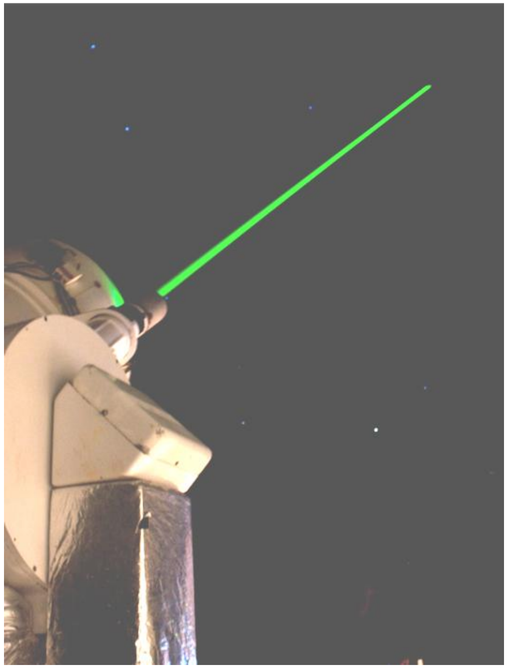
SLR energy density modelled and measured at Jason-2 and at the Herstmonceux station



Matthew Wilkinson, Jose Rodriguez.
NERC Space Geodesy Facility, Herstmonceux, UK

With thanks to P. Exertier, E. Samain and Ph. Guillemot, Observatoire de la Côte d'Azur and Centre National D'Etudes Spatiales

Introduction

The Jason-2 satellite was launched in the summer of 2008.

From that time, as part of the OCA/CNES time transfer by laser link (T2L2) payload, it recorded energy densities of incoming SLR laser pulses.

The Herstmonceux station calculates SLR return rate which can be converted to energy density.

This talk reports on our investigation into these two simultaneous energy densities.

Introduction

The radar link budget for Herstmonceux gives expected energy densities from Jason-2 and these were compared with the measured values.

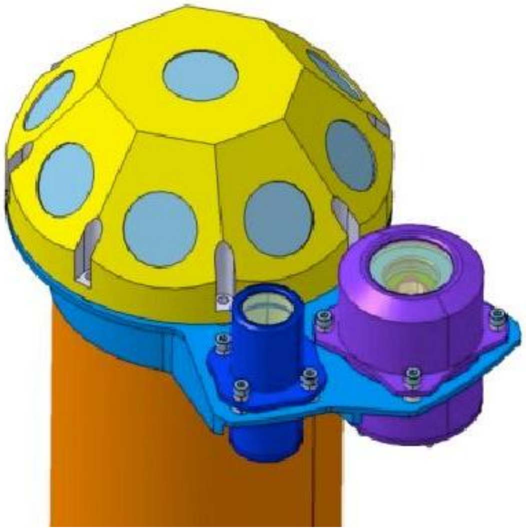
And using the measured values at Jason-2 and the Herstmonceux station we calculate the cross section of the retro-reflector array for different ranges.

Energy detection at Jason-2

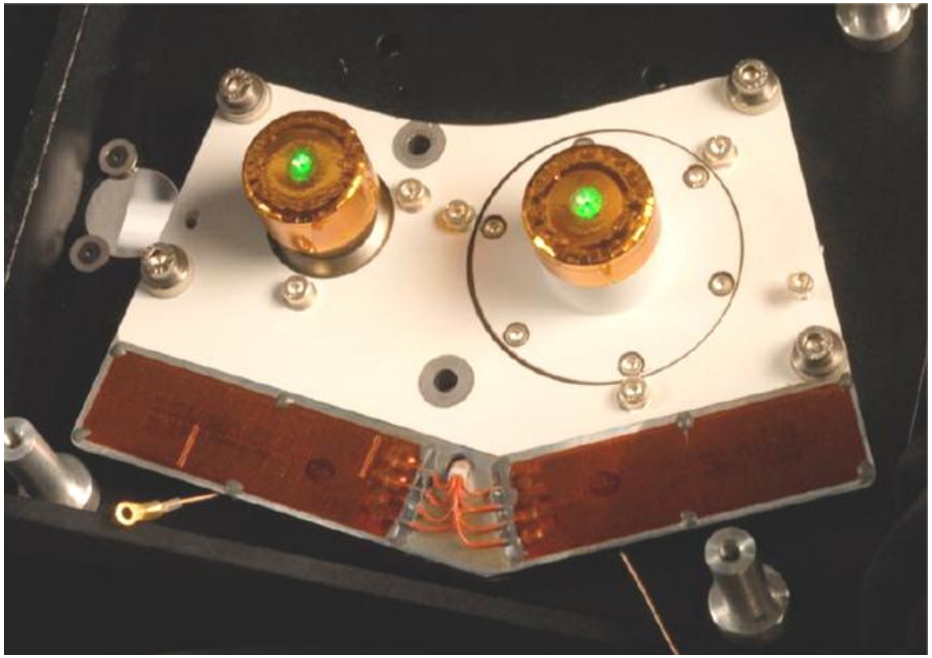
The T2L2 payload onboard Jason-2 includes two photo detectors.

The first is linear and is used to measure the energy of the incoming laser pulse and the background from the Earth's albedo.

The second detector is non-linear and this triggers the event timer for the T2L2 time transfer experiment.



Pictures taken from "T2L2 – First Data", E. Samain, Ph. Guillemot, P. Exertier et al, 16th ILRS Workshop, Poznan, 2008.

