УДК 524.74-36 Астрофиз.исслед. (Изв.САО), 1991, 33, 125-131

GAS KINEMATICS IN THE CENTRAL REGIONS OF SEYFERT GALAXIES. IV. NGC 5929

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ABSTRACT. *We have investigated the kinematics of ionized gas in the centre of Seyfert 2 galaxy NGC 5929 at the 6-m telescope. Two gas clouds being the main forbidden line emitters in the centre of NGC 5929 are found to possess the relative line-of-sight velocities -50 km/s (the eastern cloud) and +270 km/s (the western cloud); these values exceed the maximum projection of the galaxy rotation velocity on the line of sight (30 km/s). The clouds are rather extended: the eastern cloud is aligned at the position angle 80-85° by 0.7 kpc, the western cloud - at the position angle 130° by 3 kpc; the western cloud shows the own rotation. The emission brightness centres which coincide with the radio lobes are probably the shock wave regions forming on the border between the clouds and the galactic disk.*

На 6-метровом телескопе исследована кинематика ионизованного газа в центре сейфертовской галактики 2 типа NGC 5929. Обнаружено, что два облака, являющиеся основными источниками эмиссионного спектра в центре галактики, имеют относительно центра галактики лучевые скорости -50 км/с (восточное облако) и +270 км/с (западное облако), что превышает максимальную проекцию скорости вращения галактики на луч зрения (30 км/с). Облака являются протяженными объектами: восточное облако имеет размер 0.7 кпк в позиционном угле 80-85°, а западное - около 3 кпк в позиционном угле 130°; причем западное облако показывает признаки собственного вращения. Центры яркости в эмиссионных линиях, совпадающие с радиоконденсациями, вероятнее всего являются областями ударной волны на границе облаков и диска галактики.

INTRODUCTION

NGC 5929 is a nearby ($D \cong 35$ Mpc) Seyfert 2 galaxy; it belongs to the close interacting pair with NGC 5930: a distance between the galaxies in projection on the celestial sphere is 5 kpc, and on the prints made by Arp (his Atlas presents NGC 5929 under number 90) one can see that the spiral arm of NGC 5930 twines round the neighbour. NGC 5929 is of SO morphological type and is seen face-on: according to different catalogues the visible axis ratio

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b/a is from 0.94 up to 1.00.

In recent years the central region of NGC 5929 has attracted much attention: probably this is the closest galaxy with emission line splitting in the centre.

In their survey Ulvestad and Wilson (1984) have registered the double radio structure in the central region of NGC 5929 aligned at P.A. 62°; a distance between radio lobes is 1.3″ (220 pc), the optical nucleus is located approximately in the middle between them. More later works have confirmed this result; only Wilson and Keel (1989) have noted the third faint radio lobe being identified with the galaxy nucleus.

A great similarity between the structure of the central region of NGC 5929 in the radio and in emission lines in optics was detected then immediately. Keel (1985) has obtained NGC 5929 spectrum in H_α range at P.A. 60° (coinciding with the direction of radio structure) and noted existence of two compact emitting regions (gaseous clouds) separated both spatially (Δr = 1.3″) and kinematically (ΔV_r = 291 km/s). According to the degree of spectrum excitation the both clouds might be Seyfert nuclei. In the intermediate-band filter ($\Delta\lambda$ = 75 A) in H_α + [NII] Keel has obtained an image of the central region of ≃ 4″ in size, aligned at P.A. 85°, somewhat differing from the radio structure direction.

Whittle et al. (1986) have obtained the spectra and direct images of the central region of NGC 5929 in [OIII]λ5007 emission line and nearby continuum band under very good seeing conditions. The [OIII] image shows two brightness centres located at P.A. 64° symmetrically relative to the continuum isophote centre and separated by ≃ 1″. They fully resemble the radio structure, if not consider for some smaller separation of lobes. On scales ≃ 2″ from the centre an isophote major axis turns at P.A. ≈ 80° that is in a good agreement with Keel's (1985) results for the H_α+[NII] emission lines. Isophotes in continuum are absolutely round that ought to be expected taking into account that the galaxy is seen face-on.

A detailed spectral investigation of both galaxies NGC 5929 and NGC 5930 was made by Wakamatsu and Nishida (1988). In NGC 5930 they have detected the same dichotomy of emission lines in the centre as in NGC 5929. For NGC 5929 they have obtained spectra at 4 position angles in every 45°. The existence of two emitting clouds is confirmed which are clearly separated in the cross-section at P.A. 48° (close to the galaxy major axis, which in accordance with measurements from the Arp's print has $P.A._0$ 46°) by a distance of 1.5″ and velocity difference of 282 km/s. In contrast to their precursors, Wakamatsu and Nishida did not think the clouds to be point objects and at P.A. 48° and 90° they noted proper cloud rotation such that their north-east edges are moving away from us. Starting from the fact that the clouds are located on the galaxy major axis where the projections of radial velocities turn into zero, and following Keel (1985), they refer the difference in line-of-sight velocities of the clouds on their participation in regular rotation of the galaxy. However, the galaxy inclination, which they take into consideration, is incorrect and their estimate of the angular rotation velocity of the central galaxy region must be increased from 1500 km/s·kpc to 4000 km/s·kpc that appears to be unlike.

