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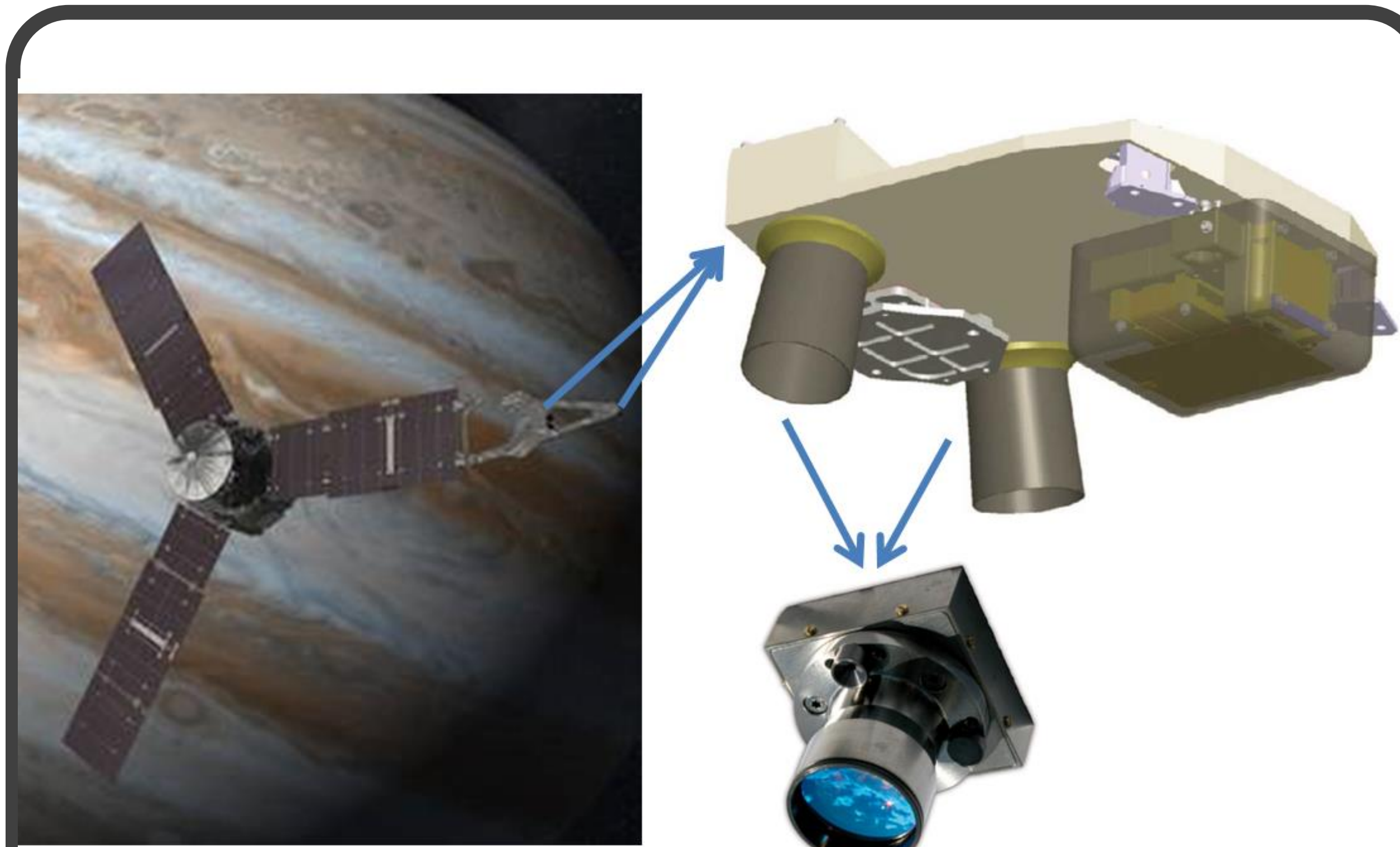
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The high energy particle flux distribution of Jupiter measured by the ASCs of the Magnetometer Investigation

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Credit: NASA/GSFC/JPL-Caltech/DTU Space

Introduction

The Juno mission offers an excellent opportunity to study the flux and distribution of very high energy particles moving in the Jovian magnetosphere. The Magnetometer Investigation is equipped with two star trackers collocated with each of the two vector-magnetometers at the end of one of the solar panels. The primary objective for the star cameras is to provide accurate attitude recovery data for the magnetic mapping mission. The star trackers were provided with limited shielding, which in turn result in sensitivity to >15MeV electrons and 85MeV protons.

