Two new very close pairs of quasars with discordant redshifts and a gravitational lens candidate

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Abstract: We present observations of two new close pairs ($\Delta\theta \leq 5$") of quasars with discordant redshifts which were found in a program of systematic direct imagery of Highly Luminous Quasars carried out at the European Southern Observatory (La Silla, Chile). It is very likely that one of these quasars (1009–025) is multiply imaged. Amplification due to gravitational lensing along some preferential lines-of-sight is suggested to be responsible for this observed excess of apparent quasar associations.

1 Thirty, twenty and ... ten years ago!

It is interesting to begin by remembering that the extragalactic nature of quasars was proposed exactly 30 years ago, i.e. in 1963, by Maarten Schmidt who, twenty years later, was in 1983 (i.e. exactly 10 years ago) the President of the 24th Liège International Astrophysical Colloquium devoted to "Quasars and gravitational lenses".

Twenty years ago, Wampler et al. (1973) reported the discovery of two quasars having the smallest angular separation ($\Delta\theta = 4.8$") as well as very different redshifts ($z_A = 0.44$ and $z_B = 1.90$). Estimates of the statistical probability of a chance identification on the sky of such a close pair ($\Delta\theta \leq 5$") of moderately bright quasars have first been shown to be very unlikely (Wampler et al. 1973), but were found later to be possibly consistent with a random distribution of quasars (Shaver and Robertson 1985). Gott and Gunn (1974) have argued

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that the gravitational lensing effects due to the foreground quasar (1548+114A, R=18.1) on light from the background one (1548+114B, R=18.8) should appreciably enhance the chance of observing such a tight pair of quasars. We report here on the discovery of the two closest pairs of distinct, moderately bright quasars: 1009–025 A/B ($z_{A/B} = 2.74$) and C ($z_C = 1.62$) separated by 4.6" and 1148+0055 A ($z_A = 1.87$) and B ($z_B = 1.41$) separated by only 3.9". We also present good evidence that 1009–025 A/B is a new case of multiply imaged quasar. We conclude that preferential amplification due to gravitational lensing along the line-of-sight to 1009–025 A/B-C, and probably also towards the second pair of objects, is most likely responsible for the observed excess of apparent quasar associations.

2 Q 1009–025

During the course of a routine imagery survey of highly luminous quasars ($M_V \leq -27$, calculated for $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0.5$) with the ESO-MPI 2.2m telescope at the end of February 1992, we obtained direct CCD frames for the quasar 1009–025 (z = 2.74, B_J = 17.6, see Hewett et al. 1991). These observations were part of the ESO Key Programme 'Gravitational Lensing' (Surdej et al. 1992).

The immediate surrounding of the quasar 1009–025 was found to consist of three well resolved point-like components, referred hereafter to A, B and C (see the R CCD frame in composite Figure 1 presented by Surdej and Soucail in these proceedings). This interesting image configuration was confirmed on direct CCD frames obtained with the B and i filters. The angular separation between A and B has been derived as 1.55", and that between A and C, as 4.60". The B, R and i magnitudes of 1009–025 A, B and C have been measured to be:

	$B(\pm 0.1)$	$R(\pm 0.1)$	$i(\pm 0.1)$
A	18.2	17.6	17.5
B	21.2	20.0	19.6
C	19.3	18.9	18.7

Photometric observations of 1009–025 carried out in May 1993 confirm these values. Numerous spectra of 1009–025 A, B and C have been obtained with EMMI at the NTT (seeing between 0.7 and 1.2", slit width of 1", pixel size of 0.44", exposure times between 15 and 30 min., spectral resolution of $\simeq$ 10 Å).

