Astron. Astrophys. 169, L1–L3 (1986)

ASTRONOMY AND ASTROPHYSICS

LETTER

Letter to the Editor

Overluminosity of distant radiogalaxies: Evolution or gravitational amplification?

F. Hammer[1], **L. Nottale**[1], **and O. Le fèvre**[1,2]

[1] Laboratoire d'Astrophysique, DAPHE, Observatoire de Meudon, F-92195 Meudon Principal Cedex, France
[2] C.F.H.T. Corporation, P.O. Box 1597, Kamuela, HI-96743, USA

Received July 14, accepted July 31, 1986

SUMMARY

We suggest in this letter that the overluminosity of up to 5 magnitudes for distant radiogalaxies observed by Spinrad and Djorgovski (1984b, hereafter called SD) may be accounted for by gravitational lensing better than by ad hoc evolution. This is confirmed by a detailed analysis of imagery and spectroscopy available for 4 out of the 13 SD objects. Indeed lens candidates are actually observed around 3C13, 3C324, 3C266 and 3C238 : for all of them large amplification is predicted, and possibly multiple images for the two first of them.

Keywords : Galaxies – Redshifts – Gravitational lens.

I – INTRODUCTION

Djorgovski et al (1984) have tried to extend the Hubble diagram of bright cluster galaxies by high z radiogalaxies. They find a luminosity excess of about 3-6 magnitudes to the K-corrected "no evolution" curves. Then they interpret this significant excess using the evolutionary models of Bruzual (1981, 1983). These models fit correctly the Djorgovski et al 's data : with a constant galaxy mass, elliptical galaxies were about hundred times more luminous at $z = 1.6$ than at $z = 0$ or $z = 0.6$. However, these models are very dependent on the choice of the IMF parameter, cosmological parameters and galaxy formation epoch : it is not surprising that the choice of $z = 5$ for galaxy formation corresponds to an important evolution for $1 < z < 2$.

We suggest here another scenario to understand the redshift-magnitude relation of distant radiogalaxies : we are able to observe these sources (and especially those with $z > 1$) precisely <u>because</u> they are subjected to gravitational amplification effects due to density inhomogeneities near their line of sight. Recall that the gravitational amplification theory ensures energy conservation for an unbiased sample (Weinberg, 1976; Hammer, 1985) : a few number of sources are (gravitationally) amplified by several magnitudes, and this is balanced by very faint (gravitational) attenuations but for a large number of sources. The SD's sample is contrariwise a flux-limited sample ($V < 24$) which may be subjected to large selection effects coming from gravitational lensing. In this way, we suggest an explanation of these observations. Suppose that the redshift-magnitude relation of radiogalaxies actually fits the no-evolution relation of bright cluster galaxies. Then radiogalaxies having $z > 1$ should not be observable ($V > 24$) except a small number which are gravitationally amplified by several magnitudes. Then we propose that the SD's radiogalaxies are strongly gravitationally lensed : this may explain the observations without large evolution.

Our approach needs to weigh up the consequences of gravitational lensing which concerns a wide range of configurations : the deflected source may be a quasar as usual, but <u>also a galaxy</u>. Hammer and Nottale (1985) elucidated the discordant quintet VV172 by the way of considering gravitational amplification of the discordant galaxy by the massive halo of the foreground compact group. Hammer and Nottale (1986) showed that the Hubble diagram is widely affected by gravitational amplification effects by foreground clusters : a consequence of which is to cause selection effects which considerably change the mean properties of the sample. Then we have to expect the same kind of selection effects but even larger in the case of the high redshift radiogalaxies. Recall that the gravitational amplification by a galaxy or a cluster is maximum when the deflector redshift satisfies $z > 0.2$ and the source redshift $z > 0.8$; the latter condition concerns quasars <u>and</u> distant radiogalaxies.

II – GRAVITATIONAL AMPLIFICATION EFFECTS ON DISTANT RADIOGALAXIES

To verify such a hypothesis, observational work is needed so as to know the precise material content, i.e. density fluctuations like galaxies or clusters, near the line of sight of each SD's source (Le Fèvre et al, in preparation). If indeed observations are conditioned by gravitational lensing, we should expect that, again because selection effects, the SD's radiogalaxies were in very peculiar configurations : these galaxies have to lie behind galaxies or clusters in such a way as to maximize the following function :

$$\frac{H_o}{c} D_d \frac{D_{ds}}{D_s} =$$

$$\frac{(1+2q_o z_d)^{1/2}}{q_o^2(1+z_d)^3}\left[q_o z_d+(q_o-1)(-1+\sqrt{1+2q_o z_d})\right]\left[1-\frac{(q_o z_d+1-q_o)(1+2q_o z_d)^{-1/2}+q_o-1}{(q_o z_s+1-q_o)(1+2q_o z_s)^{-1/2}+q_o-1}\right]$$

where z_d and z_s are respectively the deflector and the source redshift. However, on the basis of presently available observational work, we are already able to claim that there are several significant clues to the gravitational lens hypothesis : this is the aim of the present letter. Let us examine in detail the more striking individual cases.

