

# A Potential Mission Concept for the M3 2022 Launch: Investigation of MagnetoPause Activity using Longitudinally-Aligned Satellites (IMPALAS).



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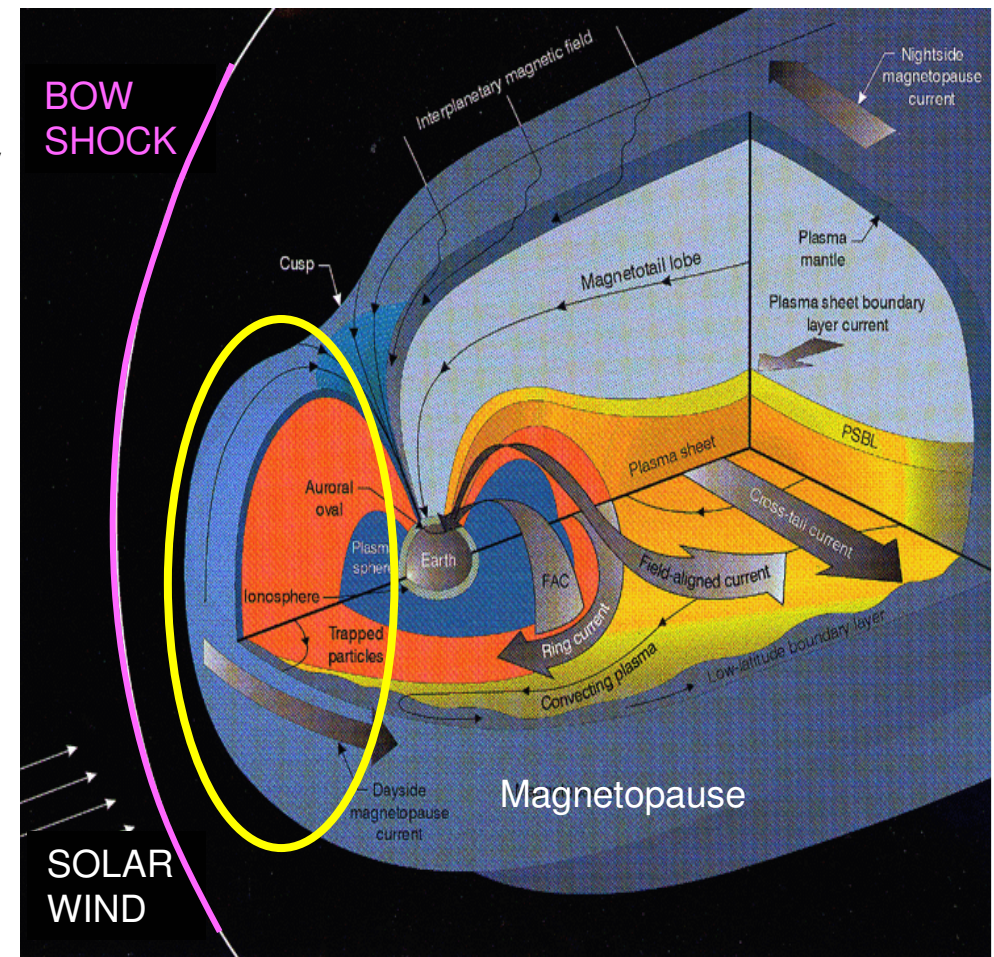
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# Lessons Learnt

- You can't do very much within the M-Class budget under the ESA model (Cross-Scale);
  - There is still compelling science to do with targeted multi-point measurements in the terrestrial magnetosphere (NASA/Themis);
  - Tightly focussed science goals may not necessarily be a bad thing:
    - Options for augmentations to a clearly achievable baseline may be more palatable to the community and more convincing to the assessors?
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# IMPALAS: Why target the dayside terrestrial magnetopause?

