THOR – Turbulence Heating ObserveR

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Introduction

The Universe is permeated by hot, turbulent magnetized plasmas. They are found in active galactic nuclei, supernova remnants, the intergalactic and interstellar medium, the solar corona, the solar wind, and the Earth's magnetosphere, just to mention a few. Our knowledge and understanding of the Universe is largely based on measurements of electromagnetic radiation such as light or X-rays which originate, in most cases, in hot plasmas. We believe that energy dissipation of turbulent fluctuations in plasmas play a key role in plasma heating and energization. It is remarkable that we still do not understand the underlying physical mechanisms! Understanding these mechanisms is the unique mission of THOR.

THOR will address the fundamental science theme **Turbulent energy dissipation and particle energization** which ties in with ESA's Cosmic Vision. In particular, THOR will address the following specific science questions:

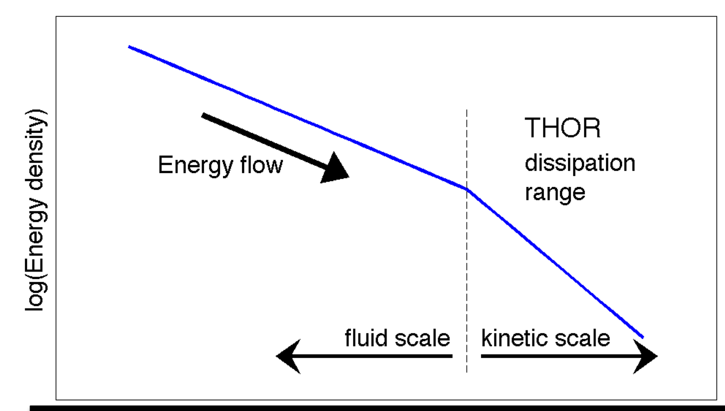
- How is plasma heated and particles accelerated?
- How is the dissipated energy partitioned?
- How does dissipation operate in different regimes of turbulence?

Mission summary

- Slow spinning spacecraft at 2rpm
- Sun-pointing, allowing high quality electric field and particle measurements.
- Active spacecraft potential control to improve plasma and field measurements.
- Orbit:
  - 1st year: 4 R_E x16 R_E
  - 2nd year: 4 R_E x26 R_E
  - 3rd year: 14 R_E x60 R_E
- Payload mass 173 kg, total dry mass 752 kg, total wet mass 1245 kg
- Payload: 10 instruments. Electric and magnetic field, thermal plasma and energetic particle instruments. In comparison to earlier/upcoming missions key major improvements include:
  - accuracy/sensitivity of **E** & **B**
  - temporal resolution of mass resolved ions
  - temporal/angular/energy resolution of electrons
- Regions of interest:
  - pristine solar wind 60 days
  - foreshock 47 days
  - bow shock 21 days
  - magnetosheath 14 days
- Average telemetry rate 2130, 811, 99 kbps for year 1/2/3.
- Selective downlink, 100+ Tbit (compressed) produced on-board during the mission, from those scientifically most interesting 20+ Tbit are downloaded.
- Launch 2026 with Ariane 6/Soyuz.
- Nominal science mission: 3 years, with capability for 2 years mission extension and L1 orbit