Up to now the "jet" hypothesis has been developed by all the authors studying this galaxy. We have also carried out spectral investigation of the central region of NGC 5929 and derived the picture that differs greatly from the simple model of jet which emerges from the nucleus and illuminates two gaseous clouds in the rotating disk of the galaxy.

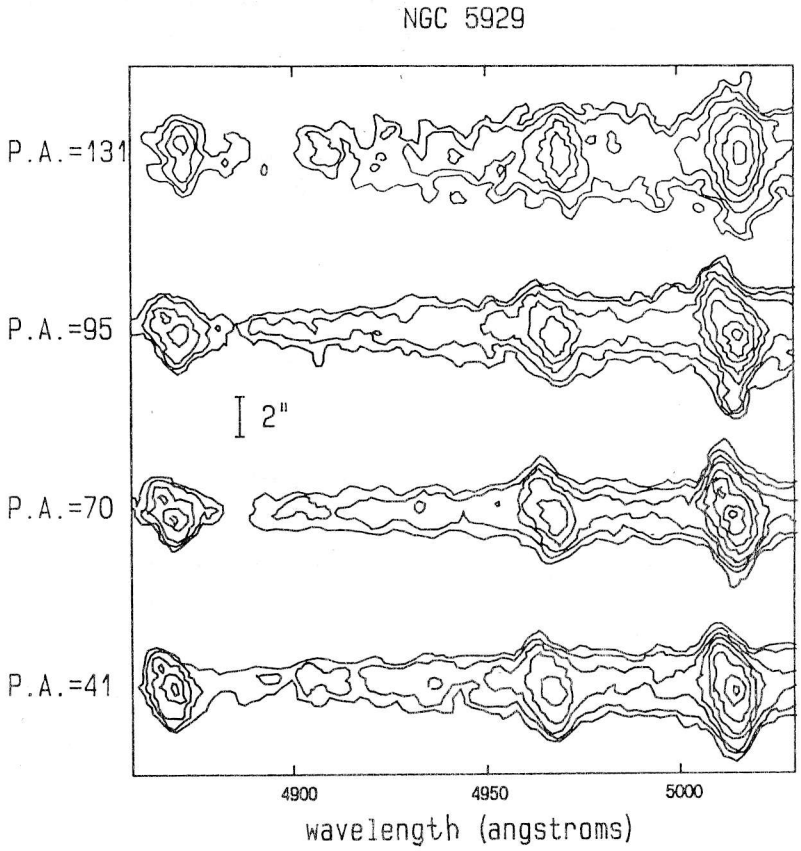

Fig.1. The emission lines [OIII] and H_β in the spectra of NGC 5929 at various position angles.

OBSERVATIONS

In October, 1987 we have carried out observations of NGC 5929 in the prime focus of the 6-m telescope using the long-slit spectrograph and two-dimensional photon-counting system for spectrum registration (for description of the equipment see Afanasiev et al., 1986). Four spectra at various position angles in the green spectrum band including emission lines [OIII]λλ4959, 5007 and *H*, have been obtained. A dispersion, linear scale along the spectrograph slit, the slit sizes, and the seeing quality during the observations were 1.5 A/pix, 0.37″/pix, 100″×2″, and 1.5″ respectively. Emission lines near the galaxy centre really have a strongly noticeable two-component structure, therefore we determined the line-of-sight velocities

of ionized gas by two methods: the first one, the standard reduction (Alyavdin et al., 1988) which allows to measure the emission line peak position, was used for distances from the centre larger than 3″, and the second one, the interactive Gaussian component analysis, was applied to the central regions ($r \leqslant 3''$). The spectra with emission lines are presented in Fig. 1. Two components are easily seen in every emission line, that confirms the applicability of Gaussian component analysis. Fig. 2 presents the radial distributions of gas line-of-sight velocities, after the component separation, at the 4 position angles. Maximum extension of the measured emission is 10″ from the centre or R = 1.7 kpc.

