

# SLR energy density estimations and measurements for the Herstmonceux station

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SGF, Herstmonceux



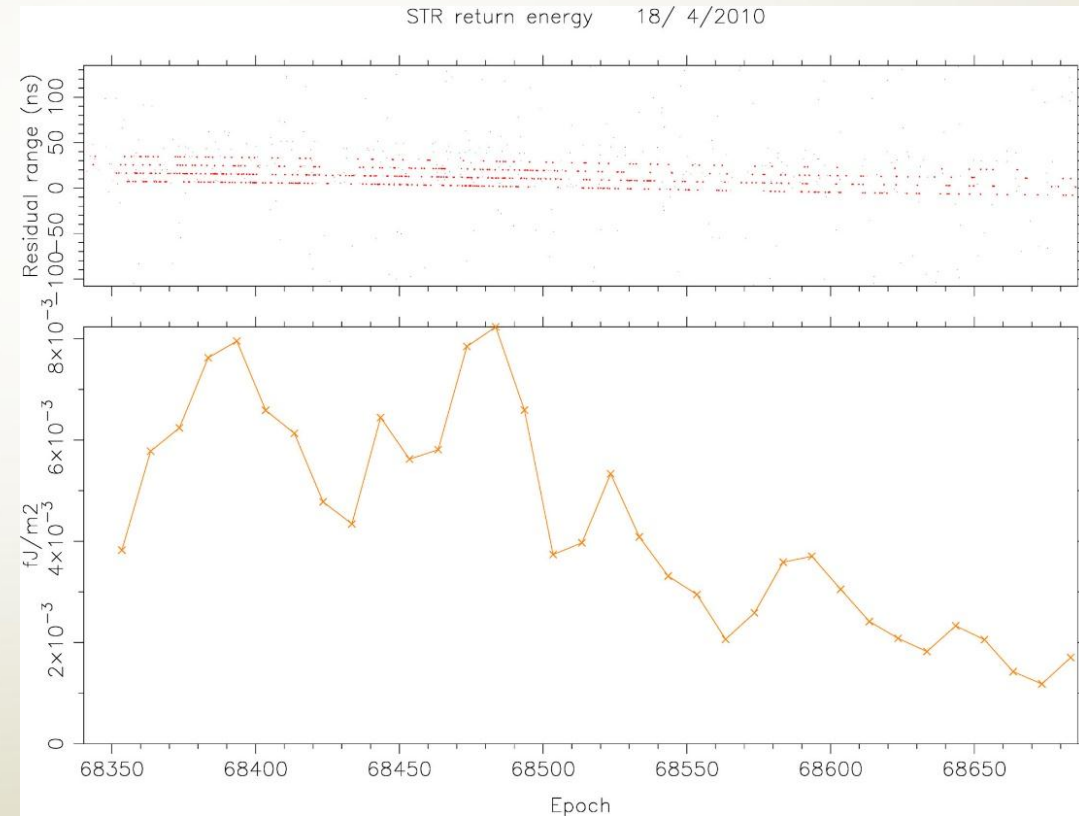
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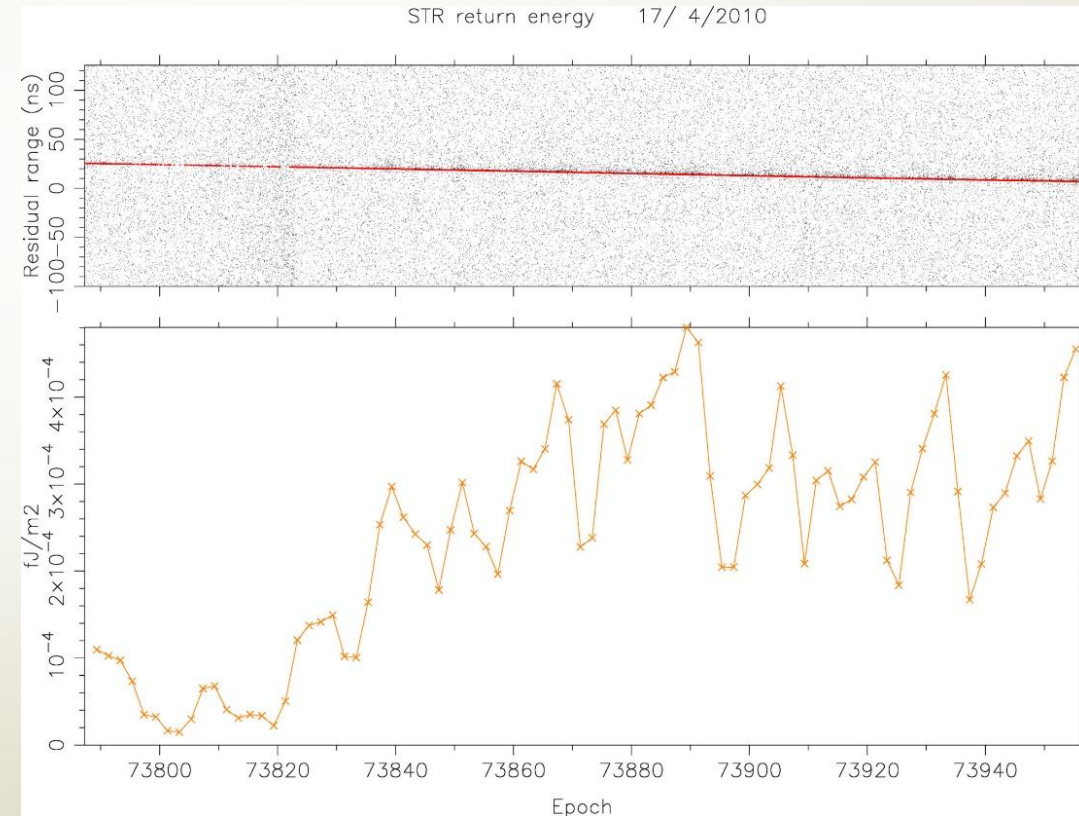
# Reprocessed return energies

- Return rates were recalculated using fullrate data files, raw range files and corresponding records of the applied filters.
- Reversing part of the link equation gives the number of photo-electrons per shot from the probability of detection.
- This is then scaled by the QE of the detector, the wavelength and Planck constant, the applied filters, receive optical efficiencies and the area of the telescope.