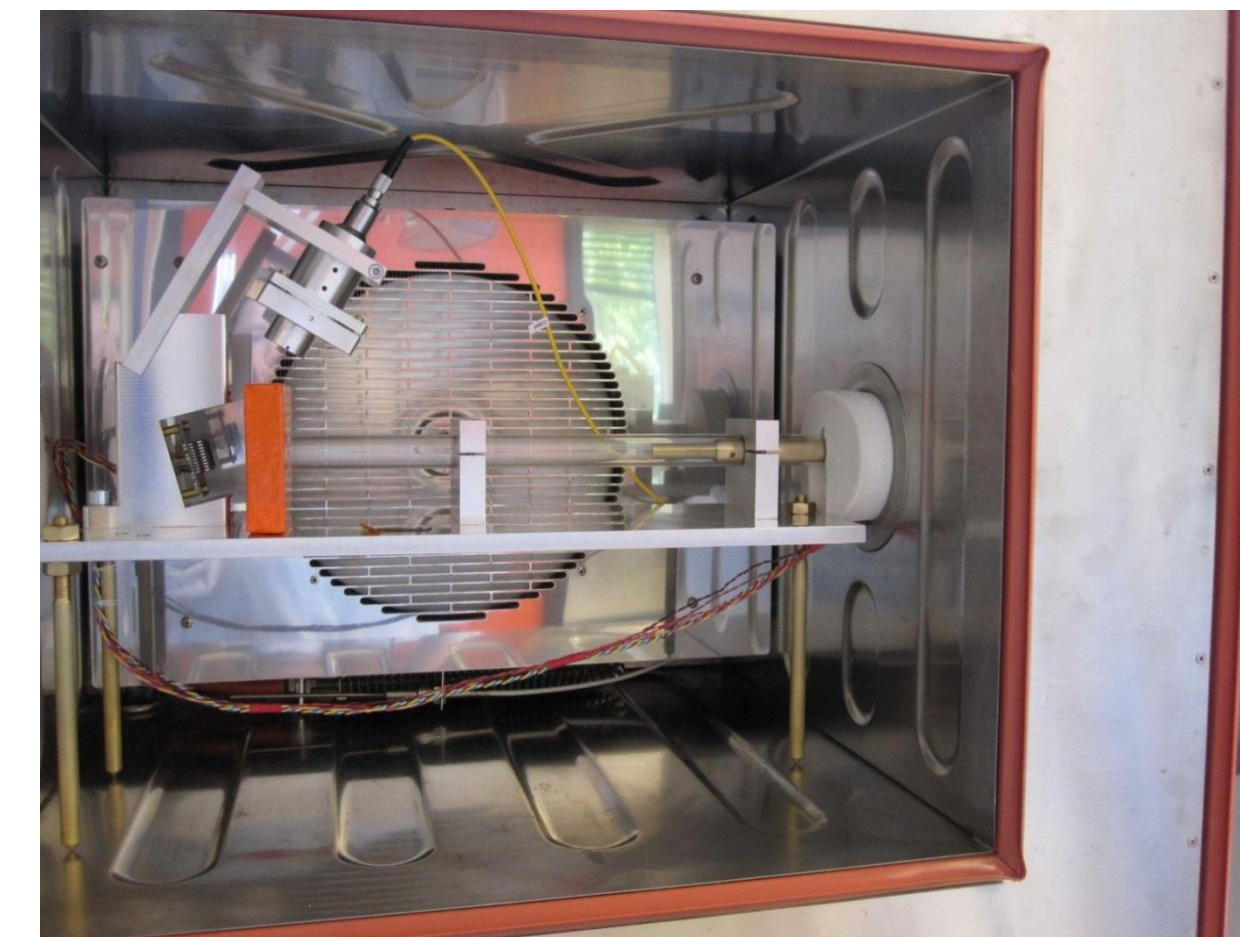
The star trackers, reporting the number of particles penetrating to the CCD at 4Hz, thus realize a very high energy particle detector.

micro Advanced Stellar Compass μ ASC

- Designed and produced by the Measurement and Instrumentation Systems (DTU)
- one of the most successful star tracker worldwide
- autonomously calculates attitude based on all bright stars in the CHUs Field of View
- provides 22 true solutions per second with one single CHU
- absolute accuracy of < 1 arc second
- operating on many satellite missions without a single hardware or functional failure