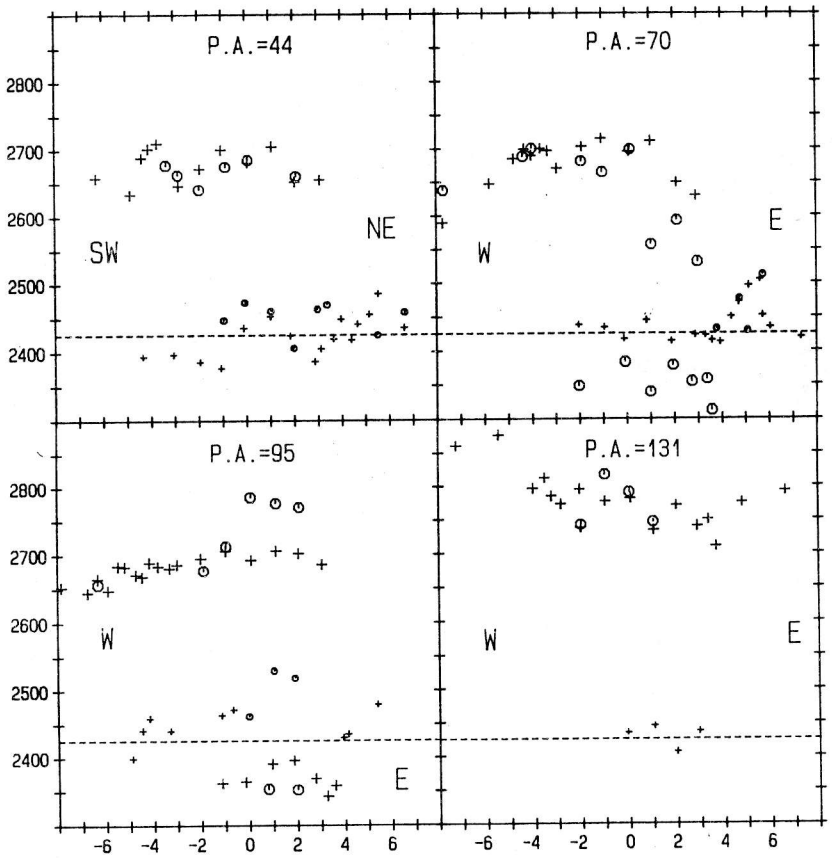

Fig.2. Radial distributions of gas line-of-sight velocity in NGC 5929 at various position angles. Crosses - [OIII] emission lines, circles - H_β. The symbols of larger size show the high- and low-velocity components (gas clouds).

Absorption lines MgI λ5167+5173 and 5184, FeI λ5269 are also well noticed in the spectra up to 2″ from the centre. They allow to determine the line-of-sight velocity of the stellar population in the galaxy nucleus, i.e. the true galaxy systemic velocity.

Table 1. The journal of observations for NGC 5929

Spectrum	Date	Exposure	P. A. of slit	Spectral range (A)
M06501	17/18.X.87	20^m	44°	4700-5400
M06502	17/18.X.87	20	70	4700-5400
M06503	17/18.X.87	20	95	4700-5400
M06504	17/18.X.87	20	131	4700-5400

GAS KINEMATICS IN THE CENTRE OF NGC 5929

Up to now the mean line-of-sight velocity of two gaseous clouds was taken for the galaxy systemic velocity. However, measurements of V_r from absorption lines in the spectrum of NGC 5929 nucleus give the following values:

from MgI λ5184 A line $V_r = 2454\pm50$ km/s,
from FeI λ5269 A $V_r = 2391\pm50$ km/s,

i.e. taking the mean, the line-of-sight velocity of stellar population in the galaxy centre (which can be naturally identified with the systemic velocity) is equal to 2422±30 km/s. This fact changes everything essentially: the phenomenon, which in the cross-section at P.A. 44° could be considered as low-velocity cloud, is in reality the main disk of the galaxy. This agrees with the rather symmetrical distribution of the low-velocity emission relative to the nucleus in the cross-section at P.A. 44°: it extends by 4″ to the south-west and by 7″ to the north-east. In general we see the main disk at all four position angles; but the traces of rotation can be noticed only at P.A. 44°, which is close to the location of photometrical major axis. An amplitude of ΔV_r, which can be referred as to the main galaxy disk rotation, does not exceed 30 km/s, that can be explained by small inclination of the galaxy disk to the sky plane; the south-west side of the galaxy is moving toward us. Near the nucleus itself we can suspect an area of reverse inclination, the middle of which is shifted by ≃2″ to the north-east from the nucleus. If this result is confirmed, it would be explained by the bar-like perturbation of the central potential which should result from the close interaction with NGC 5930 (Noguchi, 1987)