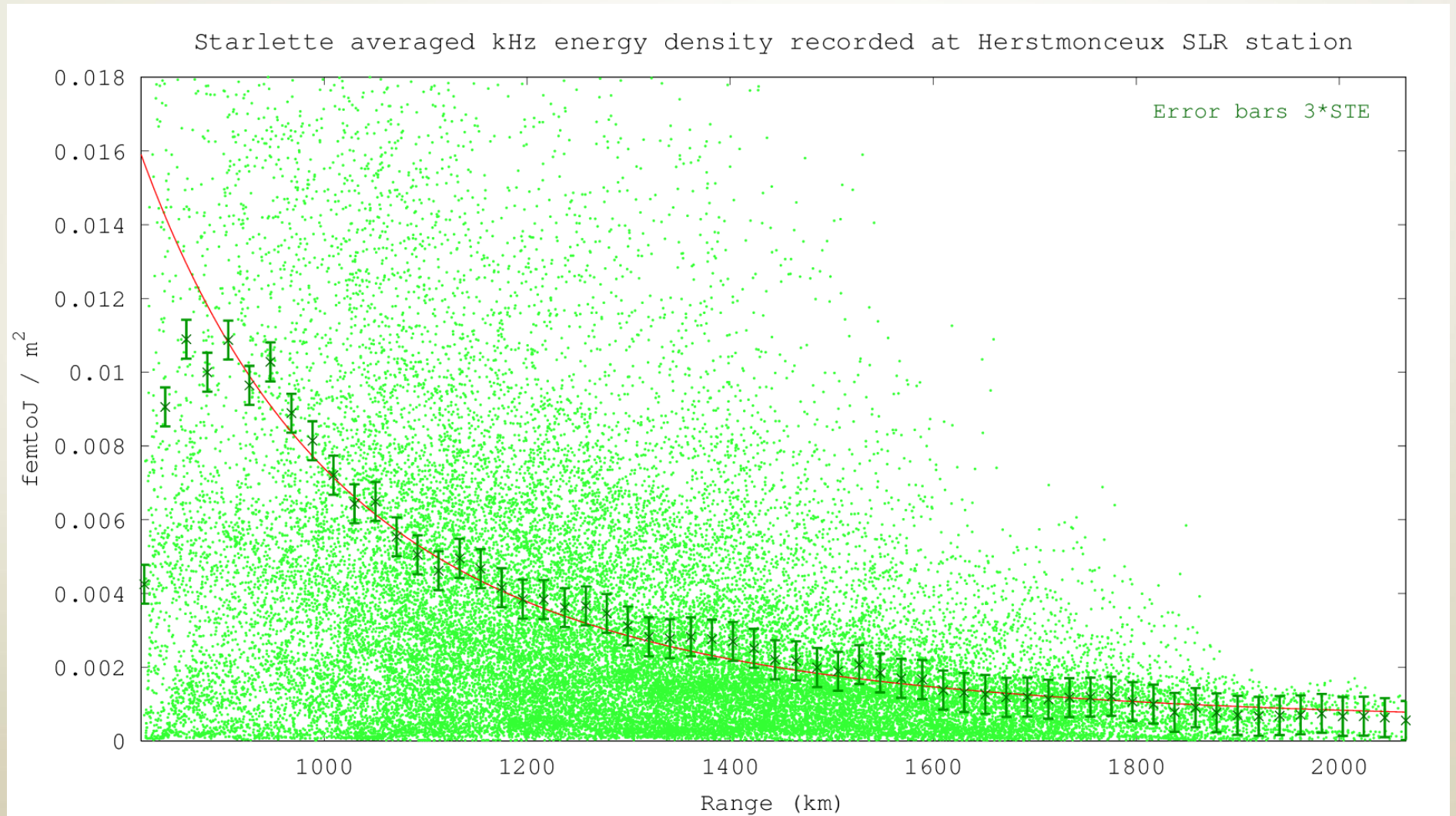


# Reprocessed return energies

- The data set begins in June 2009 when the narrowband oven filter was last retuned.
- The dataset is not perfect and includes laser services, SPAD swaps and optic changes.
- Energy densities were calculated for both SLR systems, although the kHz laser was operational for less than half of the period.



