letters

SS433—a massive black hole?

THE peculiar emission line object SS433 has recently been the subject of interest following new spectrophotometric observations by Margon *et al.*[1], and previous suggestions identifying it with the supernova remnant (SNR) W50 (ref. 2) and also with the X-ray source A1909+04 (ref. 3). Margon *et al.*[1] report "three very strong (equivalent widths 50–150 Å) broad emission features in the green, red and IR, which change in intensity, profile and wavelength daily." In this note we propose that the reported red and IR lines (at ~6,000 Å and ~7,400 Å, respectively) are Doppler-shifted Hα lines which are emitted from a ring of matter orbiting around a $\sim 10^6 M_\odot$ black hole. (The green line at ~5,200 Å may be the redshifted Hβ line.) The ring itself may be part of an accretion disk and its radius is ~20–25 gravitational radii ($R_g \equiv 2GM/c^2$). The intensity of an emission line per observed Doppler-shifted frequency interval in such a ring is maximal at the two extreme ends of the spectrum[4], in any case of emission constant along the ring. These maxima are quite sharp; in the non-relativistic case, we have

$$dI_\nu/d\nu \propto \{\nu_0^2 - (\partial\nu)^2\}^{-\frac{1}{2}}$$

where $\partial\nu$ is the frequency shift and ν_0 depends on the radius of the ring and on its inclination with respect to us. Also, due to the gravitational redshift in our case, the centre-of-mass of the red and IR lines emitted from such ring is additionally redshifted.

It is difficult to determine the relative intensity of the Doppler-pair members observationally, because of the uncertainty in the reddening out to SS433; if one takes $A_v \sim 7$ mag, as is reasonable for a distance of ~3.3 kpc in the galactic plane, the data of Margon *et al.* are consistent with both members having roughly equal intensities or even having the blueshifted member slightly stronger, as expeced for such a model[4]. Also, to match these observed shifts[1], the plane of the ring should be inclined towards us[4]. Our numerical calculations for a model line emitted from such a ring are consistent with the structure of the observed pair in Fig. 3 of ref. 1 for inclination angles of 45–60°.

Accumulated results of observations (J. Katz, personal communication) of the above and other shifted lines from SS433 show the following characteristics:

(1) Let $B = (\lambda_{\text{blueshifted}} - \lambda_0)/\lambda_0$, $R = (\lambda_{\text{redshifted}} - \lambda_0)/\lambda_0$ and let c be the velocity of light. then, $\frac{1}{2}c(R-B)$ has now varied between $\sim 10{,}000\ \text{km s}^{-1}$ and $\sim 40{,}000\ \text{km s}^{-1}$. These high velocities strongly point to processes in a region of high gravitational field, near a neutron star or black hole.

(2) During these variations of B and R, the centre-of-mass (COM) of the lines ($\frac{1}{2}c(R+B)$) remains fairly constant[5], redshifted at $\sim 10{,}000\ \text{km s}^{-1}$. This poses severe difficulties on models in which the changes in R and B are due to velocity magnitude changes alone (rather than to changes in angle, such as a precession of the ring[6], say, which is suggested by a possible periodicity in the data[5,7]). It also indicates that the emission region for the shifted lines remains at a fairly constant gravitational redshift (that is, distance from the compact object).

(3) The shifted lines are accompanied by an unshifted line. This poses a difficulty on any interpretation of the shifted COM as an overall motion of SS433.

(4) The shifted lines are quite narrow, $(\delta\lambda/\lambda)/B_{\max} \lesssim 10\%$, suggesting a reasonably narrow emission region.

(5) Let the line-emitting region be of surface area $4\pi R^2$. Then its brightness temperature T_b must satisfy $T_b > 10^9$ K $(R/10^9\ \text{cm})^{-2}$. This poses severe difficulties on neutron star models and on models having black holes with $R_g \lesssim 10^{11}$ cm ($M \lesssim 3\times 10^5 M_\odot$), particularly with no observational evidence for coherent emission.

(6) In several of the Hα Doppler-shifted pairs[1], one line seems to be the mirror image of the other (imaging on the λ axis, mirror located at the COM). This indicates a correlation between the geometries of the two emission regions, such as that found in emission from a ring. In pairs observed at other times, no such symmetry was found (J. S. Gallagher, personal communication), suggesting that the emission region has variable structure, or that its appearance to us is variable.

We infer from these considerations that the compact object, around which the emission takes place, cannot be a neutron star or a light black hole, but rather the above mentioned $\sim 10^6 M_\odot$ black hole. An optically thick accretion disk around such a black hole has indeed most of its flux coming from such ring, at UV and visible frequencies[8]. Note, that if the centre of the SNR W50 is at distance ≳10 pc from SS433 (ref. 1), the disk may be fed by the SNR (although interstellar matter, if its density near the black hole is close to its average value in the Galaxy, can do the same); for typical values[9] of the particle density ($\sim 1\ \text{cm}^{-3}$) and velocity ($\sim 100\ \text{km s}^{-1}$) in such SNR, the feeding is at a rate of $\lesssim 10^{-7} M_\odot$ per yr, giving a total luminosity of $\lesssim 10^{39}\ \text{erg s}^{-1}$ if the disk is in steady state. This is consistent with the observed optical luminosity, which seems to indicate that $M_v \lesssim -3.5$ (ref. 1).

The unshifted H_α line[1] could arise from reprocessing of some of the $\lesssim 10^{39}\ \text{erg s}^{-1}$ optical and UV radiation from the black hole, in the rim of the disk[10,11]. This suggests that SS433 might be a strong UV source and that the shifted lines may also be due to reprocessed UV radiation.

Our model also suggests that the whole system may be part of an old globular cluster.

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