HEAO 3 UPPER LIMITS TO THE EXPECTED 1634 KEV LINE FROM SS 433

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1. Introduction. We have previously reported (1, hereafter paper I) evidence for gamma-ray line emission at energies near 1.5 MeV and 1.2 MeV from the peculiar optical, radio, and x-ray variable star SS 433. Because of the pattern of energy variability, as reported in paper I, we interpreted the observed spectral features as originating from the 1369 keV excited state of ^{24}Mg, Doppler-shifted according to the ephemeris (2) for the optical emission lines, which is explained by the standard kinematic model (3, 4) in terms of oppositely-directed relativistic jets. An alternative explanation (5) attributes the features to Doppler-shifted ^{14}N emission at a rest energy of 1380 keV arising from thermonuclear processes, essentially the CNO cycle, occurring in the jets. However, this model predicts a companion 6176 keV (rest energy) line which is only marginally observed (6) if it is present at all, and which does not appear to have the required intensity.

Ramaty, Kozlovsky, and Lingenfelter (7) have developed a model based on ^{24}Mg(1369) as the source of the lines in which refractory grains in the jets, containing Mg and O, are bombarded, (as seen in the frame at rest with respect to a the jet), by ambient protons in the local ISM. The narrowness of the features results because the recoil Mg nucleus is stopped in the grain before the 1369 keV excited state decays. However, as was pointed out by Norman and Bodansky (8), a consequence of the ^{24}Mg interpretation is the expected appearance of other emission lines, due to ^{20}Ne and ^{23}Na, which are produced by proton bombardment of ^{24}Mg at the 33 MeV/nucleon energy corresponding to the velocity (β=0.26) of the jets. These lines appear at rest energies of 1634 keV and 1636 keV, respectively, and should, if the observed features arise purely from proton bombardment of magnesium, have essentially the same total flux as that emitted at 1369 keV.

We have examined the HEAO 3 data in order to search for the 1634 keV (rest) emission predicted by Norman and Bodansky (8). Section 2 describes the observation and analysis, section 3 the results, and section 4 discusses the implications for our understanding of SS 433.

2. Observation and Analysis. The Jet Propulsion Laboratory High Resolution Gamma-Ray Spectrometer, flown on HEAO 3 from 1979 to 1980, has been described by Mahoney et al. (9). The experiment observed the region of SS 433 from 1979 September 26 until the HEAO scan plane moved away from the source in early November. The most compelling spectral features reported in paper I were observed during the October 10.6 to October 29

time period, and only these data are discussed here. During this period the resolution of the instrument ranged from about 3 to 7 keV (FWHM) for energies between 1 and 2 MeV (10).

Data were excluded at high geomagnetic latitude ($L > 2$), after passages through the South Atlantic Anomaly, when contaminated by charged particles, or when the instrument viewing axis pointed more than 100° from the zenith. We then fit the data within ±160° of the source to a 3-component linear model, independently for each detector, in each energy channel. The 4 keV energy channels used in the analysis were chosen to match the instrument resolution. The linear model included a constant background component, a background component proportional to the high energy radiation environment, and a source at the position of SS 433. We have found the radiation environment to be proportional, to a good approximation, to the observed detector count rates over 10 MeV. The functional form of each term being known, in particular the instrument point-source response as a function of angles and energy (9), the fit returns estimates of the amplitude of each term and its error. In order to reduce the effects of systematic errors in background subtraction, we have performed the analysis on an individual scan basis, first fitting to obtain a background-subtracted flux estimate for each, and then combining fluxes by weighted averaging (11). In effect this allows the nominally constant part of the background to vary on a timescale longer than the 20-min spacecraft spin period.

Because other possible cosmic sources of MeV radiation in the region have been ignored, especially the Cygnus sources and the Galactic Center, broad-band continuum fluxes obtained are subject to possible contamination. However, in the absence of a fortuitous energy coincidence with an actual strong narrow cosmic emission feature, we expect no effect on our estimates for narrow line fluxes.