In order to extract the spectra of components A and B, we adapted the method proposed by K. Horn for a single object spectrum to the case of a double object. This method performs an optimal extraction by translating a mask constructed from the spectrum of the bright component, taking into account noise due to the CCD read-out, the object and the sky; it has here the additional advantage of preserving relative spectro-photometry between the two components of 1009–025. Assuming that the spectrum profile along the slit is symmetrical (this turns out to be a very sound approximation), we have then "decontaminated" the spectrum of the faint component by light due to the bright one, and vice versa. Typical spectra extracted in this way are shown for the A, B (and also C) components in Figs. 1 and 2.

The redshifts of 1009–025 A and B turn out to be identical (z = 2.74 with $\Delta z \leq 0.001$) and the line profiles of Lyα+NV, CIV and CIII] look very similar. There is however an excess of blue light in the continuous spectrum of A (see the emission excess near λ = 5000 Åin the

spectrum of 1009–025 A, Fig. 1). We propose that 1009–025 A and B are multiply lensed images of a same quasar, and that the excess of blue light is possibly due to micro-lensing affecting the bright image. A similar interpretation has been recently proposed by Wisotzki et al. (1993, see also their contribution in these proceedings) for the gravitational lens candidate HE1104–1805. It can however not be totally excluded at present that 1009–025 A and B consist of twin quasars.

The spectrum of 1009–025 C turns out to be that of a quasar at a redshift of 1.62 (cf. Fig. 2).

Absorption lines due to MgII, MgI and numerous FeII lines are seen in the spectra of 1009–025 A, B at redshifts $z_a = 0.866$ and $z_a = 1.622$. The system of metallic absorption lines at $z_a = 1.622$ certainly corresponds to gas associated with a cluster containing the quasar 1009–025 C. The system of absorption lines at $z_a = 0.866$ is not detected in the spectrum of the latter quasar. Constraints on the size of metallic absorption line clouds derived from these and other published data will be reported soon by Smette and collaborators.

It is also quite interesting to notice the remarkable resemblance between the spectra of 1009–025 A, B and of UM673 A, B (Surdej et al. 1987, 1988).

3 Q 1148+0055

Another close pair of quasars with different redshifts ($z_A = 1.89$ and $z_B = 1.41$) has been discovered during the same observing run at La Silla (see Fig. 3). The angular separation between these two quasars turns out to be the smallest one presently known ($\Delta\theta = 3.9$") among pairs of quasars with different redshifts. The magnitudes of the two objects are $R_A = 17.9$ and $R_B = 20.7$.

4 Conclusions

Although it is unsafe to determine statistical probabilities a posteriori, we nevertheless estimate that the probability of randomly identifying two tight (≤ 5") associations of moderately bright (typically $R \leq 21$) quasars with discordant redshifts within our own sample of (definitely less than) 400 highly luminous quasars is definitely unlikely, at the 97.5% confidence level. It is thus very suggestive that a preferential amplification due to gravitational lensing along the line-of-sight to 1009–025, and probably also towards the second pair of objects, is responsible for this excess of apparent quasar associations. As in the case of 1548+114 A and B (Gott and Gunn 1974, Iovino and Shaver 1986), the two new close associations of quasars with different redshifts reported in the present paper provide unique astrophysical tools in order to set interesting constraints on the mass of (the foreground) quasars. Such a work is in progress amongst some members of the present team.

