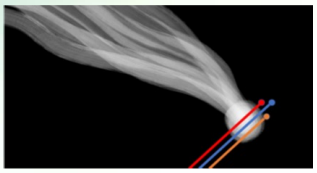


FGM-B2:
Dust, Field, & Plasma (DFP) / Fluxgate Magnetometer on B2 (BFG)

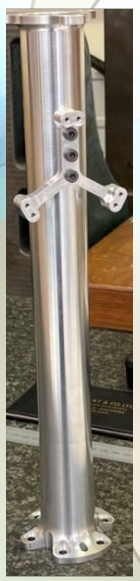
Lead Institution: Imperial College London

Marina Galand (Unit Co-PI), Emanuele Cupido (Instrument Manager),
Chris Carr (Eng. oversight, EMC Lead), Irene Ruiz Rodriguez (Instrument Engineer),
Pete Stephenson and Zoë Lewis (Science actors)

Key hardware contributor: IWF Graz

Martin Volwerk (Deputy Unit Co-PI), Aris Valavanoglou (Technical Manager),
Werner Magnes, Irmgard Jernej (Instrument Engineers)

DFP-Fluxgate Magnetometer (BFG) on B2 probe



→ **3D magnetic field measurements**
- **B2 probe closest to comet**

Essential for science:
- To identify **boundaries and regions** (e.g., bow shock, diamag. cavity)
- To assess **energy transfer** through the coma

Critical for multi-point aspect of CI mission:
- Magnetometers: only instruments on all 3 S/Cs
- 3D structure of boundaries and wave growth through coma

Strong heritage (TRL8):
- VEx, THEMIS, MMS

Lighter version than on S/C A

Low power consumption: Total 1.8 W (secondary)

Solar wind-comet interaction: Weakly outgassing

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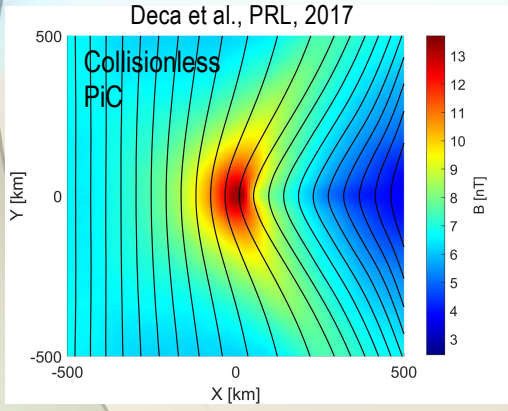
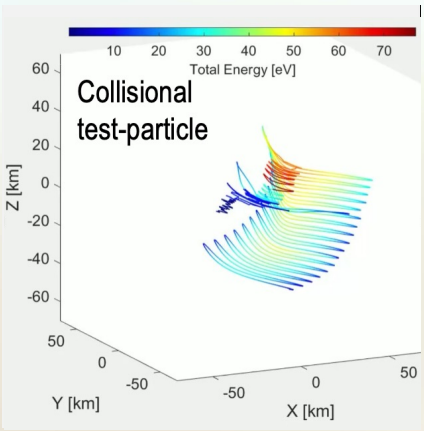
Electric & magnetic fields

Collisional plasma processes

Deca et al., PRL, 2017



Stephenson et al., MNRAS, 2022



- No boundary formed
- Cooling of the cometary e-

Solar wind-comet interaction: Higher outgassing

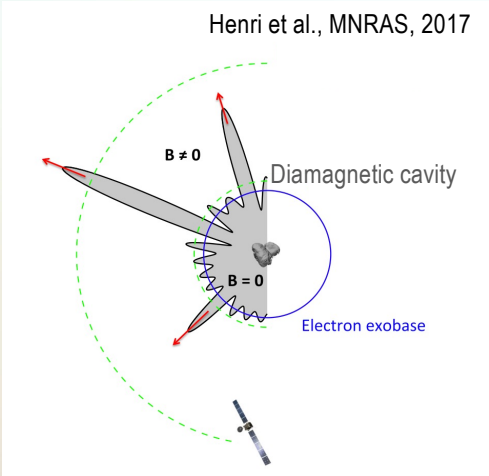
Imperial College London | IWF | Technische Universität Braunschweig