- It is the boundary between the solar and terrestrial plasma regimes:
  - The coupling processes that ultimately control all magnetospheric dynamics occur there;
  - The site of some fundamental plasma processes (e.g. magnetic reconnection, particle acceleration, boundary wave generation);
  - A key boundary for defining the influence of ‘space weather’;
- It is the most readily accessible analogue to other space and astrophysical plasma boundaries:
  - Magnetopause of other planets;
  - Heliopause
  - Interactions between Stellar/Galactic spheres of influence

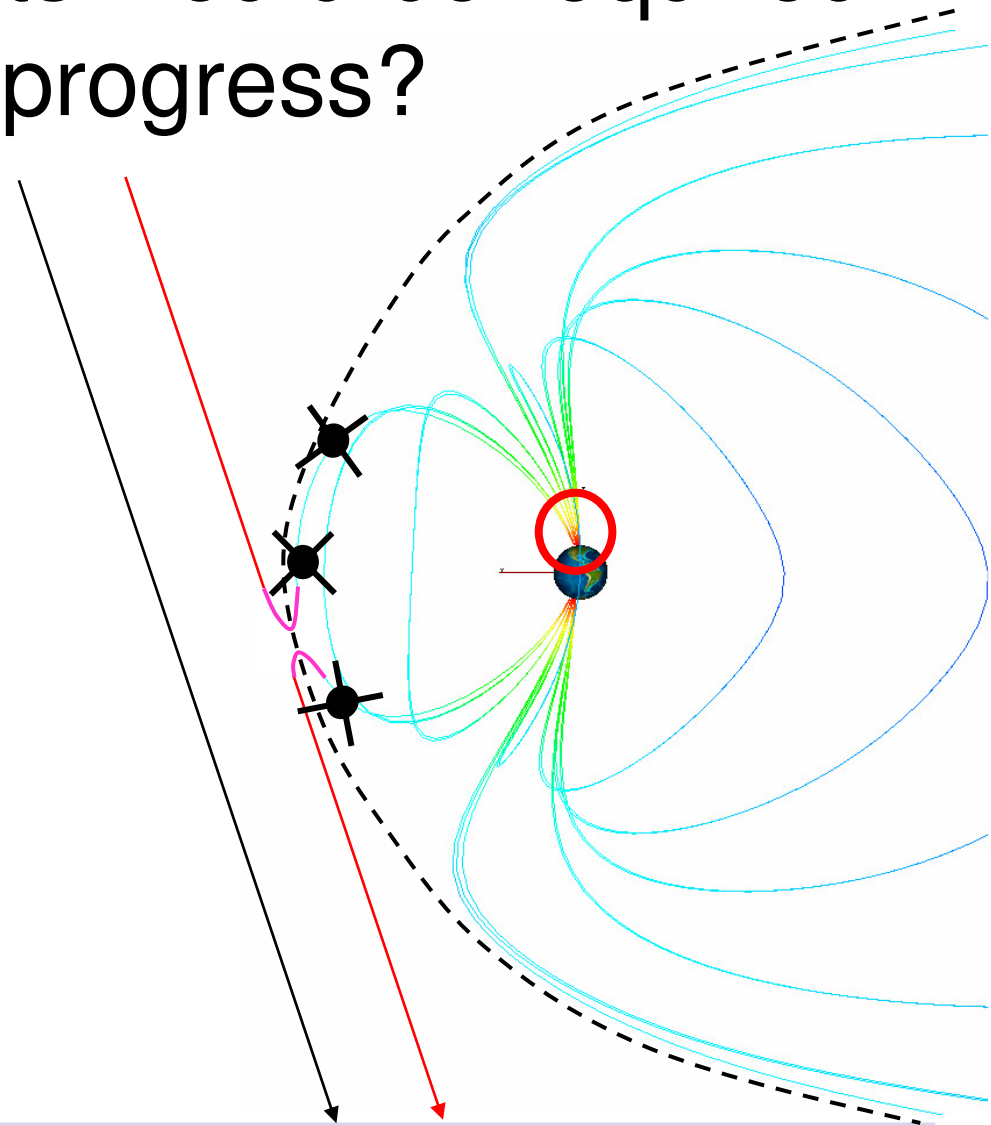


# What measurements have we made to date?

- Multiple single spacecraft traversals of the MP from a number of missions:
    - Indications of a dynamic boundary;
  - Multi-point measurements over a relatively small scale (c.f. extent of MP) by Cluster (and MMS):
    - Insight into the underlying physics of the interactions;
  - Relatively rare and fortuitous spacecraft conjunctions (e.g. Cluster and Double Star):
    - Sporadic indications of the more global dynamics of the MP
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# What measurements would be required to make progress?

- A statistically significant number of ‘controlled’ conjunctions with multiple spacecraft taking in situ measurements simultaneously at the MP and spread widely ( $\Delta s \sim 5 R_E$ ) along, say, a reconnecting field line;
- Additional conjunction with European (or other) ground-based facilities at the magnetic foot-points.



