

## Two quasars seen near the spiral galaxy NGC 470\*

H. Arp<sup>1, \*\*</sup>, J. Surdej<sup>2, \*\*\*</sup>, and J.-P. Swings<sup>3, \*\*\*\*</sup>

<sup>1</sup> Mount Wilson and Las Campanas Observatories of the Carnegie Institution of Washington, Pasadena, USA

<sup>2</sup> European Southern Observatory, Karl-Schwarzschild-Strasse 2, D-8046 Garching bei München, Federal Republic of Germany

<sup>3</sup> Institut d'Astrophysique, Université de Liège, Avenue de Cointe 5, B-4200 Cointe-Ougrée, Belgium

Received January 26, accepted March 6, 1984

**Summary.** The discovery of two quasars with 16" separation from each other on the sky and within 95" of the nucleus of the spiral galaxy NGC 470 is reported. The quasars were discovered in a search for ultraviolet-excess objects in four overlapping fields of about 25 square degrees each. Preliminary spectroscopy of the quasars yields  $z=1.875$  ( $m_v=19.9$  mag) and  $z=1.533$  ( $m_v=18.2$  mag).

**Key words:** ultraviolet – excess objects – quasars – galaxy – NGC 470 – spectroscopy

### 1. Introduction

In 1980, the present authors initiated a program of searching certain specified areas of the sky uniformly for ultraviolet-excess objects down to about  $B=20.0$  mag (cf. Arp and Surdej, 1982; Surdej et al., 1982). Palomar and ESO Schmidt plates were taken with adjacent ultraviolet and blue ( $U/B$ ) images. Several plates of a large field ( $\sim 100$  deg<sup>2</sup>) centered near R.A.  $\sim 1^h 12^m$ , Decl.  $\sim +2^\circ$  were searched at the Institut d'Astrophysique in Liège and quasar candidates were identified over more than 60 deg<sup>2</sup> (although yet unpublished). Spectroscopy of about 110 of these candidates has been done using the 2.5 m Irénée Dupont reflector on Las Campanas and the ESO 3.6 m telescope at La Silla (Chile). Some preliminary results have been communicated in Arp (1983) and in Swings et al. (1983).

The finding of two quasars near the projected edge of a faint spiral arm of the Sbc galaxy NGC 470 is reported here in advance of the final analysis because of the special importance which quasars found near each other and/or found near galaxies have for a number of astronomical investigations.

### 2. Observations

Figure 1 illustrates the field of interest near NGC 470. The print displayed here was made from the superposition of three direct plates (No. CD 2334/35/36) taken with the Dupont 2.5 m telescope

Send offprint requests to: J. Surdej<sup>2</sup>

\* Based on observations partly collected at the European Southern Observatory, La Silla, Chile

\*\* Research Visitor, European Southern Observatory

\*\*\* Also, Chercheur Qualifié au Fonds National de la Recherche Scientifique, Belgium

\*\*\*\* Research Associate, European Southern Observatory

at Las Campanas Observatory. Each of the three exposures was 60 min duration on a baked 103a-J plate, with no filter and the seeing was about 1". Figure 2 consists of an enlargement of part of Fig. 1 showing the spiral galaxy NGC 470 and its direct surroundings. This photograph allows one to see the structure of the galaxy with much better resolution and contrast. The two quasars found near the projected edge of the south-eastern spiral arm of NGC 470 are labelled 68 and 68D in Figs. 1 and 2. Direct CCD exposures have been obtained with the Danish 1.5 m telescope at La Silla and are presently being analyzed by A. Henry. The results of this deep imaging will be reported later.

Spectra of both 68 and 68D were taken on 20 Nov. 1981 with a reticon detector on the Cassegrain spectrograph of the 2.5 m Las Campanas reflector. The wavelength coverage was about 3400 to 6700 Å with a resolution of approximately 8 Å. The spectrum of the fainter of these two quasars, i.e. 68 ( $m_v \sim 19.9$  mag), is reproduced in Fig. 3. The brighter quasar (68D,  $m_v \sim 18.2$  mag) was reobserved in September 1982 with the ESO 3.6 m telescope using an IDS attached behind a Boller and Chivens spectrograph (slit  $4'' \times 4''$ , FWHM  $\sim 12$  Å, spectral range 3700–7300 Å). The relevant spectrum is illustrated in Fig. 4. In Figs. 3 and 4, the ordinates refer to a relative flux scale and the abscissae to observed wavelengths. Reduction of these spectra has been performed with the "image handling and processing" system (IHAP) of ESO at Garching bei München (FRG).

