Background variability in the Chandra High Resolution Camera

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1. BACKGROUND VARIABILITY IN THE HRC-I

The background variability of the Chandra High Resolution Camera (HRC) was studied in order to understand the relationship between the radiation environment encountered by the Chandra spacecraft and scientific usefulness of data gathered by the HRC. Scalar total rate data covering approximately four years of operation was collected and analyzed.

In order to provide quantifiable analysis, a Variability Metric (VM) was employed. The VM is a dimensionless measure of the total count rate variability above that expected by Poissonian noise, calculated by dividing standard deviation of the total event count by the square root of the mean counts.

For radiation data, we made use of the the Chandra Radiation Model (CRM): a prediction of 100-200 keV proton flux as a function of spacecraft location and the magnetic activity Kp index. The CRM identifies three distinct spatial regions and models them separately: solar wind, magnetosheath and magnetosphere. (Blackwell, W.C. et al., "Modeling the Chandra Space Environment," Proceedings of SPIE Vol. 4140 (2000))

In order to provide uniform statistics, total rate data were broken down into one kilosecond blocks, with a single VM value calculated for each block. This resulted in 2306 VM values sampled between August 1999 and September 2002.

A histogram of VM values (Figure 1) clearly demonstrates a non-Poissonian rate distribution. The main peak around unity, is expected for random background. But the VM values beyond this peak indicate non-Poissonian variability within the data set, which we identify as excess noise associated with the radiation environment. For the purpose of analysis, we somewhat arbitrarily select VM=1.2 as a threshold between these two regimes.

By displaying the fraction of blocks for which VM exceeds 1.2 as a function of CRM, we can see the effect of environment on the quality of the data. In Figure 2, we can see that VM generally increases with CRM, with over a third of HRC-I data falling in the excess noise regime for CRM values above approximately 10,000.

2. BACKGROUND VARIABILITY IN THE HRC-S

The same analysis was performed on HRC-S total rate data. Again, data were compiled into kilosecond blocks, resulting in 6319 VM values, sampled between August 1999 and June 2003. Since the HRC-S is operated in different modes which may affect the results, the largest subset (S mode with LETG inserted, 5331 blocks) was used for calculating statistics.

The histogram of VM values (Figure 3) displays a peak which, unlike the HRC-I, is centered well to the right of unity. This shift is consistent with the double counting behavior that is unique to the HRC-S (Juda, M., "Telemetered vs Processed Events" `http://hea-www.harvard.edu/~juda/memos/proc2valid/` and "HRC-S Double Pulse Fraction" `http://hea-www.harvard.edu/~juda/memos/proc2valid/pha_fraction.html`). When the event amplitude is sufficiently large, the rate scalar double-counts the events because of overshoot, thus skewing the rate statistics. Modeling of the double-counting behavior confirms that double counting results in an inflated standard deviation consistent with the shift in VM values we find here. For that reason, we are using a threshold value of VM=1.45 for HRC-S data instead of 1.2.

By displaying the fraction of blocks for which VM exceeds 1.45 as a function of CRM, we can see the effect of environment on the quality of the data. In Figure 4, we can see that VM generally increases with CRM, with over a third of HRC-S data falling in the excess noise regime for CRM values above about 20,000.