Electric & magnetic fields

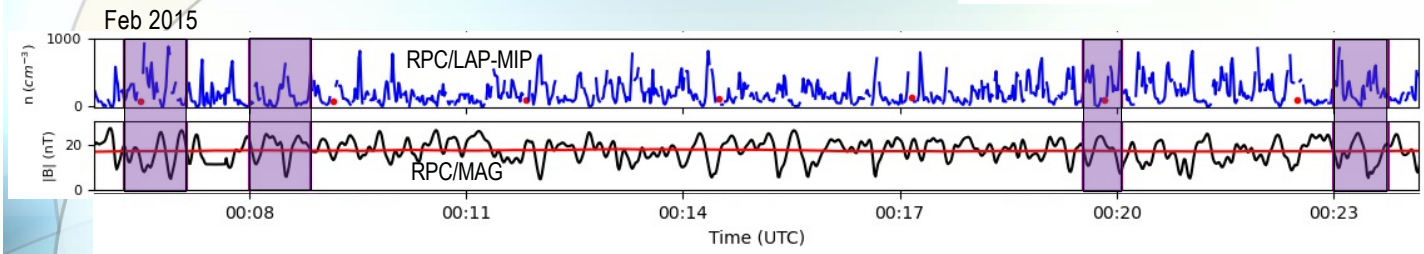
Collisional plasma processes

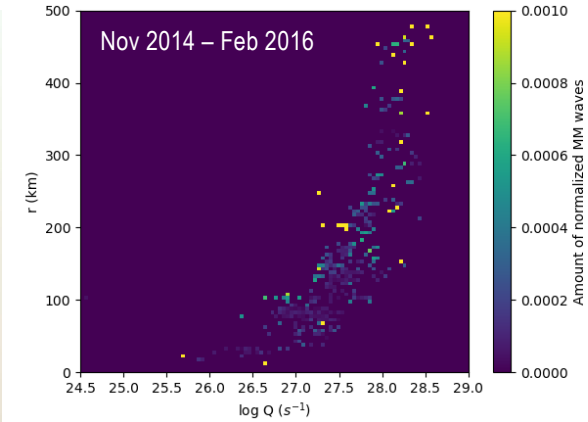
- Formation of boundaries: BS, Diamagnetic cavity boundary
- Inclusion of e-neutral collisions in PiC

Henri et al., MNRAS, 2017



Mirror-mode waves @ 67P





- **Source** of MM waves?
  - Ring distribution of ions with T asymmetry (T_perp > T_paral) → Instability

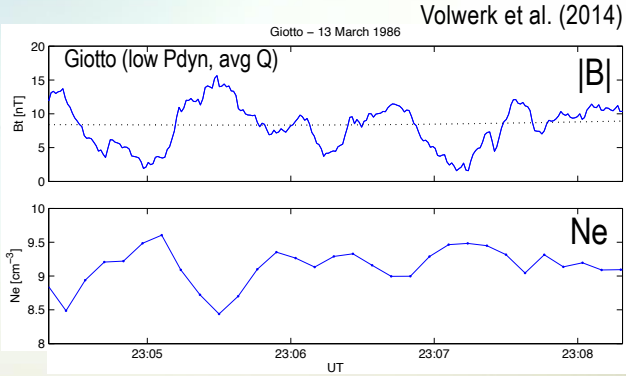
✓ Found 100s of MM waves
  - Over a **large range of r & Q**
  - Observational bias

Tello Fallau, Goetz et al. (in prep) [charlotte.goetz@northumbria.ac.uk]

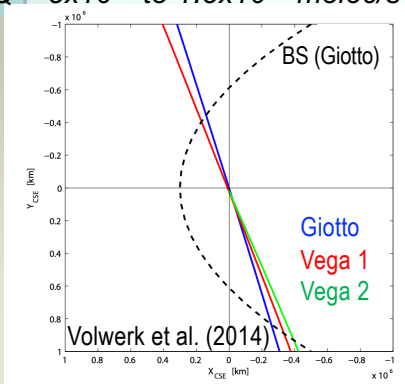
Mirror-mode waves @ high outgassing

- At **Halley** detected from 3 s/c (6-13 March 1986)
  - In cometosheath (from BS to pile-up)
- Conditions:
  - ✓ High Q --> more ion pick up --> assist growth
  - ✓ High Pdyn(sw) → compress CS → inhibits growth

