An Exceptionally bright flare from SGR 1806-20 and the origins of short-duration γ -ray bursts

K. Hurley et al.　/nature/vol434/28 April 2005/

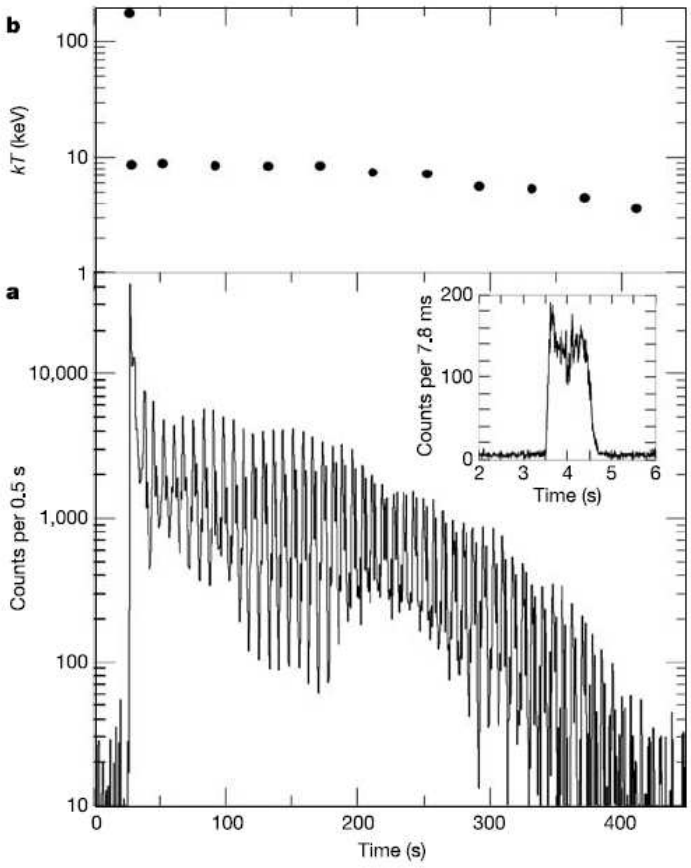

Figure 1 Profiles of the 27 December 2004 giant flare. **a**, 20–100-keV time history plotted with 0.5-s resolution, from the RHESSI γ-ray detectors. Zero seconds corresponds to 77,400 s Universal Time (UT). In this plot, the flare began with the spike at 26.64 s and saturated the detectors within 1 ms. The detectors emerged from saturation on the falling edge 200 ms later and remained unsaturated after that. Photons with energies $\gtrsim$ 20 keV are unattenuated; thus the amplitude variations in the oscillatory phase are real, and are not caused by any known instrumental effect (Supplementary Information). Inset, time history of the precursor with 8-ms resolution. Zero corresponds to 77,280 s UT. **b**, Spectral temperature versus time. The temperature of the spike was determined by the RHESSI and Wind particle detectors; the temperatures of the oscillatory phase were measured by the RHESSI γ-ray detectors. Although RHESSI measured time- and energy-tagged photons >3 keV continuously, unattenuated spectra were measured for short 'snapshot' intervals only twice in each 4.06-s spacecraft spin period during the oscillatory phase (Supplementary Information). Preliminary spectral analysis (3–100 keV), using the RHESSI on-axis response matrices, are generally consistent with a single-temperature blackbody or optically thin thermal bremsstrahlung model; the blackbody temperatures have been plotted. The formal uncertainties in the oscillatory phase are smaller than the data points and are not shown.

Fig1.Giant flare のプロファイル

☆ **precursor** に関する記述

- Flare の 120 秒前に precursor
- Roughly flat-topped profile
- スペクトルは optically thin, thermal bremsstrahlung with 15kev でフィット
- 3kev 以上のフルエンスは 1.8×10^-4 erg/cm^2 で、4.8 ×10^42 d_{15}^2erg を示唆

☆ **initial spike** に関する記述

- 継続時間～0.2 秒
- rise time は τ_{rise} < 1ms
- decay time は τ_{decay} < 65ms
- 以上の特徴的な時間は他の giant flare と一致
- 30kev 以上の photon で検出した spike の fluence は～1.36 erg/cm^2
- time-resolved energy spectrum は平均温度 175kev(E_{spike}～3.7×10^46 d_{15}^2erg)の cooling black body と一致
- 最初の 0.125 秒での peak flux は L_{spike}～2×10^47 d_{15}^2 erg/sec

☆ **硬 X 線 tail** に関する記述

- hard X-ray tail は 380 秒継続。
- 7.56 秒で変調（NS の回転周期）
- tail phase の間の 3-100kev でのフルエンスは 4.6×10^-3 erg/cm^2(E_{tail}～1.2×10^44 d_{15}^2 erg）