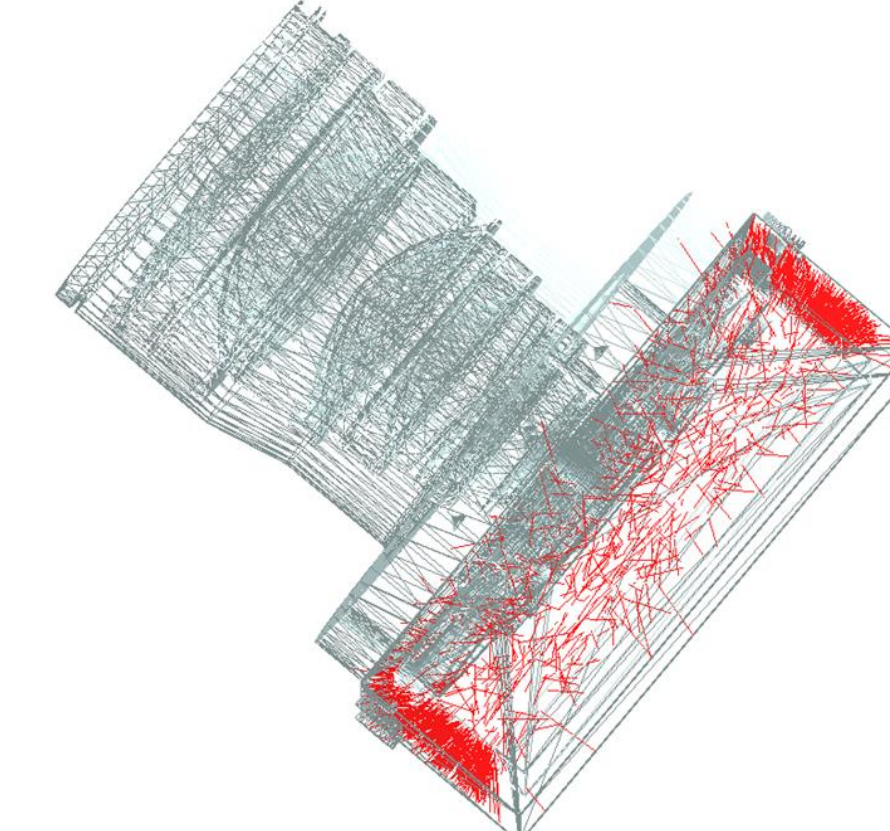
Calibration

The μ ASC response to the high energy irradiation is fully calibrated using 1-2 MeV electron and 30-200 MeV proton irradiation with varied incidence angle, flux, dose rate, temperature, TID, and DDD doses.



Calibration test setup mounted inside the thermal chamber consist of a pre-irradiated rotatable CCD under test, the star stimulator optics and grating, and a movable Sr90 e- source.

The shield-depth of the CCD sensor onboard Juno is analyzed using a Monte Carlo simulator. Here red rays show where materials are traversed.



Calibrating images acquired during irradiation with high flux of electrons (left) and heavies (right).

