Meteoroid Impact Detections by the Gaia spacecraft at L2

Gaia Flight Control Team
European Space Operations Centre
Germany

Meteoroids 2016

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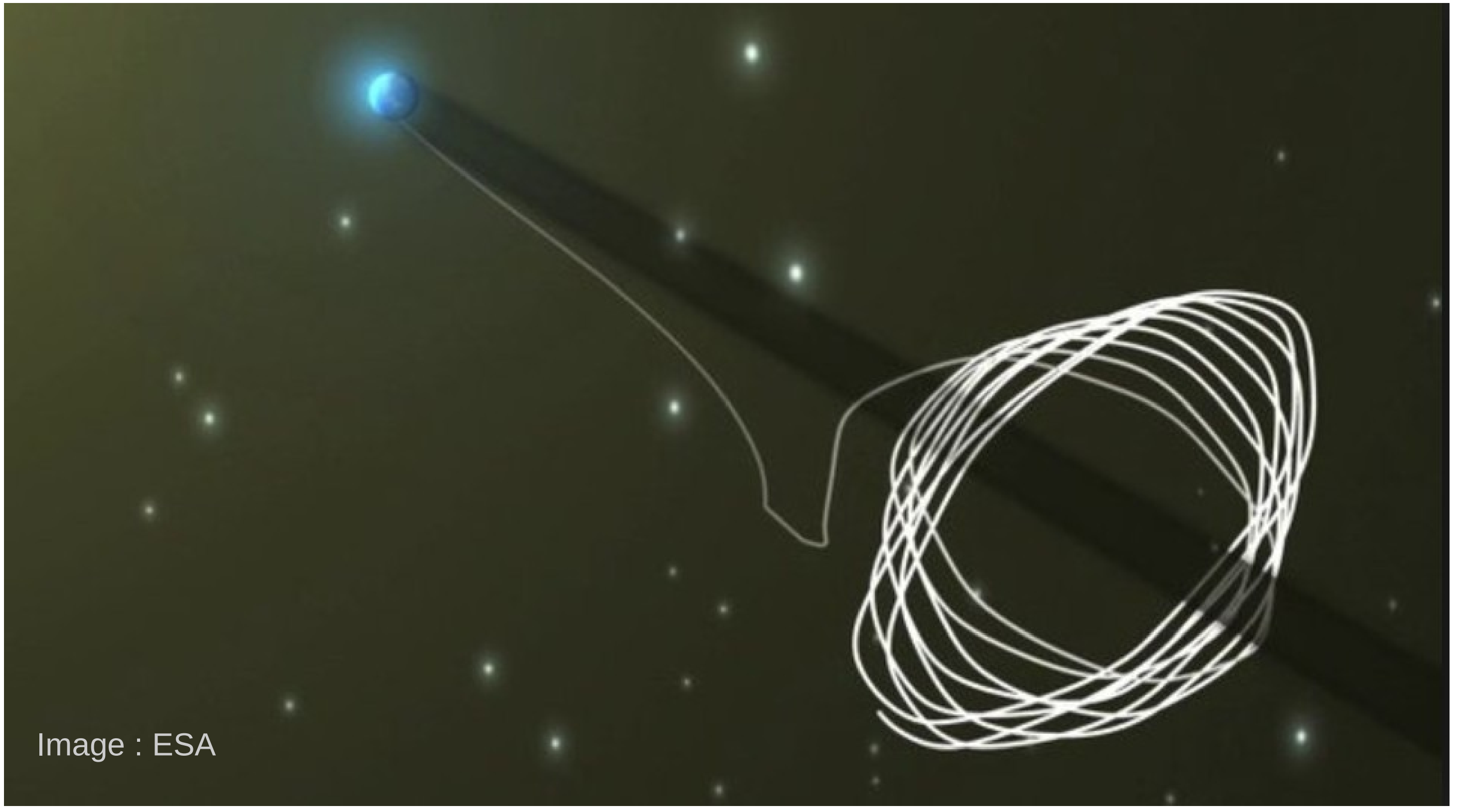
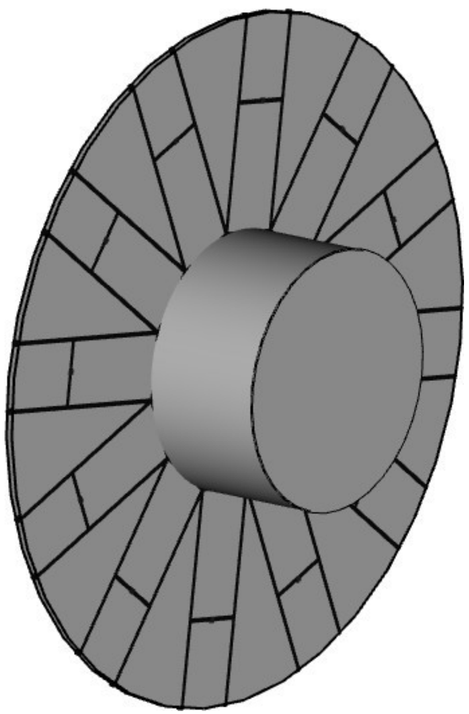
Introduction to Gaia

- Gaia is the European Space Agency's astrometry mission to measure the positions of >1 billion stars in the Milky Way galaxy
- In a halo orbit around the second Sun-Earth Lagrange point (L2) 1.5 million km away from Earth, it has been conducting routine measurements since July 2014 and will continue to at least 2019.
- Gaia is a survey mission which equipped with two 35m telescopes (~f35) separated by a fixed angle of 106.5°



Measurable meteoroid influences on Gaia

- Gaia is shaped like a top-hat with a cylinder containing the service and payload modules and a disk that performs the function of a sun-shield.



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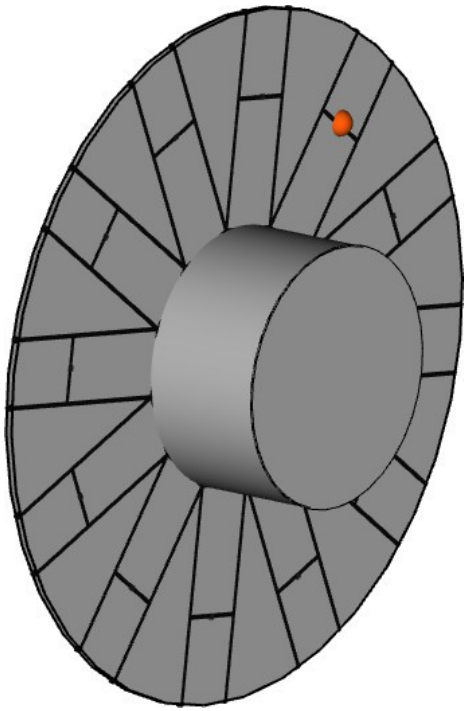
- Meteoroid impact energy dissipation causes local heating and structural deformation