### 3. The two quasars 68 and 68D

Within the small field ( $20' \times 27'$ ) pictured in Fig. 1, the objects labelled 68 and 76 ( $m_v \sim 17.4$  mag for the latter) were the only two UV-excess candidates to be identified on the dual image ( $U/B$ ) plate PS 26678 that was first inspected. Both these objects (68 and 76) are found to lie quite near a conspicuous galaxy, i.e. at  $\sim 93''$  from the nucleus of NGC 470 and at  $\sim 47''$  from the center of an anonymous galaxy (R.A. =  $1^h 16^m 56^s$ , Decl. =  $+2^\circ 57' 35''$ , equinox 1950.0), respectively. The additional UV-excess object 68D was later identified on a separate  $U/B$  dual image plate taken with the Swope 1 m telescope by Oscar Duhalde. Later, 68D and 76 (but not 68) were independently rediscovered by Eric Gosset on a second  $U/B$  plate (PS 26672) obtained with the Palomar 48 inch Schmidt telescope. The UV-excess object 68D lies approximately 96" south-east from the nucleus of NGC 470 and at 16" only from 68.

Spectroscopic observations (see Sect. 2) have revealed the stellar nature of the UV-excess object 76 but that 68 and 68D were quasars with redshifts  $z=1.875$  and  $z=1.533$ , respectively. For

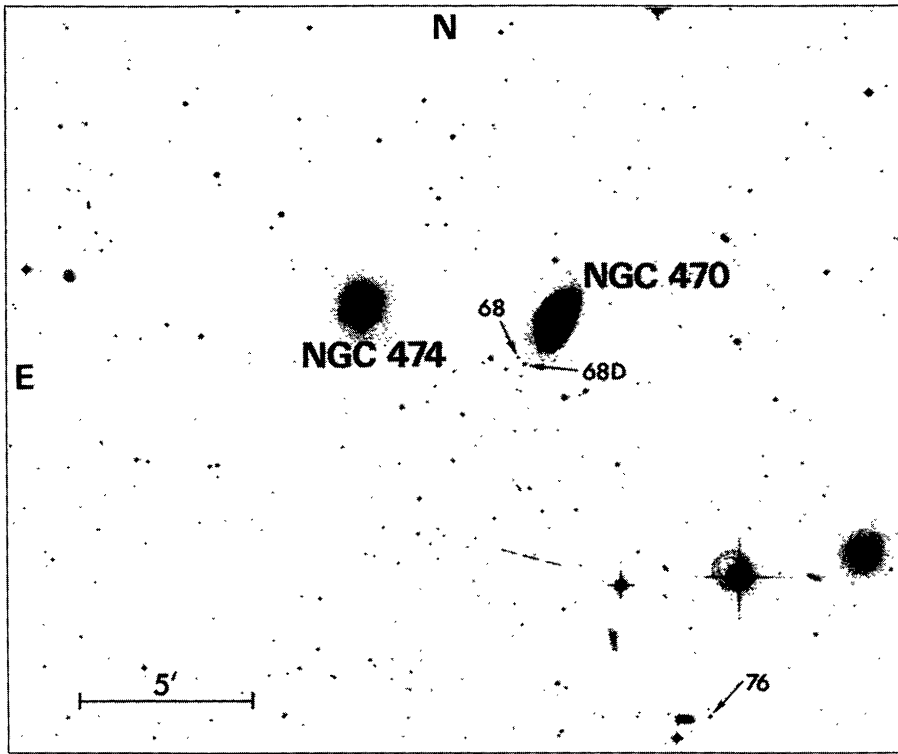


Fig. 1. Superposition print of three 60 min exposures showing the field centered around NGC 470 (see text). Note the faint and somewhat diffuse spiral arm extending very near the position of the quasars 68 and 68D. The UV-excess object 76, located close to an anonymous galaxy, turned out to be a star. One can also notice in this photograph the early-type galaxy NGC 474 with its discrete shells (Atlas No. 227 in Arp, 1966) and the interrupted trails of two passing minor planets