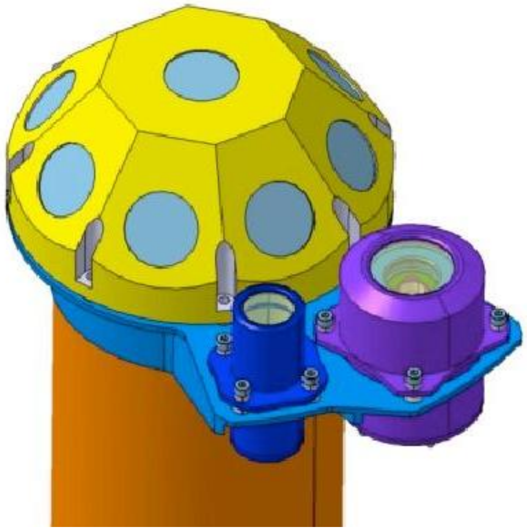


Energy detection at Jason-2

Both detectors have a graded neutral density filters in front of them. This is to minimise the dynamic energy received during a pass.

The profile of the ND takes into account the distance to the satellite and the atmospheric attenuation.

The raw data is corrected for this filter to give a measure of J/m^2, in the plane perpendicular to the line of sight.



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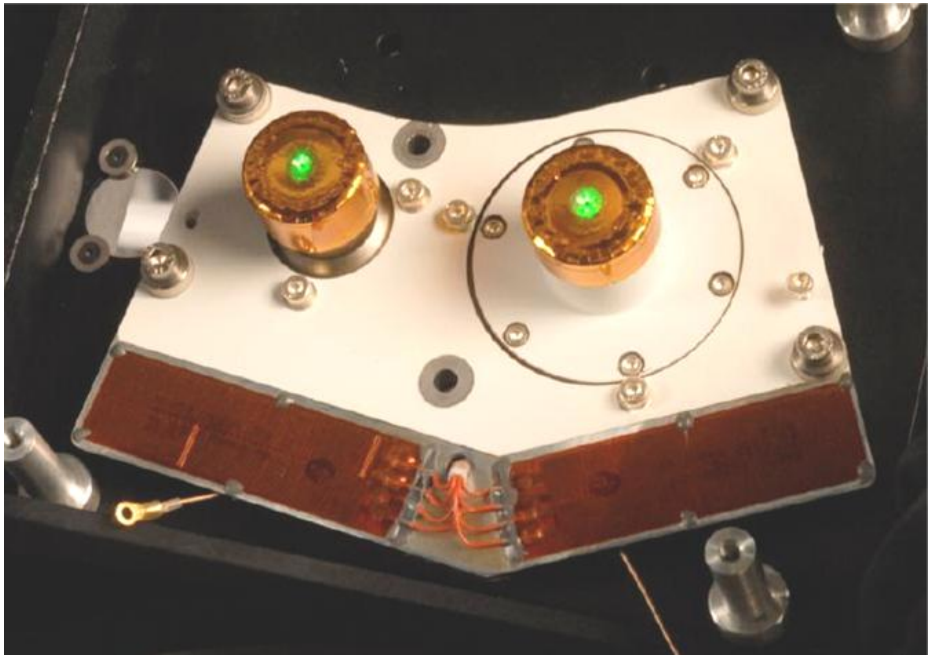
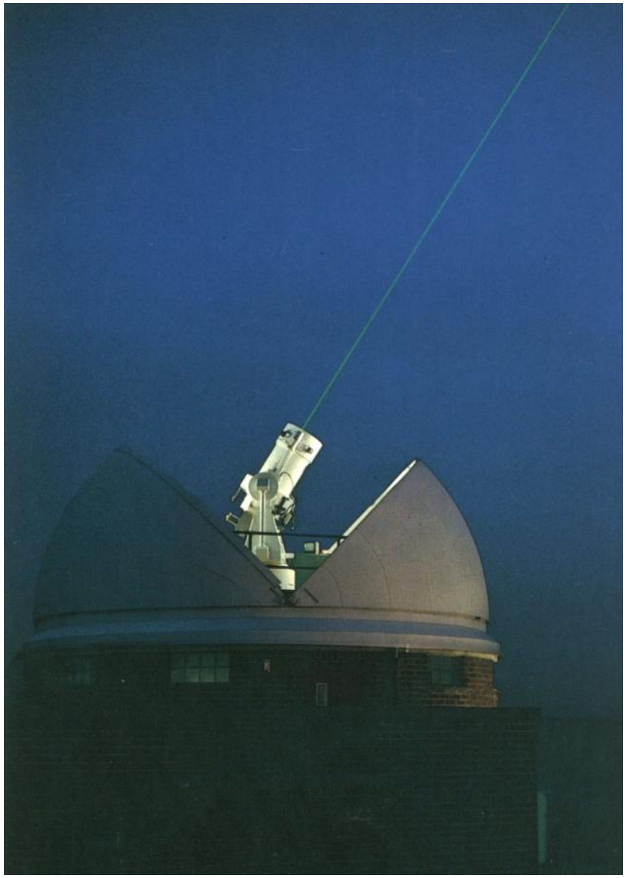


Return energy from Jason-2

At Herstmonceux, the return rate is calculated as the number of track returns over the number of opportunities.

To obtain an energy from this value it is:

- Converted to number of photoelectrons using a Poisson distribution
- Scaled for detector quantum efficiency
- Converted to joules using the Planck constant
- Scaled for telescope receive efficiency
- Adjusted for the semi-train
- Corrected for applied filters (ND and spectral)
- Scaled for the area of the telescope to give energy density.