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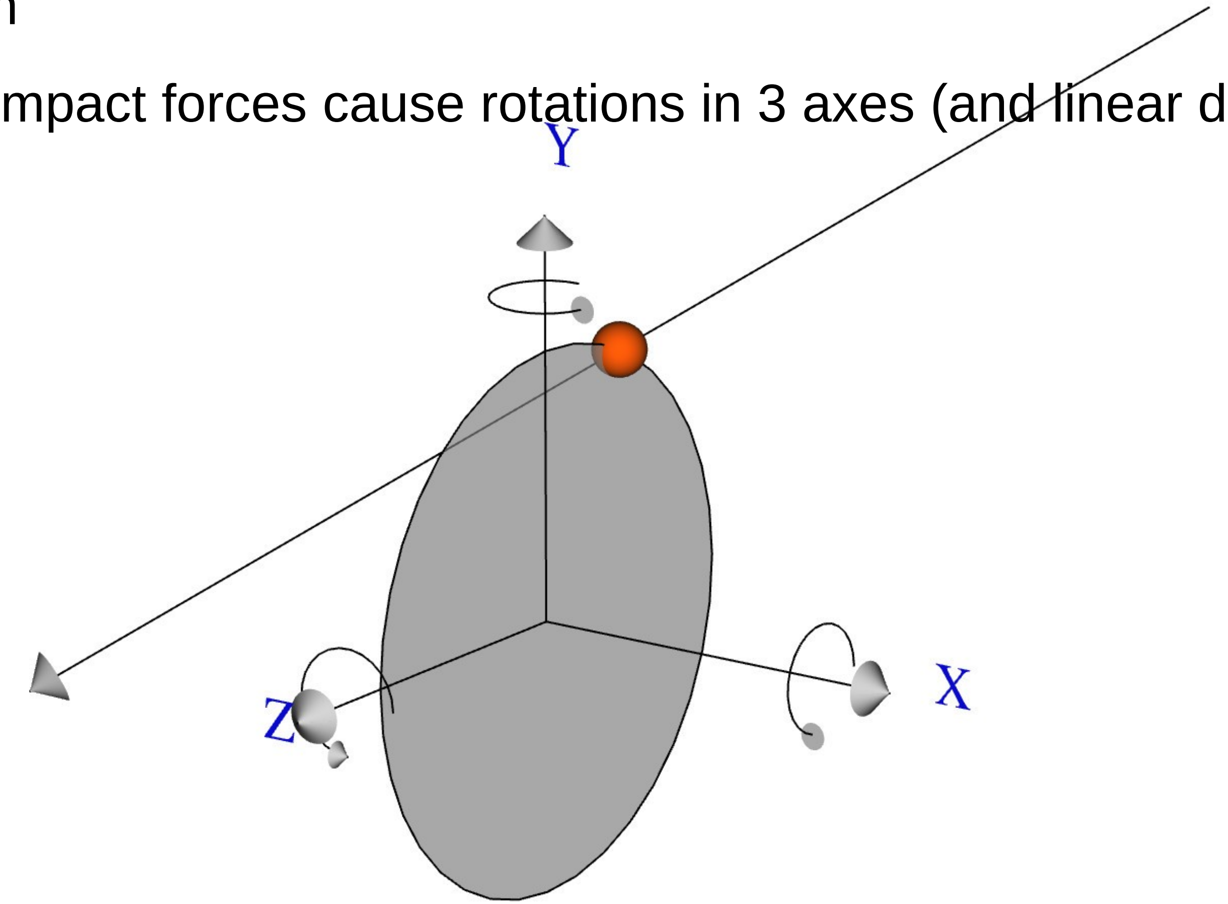
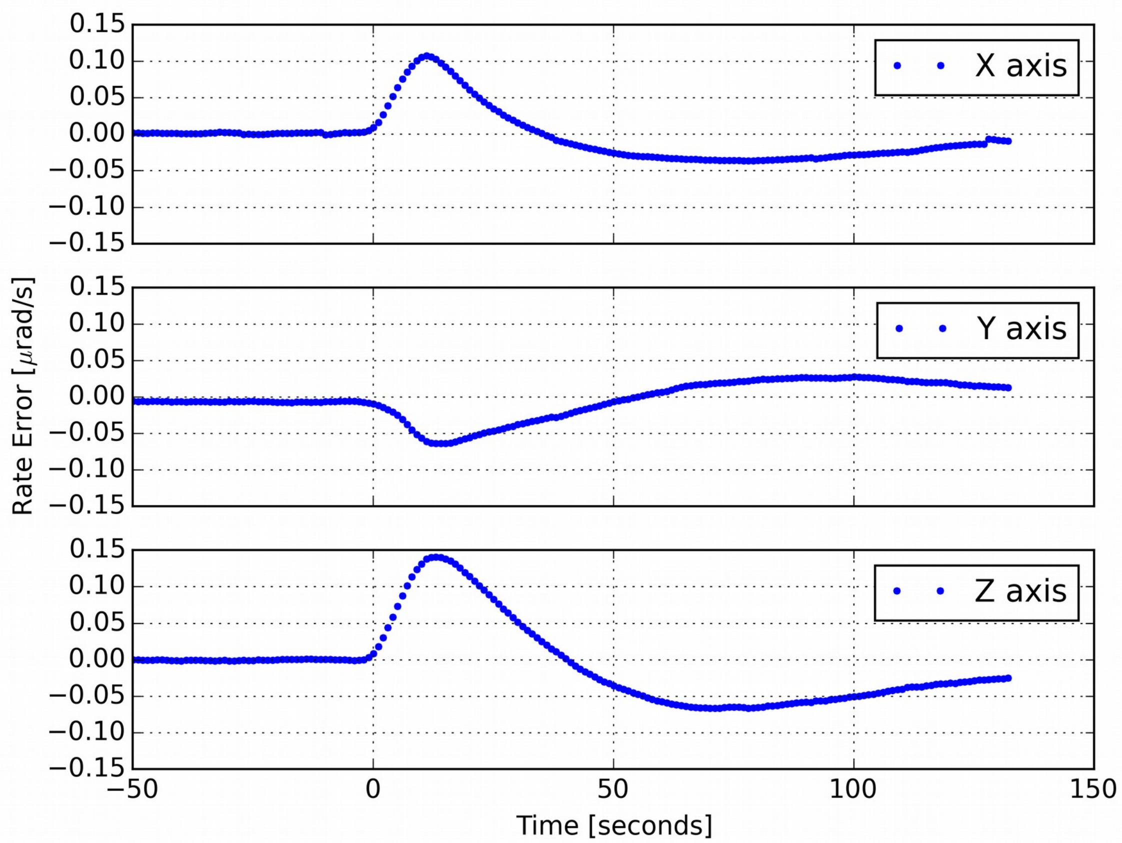
- Meteoroid impact forces cause rotations in 3 axes (and linear delta V)



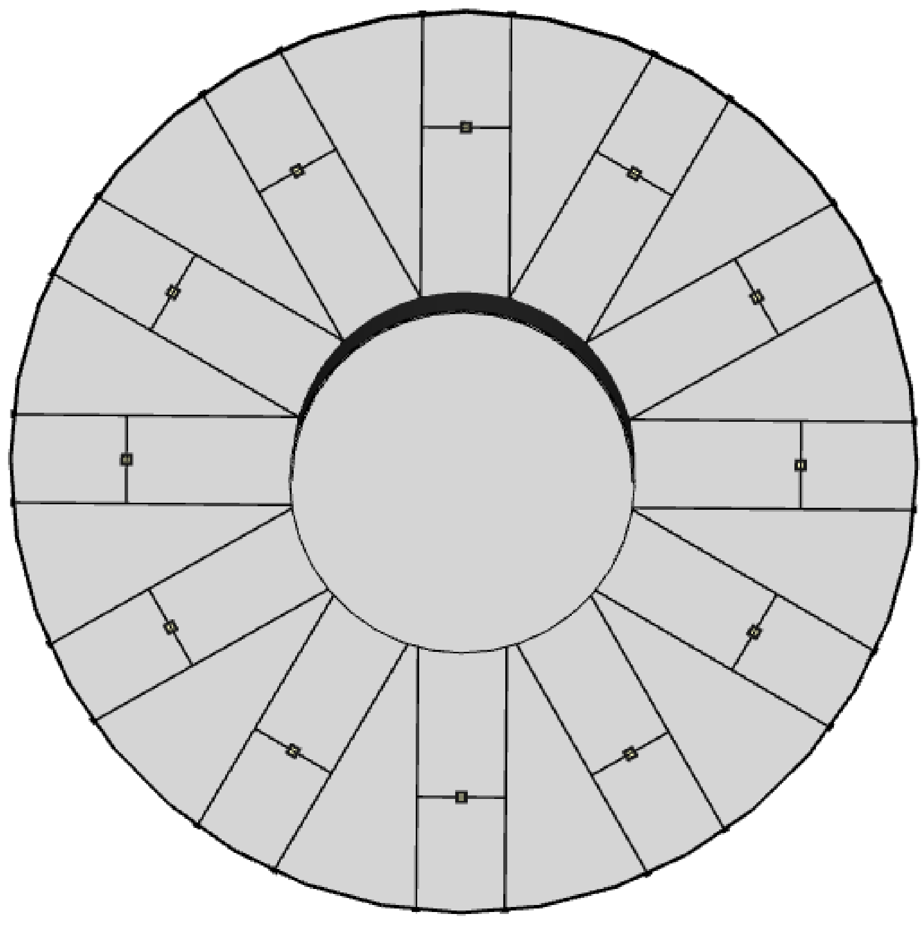
Meteoroid detection by rate disturbance

- From the payload data the attitude computer calculates body rate errors and applies corrective torques with the cold gas thrusters
  - Reaction time typically 10 seconds
  - To create these spacecraft rates requires ~100pJ of energy



Meteoroid detection by thermal disturbance

- The sun-shield temperature is monitored at 12 points equally distributed on the support structure