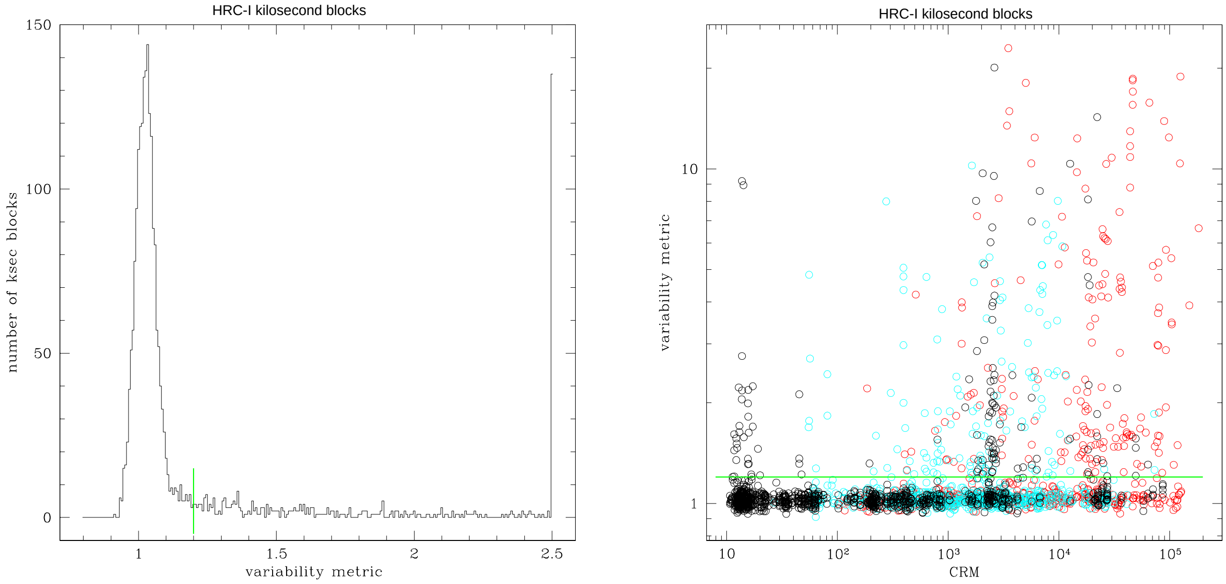

Figure 1. On the left, histogram of HRC-I kilosecond blocks binned by Variability Metric (VM). On the right, a Scatter plot of VM and CRM for HRC-I kilosecond blocks. The VM=1.2 threshold is indicated. The color indicates region: black is solar wind, blue is magnetosheath and red is magnetosphere.

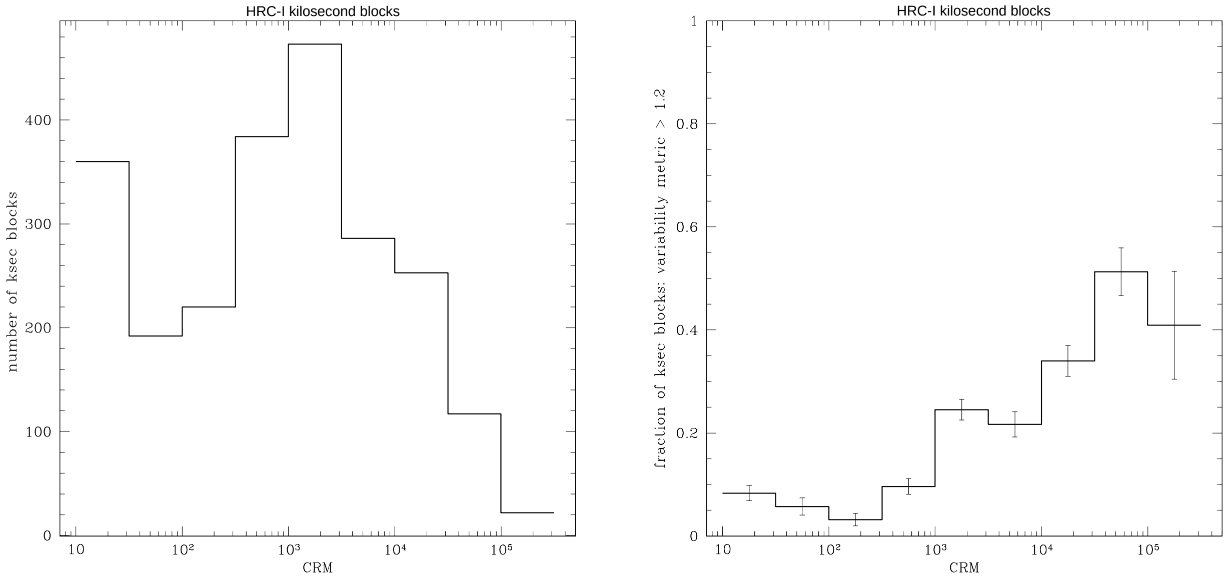

Figure 2. The histogram on the left is the number of HRC-I kilosecond blocks binned by Chandra Radiation Model (CRM). On the right is the fraction of those blocks whose VM exceeds 1.2.

