Swarm's Absolute Scalar Magnetometer (ASM) can do more

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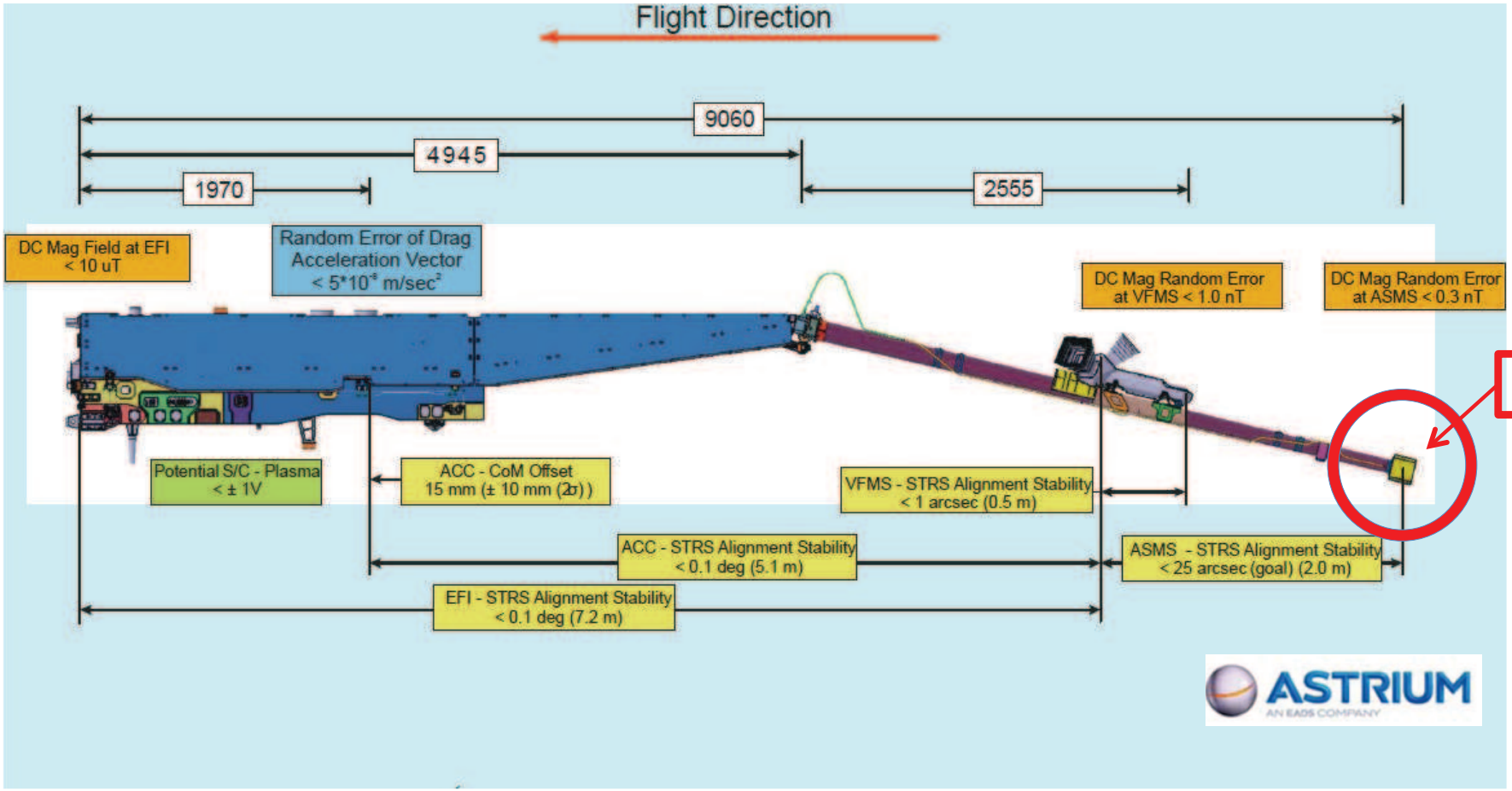
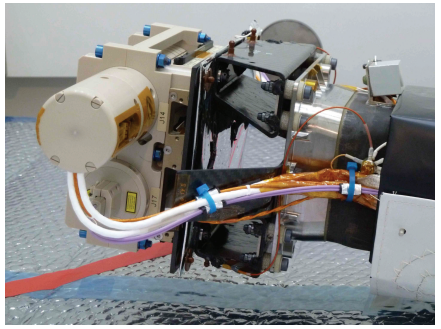
