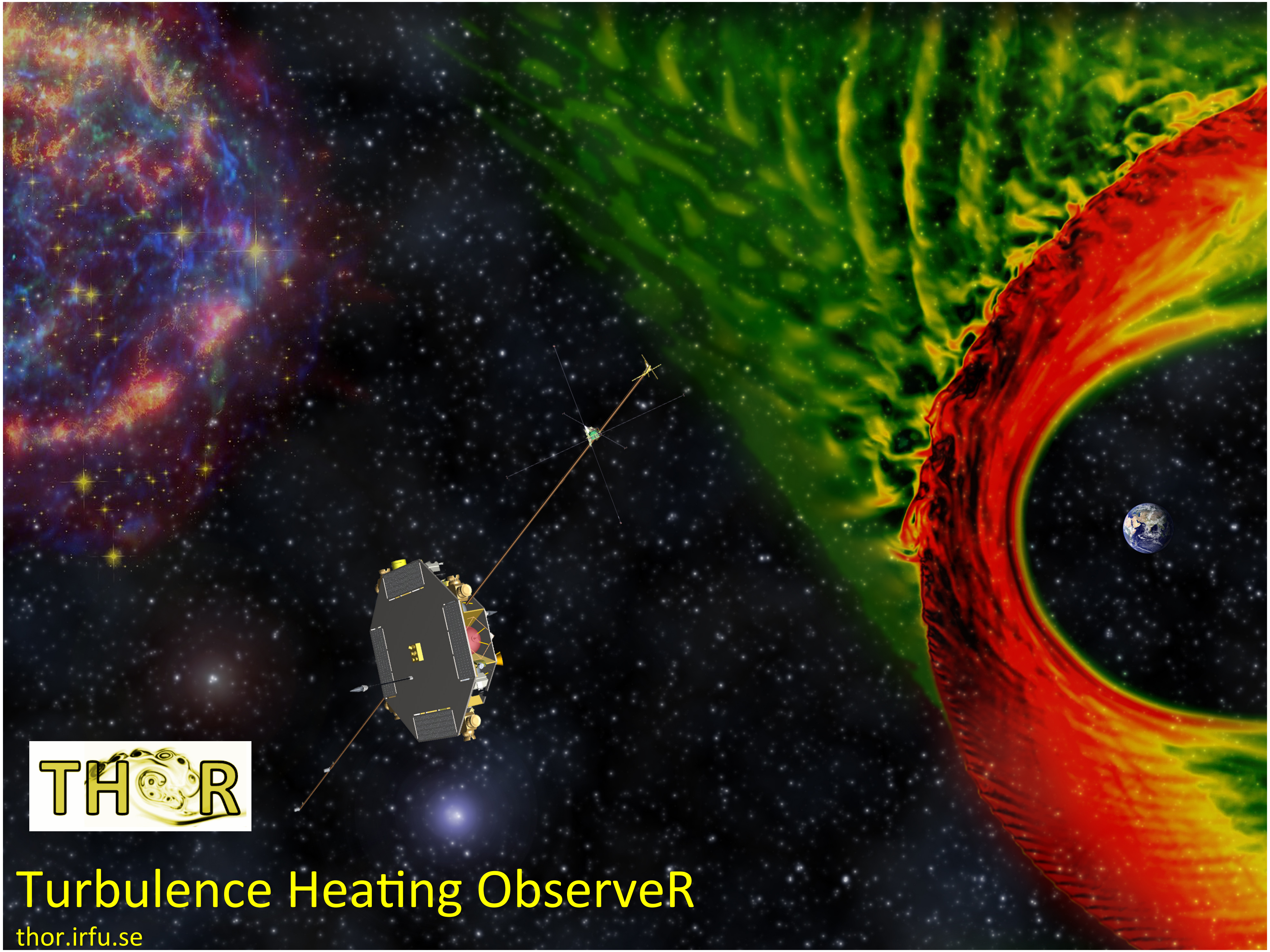
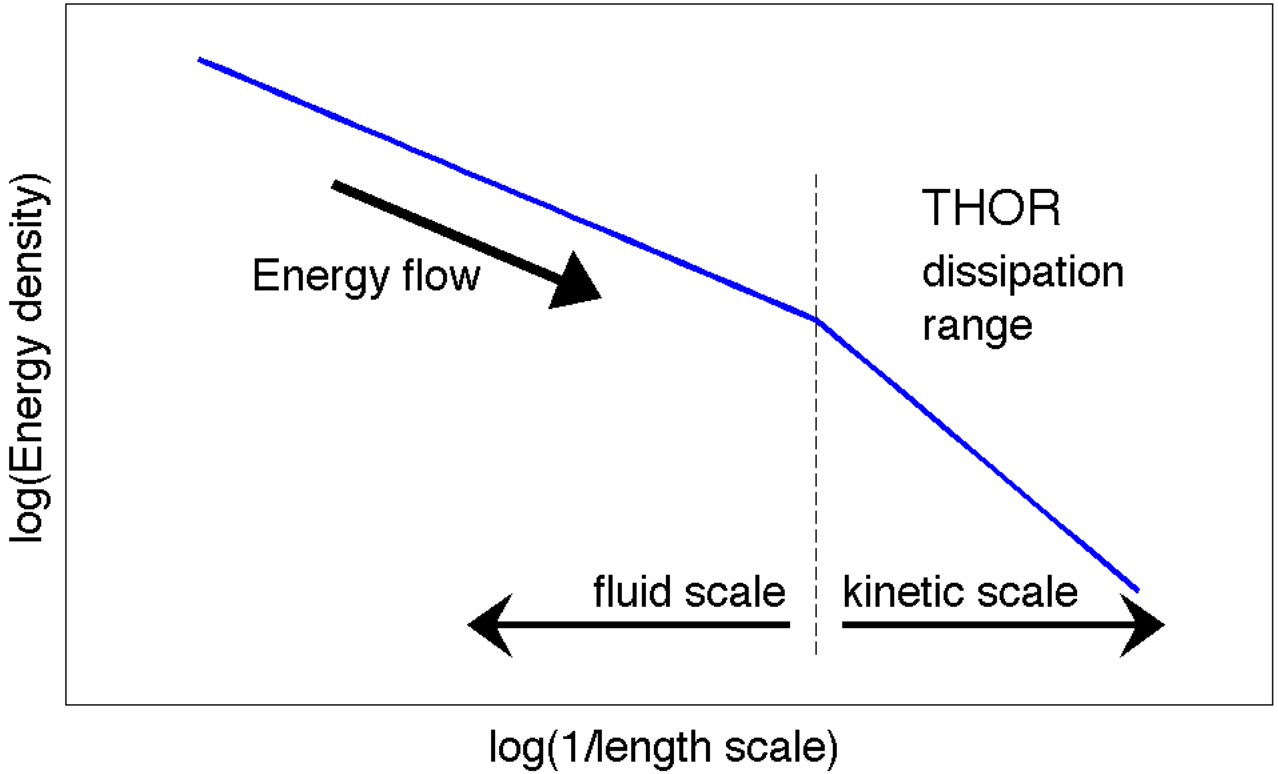
