Доклады Болгарской академии наук
Comptes rendus de l'Académie bulgare des Sciences
Tome 34, N° 4, 1981

ASTRONOMIE
Astrophysique

PHYSICAL CONDITIONS IN DOUBLE GALAXIES WITH EMISSION LINES. MARKARIAN 171 a, b

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(Submitted by Corresponding Member K. Serafimov on December 8, 1980)

This is a continuation of the spectrophotometric investigation of the physical conditions in the nuclei of double galaxies, started in [1] with the couple NGC 5929/5930. The double galaxy IC 694+NGC 3690 is included in the second list of galaxies with a UV continuum under No. 171, [2] while in Holmberg's list of double galaxies it figures under No. 256. The system is known as interacting (VV 118, Arp 299) and subsequently was included in the catalog of isolated double galaxies of Karachentsev K 288. According to Huchra [3], the summary stellar magnitude of the galaxies is $M_V = 12.86$. The system's radial velocity determined by Sargent [4] and corrected for the Sun's movement is $V_0 = 3060$ km. sec $^{-1}$. The couple has already been investigated spectrophotometrically [5–7], but the obtained data are not in good agreement. It is this which aroused our interest. The observation material processed by us was obtained through a 125-cm telescope in the Southern Station of Sternberg State Institute of Astronomy by means of an A-spectrograph and a one-cascade image tube system type FCT-1. The spectrogram obtained on a Kodak 103 aD emulsion were processed on a photometer recording in intensity of the Crimea Astrophysical Observatory of the Soviet Academy of Sciences. The original dispersion of the spectrograms was 100 A/mm, which corresponds to a spectral resolution of 4—5 A. The method of calibration and processing has been described in [8]. The registrograms of the spectra of the galaxies Mrk 171a=IC 694 and Mrk 171 b=NGC 3690 are shown in Fig. 1. Wave length λ is plotted along the abscissa and the photographic blackening along the ordinate. The lines of the night sky [*O* I] $\lambda\lambda$ 6300, 6363 are denoted by NS.

The equivalent widths and relative intensities of some emission lines are given in Table 1.

According to Alloin et al. [7], gas ionization in the system Mrk 171 is not purely radiational, as a shock ionization of high-speed particles is also present. This ionization is characteristic of the supernova remnants. The authors did not examine the two components by themselves, whereas our material permits to discuss the ionization mechanisms for each of the terms of the couple. Alloin et al. [9] calculated the dependence of the degree of ionization ($I\lambda 6717/I\lambda 6731$) for the supernova remnants. This dependence is shown in Fig. 2, where the region occupied by the supernova remnants is denoted by a dotted line. The points correspond to the galaxies Mrk 171 a, b. Their position on the diagram suggests that probably only in the nucleus of Mrk 171 b is there

a more considerable shock ionization. The situation is similar to that in the couple NGC 5929+5930 [1].

As described in [8], certain parameters characterizing the physical conditions in the nucleus can be determined by the magnitude of the nucleus, the equivalent width of the line H_β and the distance to the galaxy. The magnitudes

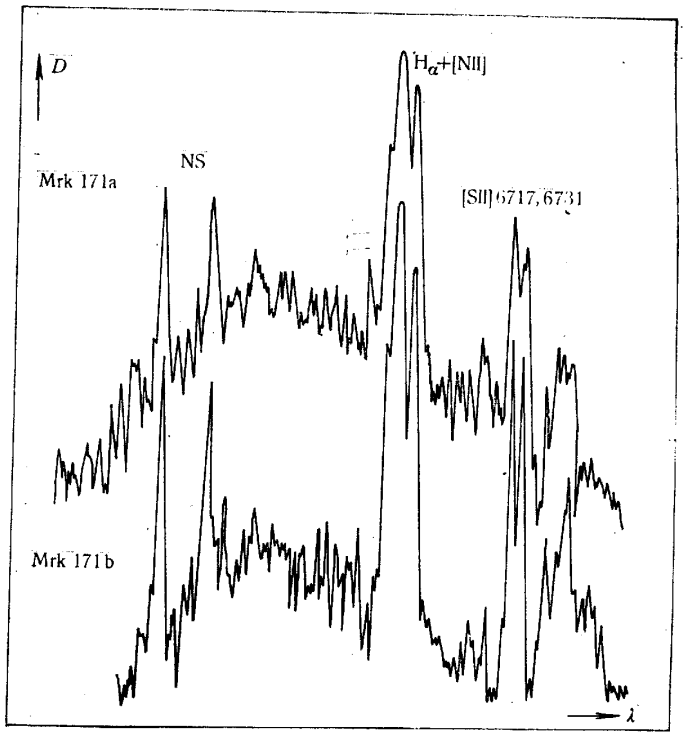

Fig. 1

of the nuclei of the investigated galaxies have not been determined as yet, wherefore we made an assessment by the dependence

$$m_{\text{nucl}} = 0.47\ m_{\text{gal}} + 9.27$$

obtained by us on the basis of the data adduced in [10] for all morphological types of galaxies. The electronic density n_e of the emitted gas was determined

Table 1

Object and year	W_{H_α} Å	W_{H_β} Å	$\frac{I\lambda 4959, 5007}{I\ H_\beta}$	$\frac{I\lambda 6584}{I\ H_\alpha}$	$\frac{I\lambda 6724}{I\ H_\alpha}$	$\frac{I\lambda 6717}{I\lambda 6731}$	Source
171 a, b (1970)			1.75	0.2		0.66	7
171 a, b (1970—1971)			1.2	0.7			4
171 a (1970)		45	0.87				5
171 b (1970)		45	0.87				5
171 a (1978)	56			0.84	1.00	0.83	this work
171 b	92			1.11	0.64	1.22	this work

by the ratio $I\lambda 6717/I\lambda 6731$ of the forbidden lines of ionized sulfur, while the electronic temperature T_e of the gas was, as usual, assumed to be 10^4K.