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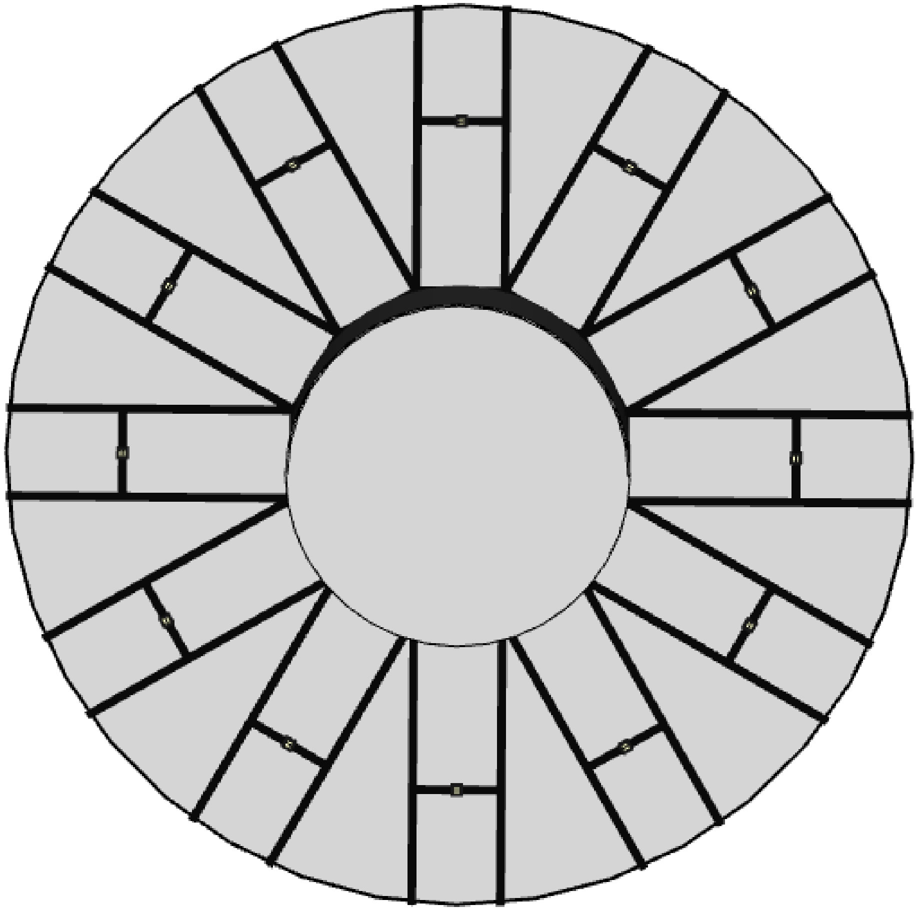

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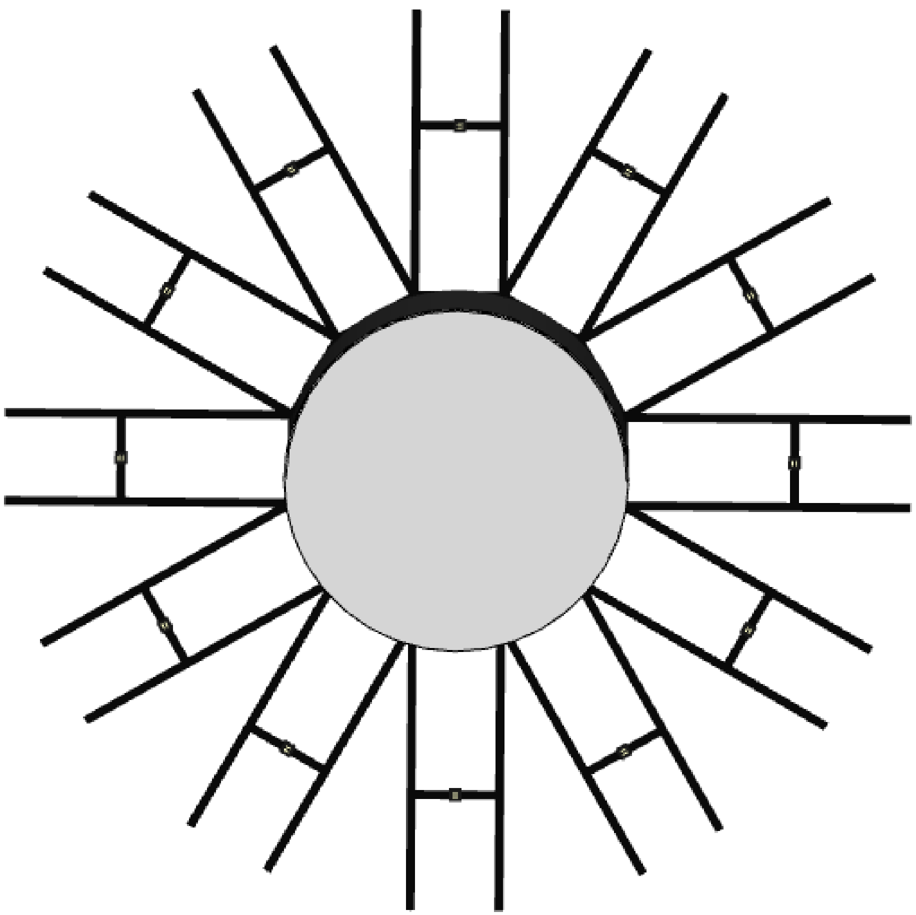

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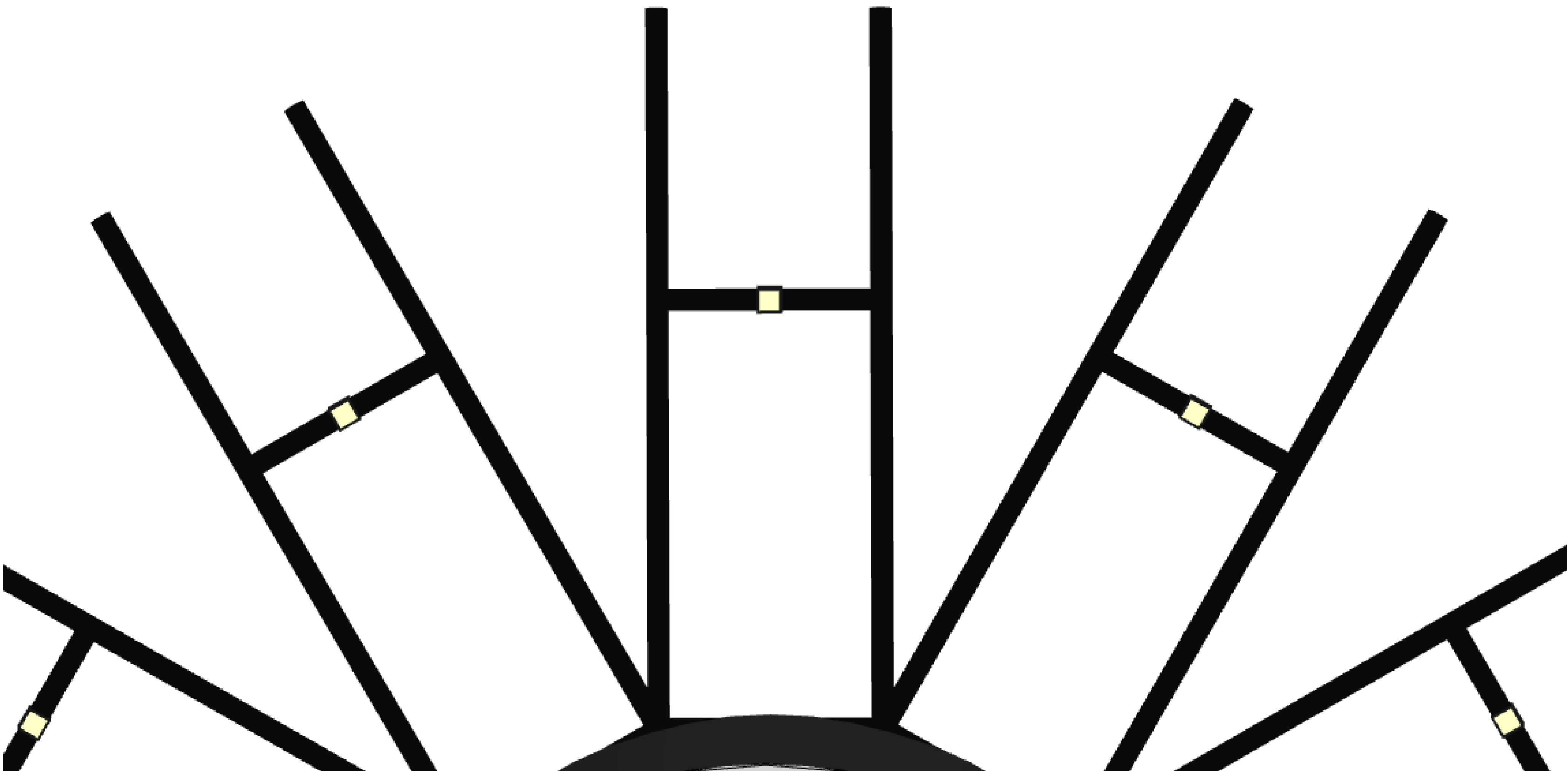