## Example science questions which would be closed:

Question:	How solved:
What is the location of the MP reconnection site for given conditions?	Large number of measurements of particle dispersions/cut-offs on the same reconnected field line
What is the importance of Flux Transfer Events (FTEs) in global dynamics of the magnetosphere?	Determine if FTEs appear in only one or in both hemispheres simultaneously (adding open flux or not?)
How do boundary waves evolve as they propagate across the magnetopause?	Regular multi-point observations of boundary deformations at different distances from their origin.
Which mechanisms form boundary layers at the MP and how do they vary or evolve with position?	Regular and simultaneous multi-point observations of boundary layers across the dayside MP.
How do disturbances, discontinuities and waves propagate within the magnetosheath and how and where can they impact the MP?	Widely spaced measurements within the magnetosheath at times when the magnetosphere is compressed and MP is located below average position.
How do MP disturbances propagate along field lines and into the ionosphere?	Multi-point measurements of Alfvénic disturbances and field aligned currents along the same field line, combined with regular observations of those field line foot-points by ground-based facilities.

# Example science questions which would be closed:

Question:	How solved:
<p>What is the location of the MP reconnection site for given conditions?</p>	<p>Large number of well-separated measurements of particle dispersions/cut-offs on the same reconnected flux tubes</p>
<p>What is the importance of Flux Transfer Events (FTEs) in global dynamics of the magnetosphere?</p>	<div style="text-align: center;"> </div> <p>From Fuselier et al., 2004</p> <p><b>Figure 1.</b> Two-dimensional geometry used to compute inflow velocity and the distance to the reconnection given two spacecraft observations in the reconnection la</p>
<p>How do boundary waves evolve as they propagate across the magnetopause?</p>	
<p>Which mechanisms form boundary layers at the MP and how do they vary or evolve with position?</p>	
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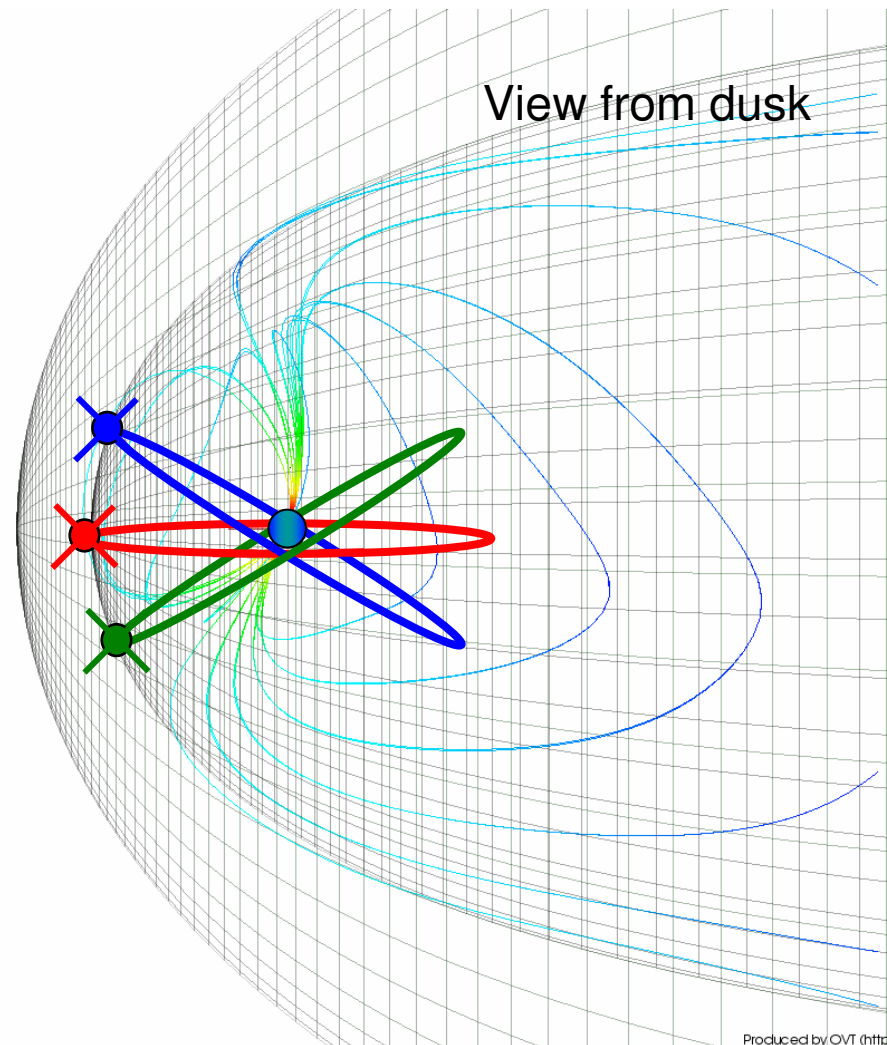
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<p>(a) No dipole tilt case</p> <p>(b) Large dipole tilt case</p>	



