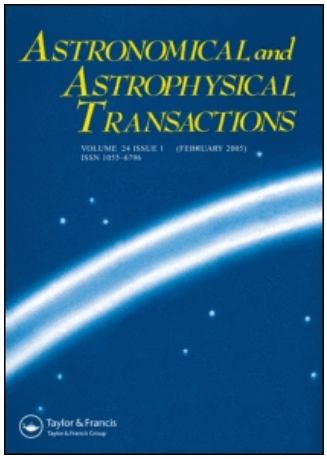

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

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Online Publication Date: 01 January 2003
To cite this Article: Pronik and Metik (2003) 'Signs of flows and shocks in variable Balmer line profiles of the Seyfert galaxies NGC 3227 and NGC 7469', Astronomical & Astrophysical Transactions, 22:4, 713 - 717
To link to this article: DOI: 10.1080/1055679031000086577
URL: http://dx.doi.org/10.1080/1055679031000086577

Astronomical and Astrophysical Transactions
Vol. 22, Nos. 4–5, August–October 2003, pp. 713–717

SIGNS OF FLOWS AND SHOCKS IN VARIABLE BALMER LINE PROFILES OF THE SEYFERT GALAXIES NGC 3227 AND NGC 7469

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(Received September 10, 2002)

There is a widely held opinion that the narrow components of the emission line profiles in the spectra of AGNs are produced by gas streams and flows. The spectral data obtained and collected for the Seyfert galaxies NGC 3227 and NGC 7469 showed that the profiles of the Balmer lines contain components that maintained their positions over 9–25 years. We suppose that the components can be caused by long-lived flows or jets in broad-line regions. Night-to-night variations in the emission line H_β and H_γ profiles over 3 days were detected. We suppose that short-term variability of the Balmer lines can be produced in short-lived shocks in gas flows or jets.

Keywords: NGC 3227; NGC 7469; Seyfert galaxies; Active nuclei; Optical variability

1 OBSERVATIONS

53 spectra for NGC 3227 and 23 spectra for NGC 7469 in the spectral region 3700–7300 Å were obtained with a 6 m telescope on January 12–15, 1977, during the maximum and minimum respectively of the nucleus brightness. The seeing was (1–3)″, the spectral dispersion about 95 Å mm^{-1} and the spectral resolution about 8 Å. Details of the observations and the treatment have been given by Pronik et al. (1997).

Equivalent widths (EW_λ) and profiles of the emission lines H_γ, H_β, [O III] ($\lambda = 4959$ and 5007 Å), (H_α + [N II]) were obtained. The profiles were studied to reveal their night-to-night variability and were compared with the profiles observed by different workers in different epochs to reveal long-term variability.

2 LONG-LIVED COMPONENTS OF THE BALMER LINE PROFILES

Figure 1 shows the profile of the H_β line obtained by us on January 12, 1977 (solid curve). Five individual components 1–5 in the line profile are clearly seen. Their shifts of component 2 are +25, −6.5, −12 and −32 Å (+1500, −400, −725 and −2000 km s^{-1}) respectively.

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ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/1055679031000086577

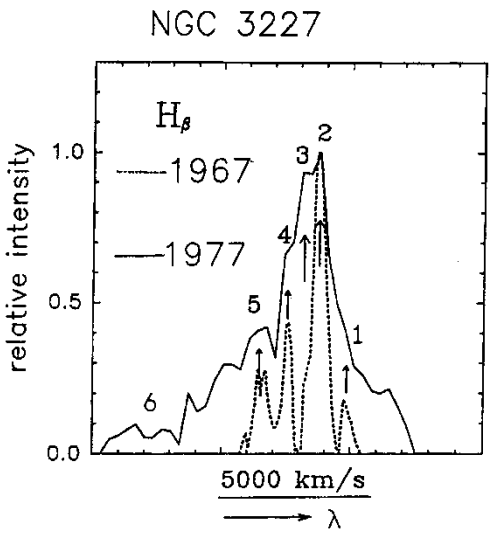

FIGURE 1 Comparison of the H_β line profile in the spectrum of the Seyfert galaxy NGC 3227 obtained on January 12, 1977 (——), with the profiles on March 8, 1967 (– – –), obtained by Rubin and Ford (1968). The arrows show the common components of the emission lines for these two dates.

Components 1 and 5 were identified in the H_γ profile and estimated in the H_α line profile. The dashed curve in Figure 1 gives the profile of the H_β line observed on March 8, 1967, by Rubin and Ford (1968). The NGC 3227 nucleus had minimum brightness on March 8, 1967, and maximum brightness on January 12, 1977. From minimum to maximum brightness the profile of the H_β line changed drastically. It became twice as broad, the blue wing became broader than the red wing, and a blue bump 6 appeared at the end of the blue wing. At the same time, components 1–5 coincided markedly on both dates, maintaining their radial velocities over 9 years, from 1967 to 1977.