1)-<u>Gravitational lensing of radiogalaxies due to foreground galaxies.</u>

-<u>3C13</u>- Identification by SD is with a 22th magnitude

Send offprint requests to : F. Hammer

galaxy at $z_s = 1.351$. There is also a 20th magnitude galaxy lying by some 4 arcsec away : this is a giant elliptical galaxy at $z_d = 0.477$, which evidently acts as a powerful deflector to 3C13 since in that case $D_d D_{ds}/D_s \approx 0.15$. In fact, we may expect a multiple image configuration for a deflector M/L ratio between 11 and 28 from the condition written down by Subramanian and Cowling (1986). In any case, the optical galaxy identified with 3C13 is gravitationally magnified by more than 1 magnitude and eventually by some 4-5 magnitudes (see Table 1).

σ(km/s)	300	350	400	450
M/L				
5	-0.7	-1	-1.4	-2
14	-0.7	-1	-1.5	-2.1
28	-0.9	-1.3	-1.8	-2.8
42	-1.2	-1.8	-2.9	-3.5

Table 1 : Estimation of the 3C13 magnification, where σ is the velocity dispersion of the deflecting E galaxy, the impact parameter being ℓ = 20kpc (for H_o = 75km/s/Mpc). The amplification is given by : $Amp^{-1} = (1 - 3\pi\ \sigma^2/c^2\ D/\ell)^2 - (4GMD/c^2\ell^2)^2$, where $D = D_d D_{ds}/D_s$; the magnification is simply given by $\delta m = -2.5\ \log(Amp)$.

-3C324- It has been identified by Spinrad and Djorgovski (1984a) with a 21-22th magnitude galaxy at $z_s = 1.2063$. However a careful examination of the published spectra of 3C324 reveals another line system at $z_d = 0.84$, including the H and K absorption lines, the OII λ3727 and possibly NeV emission lines (see Fig. 1). We are observing this source : the preliminary results (CCD imageries at C.F.H.T.) reveal a complex structure containing more than five components in 15 arcsec² ! The lines at $z_d = 0.84$ seem to be due to the central object of the configuration. Then, multiple imaging hypothesis in the case of 3C324 must be seriously taken into account (see Le fèvre et al, 1986). Once more the galaxy identified with 3C324 is certainly gravitationally magnified by a large amount.

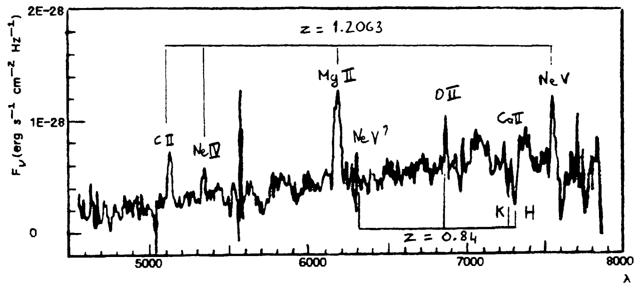

Fig.1 :Visual spectrum of 3C324 (from Spinrad and Djorgovski, 1984a). It reveals a superposition of two distinct systems :
-the first is the optical galaxy identified with 3C324 at $z_s = 1.2063$.
-the second is probably a foreground galaxy at $z_d = 0.84$.

The presence of 3C13 and 3C324 in SD's sample is a fair confirmation of our assumption that strong selection effects due to gravitational lensing are at work in this sample. From the statistics of gravitational lenses, Vietri (1985) predicted that 24 to 64 quasars out of 1,176,000 should be multiple imaged. This is an overestimation of multiple imaging for radiogalaxies since they are nearer than quasars ($z < 2$). There are only two sources (3C13 and 3C324) among 13 for which we have enough informations on the matter distribution near their lines of sight (i.e. the spectra and the photometry with an angular resolution ⩽ 2 arcsec.). The fact that these two sources are good candidates for multiple imaging is due either to an extraordinary chance or simply to gravitational lensing which has yielded the practicability of SD's observations.

2)-Gravitational amplification of radiogalaxies by foreground clusters.

-3C266- Identification of this source by SD yields a 22th magnitude galaxy at $z_s = 1.272$. It lies only 2'50" from the center of the cluster A1374 (or Zw243-30), the redshift of which being $z_d = 0.209$ (Leir and Van den Berg, 1977). From Hammer and Nottale (1986)'s formula, we predict the gravitational magnification range of 3C266 by A1374 :

$-2 \leqslant \delta m \leqslant -0.7$ if the ratio of the average density of A1374 over the mean cosmological density varies from 800 to 2500.

