Lessons Learned from Radiation Monitor Data Analyses

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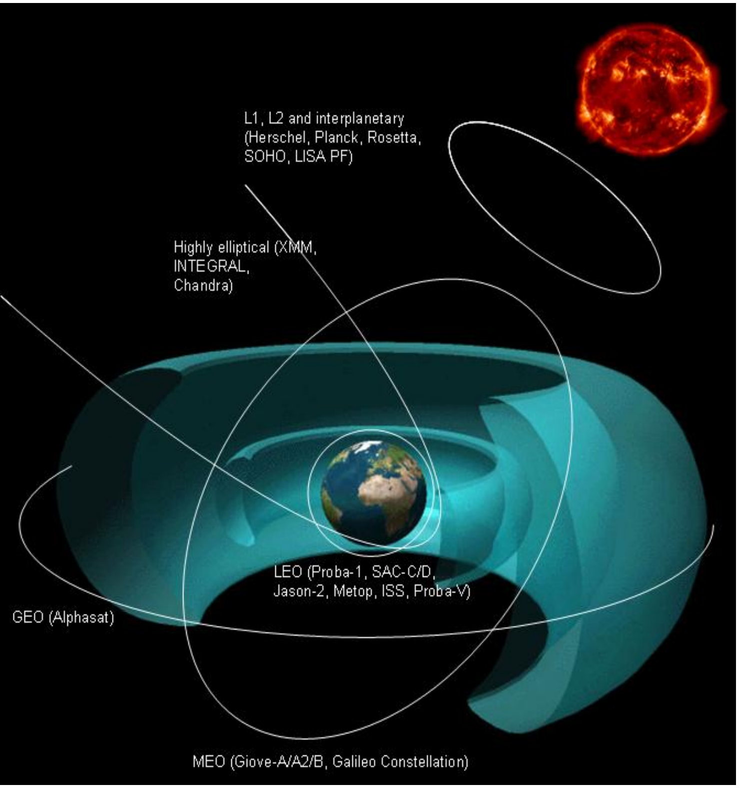
Why?

Reasons for collecting radiation environment data:

1. **Scientific** interest:
    a. Curiosity: because it's there to be measured and understood
    b. Validation of physical models
    c. Provide boundary conditions for physical models
2. **Engineering** interest:
    a. Constructing Engineering (empirical) Models
    b. Validating Models - uncertainty (margins)
    c. Establishing engineering limits
3. **Operational** interest
    a. Post flight analyses
    b. Anomaly analyses
    c. Mission extension analyses
    d. Operations – automated "safe-ing" of spacecraft

SREM – ESA's Standard Radiation Environment Monitor (1996-)



ESA, Oerlikon Contraves (RUAG), Paul Scherrer Institute (PSI)

STRV-1c 2000

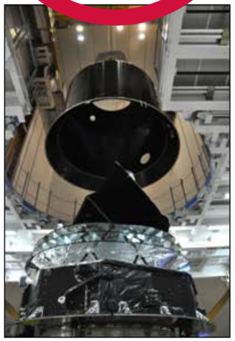
PROBA-1 2001

INTEGRAL 2002

Giove-B 2006

Rosetta 2004

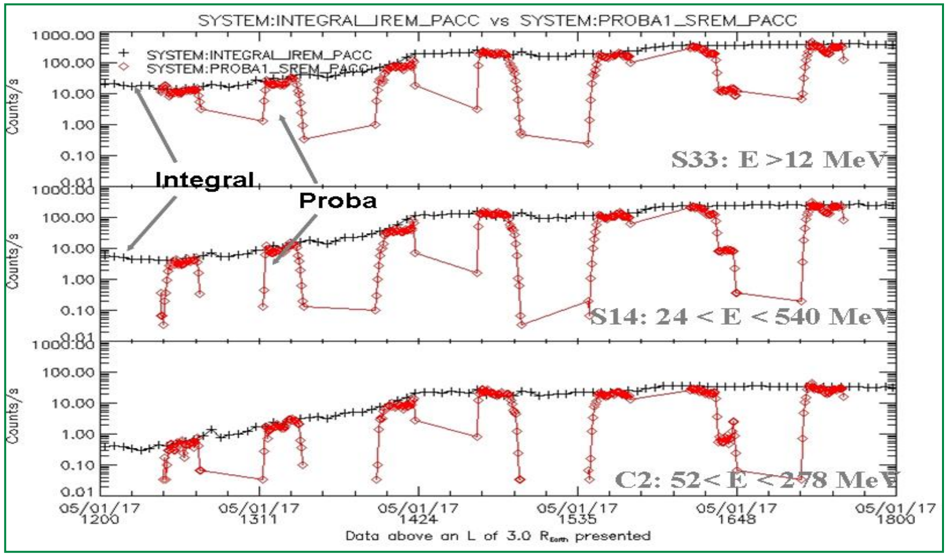
Herschel 2009

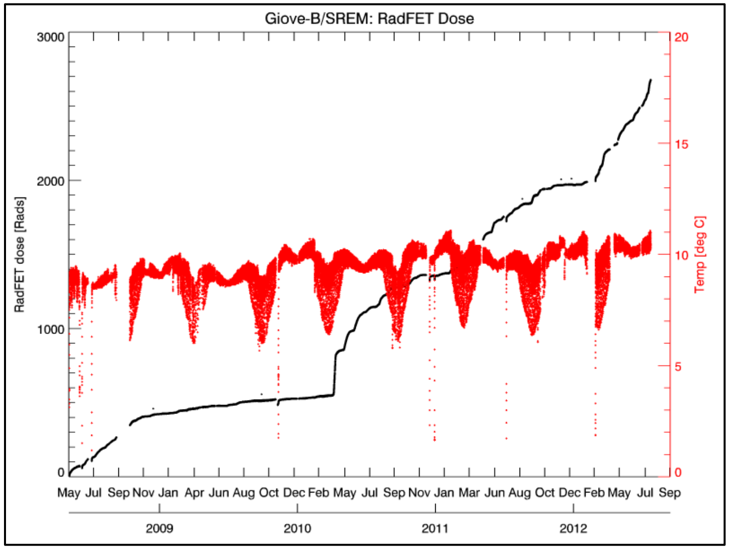


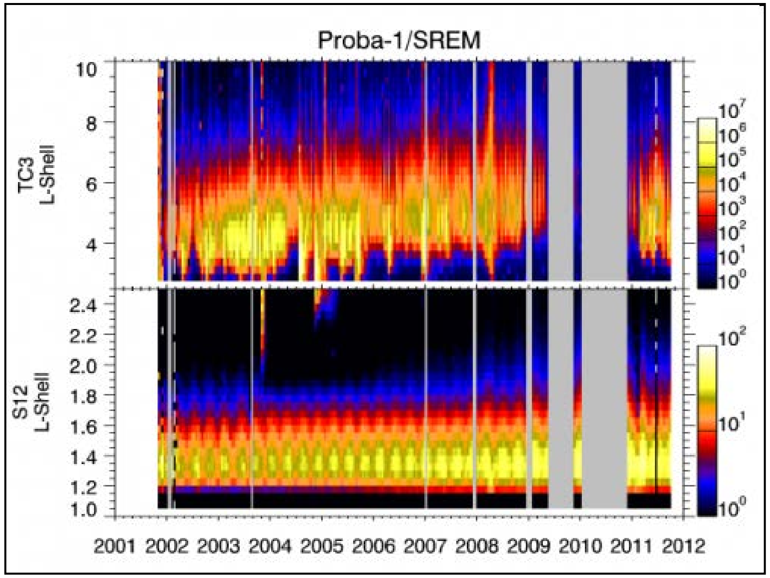
Planck 2009

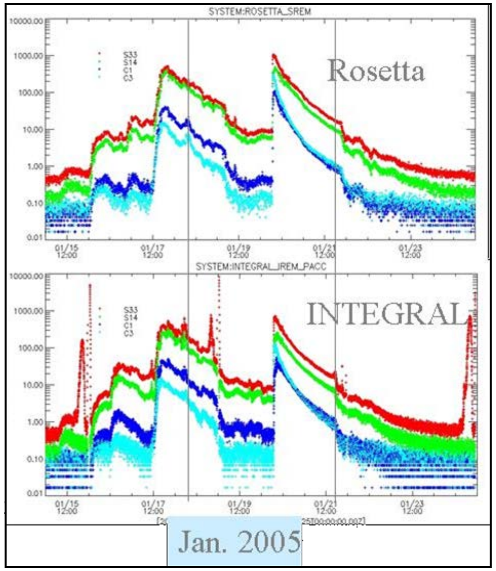
Part of a constellation of European monitors, coordinated via SEENoTC