Spectra obtained in 1971–1972 allowed Pronik (1975) to suppose that the profiles of the H_δ, H_γ and H_β lines in the spectrum of the NGC 7469 nucleus contain components that maintain their positions over a year. Pronik et al. (1997) compared the profiles of the emission lines H_γ, H_β and [O III] ($\lambda = 4959$ and 5007 Å) obtained in the spectra of the NGC 7469 nucleus on January 13–15, 1977, with the profiles observed by different workers in 1943–1989 during different phases of brightness of the nucleus. Among these profiles were obtained in the phase of extremely high nucleus brightness in October 1975 and during the deep minimum at the end of 1989. In these results, four components in the central part of the H_β profile were revealed to be shifted by $+25$, $+7$ and -6 Å ($+1500$, $+500$ and $-250\,\mathrm{km\,s^{-1}}$) from the central component. They maintained their radial velocities for about 25 years.

3 NIGHT-TO-NIGHT VARIATION OF HYDROGEN LINE PROFILES

The profiles of the H_α, H_β and H_γ lines obtained by us on January 12–15, 1977, for NGC 3227 and NGC 7469 were examined for night-to-night variations.

The comparisons of the shapes of the profiles of the H_γ, H_β and H_α lines in the NGC 3227 spectra on January 12, 1977, with those obtained on January 14, 1977, allow us to speculate the following.

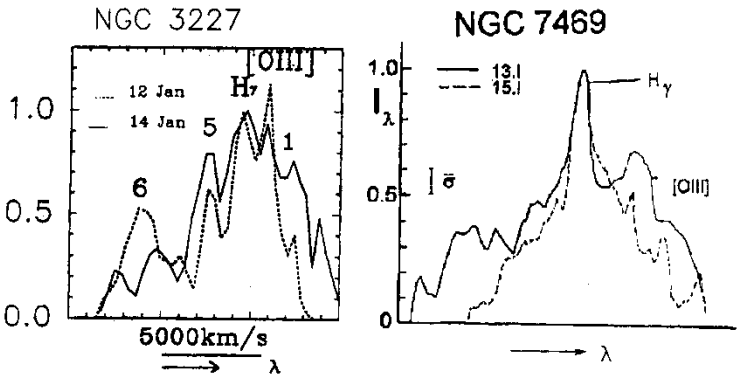

FIGURE 2 (left) Comparison of the H_γ line profiles in the spectrum of the NGC 3227 nucleus for January 12, 1977; profiles were matched by the [O III] ($\lambda = 4363$ Å) line. Components 1, 5 and 6 are the same emission components as in Figure 1. (right) Comparison of H_γ line profiles in the spectrum of the NGC 7469 nucleus for January 13, 1977, and January 15, 1977; σ is the average error of the nightly mean profile.

(i) From January 12, 1977, to January 14, 1977, the intensities of components 1 and 5 increased compared with the intensity of the central component and the intensity of blue and red broad wings increased too.
(ii) The degree of variability in the profiles increased with increasing number of lines in the Balmer series. The highest variation was observed for the H_γ line profile, which can be seen in Figure 2(left).
(iii) A 3 day variation was detected mainly in the blue parts of the H_γ and H_β line profiles.
(iv) The blue and red wings and components 3–5 shown in Figure 1 became brighter compared with component 2 when EW_β decreased. If it is assumed that a decrease in the EW_β is caused mainly by increasing of the continuum level then increasing of the continuum is accompanied by increases in the intensities of the blue emission components 3–5. These facts permit us to speculate that the lag in the flux variation of the emission lines from continuum variation was not more than 1 day.

The data obtained on the variation in the profiles and on EW_λ for the H_α, H_β and H_γ lines permit us to argue that there was a flare in the region of the emission lines of the NGC 3227 nucleus on January 12–15, 1977.

Pronik et al. (1997) observed the emission line variability of the nucleus of NGC 7469 on January 13–15, 1977. The variability was interpreted as being connected with the decline of a short-lived flare, which probably occurred before these dates. In Figure 2(right), one can see the decrease in the broad H_γ wings from January 13, 1997 to January 15, 1977. This event looks like that of the three day flare in the NGC 3227 nucleus. The difference was in the phase of the flare activity of the nucleus. In the case of NGC 3227 we observed an increasing flare phase, and in the case of NGC 7469 a decreasing flare phase.

4 DISCUSSION

4.1 Multicomponent Profiles as Evidence of Flows in the Nuclei of NGC 3227 and NGC 7469

One can suppose that the emission components of Balmer line profiles in the spectra of Seyfert galaxies NGC 3227 and NGC 7469 that maintain their position for 9 and 25 years

respectively reflect the ingredients in the gaseous structure of nuclei. One can speculate that these narrow components of Balmer emission line profiles are produced by gas streams and flows.

