ESTIMATE OF JOVIAN HIGH-ENERGY EQUATORIAL ELECTRON FLUX AT RANGE R > 2 RJ, USING DATA FROM THE GALILEO SPACECRAFT'S FINAL FULL ORBIT

J. M. Ratliff, P. D. Fieseler, I. Jun, H. B. Garrett

Jet Propulsion Laboratory, California Institute of Technology [martin.ratliff@jpl.nasa.gov]

Periapse of the Galileo spacecraft's 34th orbit of Jupiter occurred at a magnetic radial L-value of 2 Rj (jovian radii) and +4 degrees magnetic latitude (both as given by an Offset Tilted Dipole magnetic field model). This is Galileo's only orbit to sample the jovian radiation belts inside 4 Rj. The primary Galileo instrument for this measurement is the Applied Physics Lab's Energetic Particle Detector (EPD), whose data are, as of this writing, being downlinked to Earth. Evidence of the electron radiation was also recorded as background noise in the star scanner (SS). That data is available, and will be reported here. Comparison of the EPD's DC3 channel with SS background counts on previous orbits shows that the SS and DC3 count rates approximately track one another from 10 Rj, inward to the measurement limit of 5.5 Rj. The DC3 channel measures electrons of energy E > ˜11 MeV. This is consistent with the energy of electrons that are expected to penetrate the thick shielding around the SS. Therefore, the SS data can be used as a proxy for ˜11 MeV electron data. A multiplicative factor of ˜ 500 makes the SS counts numerically equal to the DC3 count rates. Inside of 6 Rj, the SS data begins to require correction for photomultiplier tube dead-time. The corrections become quite significant, but a unique aspect of the SS allows us to determine the correction factor to a fair degree of accuracy. The SS is continually measuring the light from a known star. The change in this starlight's measured intensity due to dead-time effects is inversely proportional to the dead-time correction factor we need to apply to the background of radiation-induced counts to get the true magnitude of the counts. Then by scaling the corrected SS counts to produce an equivalent DC3 count rate, and applying the appropriate geometric factor, we derive an integral flux of ˜ 11

MeV, near-equatorial electrons. The results, with comparisons to existing models and data, will be presented.