Volwerk et al. (2014)



Q ~ 5x10²⁹ to 1.5x10³⁰ molec/s



- Detection by **CI S/C**?
  - ➢ DFP/FGM: Presence of ion pick-up
  - ➢ DFP/FGM+DFP/SCIENA: Locally pdced vs growth
  - ➢ DFP/FGM multi-point: To constrain the size of the region where they are produced and grow

Data compression for FGM-B2 (1/2)

- **Challenges on B2**:
  - Limited data rate
    → Compression needed
  - Data to be ready in near real time for transmission
    → Compression algorithm simple and quick
- To be applied to the **B field vector** (3 components):
  - **Time series**

➢ **Differential compression method** ideal to minimize data rate

Here, lossless algorithm →

Block size = 6

Reference value

	70	80	62	65	71	70
$x_j - x_{j-1}$	70	80 -70	62 - 80	65 - 62	71 - 65	70 - 71
Δx	70	10	-18	3	6	-1

Data compression for FGM-B2 (2/2)

- **Testing (at Imperial):**
  - To assess efficiency of differential compression method
  - **Compression ratio** = Compressed data volume / Uncompressed data volume

- **Application to Cluster dataset**:
  - Cluster sw dataset + noise added + reaction wheel contribution
  - ➢ Lossless
    → Compression ratio = 0.42 ; Data rate = 3394 bits/s
  - ➢ Lossy
    → Applied to explore accuracy lost due to bit removal vs benefits in data compression

  - **However**:
    - **Very optimistic values** as B2 expected to have noisier magnetic environment

Hardware for FGM-B2

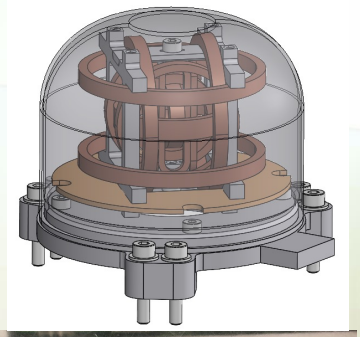
FGM-B2 boom:

- Made of **Aluminium 6061 T651**
- Supports **2 FGM sensors**
- **Metrology** inspection completed:
  - Mass: ~ 300 g
  - Length: 330 mm
  - Outer diameter: 34 mm

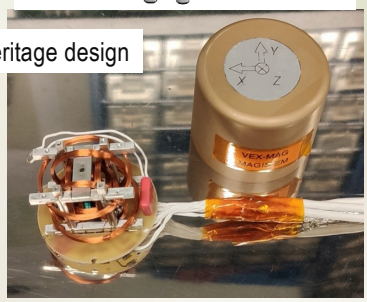
FGM-B2 sensors:

- Heritage design adapted to CI

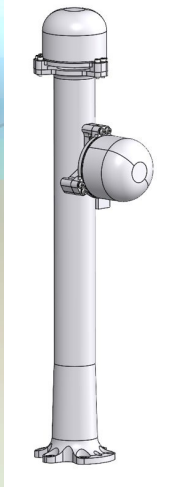
Comet Interceptor design



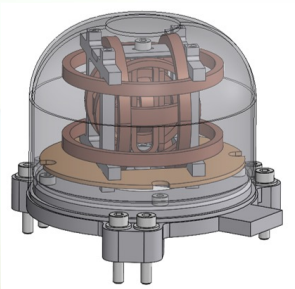
Heritage design

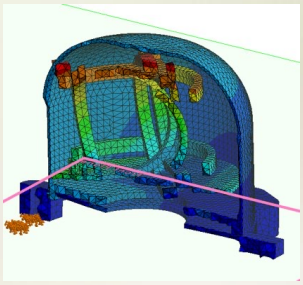


FGM-B2 mechanical analysis



- Mechanical design of boom & sensors verified by analysis (at Imperial)
- Design compliant with mission requirements