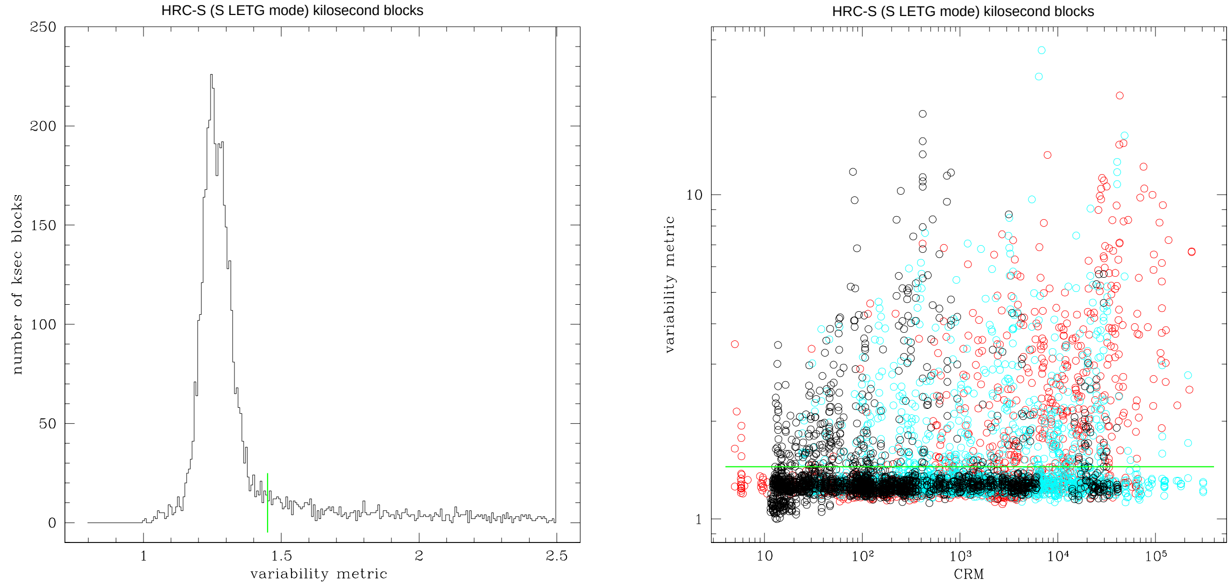

Figure 3. On the left, histogram of HRC-S kilosecond blocks binned by Variability Metric (VM). On the right, a Scatter plot of VM and CRM for HRC-S kilosecond blocks. The VM=1.45 threshold is indicated.

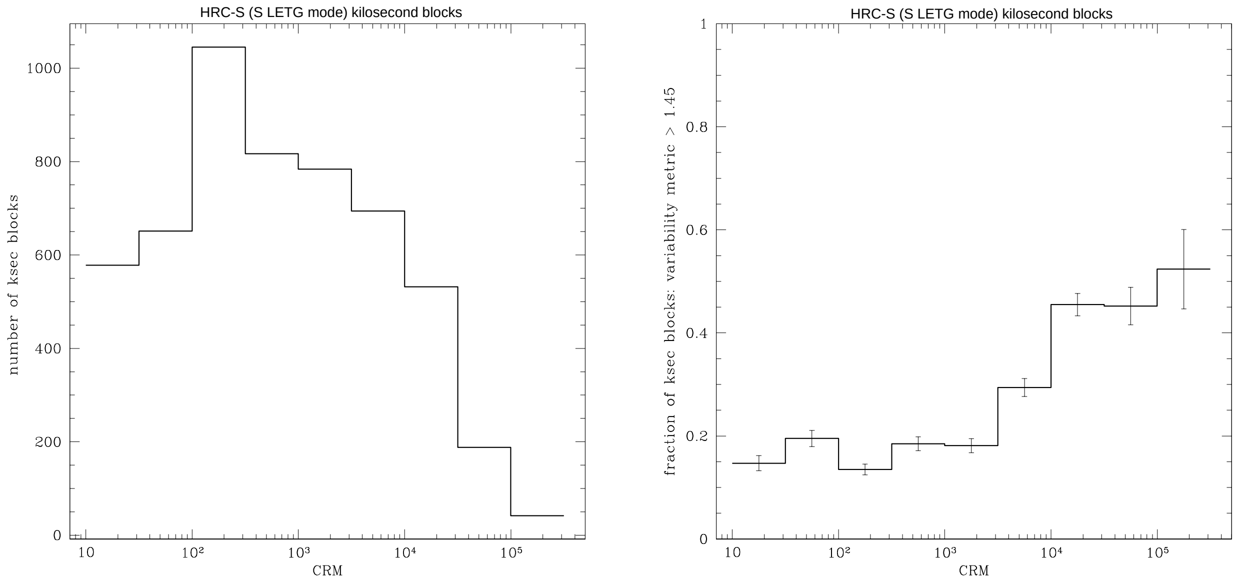

Figure 4. The histogram on the left is the number of HRC-S kilosecond blocks binned by Chandra Radiation Model (CRM). On the right is the fraction of those blocks whose VM exceeds 1.45.

3. GSM PROJECTIONS OF BLOCKS

Plotting the data in Geocentric Solar Magnetosperic (GSM) coordinates and scaling the size of each data point such that the area is directly proportional to VM, we can see how variability changes with position (See Figures 5 and 6). In all the figures, black data points identify when the spacecraft was in the solar wind regime. Red indicates magnetosphere and blue the magnetosheath.