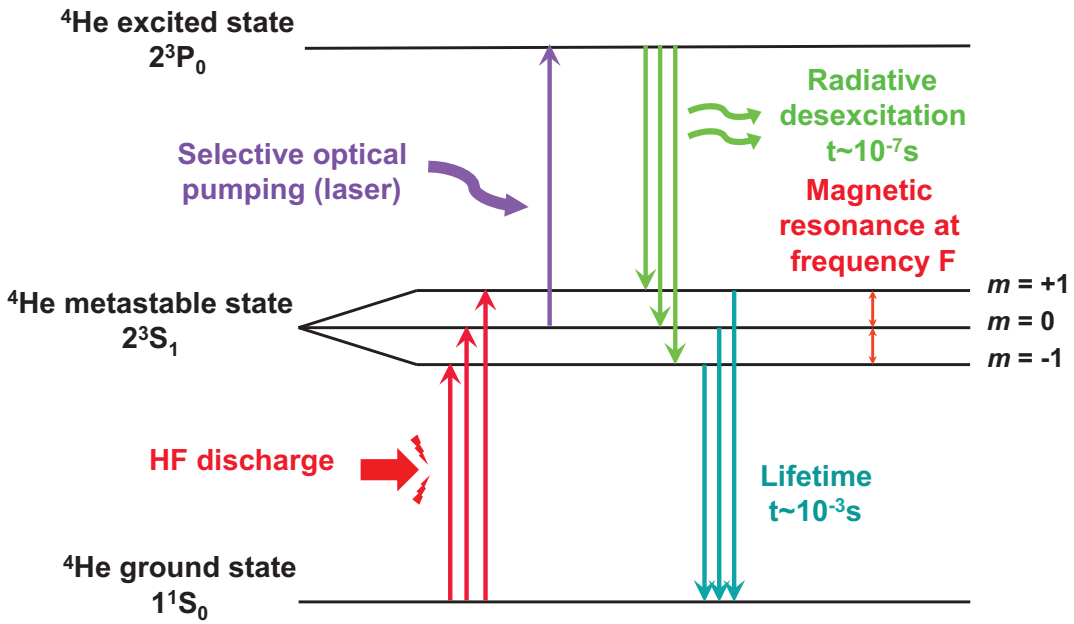
The nominal role of the ASM is to provide very accurate absolute scalar field measurements on each satellite



