1983LIACo..24...78S

THE QUASARS Q2345 + 007 A, B AND 3C273: GRAVITATIONAL LENSES?

Paper n° 13

K. Subramanian, D. Narasimha, S. M. Chitre, J. V. Narlikar
Tata Institute of Fundamental Research, Bombay - 400005, India

A double lens model involving two intervening galaxies situated at different redshifts is demonstrated to account for the observed features of the recently reported double quasar Q2345 + 007 A, B with a large separation of $\sim$ 7. 3" between its components.

The VLBI observations of the abnormally bright quasar 3C273 indicate that the structure within its radio component B reveals evidence for superluminal separation. It is argued that these features can be explained in the framework of a gravitational screen model.

The quasar Q2345 + 007 A, B was reported by Weedman et al. (1982) to be the third example of gravitational lensing. The two components of the quasar Q2345 + 007 A, B, with approximate magnitudes of 19. 5 and 21, have almost identical redshifts of 2. 152 $\pm$ 0. 005 and 2. 147 $\pm$ 0. 005 and a large separation of 7. 3". This separation is the largest image separation observed so far in cases of gravitationally lensed quasars and sets stringent constraints on possible gravitational lens models.

We considered various models for the lens involved in imaging Q2345 + 007. The first model examined was that of one galaxy coming between the quasar and the observer. It turns out that such a single galaxy model can produce the required image separation, for "reasonable" values of its mass (M) and velocity dispersion (σ_V), only if it is placed close to the observer at a redshift $z \lesssim 0.14$. (here we adopted as "reasonable" limits $M \lesssim 20 \times 10^{11} M_\odot$ and $\sigma_V \lesssim 400$ km/sec.) Even in this case, say with the lens at a redshift of 0. 1, our computations indicate that the galaxy mass required is $\sim 15 \times 10^{11}\ M_\odot$, with a velocity dispersion of $\sim$ 390 km/sec. Such a lens galaxy should be easily observable, unless its M/L is abnormally large, say $\gtrsim$ 900. It is worth noting, in this context that as yet no lens galaxy has been found in the field of Q2345 + 007.

We went on to consider a model involving two intervening galaxies at different redshifts, which we refer to as "the double lens". The basic idea behind the double lens model is that the second intervening galaxy further bends light rays from the source leading to an increased image separation. Since each galaxy in this picture need only produce part of the 7. 3" image separation, the requirements on the mass and velocity dispersion of each galaxy is reduced. A detailed formalism, to examine the viability of this scenario, was set up using the basic ideas of Bourassa et al. (1975) and extending it to the case of the double lens. From extensive computations, we find that not only are the requirements on the masses and velocity dispersions of the lens galaxies reduced for the double lens, but also that the lenses can be much farther out. A typical solution with the double lens model has the two galaxies say A and B at redshifts $z_A = 0.45$, $z_B = 0.3$ with $M_A \sim 16 \times 10^{11}\ M_\odot$, and $M_B \sim 14 \times 10^{11}\ M_\odot$, $\sigma_A \sim 370$ km/sec and $\sigma_B \sim 340$ km/sec.

"Quasars and Gravitational Lenses"; 24th Liège Astrophysical Colloquium, Institut d'Astrophysique, June 1983.

© IAGL • Provided by the NASA Astrophysics Data System

1983IACo..24...78S

A crucial question concerning the double lens models is their low probability which should be compared with probability of simply finding two QSO's within 7.3" of each other. We estimate the latter to be $\sim 10^{-4}$, following the method of Gott and Gunn (1974). Further restriction that the redshifts of the two quasars be nearly identical within $\pm$ 0.005, reduces this to $\sim 3 \times 10^{-7}$. This is to be compared with the probability for the double lens, which we estimate to be $\sim 10^{-3}$. An important point which is taken into account in calculating the probability for the double lens is that the cross-section for the double lens is larger, than for the single lens. This is due to the fact that when two galaxies act as deflectors, the source may be much further out from the lens center and still produce multiple images.