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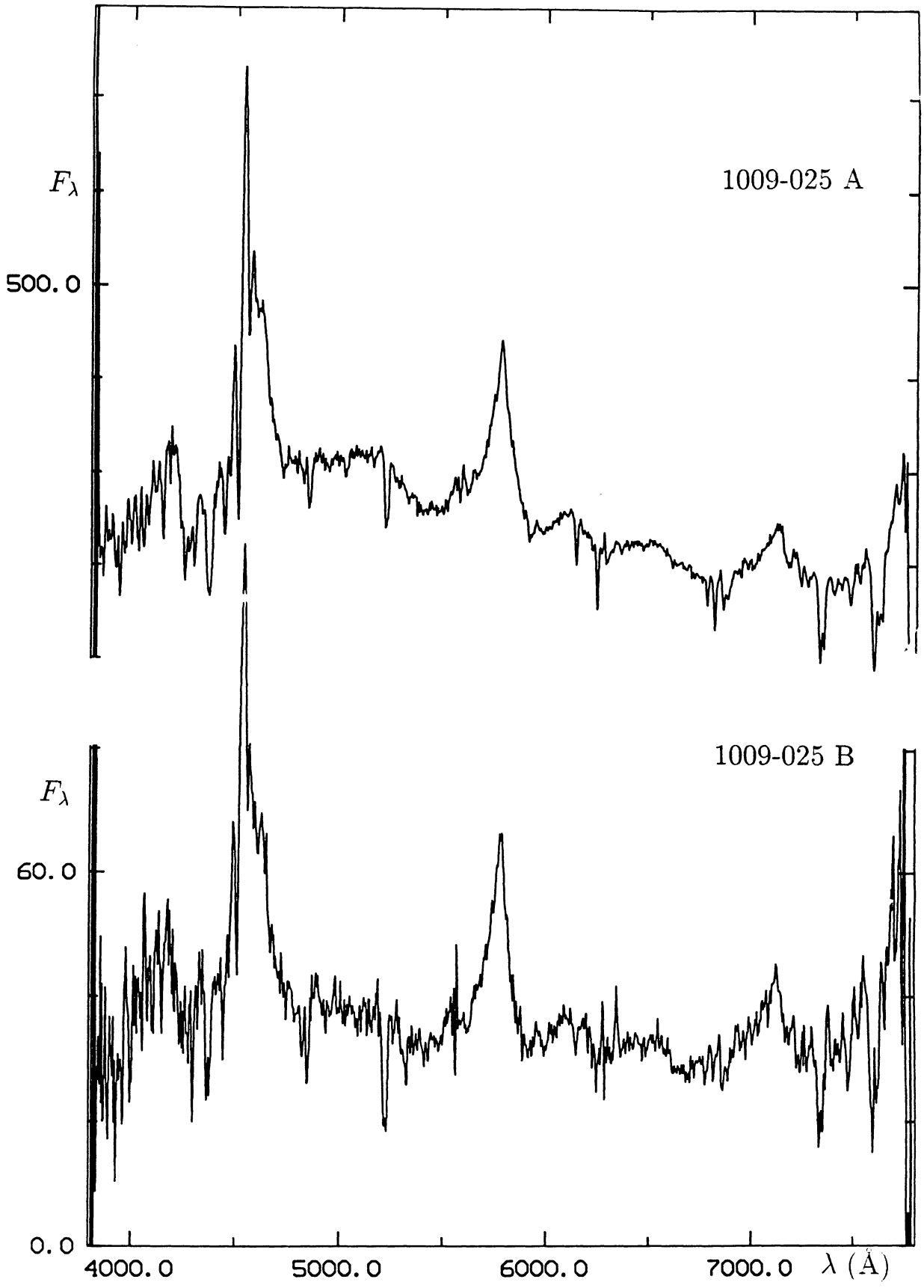

Figure 1: NTT spectra of 1009–025 A and B (see Text)