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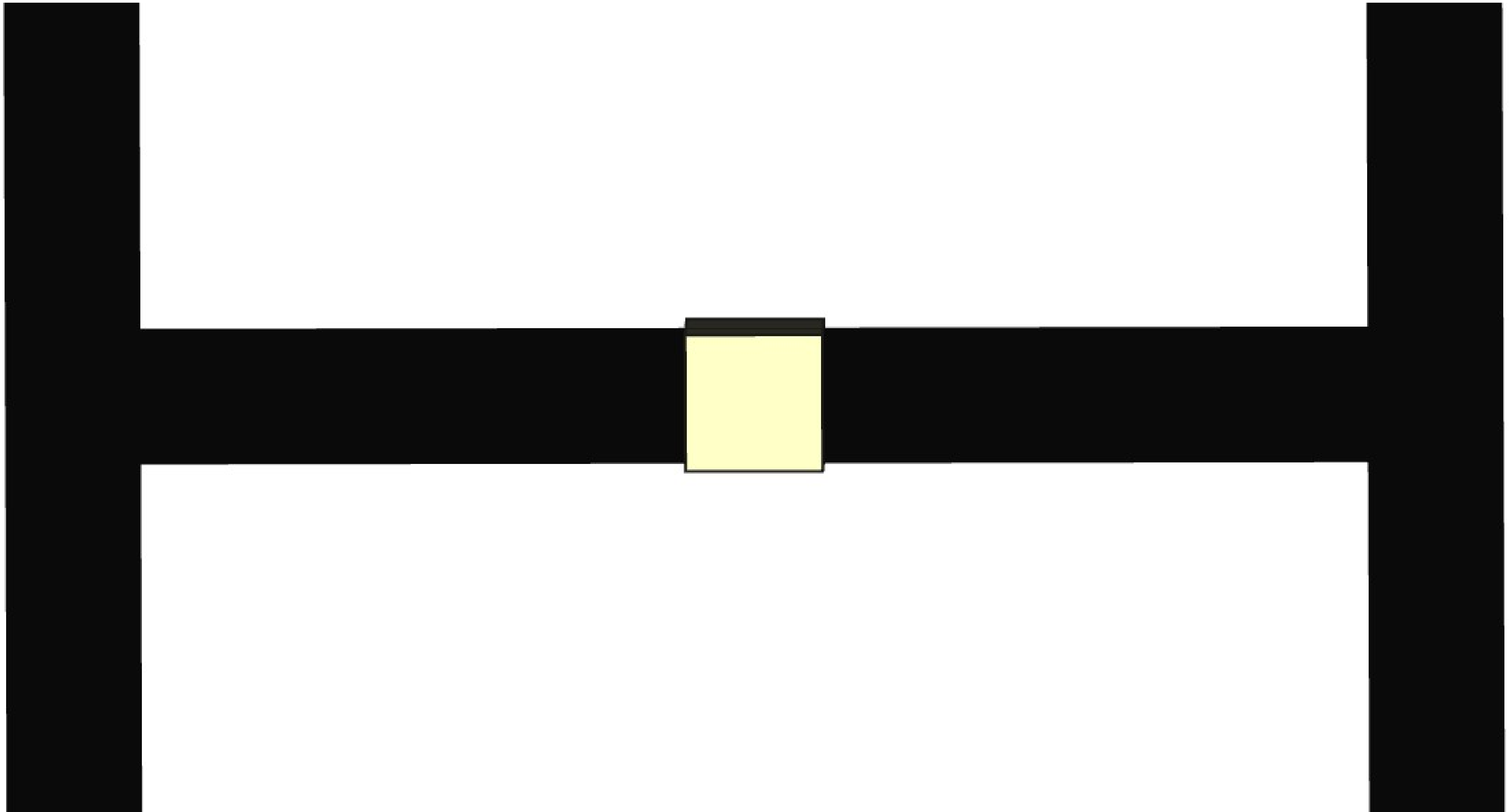

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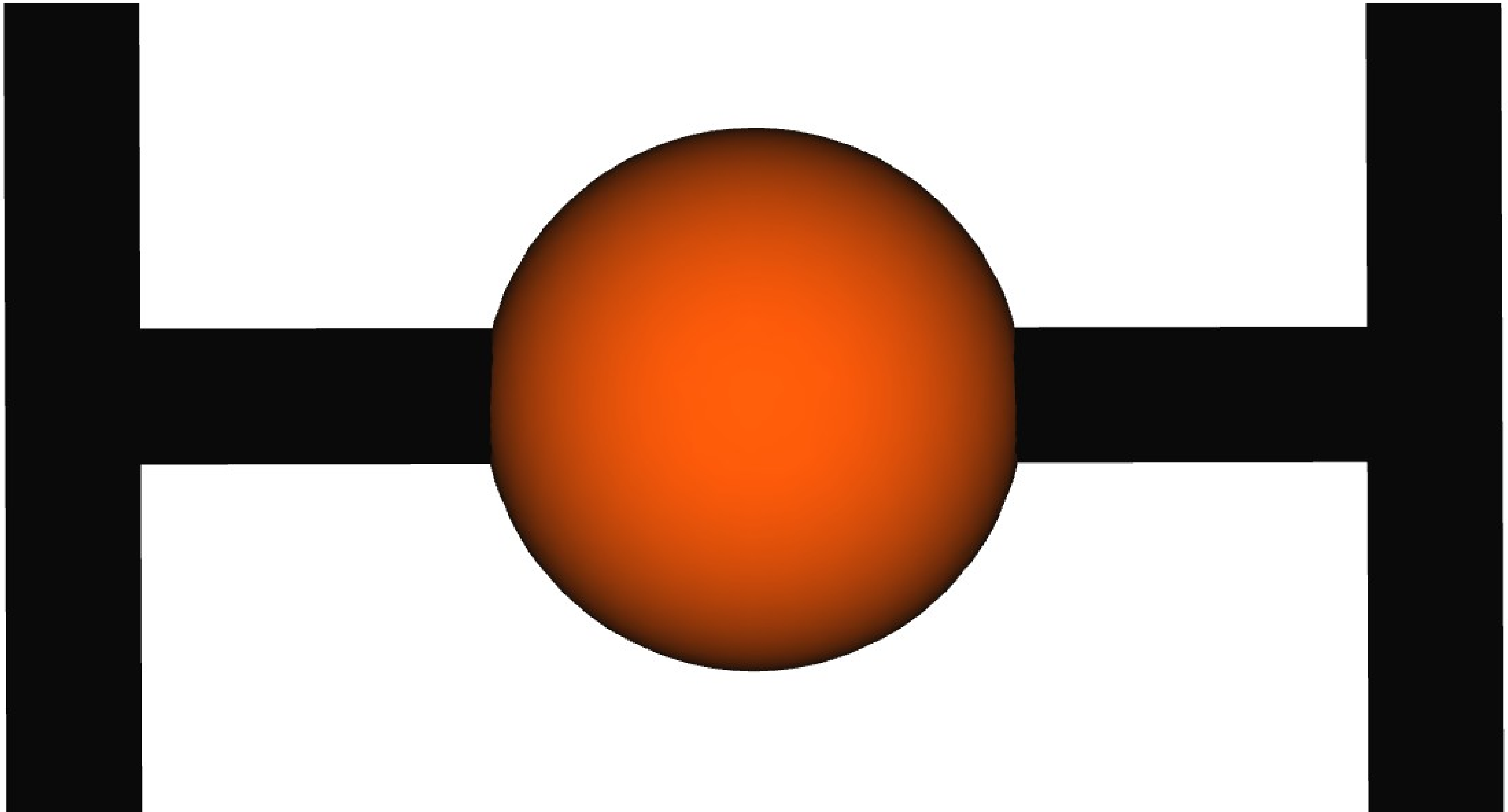
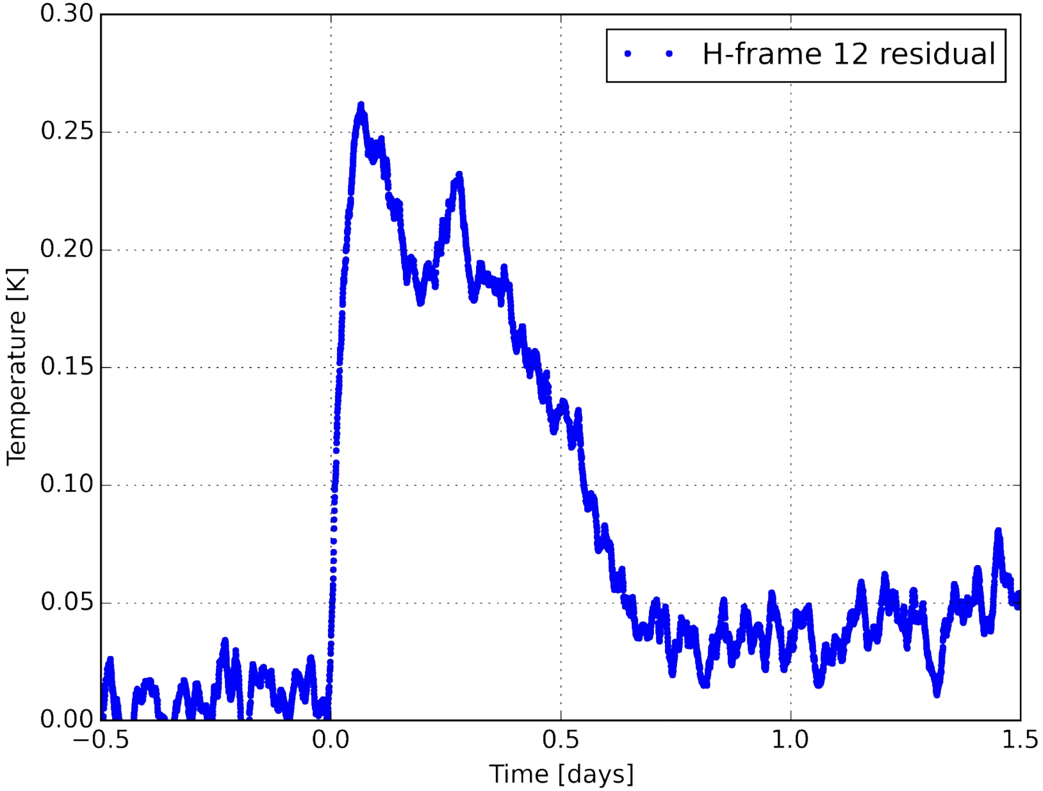