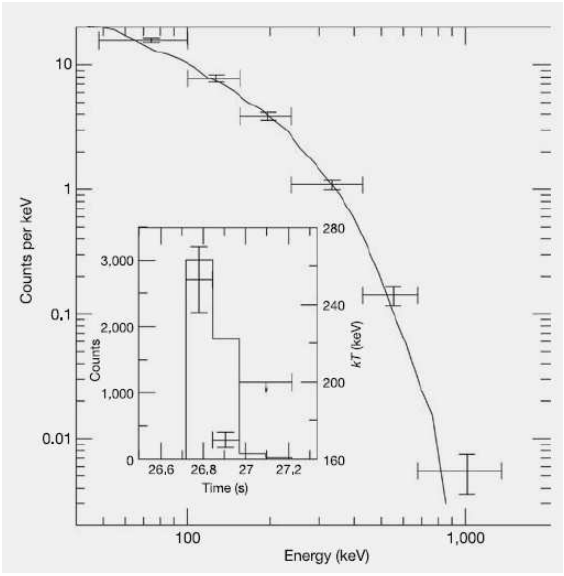

Fig2.initial spike のスペクトル

・**BB** でフィットできてその時の温度は **T～175±25kev**

Figure 2 Spectrum and time history of the initial spike, from the RHESSI and Wind particle detectors. The crosses show the spectrum measured by the Wind 3D O detector[52] with coarse time resolution that averages over the peak. The error bars are 1σ, plus 10% systematic errors. The line is the best-fitting blackbody convolved with the detector response function; its temperature is 175 ± 25 keV (Supplementary Information). Inset, the time history of the peak (histogram, left-hand scale) and of the blackbody temperature (error bars, right-hand scale) with 0.125-s resolution, from the RHESSI particle detector (ref. 35 and Supplementary Information). The error bars are 1σ, plus 25% systematic errors.

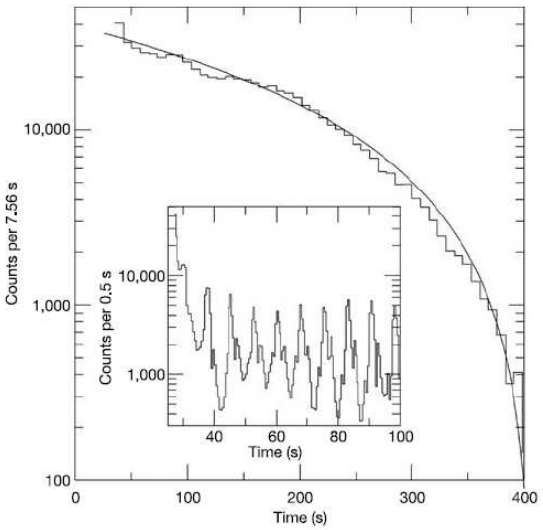

Fig3.Tail phase での **time-averaged counts** と理論値**(trapped fireball model)**の比較

・**Trapped fireball model**：磁気的に **confine** されたプラズマの **cool surface** が収縮し **evaporate** する時に放射が起こるというモデル

・**Lx(t)=L0[1-(t/t evap)]^(a/1-a)**で記述される

・**t evap =382±3 sec, a=0.606±0.003** でフィット

・この値は一様な球対称の **fireball** から期待される値に非常に近い

Figure 3 Time-averaged counts in the tail phase of the giant flare, compared with the 'trapped fireball' model. Zero corresponds to 77,280 s UT. The step plot shows the RHESSI γ-ray detector data averaged over the 7.56-s rotation period of the neutron star. It is fitted by a simple model (smooth curve) that describes the emission from the cool surface of a magnetically confined plasma as it contracts and evaporates in a finite time: $L_x(t) = L_0[1 - (t/t_{evap})]^{a/(1-a)}$ (ref. 49). We find $t_{evap} = 382 \pm 3$ s, and the index $a = 0.606 \pm 0.003$ is near the value $a = 2/3$ expected for a homogeneous, spherical trapped fireball[19,49]. Inset, RHESSI γ-ray detector light curve for the first ten cycles of the flare tail. The energy range is 20–100 keV. The first peak of the trapped fireball emission is evident on the falling edge of the hard spike at $t = 30$ s. A changing two-peaked pulse–interpulse structure is present.

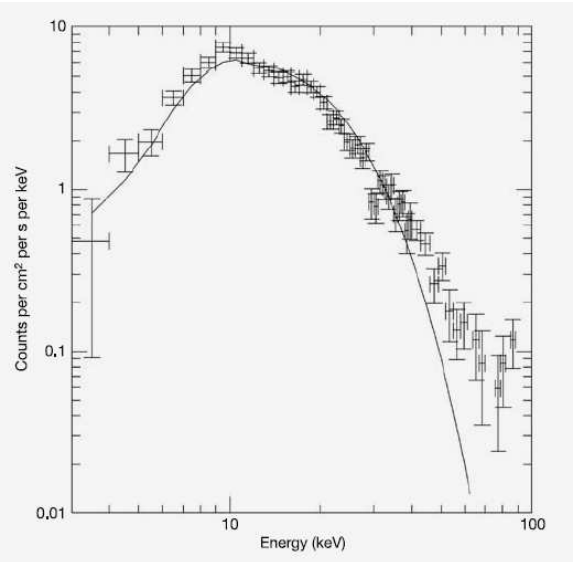

Fig4.Tail phase での **phase-averaged spectrum**

・**Fig1** の **272-400 sec** のフェーズの時間平均

・**solid line** は **black body** を示していて、この時の温度は **kT=5.1±1.0kev**

・**BB function ∝ E^2[exp(E/kT)-1]^-1**

・**Optically thin** な **thermal bremsstrahlung (kT～22kev)**とも良い一致を見せる。