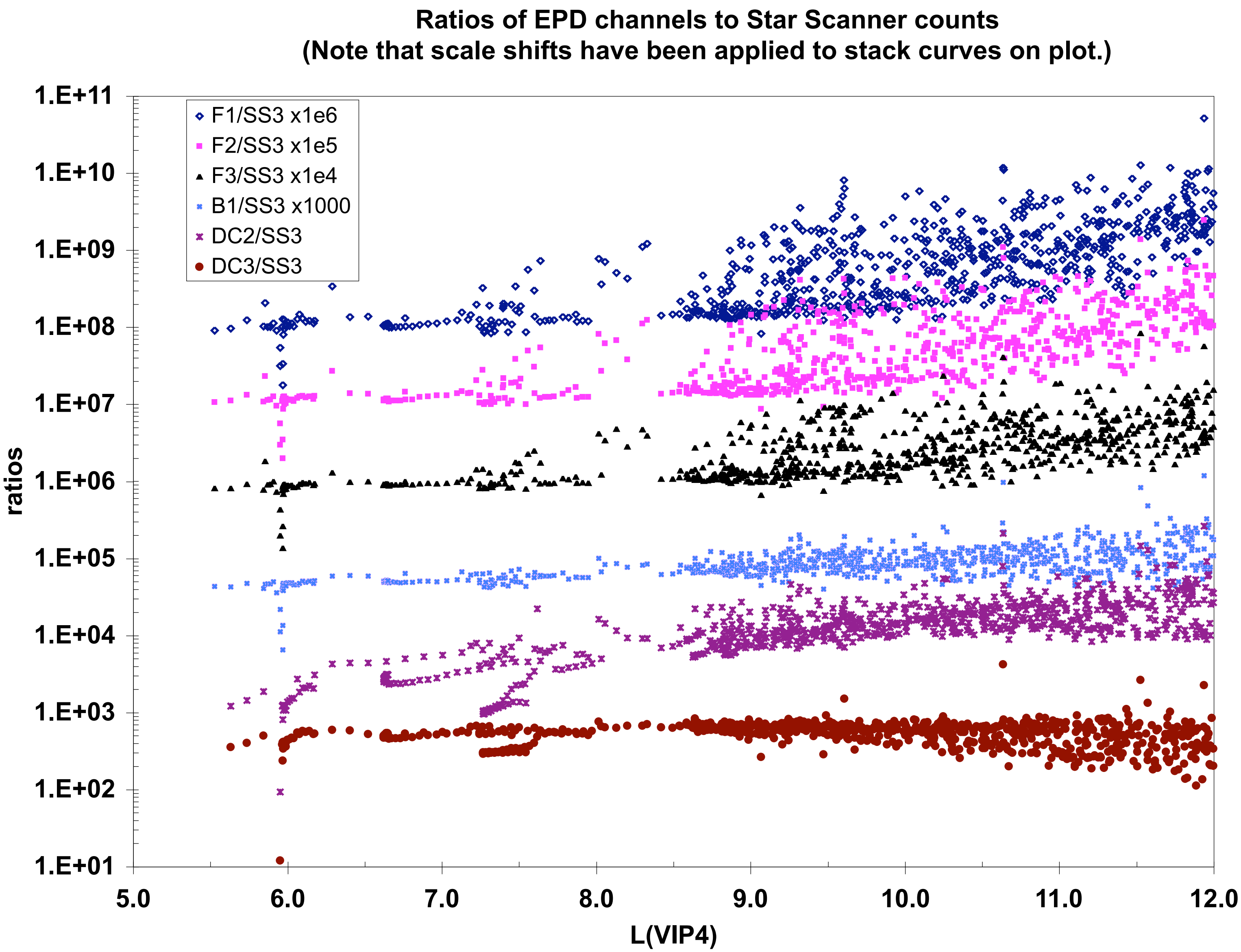
SEEING STARS? Its only electrons…

Jupiter's trapped electron radiation produces noise counts in the "star scanner", the star-sighting instrument that the Galileo spacecraft uses for navigation.

(See, for example, Fieseler 2000, Russell 2003)

When the radiation-induced noise dominates the star scanner's background, the background counts most closely vary in proportion to the DC3 (~ 11 MeV) electron channel of the Energetic Particle Detector (EPD) science instrument.

This suggests that we can treat the star scanner as a particle detector of ~ 11 MeV electrons, and can calibrate it with EPD data.


Ratios of EPD channels to Star Scanner counts
(Note that scale shifts have been applied to stack curves on plot.)
F1/SS3 x1e6
F2/SS3 x1e5
F3/SS3 x1e4
B1/SS3 x1000
DC2/SS3
DC3/SS3
ratios
1.E+11
1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
L(VIP4)

WHAT'S THE POINT OF CALIBRATING NOISE?

The radiation flux inside 6 Rj is high enough that significant dead-time corrections have to be applied to both the star scanner and the EPD. The star scanner's estimate of the radiation flux is independent of the EPD's, to the extent that the star scanner and EPD have independent methods of correcting for dead-time.

The star scanner calibration is done at count rates where dead-time corrections are not needed for either the star scanner or the EPD instrument.

At high count rate the star scanner data is important because a dead-time correction can be extracted from the star scanner's measurements of star brightness.

The resulting flux estimate can be used to evaluate the success of dead-time corrections that must be made to the EPD's DC3 channel measurements of high flux.

To convert star scanner counts to flux, we can use

the results of our EPD instrument calibration

and our spectral fits of the EPD data,

to determine the 11 MeV integral flux,

and then determine the average value Z of the measurement ratios

(EPD 11 MeV integral flux) / (Star Scanner counts).

