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EVIDENCE FOR X-RAY EMISSION FROM CAPELLA

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ABSTRACT

X-ray emission in the range from 0.2 to 1.6 keV has been detected from an area of the sky which contains the binary star system Capella. The X-ray source is at most a few arc minutes in extent and shows no spectral turnover at low energy, consistent with a nearby source. We suggest Capella as the source of this emission and that this object belongs to a new class of galactic X-ray sources with a luminosity of 10^{31}–10^{34} ergs s^{-1}. Emission from this class of objects is variable, predominantly below 2 keV, and originates from nearby stellar objects.

Subject headings: spectra, X-ray — stars, individual — X-ray sources

I. OBSERVATIONS

In a rocket flight on 1974 April 5 a star sensor pointed the payload axis at Capella (α Aur) briefly to calibrate the attitude control system. During this period, X-rays in the range 0.2–1.6 keV were detected significantly above background by an X-ray reflector system which was co-aligned with the star sensor (instrument described by Catura *et al.* 1972).

Capella is a spectroscopic binary consisting of an F8–G0 giant of 2.9 $M_\odot$ and a G5 giant of 3.0 $M_\odot$ (Wright 1954). The system rotates in a nearly circular orbit with a period of 104.023 days and a separation between the stars of about 1 a.u. (Struve and Kilby 1953). The spectrum lines of the F component are broadened by an amount corresponding to a turbulent or rotational velocity of 10–12 km s^{-1} (Franklin 1959). No radio detection of the Capella system has been reported. There are no characteristics of this system which would *a priori* indicate it to be a strong X-ray emitter. The X-ray observations reported here were obtained nearly at conjunction, with the so-called F star toward the Earth.

The counting rate in a proportional counter at the focus of the X-ray reflector is shown in figure 1 for a time interval early in the flight bounded by the end of calibration with a radioactive source and the beginning of a scan over the extended X-ray source in Perseus. Analysis of aspect photographs indicate that the payload was pointed at Capella for a short period at 133 s after launch. As shown in figure 1, the X-ray detector experienced a large increase in counting rate for the $1^s.2$ interval of stable pointing. The average counting rate in figure 1, excluding this interval, is 3.3 counts s^{-1}. The number of counts obtained when Capella was within the field of view of the reflector system was 22, while on the average only four counts would be expected. Thus, it is very improbable that this signal is a random fluctuation in the background counting rate.

The signal obtained while pointing at Capella is definitely not from an ultraviolet flux. Later in the same flight, the payload axis was pointed at Sirius and an ultraviolet signal was clearly observed. The difference in pulse amplitude distributions obtained when the reflector system was pointed at Sirius and at Capella is shown in figure 2. In the spectrum of Sirius, note the large predominance of pulses of the lowest amplitude, a result characteristic of the detector response to ultraviolet radiation. While pointing at Capella, however, the observed spectrum below 0.4 keV is consistent with an incident flux of X-rays passed by the carbon transmission band of the 1-μ polypropylene detector window. This spectrum also contains appreciable flux

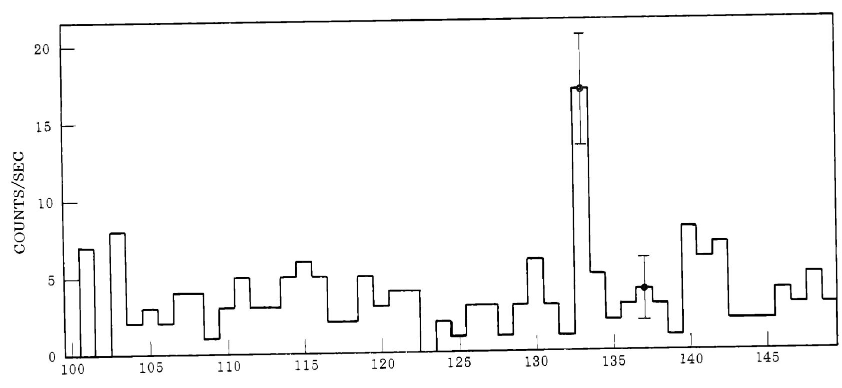

FIG. 1.—Counting rate of a detector at the reflector focus in the range 0.2–1.6 keV. The field of view of this detector was pointed at Capella for a $1^s.2$ period 133 s after launch.