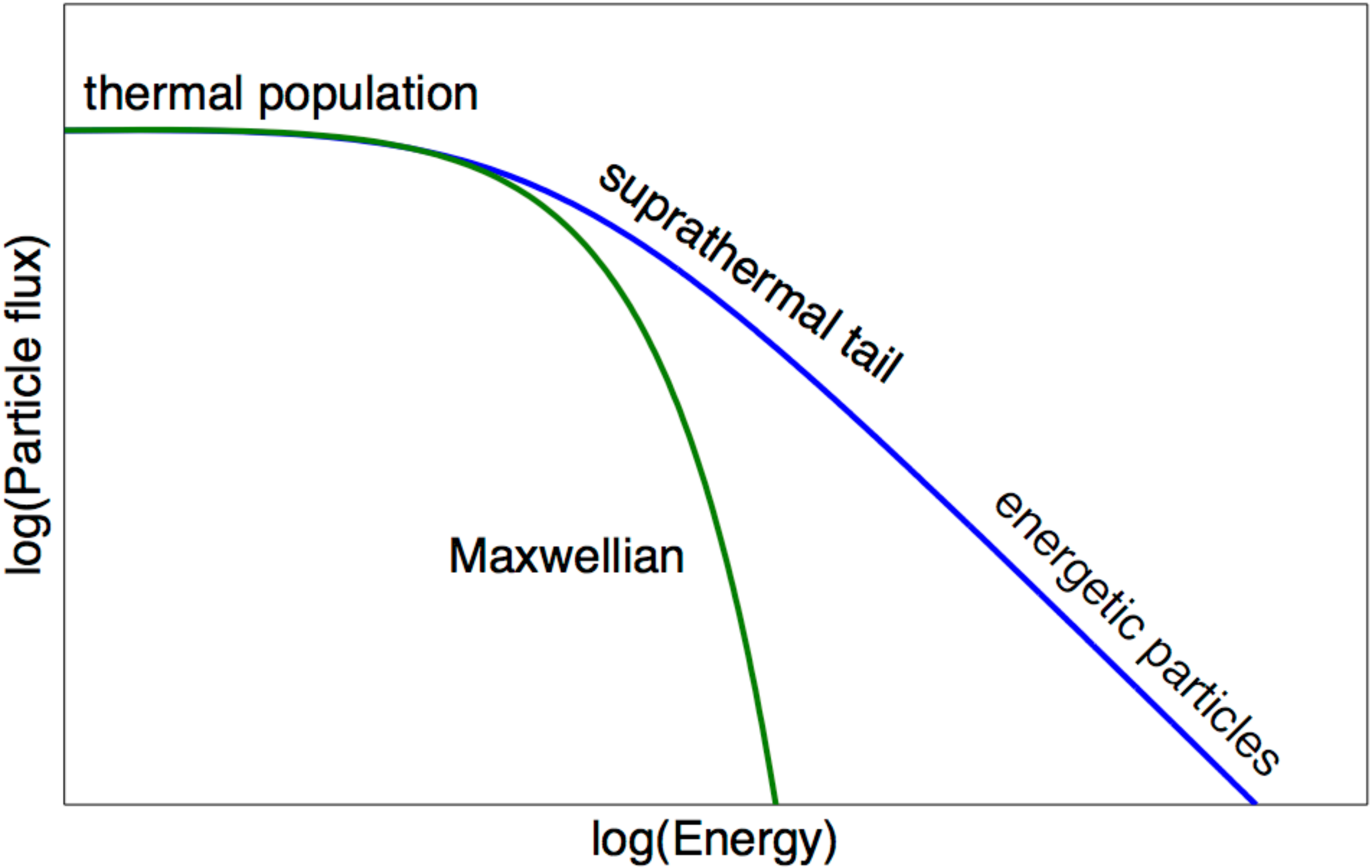