Science

1. Energy flow from fluid to kinetic scales

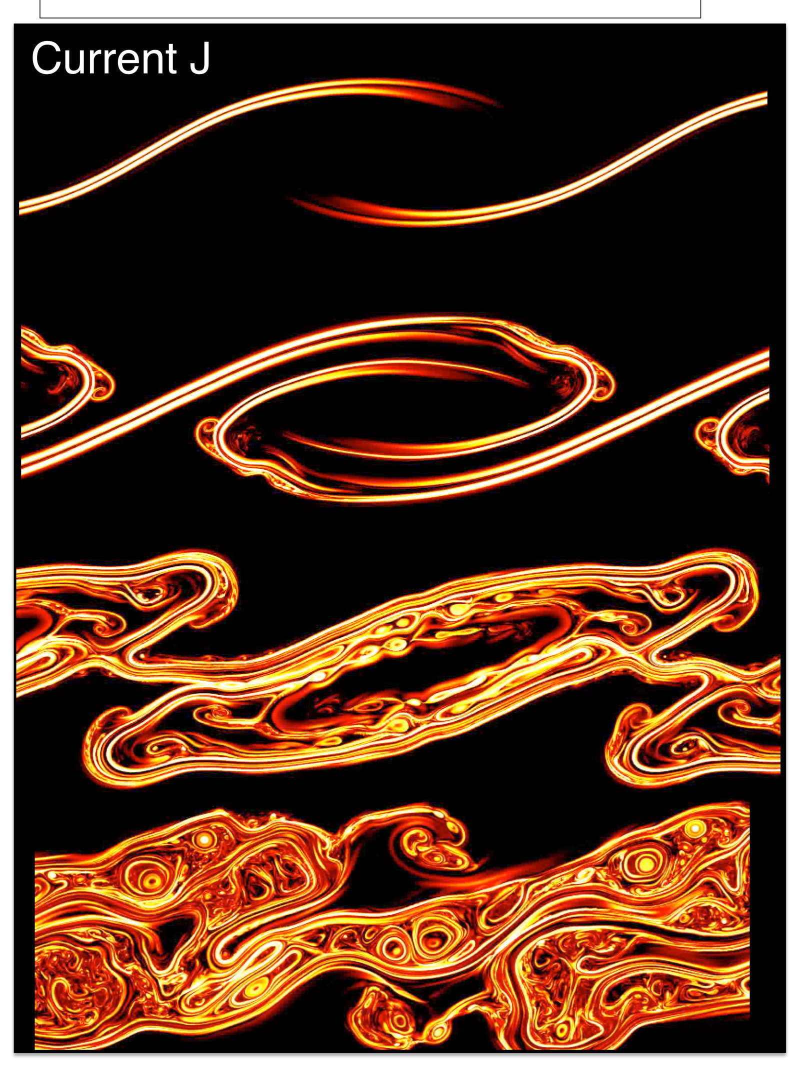


T=159

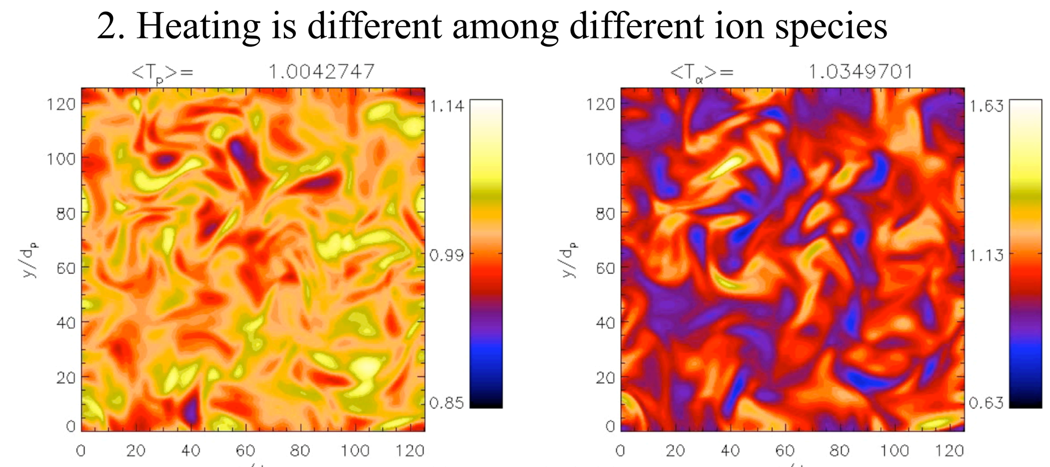
T=248

T=308

T=384



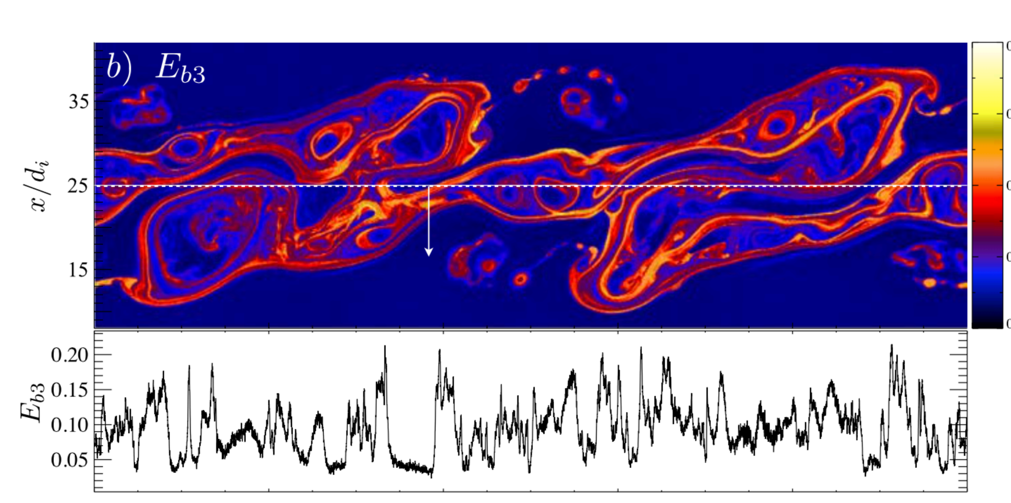