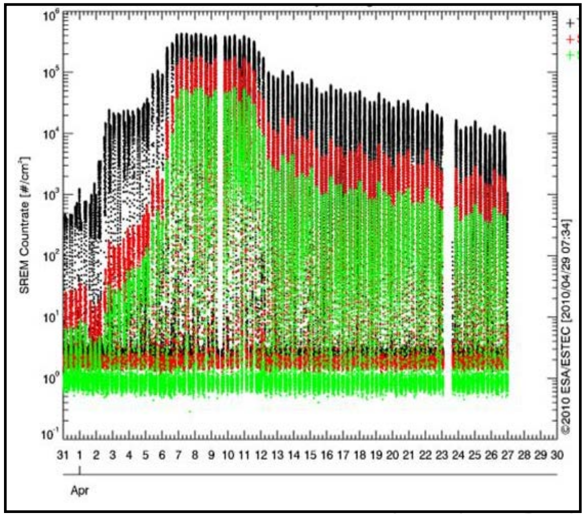
SREMs have returned a wealth of data



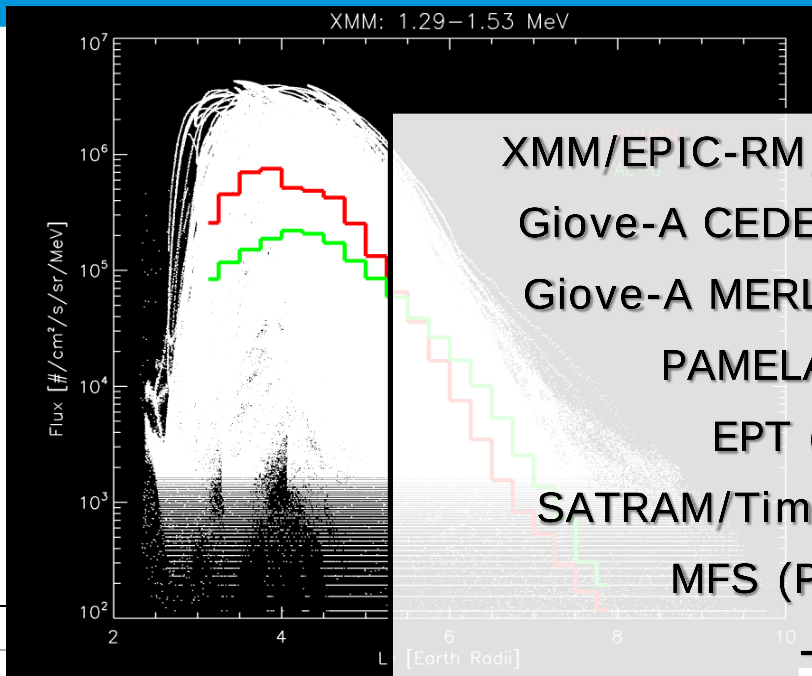


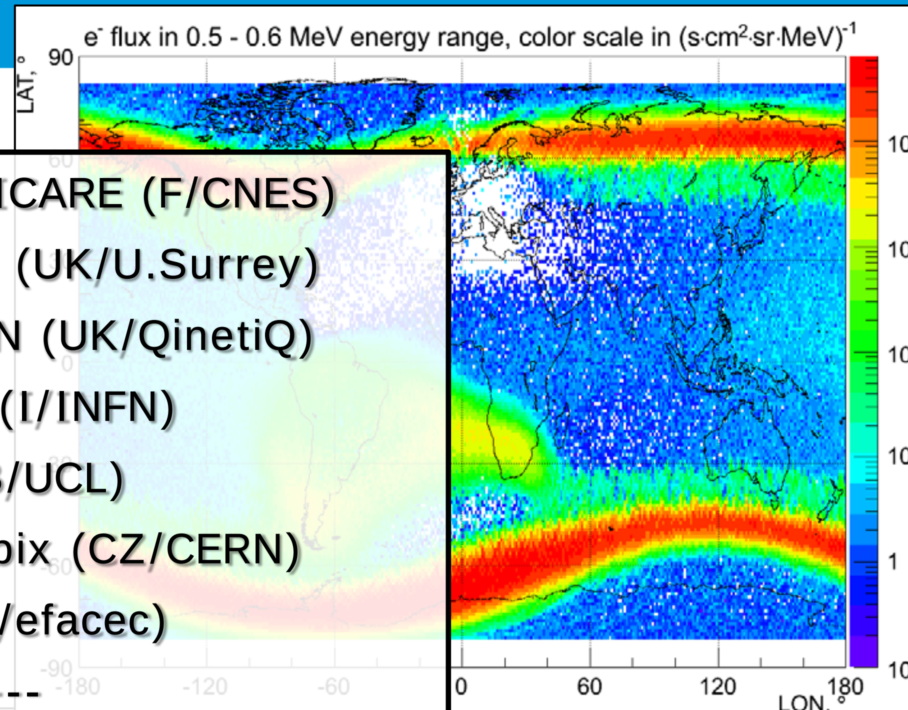






Other Radiation Instruments (incomplete list)





XMM/EPIC-RM; ICARE (F/CNES)

Giove-A CEDEX (UK/U.Surrey)

Giove-A MERLIN (UK/QinetiQ)

PAMELA (I/INFN)

EPT (B/UCL)

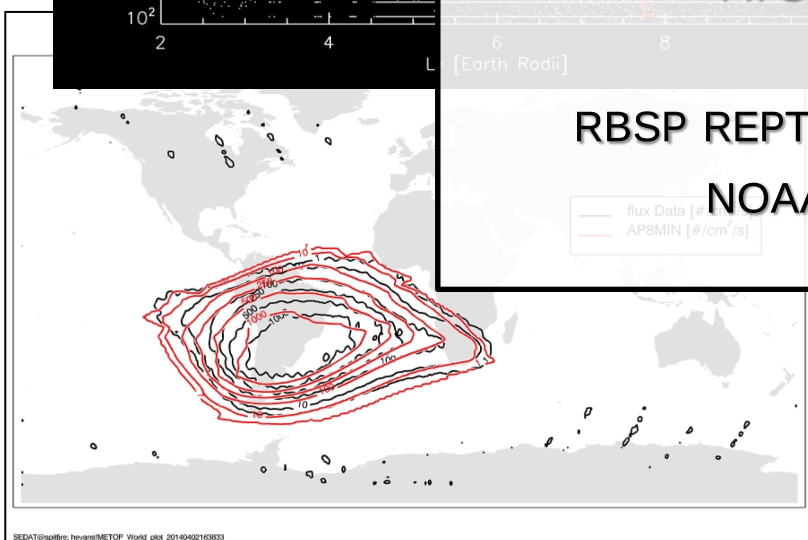
SATRAM/Timepix (CZ/CERN)