The physical parameters of the gas in the nuclei of the galaxies as well as the content of some ions are shown in Table 2. The kinetic energy of the gas was calculated for the width of the lines 200 km/sec, determined by the

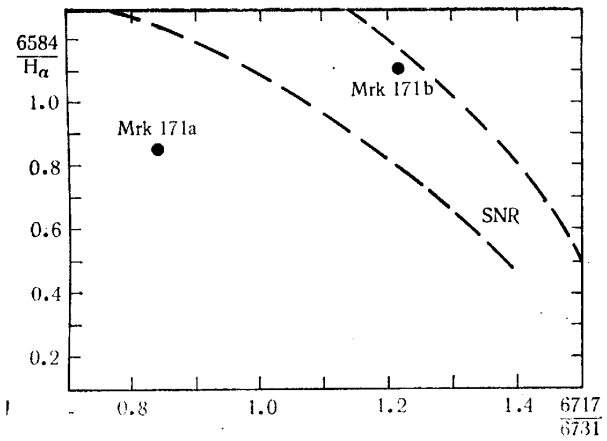

Fig. 2

spectrograms. The content of the ions was in units lg $X^+ + 12.00$. The value of 75 km/sec. Mps was accepted as Hubble constant.

As our data show, the galaxies Mrk 171 a, b are moderately active objects, the latter being more active and revealing signs of shock ionization. The mass of the emitted gas in them was respectively 4×10^4 and 3×10^5 $M_\odot$, i. e. quite a bit larger than the gas mass in the nuclei of the normal galaxies, and resemble that in the Seyfert galaxies of type 2. The same goes for the luminosities of the hydrogen lines. The kinetic energy of the gas, however, was by one order less, indicating a weaker activity of the ionization processes

Table 2

Parameters	Mrk 171 a	Mrk 171 b
Magnitude of nucleus	15.5	15.5
Equivalent width of line N_α [A]	56	92
Flux on boundary of Earth atmosphere $F_{H\alpha}$ [erg. cm^{-2}. sec^{-1}]	1.78×10^{-13}	2.88×10^{-13}
Electron density for $T_e=10^4K$ [cm^{-3}]	2240	450
Coefficient of emission ε_{H_α} [erg. cm^{-3}. sec^{-1}]	1.68×10^{-18}	6.76×10^{-20}
Effective volume occupied by gas V_{ef} [cm^3]	2.11×10^{58}	8.46×10^{59}
Mass of emitting gas M_{gas} [g]	7.84×10^{37}	6.32×10^{38}
Kinetic energy of gas E_{kin} for $V_{source}=200$ km/sec [erg]	1.57×10^{52}	1.26×10^{53}
Number of Balmar quantas N_{Bal}	1.31×10^{53}	1.26×10^{53}
Power of source of ionization L_{tot} [erg. sec^{-1}]	2.35×10^{42}	4.60×10^{42}
Luminosity in line H_α [erg. sec^{-1}]	3.53×10^{40}	5.72×10^{40}
Number of 05 V stars necessary to keep gas in ionization-recombination balance	6490	10465
Relative number of ions N^+	7.61	7.72
Relative number of ions S^+	7.13	6.92

We then proceeded to evaluate the excitation energy of the shock wave in the nucleus of Mrk 171 b. The movement of the gas masses around 3×10^5 $M_\odot$ with a velocity of ca. 200 km/sec gave a kinetic energy of $E_k \sim 2.11\times 10^{53}$ erg. Knowing the distance to the galaxies and the dimensions of the emitting region (1000—2000 ps), we obtained as age of the explosive formation $\sim 10^7$ years. The total energy of the recombination glow for this time is $E_{tot} \sim 10^{56} - 10^{57}$ erg, i. e. much greater than E_k. In other words, the kinetic energy of the moving gas, excited by the shock wave, is clearly insufficient to explain the flux observed in the emission lines. The heat mechanism of excitation predominates to a considerable extent, as testified to also by the numbe of stars of the 05 V class, which would be sufficient to ionize the gas.

In conclusion let us note that, inasmuch as the data of different authors differ substantially, it is quite possible that the galaxies or some of them show variability. Certain Seyfert galaxies and most quasars are known to show variability of the lines or of the flux. The elucidation of this question, which requires regular observations under similar conditions, may lead to a complete clarification of the ionization state of the gas in the nuclei of these galaxies.

Acknowledgements by one of the authors (G. P.) is due to the Administration of Sternberg State Institute of Astronomy for enabling him to make use of the telescope and the apparatus of its Southern Station.

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