- Absolute Scalar Magnetometer (CEA/LETI, CNES), 1Hz
- Vector Field Magnetometer and Star Tracker (DTU Space), 50Hz, 1Hz
- Accelerometer (VZLU, CZ), 1Hz
- Electric Field Inst. (Charge particle imager, UC; Langmuir Probe, Uppsala), 2Hz
- GPSR (Ruag), 1 Hz

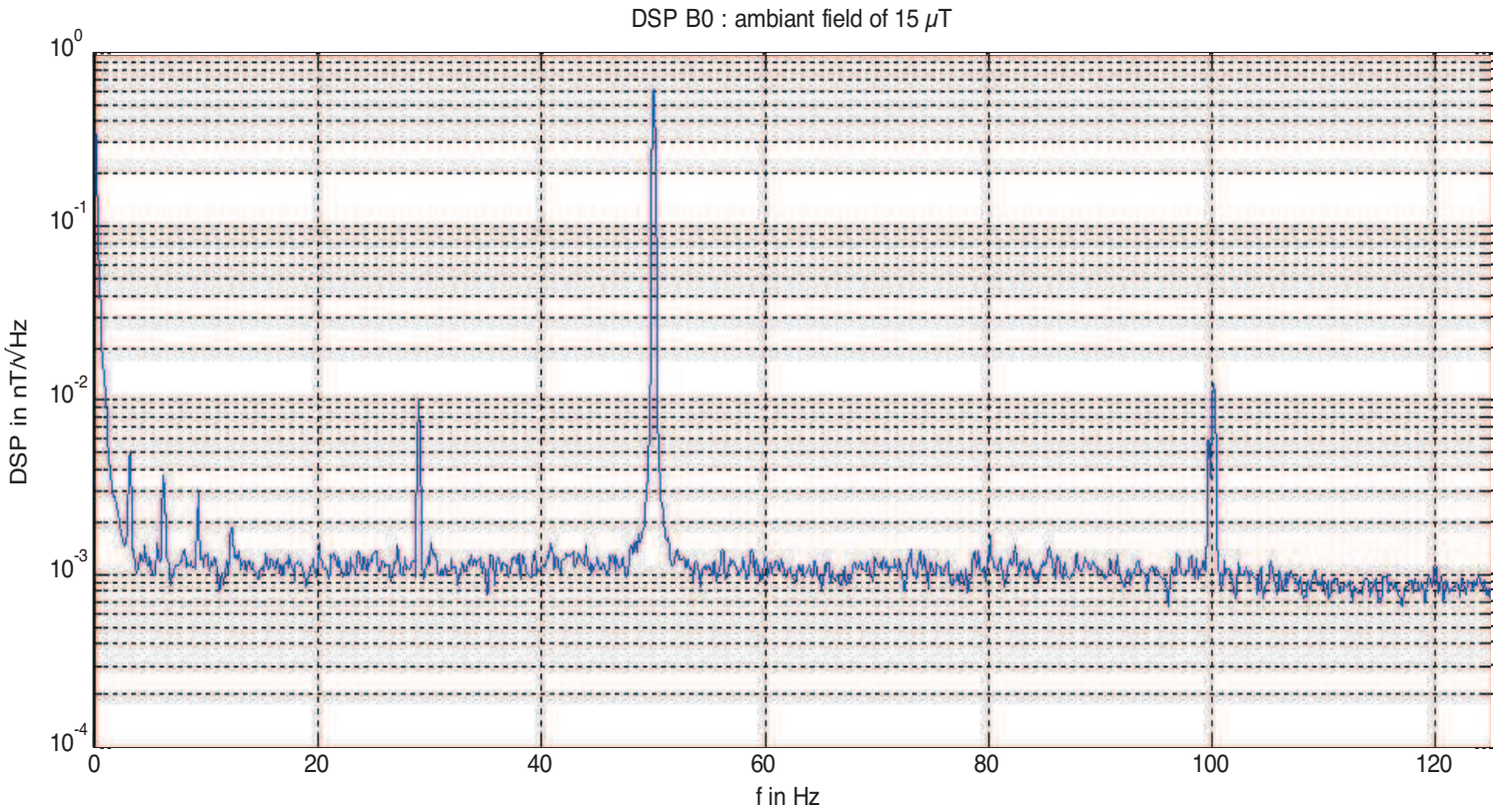
Principle of the ASM scalar measurement





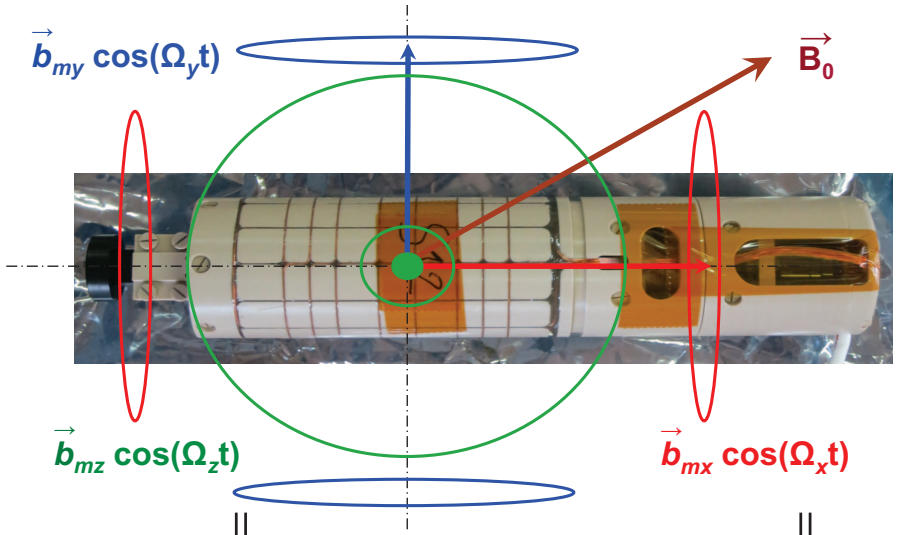
- The ASM is a magnetic field to frequency converter, with B=F/γ
- γ is the (known) ^{4}He gyromagnetic ratio for the 2^3S_1 state, and F is the magnetic resonance frequency between the Zeeman sublevels (proportional to B)