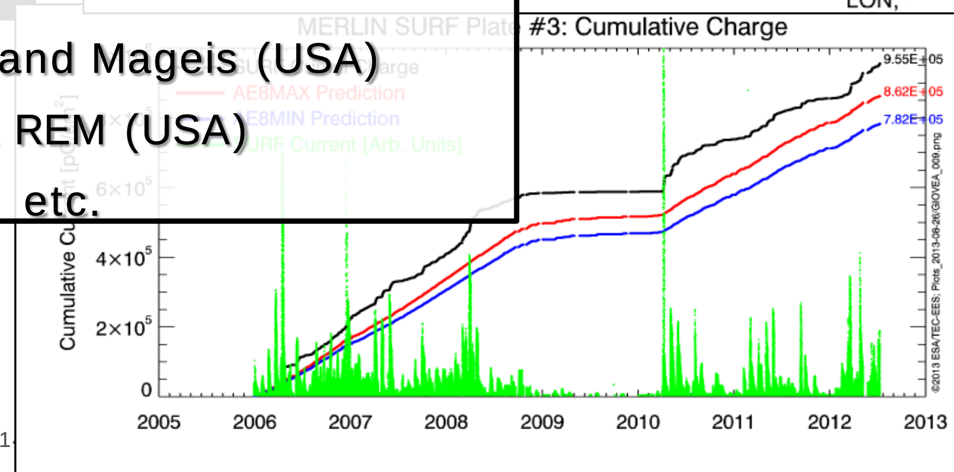
MFS (PT/efacec)

RBSP REPT and Mageis (USA)

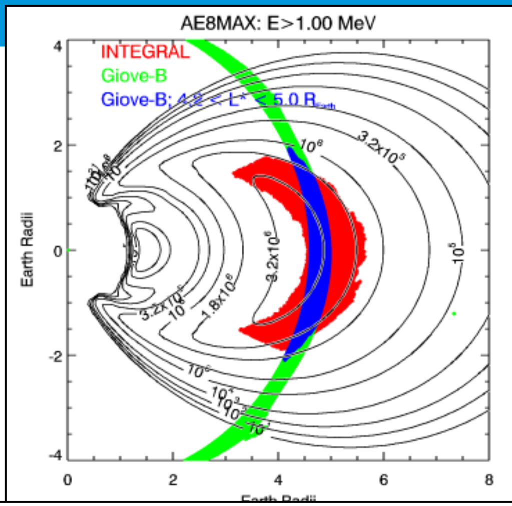
NOAA REM (USA)

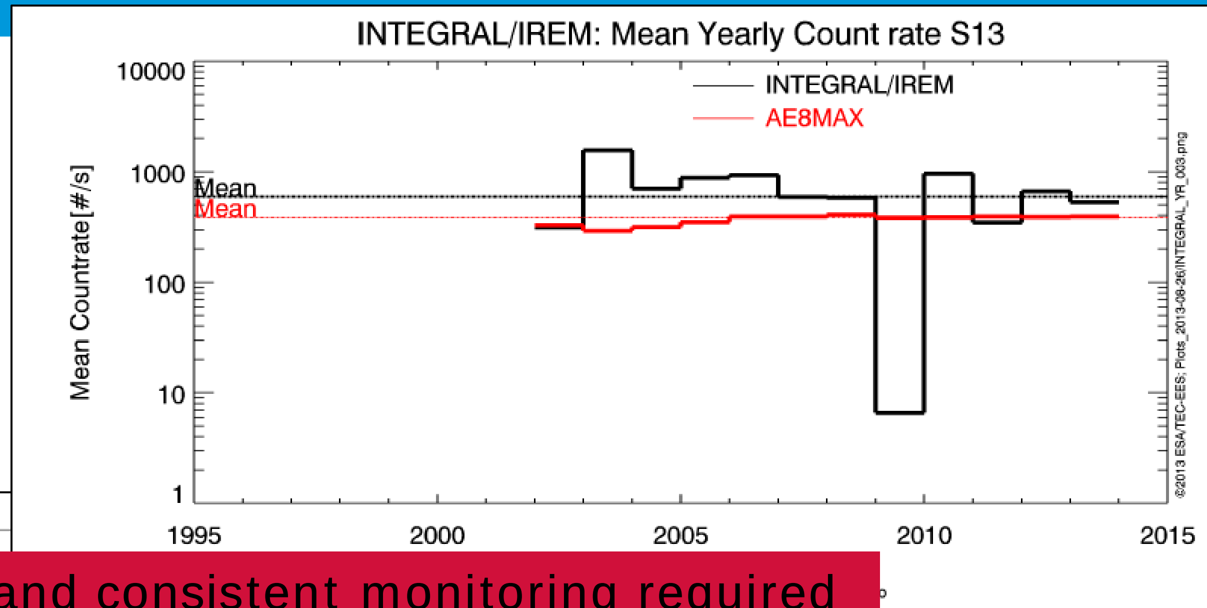
etc.

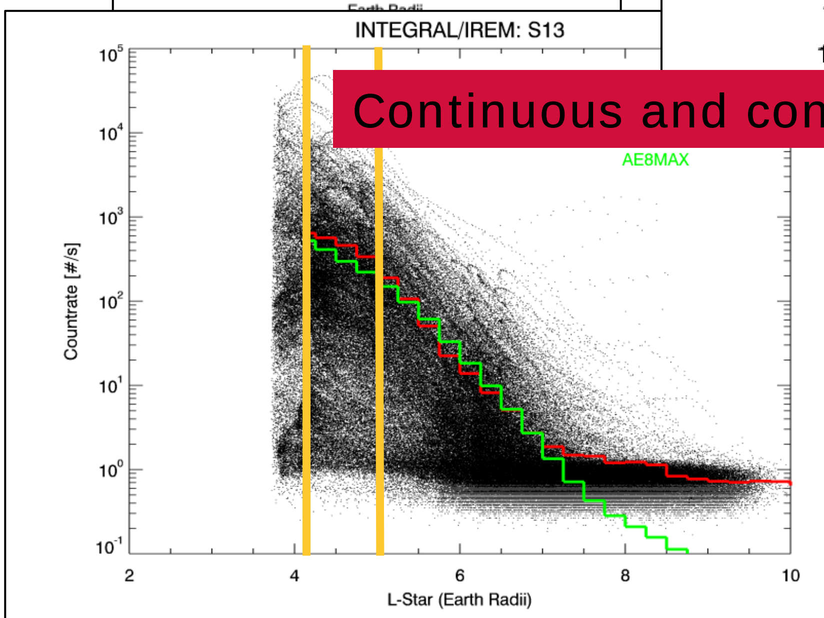




Radiation Belt Validation / Modelling – Temporal coverage







Continuous and consistent monitoring required

Sampled data from:

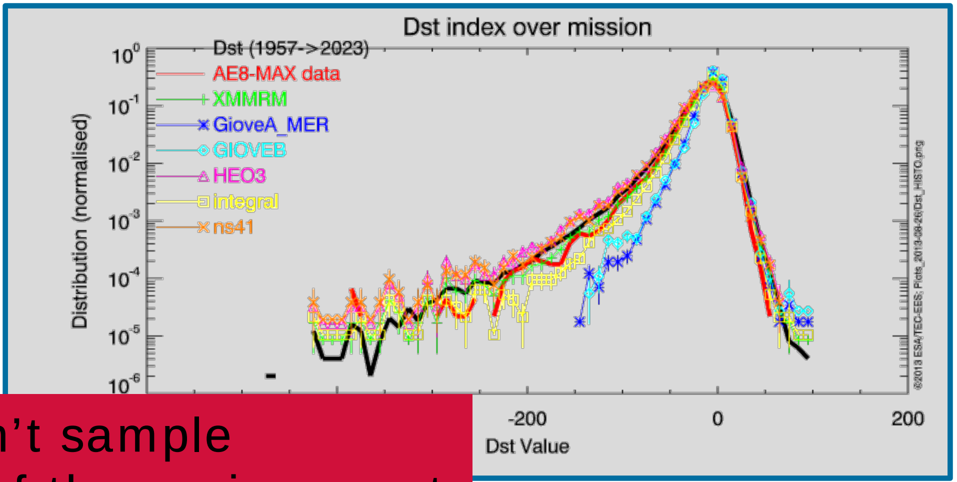
$4.2 \leq L \leq 5$ Earth Radii, and

$Lat_{mag} < 25°$ (equatorial)

