Active Galactic Nuclei and Related Phenomena
IAU Symposium, Vol. 194, 1999
Yervant Terzian, Daniel Weedman, Edward Khachikian, eds.

Variable Sources in Active Galactic Nuclei

V. A. Hagen-Thorn, S. G. Marchenko, V. A. Yakovleva, A. V. Hagen-Thorn

St.-Petersburg State University, Bibliotechnaya Pl.2, St.-Petersburg 198904, Russia, vaht@aispbu.spb.su

1. Introduction

The problem of the activity of extragalactic objects is one of the main problems of current astrophysics. There are many manifestations of activity but the photometric and polarimetric variability in IR, optical, UV and X-ray regions is probably one of the most important. The sources responsible for the variability are placed in the nearest neighbourhood of a central engine. Clarifying the nature of these sources might give a tool to the solution of the problem of nuclear activity in general.

Several components (host galaxy, accretion disk, etc) contribute to the observed radiation. Because in the photometric and polarimetric observations their radiation is fixed in common, extracting the radiation of the variable source is not a simple task. In various spectral regions the contributions of those components are different. However in all regions the radiation of active sources may be extracted by the most reliable way on the basis of variability studies.

For clearing up the nature of the variable sources, it is of first rate importance to know their spectral energy distributions. These distributions may be found from the analysis of the multicolour data on photometric variability.

Another important feature of the active sources is polarization of their radiation. The analysis of the data on polarimetric variability may give information about their polarization properties.

It is well known that the highest activity among the extragalactic objects is observed in blazars. Therefore, just the blazars are investigated more extensively with the purpose to find the properties of variable sources though the other active extragalactic objects (for instance, Seyfert galaxies) are suitable for such analysis also.

At present the instantaneous spectra of active objects in a wide frequency range (from radio to X-rays or even γ-rays) are constructed as a result of cooperative work. These spectra are obtained for different brightness levels of the objects, and some correlations between various *observed* parameters are studied. But the success of such an approach for studying the properties of *variable sources* is limited and some conclusions about their nature are not strictly based.

The comparison of variations in different regions shows that variable sources seen in these regions are connected with each other because the variations (maybe with the exception of X-rays) are correlated (sometimes with time lag). But to confirm the identity of these sources it is necessary to compare the spectral and polarization properties of the sources acting in various spectral regions.

https://doi.org/10.1017/S0074180900162333 Published online by Cambridge University Press

2. The technique of extracting variable sources from the observations of photometric and polarimetric variability

Let us suppose that the variability within some time interval is due to a single variable source and we have multicolour photometric and polarimetric data distributed within this interval. As was shown by Choloniewski [1] for photometric data and by the author [2] for polarimetric ones, if the variability is caused only by flux variations but the relative spectral energy distribution (for photometry) and relative Stokes parameters (for polarimetry) of the variable source are unchanged, then in the flux space $\Phi_1, \ldots, \Phi_n$ (for photometry, here n is the number of spectral bands used) or in the space of absolute Stokes parameters I, Q, U (for polarimetry) the observational points must lie on straight line. The direction of this line give the flux ratios for the *variable source*, i.e. its relative spectral energy distribution (for photometry) or relative Stokes parameters for the source (for polarimetry).

Thus if observational points in fact lie on the stright line within the observational errors (of course we may verify this considering two-dimensional pictures) one can conclude that the model of a single variable source with unchanged spectral energy distribution (for photometry) or with unchanged relative Stokes parameters (for polarimetry) is valid. Determination of direction (the slope) of the straight line gives the relative spectral energy distribution of the variable source (for photometry) or its polarization parameters (for polarimetry).

This technique has two advantages. (1) The information about the variable source may be obtained *without* the knowledge of its contribution to the total flux (for photometry) or to the observed absolute Stokes parameters (for polarimetry). (2) For the construction of the relative spectral energy distribution of the variable source in a wide spectral range it is not necessary to have *simultaneous observations in all wavelengths.* For instance, the variable source may be extracted in JR and optical separately and then these spectra may be connected by the comparison of the simultaneous data in only two spectral bands (say, K and B).