ASM bandwidth and scalar modes

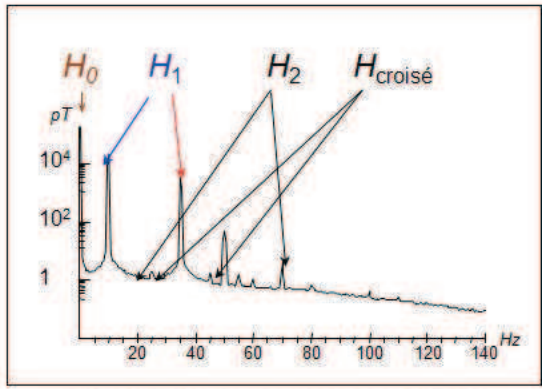


- Nominal mode : 1 Hz sampling (0-0.4 Hz bandwidth)
- Burst mode : 250 Hz sampling (0-100 Hz bandwidth)
- Resolution : better than 1pT/√Hz
- Precision : better than 1pT
- Accuracy : (after instrument correction) σmax of 65 pT

Principle of the ASM vector measurement



$$\left\|\vec{B}_{tot}\right\| = \left\|\vec{B}_o + \sum_{i=x,y,z} \vec{b}_{mi}\cos\left(\Omega_i t\right)\right\|$$