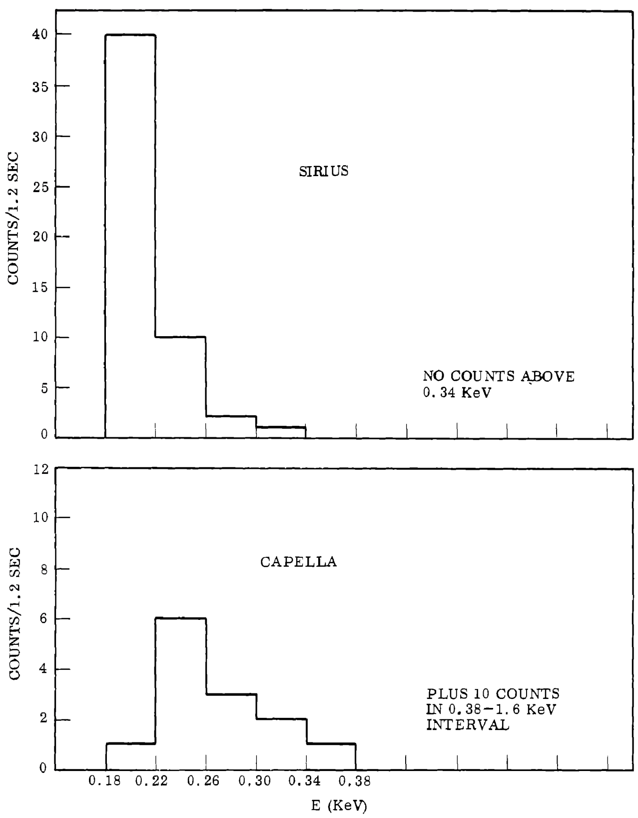

FIG. 2.—Energy spectra of pulses observed when the rocket was pointed at Sirius and Capella.

at higher energies which is not present in that from Sirius.

The data of figure 2 for Capella have been fitted to a function describing thermal bremsstrahlung of the form

$$\frac{dN}{dE} = AE^{-1}T^{-0.5}\left(\frac{E}{kT}\right)^{-0.3} e^{-E/kT}$$

$$\text{photons cm}^{-2}\,\text{s}^{-1}\,\text{keV}^{-1}\,,$$

where E is in keV and T is in degrees K. The parameters resulting from the least-squares fit are $T = 8 \times 10^6$ and $A = 1200$. Statistical uncertainties in the data allow temperatures ranging from 5 to 15×10^6 ° K. The spectrum shows no indication of a turnover at 0.25 keV from X-ray absorption by interstellar matter.

The X-ray emission originates within an area 0°.1 by 18° centered on Capella. The long dimension of this rectangle extends along a line through Capella defined by position angles of 147° and 327°. Angular extent of the emission perpendicular to this line is at most a few arc minutes. No known X-ray sources lie in this region, and the most prominent object within the error box is Capella. The lack of X-ray absorption at low energies is consistent with such a nearby source (14 pc), and the upper limit to its angular extent is consistent with a starlike object. On the basis of these results, we suggest that Capella is the source of the observed X-ray emission. If this identification is correct, it indicates a galactic X-ray source with a luminosity of $\sim 10^{31}$ ergs s^{-1}.