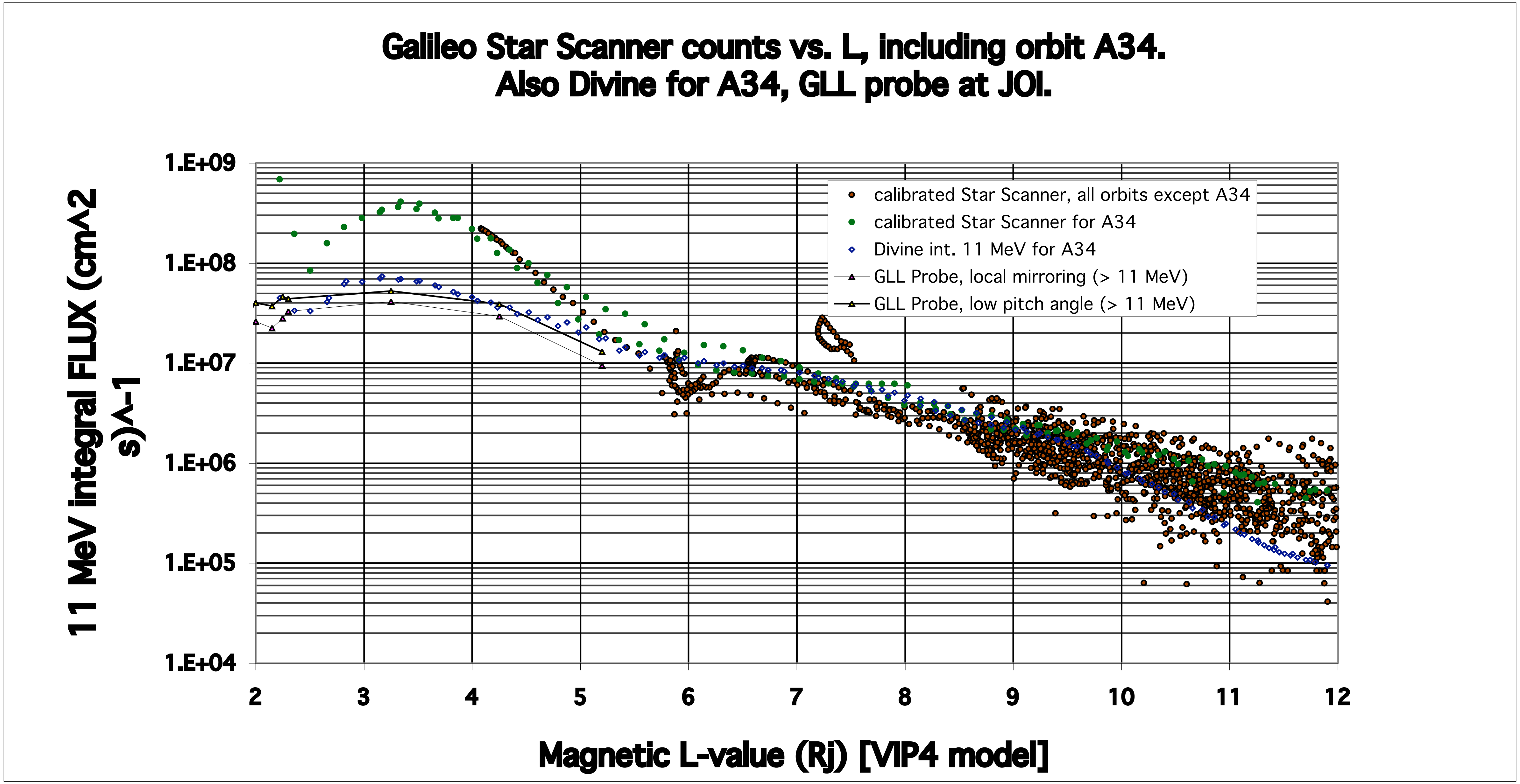
The multiplicative scale factor Z provides the calibration of the star scanner counts:

$$Z = (2.0 \pm 0.6) \times 10^{4}, (cm^{-2}\ s^{-1})/(\text{star scanner counts})$$

See H. B. Garrett, et al., poster PS11-1Mo3P-1343; also I. Jun, et al., 2002.

We can now apply the calibration factor Z to the star scanner data from orbit A34, to produce an estimate of the 11 MeV integral flux inside 6 Rj.

