3C324 : A PROBABLE NEW GRAVITATIONAL LENS

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ABSTRACT. 3C324, a giant radiogalaxy at z = 1.206 has been suspected by us to be a gravitational lens : in a previous work, we have identified an additional line system at z = 0.845 in its spectrum. We present here new observations of 3C324 at C.F.H.T. in R broad band imaging and in adequate filters; they strongly suggest that 3C324 is the first example of a multiply imaged radiogalaxy. The 3C324 case is also a fair confirmation that gravitational lensing may well explain the overluminosity of distant radiogalaxies.

1. INTRODUCTION AND OBSERVATIONAL RESULTS

3C324 has been identified by Spinrad and Djorgovski (1984a, hereafter called SD) with a 21-22 magnitude galaxy at z = 1.206. By a careful examination of their high quality data, we have identified another distinct line system in its spectrum : i.e. H and K CaII absorption lines, Hβ in absorption and [OII] emission line at z = 0.845 (Hammer et al, 1986). This new system is probably due to a foreground galaxy very close to the 3C324 line of sight. Then we have decided to get more photometric data about this source.

We have made CCD imagery with the new RCA2 CCD Camera available at C.F.H.T.. Exposure times was 4500s in R, the seeing were less than 0.7 arcsec. with a magnitude limit higher than 25.5. There are about one hundred galaxies in two arcmin² confirming the SD idea of a distant cluster lying around 3C324. The structure of 3C324 is evidently very complex with more than five components in 15 arcsec² (Le fèvre, IAU Telex 4233, 1986). Plate 1 and 2 reveals two proeminent components noted (a) and (b) separated by 1.1 arcsec., a faintest component noted (c) 0.8 arcsec. east from (a) and a probable faint component noted (d) 1.0 arcsec. NW from (a). Note also the presence of two other components : (e) 2.2 arcsec. west from (b) and (f) 3 arcsec. SW from (a). To distinguish the two distinct systems at z = 1.206 and at z = 0.845, we have pursued our observational work. Only the (a) component is detected in an image through a filter including the [OII] emission line at z = 0.845; (b) and (c) are not detected up to the level expected from the brightness ratio between (a), (b) and (c) in R broad band filters (Le fèvre et al, 1986). These two latter components are detected in the [CII emission line at z = 1.206 while (a) disappears. From these data, we deduce that the (a) component is the

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foreground bright galaxy at z = 0.845 (m_R=22.5), the (b) and (c) components being background sources at z = 1.206.

2. NATURE OF 3C324

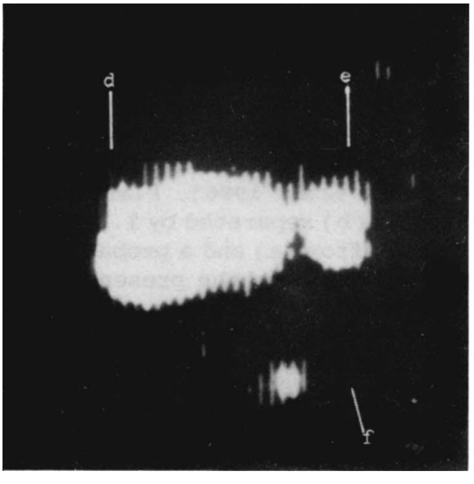
The angular proximity between (a) and (c) leads us to ask a question : what about the gravitational lensing of (c) due to the (a) foreground galaxy?. From a condition of Subramanian and Cowlings (1986), we show that there must be two images of (c) due to gravitational lensing by (a) only if the (a) mass is more than 1.5 10^{11} $M_\odot$ (for q_o=0 and H_o=50). This condition is easily verified because (a) is ten times brighter than our galaxy. Moreover (a) is just on the line joining (c) and (b) : this geometry is well explained by the simple model of Young et al (1980), where (c) and (b) are both images of a single galaxy at z = 1.206. The required (a) mass is 10^{12} $M_\odot$, but we have to take into account the influence of the elliptical geometry of the lens, and of a possible cluster at z = 0.845. Now we conclude on the nature of 3C324 :

*gravitational lensing of background sources at z = 1.206 by the (a) foreground galaxy at z = 0.845 occurs; a definive confirmation should wait spectroscopic observations showing the spectra of each images (Space Telescope project).

*it contributes to explain the complex configuration, but merging is not excluded to interpret the presence of the other (d), (e) and (f) components.