THOR
Turbulence Heating ObserveR
thor.irfu.se

Kinetic scales



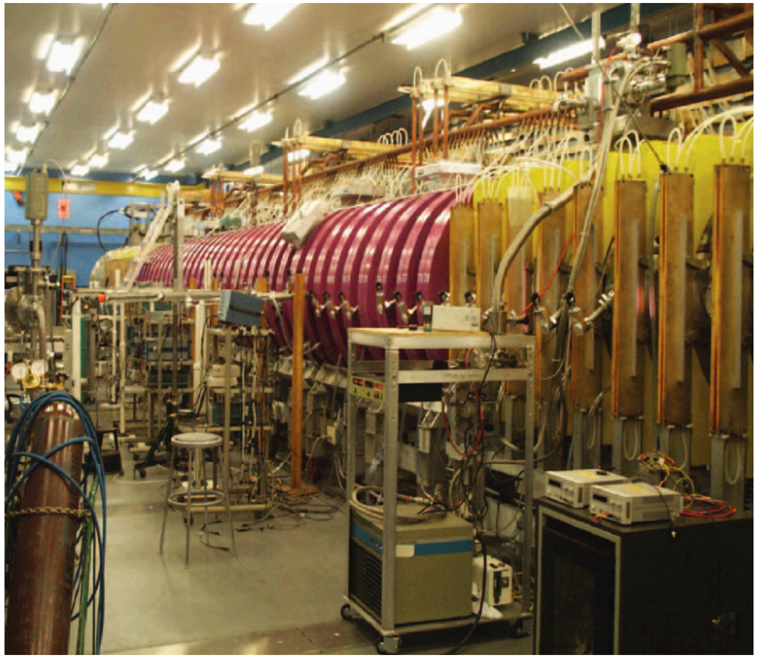
Particle energization



Turbulence laboratory

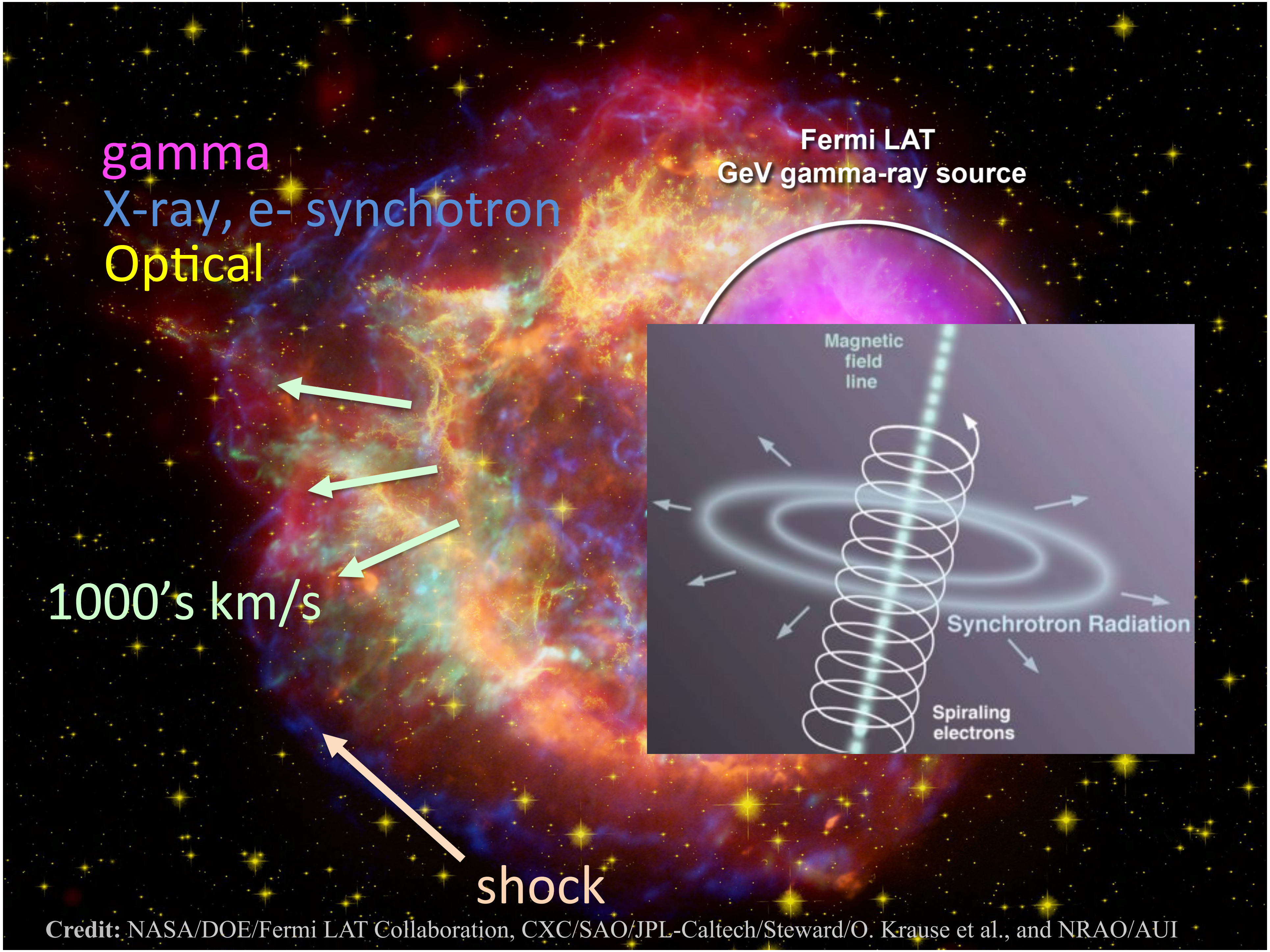
near Earth space

on ground



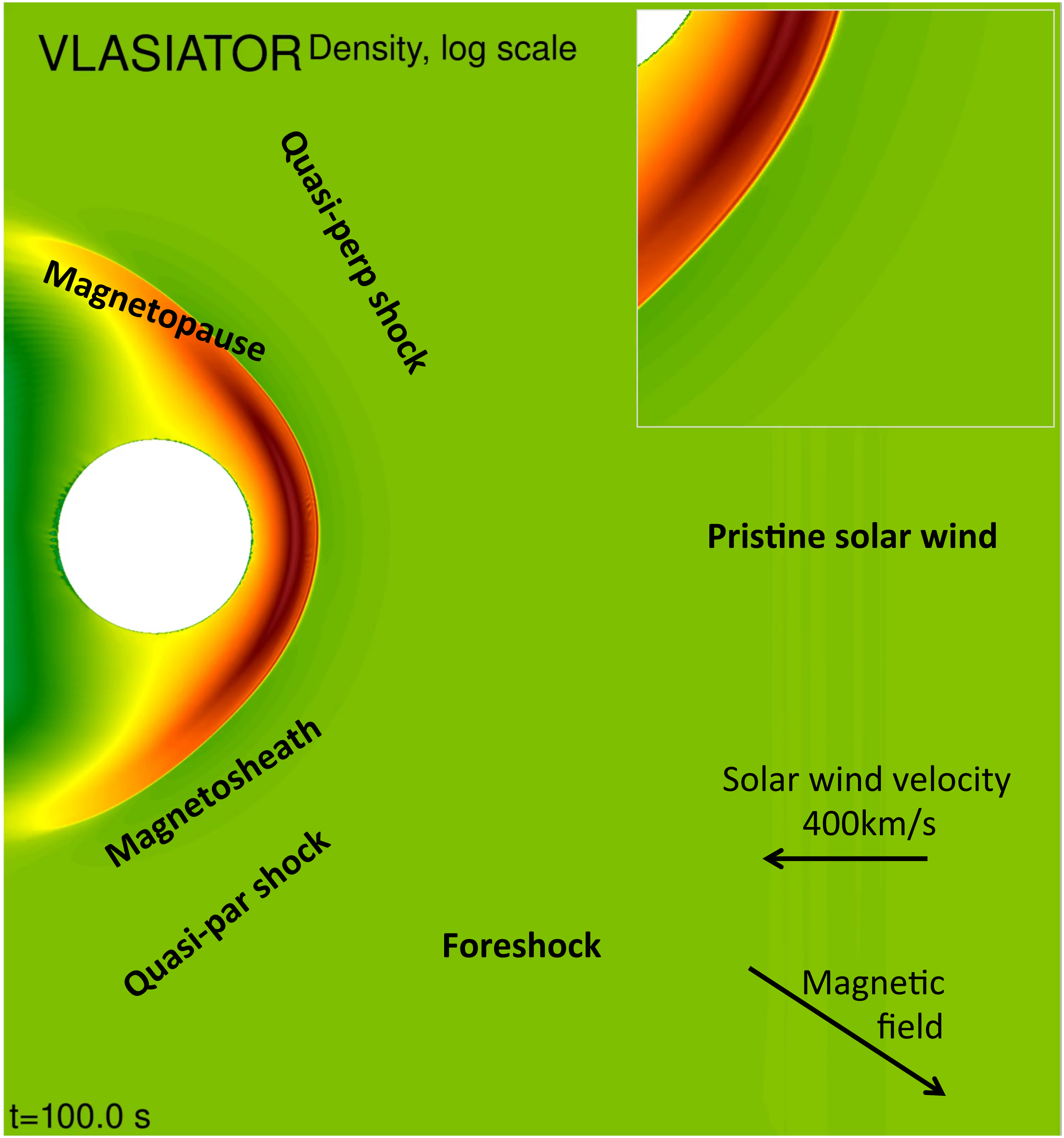
1 km electron scales 0.1 mm

Near Earth space is the best laboratory to study plasma energization in turbulence on kinetic scales