2. Heating is different among different ion species



H^+ temperature

He^{2+} temperature

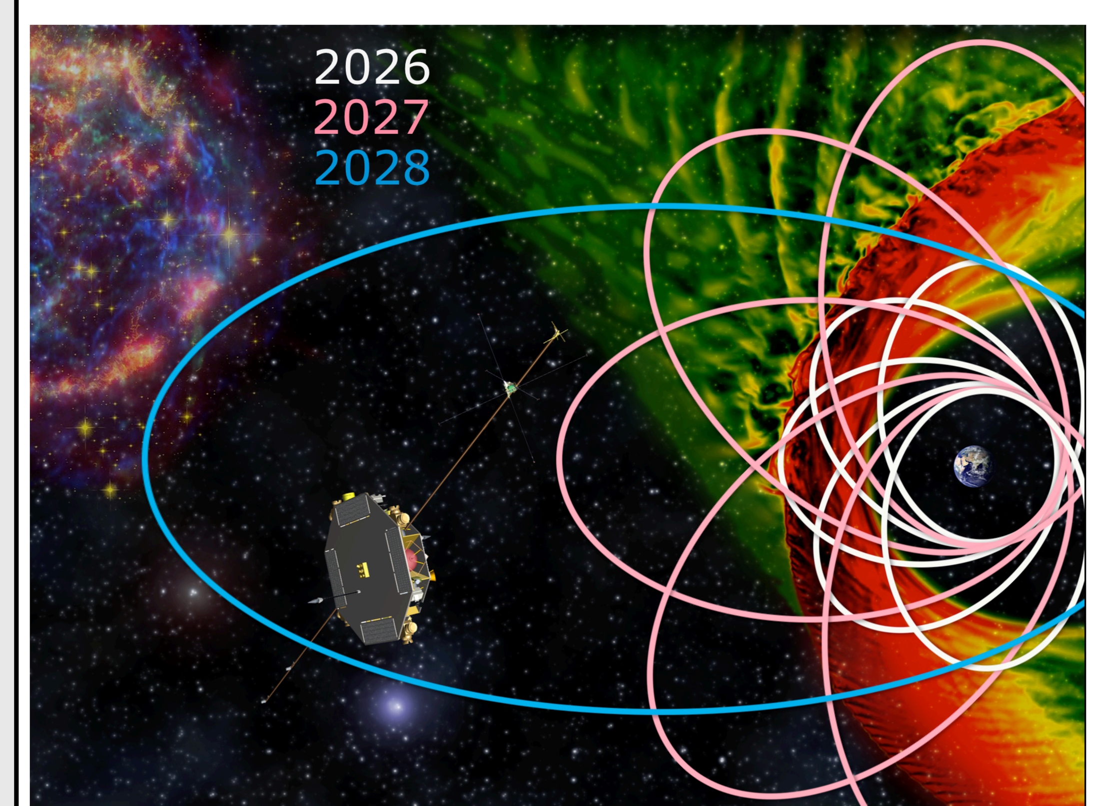
3. Particle acceleration



Acceleration of suprathermal electrons (6-9 T_{e0})