For comparison, we also plot the Divine model estimate (Divine 1983), and the estimate from the probe that was released from the Galileo spacecraft at Jupiter orbit insertion (Mihalov 2000).


Galileo Star Scanner counts vs. L, including orbit A34.
Also Divine for A34, GLL probe at JOI.
11 MeV integral FLUX (cm^2 s)^-1
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
2
3
4
5
6
7
8
9
10
11
12
Magnetic L-value (Rj) [VIP4 model]
calibrated Star Scanner, all orbits except A34
calibrated Star Scanner for A34
Divine int. 11 MeV for A34
GLL Probe, local mirroring (> 11 MeV)
GLL Probe, low pitch angle (> 11 MeV)

CONCLUSION:

The calibrated star scanner data suggests that on orbit A34, the trapped electron environment --

for R > 5 Rj: was similar to that seen by the Pioneer 10 and 11 spacecraft (as represented in the Divine model) and the Galileo probe;

for R ~ 3.5 Rj: was about 6 times higher than Divine and the Galileo probe.

It is surprising that the magnitude and radial dependence of the 11 MeV electron environment would vary so dramatically from previous measurements; further evaluation of the star scanner calibration method is warranted.

The probe data may be perhaps a factor of 2 low, because it was taken at somewhat higher magnetic latitude (10 degrees).

The star scanner dead-time correction is determined by taking the difference of two measurements, which amplifies the uncertainty in the result. We may not have converged on the best fit of the data to the correction function.

It is also possible that the star scanner is seeing and counting bremsstrahlung radiation that is produced in the star scanner's heavy housing. The star scanner calibration would be thrown off only if the relative amount of bremsstrahlung to electrons changed. This could occur if the energy dependence of the electron spectrum changed. The GLL probe data does not, however, show much evidence of a changing electron spectral slope in the region 3 Rj $<$ r $<$ 5 Rj.

References:

N. Divine and H. B. Garrett, "Charged Particle Distribution in Jupiter's Magnetosphere", J. Geophys. Res. V.88(A9), 6889-6903, 1983.

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H. G. Garrett, et al., "Galileo Interim Radiation Electron Model", JPL Publ. 03-006, Jet Propulsion Laboratory, California Institute of Technology, 2003.

I. Jun, et al., "Monte Carlo Simulations of the Galileo Energetic Particle Detector", Nucl. Inst. And Meth. A, v.490, 465-475, 2002.

J. D. Mihalov, et al., "Energetic Trapped Electron Measurements from the Galileo Jupiter Probe", Geophys. Res. Let., v.27(16), 2445-2448, 2000.

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D. J. Williams, et al., "The Galileo Energetic Particle Detector", Sp. Sci. Rev. v.60, 385-412, 1992.

Star scanner data: Extracting background counts and correcting for dead-time.

It is reasonable to assume that dead-time effects will cause the same decrease in both the apparent brightness of the navigation reference star, and the radiation-induced background noise.

The star scanner data contains measurements of both the star brightness and the background counts seen immediately before the star sighting.

We know the true brightness of the star, and we measure the apparent brightness at a given total count (star plus radiation, over the fixed integration time interval), so we can determine the amount by which dead-time is suppressing the true background radiation signal.

This is done by an iterative process in which an initial estimate of the correction curve is used to correct for the fact that the dead-time correction is larger for $(\text{star + radiation})_m$ than it is for $(\text{radiation})_m$, where subscript m denotes the measured counts.