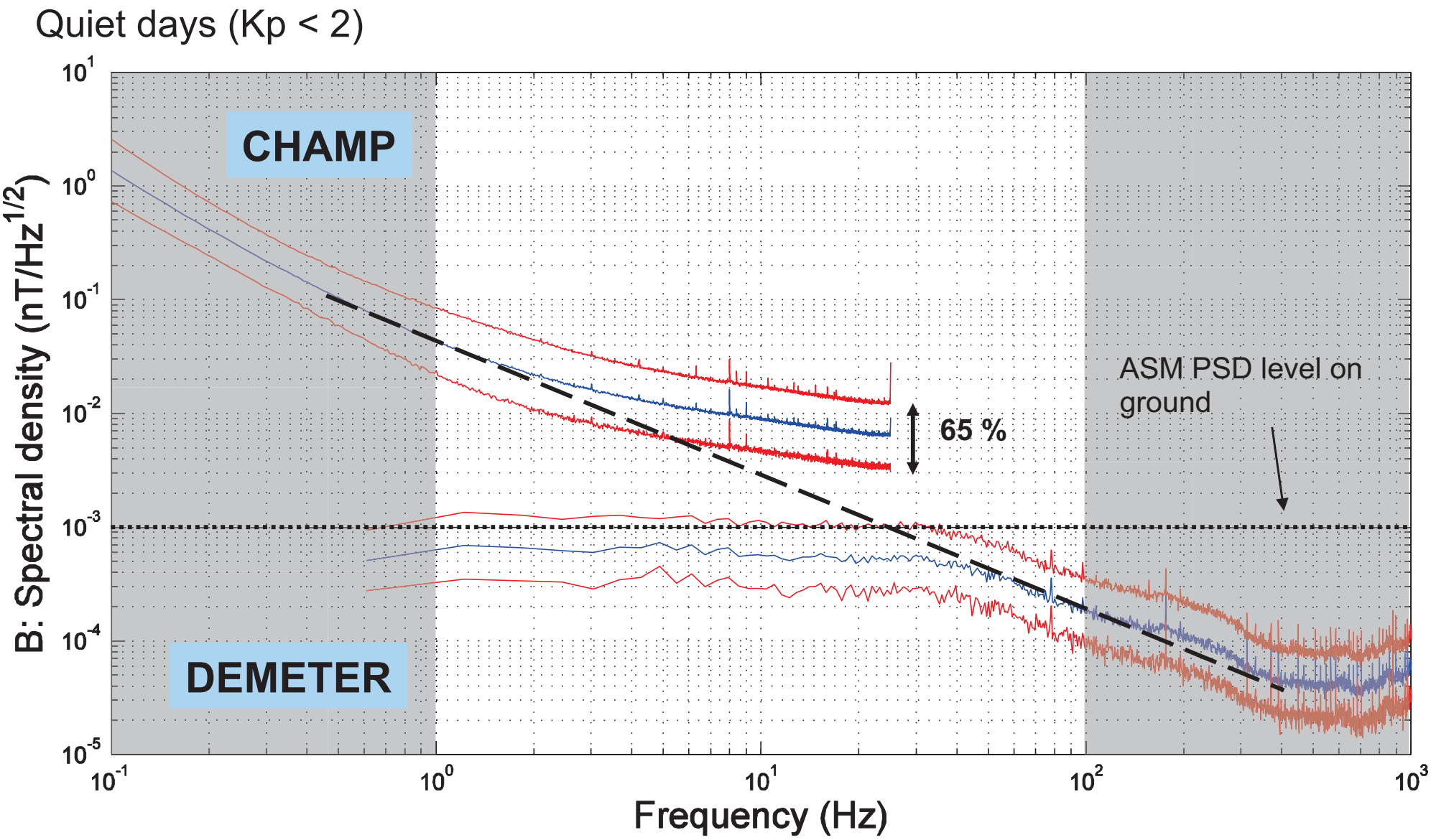
Real time analysis of the scalar output

- Three perpendicular coils generate periodic magnetic fields with known amplitudes (~ 50 nT) and three different known (and adjustable) frequencies beyond 1 Hz (typically 10 Hz and above).
- Real time analysis (with appropriate sampling rate) of the scalar field measured by the (scalar) sensor makes it possible to measure the scalar field at 1 Hz (with near nominal performance) together with all field components along the three coil axis.

