Debye: A thermal electron telescope
ESA F-Class Mission Proposal

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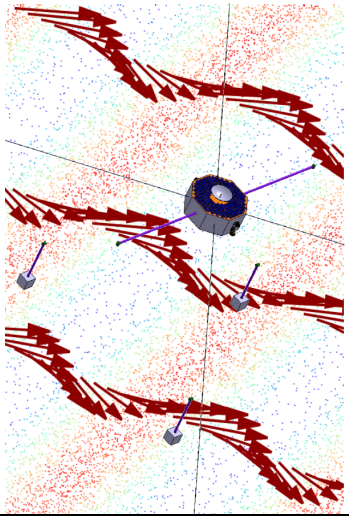
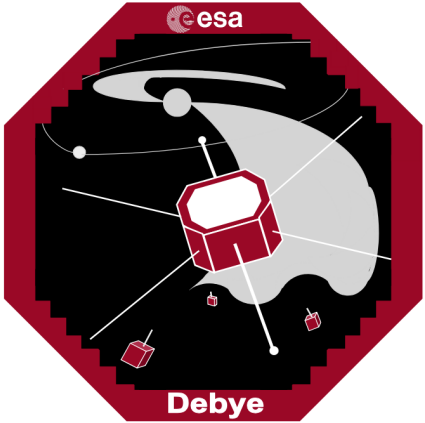
Exploring the smallest scales
ESA F-Class proposal *Debye*



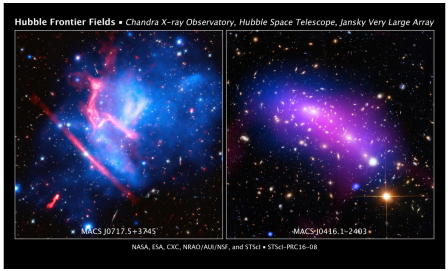
- *Debye* is a UCL-led proposal for ESA's F-Class programme.
- Science goal: *How are electrons heated in space and astrophysical plasmas?*
- In competition with five other F-Class candidates.
- Full proposal due: 20 March 2019.



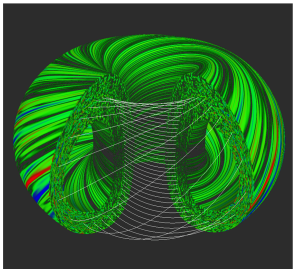
Three steps required to answer our science question:

- What is the nature of waves and fluctuations on electron scales in space plasmas?
- How do electron-scale fluctuations rapidly transfer energy to the electrons?
- How is energy partitioned, and how does energy transfer depend on plasma parameters?

Why is this important?
Relation to astrophysics and lab plasma physics



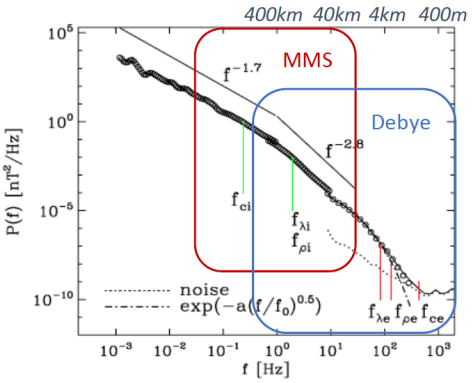
Cooling-flow problem: Centres of galaxy clusters are hotter than expected. Thermal electron conduction is possible explanation.



(Credit: G. Hammett, GS2)

Turbulence in fusion and lab plasmas is mostly electrostatic.

These systems cannot be measured directly!



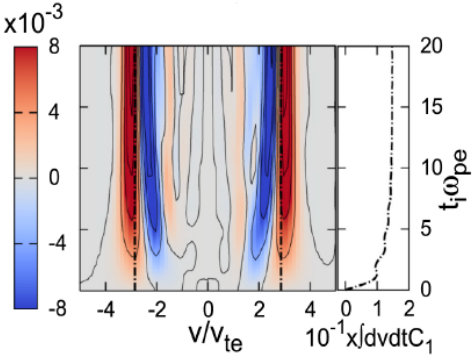
(After Alexandrova et al., 2009)

Taylor's hypothesis:

$$P_f(f) = \int P_{3\mathrm{D}}(\boldsymbol{k})\,\delta(2\pi f - \boldsymbol{k}\cdot\boldsymbol{U} - 2\pi f_0)\,\mathrm{d}^3k$$

- Convected structures at small (electron) scales appear at high frequencies in the spacecraft frame.
- Overcome Taylor's hypothesis through multi-point measurements.
- Constraints on temporal and spatial resolution to focus on electron scales.

Colour axis: $\int_0^{t_i} C_1(v, t_i')\mathrm{d}t_i'$



(Klein and Howes, 2016)

Particles only gain or lose energy through interactions with the electric field.
Define correlation as

$$C_1(v, t_i) = \frac{1}{N} \sum_{j=i}^{i+N} q \frac{v^2}{2} \frac{\partial \delta f(v, t_j)}{\partial v} E(t_j).$$

This diagnostic requires electric-field (E) and detailed particle (δf) measurements.

The spacecraft
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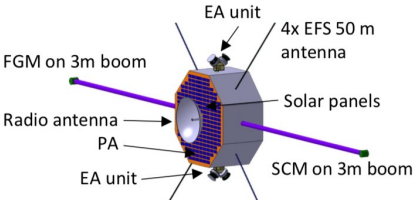

- Mother spacecraft will measure electric/magnetic fields, electron distributions, proton properties.
- 3 Daughter spacecraft will measure high-frequency magnetic-field fluctuations.
- Scale coverage: 300 m to 3,000 km.

The instrumentation
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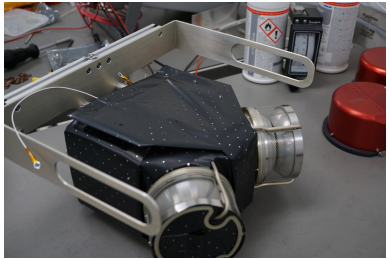

SO EAS (UCL/MSSL)

PSP SCM (CNRS/LPC2E)

- Electron analyser.
- Search-coil magnetometer.
- Electric-field suite.
- Fluxgate magnetometer.
- Proton analyser.

- Electron-scale plasma processes are not well understood.
- Important implications for space, astrophysical, and laboratory plasmas.
- *Debye* is a highly focused mission, designed to answer the electron-heating problem.

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Hardware partners: UCL/MSSL (UK), CNRS (France), LPP (France), CAS (Czech R.), PAN/CBK (Poland), IRFU (Sweden), NASA/GSFC (US), IWF (Austria), Imperial College (UK), TU Braunschweig (Germany), Charles U. (Czech R.), INAF (Italy), JAXA/ISAS (Japan)

Literature

O. Alexandrova, J. Saur, C. Lacombe, A. Mangeney, J. Mitchell, S. J. Schwartz, and P. Robert. Universality of Solar-Wind Turbulent Spectrum from MHD to Electron Scales. *Physical Review Letters*, 103(16):165003, October 2009. doi: 10.1103/PhysRevLett.103.165003.

K. G. Klein and G. G. Howes. Measuring Collisionless Damping in Heliospheric Plasmas using Field-Particle Correlations. *Astrophys. J. Lett.*, 826:L30, August 2016. doi: 10.3847/2041-8205/826/2/L30.