We finally considered whether the presence of a cluster in addition to a galaxy, eases the constraints on the parameters of the lenses. The galaxy + cluster lens model does produce a larger image separation than one involving the galaxy acting as a lens alone. However the effect of the cluster turns out to be decisive only if the cluster strength (which we define to be $4GM_{cl}/R_{cl}{}^2c^2$) is close to a critical value, whereby the cluster itself is able to produce multiple images.

Future observational tests can provide ways of deciding on the nature of the lens. The detection of a lens galaxy with a redshift greater than $\sim$ 0.14 would virtually rule out the single lens model. On the other hand if no intervening galaxy is detected, it would not auger well for the lens scenario, especially those involving galaxies as lenses, unless a large value of M/L for the galaxy is invoked. Further, it turns out that the time delay $t_b - t_a$ for the single lens is necessarily negative. (Here a refers to the brighter 19m image.) For the double lens model and the one involving the cluster $t_b - t_a$ is positive, except for solutions where the bright image is actually made up of two components separated by $\sim$ 0.1". Future inteferometric measurements to resolve the bright image, and also observations of both the sign and magnitude of the time delay $t_b - t_a$, will thus prove to be of importance.

The quasar 3C273 is known to be an abnormally bright optical object (13m). It has also another unusual property: the VLBI observations of structures within its core show evidence of superluminal separation on the angular scale of about a milli arcsecond per year. We suggest that both these features can be interpreted as being due to the gravitational lensing of the quasar by an intervening galaxy.

The concept of the gravitational screen has been outlined earlier by two of the authors (SMC and JVN, 1980). Here an intervening matter distribution bends light rays from subluminally separating components in the core say A and B, in such a way that the observer sees the images of A and B separating superluminally.

In the case of 3C273, in order to obtain an apparent separation velocity of $\sim 10c$, we need the amplification of the linear dimensions by at least a factor of 10. Further, in 3C273 there is no evidence for secondary images. It turns out that it is possible to produce an image configuration, for a small range of the lens parameter $\mu = 4GMD/r_c{}^2c^2$, when there is only one bright image and a significant superluminal motion of the components. (Here M is the mass of the galaxy, r_c is the core radius and D the reduced distance defined in Bourassa et al. (1975).) A typical solution with a screen galaxy located at a redshift of 0.1 and core-radius r_c = 1 kpc has a mass $\simeq 1.7 \times 10^{11}$ M$_\odot$, line of sight velocity dispersion, $\sigma_v \simeq 170$ km/sec and yields linear amplifications of $\sim$ 9 and intensity amplification of $\sim$ 80. Interestingly, such a solution not only accounts for the apparent superluminal motion of $\sim 9c$ but

© IAGL • Provided by the NASA Astrophysics Data System

1983IACo..24...78S

also implies that 3C273 is really an 18 mag source like other typical quasars, but one whose intensity has been increased enormously (by a factor of ~ 80).

We find that recent studies of the nebulosity of 3C273 by Tyson et al. (1982) furnishes possible evidence for such a lens galaxy. The conventional interpretation for the nebulosity is that it is a galaxy with the quasar embedded in its nuclear region. Earlier observation by Wyckoff et al. (1980) of the redshift of the nebulosity gave support to its physical association with 3C273. However, if such a nebulosity around 3C273 is screened by an intervening galaxy it may be observationally difficult to separate the superposed galaxy-nebulosity system with the present day techniques. In this context it is also interesting to note with Tyson et al. that the quasar is off-set to the east with respect to the center of the nebulosity.

Our work suggests that quasars with unusually bright optical emission are likely candidates for gravitational lensing and possible superluminal separation of components. However, it is important to note that a large amplification can be achieved without recourse to multiple images.

References

Bourassa, R.R. and Kantowski, R. 1975. Ap.J. 195, 13.
Chitre, S.M. and Narlikar, J.V. 1980. Ap.J. 235, 335.
Gott, J.R. and Gunn, J.E. 1974. Ap.J. 190, L105.
Tyson, J.A., Baum, W.A. and Kreidl, T. 1982. Ap.J. Lett. 257, L1.
Weedman, D.W., Weymann, R.J., Green, R.F. and Heckmann, T.M. 1982. Ap.J. 255, L5.
Wyckoff, S. et al. 1980. Ap.J. Lett. 242, L59.

© IAGL • Provided by the NASA Astrophysics Data System