Link budget calculations

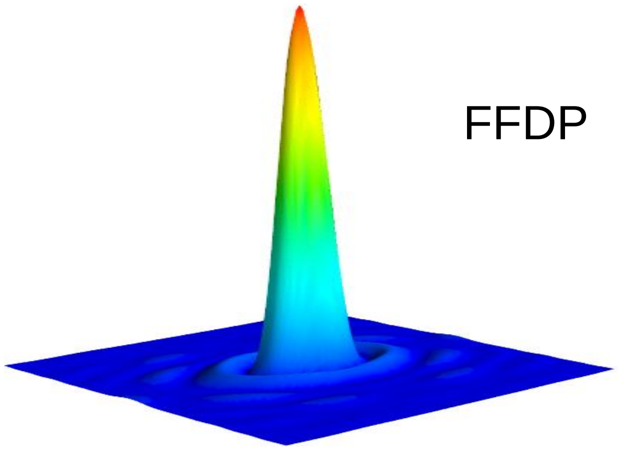
The radar link budget for Herstmonceux SLR was formed using:

- **Known parameters** such as laser energy (E_T) and effective telescope area (A_r).
- **Measured parameters**, such as transmission efficiency (η_t)
- **Estimated parameters**, such as receive efficiency (η_r).
- **Parameters determined from empirical data**, such as laser divergence and atmospheric transmission (T_a)

Degnan, J.J. *Millimeter accuracy satellite laser ranging: a review*, in: Contributions of Space Geodesy to Geodynamics: Technology, Geodynamics Series. Series, vol. 25, pp. 133–162, 1993.

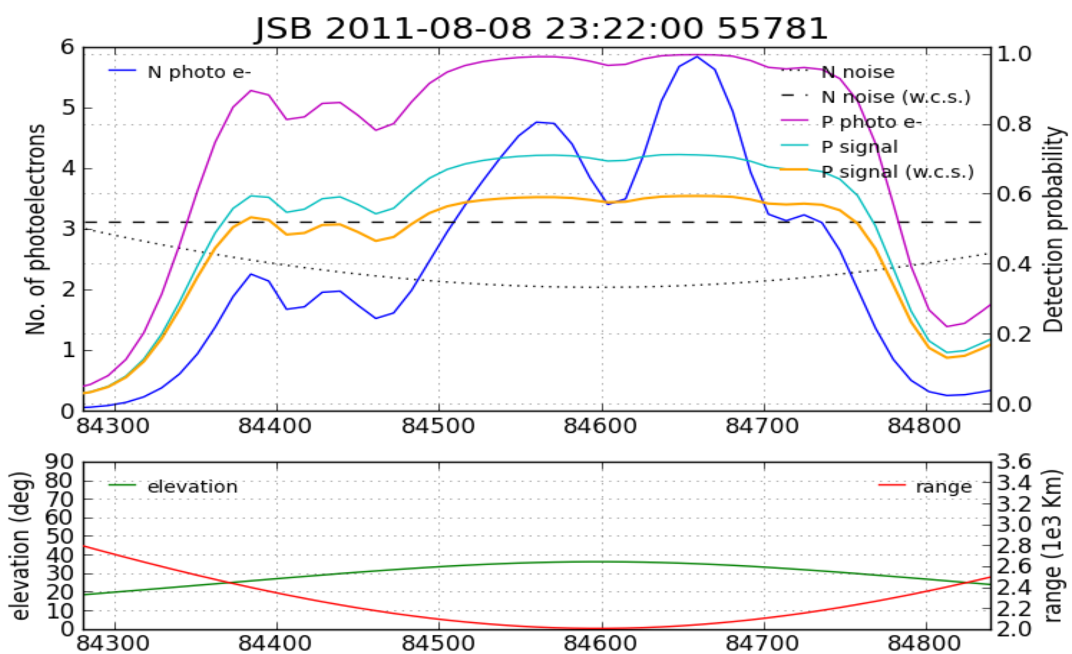
Link budget calculations

The retro-reflector array cross section was calculated using the far field diffraction pattern, the velocity aberration and the satellite attitude.

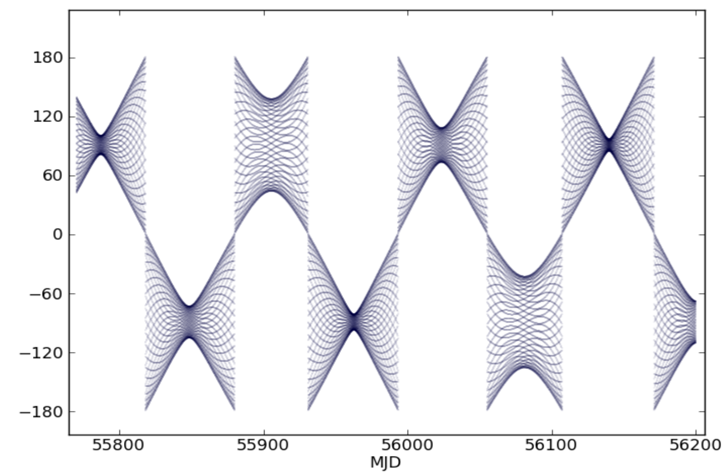


FFDP

Expected return signals were calculated for individual passes.