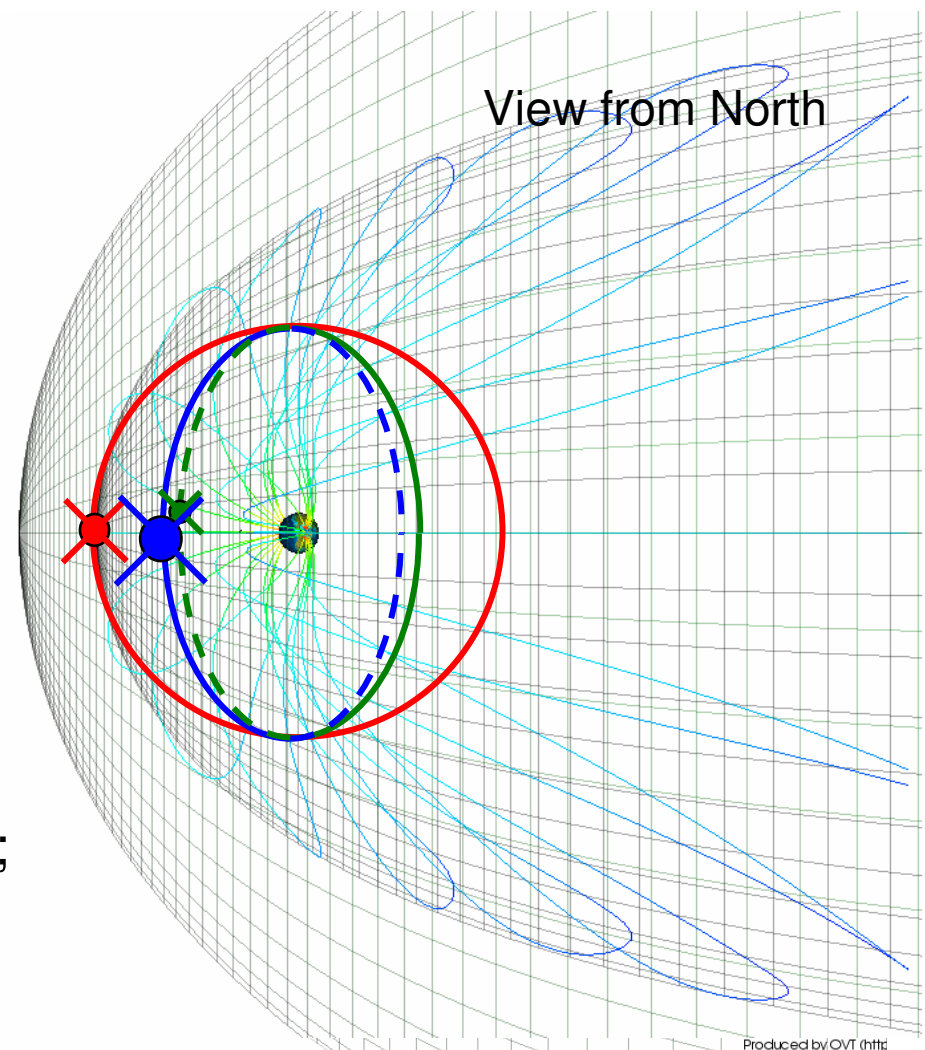
# A Possible Mission Scenario

- Baseline a 3 s/c mission:
  - I1 in circular orbit,  $10.48 R_E$  radius,  $0^\circ$  inclination.
  - I2 in slightly eccentric orbit with apogee  $\sim 11 R_E$  and  $+30^\circ$  inclination.
  - I3 in similar eccentric orbit as I2 but with  $-30^\circ$  inclination.



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- So each spacecraft:
  - has an exactly 2 day period;
  - ‘skims’ dawn-to-dusk along the average position of the dayside magnetopause;
  - is phased to be in longitudinal (magnetic) alignment with other 2;
  - is phased to have a magnetic foot-point over European ground-based facilities at local mid-day.