And what about the low-velocity cloud? Does it exist? Really we observe it at P.A. 70° and 95°: at P.A. 70° we observe it in H_β line (which is shifted down by its line-of-sight velocity relative the low-velocity component of [OIII]), and at P.A. 95° it dominates in the low-velocity component of [OIII] and H_β. The mean line-of-sight velocity of this gaseous cloud is 2370 km/s, i.e. by 50 km/s lower than the systemic galaxy velocity; at P.A. 95° it extends by 4″ to the east from the nucleus and thus it is easily identified with that extended structure in emission lines which was observed by Keel (1985) and Whittle et al. (1986): ellipsoid of 4″ in diameter, extended at P.A. = $80\text{-}85^\circ$ mainly to the east from the nucleus. Apparently we observe emission stratification in this cloud: H_β is well seen in the direction of P.A. 70°, and [OIII] - in the direction of P.A. 95°. On the west boundary of

this cloud, by 0.7″ from the nucleus, there is one of the brightness centres in radio continuum and in optical forbidden lines.

The high-velocity cloud according to our data is also an extended object: it extends by 7″ (1.2 kpc) in the direction of P.A. 44° (cloud minor axis?) and by 18″ (3.1 kpc) perpendicularly to this - at P.A. 131° (cloud major axis?). Except this, at all position angles emission lines reveal some velocity gradients. But if at P.A. 44°-95° this gradient can be explained by the proper rigid-body rotation of the cloud, in the same sense as the galaxy itself, with a linear rotation velocity of ≃ 30 km/s on the edge, around the axis which is coincident with the major axis of this ellipsoidal cloud, then at P.A. 131° the line-of-sight velocity of the high-velocity component, which dominates along all the slit, grows to both sides from the nucleus. It is difficult to imagine kinematical picture which could naturally agree with our data for high-velocity component. The brightness centre in radio continuum and in optical forbidden lines is on the cloud edge being close to the nucleus. The mean line-of-sight velocity of the cloud is 2690 km/s, i.e. by 270 km/s differs from the systemic velocity of the galaxy.

DISCUSSION

After we have measured line-of-sight gas velocities in the main disk of the galaxy, we have faced to the necessity to reconsider everything that occurs in the central region of NGC 5929. In the model of "jet", two plasmons, thrown out of the nucleus in the opposite directions which generate both compact brightness centres in radio continuum and in optical emission lines, and as well as velocity anomalies (Taylor et al., 1989) - it is supposed that the both clouds are absolutely symmetrical according to their geometry and velocity, and also are very compact. In our case it is quite different. The mean line-of-sight velocity of the eastern, low-velocity cloud with respect to the galaxy centre is -50 km/s, and that of the western, high-velocity one is +270 km/s. The eastern cloud is extended at P.A. 80-85° by 0.7 kpc, and the western one - at P.A. 130° by 3 kpc! Relative velocities of both clouds cannot be explained by their participation in the galaxy rotation, since they move oppositely to the galaxy rotation sense. As to the eastern cloud, we can suppose that we deal with the radial gas motions in the galaxy plane, similar to what we have detected in galaxies with the nonaxisymmetrical potential in the centre - *Mrk* 573, 79 and 1126 (Afanasiev and Sil'chenko, 1990a and 1990b). However, for the western cloud this interpretation is not applicable: its ΔV_r= 270 km/s exceeds by an order the maximum projection of the rotation velocity onto the line of sight! Taking into account that NGC 5929 is seen face-on, it is naturally to suppose that the western cloud moves as a whole perpendicularly to the galaxy plane. Since the systemic velocity of NGC 5930 is also higher than that of NGC 5929, it is more likely that the western cloud is perturbed by interaction of two galaxies: remember that the end of the spiral arm of NGC 5930 penetrates into NGC 5929 nucleus just from the west. But to draw the final conclusion on the nature of the western cloud, additional observations are necessary, which we are going to carry out with

the new spectrograph MPFS (Afanasiev et al., 1990).

The emission spectra of compact brightness centres, located at the cloud edges close to the nucleus, reveal rather high excitation which allows to classify them as Seyfert nuclei. However, emission line component widths in NGC 5929 are extraordinary small (174 and 192 km/s: Keel, 1985) compared with the typical values for Seyfert 2 nuclei (500 km/s). And the line intensity ratios used for classification, [OIII] $\lambda 5007/H_\beta = 4.10$ and [OII] $\lambda 3727/[OIII]\ \lambda 5007 = 1.05$ (Keel et al., 1985), in NGC 5929 are on the boundary between Seyferts 2 and LINERs. If we compare emission line intensity ratios in NGC 5929 spectrum with the theoretical calculations of gas emitting in shock waves (Raymond, 1979; Shull and McKee, 1979) then we see that such an emission spectrum may be produced by the gas being excited with the shock wave. So the compact radio centres in NGC 5929 nucleus can really be the regions of the shock wave, formed due to velocity jump on the boundary between high- or low-velocity cloud and the galaxy disk.

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Поступила в редакцию
23 мая 1990 г.