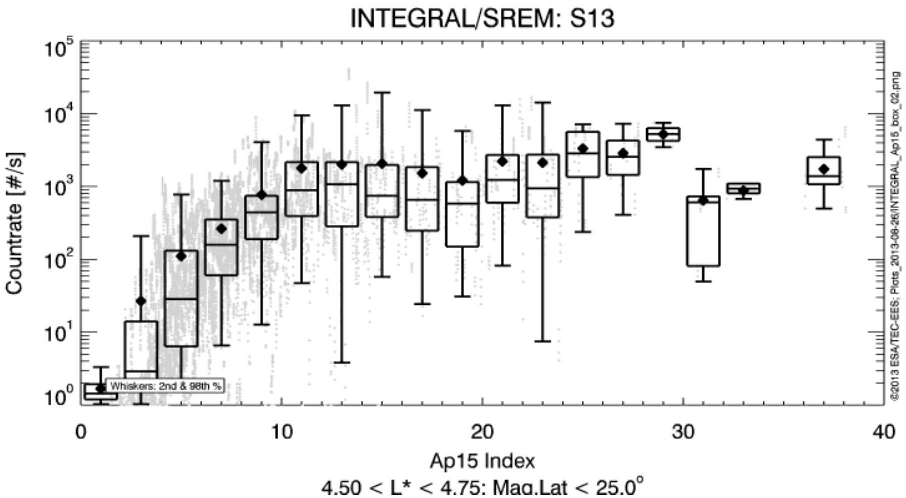
AE-8 MAX used to calculate equivalent count rates using IREM response function.

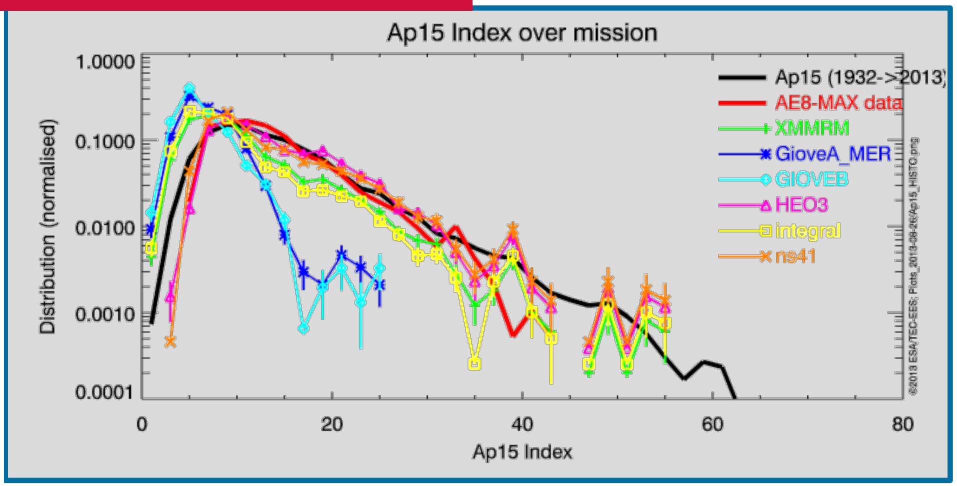
Radiation Belt Validation / Modelling - Environment sample

Various datasets have been binned with magnetospheric indices to show how the magnetospheric states encountered over the dataset compares the long-term history of the magnetospheric indices.



Short datasets don't sample the full dynamics of the environment





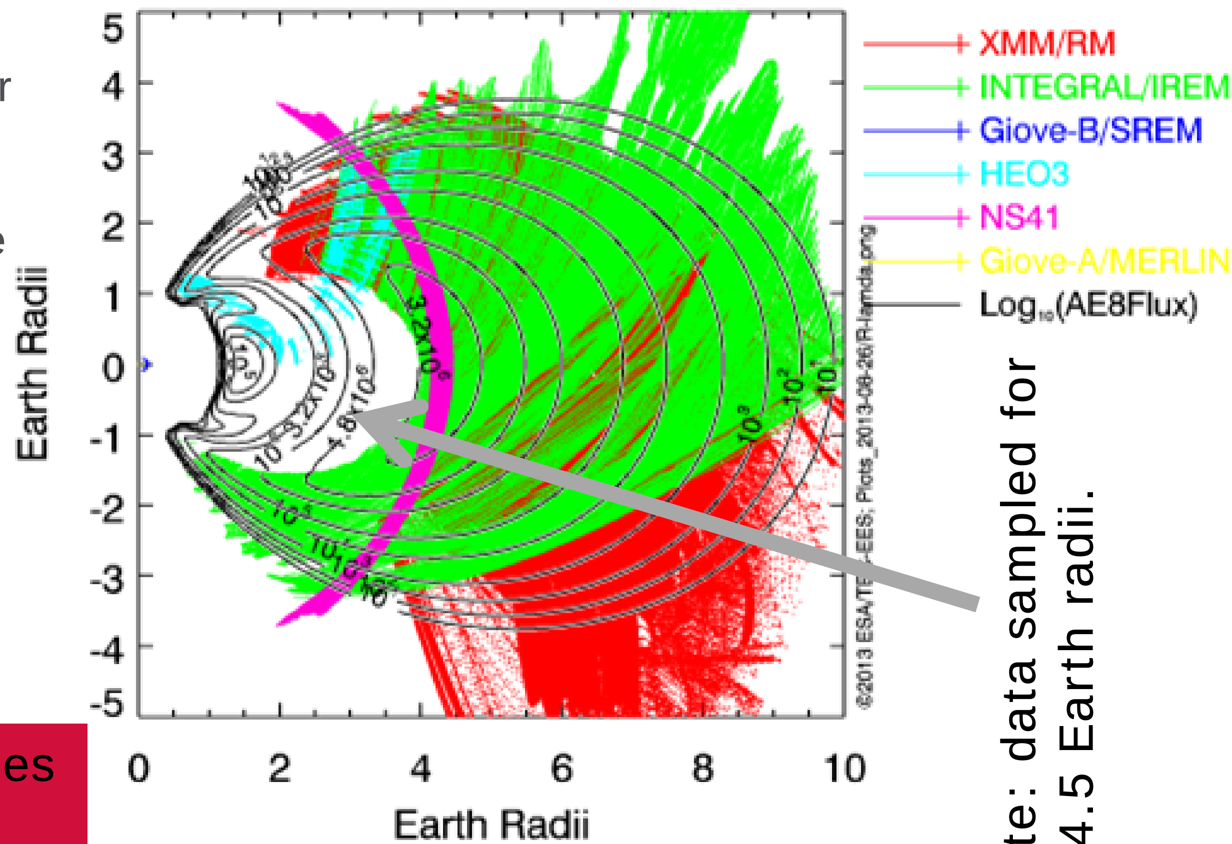
Radiation Belt Validation / Modelling - Magnetospheric Coverage

Integral and XMM provide good coverage of the outer radiation belt.

Inner proton belt coverage by Proba1/SREM, and in the last few years Integral's perigee has fallen to be within the proton belt.

Also Herschel & Planck in L-2, and Rosetta in interplanetary space.