Meteoroid detection by thermal disturbance

- The sun-shield temperature is monitored at 12 points equally distributed on the support structure
- Sun-shield temperature changes are very predictable and depend on;
  - Sun distance & solar output (it is possible to measure changes due to sunspots)
  - Sun azimuth (spacecraft rotation phase)
  - Ageing term
  - Operations activities
- Removing the effects of these influences leaves residuals which appear to be caused by meteoroid strikes
  - Permanent offsets that are due to structural deformation of the sun-shield
  - Temporary offsets that are due to dissipated energy of the impact

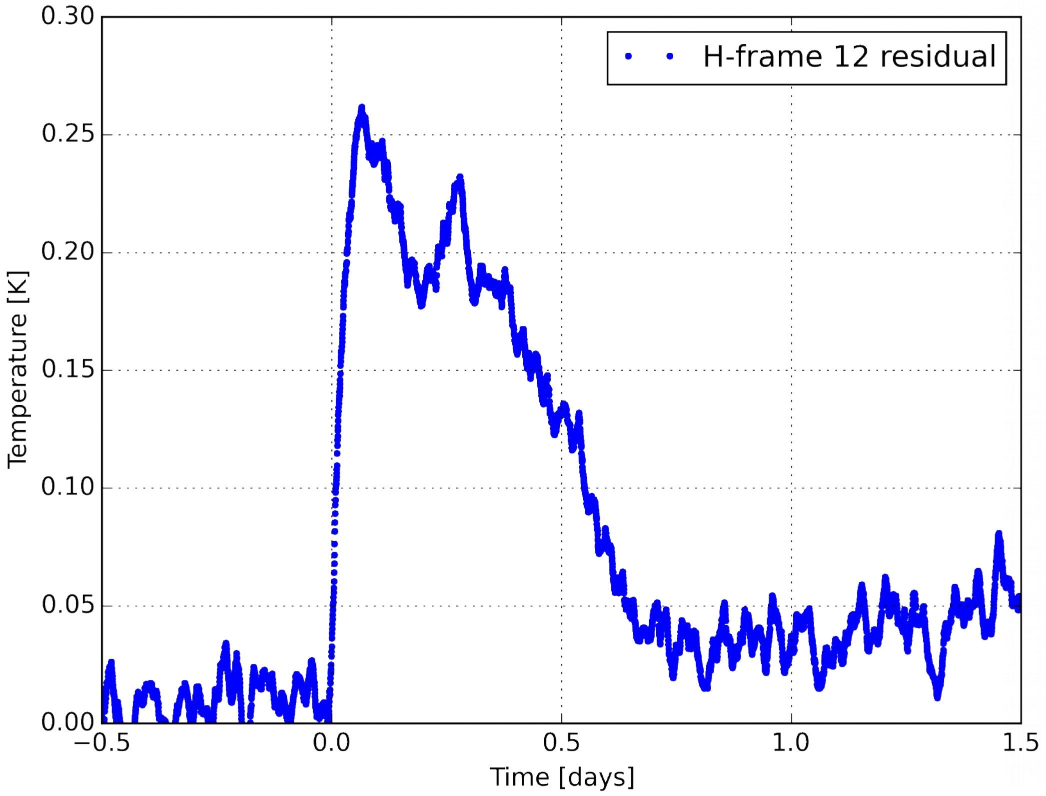
Meteoroid detection by thermal disturbance

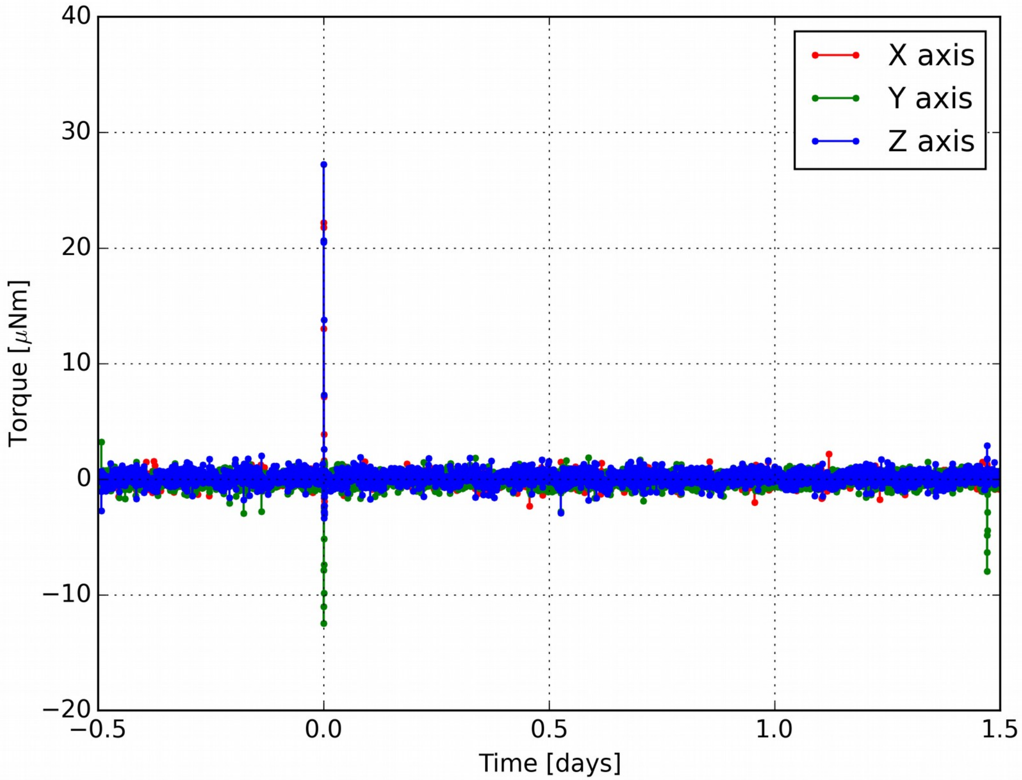
- The first observation of a thermal disturbance was initially mysterious