Advantages and limitations of the vector mode

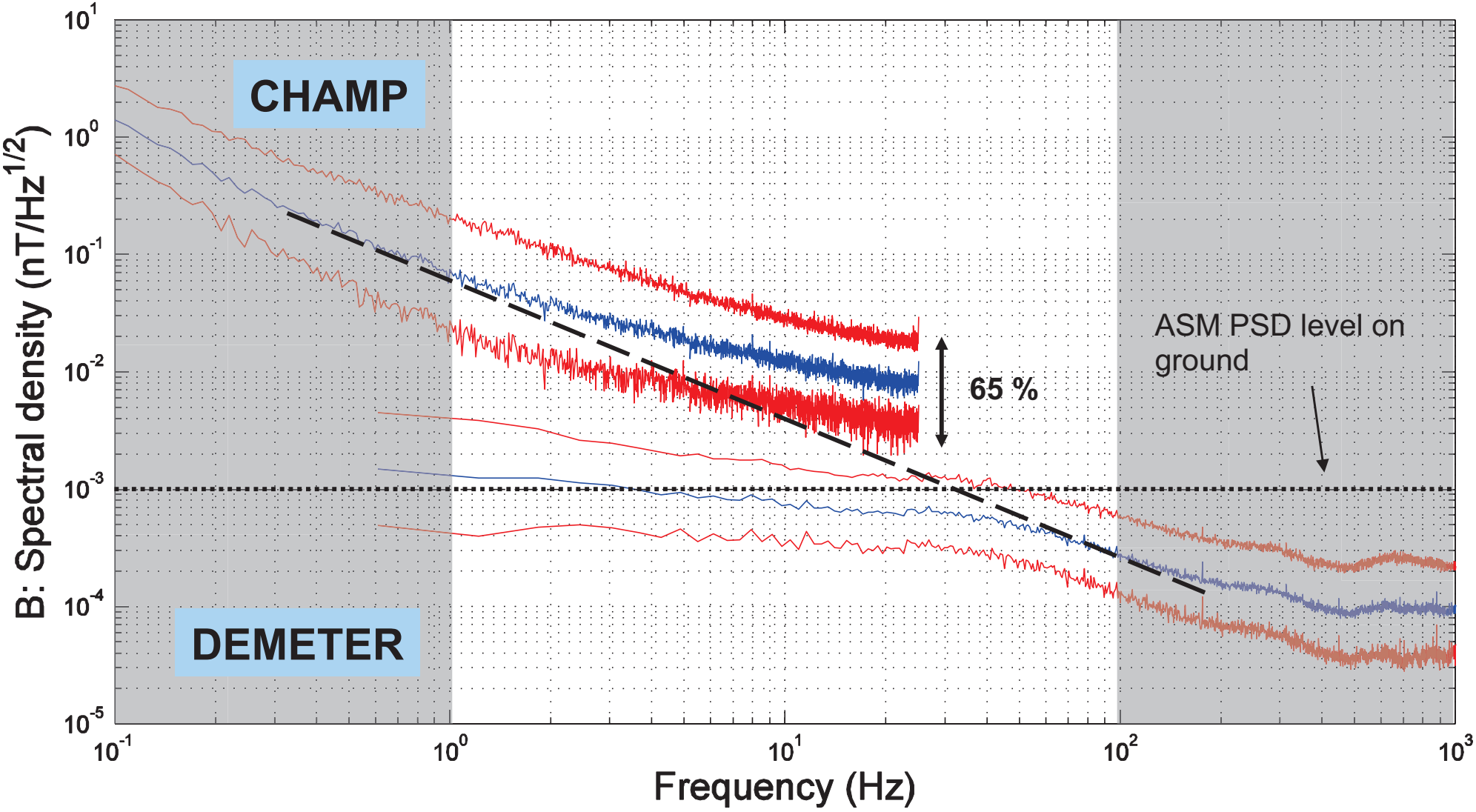
- **Scalar measurements remain absolute**, with almost unaltered performances.
- **Internal calibration is possible** : The three vector components come in addition and are independent from the scalar measurement -> provides a mean to calibrate the coils (orientation and scaling), without resorting to cross-calibration with another instrument (internal calibration), provided enough data (with enough different orientations) are acquired.
- **Quality monitoring is possible.**
- **In short: the ASM can provide fully calibrated/monitored vector field measurements in addition to an absolute scalar reading, all synchronous at the same physical location in an autonomous way** (with a 0-0.4 Hz bandwidth and 1 Hz sampling)
- However, **vector component performances are** intrinsically **degraded by a factor (b_m/B_0) compared to the performances achieved for the scalar measurement; they further depend on** the poorly known **natural background magnetic signal beyond 1 Hz** (where the modulations are to be operated)
- **On the ground, resolution for the vector component is better than 1nT/√Hz and absolute accuracy (2σ) is better than 1nT**
- Of course, **there also is still a need for the ASM to be oriented in the NEC frame** for its vector measurement to be geophysically relevant.
- For more details on the ASM, see poster J1-6 in this session later this afternoon “The Swarm absolute scalar magnetometer”.
- See also talk 5.1-7 by J.M. Léger in session 5.1 at 11am today “an absolute vector magnetometer dedicated to ground observatories”

ASM experiments planned in space: Exploration of spectral content using the 250 Hz burst mode



