PRELIMINARY RESULTS FROM A SEARCH FOR GRAVITATIONAL LENSING WITHIN A SAMPLE OF HIGHLY LUMINOUS QUASARS*

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The purpose of this communication given at the first DAEC Workshop in Paris is to describe our present optical search for gravitational lensing from a direct CCD imaging survey of known highly luminous quasars (hereafter HLQs; $M_V < -29$).
The motivation (why ?), the observational strategy as well as preliminary results of this on-going project are briefly summarized hereafter.

Why ?

Gravitational lensing may affect our view of the distant Universe in multiple and subtle ways (see Canizares, 1987, Blandford and Kochanec, 1987, and Nottale, 1988 for different reviews on this subject). The most obvious effects are the angular deformations (if the source is being resolved) or apparent brightness change (if unresolved) of the observed image of some very remote objects. The most spectacular one concerns the possible formation of multiple images (so called "gravitational mirages") under nearly perfect alignments between the source, the deflector and the observer. In the remainder, we shall only consider this kind of extreme effects because such examples of gravitational lensing are the easiest ones to be proven observationally.

Because the answer to the question "How frequent are gravitational mirages ?" is very much related to that to "How does/do the (visible and/or dark) matter distribution(s) look at different scales in the Universe ?", any prediction made for the expected number of multiply lensed objects is bound to be strongly model dependent. An observational approach is therefore required in order to evaluate the true importance of gravitational lensing. Since November 1986, we have initiated a systematic search for gravitational lensing as follows. We consider that the apparently ($m_V \lesssim 18.5$) and intrinsically ($M_V \lesssim -29$ adopting H_0 = 50 km/sec/Mpc, q_0 = 0) luminous quasars constitute very promising candidates to search for the presence of gravitationally lensed images at arcsec. and sub-arcsec. angular scales. Indeed :

(i) the HLQs form a particularly high flux limited sample of QSOs,

(ii) the HLQs are the most likely objects for which we may assume that their intrinsic brightness is partially due to lensing,

(iii) the HLQs are located at large cosmological distances so that the probability of finding an appropriate lens along the line-of-sight is higher,

(iv) we suspect that observational biases are responsible for the lack of detected gravitational lens systems with small angular separations.

With the above arguments in mind, we believe that high angular resolution imaging with ground based optical telescopes under optimal seeing conditions will bring important clues on the occurrence of lensing effects by galaxies or any other class of unknown massive objects.

OBSERVATIONAL STRATEGY AND PRELIMINARY RESULTS

As of 1 January 1988, we have used the ESO/MPI 2.2 m telescope during 18 allocated nights with a CCD camera + broad- and narrow- band filters. Under an average seeing (FWHM) of 1.2 arcsec., we have imaged a total of 111 HLQs. Twenty-five of these turn out to be interesting objects on the basis of their morphological appearance (multiple or elongated image(s), presence of a nearby galaxy, etc.). More details are given in Surdej et al. (1988a). Five of these 25 HLQs constitute excellent candidates for gravitational lensing. Two of these 5 candidates, ESO GL1 ≡ UM673 and ESO GL2 ≡ H1413+117, are now confirmed to be two definite new cases of multiply lensed quasars.

1. ESO GL1 ≡ UM673

The HLQ UM673=Q0142-100=PHL3703 was found to consist of two lensed images, A ($m_V \simeq 17.0$) and B ($m_V \simeq 19.1$), separated by 2.22 arcsec. at a redshift z_q = 2.719 (see Fig. 1). The lensing galaxy ($m_R \simeq$ 19, z_L = 0.493) has also been identified. It lies very near the line connecting the two QSO images, at ≃ 0.8 arcsec. from the fainter one. Application of gravitational optometry to this system leads to a value $M_0 \simeq 2.4\ 10^{11}\ M_\odot$ for the mass of the lensing galaxy projected between the two lensed QSO images and to $\Delta t \simeq$ 7 weeks for the most likely travel-time difference between the two light paths to the QSO. More details about this new gravitational lens system may be found in Surdej et al. (1987 and 1988 b).

2. ESO GL2 ≡ H1413+117

The well known HLQ and broad absorption line (BAL) quasar H1413+117 has recently been resolved into four lensed images having comparable brightnesses ($m_V \simeq$ 18.4-18.8) and separations of the order of one arcsec. at a redshift z_q = 2.55 (see Fig. 2). Two narrow absorption line systems have been identified at redshifts z_a = 1.44 and 1.66 in the spectrum of one of the images. If these are due to intervening gas clouds associated with the lens(es), the mass of the deflector must be of the order of $M_0 \simeq$ 4-7 10^{11} $M_\odot$, while the delay between the travel times of two opposite images is estimated to be ≃ 2-3 months. A more detailed account of our observations on this quadruply lensed quasar is given by Magain et al. (1988).

CONCLUSIONS

Our optical search for gravitational lensing can be considered to be very successful since more than 20 % of the investigated HLQs show signs which are possibly related to the HLQ phenomenon. Furthermore, at least 5 (out of 111) HLQs constitute excellent candidates for being gravitationally lensed, two of which (UM673 and H1413+117) are now definitely confirmed as being new gravitational lens systems.

We have compiled in Table 1 data on seven presently accepted (and two still suggested) cases of multiply lensed QSO images. A look at the listed absolute magnitudes of the QSOs shows that 5 (out of 7) accepted cases are HLQs. The quasar 0957+561, with $M_V \simeq -28.4$, is also quite luminous, and 2016+112, with $M_V \simeq -24.8$, is known to show an unusually narrow emission-line spectrum. The results of Table 1 confirm our early suggestion that a search for recognizable signs of gravitational lensing among HLQs would be successful.