Meteoroid detection by thermal disturbance

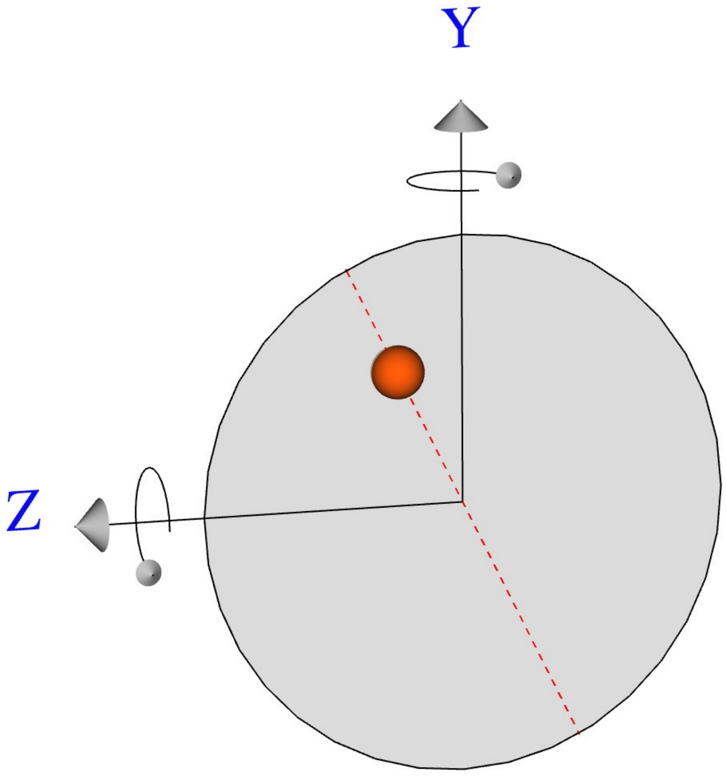
- The first observation of a thermal disturbance was initially mysterious
- It was quickly realised to coincide with a large attitude disturbance





Meteoroid detection by thermal disturbance

- The first observation of thermal disturbance was initially mysterious
- It was quickly realised to coincide with a large attitude disturbance
- Confirmation of cause and effect by calculation of impact diagonal from Y/Z spacecraft rates and correlation with location of temperature monitor
  - Additionally now know which side of disk was impacted
  - And length of lever arm



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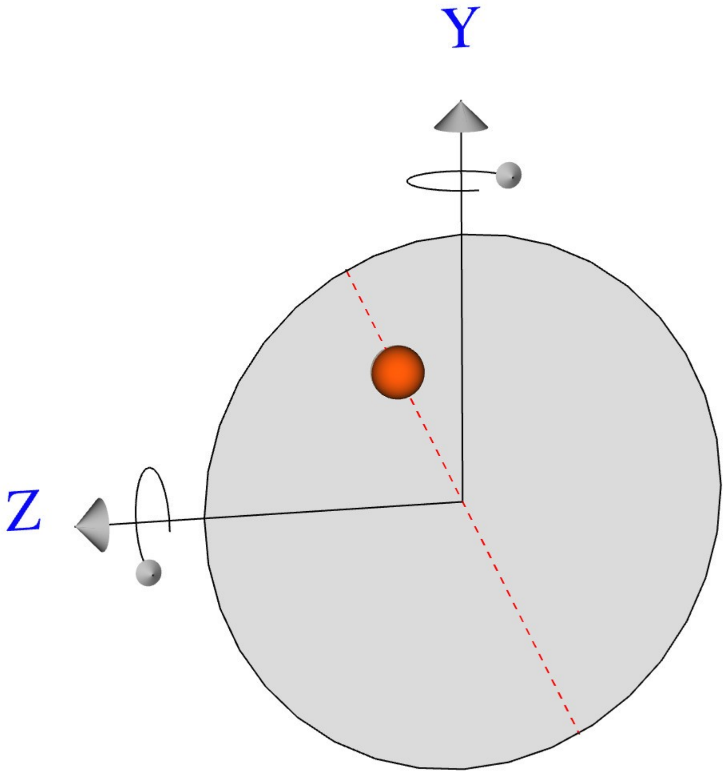
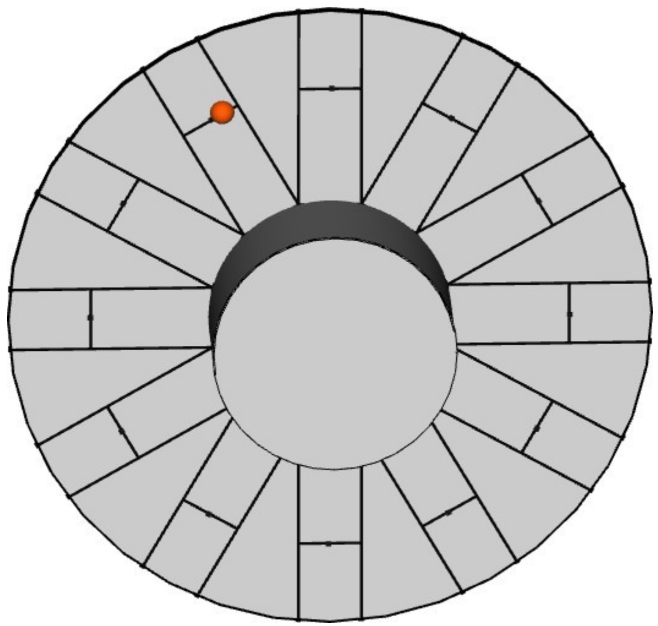
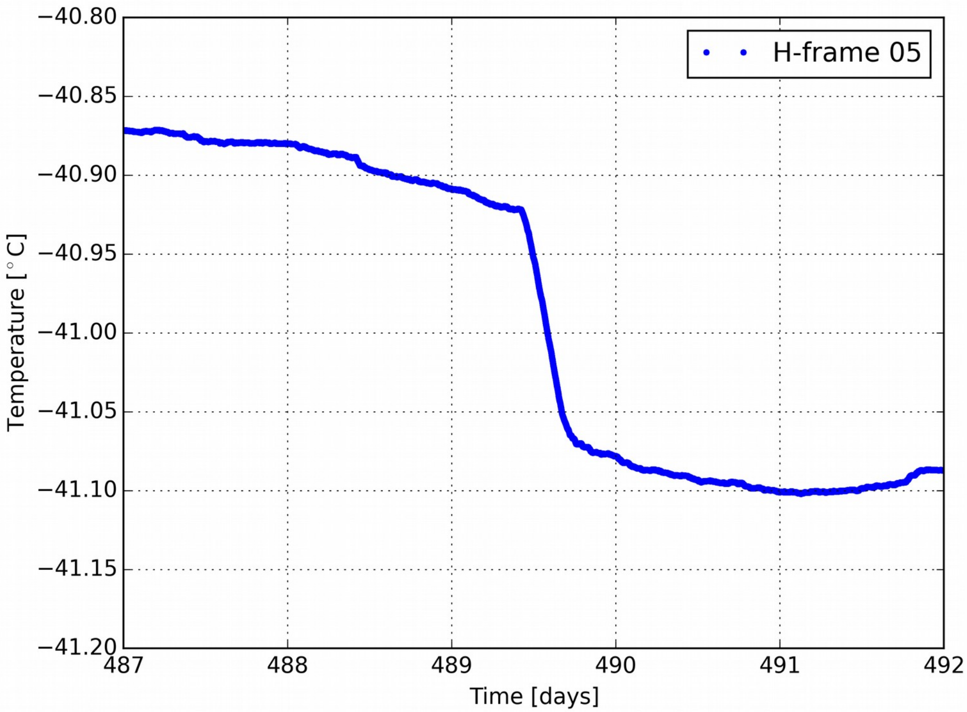
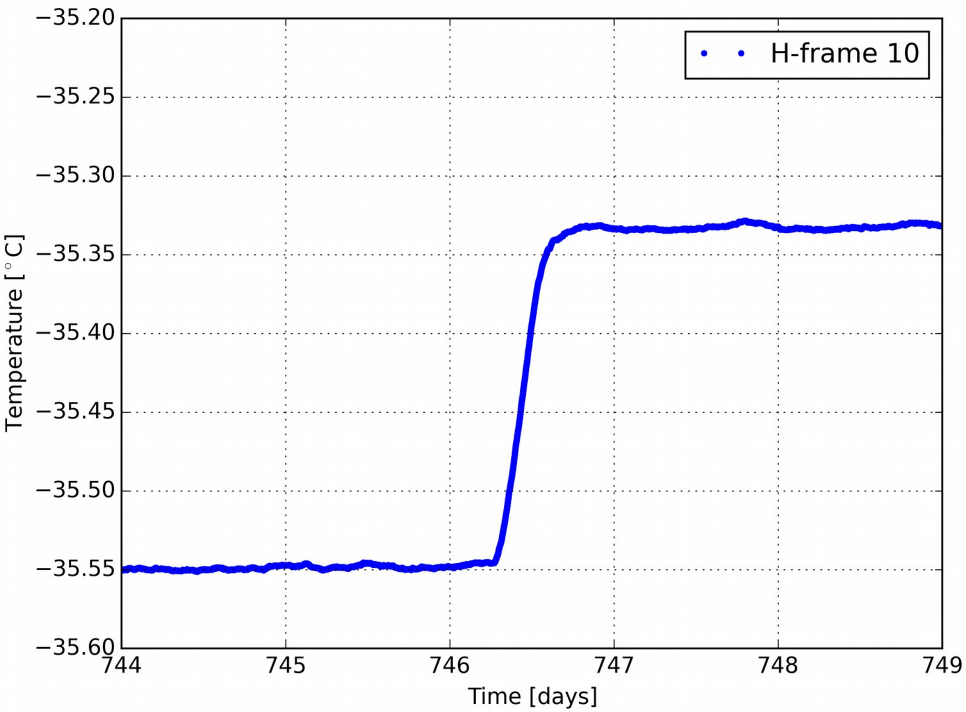