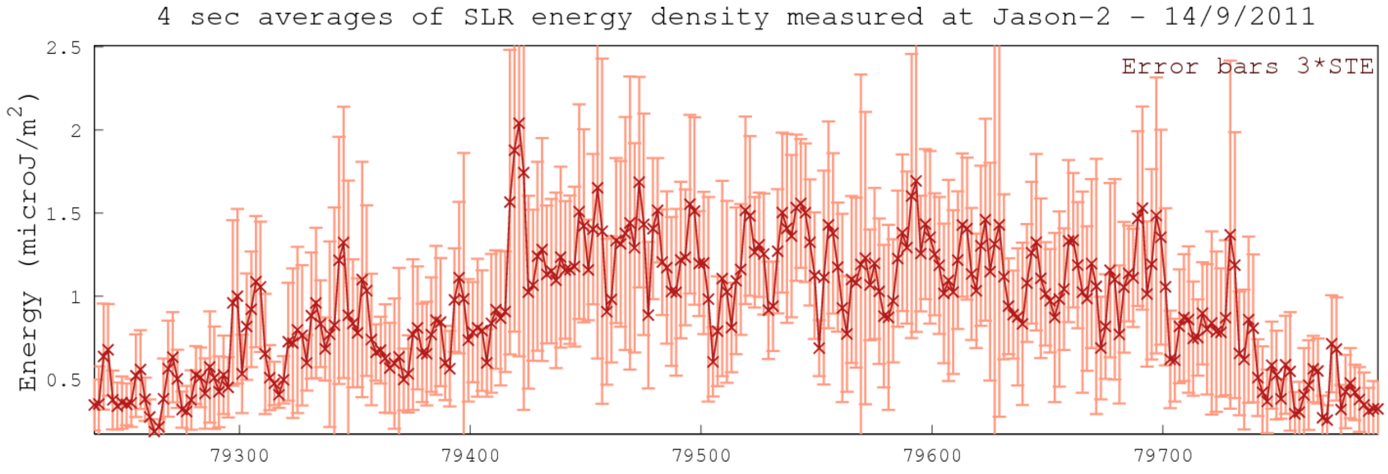


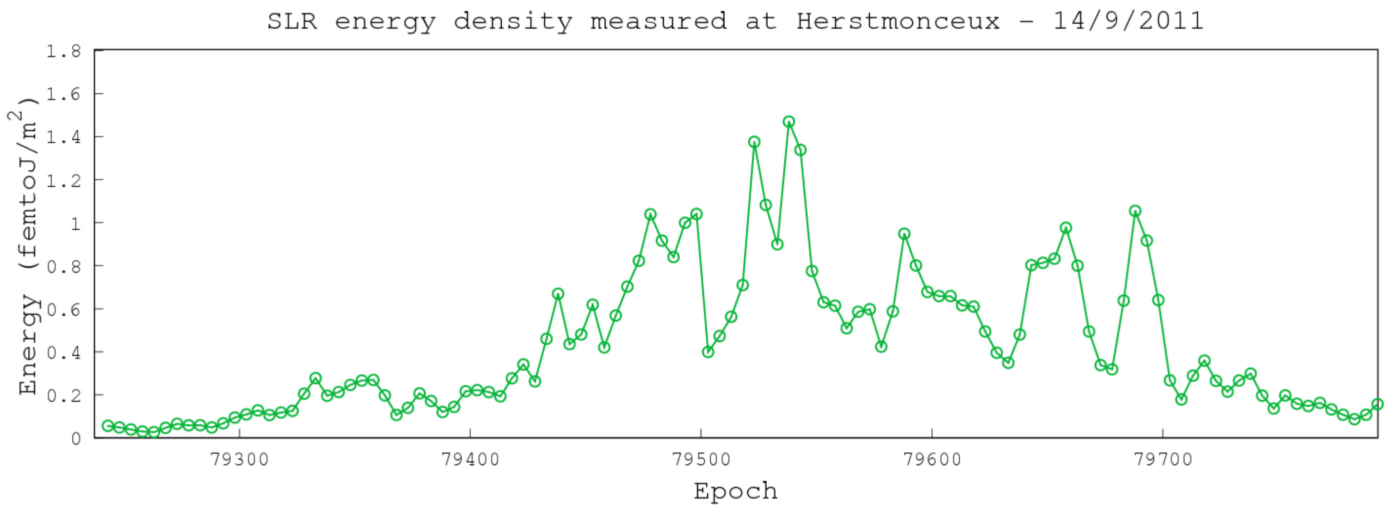
Jason-2 attitude



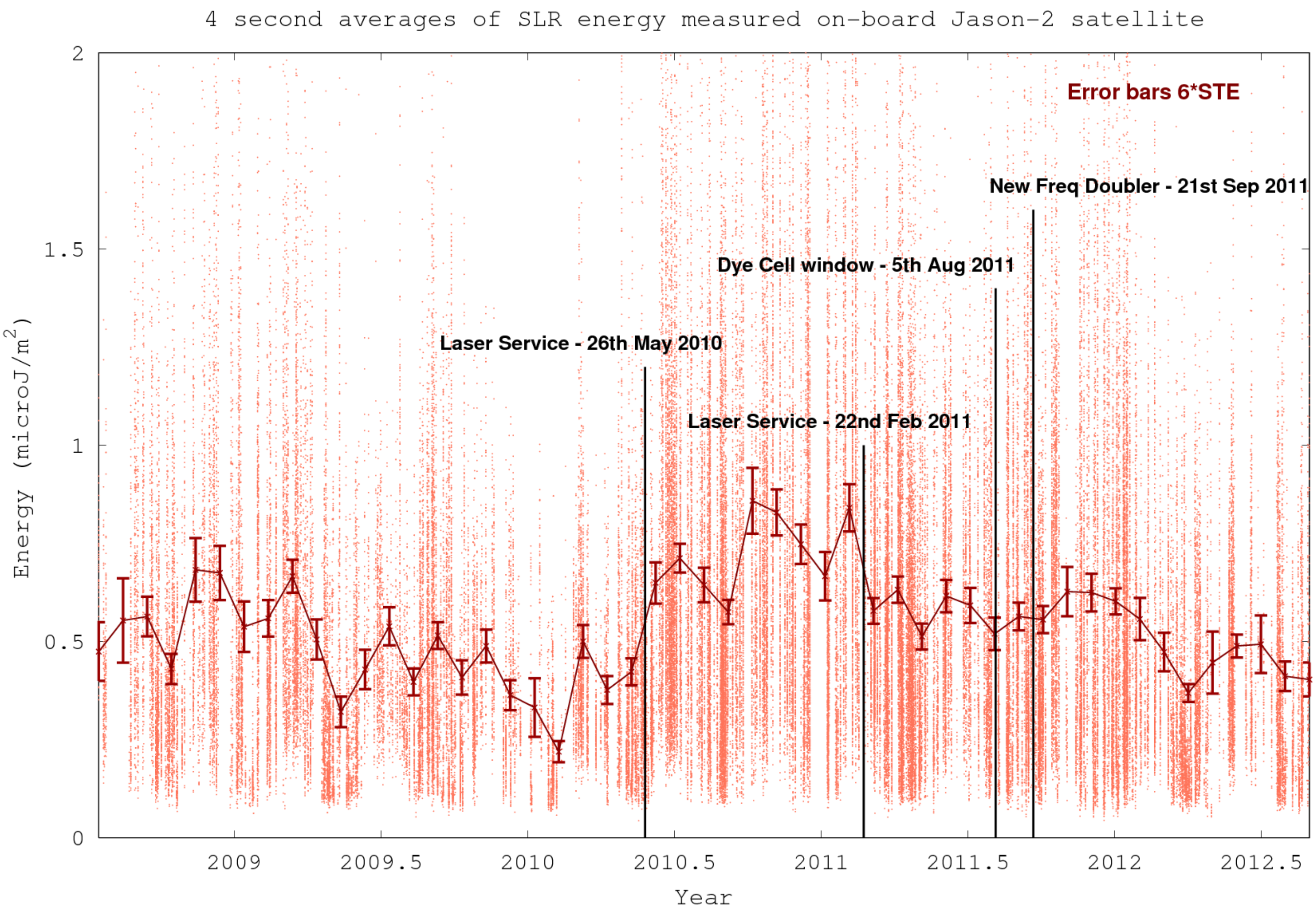
Charmaine et al. *Performance Characteristics of a Retroreflector Array Optimized for LEO Spacecraft.* Naval Research Laboratory Report, 1997.

