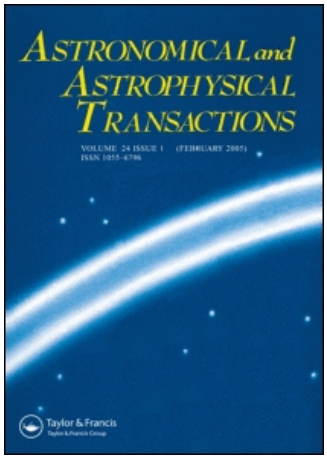


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# SPECTRAL OBSERVATIONS OF THE NUCLEUS REGION OF THE SEYFERT GALAXY 3C390.3 WITH THE 6 m TELESCOPE

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The results of panoramic spectrophotometry of the nucleus region of 3C390.3, obtained with the 6 m telescope in spring 1995, are presented. It is shown that radiation in [OIII] emission lines corresponds to the region with $r < 2''$. Blue and red "bumps" of the profile of the $H_\beta$ emission line have approximately similar velocities relative to its narrow component ($\pm 3500$ km s$^{-1}$). Ratios of their fluxes confirm sinusoidal dependence with a period of $\sim 10$ years and correspond to maximum values of 1975, 1985. Gauss-analysis of $H_\beta$ and [OIII] line profiles shows the possible presence of a component with intermediate velocity dispersion ($> 1000$ km s$^{-1}$) at the same velocities as in the narrow component.

KEY WORDS Seifert galaxies, broad emission lines, narrow emission lines, spectral variations, photometry in spectral lines

## 1 INTRODUCTION

Optical spectra of 3C390.3 were taken at the 6 m telescope as part of an ongoing global monitoring programme of variability of active galactic nuclei ("AGN Watch"). 3C390.3 is the first radio emission AGN for which this monitoring (1995–1996) is being performed.

In this paper we present some observational results of 3C390.3, obtained by methods of panoramic spectrophotometry (long slit and multi-pupil spectrograph) and briefly describe the state of the 3C390.3 nucleus in spring 1995.

## 2 OBSERVATIONS

In April 1995 spectra of 3C390.3 were obtained at the prime focus of the 6 m telescope with the UAGS spectrograph (a long slit mode) in the spectral region

4000–5400Å. The slit size was $3'' \times 80''$, the scale along the slit was $0.38''$ px$^{-1}$, and the spectral resolution was 12Å. A CCD-matrix with (530 × 580) px was used as a detector.

In May spectra of the central part of this galaxy were also taken at the prime focus of the 6 m telescope with a multi-pupil field spectrograph (MPFS) and CCD. The spectral range, dispersion and a spectral resolution were 4500–5400Å, 1.5Å px$^{-1}$, 4 Å, respectively. An array of 8 × 10 squared micro-lenses was used. The scale of the image constructed by one lens was $1.''2 \times 1.''2$. To correct for the spectral sensitivity of the equipment, a star with the known energy distribution was observed every night.

Note, that the monitoring program was fulfiled as a background one with the 6 m telescope, so the observations are carried out at non-photometrical conditions.

The journal of observations is presented in Table 1.

**Table 1.** The journal of observations

| *UT Date* | *Exposure (minute)* | *Spectal region (Å)* | *Dispersion (Å/pixel)* | *Seeing (arcsec)* | *Detector* |
|---|---|---|---|---|---|
| 1995 April 25 | 4 x 10 | 4000–5400 | 3 | 2 | UAGS+CCD |
| 1995 May 22 | 2 x 10 | 4900–5450 | 1.5 | 3 | MPFS+CCD |
| 1995 May 24 | 3 x 20 | 4900–5450 | 1.5 | 1.5–2 | MPFS+CCD |
| 1995 May 30 | 2 x 10 | 4900–5450 | 1.5 | 2 | MPFS+CCD |

*Note.* MPFS is Multi–Pupil Field Spectrograph

Reductions are done by software developed in SAO RAN (Vlasiouk, 1993) which includes: eliminating the cosmic particles, corrections for geometrical distortions, non-inhomogeneities of lens transparence, spectral sensitivity of the equipment etc. The width of the instrumental profile, determined from the comparison of spectral lines, is FWHI $\approx$ 240 km s$^{-1}$ (MPFS) and 700 km s$^{-1}$ (UAGS).