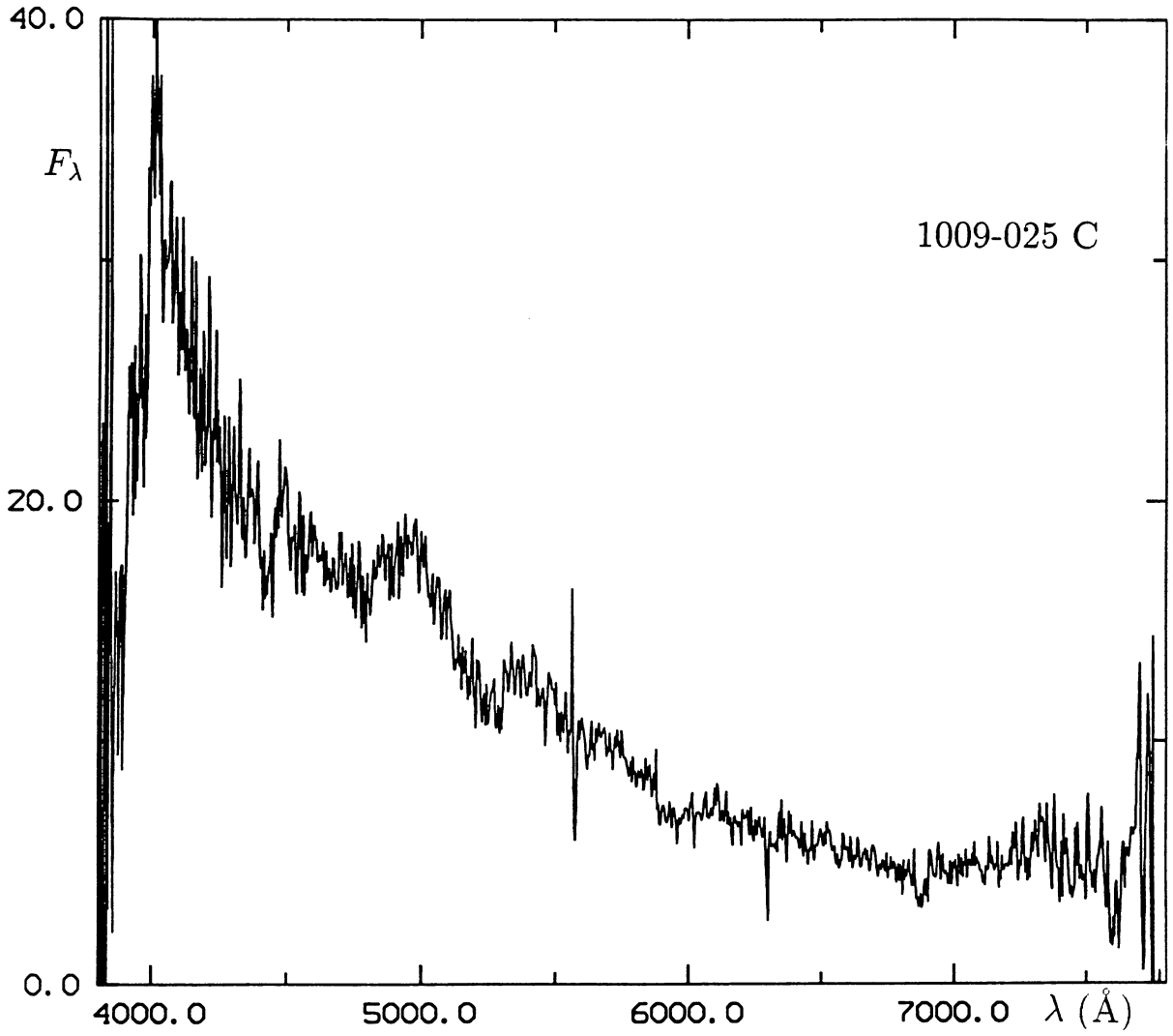

Figure 2: NTT spectrum of 1009–025 C (see Text)