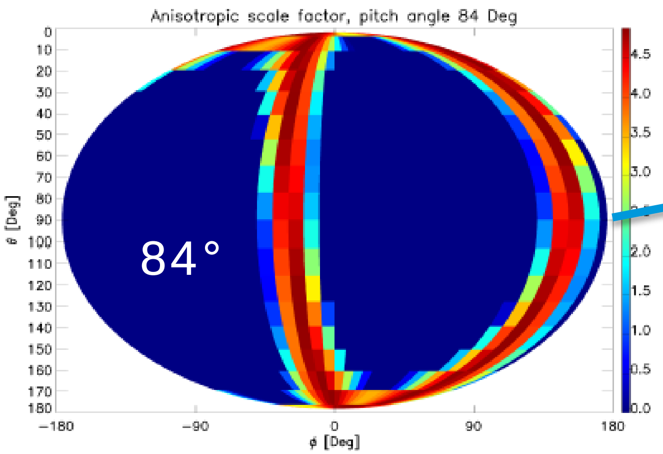
Diverse Flight Opportunities
→Global coverage

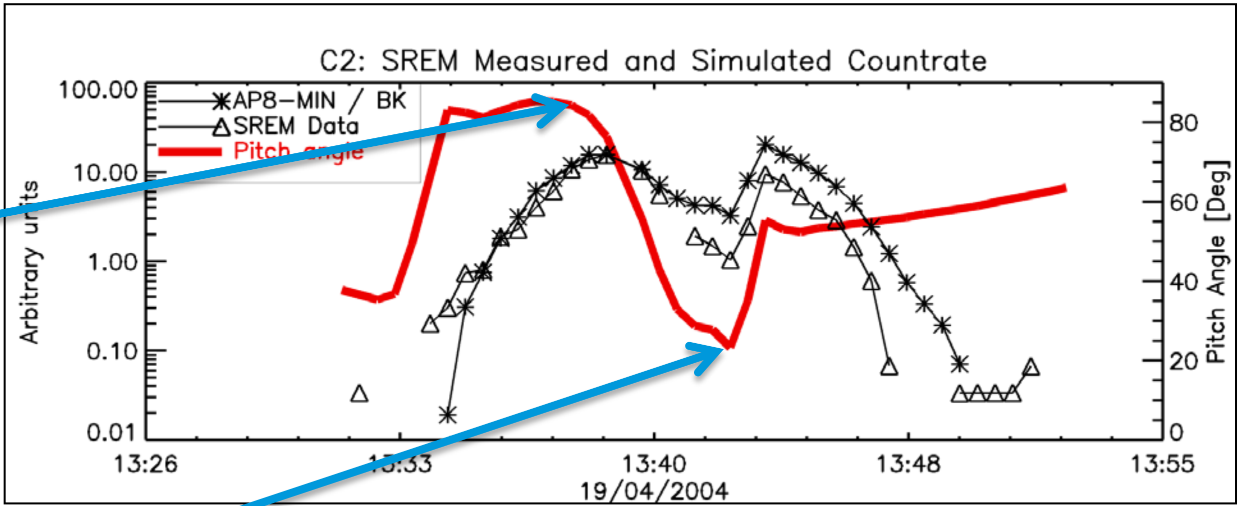


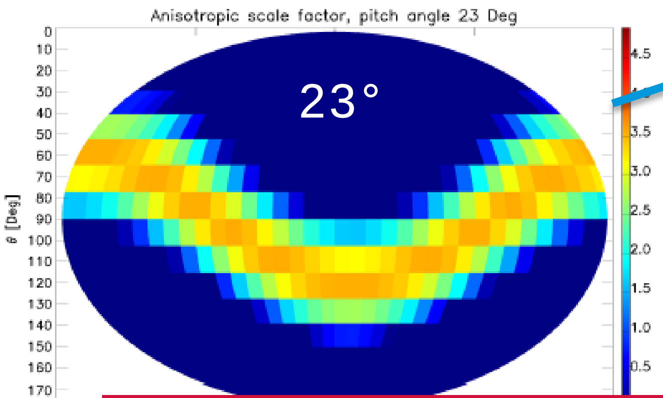
Global coverage →
Cross calibrating instruments

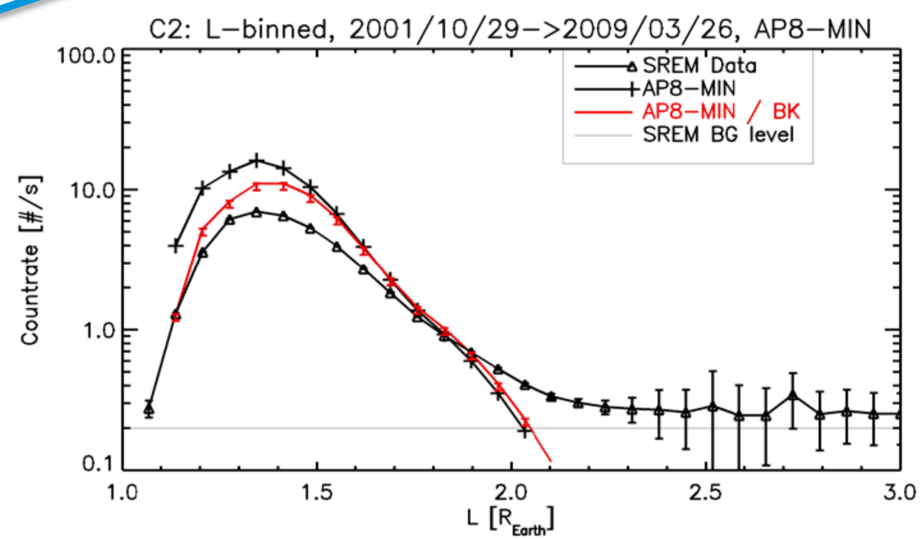
Note: data sampled for L>4.5 Earth radii.

Proton Radiation Belt Validation - Anisotropy









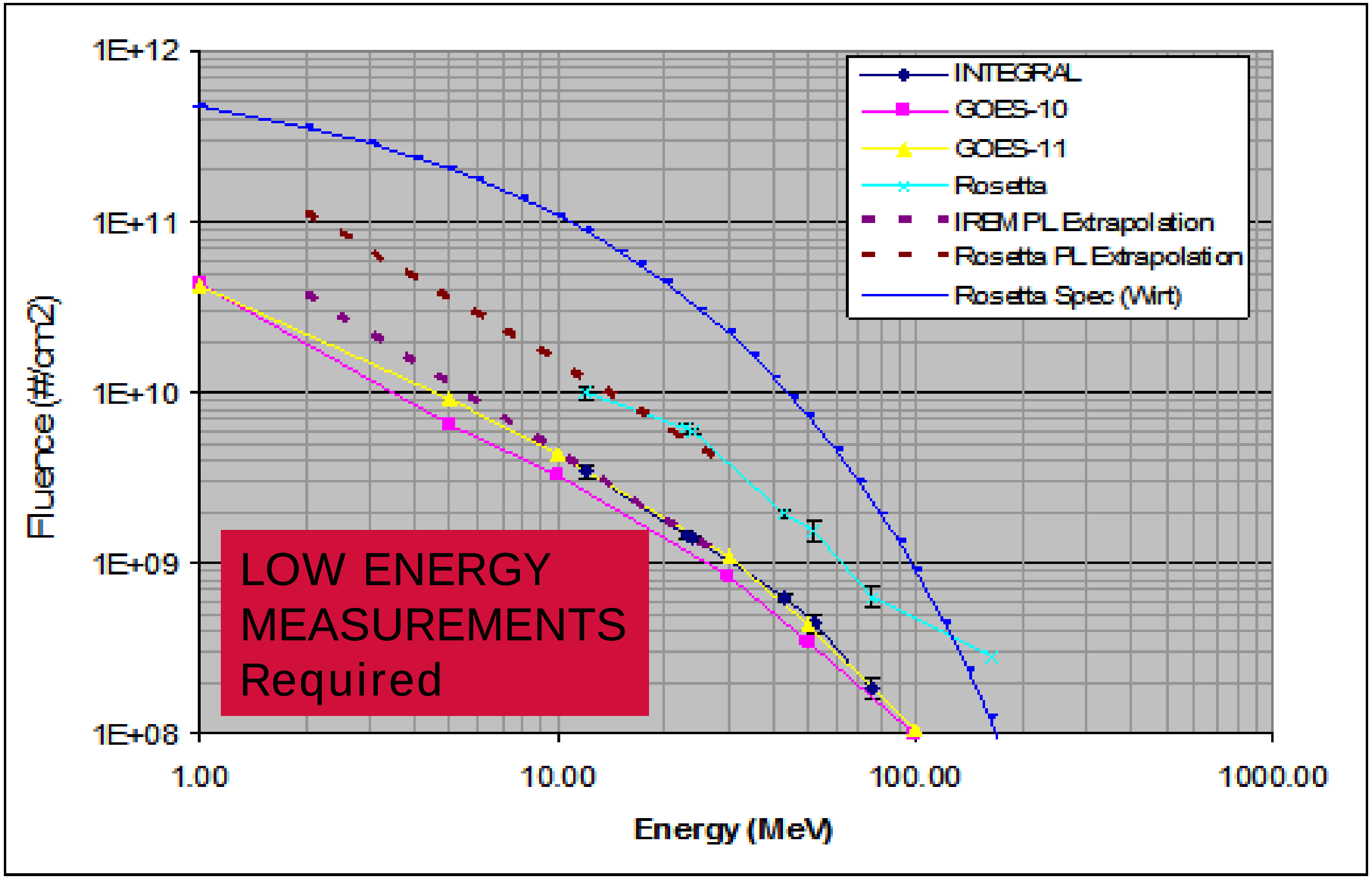
Resolution of Pitch Angle → 3D response functions