4.2 Characteristics of Several-Day Flare Regions in the NGC 3227 and NGC 7469

Night-to-night variations in the Balmer line profiles observed in spectra of NGC 3227 and NGC 7469 exhibits the characteristics of small regions of short-lived flares.

(i) The dimension of the flare region in the NGC 3227 nucleus is approximately 3 1.d ($\sim 7.7 \times 10^{15}$ cm). It is not more than 0.2 of the whole broad-line region (BLR) dimension which equals about 4.5×10^{16} cm.

(ii) Variation in the H_γ profile was more than the variation in the H_β profile and variation was not observed in the H_α profile. Therefore we speculate that the emission of broad variable hydrogen lines has an inverse Balmer decrement. Fitting of the observational data by the grid of theoretical Balmer decrements given by Gershberg and Shnoll (1974) allows us to suppose that the gas-emitting variable Balmer lines are ionized and excited mainly by a collisional process. The gas of the flare must be opaque, hot and inhomogeneous with the physical conditions of a plasma with an electron temperature $T_e \approx 25\,000$ K and electron concentration $n_e \approx 10^{12}$–10^{14} cm^{-3}.

(iii) Optical depth τ of the emitting gas depends on the number of lines in the Balmer series: $\tau_\alpha \geq \tau_\beta \geq \tau_\gamma$. If $\tau_\alpha \geq \tau_\beta \geq 1$ the observed H_α light contains mainly the emission of the outer layers of emitting gas and H_γ light contains more emission from the inner regions. The highest variations were observed in the H_γ profile; therefore we suppose that the flare is located in the inner layers of gas-emitting Balmer lines.

(iv) A 3 day variation was detected mainly in the blue parts of H_γ and H_β line profiles. During the flare the blue wings of the Balmer lines became broader than the red wings. Such variations can be modelled by an outflow of emitting material (Capriotti et al., 1982; Vrtilek, 1985).

(v) The shape of the H_α line profile does not change during the flare, demonstrating the expansion of the inner layers does not reach the outer layers of the flare gas.

(vi) The flare in NGC 7469 was observed during the minimum brightness of its nucleus. The flare in NGC 3227 was observed during the maximum brightness of its nucleus. Therefore short-time flares are not connected to the general brightness of the galaxy nuclei.

4.3 Two Gas Fractions in the Broad-Line Regions of the NGC 3227 and NGC 7469 Nuclei

The data obtained show that there were almost simultaneous variabilities in the braod H_γ line and the narrow components of the H_β and H_γ lines during the several-day flare in the nuclear spectra of the Seyfert galaxies NGC 3227 and NGC 7469. This can be explained only if there is an overlap of the BLR and the narrow-line region of these AGNs. The mixed regions were observed only during short-time flares.

As a result we suppose that in NGC 3227 and NGC 7469 there are two gas fractions in the BLRs connected with two independent sources of nuclear activity.

4.4 Characteristics of the Large Broad-Line Region of Approximate Size 4.5×10^{16} cm

(i) Variations in the large BLR lag the variation in the continuum by about 17 l.d.
(ii) Most characteristics of the optical emission spectrum of the BLR can be understood on the basis of photoionization models (Osterbrock et al., 1992).
(iii) The large BLR contain flows and streams that are around one or two dozen years old.
(iv) There are small BLRs inside these flows which are observed during short-lived flares.

4.5 Characteristics of the Small Broad-Line Region of Approximate Size 8×10^{15} cm ≈ 3 l.d.

(i) Variations in the BLR and continuum occurred almost simultaneously.
(ii) Ionization and excitation of the small variable BLR arise as a result of collisional processes.

The contribution of each region in the total emission of AGNs depends on the phase of the nuclear brightness and several-day flares.

References

Capriotti, E. R., Foltz, C. B. and Peterson, B. M. (1982). Astrophys. J., 261, 35.
Gershberg, R. E. and Shnoll, E. E. (1974). Izv. Krymskij Astrofiz. Obs., 50, 122.
Osterbrock, D. E., Tran, H. D. and Veilleux, S. (1992). Astrophys. J., 389, 156.
Pronik, I. I. (1975). In: Sherwood, V. E. and Plaut, L. (Eds.), Variable Stars and Stellar Evolution, IAU Symposium Proceedings, Vol. 67, pp. 605–609.
Pronik, I. I., Metik, L. P. and Merkulova, N. I. (1997). Astron. Astrophys., 318, 721.
Rubin, V. C. and Ford, W. K., Jr (1968). Astrophys. J., 154, 431.
Vrtilek, J. M. (1985). Astrophys. J., 294, 121.