The limitation of this technique is obvious: it is applicable in the case when within a given time range the single variable source determines the behaviour of the AGN and the variability is due to variations in its flux level only. But often this is the case. The details of using this technique may be found in our paper [3].

3. Results

The technique of extracting variable sources described above was used by the author and his colleagues many times (it was used also by Winkler et al. [4]). The most detailed investigations made by us are for blazars 3C 345 [5-7], OJ 287 [3,8-9] and BL Lac [1O,11].In these works one can find many examples confirming the constancy of polarization parameters and spectral energy distributions of variable sources responsible for photometric and polarization behaviour of the blazars.

Here we give one example concerning the Sy 2 galaxy NGC 1275 (Fig. 1). The data are from Lyuty [12,13]. The time range of observations is several

https://doi.org/10.1017/S0074180900162333 Published online by Cambridge University Press

years. We see that the points lie on straight lines quite well. This means that the spectral shape of the variable source was unchanged. The shifted points belong to one outburst of 100 days duration (J.D. 2441218 - 321). Arrows show

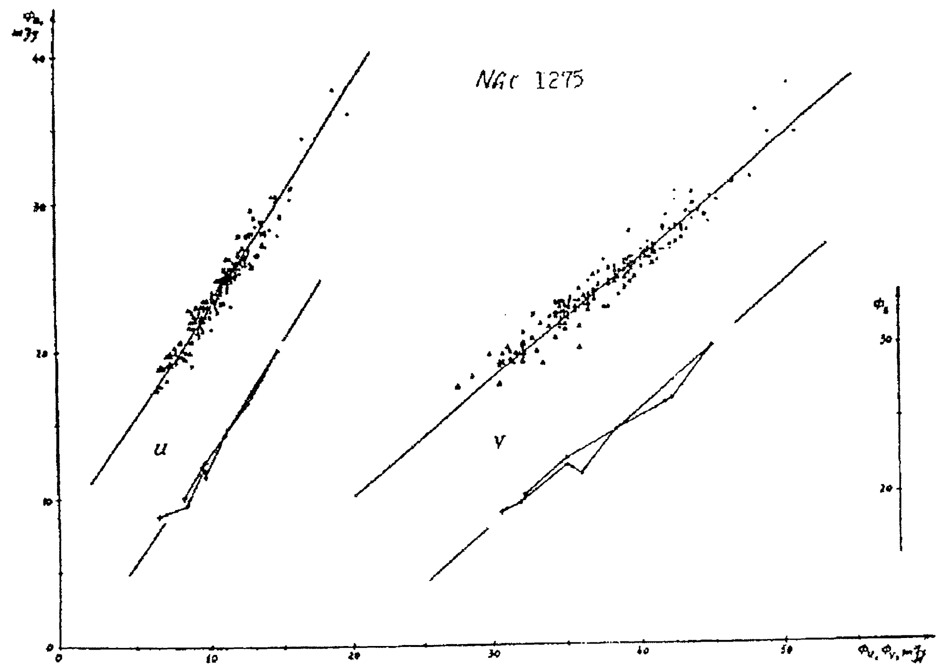

Figure 1. Flux-flux diagram for the galaxy NGC 1275, the shifted points belong to one outburst of 100 days duration.

its temporal development. The points move exactly along the straight line both at flux rise and flux decrease. This is a very important result because we must reject any variability mechanism resulting in changes of spectral shape of the variable source. In particular, if the radiation is of synchrotron nature (see below) we don't see an influence of synchrotron losses in this spectral range. One can often find in the literature that observed reddening of the spectrum in decreasing part of the outburst is due to synchrotron losses in the active point source. This is not the case.

Usually the sources in JR and optical are extracted separately and then the spectrum in the whole spectral interval is built by comparison of K and B fluxes. As a rule in the composite spectrum neither shift nor break exist. This means that the *same* source acts in both regions.