Single Jason-2 passes

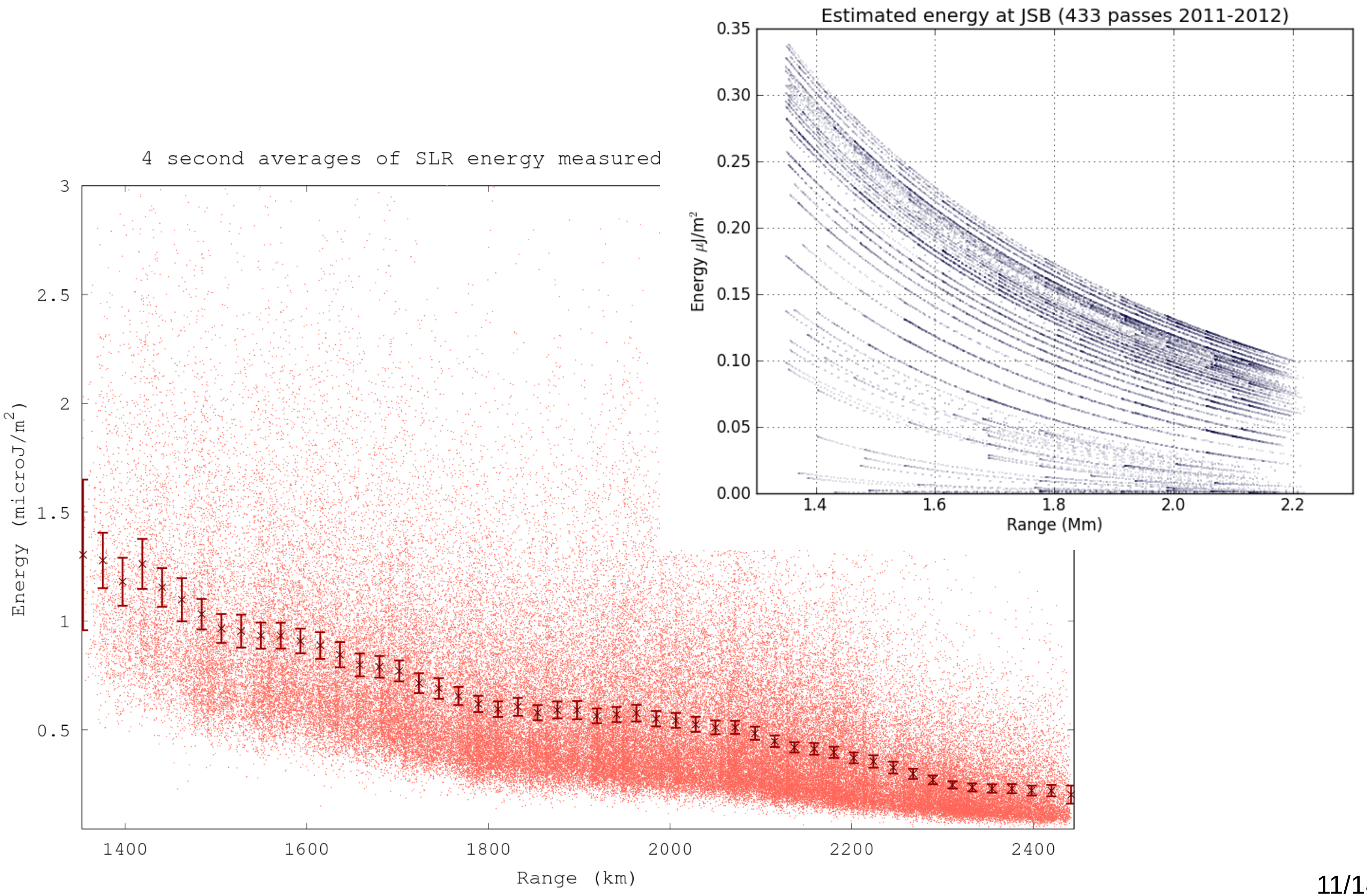




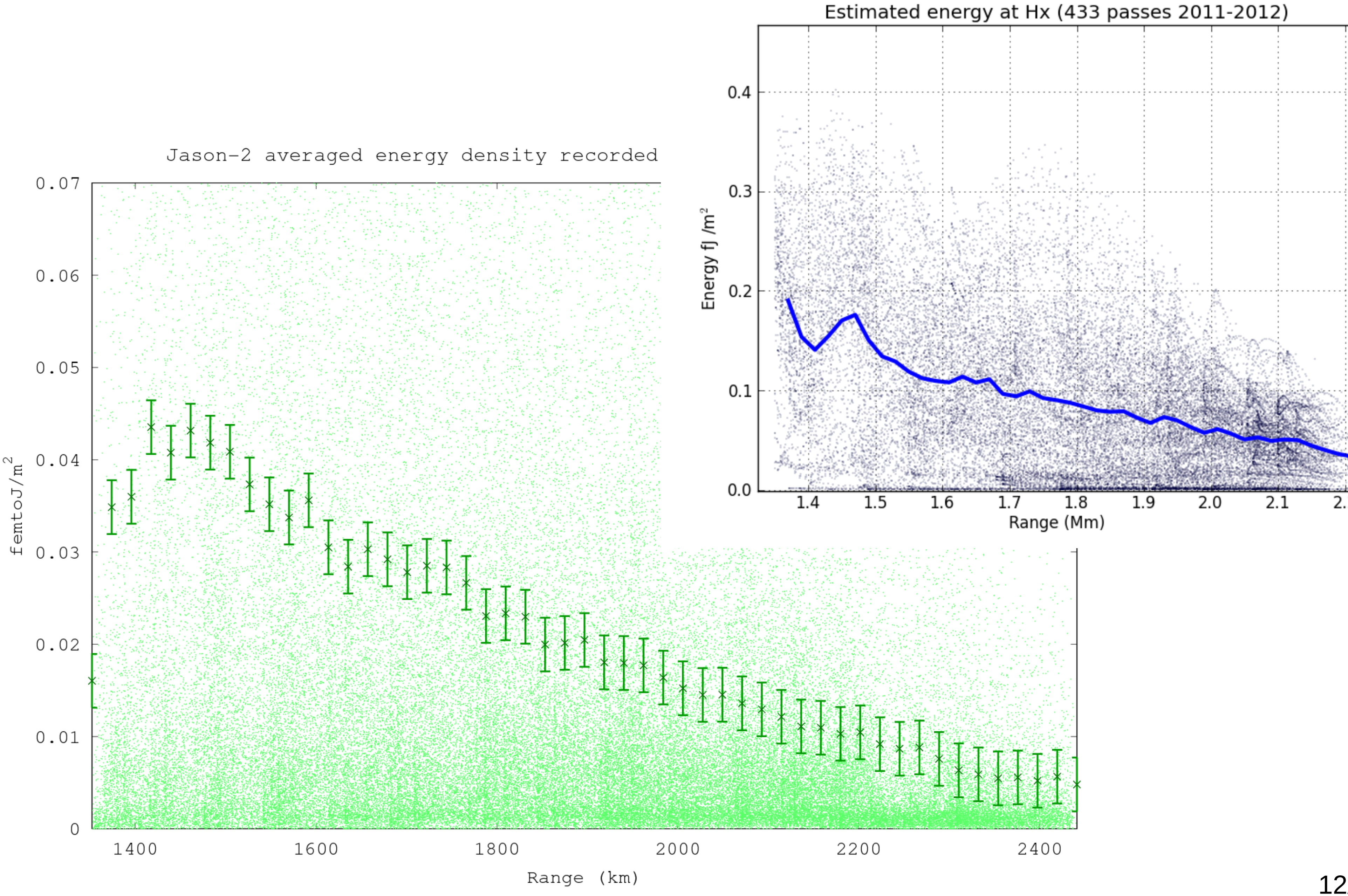
Herstmonceux energy at Jason-2



