

Research Observatory for Atmospheric Responses to Sun-magnetosphere interactions (ROARS)

PI Ravi Desai & ROARS consortium

The Science

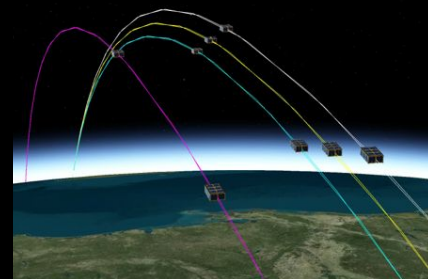
Q1: How much energy and momentum is transported from the magnetosphere into the upper atmosphere?

Q2: How is energy and momentum redistributed within the ionosphere-thermosphere system?

- **Satellites:** Four identical Micro-Satellites in formation
- **Orbit:** Polar, precessing, altitude 500 km 200 km
- **Lifetime:** 24-36 Months
- **Mass:** Payload Mass < 20 kg, each Satellite < 100 kg



The Mission



- Progressed through ESA Phase 0 study & UoPortsmouth CDF study
- Shortlisted to Stage 2 as an ESA Fast mission: F3



Left: OpenCosmos MicroSat Qualification Model, Right: Aurora visible from the ISS

The Instruments

1. Magnetometry

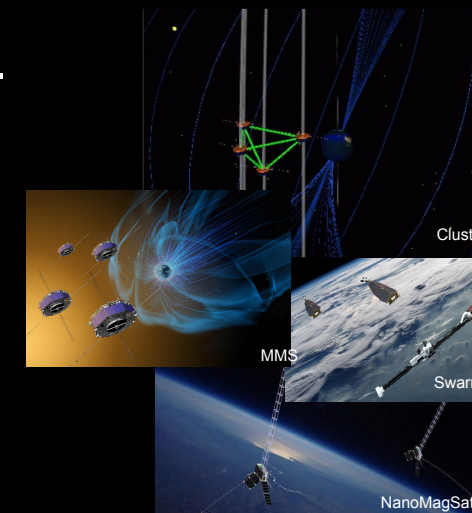
- Dual fluxgate magnetometers (IWF)
 - Quantum optically pumped magnetometer (CEA)

2. Energetic Particle Precipitation

- Energetic Particle (EPE) instrument (UCLA, RAL, Kiel, UTU)
- Low-energy Ion and Electron Analyzer (IRF)

3. Ionosphere & Thermosphere

- Multi-Needle Langmuir Probe (EIDEL/Oslo)
- Ion Drift and Energy Analyzer (Calgary)
- Ion & Neutral Mass Spec (Bern)

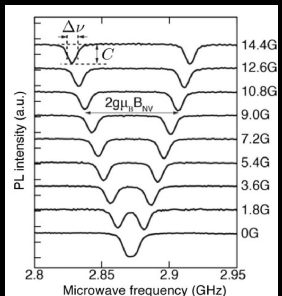


Nitrogen Vacancy in Diamond Magnetometers

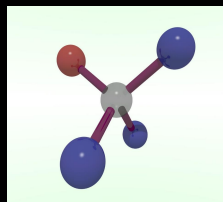
Ravi Desai, Gavin Morley, Colin Stephen, Patrick Brown, Stuart Graham, Alex Newman, Irene Ruiz-Rodriguez

Green excitation □

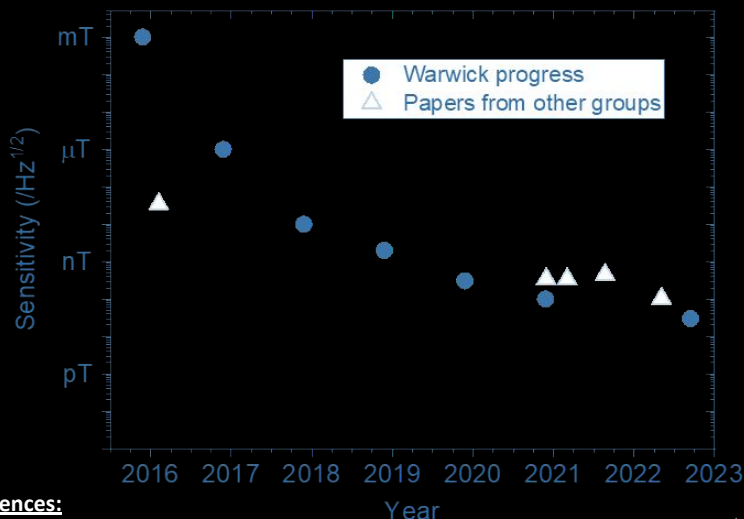
1. Spin polarization
2. Spin-dependent photoluminescence