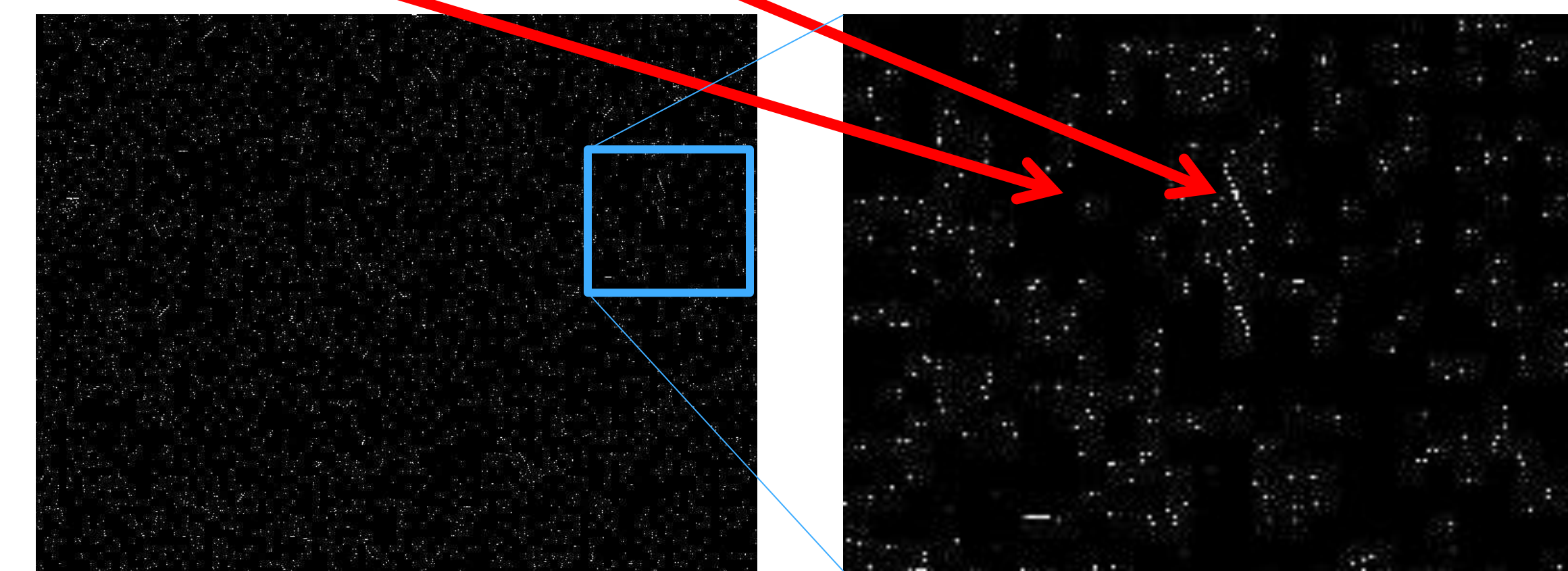
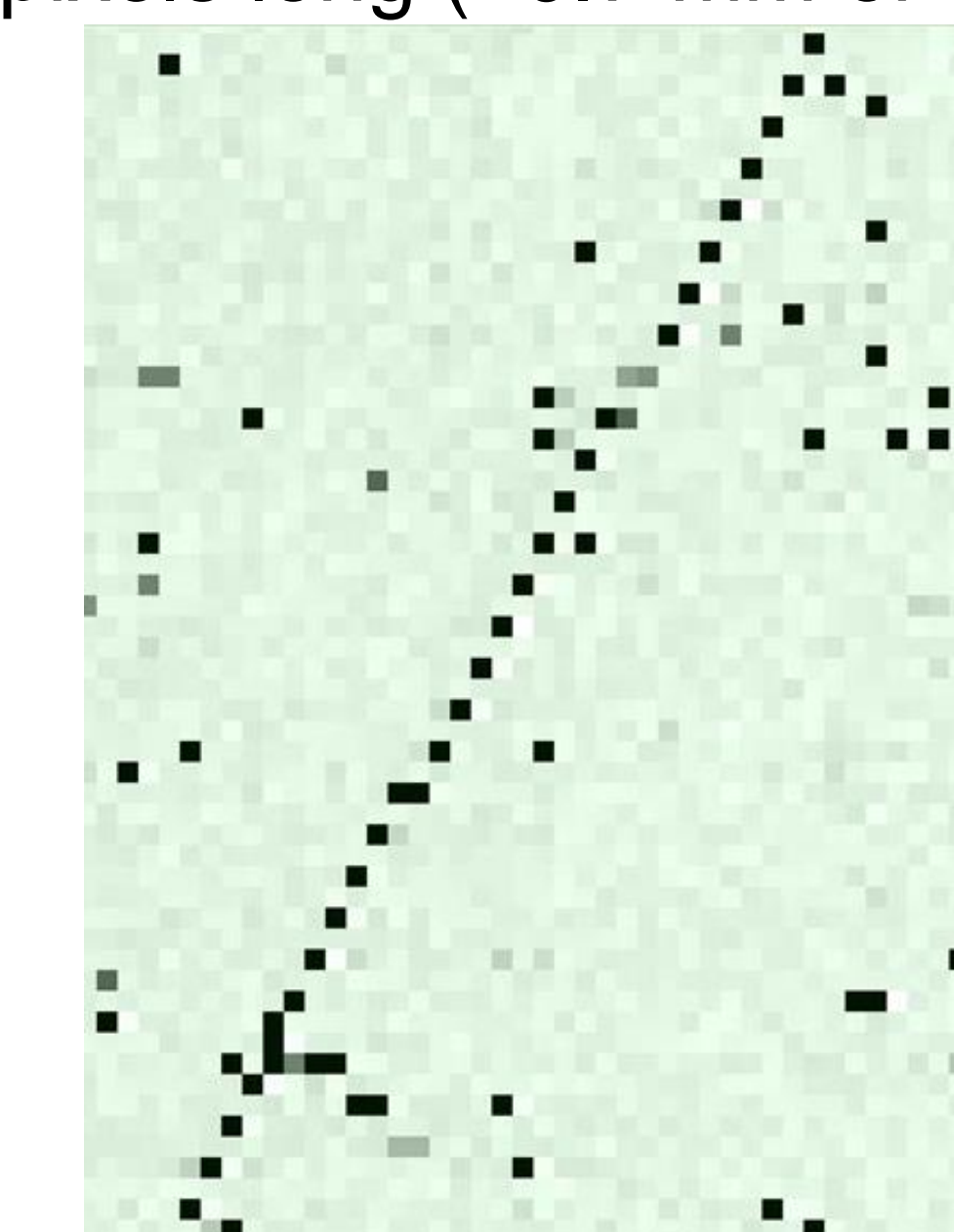