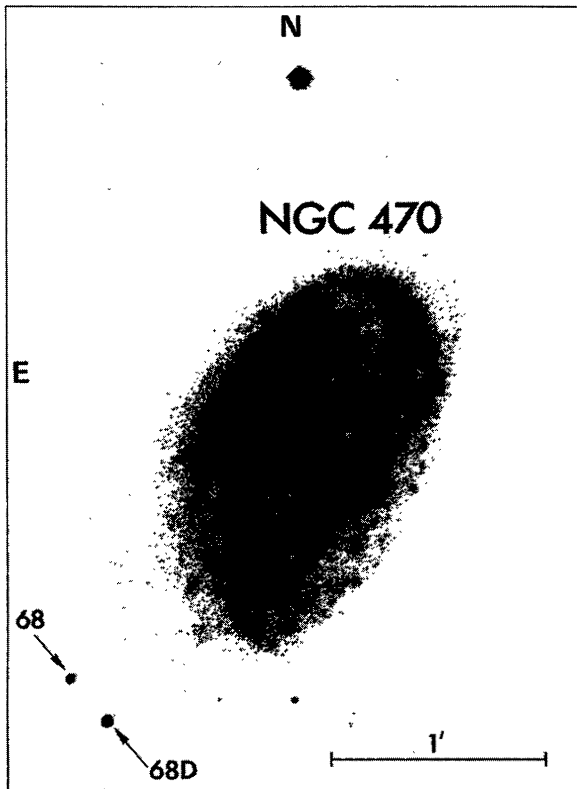


Fig. 2. Enlargement of the central part of Fig. 1 showing the detailed structure of the spiral galaxy NGC 470 and the proximity of the two quasars 68 and 68D to the edge of the disk

both of these objects, we list in Table 1 the observed emission line wavelengths, corrected for the earth's heliocentric motion ( $v_{\odot} = 30 \text{ km s}^{-1}$ ) and a galactic rotation of  $250 \text{ km s}^{-1}$  at the sun. Wavelengths based on the redshift are also listed (second line) in the rest frame of each object. The mean error reported for the redshifts is derived on the basis of an equal weight assigned to each emission line. Finally, the equivalent width of the emission lines calculated in the rest frame of the quasar has also been included in Table 1 (third line).

Unfortunately, the relatively low signal to noise ratio and resolution of the present observations prevent us from definitely reporting the presence of any absorption line in the QSO spectra. It is very probable that an absorption component is seen blueward of the  $\text{C III}]$  emission at  $\lambda \sim 4725 \text{ \AA}$  in the spectrum of 68D. Other absorption lines are also suspected to be present in that spectrum, but higher signal to noise data are strongly needed in order to ascertain the reality of the suspected features. Higher resolution spectra have recently been obtained by P. A. Shaver and J. G. Robertson with the AAT 4 m telescope and by Arp with the Palomar 5 m reflector. Analysis of these data will be reported elsewhere

#### 4. Probability of the configuration

##### 4.1. First approach (by H.A.)

If we adopt an average density of  $7 \pm 4$  ultraviolet-excess quasars per square degree down to  $B = 20.0 \text{ mag}$  (Arp et al., 1979; Arp and Surdej, 1982), we can compute the probability of finding the configuration reported. First, the probability of finding a  $20^{\text{th}}$  mag quasar (No. 68) within  $16''$  of the brighter quasar (No. 68D) is