Rosetta Experiences

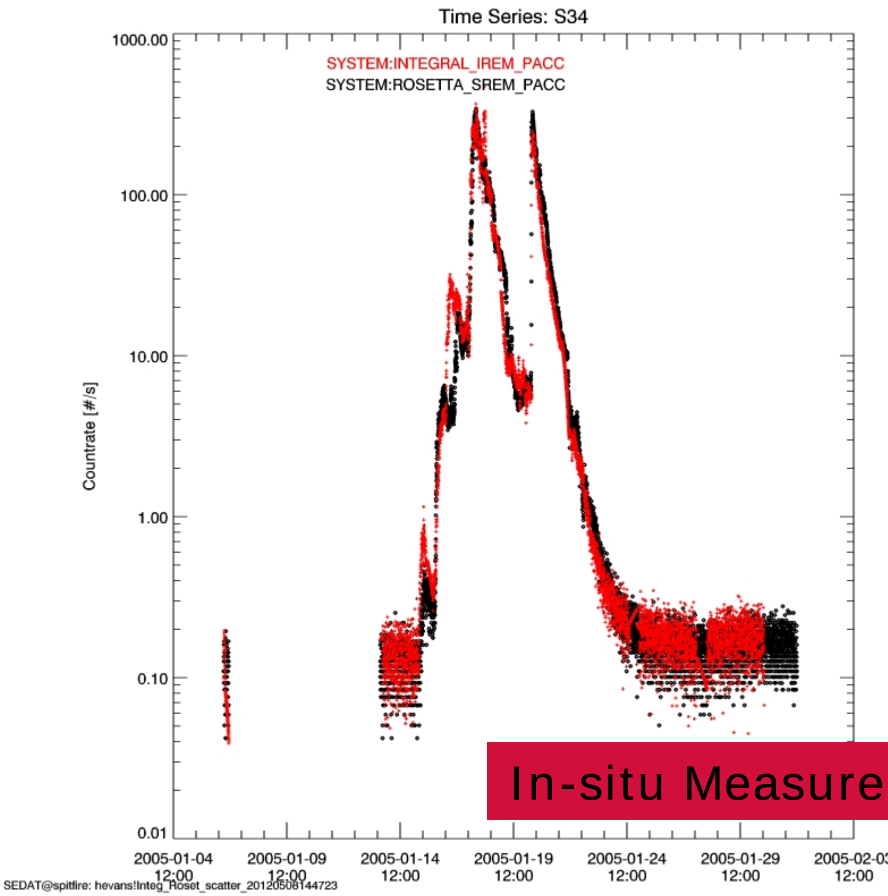
The different fluence spectra for the Rosetta Mission epoch (2004→2011).

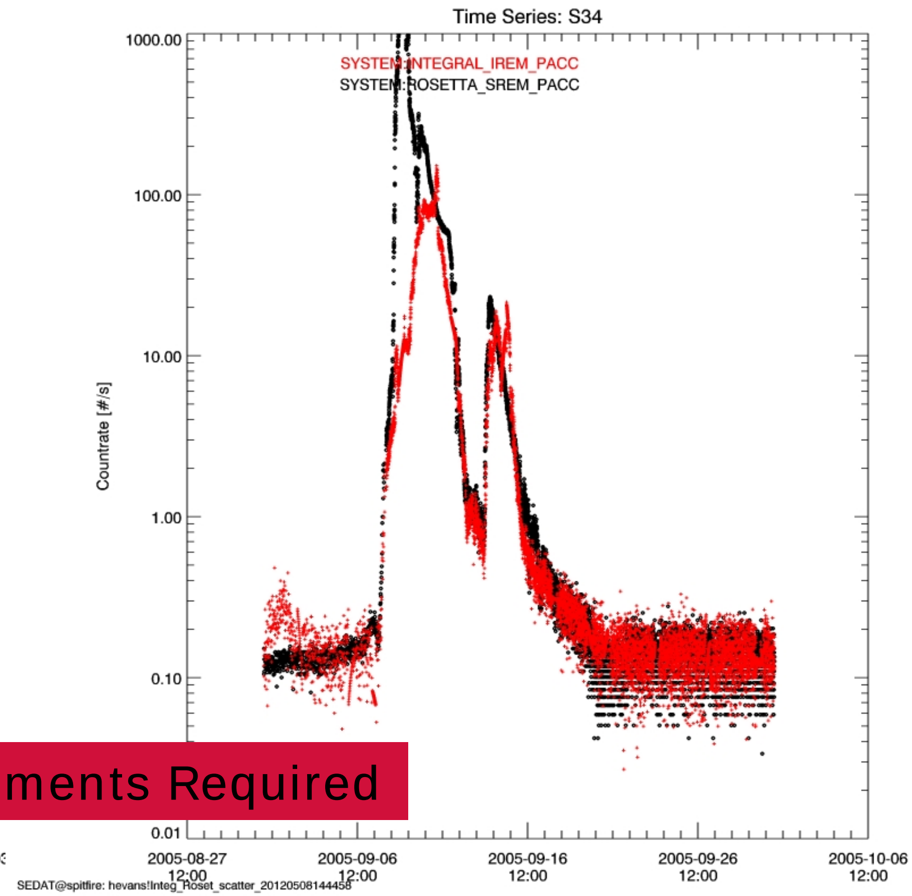
A power law fit is used to extrapolate the Rosetta and Integral SREM data to lower energies.

The Rosetta spectrum is ~5× higher than terrestrial measurements.