II. DISCUSSION

The source we report here and suggest is associated with Capella was not observed by Hill *et al.* (1974) during a survey of this region in 1972. The sensitivity (Burginyon *et al.* 1971) of their observation was such as to detect Capella at a level $\sim 5\ \sigma$ above background if it then emitted the same flux we have observed. During the past several years a number of other soft X-ray sources have been reported, many of which have also been identified with nearby stellar objects, and which other observations of comparable or better sensitivity have failed to detect. In 1969, Coleman *et al.* (1971) reported a source, Cyg X-6, whose flux was concentrated between 0.5 and 1.3 keV. Succeeding observations in 1971 (Burginyon *et al.* 1973) and 1972 (Borken, Doxsey, and Rappaport 1972) did not detect this source. Similarly, a source tentatively identified with λ Sco by Bleeker *et al.* (1973) was not observed by Hill *et al.* (1972). Recent observation with *Copernicus* failed to detect X-ray emission from λ Sco (Strong, Colley, and Culhane 1974), or from η Car (Griffiths, Peacock, and Pagel 1974), a soft source whose identification was suggested by Hill *et al.* (1972). Other sources of soft X-ray emission which have not been confirmed have been reported by Hayakawa *et al.* (1972), who suggest the Pleiades cluster as the source, and Rappaport *et al.* (1974), who identify a very soft source with SS Cyg.

One must conclude from this evidence that either many spurious observations have been reported or these sources of soft X-ray emission are strongly variable in time. Since most of the observations are of high statistical significance, we suggest that the lack of confirming observations is due to source variability. Because interstellar matter absorbs soft X-rays strongly, the emission is likely to come from nearby objects. All of the candidate objects for the emission which have been suggested are of order 100 pc or less away, except η Car which is at a distance of $\sim$1.6 kpc; and if these identifications are correct, they indicate a source luminosity ranging from 10^{31} to 10^{34} ergs s^{-1}.

We suggest, therefore, the existence of a new class of low-luminosity galactic X-ray sources whose emission is largely below 2 keV, is variable in time, and is possibly transient. The emission appears to be associated with nearby stellar objects whose X-ray luminosities are $\sim 10^{31}$–10^{34} ergs s^{-1}. If the unconfirmed observations indeed indicate real variable sources, then the rather large number which have been reported on rocket flights suggests they occur frequently and may contribute substantially to the diffuse X-ray background.

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REFERENCES

Bleeker, J. A. M., Deerenberg, A. J. M., Heise, J., Yamashita, K., and Tanaka, Y. 1973, *Nature Phys. Sci.*, **241**, 55.

Borken, R., Doxsey, R., and Rappaport, S. 1972, *Ap. J. (Letters)*, **178**, L115.

Burginyon, G. A., Cornell, C. M., Hill, R. W., and Iantuono, A. 1971, *Nucl. Instr. and Meth.*, **96**, 461.

Burginyon, G. A., Hill, R., Palmieri, T., Scudder, J., Seward, F., Stoering, J., and Toor, A. 1973, *Ap. J.*, **179**, 615.

Catura, R. C., Fisher, P. C., Johnson, H. M., and Meyerott, A. J. 1972, *Ap. J. (Letters)*, **177**, L1.

Coleman, P. L., Bunner, A. N., Kraushaar, W. L., and McCammon, D. 1971, *Ap. J. (Letters)*, **170**, L47.

Franklin, K. L. 1959, *Ap. J.*, **130**, 139.

Griffiths, R. E., Peacock, A., and Pagel, B. E. J. 1974, *Nature*, **250**, 714.

Hayakawa, S., Kato, T., Kohno, T., Nishimura, K., Tanaka, Y., and Yamashita, K. 1972, *Ap. and Space Sci.*, **17**, 30.

Hill, R. W., Burginyon, G., Grader, R. J., Palmieri, T. M., Seward, F. D., and Stoering, J. P. 1972, *Ap. J.*, **171**, 519.

Hill, R. W., Burginyon, G. A., Seward, F. D., Stoering, J. P., and Toor, A. 1974, *Ap. J.*, **187**, 505.

Rappaport, S., Cash, W., Doxsey, R., McClintock, J., and Moore, G. 1974, *Ap. J. (Letters)*, **187**, L5.

Strong, K. T., Colley, M. W., and Culhane, J. L. 1974, *Nature*, **248**, 34.

Struve, O., and Kilby, R. F. 1953, *Ap. J.*, **117**, 272.

Wright, K. O. 1954, *Pub. Dom. Ap. Obs.*, **10**, 1.

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