## 3 RESULTS

3C390.3 is a known *N*-galaxy with very wide emission lines. The high variability of the flux from its nucleus both in continuum (X-ray, UV, optical ranges) and emission lines is well determined. In broad emission line profiles of 3C390.3 an unusual velocity structure is observed, which manifests itself strongly in different properties of variability in red and blue wings and cores of the hydrogen lines (Zheng *et al.*, 1991).

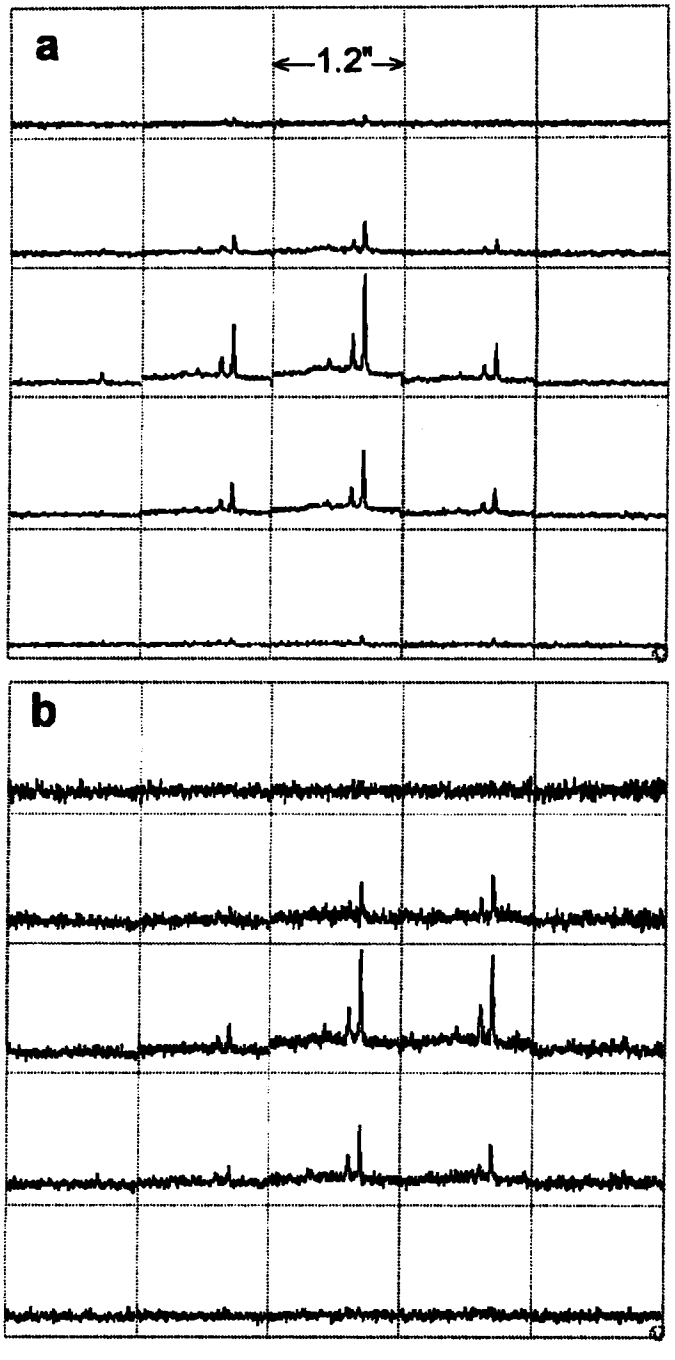


**Figure 1** Spectra of the central region of 3C390.3: *a*, 22 May 1995; *b*, 24 May 1995. Spectra recoded with a multi–pupil integral spectrograph (MPFS). The distances between the squares are equal to 1.2 arcsec.