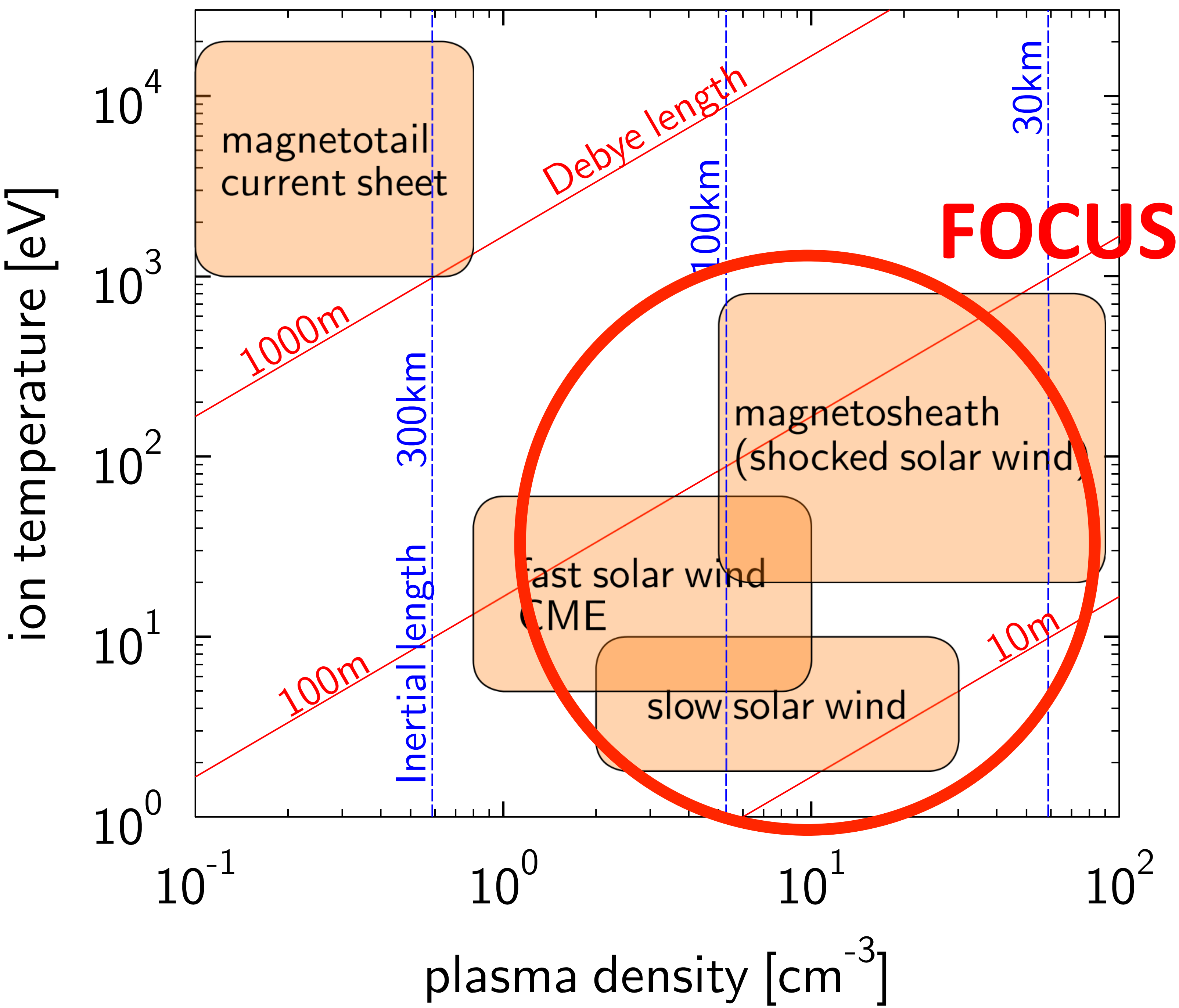

gamma
X-ray, e- synchotron
Optical
Fermi LAT
GeV gamma-ray source
Magnetic field line
Synchrotron Radiation
Spiraling electrons
1000's km/s
shock
Credit: NASA/DOE/Fermi LAT Collaboration, CXC/SAO/JPL-Caltech/Steward/O. Krause et al., and NRAO/AUI

Primary science targets

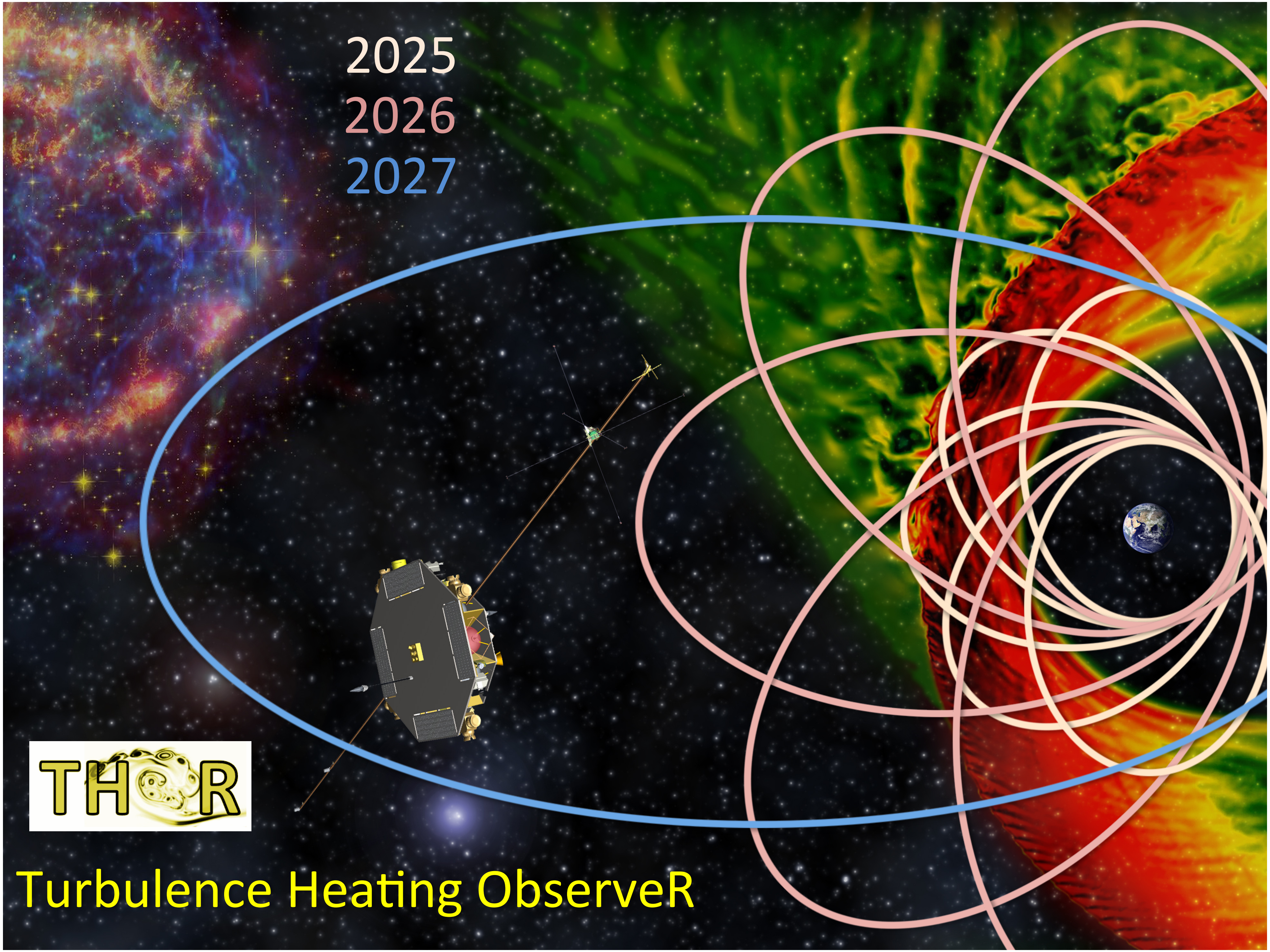
Pristine solar wind
Foreshock
Bow shock
Magnetosheath



Courtesy: M. Palmroth, FMI



FOCUS
magnetotail
current sheet
Debye length
1000m
100m
10m
300km
100km
30km
Inertial length
magnetosheath
(shocked solar wind)
fast solar wind
CME
slow solar wind
ion temperature [eV]
plasma density [cm^-3]
10^4
10^3
10^2
10^1
10^0
10^-1
10^0
10^1
10^2