Meteoroid detection by thermal disturbance

- Permanent changes to local thermal balance have also been observed to occur coincidentally with attitude disturbances
  - changes are due to structural deformation
- No temporary heating has been observed for these events
  - Did not impact hard structure (only insulation)? Did not stop?
- Approximately 1 thermal event observed per month.



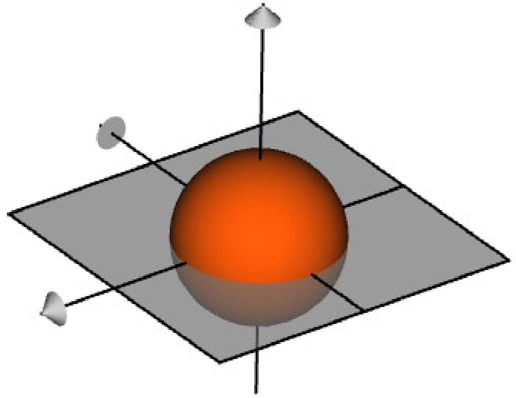


Meteoroid properties calculation

- The energy from the impactor is dissipated through several mechanisms of which only the angular momentum and thermal effects are measurable by Gaia.
- From impacts with a temporary heating effect it is possible to calculate a lower limit for the energy of the impactor
  - Assuming that thermistor location in a 350g Aluminium box has reached thermal equilibrium
  - with heat capacity just under 1J/gK
  - ΔT of 0.25K => Energy = 84J
- The heat energy is many (12) orders of magnitude greater than the angular momentum energy
- From the energy it is possible to calculate the mass, assuming a typical impact velocities;
  - At 20km/s 84J => Mass = 0.42mg
  - At 60km/s 84J=> Mass = 0.05mg

Meteoroid origin determination

- Thermal measurements provide a point of impact. Imparted spacecraft rotation rates from these impacts can be used to calculate an arc of possible impact trajectories



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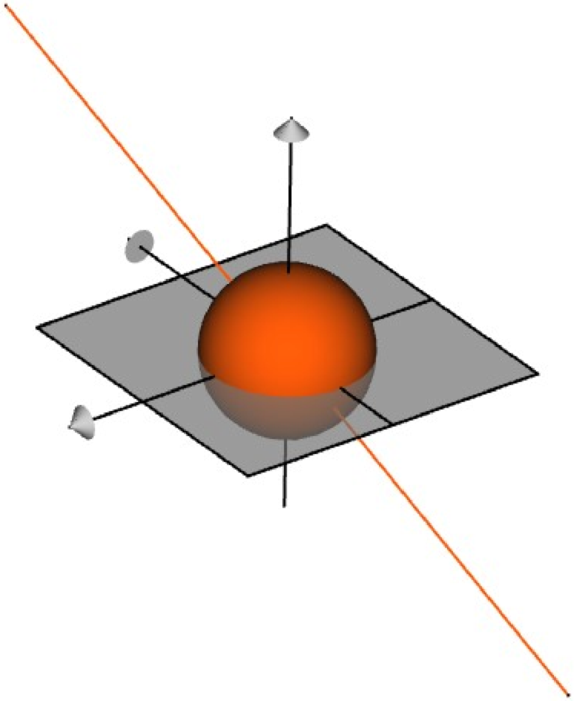

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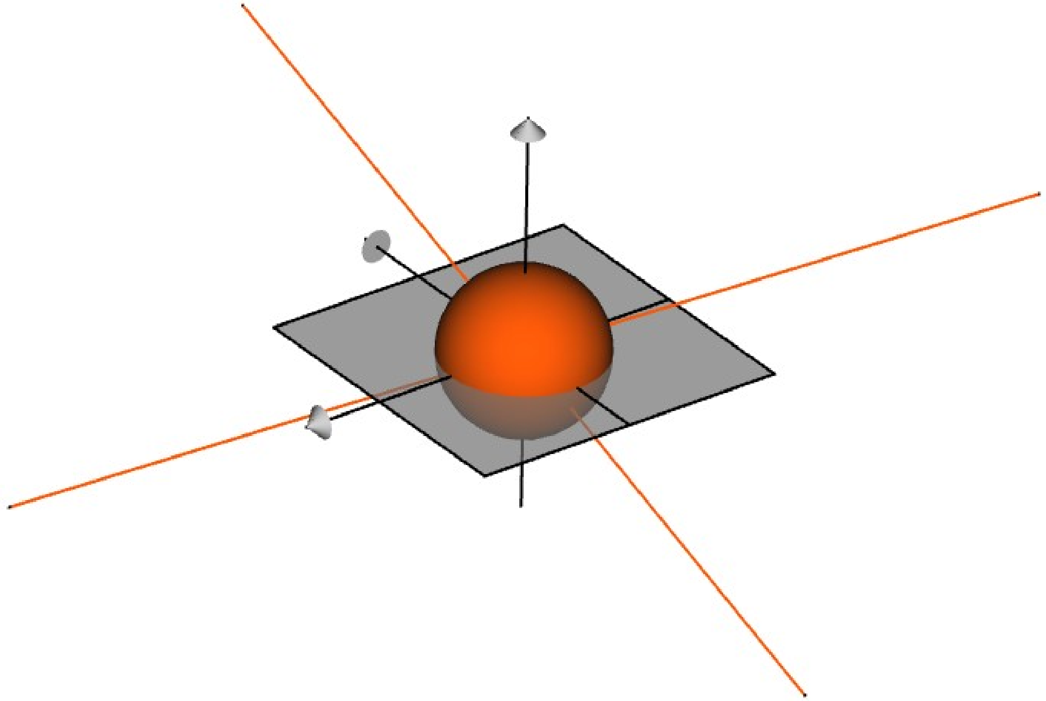