Mission

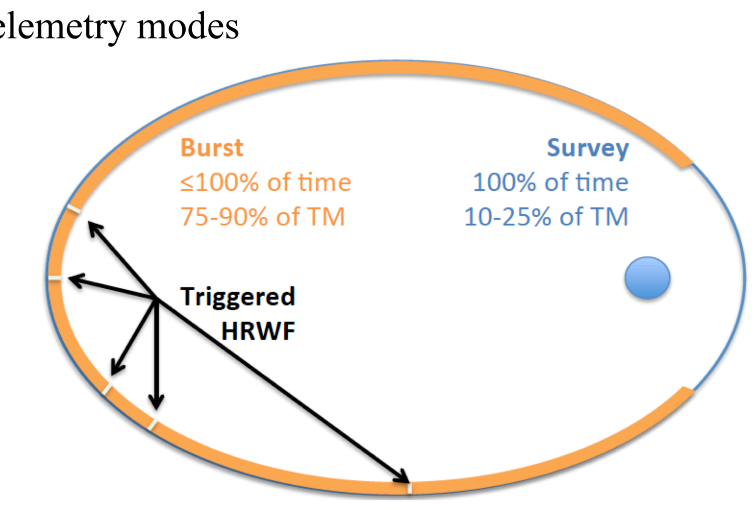
1. Three orbit phases: 1st year at 4 RE x16 RE, 2nd year at 4 RE x26 RE, 3rd year at 14 RE x60 RE



2. Payload

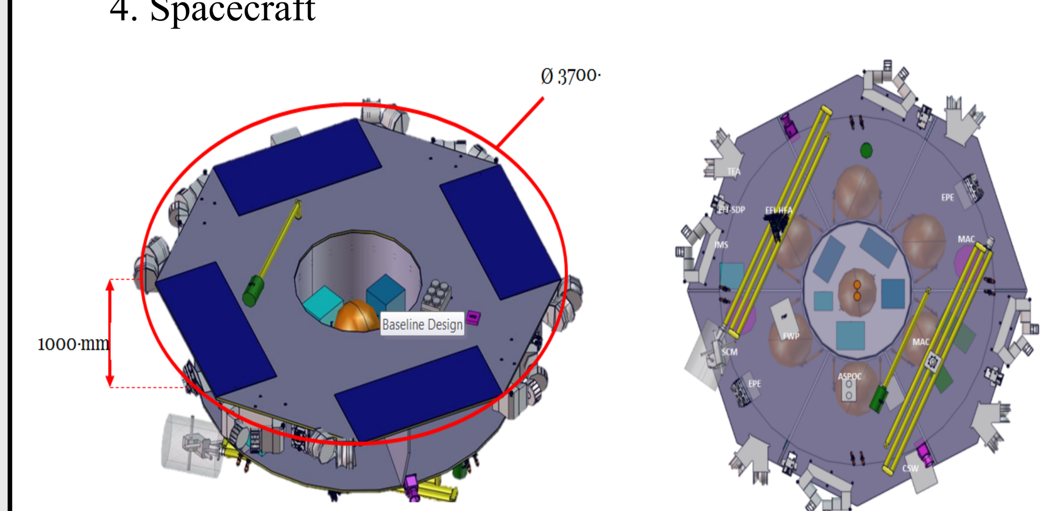
	Fields		
EFI	Electric Field instrument	Y. Khotyaintsev (S)	Electric fields and waves (0-200 kHz)
FWP	Fields and Waves Processor	J. Soucek (CZ)	Data processing, HF and LF receivers and sounder
MAG	Magnetometer	R. Nakamura (A)	Magnetic field (0-50 Hz)
SCM	Search-Coil Magnetometer	F. Sahraoui (F)	Magnetic waves (1 Hz – 200 kHz)
	Particles		
CSW	Cold Solar Wind ions	B. Lavraud (F)	Solar wind ion distribution functions at 150 ms with high detection rate
EPE	Energetic Particles Experiment	R. Wimmer-Schweingruber (D)	energy spectra and angular distributions of energetic electrons (20-700 keV) and ions (20-8000 keV)
FAR	Faraday cup	Z. Nemecek (CZ)	solar wind ion density, velocity, and temperature at 32 Hz
IMS	Ion Mass Spectrometer	A. Retino (F)	3D distribution functions of ions from 5 eV/q to 40 keV/q, mass range of 1-32 amu and time resolution of 150 ms
TEA	Turbulent Electron spectrometer	C. Owen (UK)	3D distribution functions of electrons from 5 eV/q to 40 keV/q and time resolution of 5 ms
PPU	Particle Processing Unit	F. Marcucci (I)	power, telemetry, and control interface to the particle instruments as well as power switching, commanding, and data processing