2025
2026
2027
THOR
Turbulence Heating ObserveR

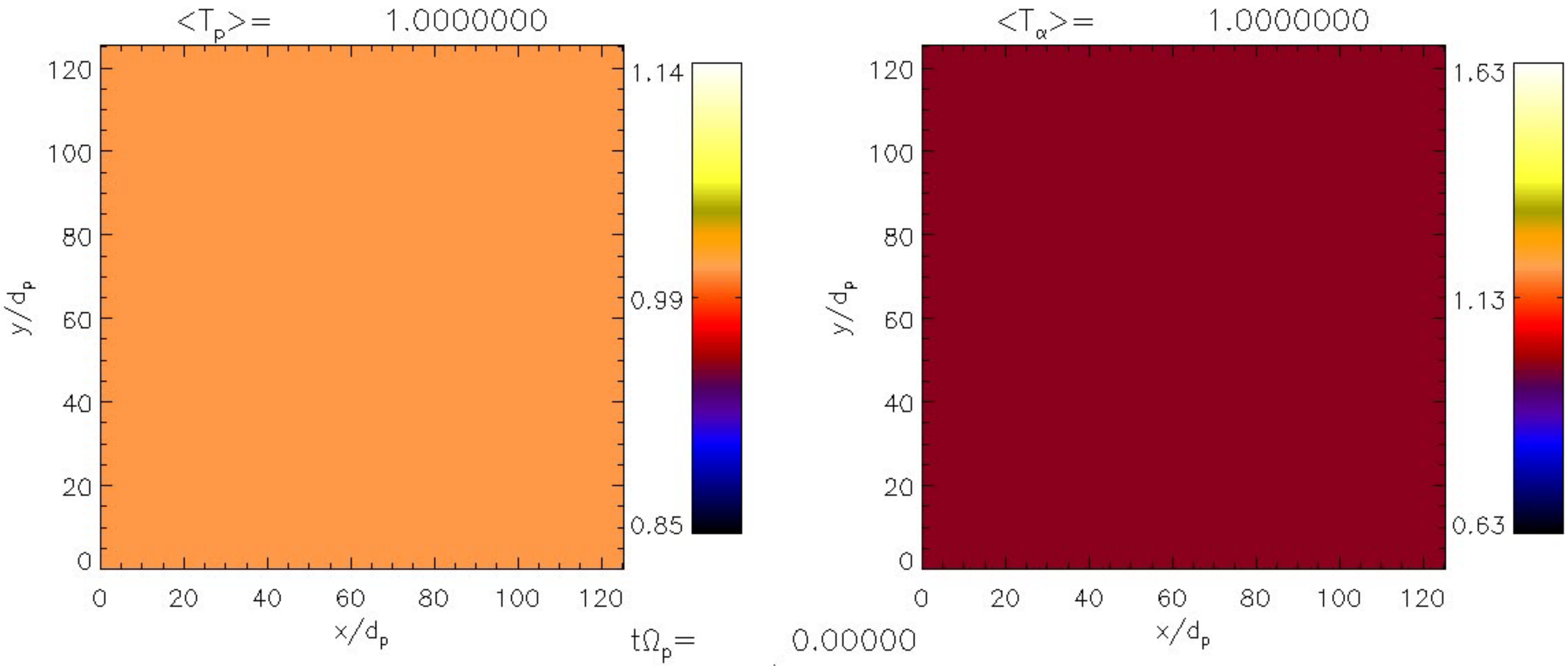
Science

Exploring plasma energization in space turbulence

- ✓ How is plasma heated and particles accelerated?
  - *Coherent structures & wave identification*
  - *Their effects on plasma*
- ✓ How is the dissipated energy partitioned?
  - *Electrons vs protons vs heavier ions*
  - *Heating vs. particle acceleration*
- ✓ How does dissipation operate in different regimes of turbulence?
  - *Pristine solar wind*
  - *Flow interaction regions*
  - *Shocks and sheath regions behind shocks*

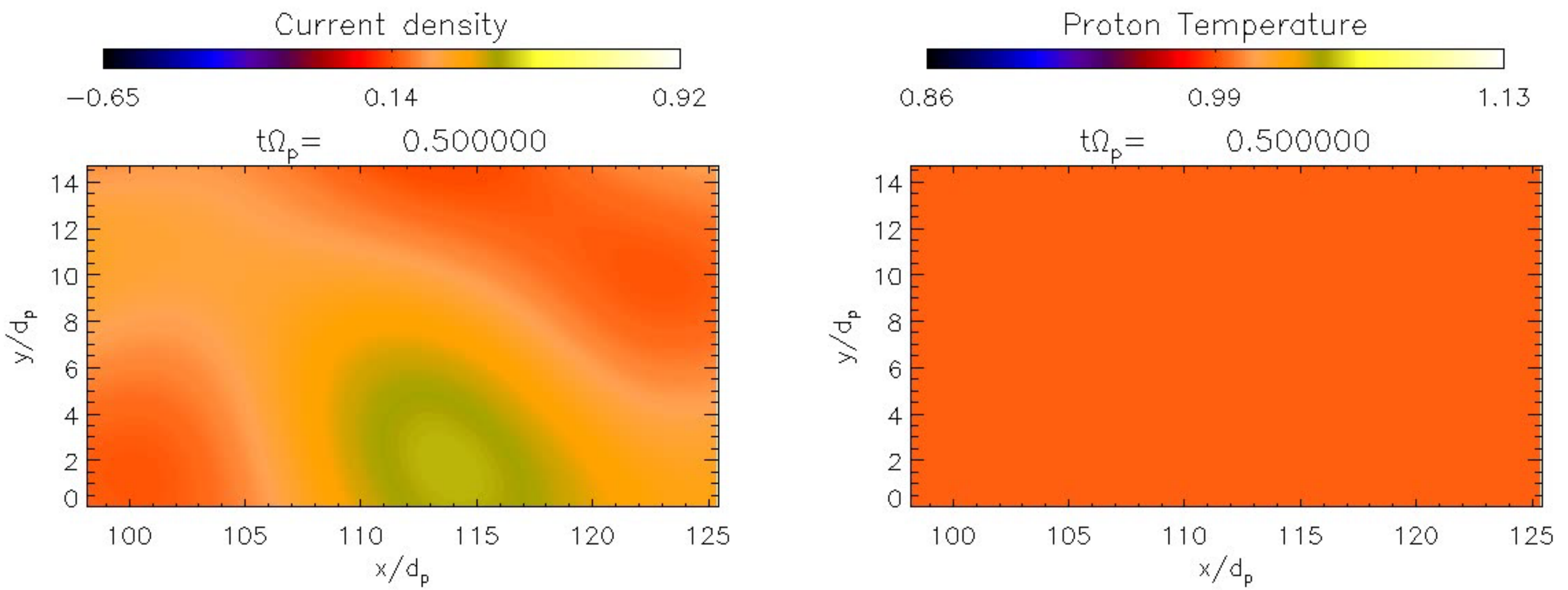
THOR - first dedicated mission!