# Starlette return energy densities

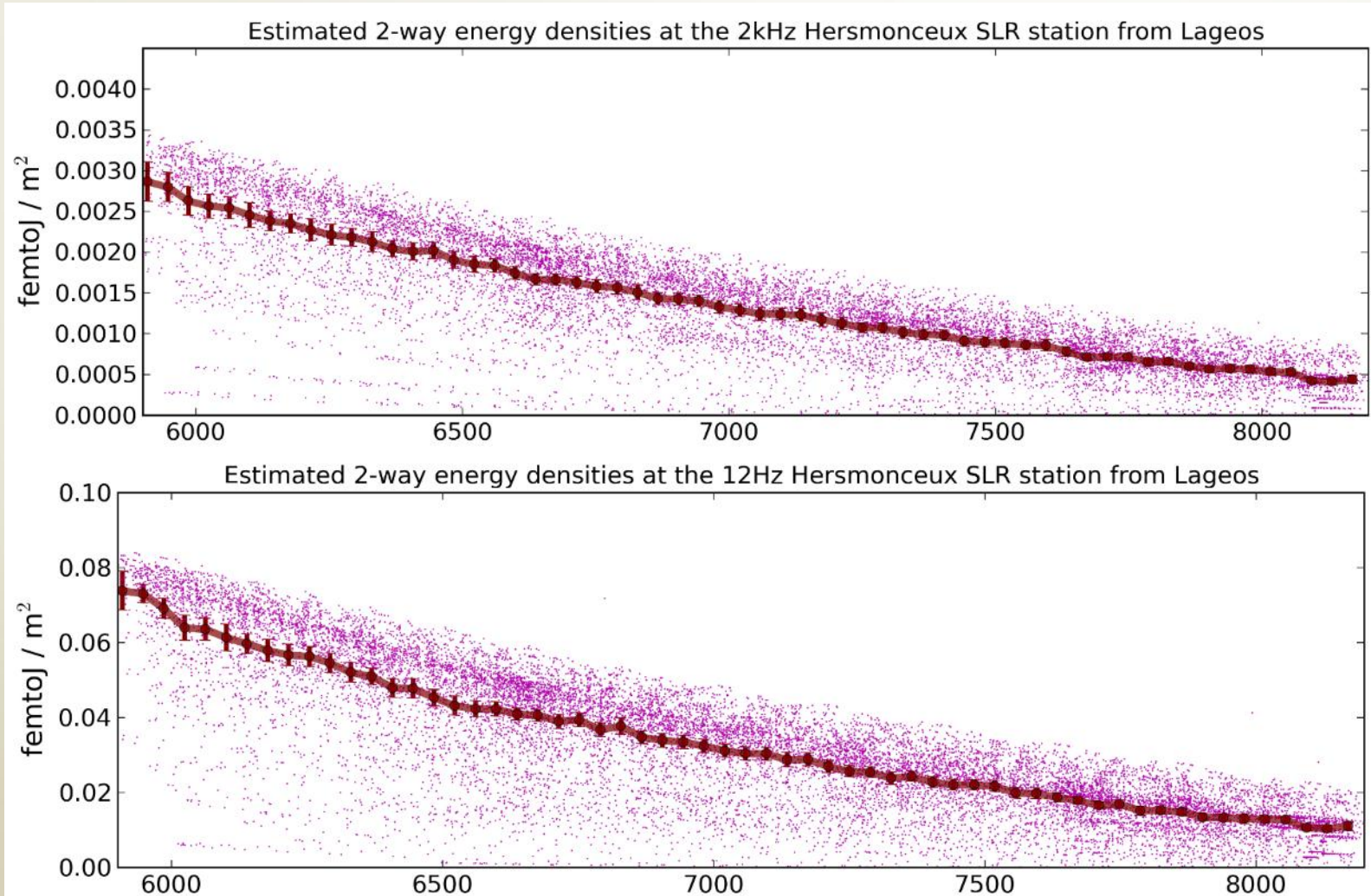


# Herstmonceux Link-budget

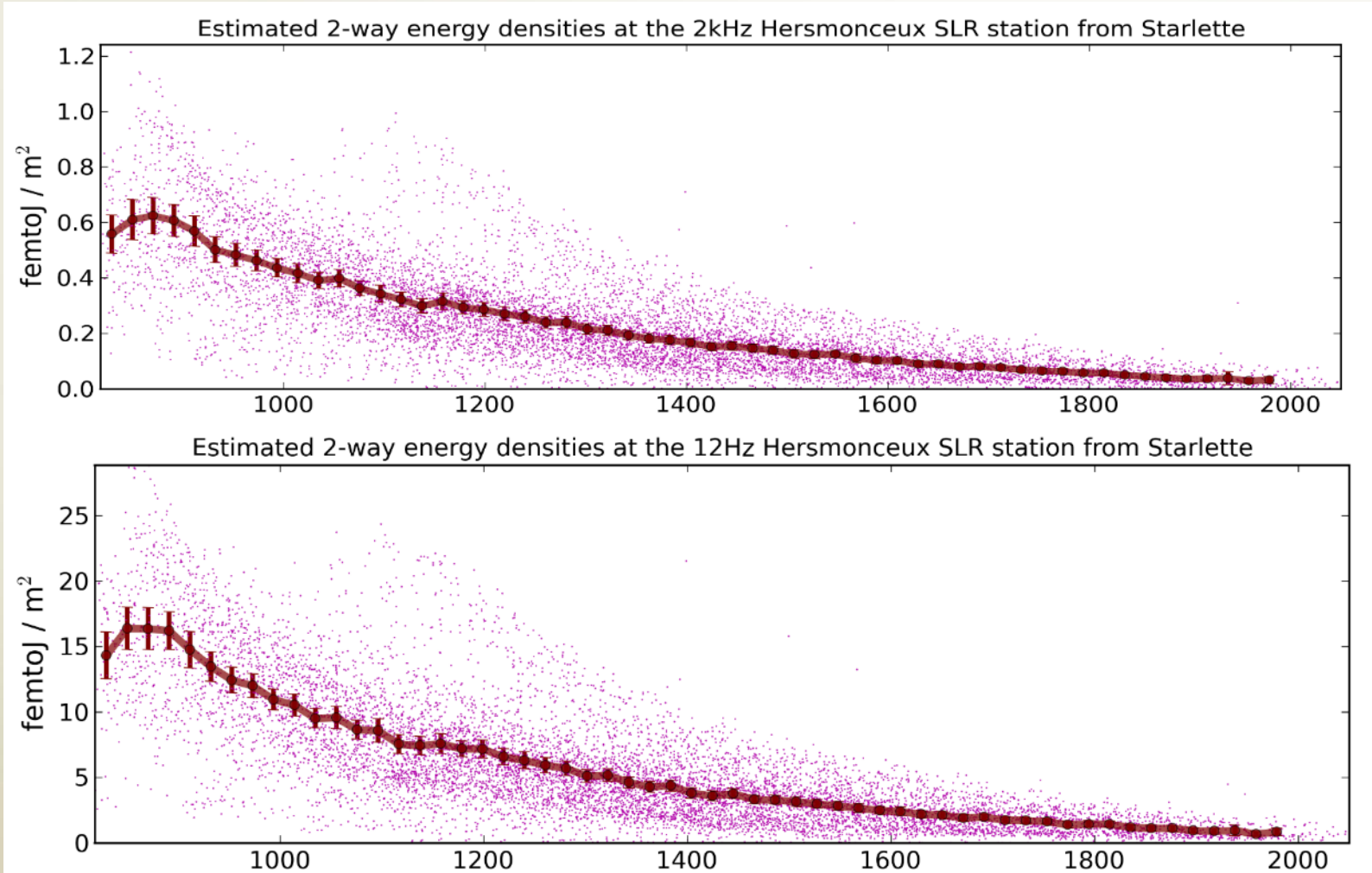
The link budget uses measurement, modelling and estimation:

- The beam divergence was measured using a scanning method (*Burris et al.*).
- Pointing errors were estimated as an average bias based on observer experience
- Atmospheric transmission was estimated from local visibility measurements and the values were tested with photometry star calibrations.
- An average value of cirrus cloud was assumed.
- Satellite cross-section was calculated by diffraction modelling and velocity aberration.
- For spherical LRA targets, the retroreflectors were assumed to be evenly distributed.
- For Jason-2, actual retroreflector positions + attitude law were calculated.