ASM experiments planned in space: Exploration of spectral content using the 250 Hz burst mode

Stormy days (Kp ≥ 7)



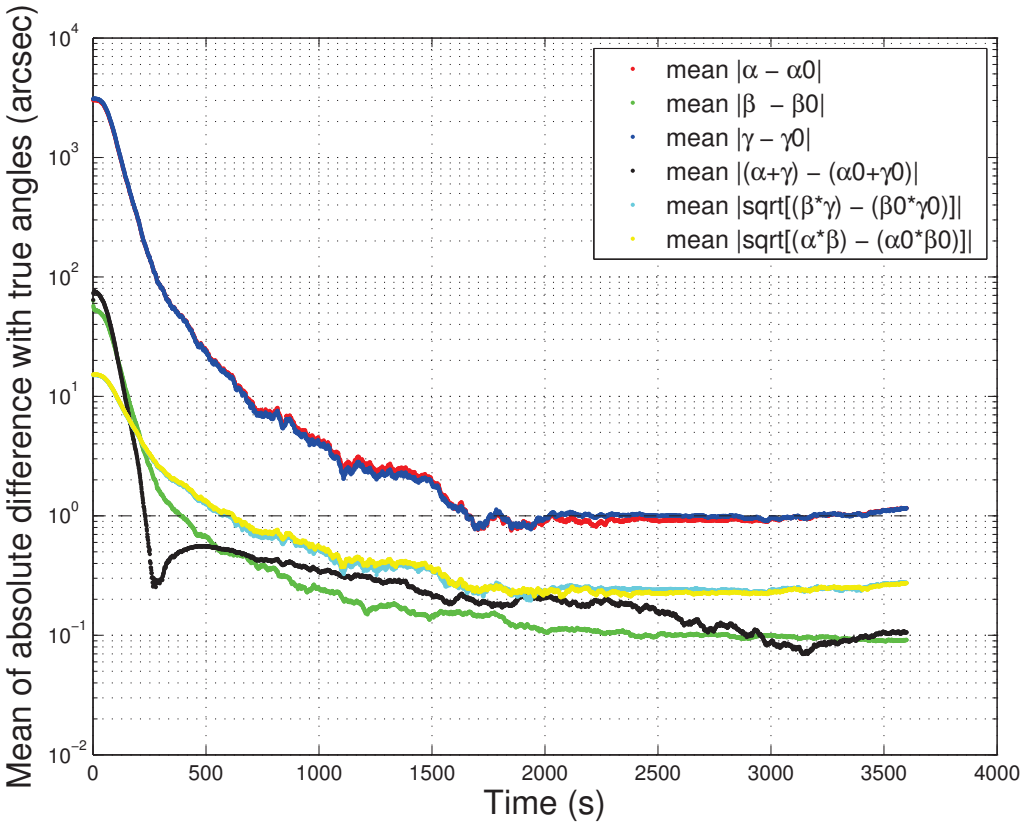
ASM experiments planned in space: Exploration of spectral content using the 250 Hz burst mode

- The burst mode is to be activated during the commissioning phase, simultaneously on all satellites, on days with different magnetic conditions: quiet, unsettled and stormy.
- This will be used to explore the magnetic field spectral content and select the vector mode modulations.
- If you have further suggestions (or interest in this experimental data), please do let us know !

ASM experiments planned in space: Cross-validation of ASM vector and nominal VFM data