Image analysis. Deposited energy

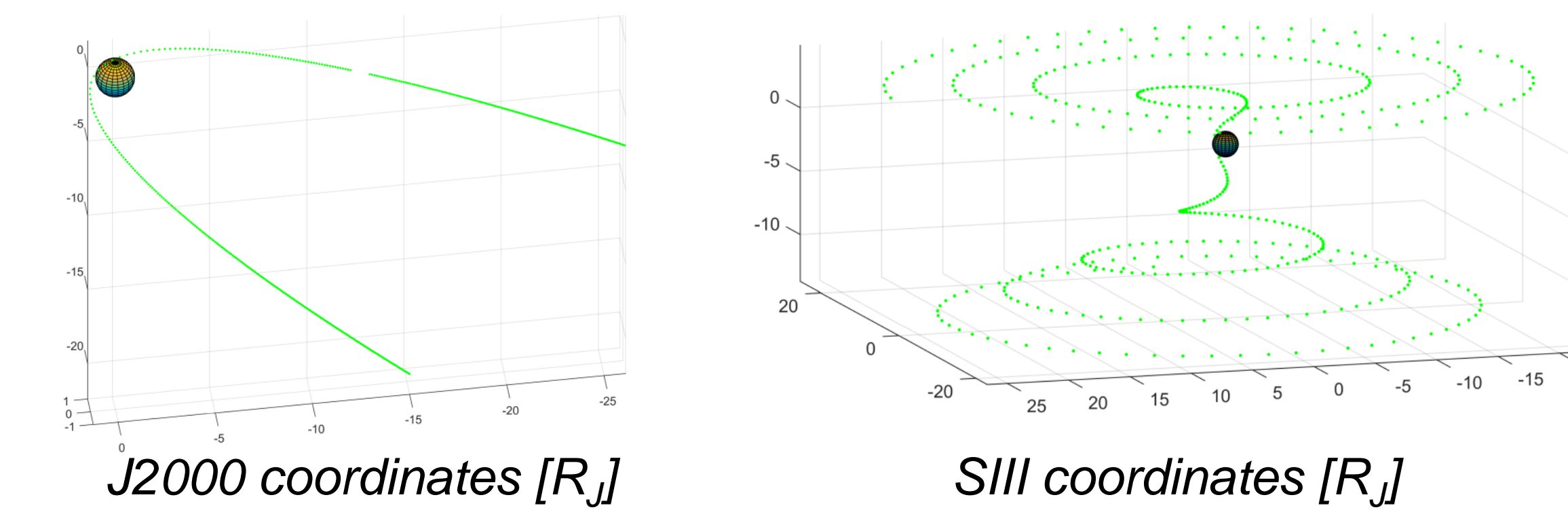
A track left by an energetic particle that hit the CCD is ~50 pixels long (~0.7 mm or 160 mg/cm²) and has 4 or 5 splits due to recoil nuclei produced by the incident particle in silicon. Estimation of the primary energy of a particle that could traverse at least 0.7 mm in Si behind the heavy shielding will involve the transport flux modelling for the μ ASC, the calibration curves of the CCD and inflight image analysis.