# Average Lageos return energy densities

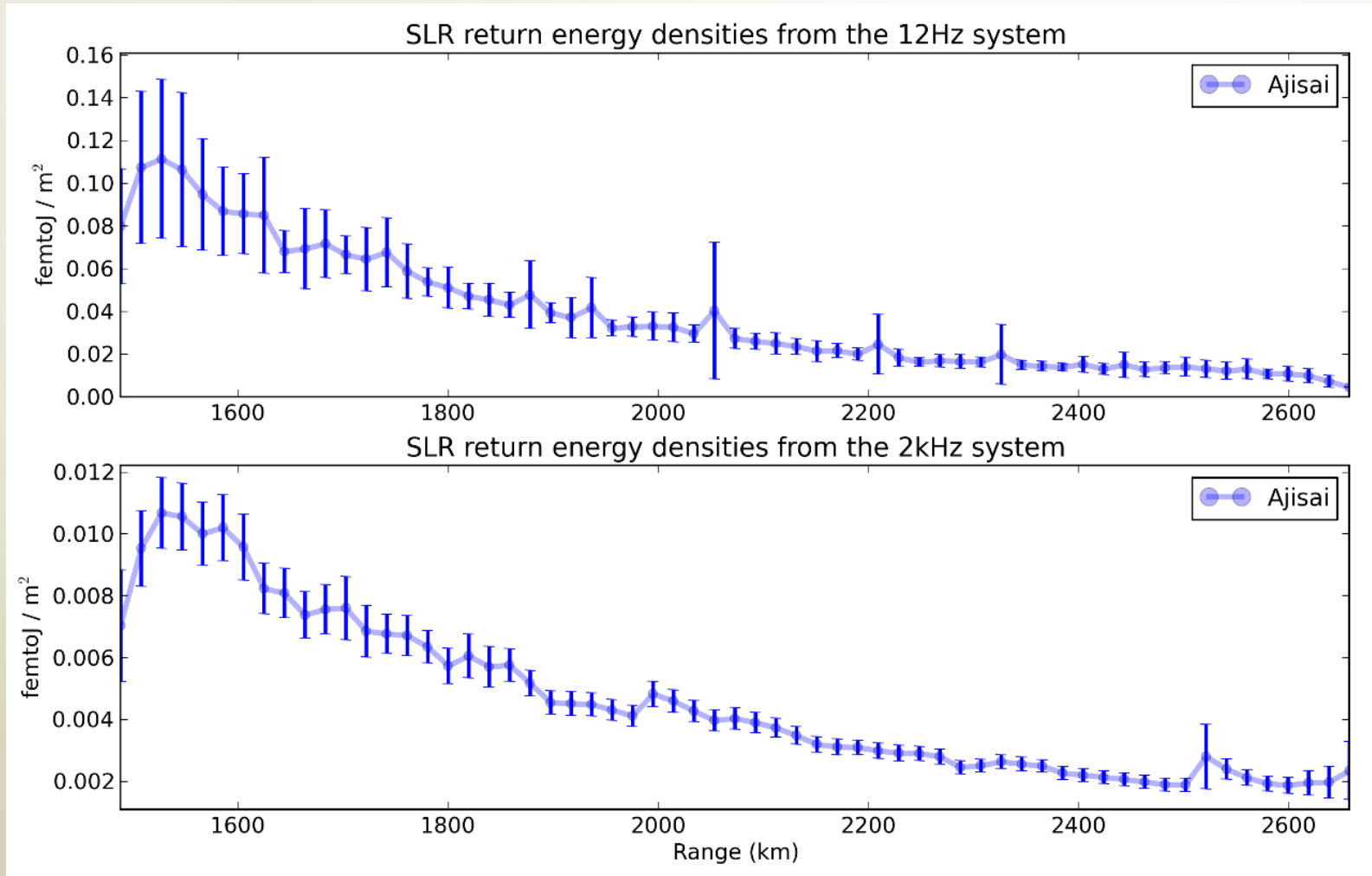


# Average Starlette and Stella return energy densities

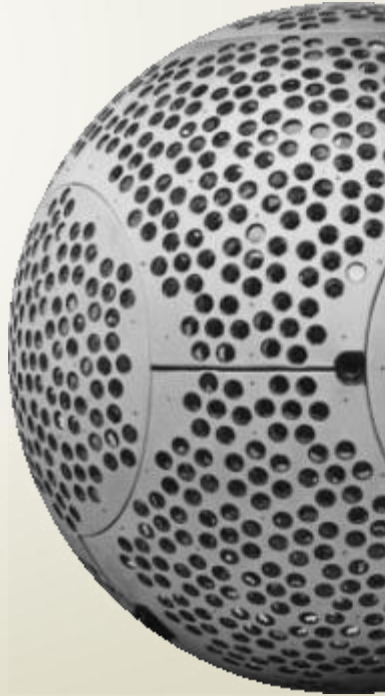
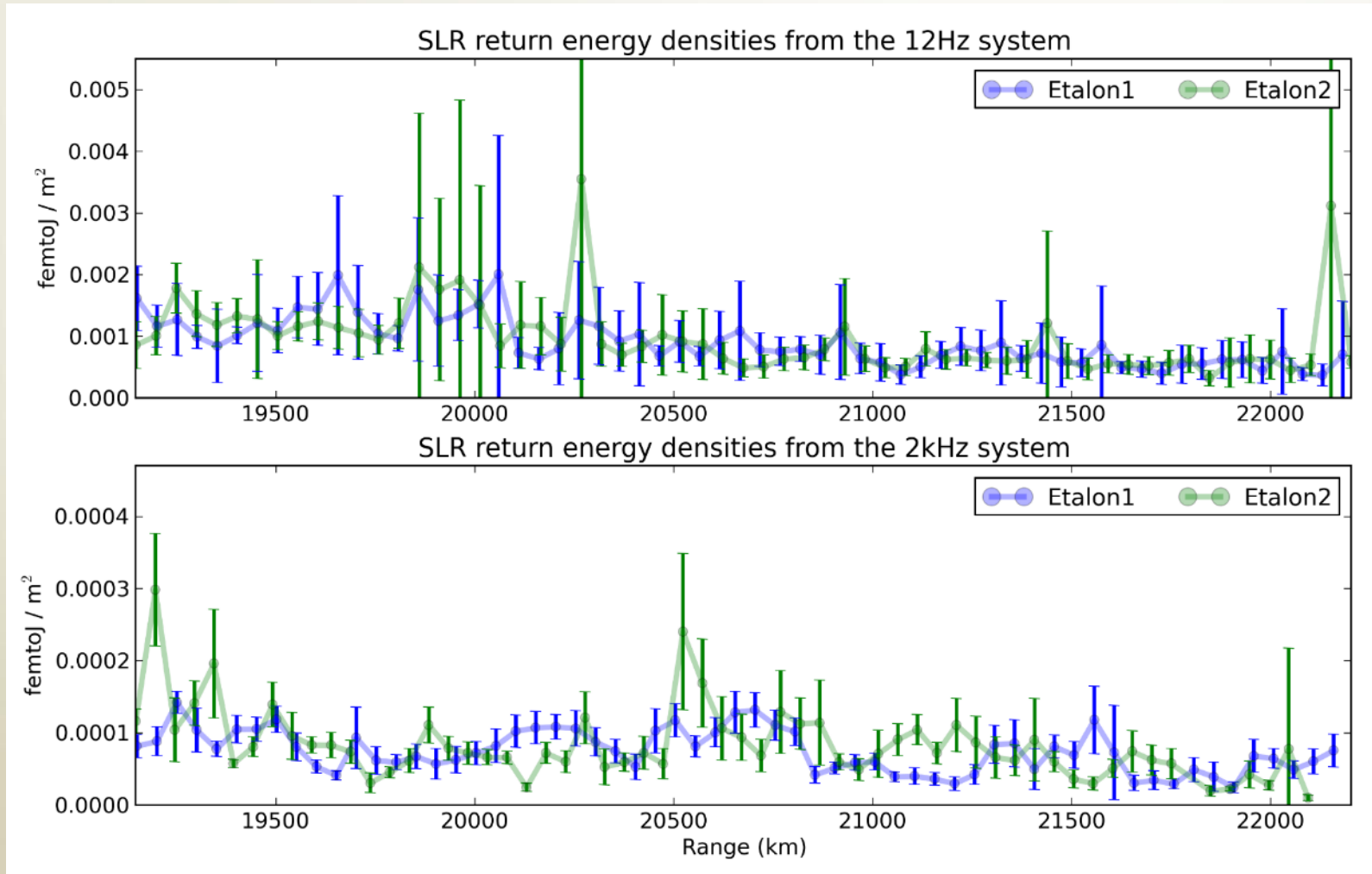