Hardware: FGM-B2 electronics (1/2)

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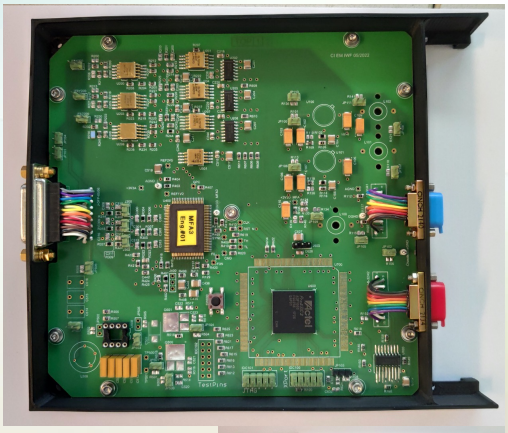
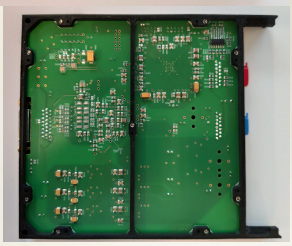
- **EM1 manufacturing**
  - PCB manufactured in FR4 material
    - EFM/STM/PFM shall be VT-901 by INVOTEC
    - INVOTEC quote => 9 weeks manufacturing time!
  - Soldering done with vapor phase reflow + hand soldering (ESA qualified processes and personal by IWF)
  - For EM1 mixed parts quality: commercial & proto parts
    - EM FPGA: A3P1000-FG256
    - PFM FPGA: RT3PE3000L-1CQ256B
  - All component footprints already for PFM
  - PCB fits in 3D printed DFP/CEBOX B2 frame

TOP side



BOTTOM side



Hardware: FGM-B2 electronics (2/2)

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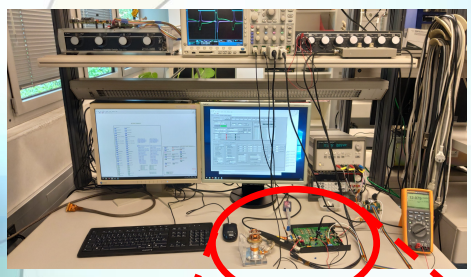

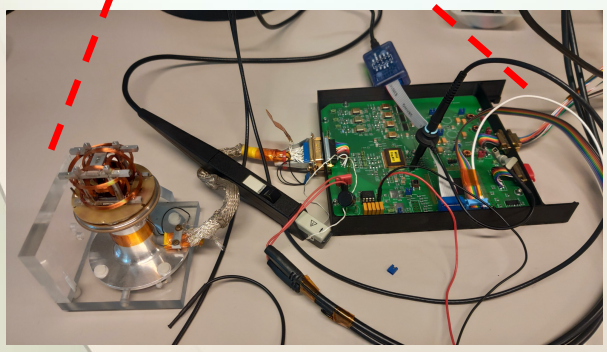

- **EM1 testing status**
  - Board electrical tests successful
    - All voltages/currents ok
  - FPGA development nearly finished
    - Function ok (95%) - test pattern generator missing
    - Syntheses ok (100%)
    - Place & Route and back annotation ok (100%)
    - FPGA programming ok (100%)
  - EGSE update finished (100%)
  - EGSE software update ongoing (80%)
  - EM1<=> EGSE communication (100%)
    - UART + Slip protocol
  - Sensor excitation with 16kHz working
  - Actual total power consumption 435mW
    - allocation 900mW per magnetometer

Plan - FGM-B2

Science:
- 3D modelling of field and plasma environment: inclusion of collisions

Data compression:
- To add more realistic magnetic disturbances from S/C & units as more input available
- To combine IB and OB; To apply to Giotto-Vega1-2/Halley dataset
- In coordination with DFP/DAPU

FGM-B2 boom & sensors:
- Mechanical design: Verified by analysis and compliant with mission requirements
- Boom prototype: Vibration/shock test planning in October 2022

Electronics:
- EM1 PCB built & tested
- Testing with DFP/DAPU late summer
- EM1 integration for DFP/CEBOX at CBK in October 2022