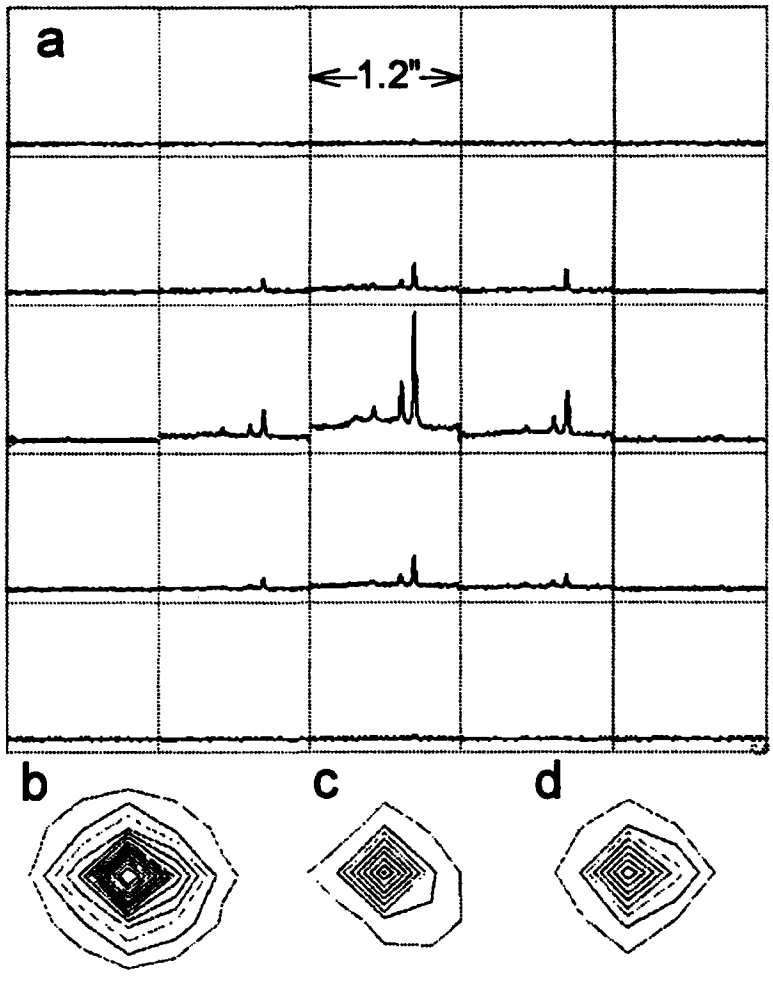


**Figure 2** The central region of 3C390.3 obtained on 30 May 1995: *a*, a MPFS spectrum; *b*, *c*, *d*, isophotes in the continuum, $H_\beta$ and [OIII] emission lines, correspondingly.

### *3.1 MPFS-Spectra*

Figures 1*a*, *b*, 2*a* show the spectra of 3C390.3 obtained with a multi-pupil field spectrograph on different nights of observations (Table 1). Each spectrum corresponds to the emission from a $1.''2 \times 1.''2$ area of the galaxy image. It is clearly seen that emission has not been registered from the emission line or the continuum of the host-galaxy behind the central region, $3.''6 \times 3.''6$ ($3 \times 3$ squares). Note also that we have not registered emission from the host-galaxy at $r > 4''$ from the centre on the average long slit spectrum with the S/N ratio $\approx 50$ in the region of the continuum from the nucleus. From the MPFS-spectra, obtained on May 30 (Table 1), summarized over the night, we constructed maps of brightness distribution for the central

