PIXIE's Front Chamber Failure and its Impact on Polar Science

The Polar Ionospheric X-ray Imaging Experiment (PIXIE) admits X-rays through an adjustable array of square apertures onto an image plane on which position, energy (2–60 keV), and arrival time are electronically recorded for each detected photon. The main purpose of PIXIE has been to obtain global energy-resolved images of auroral brems-strahlung X-rays produced by precipitating energetic electrons. Such images are reconstructed on the ground by projecting each X-ray detected within a given time interval (typically ~ 5 min) from the image plane back through the aperture plate to a corresponding latitude-longitude position on a spheroid 110 km above the Earth's surface.

On 9 November 2002 an anomaly occurred in PIXIE's front chamber, causing it to no longer provide data from which images can be reconstructed. PIXIE leaves as its legacy a 6-year database of time-tagged and energy-resolved auroral X-ray counts (2–12 keV in 64 channels), localized in the instrument's image plane so as to permit projection back to their source points on the Earth's ionosphere. Images thus constructed, typically from exposure times ~ 5 min, are publicly available in an archive at <http://pixie.spasci.com>. The same database permits images to be constructed (even in retrospect) for variously chosen time intervals and energy bands within this range. Position sensing in PIXIE's rear chamber had failed on 28 September 1998, leaving a 2-year database of similarly resolved auroral X-ray counts (10–60 keV in 64 channels) from which images are likewise archived at <http://pixie.spasci.com>.

Despite its loss of imaging capability in September 1998, PIXIE's rear chamber continues to provide a data stream of energy-resolved X-ray counts (10–60 keV) without regard for their (X, Y) coordinates on the image plane. (To be more precise, PIXIE still measures their Y coordinates but not their X coordinates, but this is not enough information to reconstruct X-ray images on the ionosphere.) Even so, total X-ray count rate at 10–60 keV is a scientifically important index of global auroral activity. We thus recommend that PIXIE operations continue as usual (requiring about 2 hours/week of effort) until the September 2003 flip of Polar's rotation axis to ecliptic-normal orientation. Continued operation of PIXIE is necessary in any case for continued acquisition of high-resolution data from SEPS, the Source/Loss-Cone Energetic Particle Spectrometer.

We do not recommend routine operation of PIXIE (even as a monitor of total count rate) after the September 2003 re-orientation of Polar's spin axis. PIXIE had provided little useful data during the March–September 2002 interval of ecliptic-normal orientation. Indeed, whenever PIXIE faced the Earth during that time interval, legitimate X-ray counts usually were swamped by noise caused by energetic-particle bombardment. Similar noise had impaired PIXIE's X-ray sensitivity throughout the mission, whenever we had tried to operate PIXIE at too low a nominal (quasi-dipolar) L value (< 12). PIXIE will remain available after September 2003 to measure total X-ray count rates (10–60 keV) during special (e.g., astrophysical) event studies.

In view of our March–September 2002 experience, we doubt that PIXIE would have been scientifically useful for regular auroral viewing after the September 2003 re-orientation of Polar's spin axis, even if PIXIE had not failed in November 2002.

Despite consultations with PIXIE co-investigators on both sides of the Atlantic, we have been unable to identify the root cause for the failure of 9 November 2002. However, we note in this context that PIXIE's front chamber had operated successfully about three times as long as the lifetime for which the instrument was designed. Thus, cumulative radiation dose would have been an issue. Because of an unanticipated electric-discharge problem that began occurring in March 1996, we needed to switch PIXIE's high voltage source on and off about 20 times per orbit instead of only twice per orbit as originally planned. Finally, PIXIE experienced overheating because of the unfavorable spacecraft attitude during most of March–September 2002, when Polar's spin axis was normal to the ecliptic instead of normal to Polar's orbit. We believe it would have been preferable to maintain orbit-normal spin orientation as long as possible, from the start of the mission until fuel for doing this ran out (presumably in March 2003).

Despite the failure of our instrument as an imager, the PIXIE data archive continues to be a major resource for collaborative studies of past magnetospheric events. More-over, it is comprehensive enough to provide the basis for statistical (e.g., superposed-epoch) analysis of geomagnetic conditions that correspond to particular patterns of auroral X-ray activity. The PIXIE data archive can thus facilitate the interpretation of future events that are otherwise similar (in some appropriate way) to past events.

Some Highlights of PIXIE's career include:

- First-ever global images of Earth's aurora at X-ray wavelengths (20 March 1996). Previous auroral X-ray detectors had required image reconstruction by montage of scans from different times, since they had orbited too low for their fields of view to contain the entire auroral oval simultaneously.
- Detailed analysis of auroral X-rays from the geomagnetic storm of 10–11 April 1997, and mappings to the equatorial source region of the corresponding precipitating electrons in various parametrizable models of Earth's magnetosphere.
- Energy spectral measurements on the transient astrophysical X-ray source XTE J1550-564, which happened to be in PIXIE's field of view when it first appeared (7 September 1998) and for a full month thereafter.
- Observation and interpretation of the X-rays that illuminated the geomagnetic polar cap on 11 May 1999, the day during which the solar-wind density was unusually low.
- First-ever simultaneous observation of northern and southern X-ray auroras (12 August 2000).
- Statistical analysis of PIXIE data in coordination with data from the Student Nitric Oxide Experiment (SNOE) satellite, so as to elucidate the dependence of NO production on the characteristics of auroral electron precipitation.
- Interpretation of PIXIE data in coordination with PWI data, so as to elucidate the dependence of auroral kilometric radiation (AKR) on the characteristics of precipitating auroral electrons.
- Regular use of PIXIE images by operations groups for the diagnosis of spacecraft anomalies.
- Studies of the aurora over a broader range of photon energies than ever before.
- Event and statistical studies of storms and substorms.
- Motivation for numerous theoretical and simulation studies of more general interest.
- Thesis topics for at least four PhD candidates (Greg Van Bavel, Univ. of Maryland; Nikolai Østgaard, Arve Aksnes, and Arne Åsnes, all at Univ. of Bergen, Norway)

Some Representative References:

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