# Spectral Feature at 3.4 keV in the Slowly Rotating Central Compact Object in RCW 103

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Abstract

A series of nineteen monitoring observations of the CCO in RCW 103 were carried out from 2000 to 2005. During these observations a large flare was observed to have occurred sometime before 2000 February 8. The following six years of observations revealed a very slow, but steady decline in the source intensity. About half way through the decline a significant absorption line appeared in the spectrum of the source at an energy of 3.4 keV. It was observed during four of the nineteen observations. The line appears to be rather narrow, but it could be a proton cyclotron line. Another possibility is that it is from an excited state of ionized Calcium in the surrounding nebula. If it is a cyclotron line, it would imply a magnetic field of greater than 10^{14} Gauss.

The CCO in the supernova remnant RCW 103, at a distance of about 3 kpc and an age of about 2000 years, was one of the first to be detected in the center of a Type II supernova remnant It lies close to but in front of the pulsar J1617 -5055 shown in the Figure below.
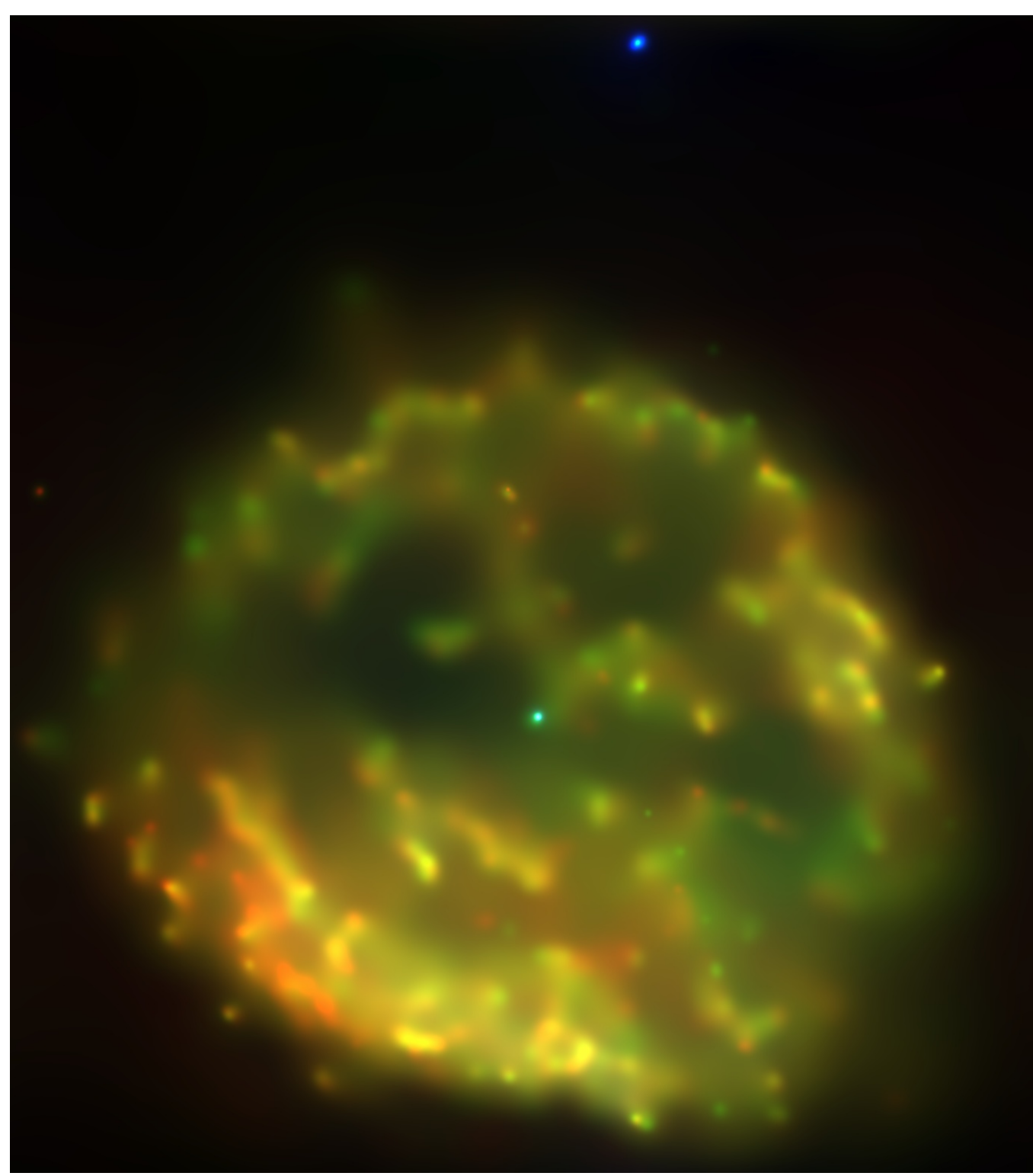
The CCO has shown considerable variability over the pas 25 years of observations. The variability is shown in the Figure below.
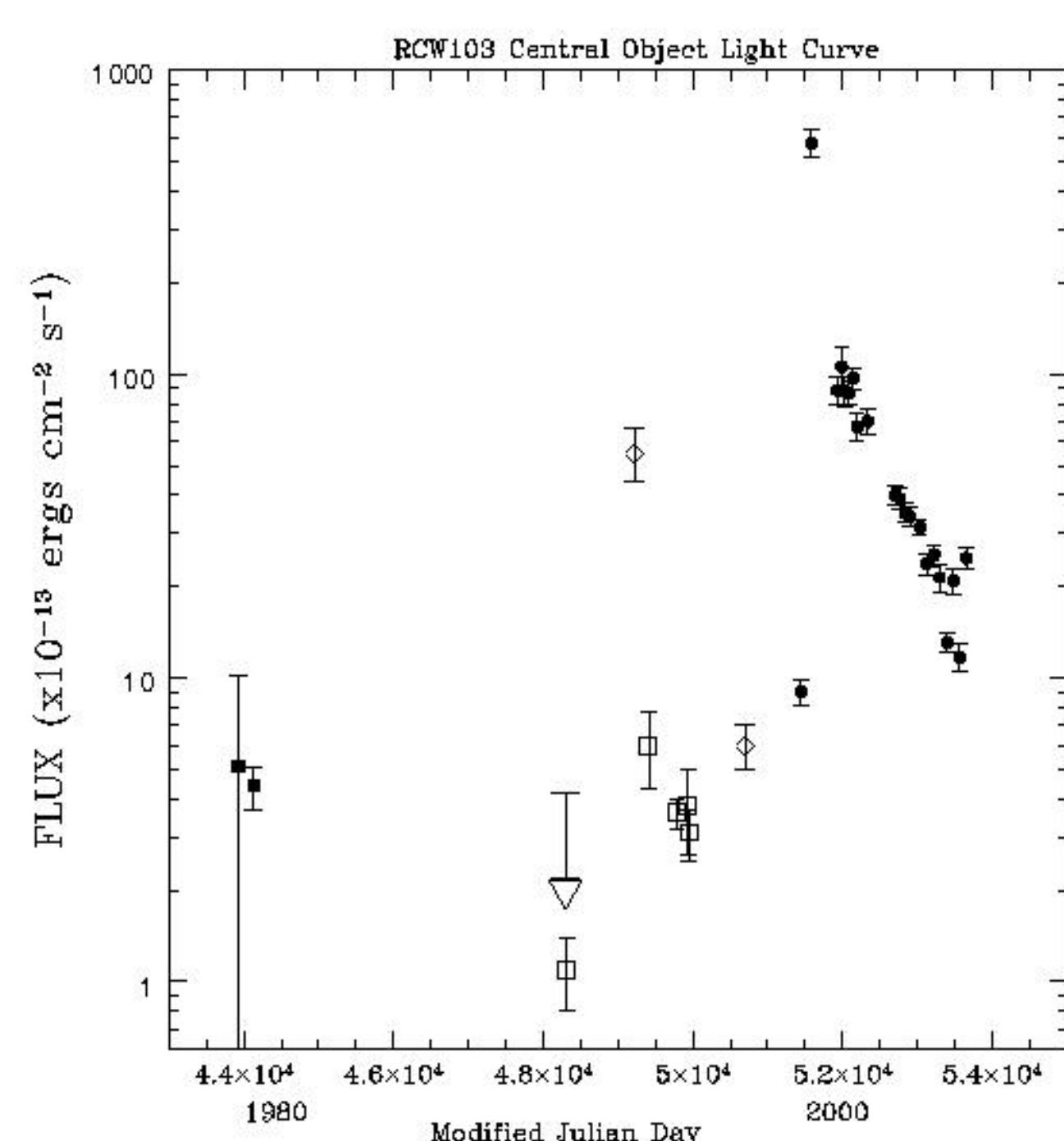
Since the first *Chandra* observation in 1999 Sept 23, a monitoring program of the CCO has been carried out by *Chandra,* the results of which are shown above. The decay of the lightcurve is one of the longest on record, some 880 days. The temperature remains almost constant during the decay implying a decreasing area of emission rather than a falling temperature.