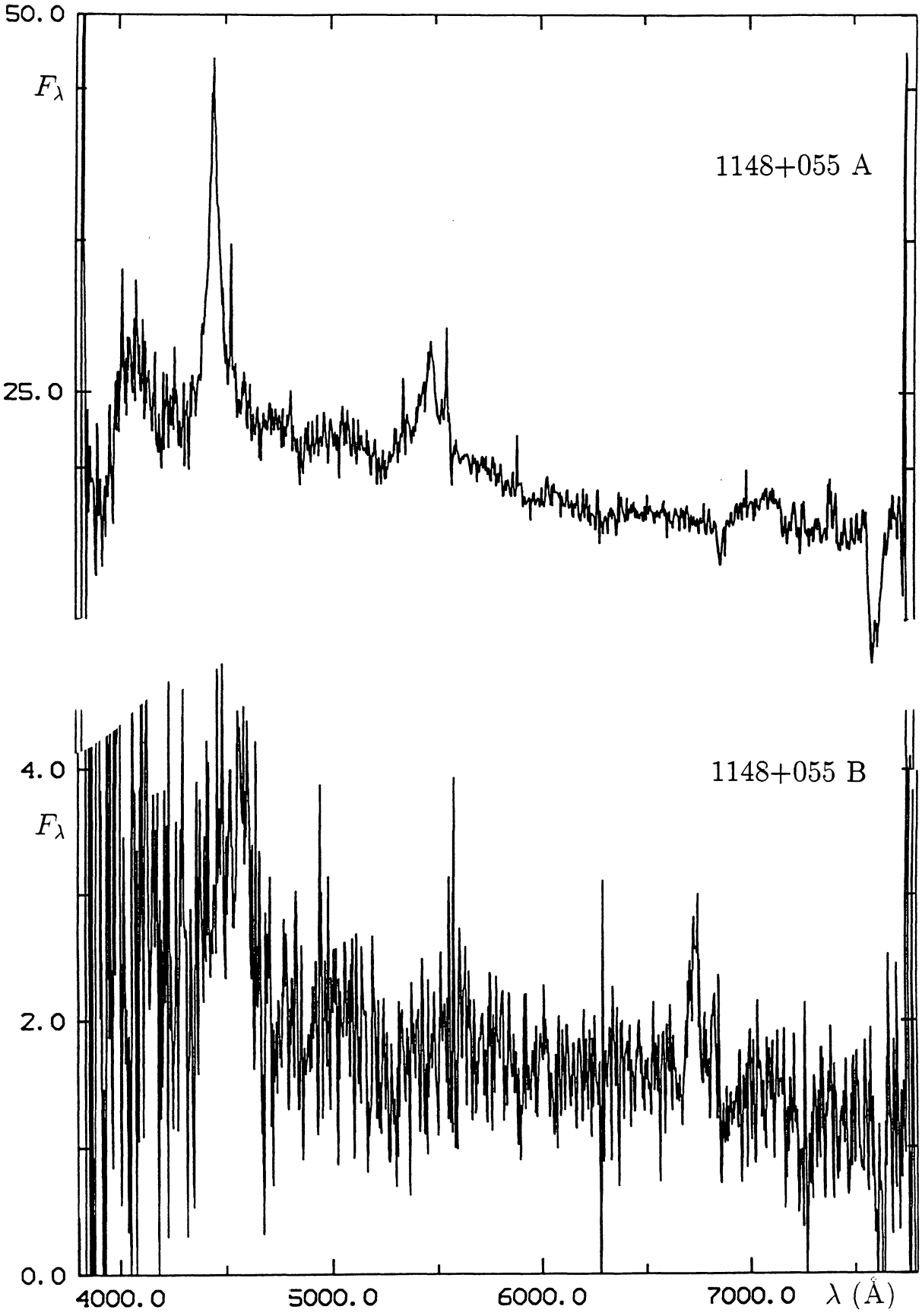

Figure 3: NTT spectrum of 1148+0055 A and B (see Text)

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DISCUSSION

D. WALSH: How were these QSOs selected for study?

J. SURDEJ: We essentially search for new gravitational lens systems among highly luminous quasars (typically $M_v \leq$ - 27) selected from the Véron-Cetty and Véron catalogue.

E. FALCO: What was the slit width in your 1009-025 observations?

J. SURDEJ: 1", with seeing 0.7"-1.3".

F. HAMMER: What limit do you have for the differences in velocity between emission lines in your close pair? I am a little bit worried about the fact that two such new systems could be due to relatively strong micro-lensing events, while in previously known cases of lenses micro-lensing does not seem to be so predominant.

J. SURDEJ: The redshift difference between 1009-025 A and B is about $\Delta z \simeq 0.001$, comparable with the observational and measurement uncertainties.