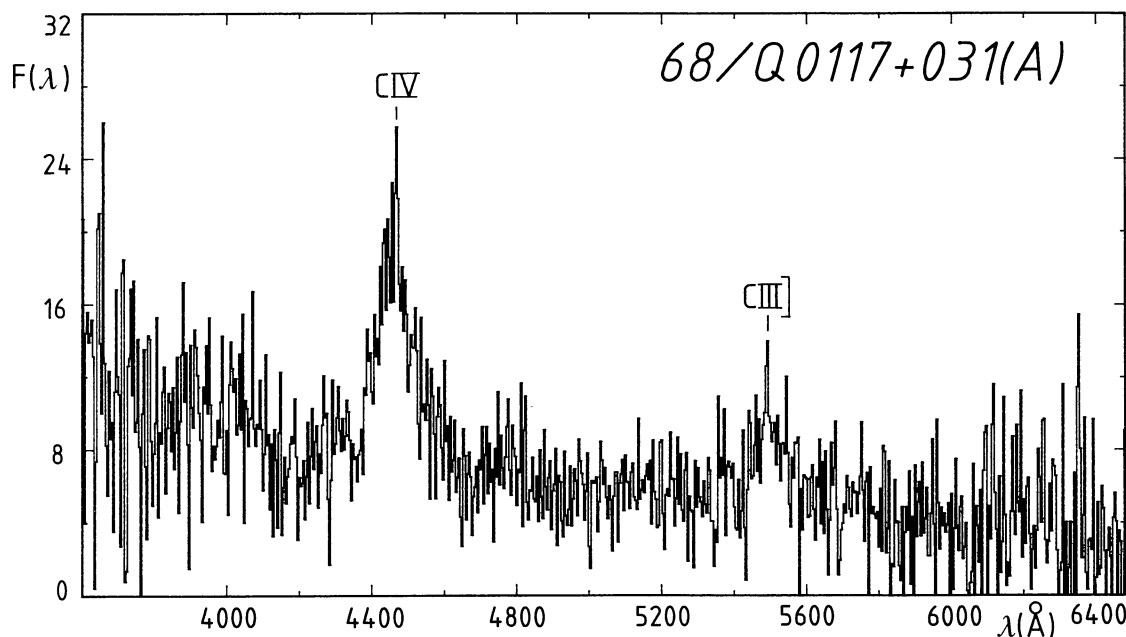


Fig. 3. Spectrum of the quasar 68 ( $z = 1.875$ ) taken with the Las Campanas 2.5 m Irénée Dupont telescope. In this and the next figure, the ordinates refer to a relative flux scale and the abscissae correspond to observed wavelengths

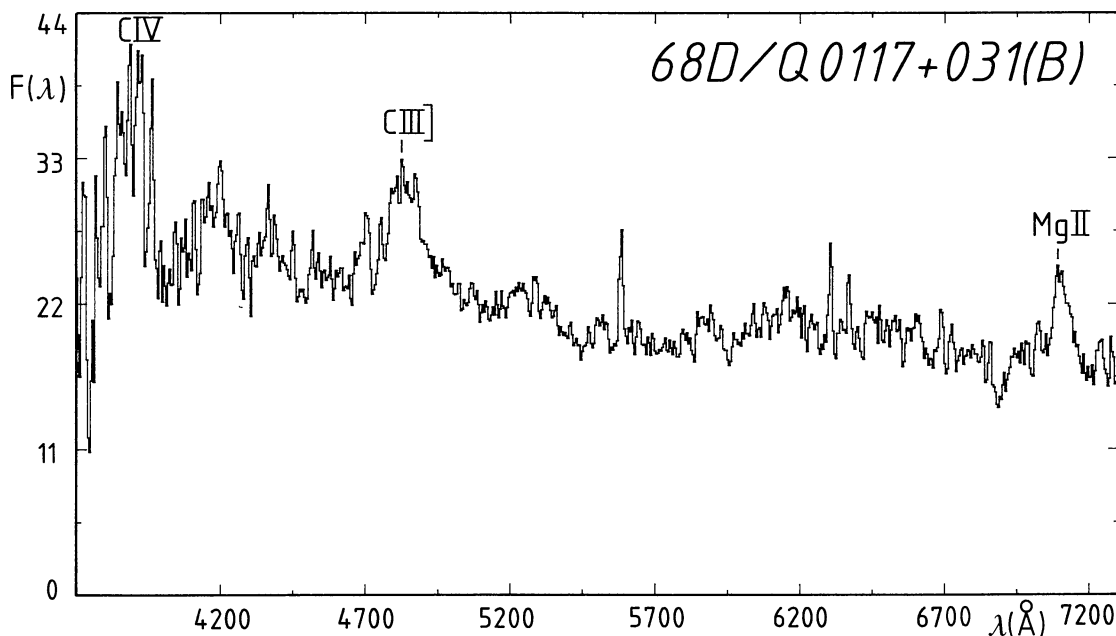


Fig. 4. Spectrum of the quasar 68D ( $z = 1.533$ ) taken with the ESO 3.6 m telescope

$P = 0.0004$ . Secondly, the probability of finding a 20<sup>th</sup> mag quasar within 95" of a galaxy (NGC 470) is about  $P = 0.015$ . The probability of finding two quasars 20<sup>th</sup> mag or brighter this close to a galaxy is  $P = 0.0002$ . Since these are a posteriori probabilities we must multiply by the number of quasar candidates brighter than  $m_v \sim 18.2$  mag examined (several tens). For the probability of the quasars near the galaxy we have to multiply by the number of galaxies this bright in the areas searched (a number equal to 5). Both final probabilities are extremely small and therefore mark the configuration as having a low probability of occurring by chance.