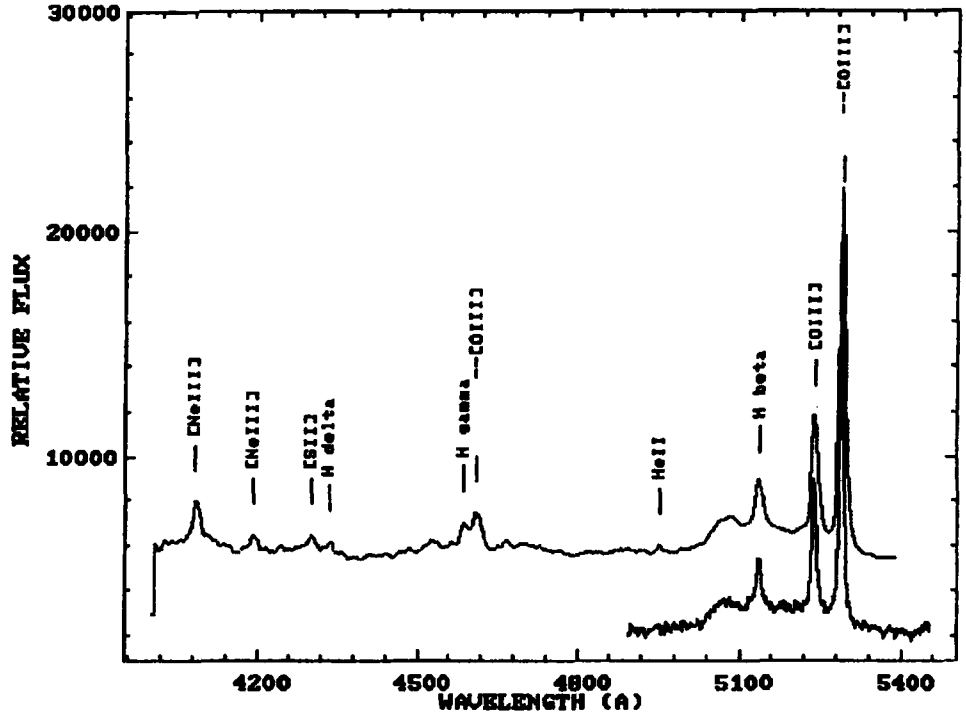


**Figure 3** A summary of the set spectrum of the 3C390.3 nucleus observed, obtained with the long slit (top), and with the multi-pupil spectrograph (MPFS) (bottom).

region of 3C390.3 in the continuum (4900–5400Å), in emission lines [OIII] 5007Å and in the narrow component $H_\beta$ (Figure 2*b–d*). The isophotes in lines and in the continuum look almost round to an accuracy of the errors in plotting isophotes from the small number of points. The full width of these images at half intensity is FWHI $\approx 2''$, which coincides with an estimate from seeing stars that night.

So, if there are structural peculiarities of brightness distribution in lines (like elongated images in [OIII] line, as is observed in several short-distance Seyfert galaxies), then they lie under the scattering circle.

Thus, from our spectra one can affirm that radiation in emission lines comes from the region with $r < 2''$.

Figure 3 (bottom) shows the MPFS-spectrum of the central, $3''.6 \times 3''.6$, region of 3C390.3 summarized during one set of observations.

### *3.2 Long Slit Spectra*

The long slit spectrum of 3C390.3 was obtained by averaging along the slit from nine pixels that corresponds to $3''.4$ (Figure 3 (top)). Visual comparison of our spectra, Figure 3, with the spectra obtained earlier by other observers (Osterbrock

*et al.*, 1976; Barr *et al.*, 1980; Netzer, 1982; Perez *et al.*, 1988, etc), shows that our spectra most closely resemble the average bright state spectrum of 3C390.3 from the INT data of 1985–1986 (Perez *et al.*, 1988, Figure 2).

### *3.3 $H_\beta$ Emission Line Profiles*

A "blue bump" is clearly seen at the blue wing of $H_\beta$ emission line (Figure 3), whereas the red side of the profile is weaker without a distinct peak in April 1995 (a long slit) and with a small peak in May 1995 (MPFS). A similar $H_\beta$ profile was observed in 1975 (Barr *et al.*, 1980).

Following Veilleux and Zheng (1991) we determined from our average spectra the ratio of the observed fluxes in the blue (5020–5100Å) and the red (5150–5200Å) wings of $H_\beta$: $F_b/F_r \approx 1.4$. This value is in good accord with the periodic ($\approx$ 10 years) sinusoidal dependence for the flux rations $F_b/F_r$, obtained by Veilleux and Zheng (1991), and corresponds approximately to the sinusoid maximum. The maximum values of $F_b/F_r$ were observed in 1975 and 1985.