The relative spectral energy distributions obtained for variable sources are found to be well represented by the spectrum of a homogeneous synchrotron source with or without high-frequency cutoff [6-7,9]. In the first case the estimation of the critical frequency $v_c = 1.608 \times 10^{13} H E_{max}^2$ may be found with high precision.

If there are no temporal changes of the relative spectral energy distribution in the region of the high-frequency cutoff, the only reason for flux variability is variation in the number of relativistic electrons in the source.

On the other hand, some flattening of the spectrum in JR region (but not in the optical) at the very top of the outburst was found for 03 287 [9]. The most probable explanation of this fact is synchrotron self-absorption.

The results of extracting the sources of polarized radiation at different variability time scales are given in Table 1. The polarization degree found for individual sources may be as high as 50%. This confirms their synchrotron nature.

Table 1. The sources of polarized radiation

OJ287	$(\Theta_{pref} = 82°)$		
Intraday:	$40\% < P < 50\%$		March 15, 1972
Interday:	$P = 43\%$	$\Theta_0 = 101°$	J.D. 2441803-808
BL Lac	$(\Theta_{pref} = 20°)$		
Interday:	$P = 27\%$	$\Theta_0 = 73°$	J.D. 2443017-022
	$P = 56\%$	$\Theta_0 = 27°$	J.D. 2443786-789
Long-term:	$P = 23\%$	$\Theta = 3°$	1972
3C 345			
Long-term:	$P = 53\%$	$\Theta = 15°$	Feb.-July, 1983

4. Conclusions

The main results of our investigations may be formulated as follows.

a) In many cases the photometric behaviour of AGN at different time scales and in different spectral regions may be explained by the existence of a single variable source which has variable flux but unchanged spectral energy distribution. In particular, this concerns the behaviour in the flares. As a rule the spectral shape in optical-*UV* region is the same from the very beginning to the end of each event.

b) The distributions are well represented by the spectrum of a homogeneous synchrotron source with or without a high-frequency cutoff. In some cases at the very top of the light curve in outburst the synchrotron self-absorption may exist.

c) The spectral shape constancy excludes all variability mechanisms resulting in a change of spectral energy distributions (for instance, fading because of synchrotron losses). Probably, the variability within each event is due to variation in the number of relativistic electrons in the source.

d)Polarization behaviour is determined by a single variable source very rarely; but if it is the case the polarization degree for the source may be as high as 50%. This may be considered as evidence of its synchrotron nature.

References

Choloniewski J., 1981, Acta Astron., 31,293-311

Hagen-Thorn V.A., 1981, Trudy Astron. Oba. Leningrad Univ., 36,20-26 (in Russian)

Hagen-Thorn V.A., 1997, Astronomy Letters, 23, 23-29

Winkler H., Glass I.S., van Wyk F. et al., 1992, MNRAS, 257, 659

Hagen-Thorn V.A., Mikolaichuk O.V., 1988, Afz, 29, 604-610

Hagen-Thorn V.A. & Yakovleva V.A., 1994, MNRAS, 269, 1069-1076

Hagen-Thorn V.A., Marchenko S.G., Takalo L.O., Sillanpää A., 1996, A&A, 306, 23-26

Hagen-Thorn V.A., 1980, A&SS, 73, 263-277

Hagen-Thorn V.A., Yakovieva V.A., Takalo L.O., Sillanpää A.,1994, A&A, 290, 1-6

Hagen-Thorn V.A., Marchenko S.G., Yakovleva V.A., 1985, Afz., 22, 1-6

Hagen-Thorn V.A., Marchenko S.G., Yakovleva V.A., 1986, Afz., 25, 634-640

Lyuty V.M., 1972, Astron. Zh., 49, 930-942

Lyuty V.M., 1977, Astron. Zh., 54, 1153-1167

https://doi.org/10.1017/S0074180900162333 Published online by Cambridge University Press