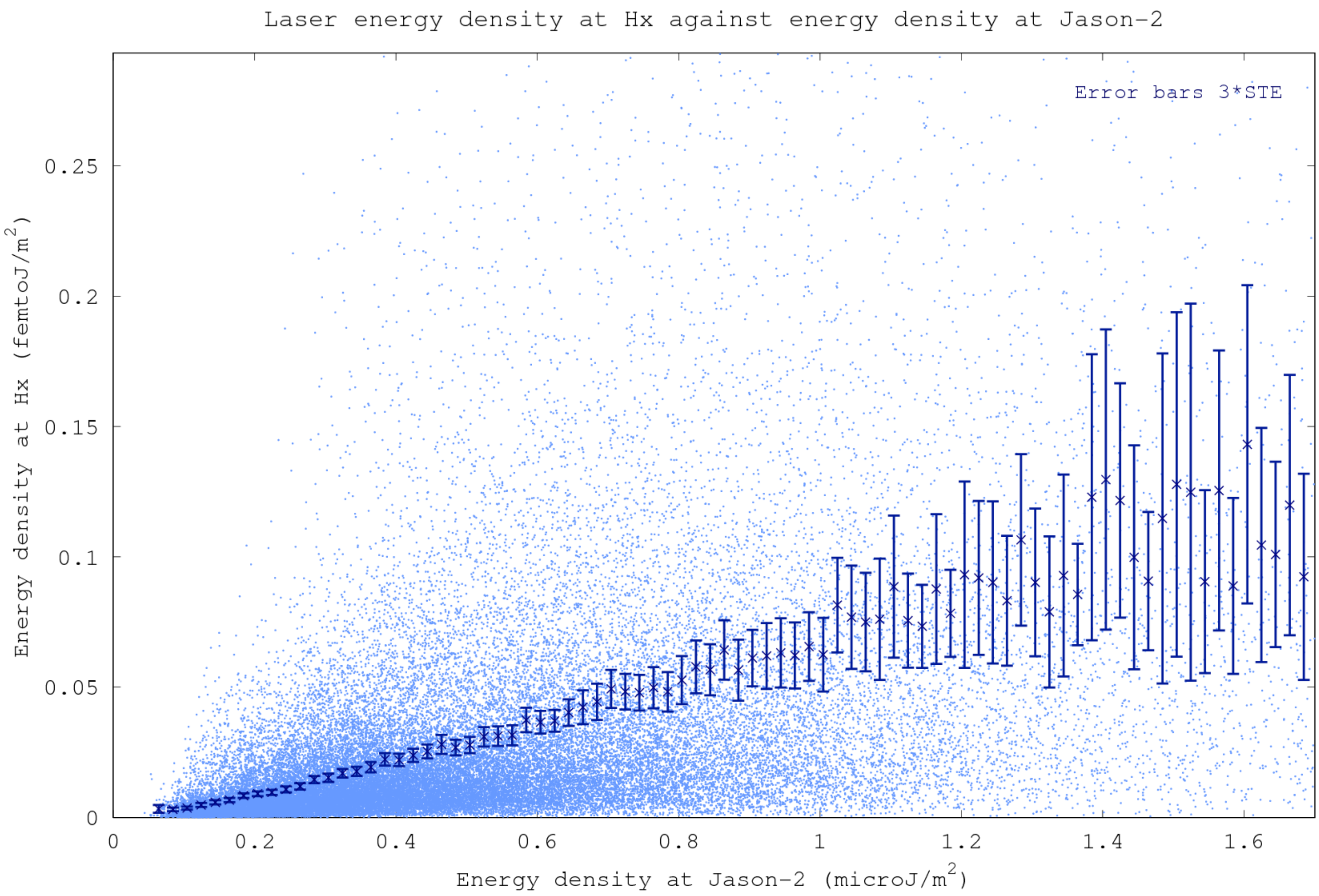
Herstmonceux energy at Jason-2



Return energy from Jason-2 at Hx



1-way and 2-way energies from Jason-2



Radar Link Equation