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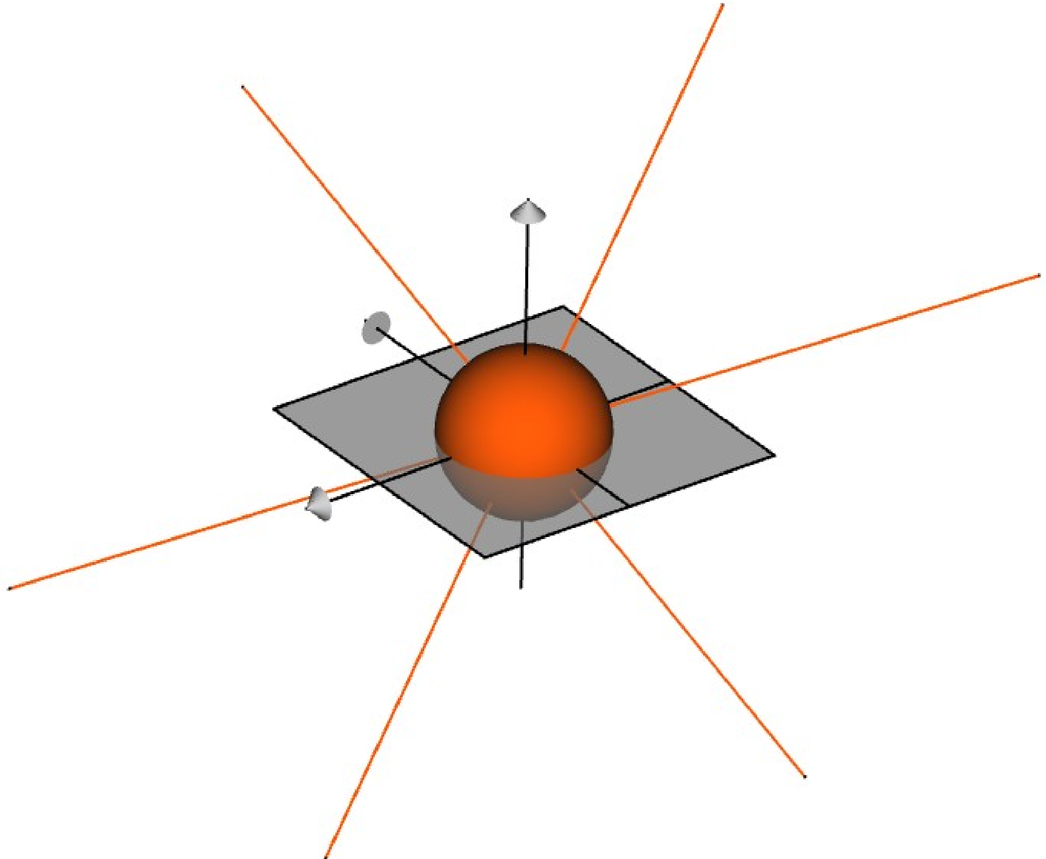

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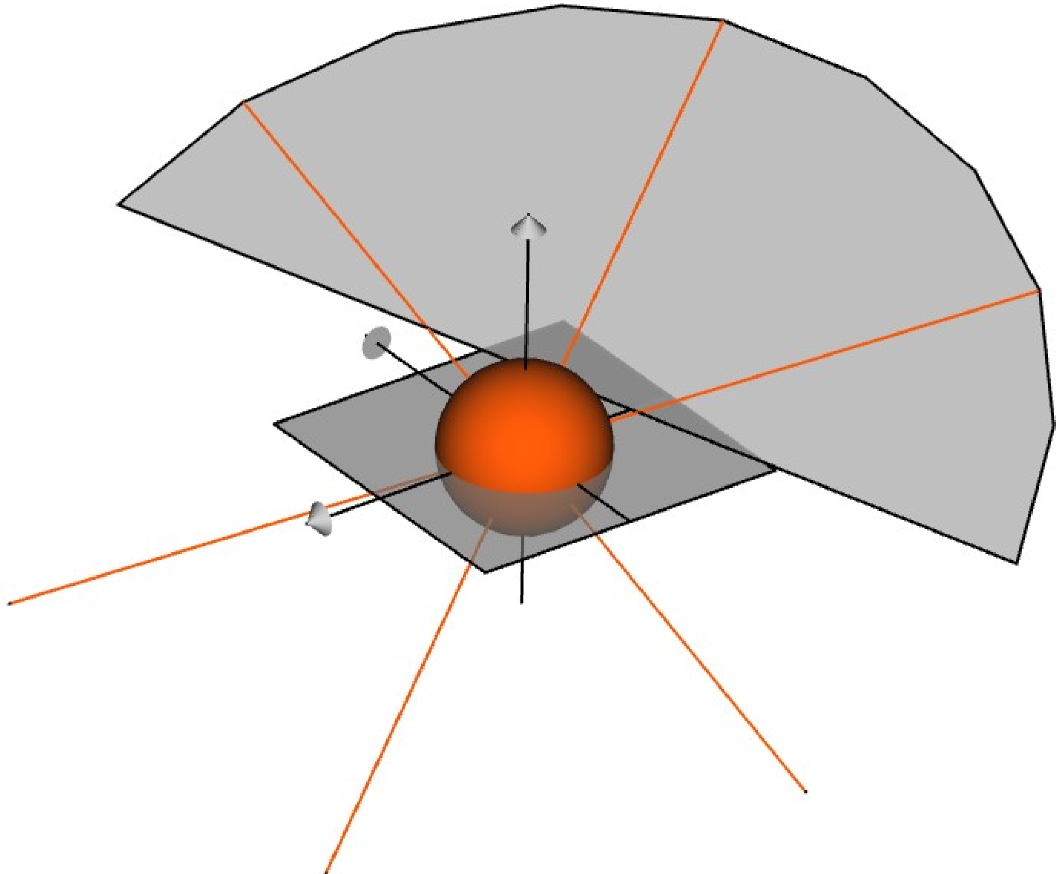
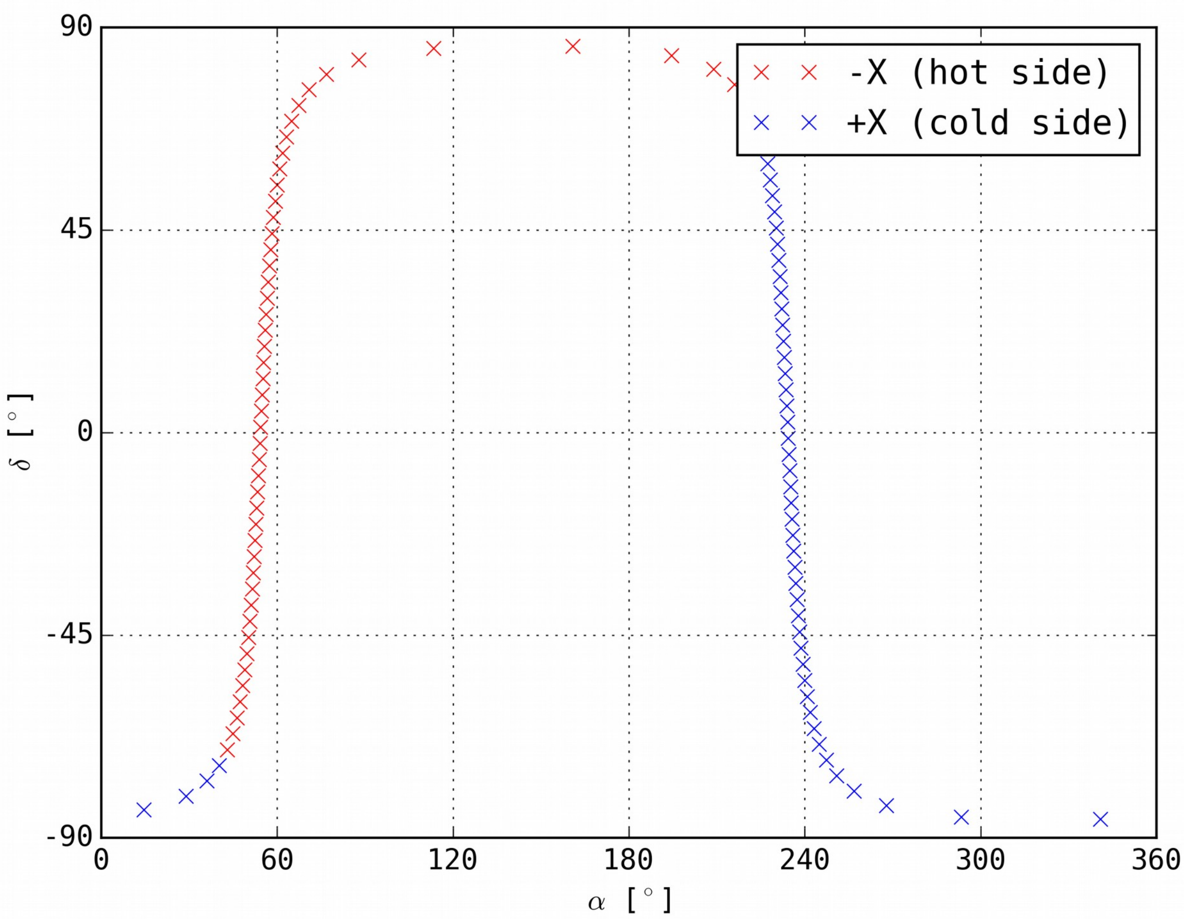


Meteoroid origin determination

- Thermal measurements provide a point of impact. Imparted rates from these impacts can be used to calculate an arc of possible impact trajectories
- Plotted onto the sky shows the arc of possible origins



Conclusion

- Gaia is detecting meteoroids in-situ at L2
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- Directional information can be used to restrict possible source origins
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