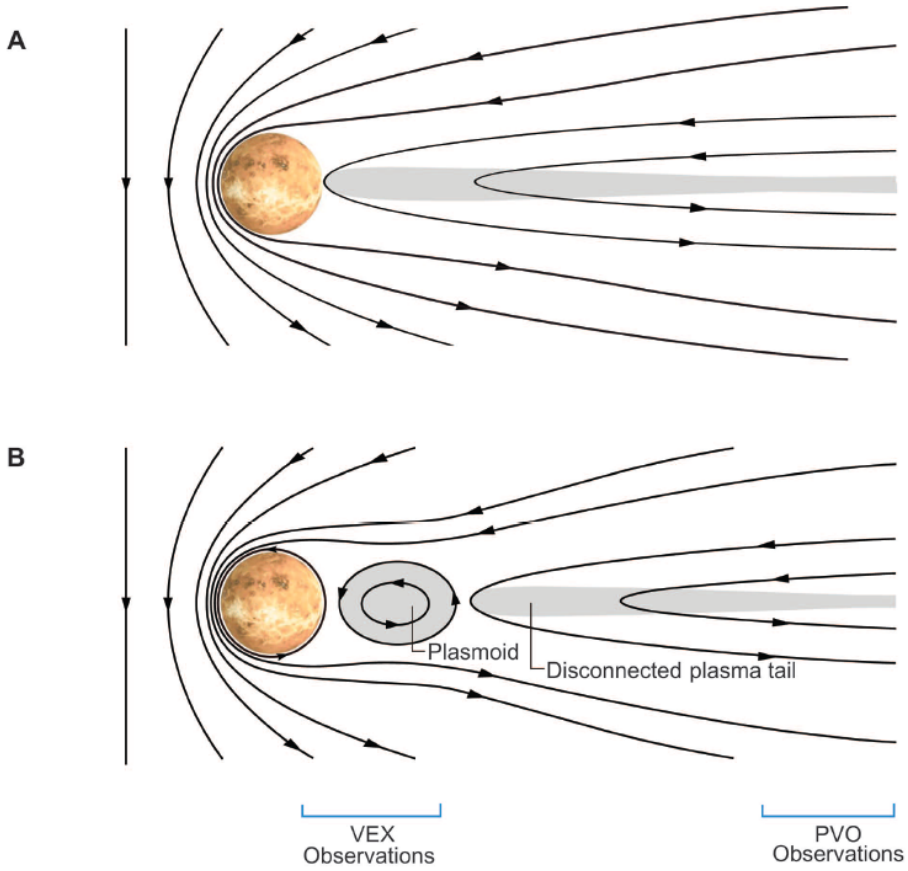
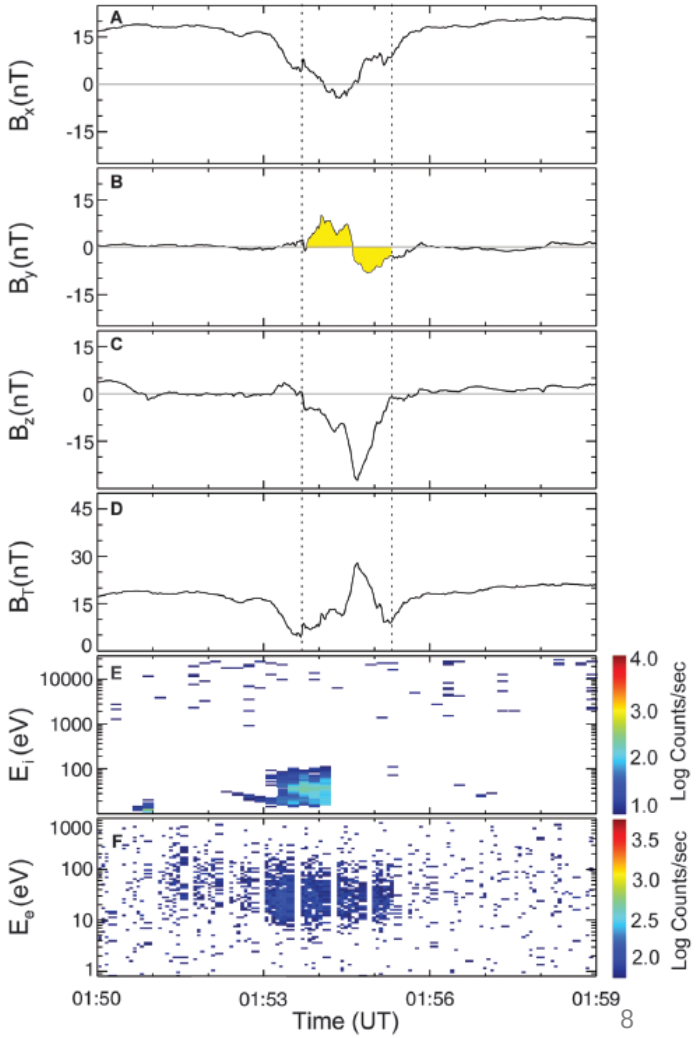