Heating in kinetic scale turbulence



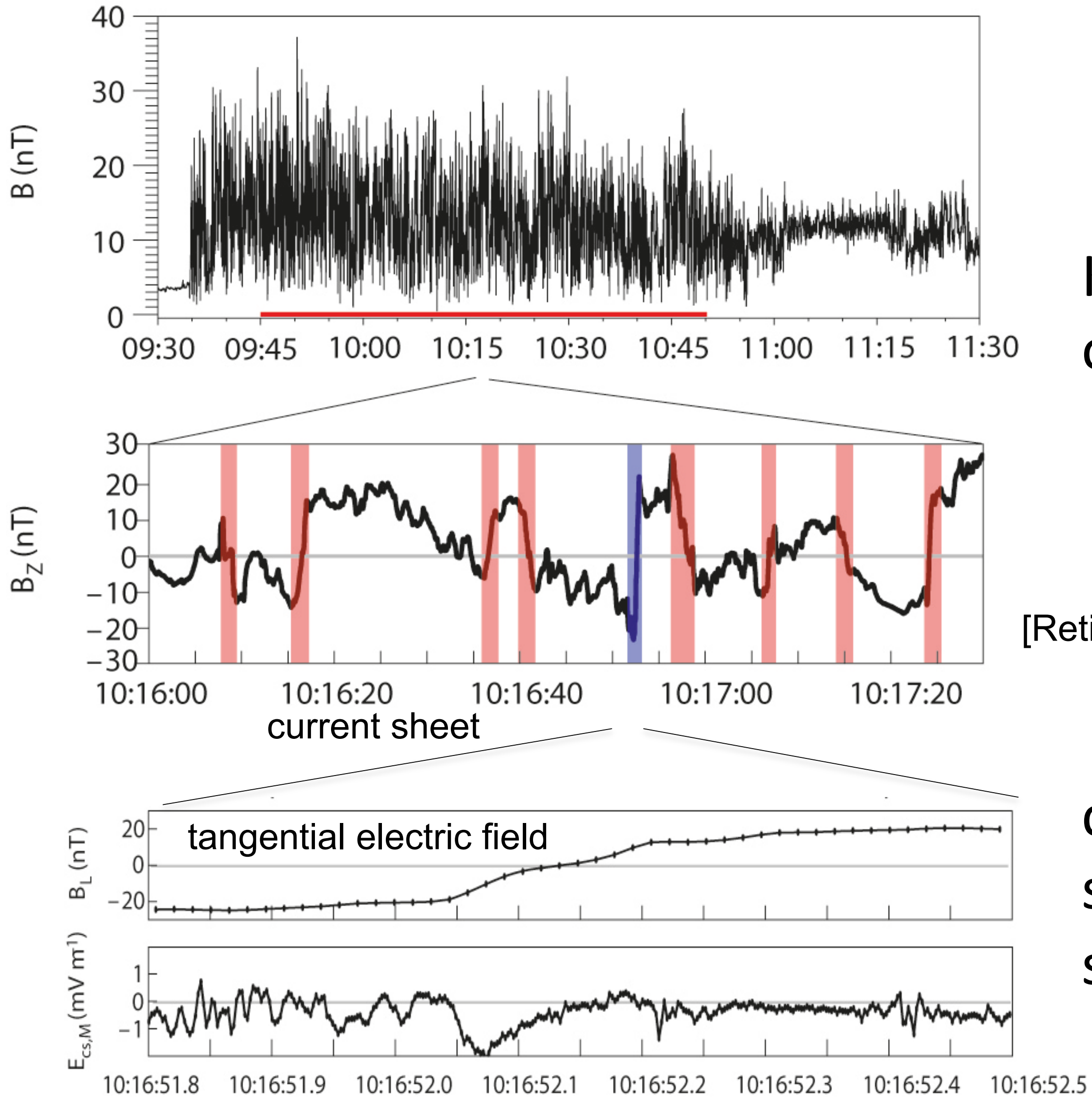
- ✓ different kinds of turbulent fluctuations contribute to heating (waves, coherent structures)
- ✓ heating is different among different ion species
- ✓ similar heating processes for electrons

Coherent structures numerical simulations



- ✓ Heating is localized in regions of strong current at kinetic scales.
- ✓ The structure is quasi-stationary over the time it would take a spacecraft to cross it.
- ✓ Phase velocity of structure can be estimated from single spacecraft measurements e.g. through conservation of E_{tang}.

Coherent structures in situ data



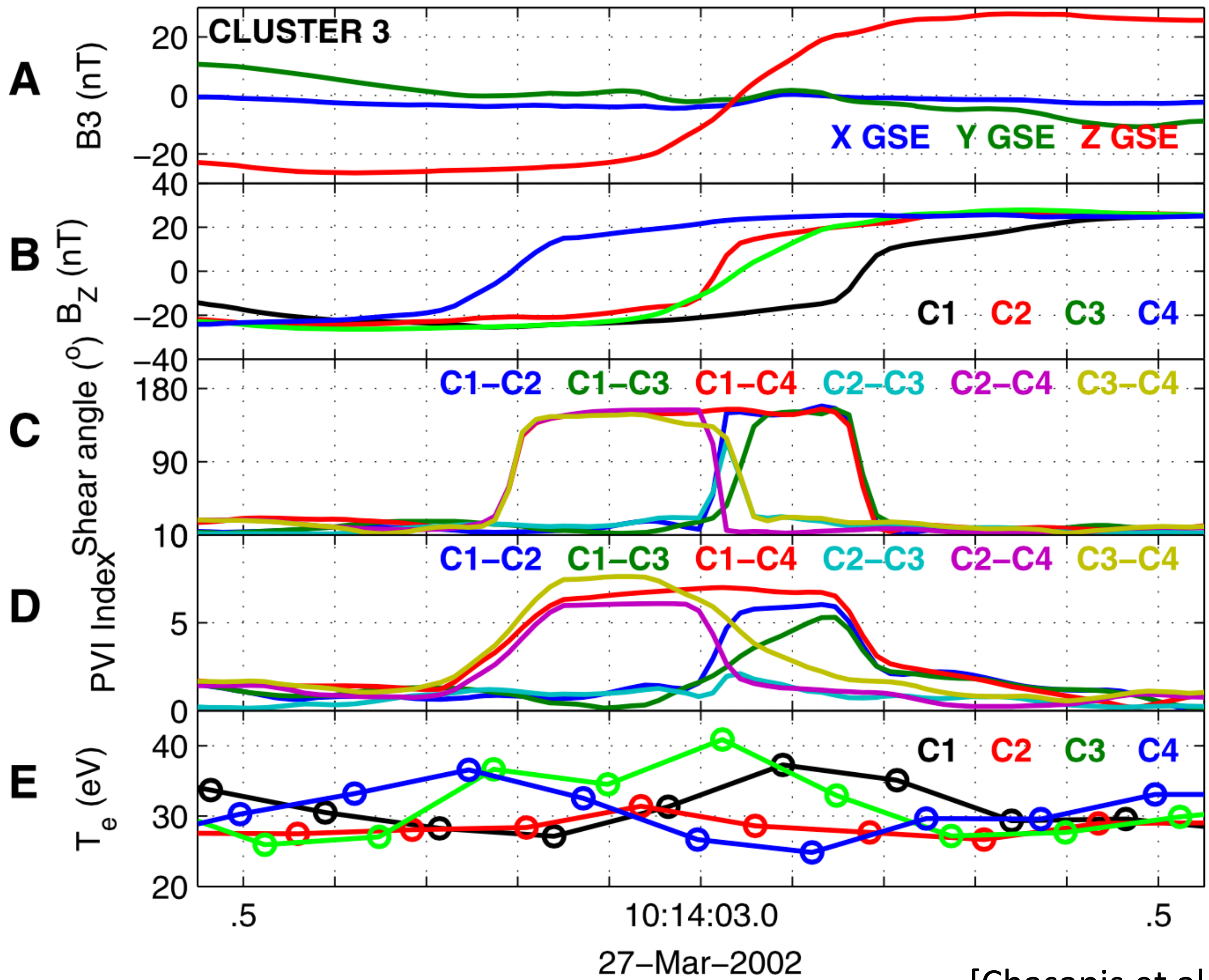
Kinetic scale current sheets observed within turbulence

[Retinò et al. , Nature Physics, 2007]

conversion from temporal to spatial scales from single spacecraft measurements

Resolution of particle measurements not adequate to quantify heating.