3. Telemetry modes



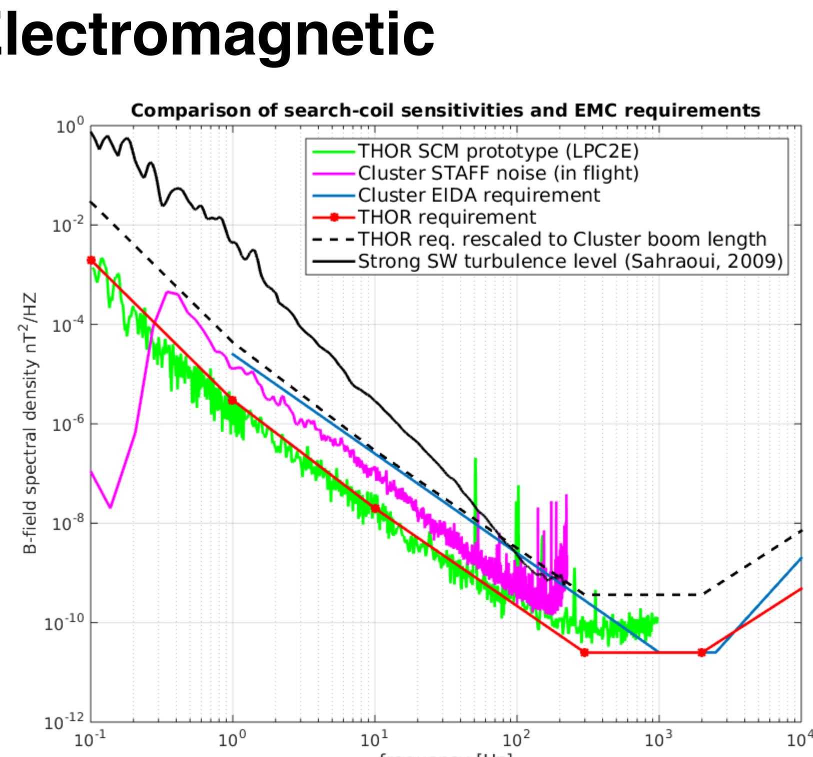
10 days of Burst data stored on board and scientist in the loop select the best events for data download.

4. Spacecraft



Top Bottom

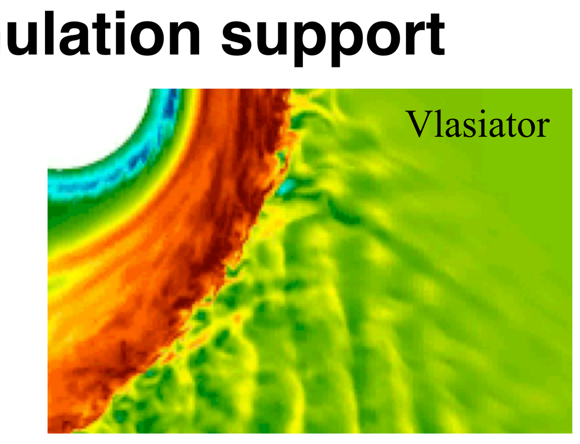
Electromagnetic

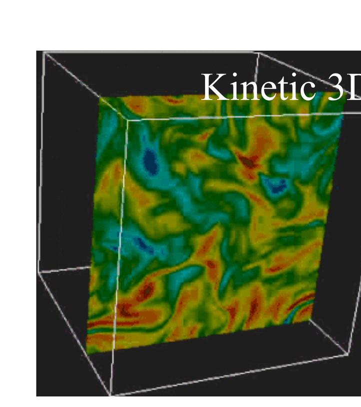


Main requirements:

- Surface charging (conductive s/c)
- potential of the spacecraft surface relative to the surrounding plasma environment
- Spacecraft DC Magnetic field below limits at magnetometer (MAG) outboard sensor
- Spacecraft generated AC magnetic field below limits at search coil (SCM) sensor position (see left figure)

Theory and simulation support





Codes available: HVM3D3V, iPIC3D, AstroGK, GENE, P3D, TFPC, Vlasiator, vpic-H3D, dHybrid, Vlem2D3V

http://thor.irfu.se