-3C238- The optical galaxy identified with it ($z_s = 1.405$) lies also near the center (9'50") of the cluster A949 ($z_d = 0.142$ estimated by Leir and Van den Berg, 1977). The predicted gravitational magnification range is :

$-1 \leqslant \delta m \leqslant -0.4$ for an average density ratio of A949 over the mean cosmological density varying from 800 to 2500.

3)- Other clues to the importance of gravitational amplification effects for distants radiogalaxies.

-Spinrad and Djorgovski (1982) noted that 3C256, 3C324 and 3C238 are very elongated galaxies. This fact may be interpreted as a distorsion of the image due to a predominant shear term in gravitational amplification by a deflecting galaxy. It may also be due to an unresolved imagery of both radiogalaxy and its deflecting galaxy.

-The radio properties of SD's sources are rather surprising, especially because of the strong asymmetry of most of their radio sources. Gravitational lensing changes also the radio-flux density and may explain the asymmetry.

III - CONCLUSION

At present, there are still few observations of very distant radiogalaxies. This leads us to a strongly biased sample : the magnitude of these sources ($V \approx$ 22-23) is too close to the magnitude limit ($V \approx$ 24-25). These observations are affected by gravitational lensing by foreground galaxies or clusters of galaxies. Recall that the gravitational magnification due to a deflecting galaxy having $z > 0.1$ or a cluster having $z > 0.2$, may reach several magnitudes. We have suggested here that indeed a few number of distant radiogalaxies are to be strongly amplified, but due to this amplification, they are the only ones observable. This is corroborated by Robertson et al (1986) suggestion that : "quasars are located in regions of higher than average matter density". This result could be a clue to the importance of gravitational lensing in extra-galactic astronomy : high density regions acts as "gravitational telescopes" amplifying quasars and distant radiogalaxies.

In this letter, we have shown that at least four radiogalaxies among the 13 SD sources belong to configurations allowing the prediction of large gravitational magnification. As a consequence, we may infer :

-(1)- an overestimation of the luminosity of these four radiogalaxies by several magnitudes.

-(2)- a strong selection effect for these radiogalaxies and probably for each radiogalaxy having z › 1. This may explain partly or totally their luminosity excess from the Hubble diagram of bright cluster galaxies.

Our approach is to interprete the observations of distant radiogalaxies, which becomes complicated by at least three facts :

-(1)- evolution of radiogalaxies is very difficult to weigh.

-(2)- radiogalaxies are liable to strong selection effects, because of their faint magnitude ($V \approx 23$) close to the magnitude limit.

-(3)- gravitational lens effects may strongly affect the radiogalaxies luminosity diagram by the mean of selection effects. Recall that optical properties and radio properties of a source are affected by gravitational lensing.

Our predictions certainly need confirmation by new observations, in particular :

(i) to know the extent of distant galaxy evolution and to adjust its parameter : in fact gravitational lensing acts concurrently and probably complementarily with evolution.

(ii) to find configurations of great interest such as multiple imaged galaxies.

Acknowledgements : we are grateful to Drs Kotanyi and Schneider for helpful discussion about this letter.

REFERENCES

Bruzual, G., 1981, Ph. D. thesis, University of California at Berkeley, USA.

Bruzual, G., 1983, Astrophys. J. 273, 105.

Djorgovski, S., Spinrad, H. and Marr, J., 1984, in "New Aspects of Galaxy Photometry", edited by J.L. Nieto, Lecture Notes in Physics 232, P193.

Hammer, F., 1985, Astron. Astrophys., 152, 262.

Hammer, F., and Nottale, L., 1985, Astron. Astrophys., 155, 420.

Hammer, F., and Nottale, L., 1986, Astron. Astrophys., in press.

Le fèvre, O., Hammer, F., Nottale, L., and Mathez, G., in preparation.

Leir, A.A., and Van den Berg, S., 1977, Astrophys. J. Suppl. 34, 381.

Robertson, J.G., Shaver, P.A., Surdej, J. and Swings, J.P., 1986, Monthly Notices Roy. Astron. Soc. 219, 403.

Spinrad, H., and Djorgovski, S., 1982, Bull. Am. Astron. Soc. 14, 959.

Spinrad, H., and Djorgovski, S., 1984a, Astrophys. J. Lett. 280, L9.

Spinrad, H., and Djorgovski, S., 1984b, Astrophys. J. Lett. 285, L49.

Subramanian, K., and Cowling, S.A., 1986, Monthly Notices Roy. Astron. Soc. 219, 333.

Vietri, M., 1985, Astrophys. J. 293, 343.

Weinberg, S., 1976, Astrophys. J. 208, L1.