Rosetta Experiences





In-situ Measurements Required

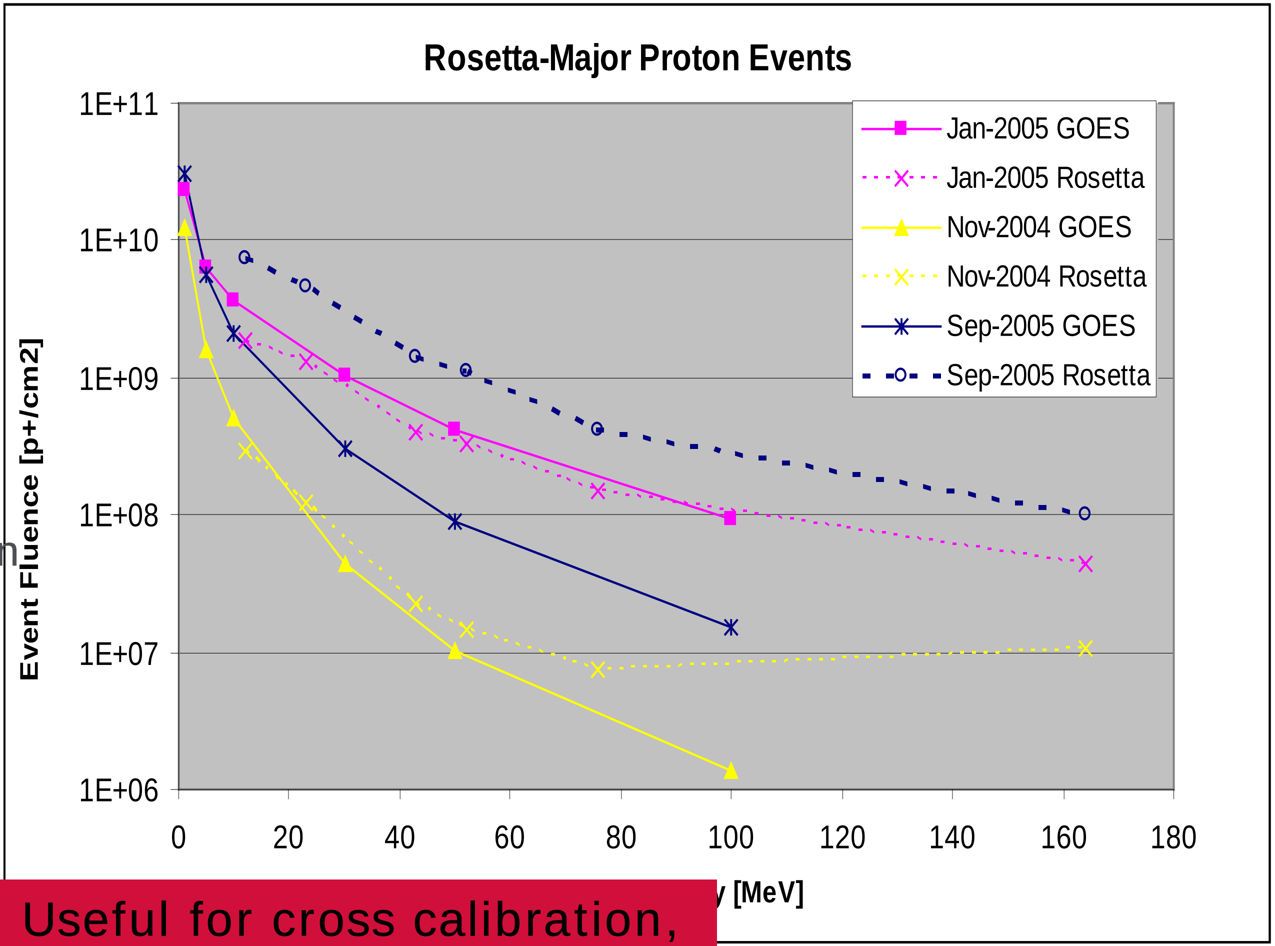
Jan 2005

Sept 2005

Rosetta Experiences

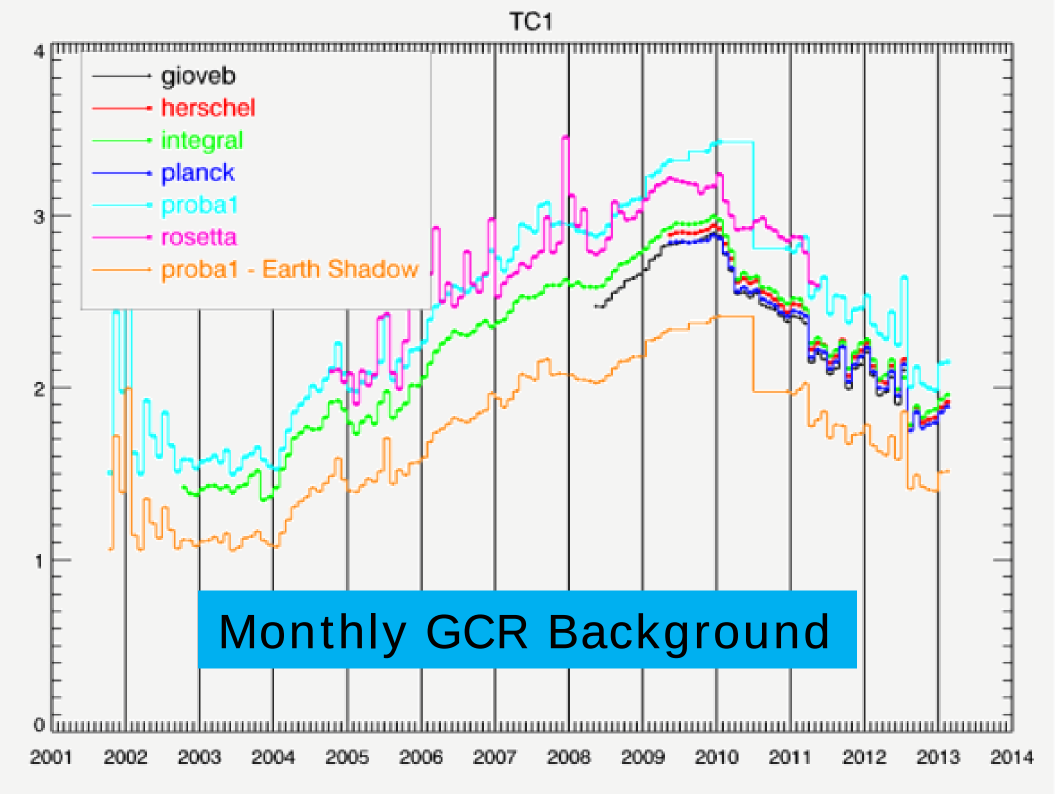
Events in 2004 and Jan 2005 result in similar spectra for GOES and Rosetta/SREM. We can use these for cross calibration and extrapolation.

The Sept 2005 event, though shows a much harder hit at Rosetta than at Earth, demonstrating the need for in-situ measurements.

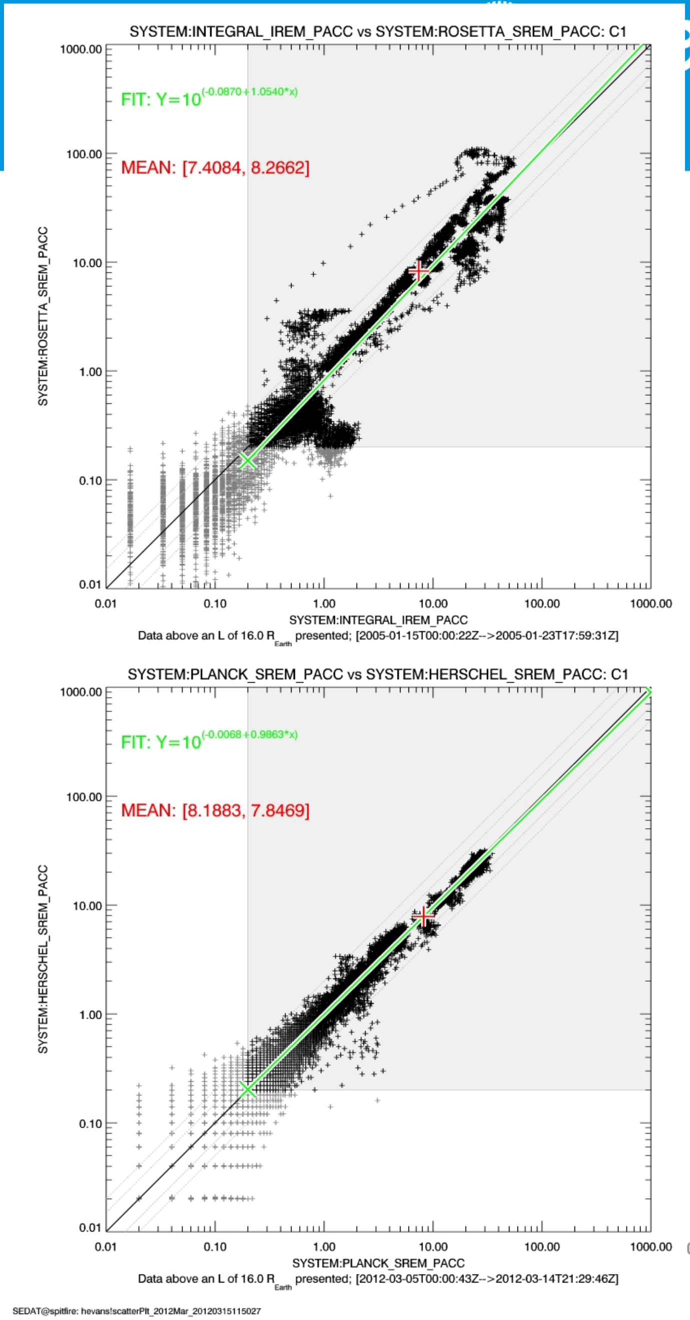


Solar Proton Events → Useful for cross calibration, but are they measuring the same population?