# Average Ajisai return energy densities

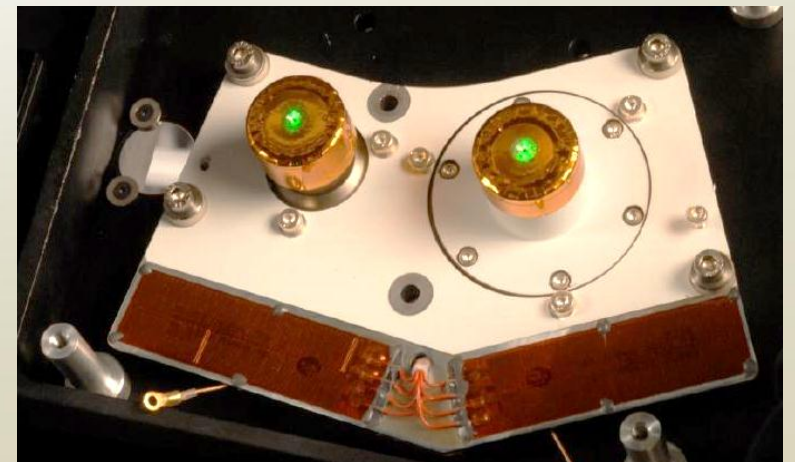


# Average Etalon return energy densities

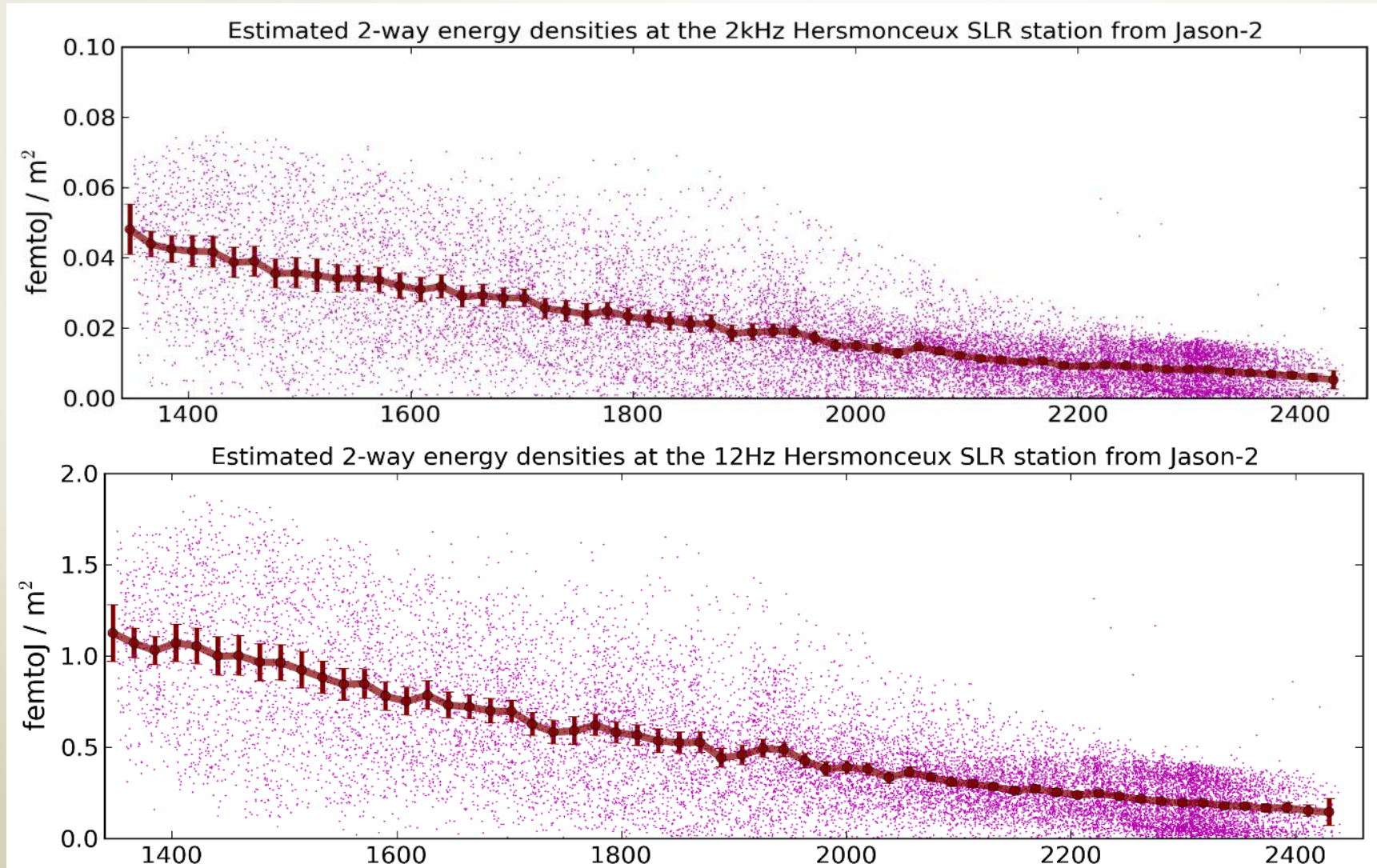


# Laser energy from and at Jason-2

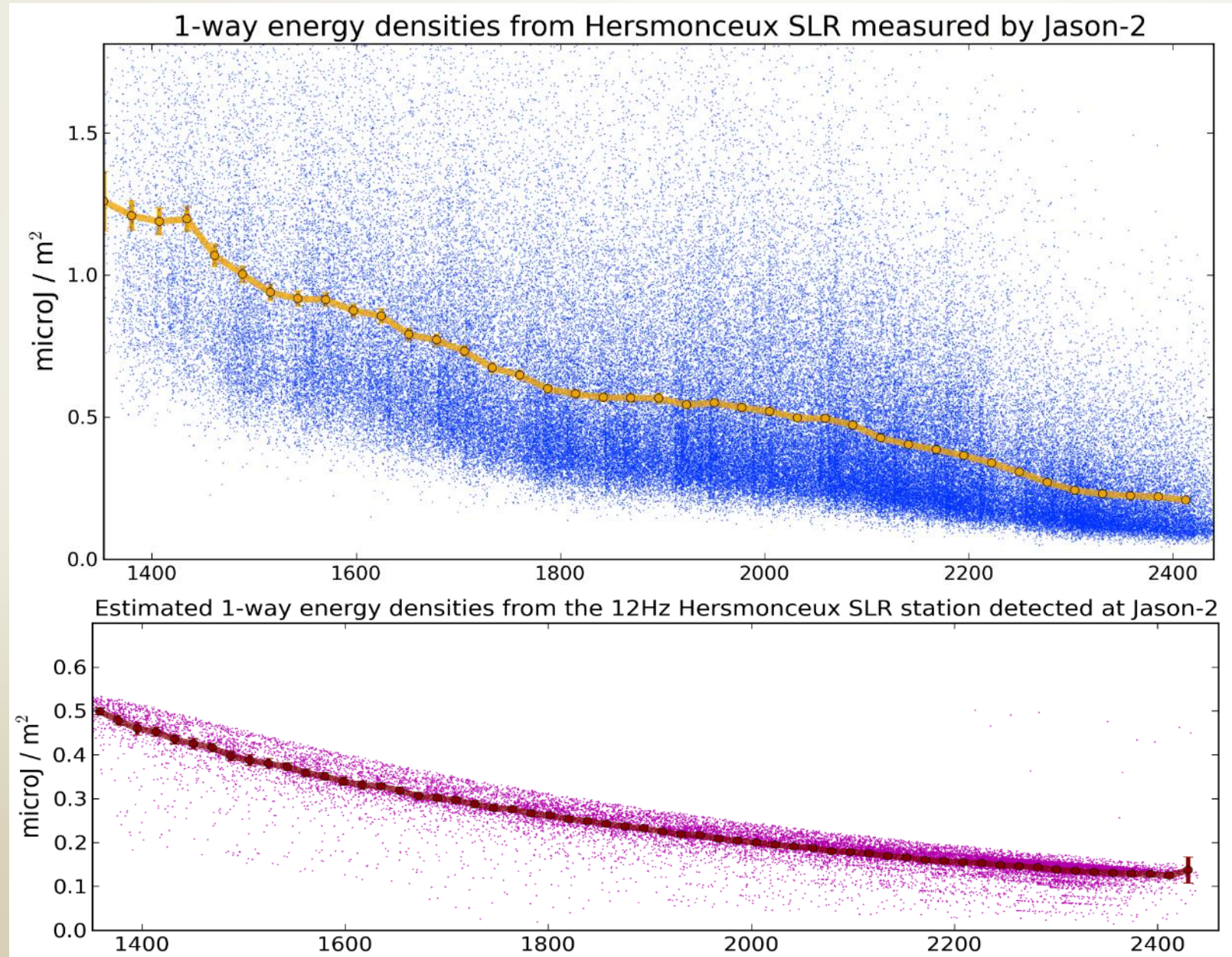
- From its launch in 2008, as part of the OCA/CNES time transfer by laser link (T2L2) payload, Jason-2 recorded energy densities of incoming SLR laser pulses.
- Both detectors have a graded neutral density filter to minimise the dynamic energy received during a pass.
- The raw data is corrected for this filter to give a measure of  $\text{J/m}^2$ , in the plane perpendicular to the line of sight.