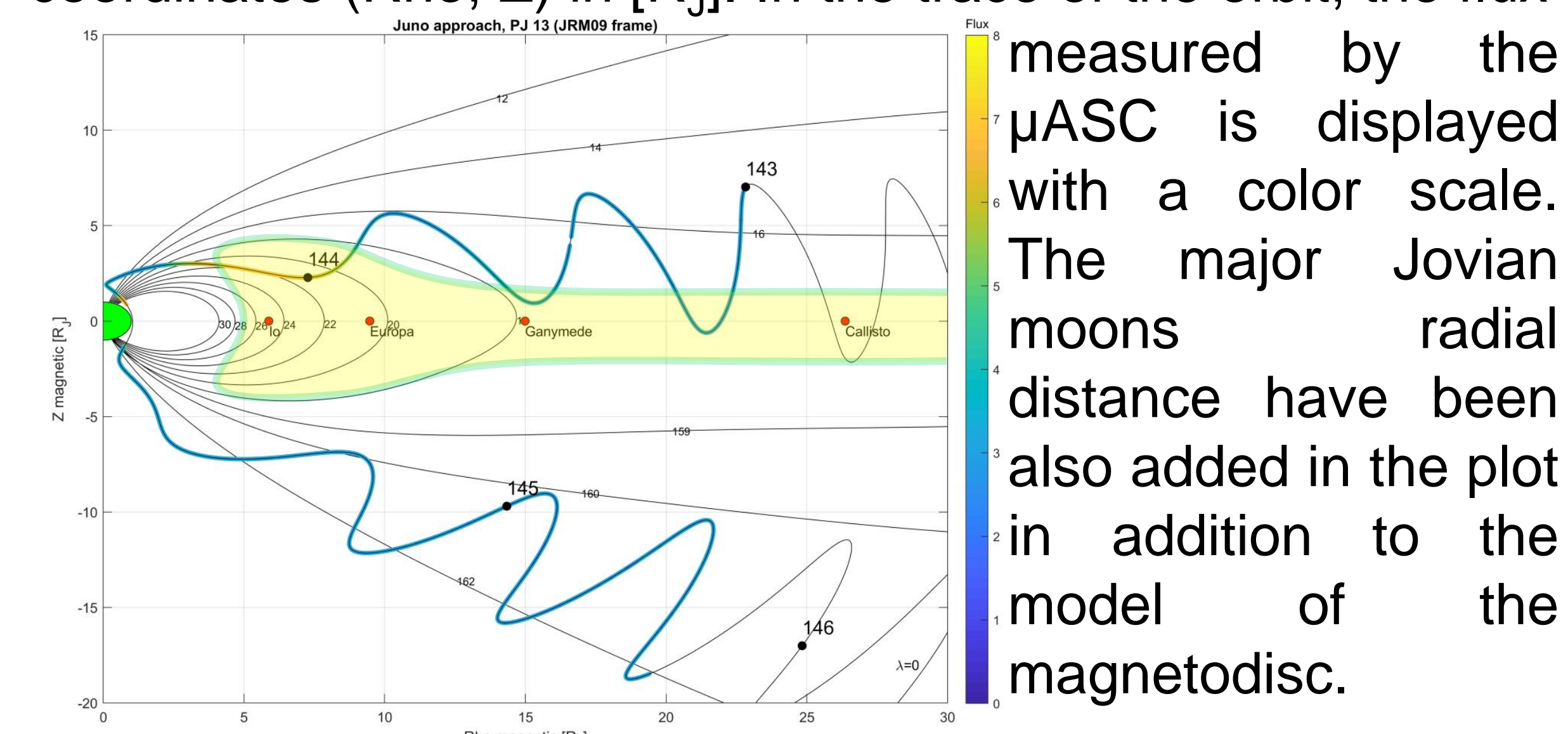
Heavy particle with incoming E >> 85MeV

Moons and Radiation

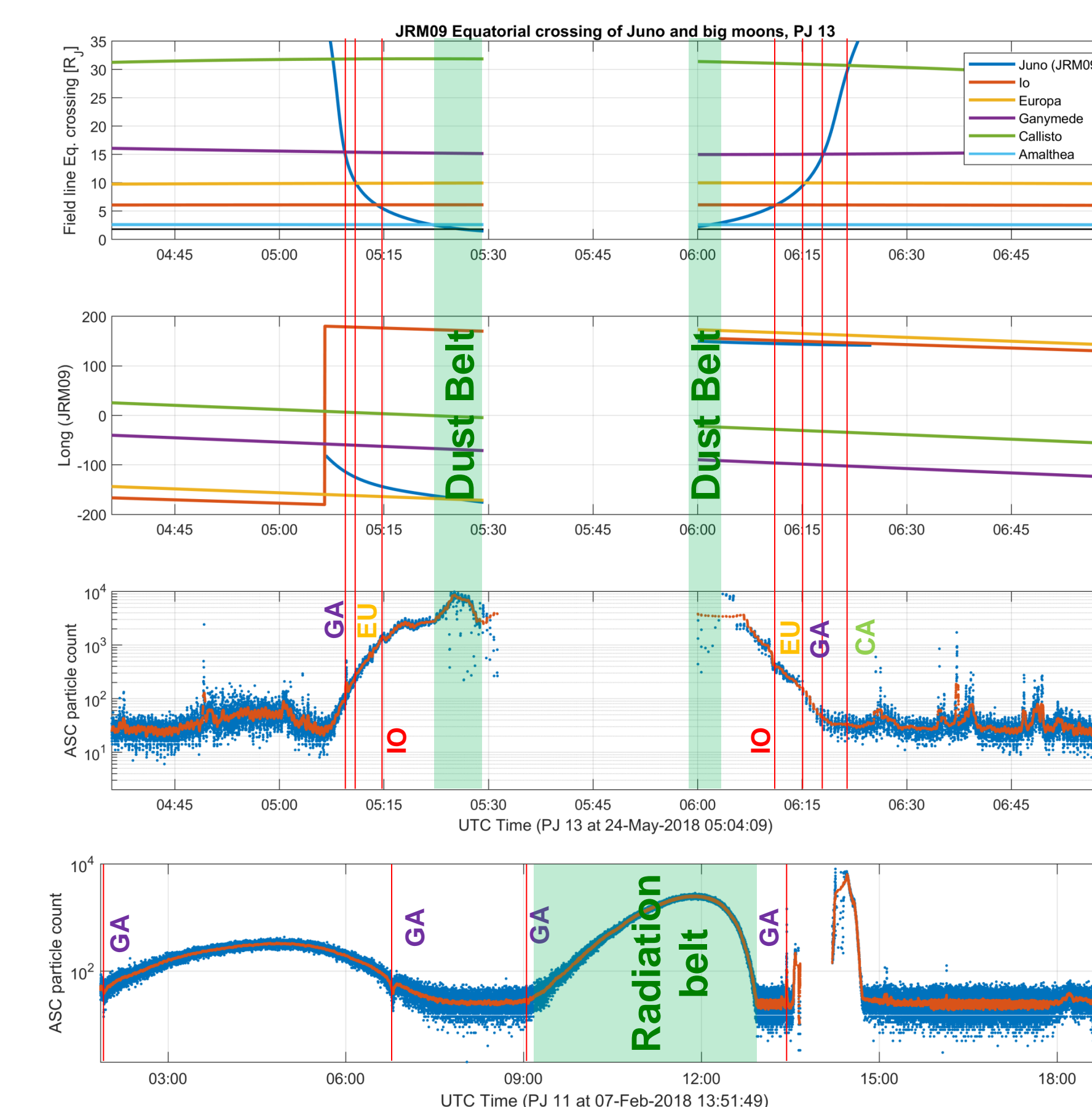
The flybys of Juno orbiting Jupiter in highly elliptical have a period of about 53 days (left, in J2000). The Juno orbit in SIII coordinates (right) shows the effect of Jupiter's rotation period (~10h).



The wiggle plot below shows Juno's position in magnetic coordinates (Rho, Z) in [R_J]. In the trace of the orbit, the flux measured by the μ ASC is displayed with a color scale. The major Jovian moons radial distance have been also added in the plot in addition to the model of the magnetodisc.