Similarly, the fact that the intensity changes by nearly a factor of 50 during the outburst while the temperature remains nearly constant implies that the area of the emitting region must have increased during the outburst.

A CC-mode observation was conducted on 2002 Mar 3 for about 50 ks. During this observation the source changed intensity in a regular pattern, although there was some noise in the intensity modulation as well. A rather complex function was used to model the temporal behavior, with the basic result that there were two periods associated with the variation that were exactly a factor of four different within uncertainties, namely a period of 6.67 hr and a period of 1.67 hr with about a 3% uncertainty in the periods. The Figure below shows the power spectrum of the lightcurve. The significance of the peaks is estimated using the Fisher (1929) test based on

$$T = I^{(1)}(\omega_{(1)})/\Sigma\, I(\omega_{K})$$

And the probability for T>g is given by

$$P(T>g) \sim N(1-g)^{N-1}$$

Where N is the total number of data pints divided by 2.
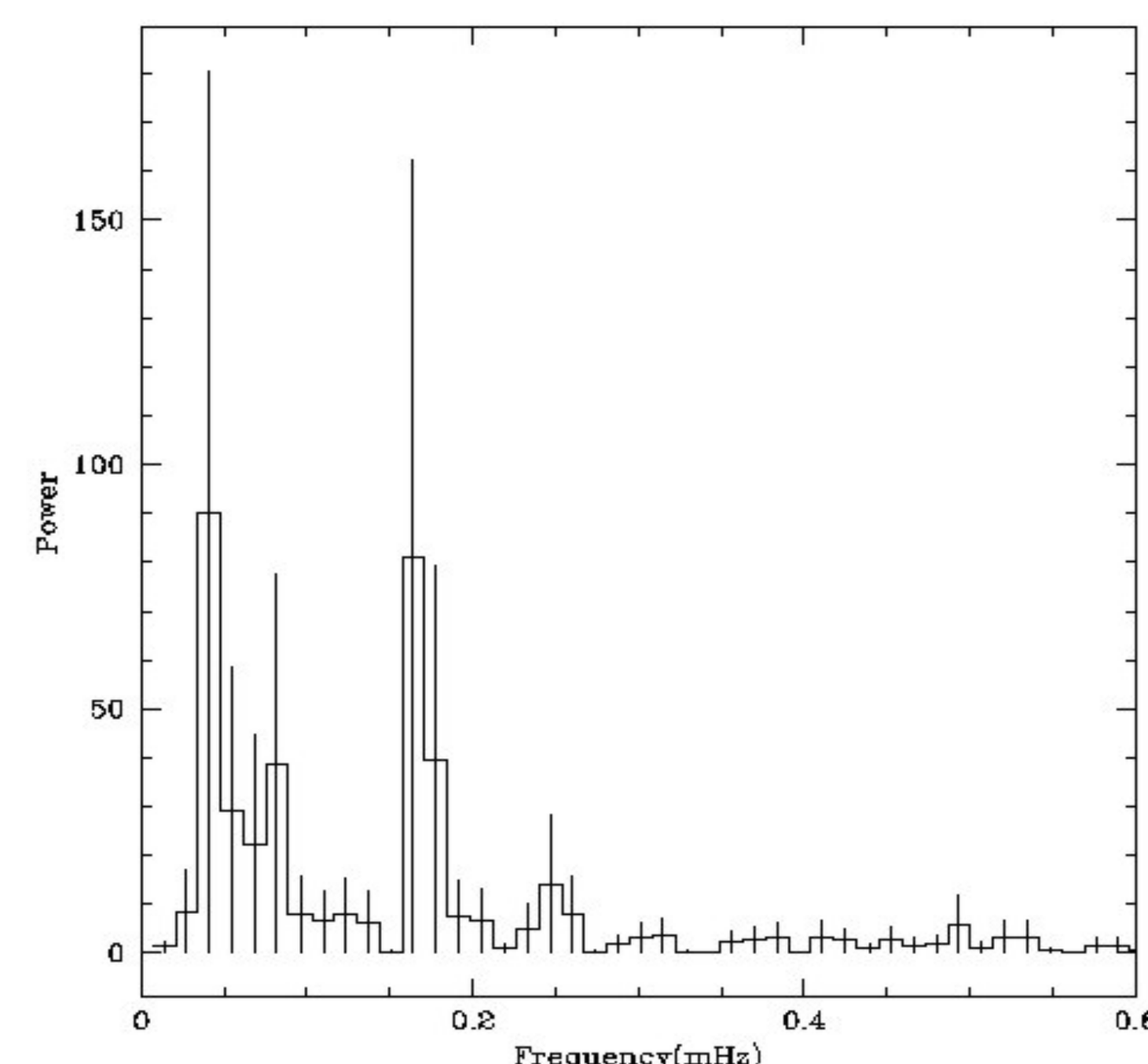
The probability of the peak at a period of 6.67 hours occurring by chance is 7.2×10^{-6} and the peak at a period of 1.67 hr is 1.3×10^{-7}. We interpret the forth harmonic to imply that the CCO is likely a neutron star with a quadrupole magnetic field with all the poles hotter than the remainder of the surface. As the poles cool, the weaker poles fade more rapidly than the stronger ones and result in a changing pulse profile. Accretion from a companion star could also play a role in changing the pulse shape. It is very likely that a companion star is in the system because it is almost impossible to slow the spin rate of a 2000 year old neutron star down to a 6.67 hr period without a magnetic coupling to an orbiting companion.