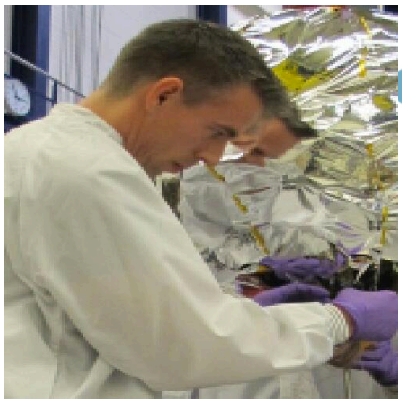
Current sheet in turbulence, e- heating



[Chasapis et al., 2015, APJL]

THOR

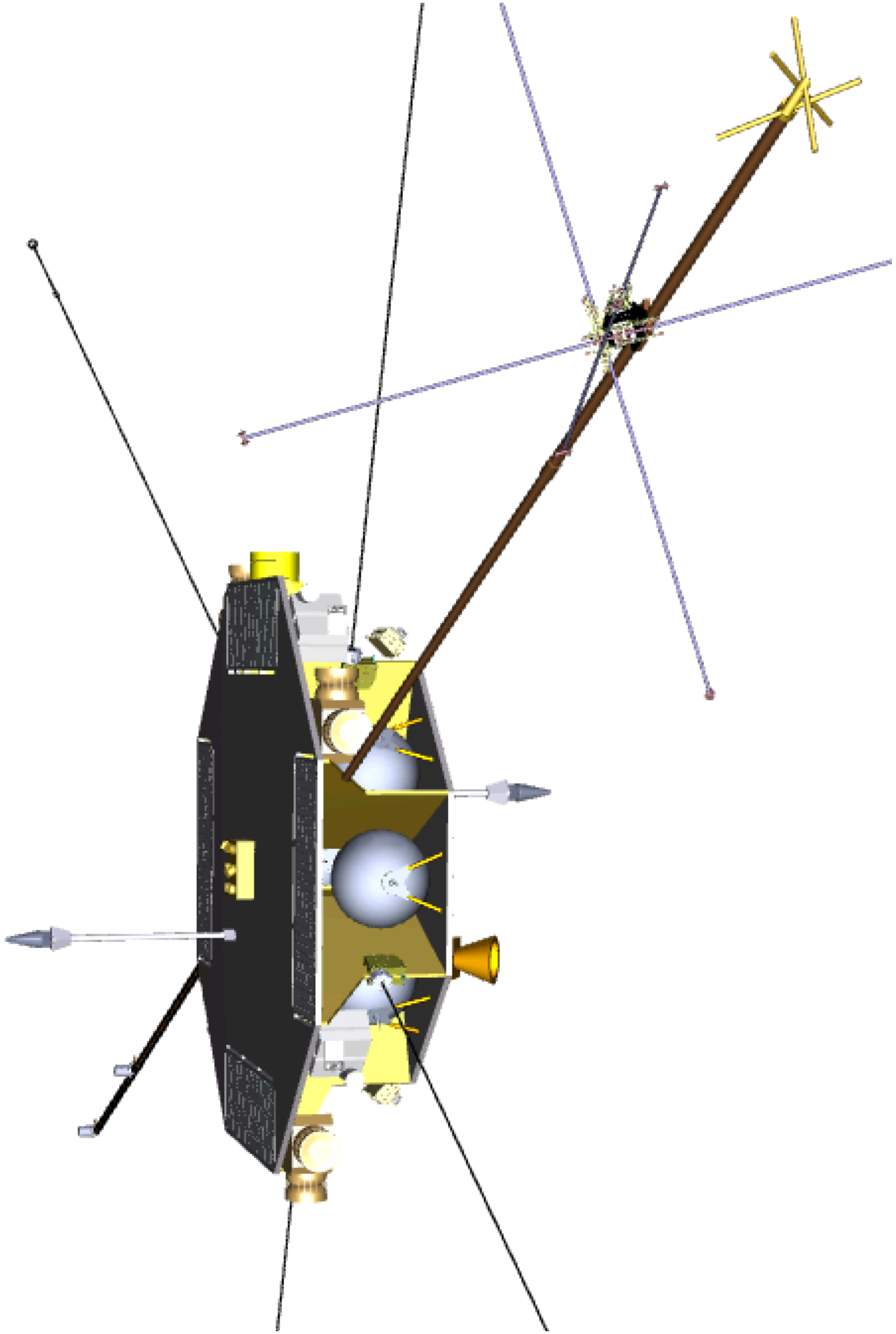
- Sun-pointer
- Slow spinner (2rpm)
- Advantages for E fields and for particle instruments