Fig. 3. Schematic illustration of the plasmoid formation and disconnected plasma tail events during the magnetic reconnection observed in the near Venusian tail. Field lines are indicated by solid lines. (**A**) Venusian magnetotail before magnetic reconnection and plasmoid formation. (**B**) The ionosphere was magnetized with a field line going all the way around the planet. The flux rope/O-line (plasmoid) was separated from the nightside magnetized ionosphere by a magnetic X-line. The more distant side of the O-line was separated from the disconnected plasma sheet by another X-line. The tail plasma sheet shedded O-lines toward the planet. The O-lines ran into the magnetized nightside, magnetically connected with it, and created first oval field lines and then circular field lines in the lower ionosphere. Later arriving O-lines reinforced the field. The region of observations by the Pioneer Venus mission (PVO) was in the distant tail, in contrast to Venus Express (VEX), which observed the near tail.



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MAG MAIN RESULTS (5)

- Upstream Proton Cyclotron Waves: **Delva et al., JGR 2013, 2015**
  case studies & statistics @ solar min., near max; generation mechanisms

  PCWs: indicators for local freshly ionized planetary hydrogen

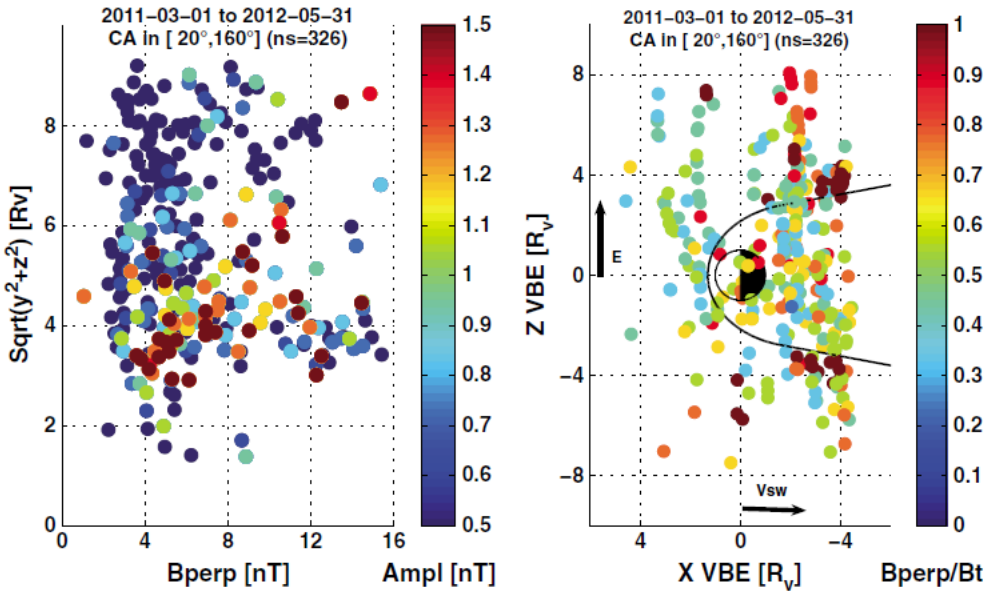

Figure 3. PCW observation positions as function of the perpendicular field component B_{perp}, restricted to cases with well-defined motional electric field, i.e., cone angle in (20°, 160°), *ns* = 326. (left) Distance to Venus-Sun line, color coding according to wave amplitude. Also for small but well-defined B_{perp} or weak electric field, waves are observed up to large distances. (right) In the VBE reference frame, color coding according to B_{perp}/B_t which is proportional to the electric field strength; waves are observed far into regions of negative electric field and far in direction toward the Sun; the black line denotes the modeled bow shock.