The spectrum of the CCO is best represented by two black bodies; a dominant one at a temperature of 6 MK and a lesser component at 15 MK. The typical corresponding areas on the neutron star range from 5 to 50 km^2 for the high temperature component to 0.1 to 0.9 km^2 for the low temperature component. Over the nineteen monitoring observations, the spectrum is generally fit quit well with one or two black bodies, however, an occasional feature is observed in the spectrum. Usually these features are of only marginal significance, but one feature stood out and was seen on four separate observations at or near 3.7 keV The most significant feature is shown in the figure below.
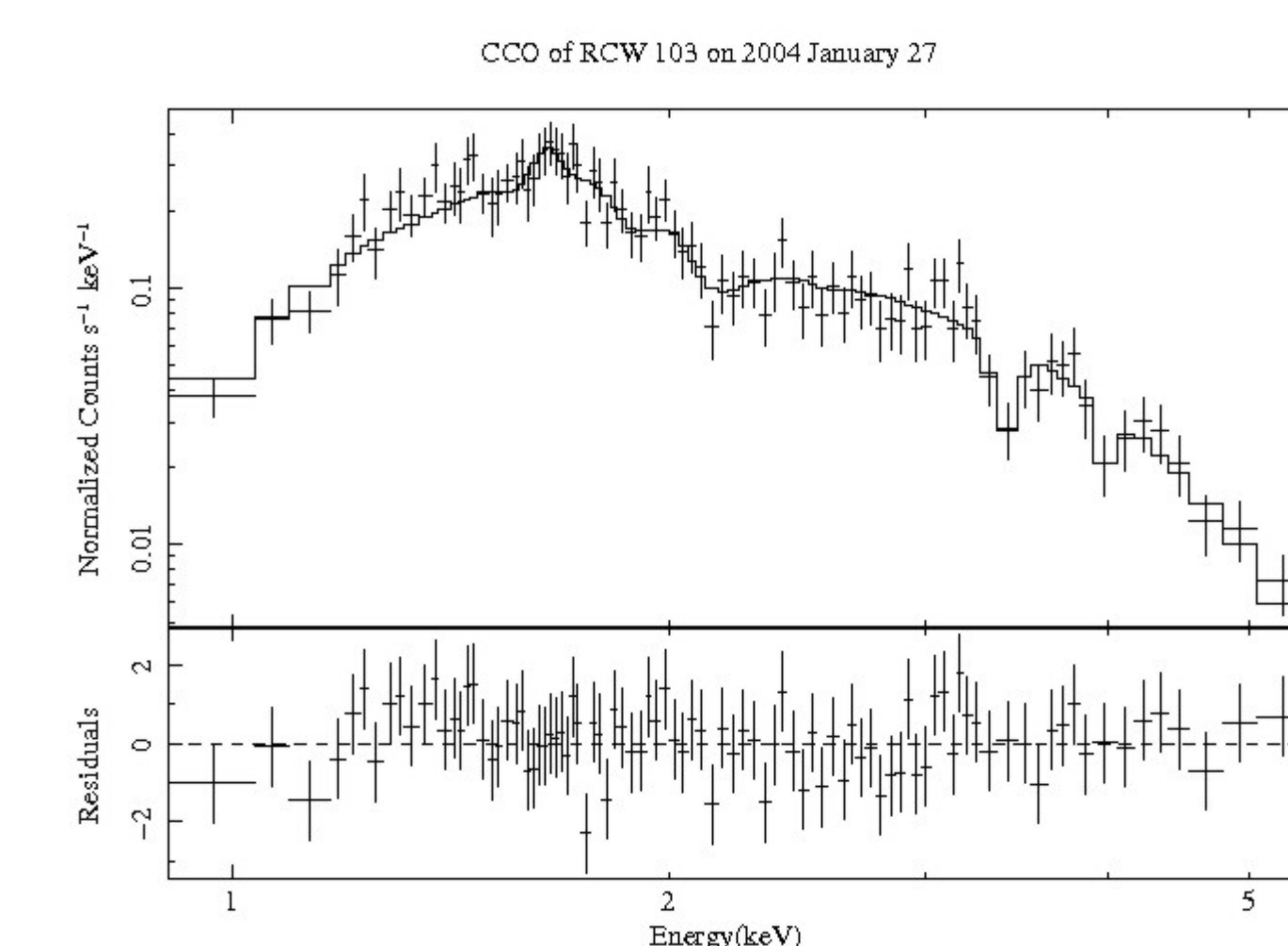
The significance of this absorption feature at 3.4 keV is 2.8×10^{-9} of occurring by chance, based on the F-test. The absorption feature at 4.0 keV has a corresponding probability of $1.6 \times 10^{-3,}$ and the emission feature at 1.65 keV has a probability of 1.3×10^{-8} of occurring by chance. The observation was checked carefully for any unusual behavior of the detector CCD I3, but nothing unusual was found. This observation was taken on 2004 January 27. Other observations exhibiting an absorption feature near this energy include ones on 2003 Sep 21, 2005 Jan 24 and 2005 April 2005, all at lower significance but greater than 2×10^{-3}.

If the absorption feature is due to the fundamental proton cyclotron frequency, then the magnetic field required is 8×10^{14} Gauss, which would aid in explaining the slow rotation rate. The CCO is then one of several magnetars, but the only one with a companion star. If the absorption is due to absorption by ionized Calcium, and the nebula surrounding the CCO seems to have an excess abundance of Ca then the variability must be due to small clouds moving quite near to the CCO in the nebula. The energy of the Ca feature should be 3.7 keV, but the observed line is slightly lower in energy. The origin of the emission feature is not understood at this time.

R. A. Fisher 1929 Proc Roy Soc A **125**, 54-59.