# Average Jason-2 return energies

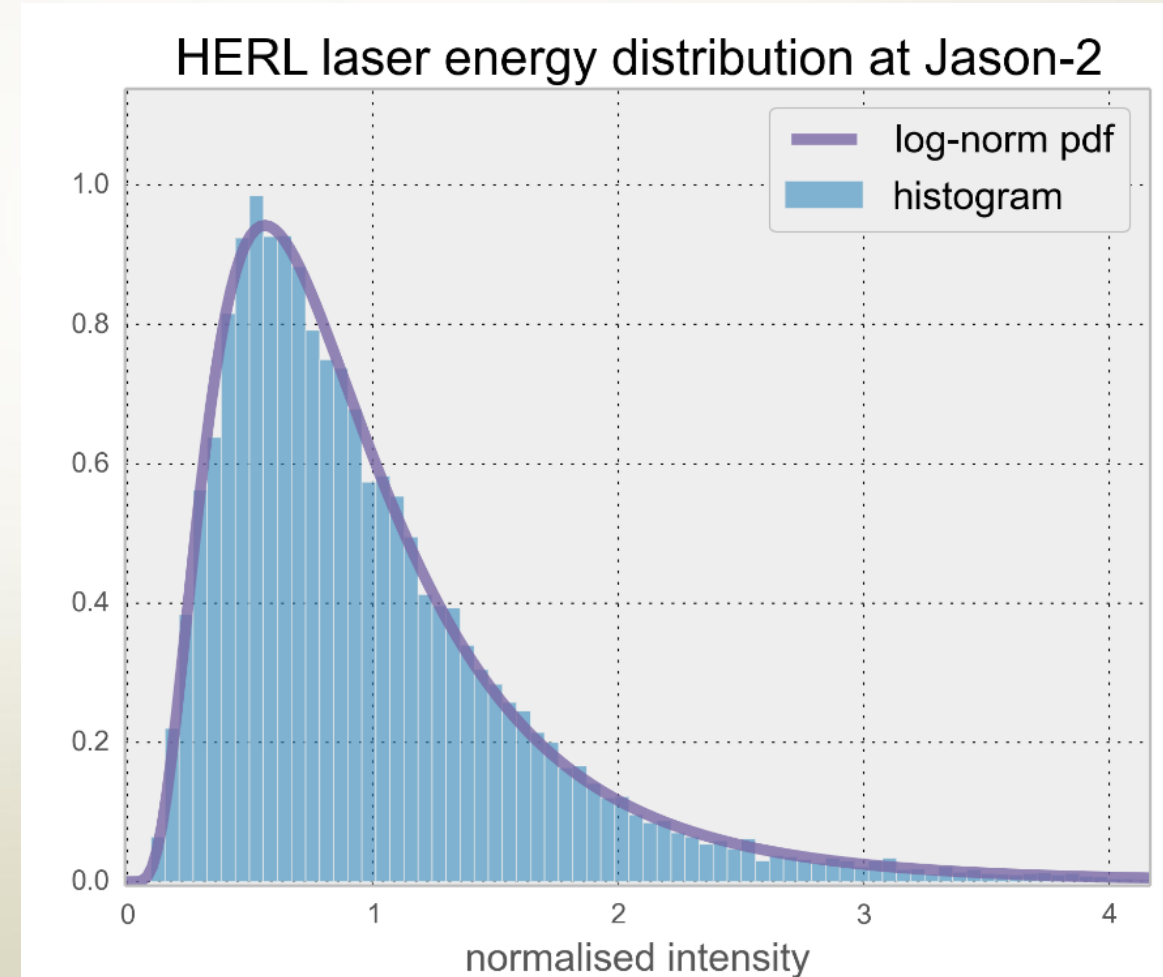


# 1-way laser energy densities at Jason-2



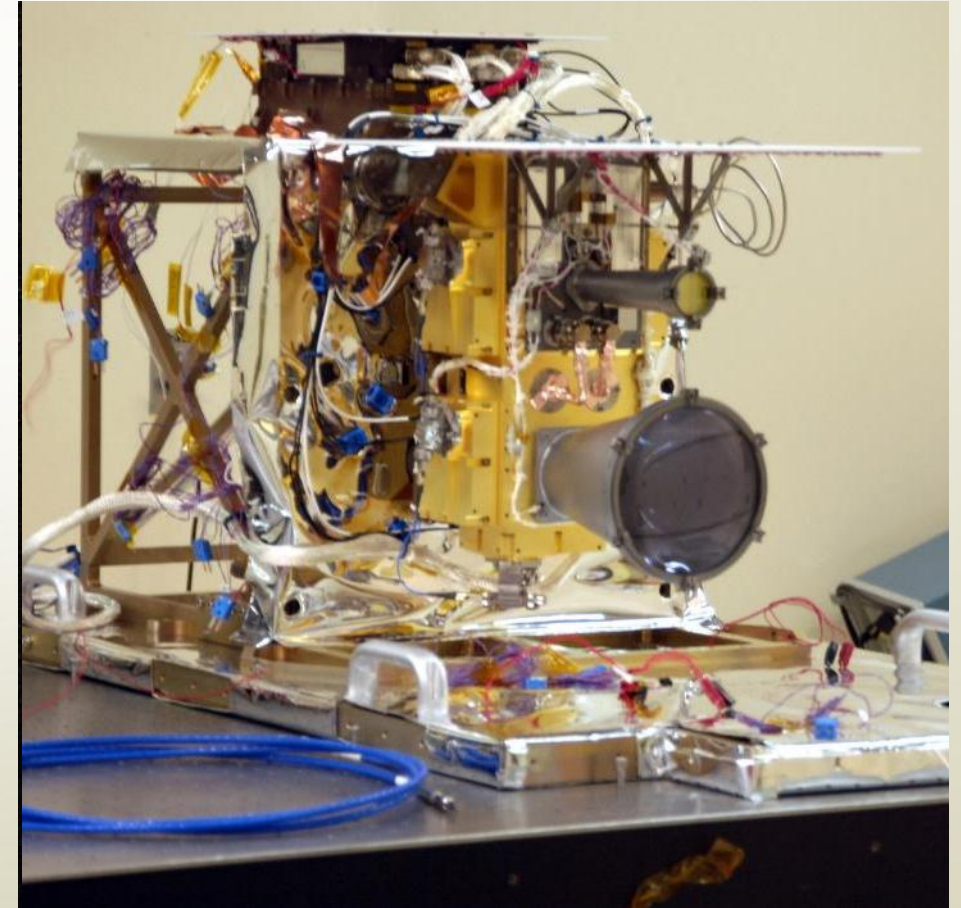
# Turbulent, asymmetric distribution

- Energy measurements at Jason-2 show a asymmetric distribution with the majority of values concentrated at the lower end.
- This is explained by turbulence-induced scintillation
- A log-norm distribution with the variance of the logarithm of the intensity as sole parameter (no curve fit) describes perfectly the empirical PDF.

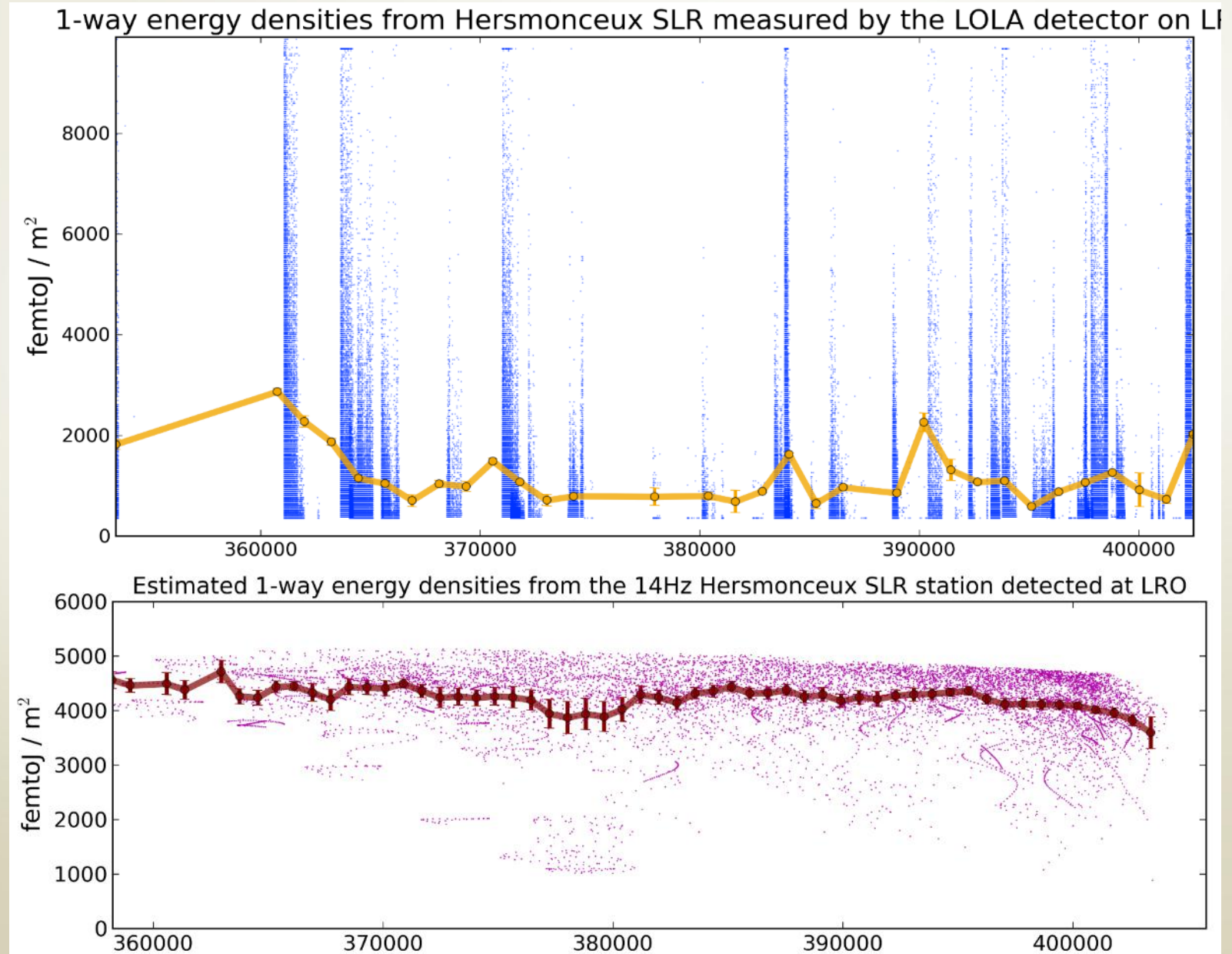


# Lunar Reconnaissance Orbiter (LRO) energies

- The Lunar Orbiter Laser Altimeter (LOLA) is an instrument on NASA's LRO which detects incoming laser signals and records the pulse energy.
- The Herstmonceux station began one-way tracking soon after its launch in June 2009.
- The clear aperture of the telescope is 1.9 cm



# Lunar Reconnaissance Orbiter (LRO) energies





# Conclusions

- The SGF, Herstmonceux has a varied selection of laser pulse energy density measurements in its possession.
- We are beginning to make sense of the data by comparing the results with our best estimates using the radar link equation.
- However further progress is needed, particularly on the large 2-way estimation and measurement disagreements .

# Conclusions

- Poor performance of the SLR system could also be the cause of some of the disagreements observed.
- Other known errors include:
  - Diffraction calculation. Even retroreflector spacing is assumed and the intensity is artificially concentrated on centre of FFDP resulting in cross-section underestimation.
  - Scintillation effects in the data and to pointing.

# Thankyou

*Special thanks to our NASA , OCA and CNES colleagues  
for providing the satellite energy data for Herstmonceux.*



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