# Strawman Payload

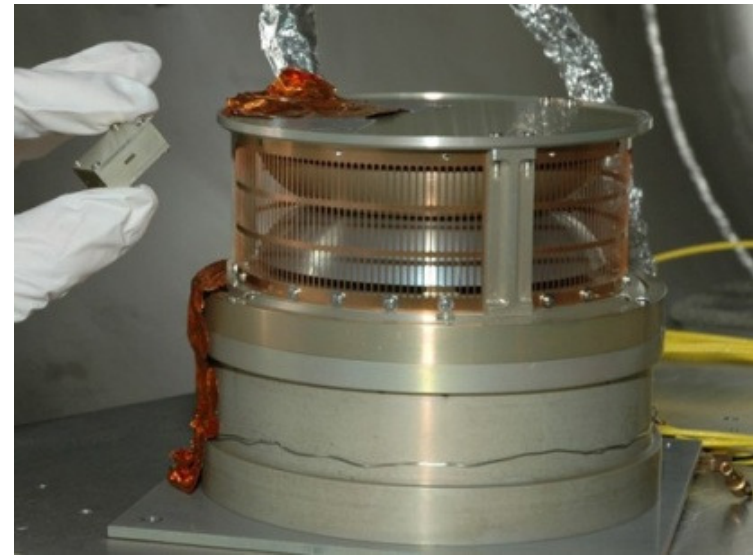
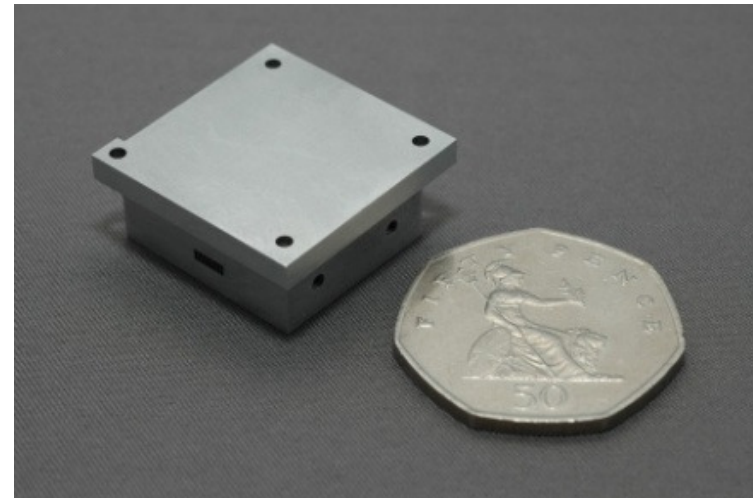
- Baseline is largely current state-of-the-art (or where appropriate next generation) fields and plasma package on all 3 spacecraft:

Required Instruments*	Required for:
Magnetometer	Identification of MP crossings plasma waves and FTEs, Walen tests.....
Ion & Electron Spectrometer	MP crossing, particle cut-offs to locate reconnection site, Walen tests.....
Energetic Particle Detectors	Determine boundary motions, particle acceleration signatures.....
Desirable Instruments*	
Auroral Zone Imager	Provides context and additional link between MP and ground-based measurements.....
Electric field booms	Identification of plasma waves,
Ion Mass Spectrometer	Plasma composition for correct analyses, tracers of particle origins within boundary layers;

- \* Confirmation of required/desired instruments needs to be done on the basis of the developing science case, but this will, by necessity, have to remain focussed (lessons learnt from Cross-Scale)

# Technical/Programmatic Issues

- Payload – None – but it is a potential flight opportunity for next generation instruments?
- How difficult is it to get 3 spacecraft to 3 distinct orbits from a single launch?
- Cost – baseline is a fraction of Cross-Scale hardware and therefore hopefully well-within the M-Class budget – build up from there if resources allow.
- Community interest, involvement and leadership – who would like to participate?



# Summary

- IMPALAS a modest (affordable) mission with focussed and doable primary science goals at the dayside magnetopause;
    - (However, it is clear that secondary goals in the magnetotail, flanks could also be readily defined and/or be of interest to the community).
  - Baseline (and possible augmented) payload could provide significant opportunities for hardware groups;
  - Options exist to build mission up if resources allow (additional spacecraft/instruments, change orbit after prime mission to do, e.g., bow shock physics?);
  - Impalas is appropriate for an ESA CV M3 study phase slot if there is enough scientific interest in such a concept;
  - Suggestions and expressions of interest welcome!
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