MW Doherty et al., Physics Reports 528, 1 (2013)



- Optically detected magnetic resonance (ODMR) used to measure magnetic fields at NV centres
- Returns field projection along each four orientations of the NV point defect



References:

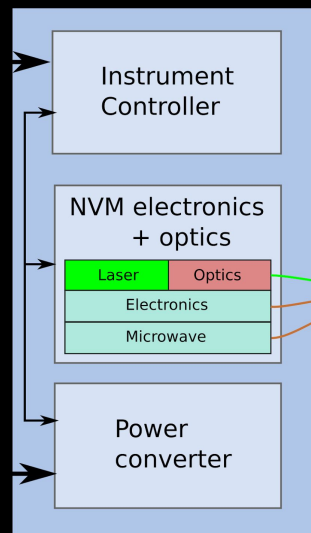
- [1] S. M. Graham, et al., *Fiber-Coupled Diamond Magnetometry with an Unshielded Sensitivity of 30 pT/ $\sqrt{\text{Hz}}$* , Phys. Rev. Applied 19, 044042 (2023).
- [2] R. Kashtiban et al., *Nitrogen Vacancy Center in Diamond-Based Faraday Magnetometer*, arXiv:2411.10437, (2025).

Critical Gap:

- Reliable absolute measurements of the magnetic field: *dual sensor designs*

NV magnetometers:

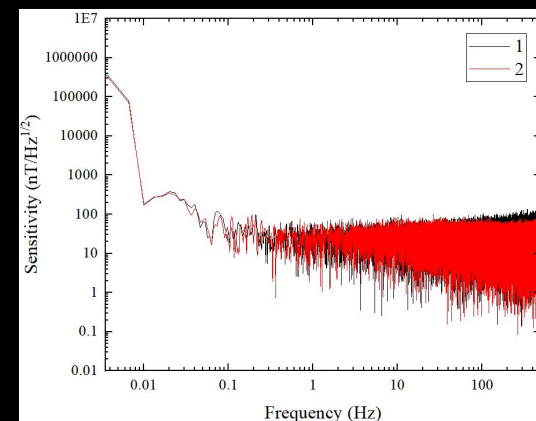
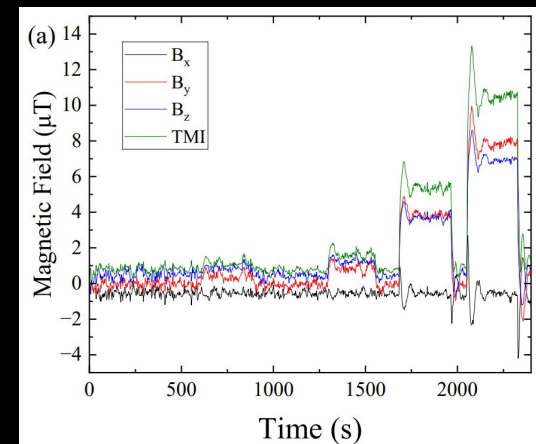
- Absolute vector measurement
- Large dynamics range (e.g. Earth field mapping through to ISM)
- Temperature insensitive



- Solid state, rugged, radiation hard
- Ultra-light sensor heads at end of boom

- Full system: <1 litre

Preliminary Results

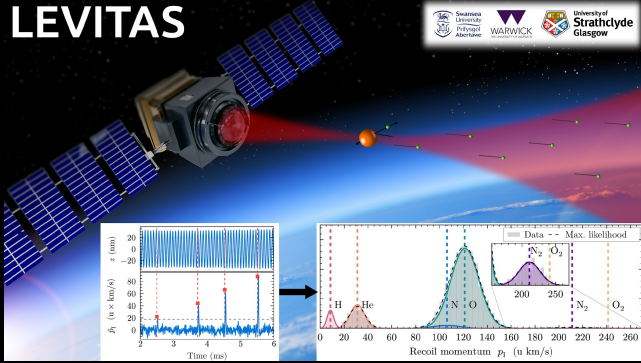


LEVITAS: Levitodynamics for Individual Particle Sensing in Space

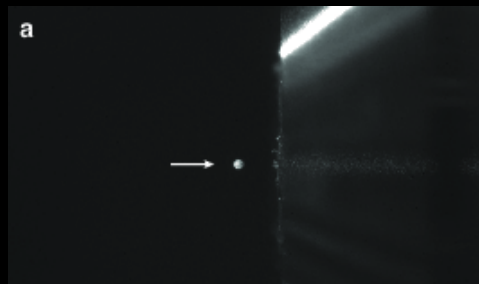
Ravi Desai, Animesh Datta, James Bateman, Daniel Oi, Bengt Eliason, Rafal Gajewski