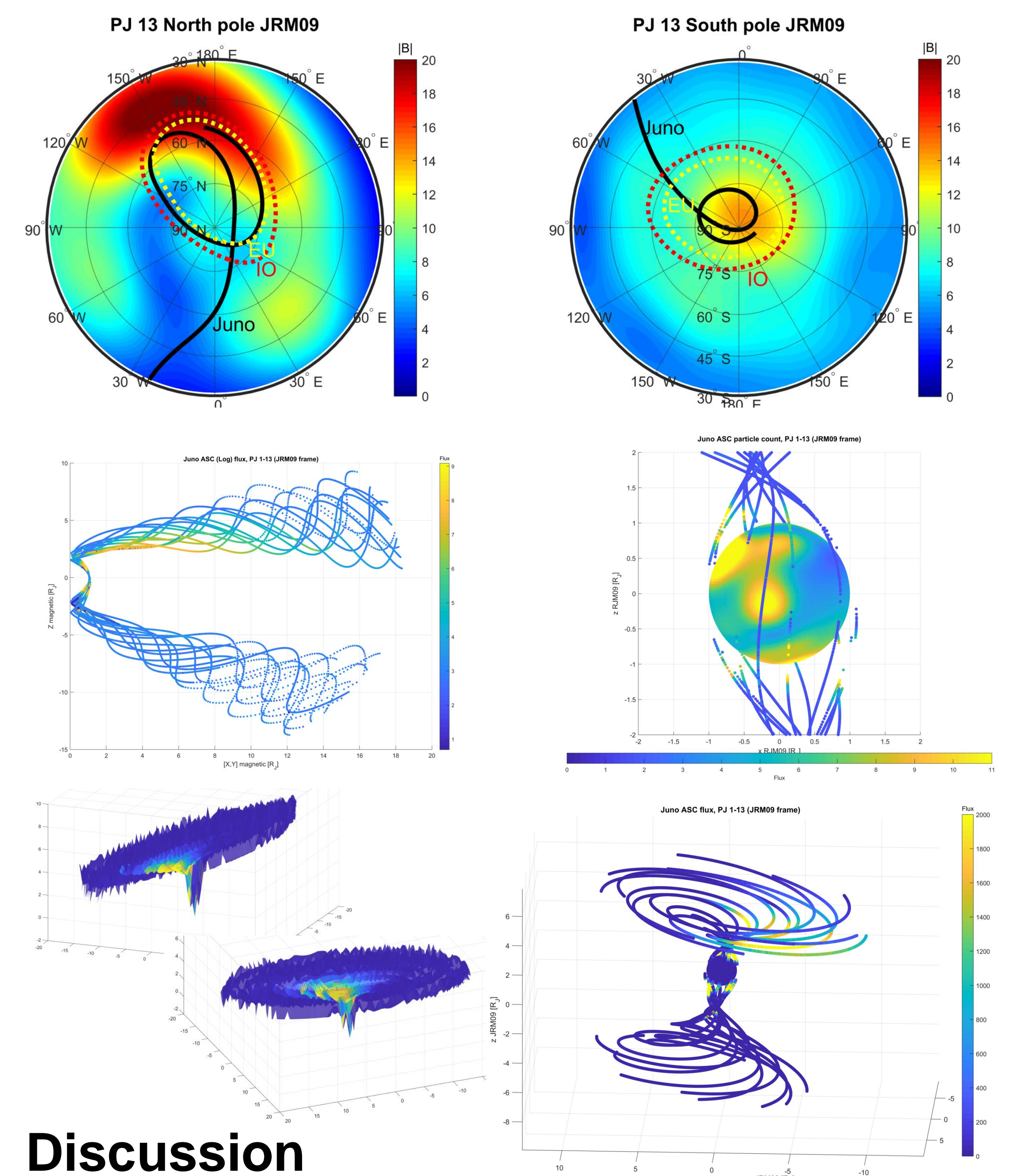


Juno's crossing of the magnetic field lines which intersect the Jovian moon orbits is shown. These crossings are correlated with observations of the μ ASC particle counter.



Jovian magnetic field

Jupiter's magnetic field model (JRM09) by Connerney (2018) describes the field with spherical harmonics up to degree 10. It is based on measurements performed near Jupiter by the Juno mission. The JRM09 model shows a more complex Jovian magnetic field in comparison to earlier models (eg. VIP4), and a clear asymmetry within the northern and southern hemispheres. For larger distances to the planet (>10R_J), the magnetic field can be represented well by a 10.5° tilted magnetic dipole and there is no apparent differences wrt VIP4 model.



Discussion

We have calibrated and demonstrated the use of the μ ASC as a high energy particle detector in the Jovian magnetosphere. As the forthcoming Juno flybys will cover more spatial regions near Jupiter, we expect to build a model of the high energy electron radiation environment near the planet solely based on the data from the star trackers.

Ref.: Jørgensen, P. S., Jørgensen, J. L., & Denver, T., 2004. μ Asc: a miniature star tracker, Proceedings of The 4S Symposium: Small Satellites, Systems and Services (ESA SP-571). 20 - 24 September 2004, La Rochelle, France. Editor: B. Warmbein. Published on CDROM, id.55.1, 2004ESASP.571E..55J