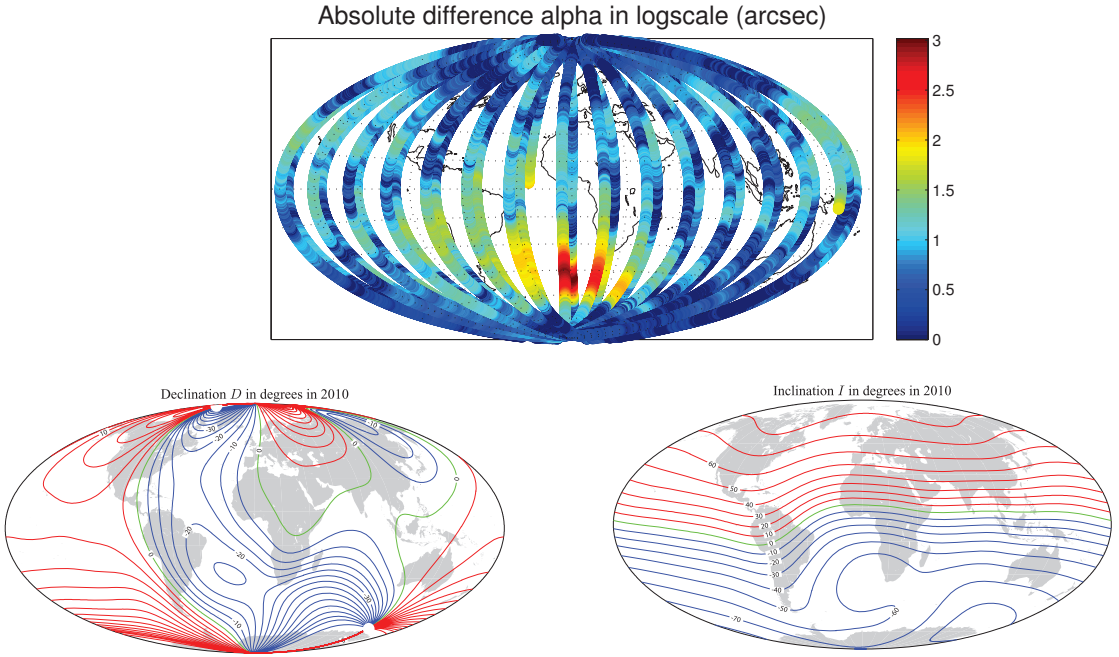
- First requires in-orbit alignment of both magnetometers.
- Not so trivial, since the ASM and VFM + Star Tracker are about 2m away from each other on the boom, with a mechanical stability on the order of 25 arcsec.

ASM experiments planned in space: In orbit alignment of the ASM and VFM magnetometers (see also Poster J1-4 in this session, later this afternoon)



- In orbit alignment requires the recovery of the rotation matrix (Euler angles) linking the ASM and VFM frames.
- Simulations based on Champ data (and relevant noise assumptions) show that, if the boom is assumed rigid, precise alignment (within one arcsec) can usually be achieved within 12 minutes, but not always (next slide).

ASM experiments planned in space: In orbit alignment of the ASM and VFM magnetometers (see also Poster J1-4 in this session, later this afternoon)



- In orbit alignment within 12 mn is not as accurate in a very specific region within which the ASM and VFM do not see enough field directional changes.
- On average, however, this shows that cross-validation between both magnetometers should be possible even if the boom displays some low frequency distortions
- Higher frequency boom oscillations would be more problematic, but could be detected (see poster)

ASM experiments planned in space: Production of experimental ASM derived “Level 1b” vector data

- If boom proves rigid enough, and cross-validation is successful, production of experimental ASM derived “Level 1b” vector data could be envisioned by directly taking advantage of the Star Tracker (not using VFM data).
- Such proof of concept data would provide a second independent set of 1 Hz vector data.
- Note, however, that such data can only be of lower quality, given the set-up on the boom, even if the ASM vector mode performs as well as the VFM magnetometer.

Summary

- The ASM instrument will provide very accurate nominal 1Hz scalar data for science studies and calibration of the VFM vector data.
- The ASM, however, can also operate a burst mode at 250 Hz. This mode will be operated during commissioning to explore the poorly known spectral content of the magnetic field beyond 1Hz.
- If this spectral content is as quiet as on ground, the ASM vector mode will produce self-calibrated 1 Hz vector data with performance comparable to that nominally required for the companion VFM magnetometer.
- Both the ASM and VFM instruments can be aligned with each other in space usually within 12 minutes.
- If the boom is not too unstable, cross-validation of both instruments will be possible.
- If the boom is rigid enough, production of proof-of-concept ASM level 1b vector data is possible.