Table 1 : Data on the seven accepted (and two suggested) cases of quasars being multiply lensed

Name	z_q	n° of lensed images	angular separation	lens (z_L)	M_V	Refs.
0957+561	1.4	2	6"	≃ 0.4	-28.4	1
1115+080	1.7	4	2	0.3:	-29.7	2
2016+112	3.3	3	4	0.8:	-24.8	3
2237+031	1.7	4	2	0.04	-29.2	4
ESO GL1 (0142-100)	2.7	2	2	0.5	-30.2	5
ESO GL2 (1413+117)	2.6	4	1	1.5:	-29.8	6
ESO GL3	1.5	2	6	?	-29.6	7
1635+267	2.0	2	4	No	-25.9	8
2345+007	2.2	2	7	No	-27.1	9

Refs. : (1) Walsh, Carswell and Weymann, 1979. (2) Weymann et al., 1980. (3) Lawrence et al., 1984. (4) Huchra et al., 1985. (5) Surdej et al., 1987. (6) Magain et al., 1988. (7) Meylan et al., 1988. (8) Djorgovski and Spinrad, 1984 and Turner et al., 1988. (9) Weedman et al., 1982 and Nieto et al., 1988.

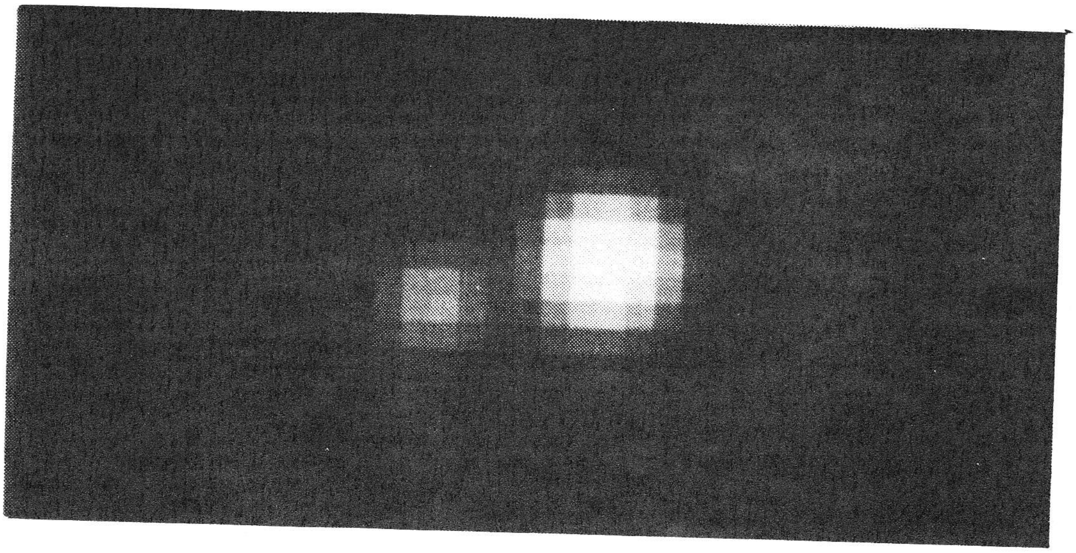

Figure 1 : Central part of a CCD frame for the gravitational lens system ESO GL1 ≡ UM673 (more details are given in Surdej et al., 1987).

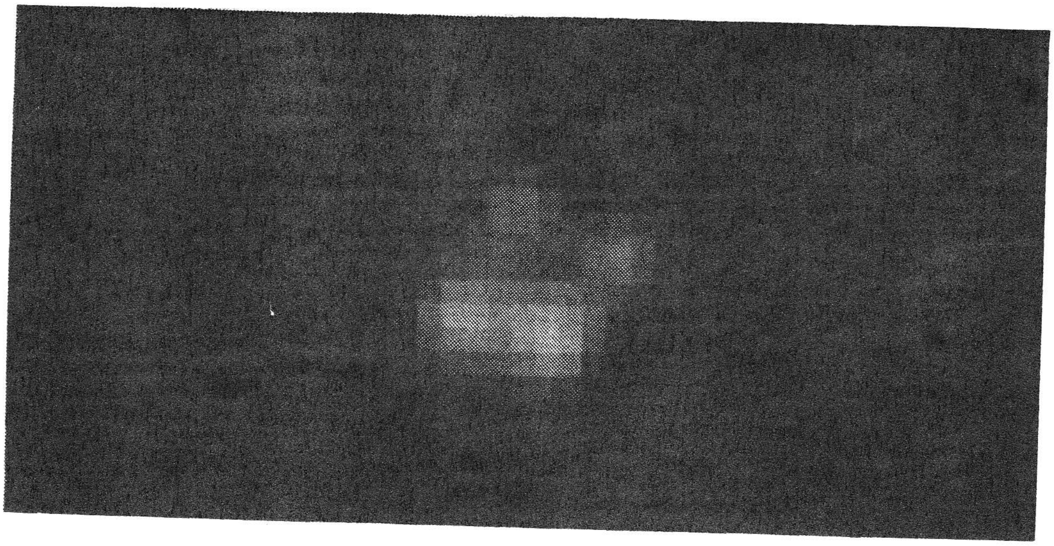

Figure 2 : Central part of a CCD frame for the new gravitational lens sytem ESO GL2 ≡ H1413+117 (more details are given in Magain et al., 1988).

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