- obs. up to large distances from planet
- obs. in both dir. of motional el. field (+/- **E**)
- more for solar max (high UV)

⇒ Indication of new-born protons from locally available planetary hydrogen

⇒ Implication for hydrogen in exosphere

⇒ Implication for hydrogen loss from Venus' atmosphere

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MAG MAIN RESULTS (7)

More topics investigated

- Foreshock ULF waves: several studies
- Mirror Mode Waves in magnetosheath:
  case studies & statistics @ solar min., max
- Waves & turbulence in magnetosheath and wake
- Waves in ionosphere
- More tail structures
- Possible intrinsic field of Venus ?
- Lightning in Venus atmosphere: case study and statistics
- MAG fields in ionosphere over North Pole **Zhang et al., JGR 2015, Scirep 2016**

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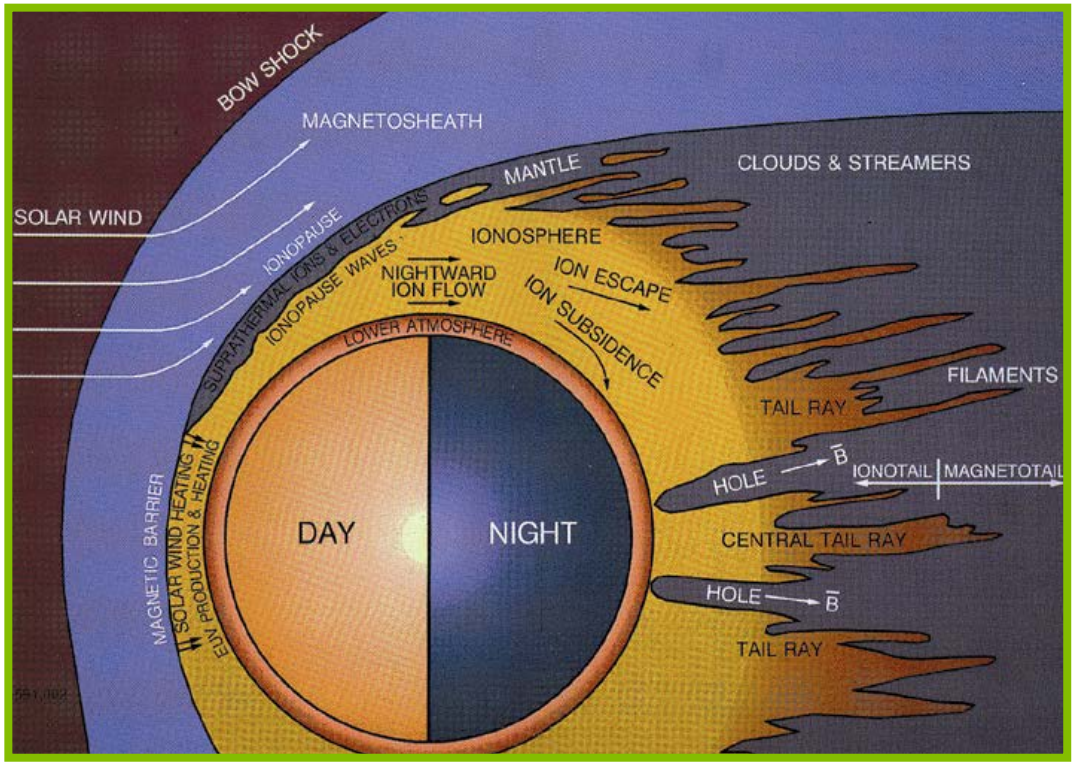
MORE THINGS TO DO

Topics to investigate

- Streamers & holes in near night-side ?
- More reconnection in tail ?
- Variability with solar min., max ?
- …….



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MAG DATA IN PSA ARCHIVE (1)

Data availability

- In principle: daily files from 1 May 2006 to end of mission 25 Nov. 2014
- For all times where observations & data transfer was possible:
  eg. no data for Venus Express behind the Sun, save modes of SC etc.

Data structure in PSA

- "RAW" data = CODMAC level 2
  - All raw data (1 Hz, 32 Hz, 128 Hz) archived;
  - BUT: USE is restricted:
    only with permission of PI !!
    all AC & DC effects of SC still contained in data
    => NO absolute levels !!!
    => danger of interpreting SC effects
    as physical reality of Venus plasma

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MAG DATA IN PSA ARCHIVE (2)

Calibrated data = CODMAC level 3

- Data corrected for AC and DC effects of SC => absolute accuracy +/- 1 nT
- Data-rate 1 Hz (in principle 86400 vectors/day)
- One **MAG**-file per day (UTC) (= 1 orbit; periapsis at time xx during day)
- Contents of file (ASCII):
- Header according to PSA rules (incl. time & pos. of periapsis etc.)
- DATA (in columns)
  - yyyy-mm-ddThh:mm:ss.sss = Time [UTC] (e.g. 2014-03-26T00:00:00.944)
  - Bx, By, Bz, Btotal = magnetic field [nT] in VSO reference frame
  - Xsc, Ysc, Zsc, Rsc = position of SC [km] in VSO reference frame