*this is probably the first multiple imaged galaxy ; its interpretation needs an improvement of the theory of gravitational lens to the extended source cases. The consequences are multiple, either on the determination of cosmological parameters or on the knowledge of the density profiles of distant galaxies.

*there is an overestimation of the 3C324 luminosity made by SD of more than two magnitudes; it is due to gravitational amplification of the background galaxy by the (a) deflecting galaxy and to the contamination of the foreground galaxy in SD 's unresolved image.



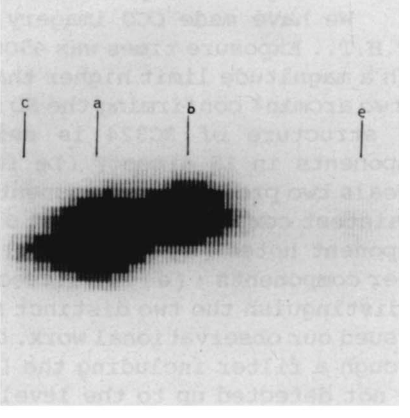


Plate 1 and 2 : **Multiple components in 3C324's structure.**

3. CONCLUSION

The latter fact leads us to explain our method of work. In fact, we think that gravitational lensing is not only a phenomenon concerning very peculiar objects like gravitational multiple imaging, but concerns the whole Universe in terms of a failure of the Hubble law due to density inhomogeneities like galaxies or clusters. Then, far more extragalactic observations than currently believed are affected by gravitational amplification of light. Hence the effect of compact groups on background galaxies has been demonstrated (Hammer and Nottale, 1986a), then the statistical effect of rich clusters of galaxies on absorption-line QSOs (Nottale and Hammer, 1986, in preparation) and on brightest cluster galaxies (Hammer and Nottale, 1986b). We have shown indeed that a selection effect precisely due to gravitational amplification induces for these last sources an overluminosity of up to 0.5 magnitude. Extrapolation of this analysis to the Spinrad and Djorgovski (1984b) very distant radiogalaxies led us to propose that their large observed overluminosity was at least partly due to strong gravitational lensing (Hammer et al, 1986). These distant radiogalaxies are obviously liable to strong selection effects because all of them come from the 3C catalog (a 10 Jy flux-limited sample), and because their faint magnitudes ($V \approx 23$) are very close to the magnitude limit. Then, gravitational lensing may strongly affect the radiogalaxies luminosity diagram by the mean of selection effects. Recall that the radio properties and optical properties of a source are affected by gravitational lensing. By a case by case examination of the SD objects, we predicted an overestimation of the luminosity for at least 4 radiogalaxies with $z > 1$ (note that we have enough informations on the matter distribution near the line of sight of only two sources among 13) :

*3C13 and 3C324 lie behind foreground galaxies that evidently act as powerful deflectors; the expected magnification is more than two magnitudes.

*3C238 and 3C266 are observed behind rich Abell clusters of galaxies at $z \approx 0.2$; the predicted gravitational magnification is about one magnitude.

Moreover the presence of the probable mirage 3C324 in the SD distant radiogalaxies sample is a fair confirmation of selection effects due to gravitational lensing in this 13 sources sample : without these kind of selection effects the chance of it should be less than 5 for 100,000 according to Vietri (1985). We conclude by asking a question : are overluminosities of distant radiogalaxies due to evolution or to gravitational lensing (amplification) or to both ?.

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DISCUSSION

SPINRAD: There could be some problem in your interpretation of 3C 324; there is a velocity gradient in [OII] across the image in the SD 1984 paper. Images are thus not identical in velocity space... $\Delta v \simeq 800$ km s^{-1}.

HAMMER: In response I would like to make two points:

First, there may be gravitational redshift effects associated with the gravitational lensing of the possibly non-static lens galaxy. But I think that these effects can't be very large. After seeing your data, I believe that the estimate of the differential velocity between C and B images requires more astrometric information. But all of your velocity gradient data in the [OII] line are well explained by the following argument: the angular size of your spatially resolved [OII] line is about 6 arc sec, which is the angular size of our 3C 324 imagery. By placing E, B, A and C components on your diagram (v,r), the differential velocity between B and C becomes very small, maybe equal to zero; the velocity dispersion along the line joining B and C is less than 300 km/s which is not surprising for a galaxy with [OII] emission lines.

SHAVER: Is there a radio core source in 3C 324?

HAMMER: The radio map of Jenkins et al. reveals only two radio lobes. But I expect to have more information from a VLA map with a smaller noise level.