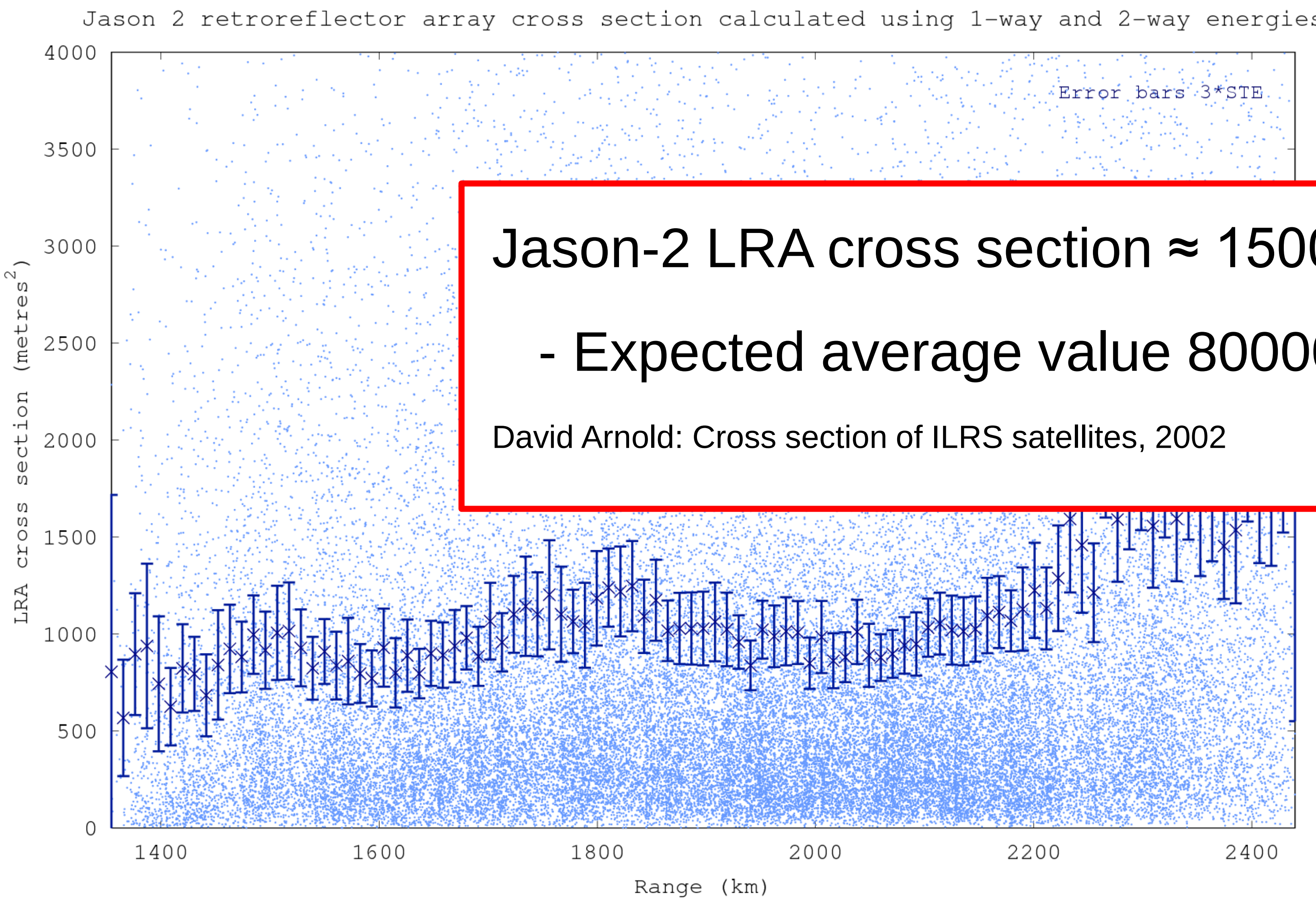
$$n_{pe} = \eta_q \left(E_T \frac{\lambda}{hc} \right) \eta_t G_t \sigma \left(\frac{1}{4\pi R^2} \right)^2 A_r \eta_r T_a^2$$