Geocentric Solar Magnetospheric (GSM) coordinates are an earth-centered, orthogonal (X, Y, Z) coordinate system. The positive Xaxis points toward the Sun. The Y-axis is perpendicular to the Earth magnetic dipole such that the Z-axis completes the right-handed system, aligned in the same sense as the North magnetic pole.

In both the HRC-I and HRC-S, we see dependence of VM on position: VM values tend to be largest in the magnetosphere at low Z values, where the spacecraft dips in close to the radiation belts.

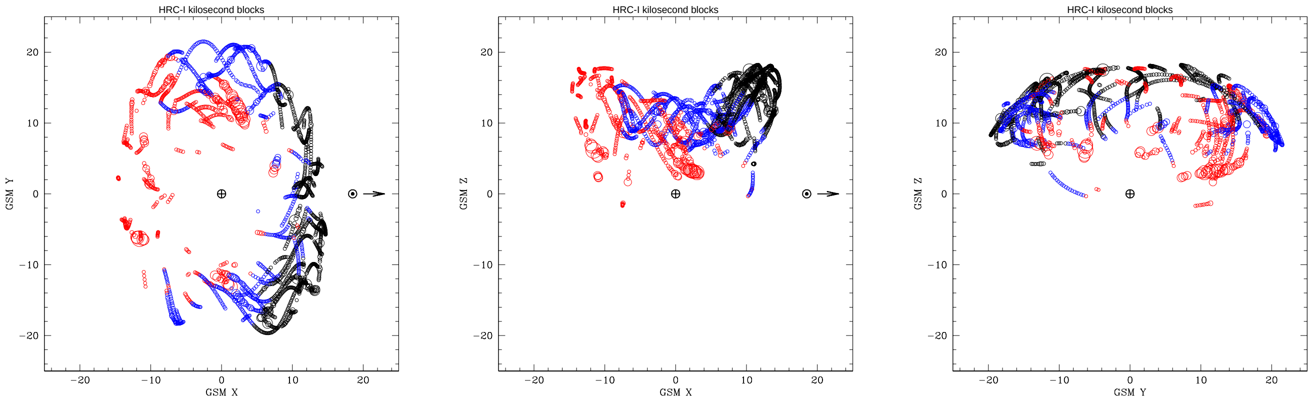

Figure 5. Projections of HRC-I kilosecond blocks in GSM coordinates, in units of Earth radii. Black data points indicate: solar wind regime, Red: magnetosphere, Blue: magnetosheath.

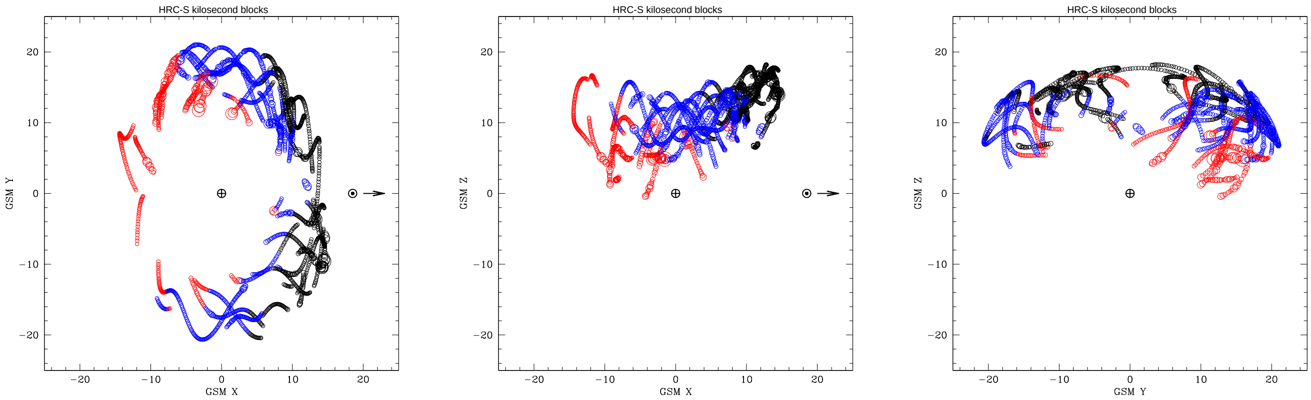

Figure 6. Projections of HRC-S kilosecond blocks (all observing modes) in GSM coordinates, in units of Earth radii. Black data points indicate: solar wind regime, Red: magnetosphere, Blue: magnetosheath.