Optomechanics

LEVITAS



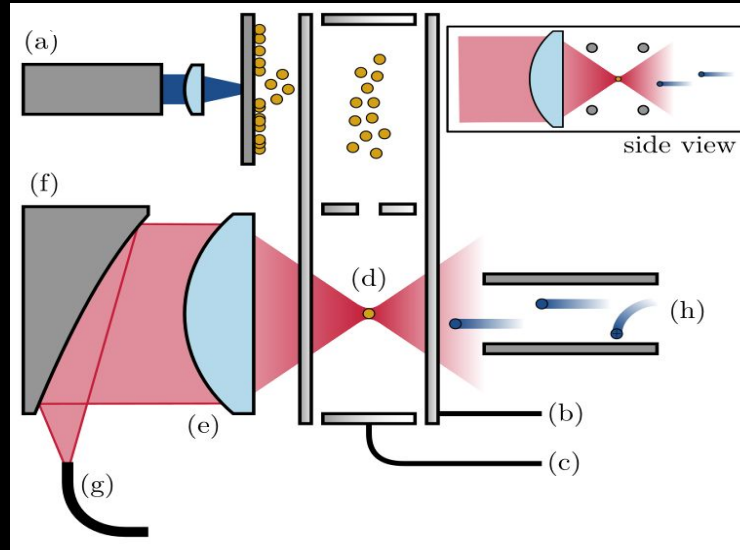
- MAQRO was proposed to probe quantum collapse [1]
- Here, a dielectric nanoparticle is exposed to the ambient medium outside the spacecraft.



Photograph of a nanoparticle held at the focus of a high NA objective lens [2]

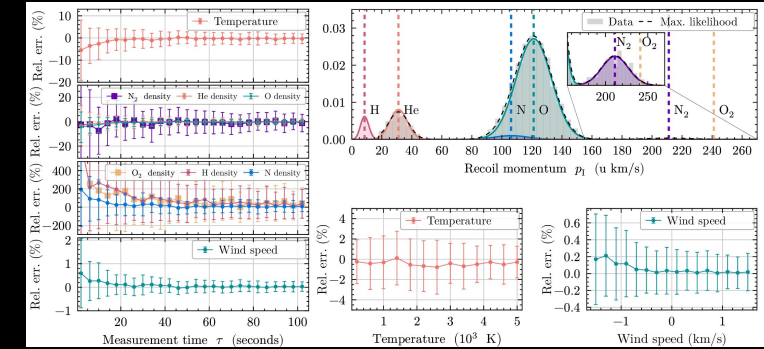
Critical Gap

- Current instruments use indirect methods to detect neutrals & extensive calibration
- LEVITAS provides a highly sensitive solution to directly measure particles in space
- Compact sensor head less than 2u, TRL



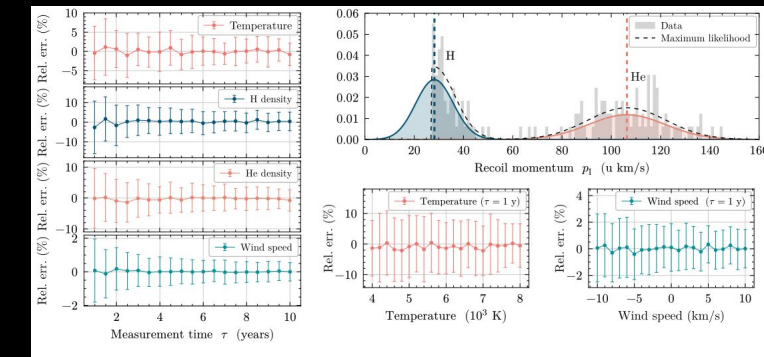
LEVITAS sensor head: Nanoparticles are ejected from a metallic substrate using a pulsed laser via laser-induced acoustic desorption

Thermosphere @ 600 km



Inference of parameters in LEO at 600 km altitude

Interstellar neutrals @L2



Inference of parameters of the interstellar medium observed at L2