Limit on the Angular Size of Cyg *XR*–1

BOTH nebular and stellar objects have been identified as discrete sources of cosmic X-rays. Representative of the first is the Crab Nebula, the size of which has been measured to be 1 to 2 arc min in the energy range 1–6 keV according to observations during a lunar occultation[1] and with a modulation collimator[2]. This size is comparable with the optical size of the nebula. Representative of stellar sources is Sco *X*–1, the X-ray size of which has been shown to be less than 20 arc s by a measurement with a modulation collimator, also in the energy range 1–6 keV (ref. 3). The optical counterpart of Sco *X*–1 is an irregularly variable blue star[4]. The tentative identifications of Cas *XR*–1 with the supernova remnant, Cas *A* (ref. 5, and of several other X-ray sources with blue stars (Cyg *X*–2 (ref. 6), Cen *XR*–2 (ref. 7)) obviously suggest that these particular sources can be assigned to the nebular and the stellar classes, respectively.

The bright X-ray source Cyg *XR*–1 presents an especially interesting problem for size measurement because it has a hard "power-law" X-ray spectrum extending to 100 keV and beyond[8] like the Crab Nebula, and is apparently highly variable[9] like Sco *X*–1. Moreover, no optical counterpart of Cyg *XR*–1 has been identified. Thus a direct measurement of its X-ray size may be the only way to determine whether it is a variable X-ray nebula or a stellar object emitting X-rays with a power law spectrum extending beyond 100 keV.

This article reports an observation that places an upper limit of 1·4 min of arc on the angular diameter of the X-ray source Cyg *XR*–1 in the energy range from 25 to 100 keV. This result is based on data from a balloon experiment on July 16, 1968, with an instrument comprising a pair of X-ray telescopes with gyro-stabilized modulation collimators.

Each collimator consists of two parallel grids of 10 mil gold wires mounted 35 inches apart in a cylindrical tube. When an X-ray source passes across the field of view along an arc perpendicular to the wires, the transmitted intensity is modulated with a period of 2·0 arc min and an amplitude that depends on the angular diameter of the source. For a point source the modulation is nearly 100 per cent, and for a source much larger than 2 arc min it is nearly zero. A slow and steady source scan is achieved by an inertial stabilization system. Two rate integrating gyroscopes are used to stabilize the collimators against random motions of the balloon gondola while rotating them at a uniform rate of several arc minutes per minute.

The X-rays transmitted by the collimators are detected by two NaI (Tl) crystal scintillator detectors which are mounted behind the collimators. The total effective area of the instrument in the direction of a transmission maximum is 280 cm^2. Its overall field of view is 10° by 10°, full width at half maximum. The instrument is orientated in azimuth and elevation and is controlled by radio command from the ground. The X-ray counting rate in each detector is telemetered to the ground once per second and recorded.

The instrument was launched from the National Center for Atmospheric Research (NCAR) balloon base at Palestine, Texas. Command and telemetry systems were provided by NCAR. The data gathering portion of the flight lasted for 5 h 30 min at an atmospheric depth of 3·74 g cm^{-2}. A source was observed when the telescope was pointed in the direction given by Giacconi *et al.*[10] for Cyg *XR*–1. The intensity of Cyg *XR*–1 at the altitude of observation was found to be $0·056 \pm 0·007$ photons cm^{-2} s^{-1} in the 25 to 100 keV energy range. Because the command equipment malfunctioned during most of the flight, only one good scan, of 8 min duration, was made of Cyg *XR*–1 by the collimators. A Fourier transformation of the data recorded during this scan revealed a strong periodicity in the X-ray intensity at a frequency consistent with the scan rate, which was determined independently from telemetered engineering data. The probability that random fluctuations were responsible for the periodicity is 10^{-3}; equivalent to a 3·45 σ deviation on the normal distribution curve. Possible instrumental effects which could cause an apparent modulation of X-ray intensity were investigated and found to be negligible. The same analysis was applied to data taken during the remaining 5 h 24 min of the flight when the instrument could be pointed toward and away from the source, but the collimators could not be stabilized. No evidence of significant periodicity was found in these other data. The Fourier coefficients computed from these other data followed the predicted probability law very closely which indicates that the statistical analysis is valid and that the probability quoted here is realistic. The observed periodicity is therefore attributed to a modulation of the Cyg *XR*–1 intensity by the collimators.

The amplitude of the periodic component indicates that the source diameter is less than 1·4 arc min. The result is actually consistent with the hypothesis that Cyg *XR*–1 is a point source, but the limited observing time and relatively poor statistics introduce too much uncertainty to justify setting a smaller limit than 1·4 arc min at this time.

Given sufficient observing time, this instrument is capable of measuring diameters of high energy X-ray sources down to 0·1 arc min. Flights are planned for both Cyg *XR*–1 and the Crab Nebula.

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Interferometric Observations of the Radio Source *VRO* 42 22 01

SCHMITT[1] has emphasized the outstandingly interesting properties of *VRO* 42 22 01 and its associated optical counterpart *BL* Lac[2]. Further interest has been aroused recently by the supposed detection of variable circular polarization at a frequency of 2,695 MHz (refs. 3 and 4). We have observed *VRO* 42 22 01 at various times and frequencies during 1968 with the interferometer of the Owens Valley Radio Observatory, always in conjunction with other programmes.

The results are summarized in Table 1. The orientation of the interferometer is specified in the second and third