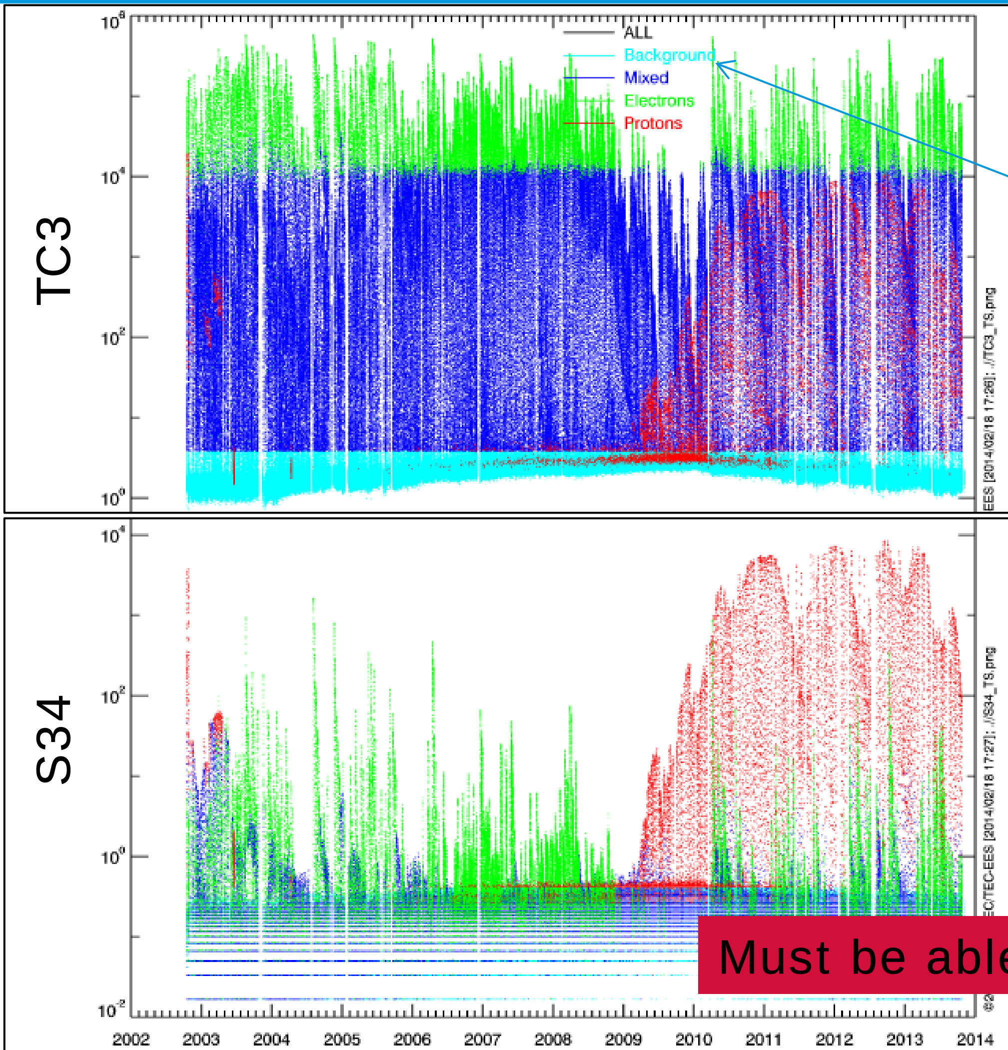
Inter calibration of Instruments

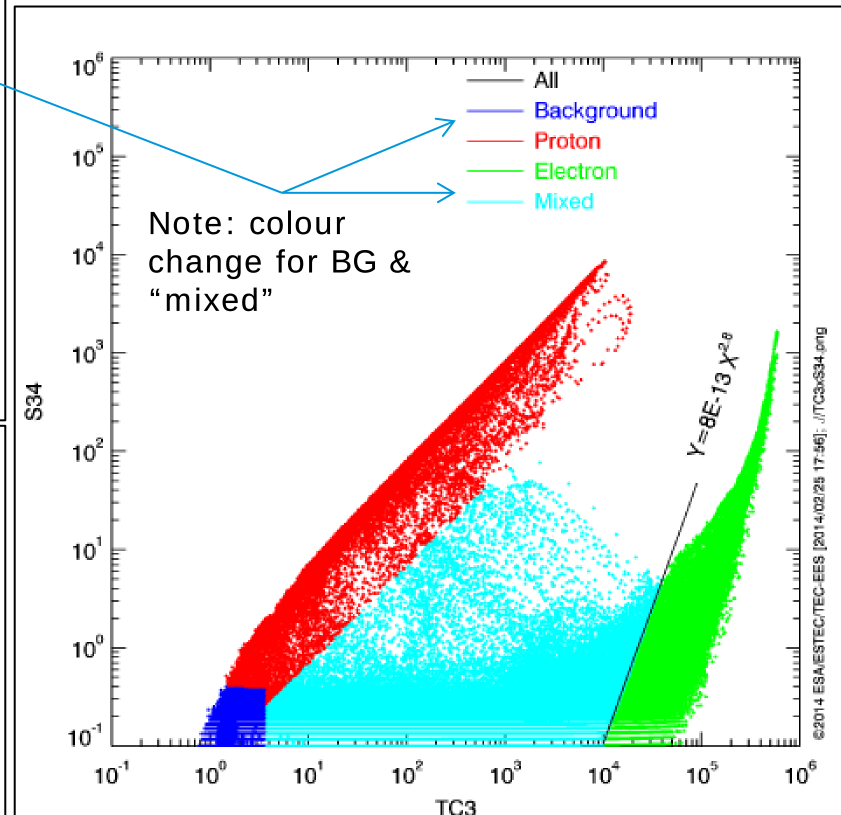


Good Cross Calibration → can resolve different populations/effects



Species Discrimination





Note: colour change for BG & “mixed”

Must be able to determine species of particle

Calibrated vs Uncalibrated Data

1. **Raw count** rate data with instrument response functions can be used for:
    a. model validation (most accurate method for validation).
    b. relative comparisons of the radiation environment state.
    c. Operational “safe-ing” of the spacecraft
2. **Calibrated data** is essential for:
    a. developing radiation environment models
    b. determining engineering effects
    (TID, NID, solar cell degradation, manned doses, etc.)
3. **Calibrated data** is essential for cross comparison of different instruments; at least one of the datasets has to be in physical units, e.g. #/cm^2/s, to make use of the other instrument’s response function.

Conclusions

1. Use of the SREM data has largely been with the **raw count rate data**, validating radiation environment models, but radiation effects have also been calculated to determine the health of spacecraft.
2. Uncalibrated/Raw data is of great use, but for full data exploitation **calibration to physical units is necessary**.
    a. The calibration algorithms and response functions must be comprehensively reported and available to the user
    b. The errors in the calibrated data must be available
    c. Ability to cross calibrate with other instruments essential (even better to have a large fleet of identical instruments!)
3. **More data is always needed**:
    a. For operational reasons – **no substitute for in-situ measurements**
    b. to constantly **improve the historical record** of the radiation environment for model improvements and to capture the "1 in a hundred" year event

Requirements:

1. Good calibration
   a. Flux Accuracy to ~10-15%
   b. Pitch angle/Anisotropy discrimination
   c. Particle discrimination (low contamination)
   d. Cross calibration with other instruments (ideally identical instruments)
2. Energy range for engineering purposes (not science!)
   a. Electrons: 0.5 → 7 MeV (>20 MeV for Jupiter!)
   b. Protons: 5 → >250 MeV
3. Long datasets
   a. Characterise the 1:100 year event (DDC/SEE)
   b. Characterise the nominal environment (dose and degradation effects)
   c. Consistency in measurement!

Report the Calibration Uncertainty/Errors!

Make the data available!