$$E_{Hx} = \frac{n_{pe} hc \eta_q}{\lambda A_r \eta_r} = E_T \eta_t G_t \sigma \left(\frac{1}{4\pi R^2} \right)^2 T_a^2$$

using $$E_J^2 = \left(E_T \eta_t G_t \left(\frac{1}{4\pi R^2} \right) T_a \right)^2$$

$$\sigma = \frac{E_{Hx} E_T \eta_t G_t}{E_J^2}$$

Retro array cross section

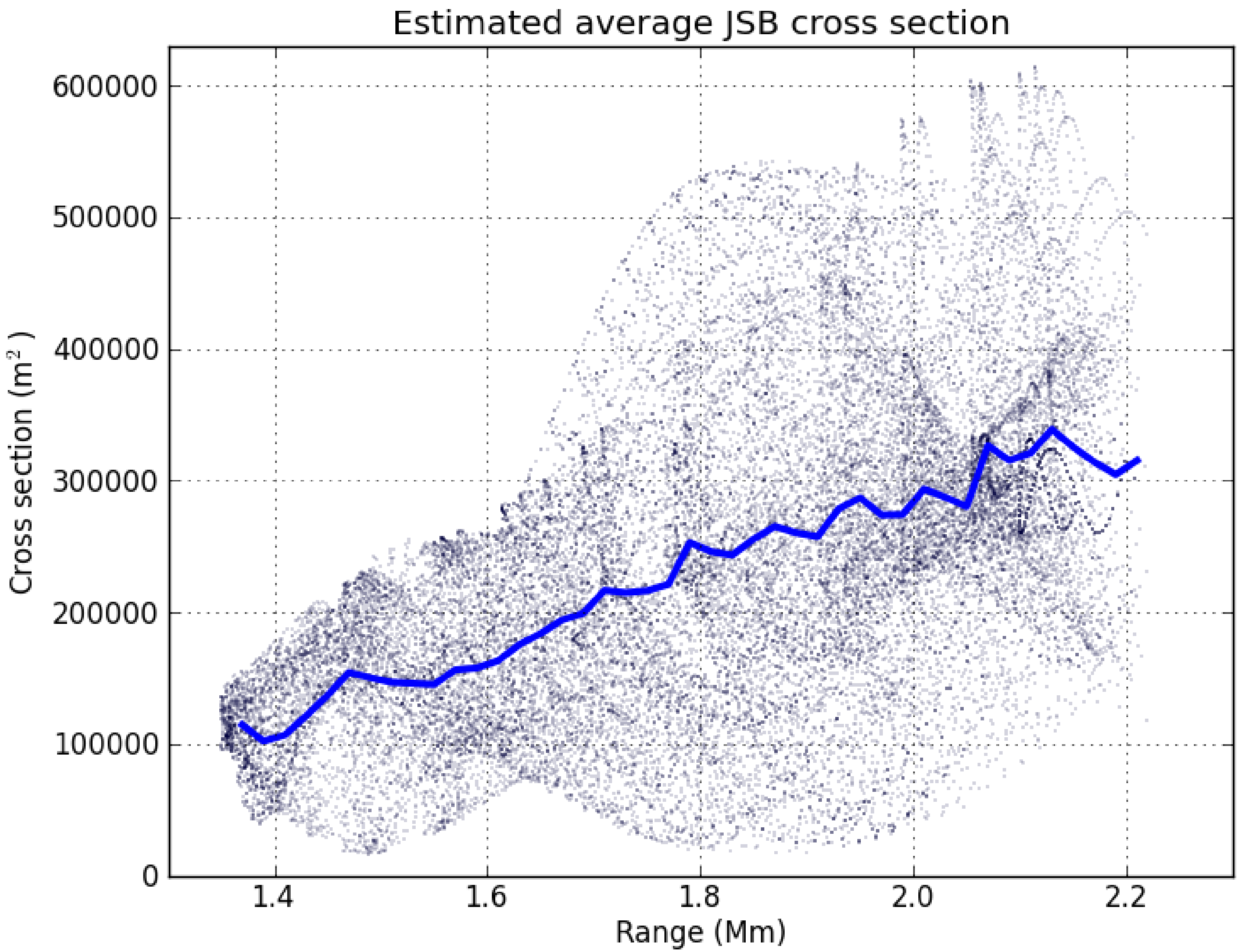


Jason-2 LRA cross section ≈ 1500m²

- Expected average value 800000m²

David Arnold: Cross section of ILRS satellites, 2002

Estimated array cross section



Conclusions... so far

The simultaneous energy density datasets look promising since they contain similar features on an individual pass by pass basis.

Comparing the whole history of both datasets shows on average a correlated relationship between the two measurements.

Having the 1-way and 2-way energy densities should allow a direct measurement of the satellite cross section.

Conclusions... so far

However, our radar link budget calculations currently give low energy density values at Jason-2, by a factor of 10, and high return values at Herstmonceux, by a factor of 5.

The cross section of the Jason-2 array, calculated from the 1-way and 2-way measurements, is much less than the expected value.

What could be the cause for this disagreement?

- Incorrect atmospheric transmission?
- Wrong gain (Gt) values due to a too large divergence?
- Incorrect treatment of the semi-train?