3. Results. Figure 1 shows the spectrum around 1787 keV, where we expect the Doppler-shifted 1634 keV ^{20}Ne feature from the approaching jet to appear, assuming the 1497 keV feature shown in Figure 1 of paper I arises from 1369 keV emission. The solid curve is a fit to a constant continuum and a Gaussian line centered at 1787 keV, with width given by the observed 1.5 MeV emission. It is clear that no indication of any line appears, the fitted flux being $(0.6 \pm 2.0) \times 10^{-4}$ photons cm^{-2} s^{-1}

4. Conclusion. As pointed out in (7), the 1369 keV feature could also arise from spallation of ^{28}Si to ^{24}Mg without producing anything at 1634. This however should produce an emission feature at a rest energy of 1779 keV from excitation of the silicon, the blue component of which, corresponding to the 1497 keV feature (1), would appear in our data near 1944 keV. Thus this possibility pushes down the requirement for the 1634 keV feature, but demands a new one at 1779 keV.

It may also be possible to save the model of ^{24}Mg emission excited by ambient protons by making use of the fact that the cross-section (12) for production of 1634 keV gamma rays by protons on magnesium drops off rapidly below about 20 MeV, but that for producing the 1369 keV excitation remains large down to about 5 MeV.

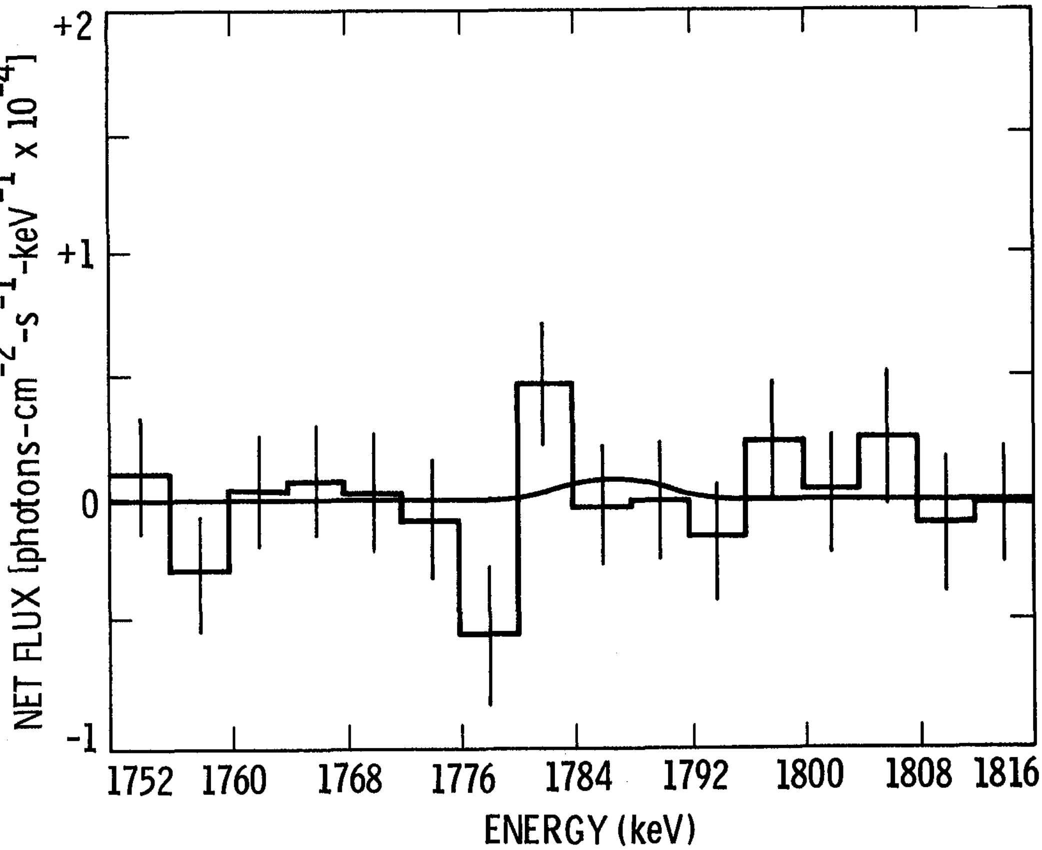

Figure 1. Spectrum of SS 433 in the region which corresponds to 1634 keV rest energy.

Thus we conclude that the emission does not result primarily from bombardment of jet ^{24}Mg with protons at an interaction energy of the 33 MeV corresponding to the jet velocity, as originally proposed (1). Whether ^{24}Mg (1634) is involved at all, either secondary to Si bombardment or at some energy lower than 33 MeV, awaits further experimental or theoretical clarification.

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