However, in the aforementioned approach the red wing of $H_\beta$ is strongly underestimated. Besides, Veilleux and Zheng (1991) studied positions of bump maxima visually. In our spectra a distinct maximum in the red wing of $H_\beta$ is not seen. For the quantitative investigation of $H_\beta$ profile Gauss–analysis method was used (Vlasiouk, 1993). As a zero-order approximation the $H_\beta$ profile was represented by two broad Gaussians corresponding to the blue and red bumps. It turned out that after subtraction of these components, the rest $H_\beta$ and [OIII] lines do not fit one Gaussian due to the broad wings with intermediate velocity dispersion (between the narrow and the broad components). The residual [OIII] and $H_\beta$ lines were approximated by two Gaussians, intermediate and narrow, with coinciding centers. The results of the Gauss–analysis described for MPFS (*a*) and UAGS (*b*) spectra are shown in Figure 4. In this procedure of decomposition a considerable residual with a maximum at $\lambda \approx 4970$Å remained in the red wing of [OIII] 4959Å, possibly an additional $H_\beta$ component. Some parameters of Gaussians which describe bumps are given in Table 2. Positions of maxima of the blue bump, determined from the MPFS and UAGS spectra, coincide, and for the red bump they differ considerably. This is caused by large errors of UAGS determinations due to the absence of distinct maxima in the red wing. So, we consider it necessary to take the maximum value of the red bump, determined from MPFS spectra. The positions of the maxima of the

**Table 2.** Parameters of $H_\beta$ bumps

| *$H_\beta$ bumps* | *$V_r = V_{bump} - V_{narrow}$ (km/s)* | | *FWHI (km/s)* | | *Flux (arbitrary units)* | |
|---|---|---|---|---|---|---|
| | MPFS | UAGS | MPFS | UAGS | MPFS | UAGS |
| blue | $-3505 \pm 121$ | $-3510 \pm 23$ | $5054 \pm 232$ | $4700 \pm 306$ | 439 | 454 |
| red | $3550 \pm 180$ | $2431 \pm 570$ | $6265 \pm 269$ | $6913 \pm 1234$ | 502 | 497 |