The apparent star intensity is given by

$$(\text{star})_m = (\text{star} + \text{radiation})_m - \{(\text{radiation})_m * P(\text{rad}) / P(\text{star+rad})\}$$

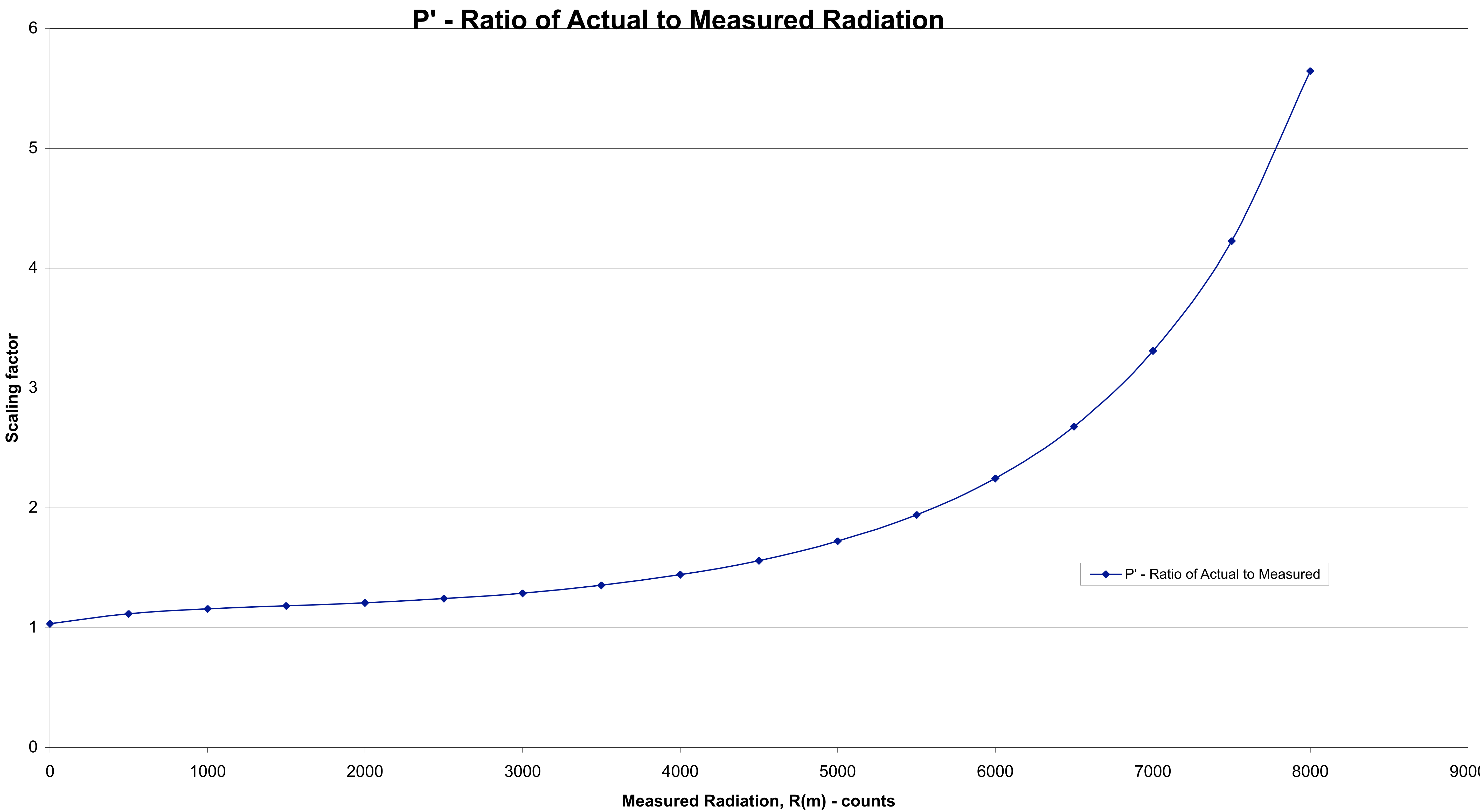
where the function P(x) is the ratio of true counts to measured counts.

A new value of P(x) is given by

$$P(\text{star} + \text{radiation}) = (\text{true star counts}) / (\text{star})_m.$$

Re-evaluation of the star scanner data, with its varying amounts of radiation along the trajectory, produces a refined version of the function P(x), which is used to determine the true radiation-induced countrate.

The correction curve P(x) is shown below.


P' - Ratio of Actual to Measured Radiation
Scaling factor
0
1
2
3
4
5
6
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Measured Radiation, R(m) - counts
P' - Ratio of Actual to Measured