Time (UTC)	(Bx, By, Bz, Bt)VSO				(Xsc, Ysc, Zsc, Rsc)VSO			
2014-03-26T00:00:00.944	-4.507	-2.282	1.581	5.294	7653.827	9442.186	-35648.328	37663.500
2014-03-26T00:00:01.944	-4.543	-2.195	1.716	5.330	7654.155	9442.858	-35645.420	37660.983
2014-03-26T00:00:02.944	-4.548	-2.029	1.800	5.295	7654.484	9443.529	-35642.511	37658.465
.....								

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MAG DATA IN PSA ARCHIVE (3)

Calibrated data = CODMAC level 4

Resampled data, 4 sec average of level 2 data; (~ASPERA time resol.)

VEX archive data-sets: Nominal mission, EXT1, EXT2, EXT3, EXT4

- Per data-set: organisation according to CODMAC level:
  - CODMAC level 2 = "RAW" data : do NOT use !!!
  - CODMAC level 3 = Calibrated data (1 Hz)
  - CODMAC level 4 = Calibrated resampled data (0.25 Hz, 4 sec data-resol.)
- Per CODMAC level: organisation of data in MONTHLY directories

  dirs for normal "in orbit" phase of mission:

  ORByyyymm_Dzzz ; zzz = data resol (D001 = 1 Hz)
- Organisation of files: 1 file per DAY

If you use data: please send notice to PI Tielong Zhang, IWF-Graz

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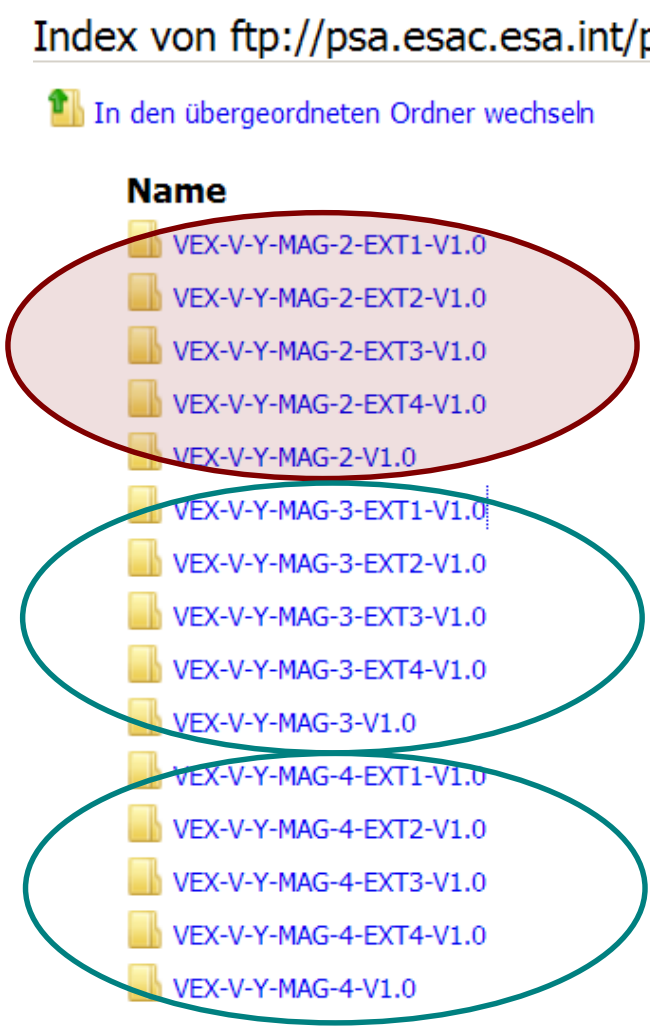
VEXMAG ARCHIVE ON PSA (1)



MAG-2 dir

CODMAC level 2 = RAW data

!!!! DO NOT USE !!!!

MAG-3 dir

CODMAC level 3 = CALIBRATED data

☺ ☺ ☺ **1 Hz**

MAG-4 dir

CODMAC level 4 = RESAMPLED data

☺ ☺ ☺ **0.25 Hz (4 sec)**

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VEXMAG ARCHIVE ON PSA (2)

VENUS-EXPRESS/MAG/ VEX-V-Y-MAG-3-EXT4-V1.0/

- DATA