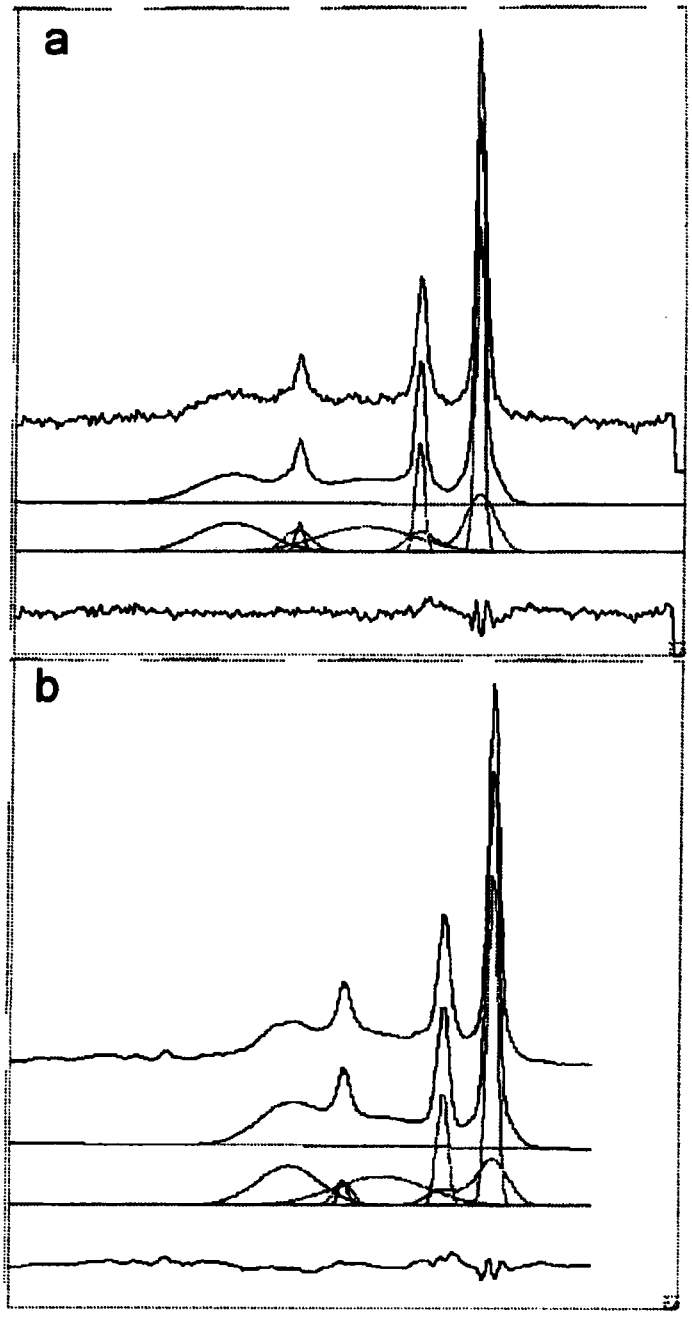


**Figure 4** The result of decomposition of emission lines in the 3C390.3 nucleus by the method of Gauss analysis for MPFS (*a*) and long slit (*b*) spectra. In both parts the upper lines represent the observed spectrum; the lower follow correspondingly: the sum of the Gauss-profiles and the Gauss–profiles separately; the lowest lines are the remainders after approximation.

blue and red bumps as related to the narrow component of $H_\beta$ do almost coincide with respect to the modulus and are at $V \approx 3500$ km s$^{-1}$.

## 4 SUMMARY

The main results of the panoramic spectrophotometry of the nucleus region of 3C390.3, obtained with the 6 m telescope in April and May 1995 are the following:

(1) The spectra of the 3C390.3 nucleus are similar to the spectra observed in 1985–1986 (Perez *et al.*, 1988).

(2) The [OIII] 4959Å, 5007Å emission comes from the nucleus region with $r < 2''$.

(3) The host-galaxy is not registered in our spectra at $r > 4''$.

(4) The $H_\beta$ profile is characterized by two emission bumps at velocities $\pm 3500$ km s$^{-1}$ relative to the narrow component. We confirm Veilleux and Zheng's (1991) sinusoidal dependence with a period of $\approx 10$ years for the ratios of the observed fluxes of the blue and red bumps. Our value of this ratio corresponds to the maximum ones which were observed in 1975 and 1985. The observed $H_\beta$ line profiles can be explained by the model of inhomogeneous line-emitting disk or biconical BLR.

(5) Our Gauss-analysis of narrow $H_\beta$ and [OIII] emission line profiles indicates the presence of a relatively broad (FWHI $> 1000$ km s$^{-1}$) component at velocities coinciding with their narrow (FWHI $\approx 400$ km s$^{-1}$) component. These relatively broad components are probably emitted by denser regions than the narrow ones.

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*References*

Barr, P., Pollard, G., Sanford, P. W., Ives, J. C., Ward, M., Hine, R. G., Longair, M. S., Penston, M. V., Boksenberg, A., and Lloyd, C. (1980) *Mon. Not. R. Astron. Soc.* **193**, 549.
Osterbrock, D. E., Koski, A. T., and Phillips, M. M. (1976) *Astrophys. J.* **206**, 898.
Netzer, H. (1982) *Mon. Not. R. Astron. Soc.* **198**, 589.
Perez, E., Penston, M. V., Tadhunter, C., Mediavilla, E., and Moles, M. (1988) *Mon. Not. R. Astron. Soc.* **230**, 353.
Vlasiouk, V. V. (1993) *Bull. Spec. Astron. Obs. (North Caucasus)* **36**, 107.
Veilleux, S., and Zheng, W. (1991) *Astrophys. J.* **377**, 89.
Zheng, W., Veilleux, S., and Grandi, S. A. (1991) *Astrophys. J.* **381**, 418.