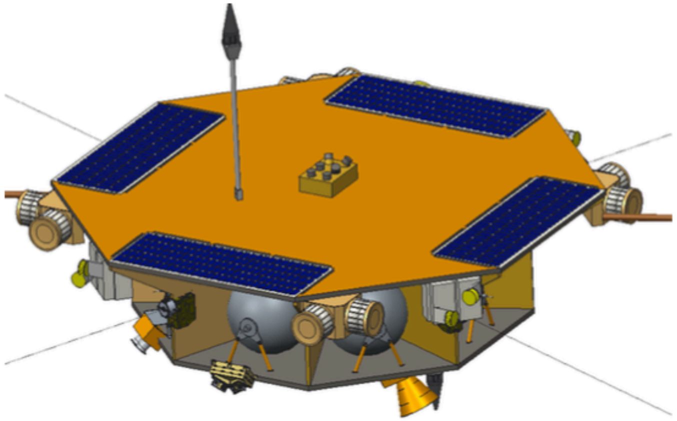


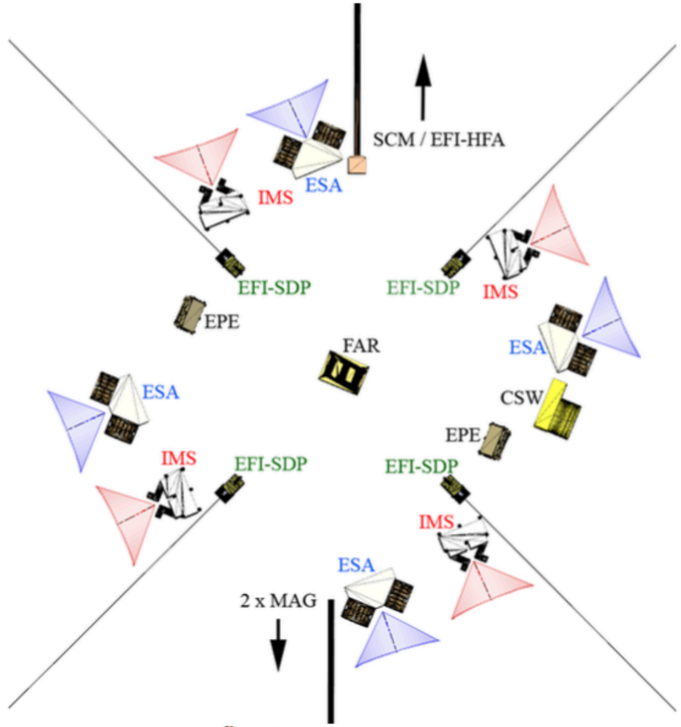
OHB SWEDEN

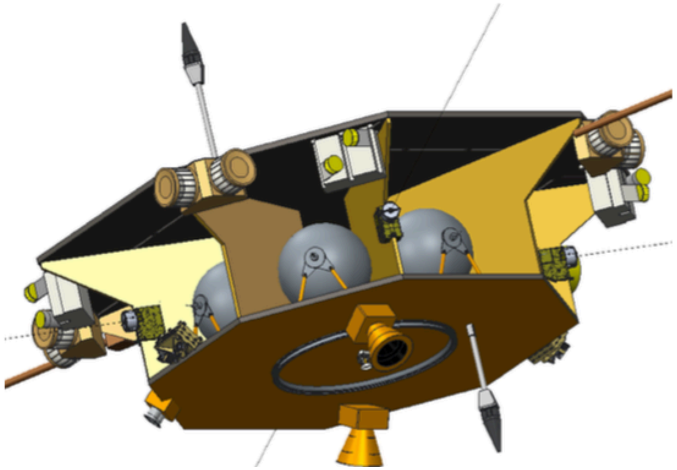
Mission profile

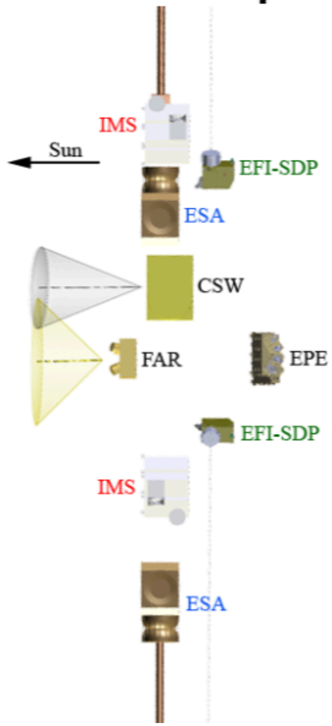
Eric Clacey
OHB Sweden






SCM / EFI-HFA
ESA
IMS
EFI-SDP
EFI-SDP
IMS
EPE
FAR
ESA
ESA
CSW
EPE
IMS
EFI-SDP
EFI-SDP
IMS
ESA
2 x MAG



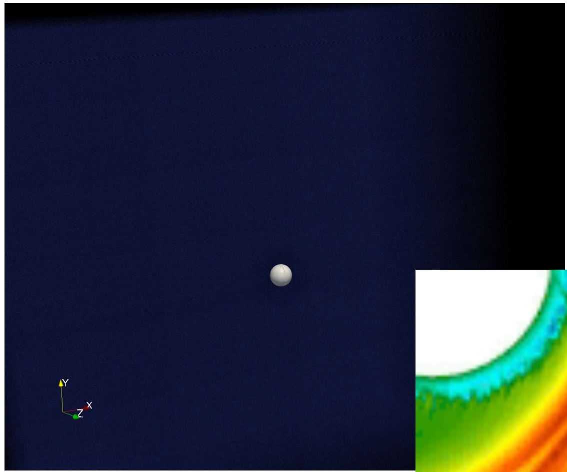

IMS
Sun
EFI-SDP
ESA
CSW
FAR
EPE
EFI-SDP
IMS
ESA

Mature payload

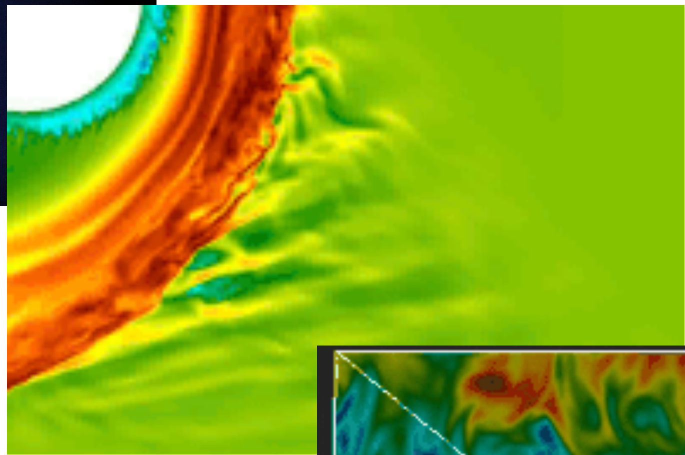
	Instrument	Measurement	Teams (PI, Co-PI, *Lead-CoI*)
FIELDS	**MAG**	B field DC	IWF(AU), ICL(UK)
	SCM	B field AC	LPP(FR), LPC2E(FR)
	EFI	E field DC/AC	IRF(SE), SSL(US), *SRC-PAS(PL), KTH(SE)*
	FWP	E&B data products	IAP(CZ), SRC-PAS(PL), *U.Sheffield(UK), LESIA(FR)*
PARTICLES	**ESA**	e^- spectrometer	MSSL(UK), NASA/GSFC(US)
	CSW	Cold solar wind ions	IRAP(FR), BIRA-ISAB(BE)
	IMS	H^+, He^{++}, He^+ ,O^+	LPP(FR), UNH(USA), *ISA/JAXA(JP), MPS(DE)*
	PPU	Particle data products	INAF-IAPS(IT)
	FAR	Faraday cup	MFF(CZ)
	EPE	Energetic particles	IEAP(DE), U.Turku(FI)

Single s/c with highest resolution field and particle measurements ever, to satisfy the THOR science requirements!

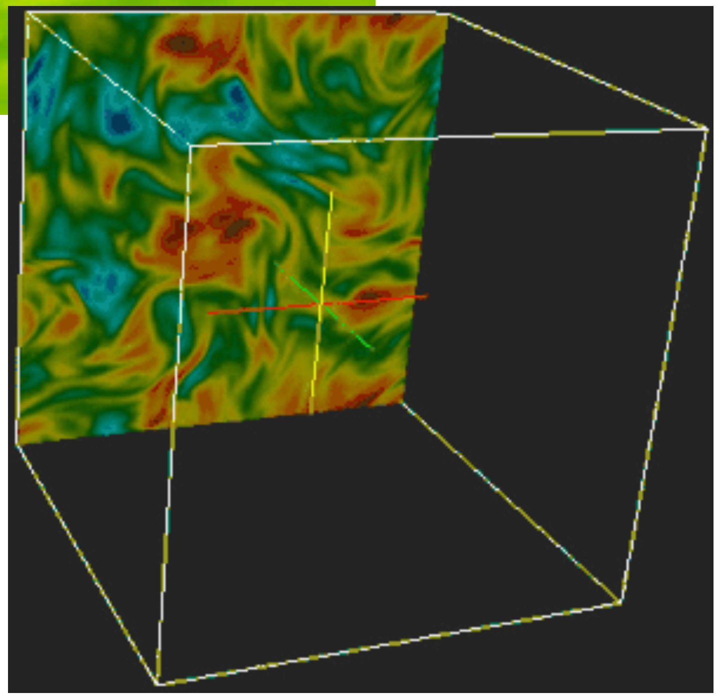
Numerical simulations in support of THOR



Global 3D



Global 2D



Kinetic 3D

- HVM3D3V
- iPIC3D
- AstroGK
- GENE
- P3D
- TFPC
- Vlasiator
- vpic-H3D
- dHybrid
- Vlem2D3V

THOR timeline

- ✓ 2015-01-15 the proposal submitted to ESA
- ✓ 2015-06-04 THOR selected for study phase
- ✓ 2015-06-11 kick-off of internal ESA phase 0 study.
- ✓ 2015 fall the end of phase 0.
- ✓ 2016 phase A study
- ✓ 2016 kick-off workshop of THOR
- ✓ 2017 spring the final down-selection
- ✓ 2026 launch

THOR science supporting team

200+ scientists from different plasma communities

space, theory, simulations, astro and laboratory

http://thor.irfu.se

New members welcome!

Thank you!