#### 4.2. Second approach (by J.S. and J.-P.S.)

In order to estimate the probability of finding two quasars lying so near the projected disk of NGC 470, let us adopt the most favorable case for the calculation of a chance occurrence. Thus, considering that the UV-excess object 68D was searched for around NGC 470 after 68 had been identified, it seems quite reasonable to calculate the chance occurrence of the observed configuration by estimating the probability  $P$  of finding one more quasar within, let us say, 2' from the nucleus of NGC 470. With the average density given above, we easily find that

**Table 1.** Line identifications ( $\text{\AA}$ ), associated redshifts and equivalent widths ( $\text{\AA}$ ) of the emission components in the quasar rest frame

Quasars	$Z_e$	CIV 1549.48	CIII] 1907.64	MgII 2799.12
68/ Q0117+031 (A)	$1.857 \pm 0.001$	$4454.8 \pm 1.3^a$ 1549.3 $61.8 \pm 7.1^b$	5485.7 1907.8 $31.6 \pm 2.2$	
68D/ Q0117+031 (B)	$1.533 \pm 0.002$	3891.1: <sup>c</sup> 1536.1 $16.4 \pm 4.1^d$	4829.0 1906.4 $25.8 \pm 1.5$	7095.2 2801.0 $13.7 \pm 1.1$

<sup>a</sup> Most of the observed emission components have been fitted with a Gaussian profile in order to derive their line centre. The error estimate of  $1.3 \text{ \AA}$  refers to the mean uncertainty affecting the determination of these line centers

<sup>b</sup> The error estimates represent r.m.s. values as derived from three independent measurements. Because the equivalent width of an emission line depends on the accurate setting of the continuum level, etc. one should be aware that the values reported in the above table are somewhat subjective and that the error estimates should just be considered as internal deviations of our measurements

<sup>c</sup> Not taken into account in the determination of the redshift

<sup>d</sup> Uncertain value

$P = 2.4 \pm 1.4\%$ , i.e., we can state that the observed “two quasars-galaxy” configuration is likely to be a chance occurrence.

## 5. Discussion

Since, in the cosmological context ( $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ ,  $q_0 = 0$ ), the projected distances between 68 and 68D and between 68D and the nucleus of NGC 470 along a plane perpendicular to the line-of-sight and passing through 68D and NGC 470 is of the order of 191 kpc and 24 kpc, respectively, i.e. typical sizes for suspected halos around quasars and galaxy disks, it is clear that the observed “68-68D-NGC 470” configuration offers a unique opportunity to look for common and/or associated absorptions (see Shaver and Robertson, 1983 plus references therein for further details) as well as for heavy element absorption lines due to matter distributed in the south-eastern spiral arm of NGC 470.

We will not discuss here the physical origin of the observed “68-68D-NGC 470” configuration but merely restrict ourselves to mentioning several alternatives:

- (i) chance occurrence;
- (ii) enhancement in the surface density of quasars near galaxies due to lensing by stars in the galaxy halos (cf. Tyson, 1981; Canizares, 1981);
- (iii) physical association of the quasars and NGC 470 (see Arp, 1983, for the latest review).

*Acknowledgements.* We should like to thank Oscar Duhalde for taking the U/B plate with the Swope 1 m telescope and Eric Gosset for communicating to us some results of his survey. Part of this research has been supported by NATO grant 111/81.

## References

- Arp, H.: 1966, Atlas of Peculiar Galaxies, *Astrophys. J. Suppl.* **14**, 1
- Arp, H., Sulentic, J.W., di Tullio, G.: 1979, *Astrophys. J.* **229**, 489
- Arp, H., Surdej, J.: 1982, *Astron. Astrophys.* **109**, 101
- Arp, H.: 1983, in *Quasars and Gravitational Lenses*, 24<sup>th</sup> Liège International Astrophysical Colloquium, Institut d’Astrophysique, Liège, p. 307
- Canizares, C.R.: 1981, *Nature* **291**, 620; erratum **293**, 490
- Shaver, P.A., Robertson, J.G.: 1983, in *Quasars and Gravitational Lenses*, 24<sup>th</sup> Liège International Astrophysical Colloquium, Institut d’Astrophysique, Liège, p. 598
- Surdej, J., Swings, J.P., Arp, H., Barbier, R.: 1982, *Astron. Astrophys.* **114**, 182
- Swings, J.P., Arp, H., Surdej, J., Henry, A., Gosset, E.: 1983, in *Quasars and Gravitational Lenses*, 24<sup>th</sup> Liège International Astrophysical Colloquium, Institut d’Astrophysique, Liège, p. 37
- Tyson, J.A.: 1981, *Astrophys. J.* **248**, L89