A SEARCH FOR SUPER-RAPID VARIABILITY OF X-RAY SOURCES AND OTHER PECULIAR OBJECTS

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Abstract. At the Special Astrophysical Observatory of the U.S.S.R., an experiment to detect super-rapid variability of brightness and polarization in a number of peculiar objects is being carried out. This includes the optical stars identified with X-ray sources, specifically Cyg X-1, Her X-1 and Sco X-1, as well as the so-called DC-dwarfs and some BL Lac-type objects (that is optical objects possessing a continuous spectrum). The time range of measurements varies for different objects; however as a rule, it lies within 10^{-5} to 10 s.

At the time of our observations no rapid and super-rapid fluctuations of radiation exceeding in amplitude 10% have been detected.

1. Introduction

At the present times in the SAO (Special Astrophysical Observatory) of the Soviet Academy of Sciences, an experiment is in progress to find super-rapid variability in a number of peculiar stellar-like sources. We are interested in the sources, whose nature of radiation may be connected with the physical processes in the neighbourhood of relativistic objects, i.e. neutron stars and black holes. Fluctuations of luminosity are searched in the range from several hundred nanoseconds up to several seconds. Because the theoretical predictions that some optical objects may possess super-rapid fluctuations of luminosity (Shvartsman, 1971) are not widely acknowledged, our experiment is called

2. MANIA

(Multichannel Analysis of Nanosecond Intensity Alteration)

and its participants are called maniacs. (Russian version: МАНИЯ – Многоканальный Анализ Наносекундных Изменений Яркости).

3. The Outline of the MANIA Experiment

The main difficulty of the experiment is that the expected duration of fluctuations in the luminosity of the objects is, as a rule, shorter than the average time between two neighbouring quanta entering the telescope. Because of this, the task is one of statistical analysis of the length of time intervals between the quanta radiated by the stars. The observational equipment including an on-line computer is shown schematically in Figure 1.

I will not dwell any longer upon the engineering and mathematical aspects of the experiment, since I described them ten months ago at the IAU Symposium in Warsaw

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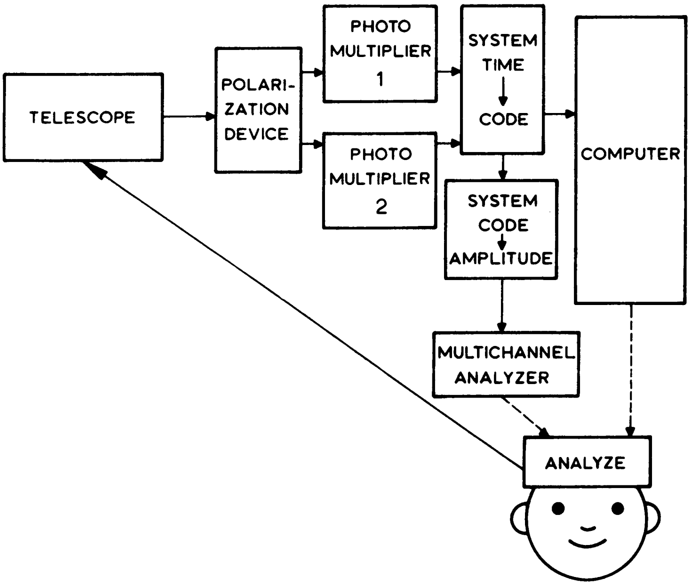

Fig. 1.

(Shvartsman, 1973), but will pass directly to the results of observations, obtained after the report in Warsaw.

4. Selection of Objects

We have observed objects belonging to three classes: DC-type white dwarfs, BL Lac-type objects and optical stars identified with X-ray sources. In the selection of the objects, the fact was taken into account that radiation generated in the neighbourhood of black holes should be of a non-thermal character, i.e. with no spectral lines. Of the objects selected DC-type dwarfs and BL Lac-type objects satisfy this criterion.

5. DC-Type White Dwarfs

DC-type white dwarfs are optical stars with no lines and with luminosities of 10^{30}–10^{31} erg s^{-1}. According to some theoretical models (Shvartsman, 1971, 1974),

TABLE I

Object	Number of sets	Time range	Limit on the amplitude of variability
EG 9	1	10^{-3} to 10s	0.04
EG 148	8	0.2×10^{-3} to 10s	0.05
EG 180	1	0.2×10^{-3} to 2s	0.06
EG 245	5	0.5×10^{-3} to 20s	0.03
EG 246	1	10^{-3} to 20s	0.04
EG 264	2	0.2×10^{-3} to 10s	0.03

isolated black holes accreting interstellar gas may manifest themselves as fluctuating objects with no lines and with optical luminosities of 10^{27}–10^{30} erg s^{-1}. Black holes must be surrounded by shining halos. However, statistical estimations show that even under optimistic assumptions the probability of coming across a black hole among ordinary DC-type white dwarfs is rather small.

At present 49 DC-type white dwarfs are known. We have so far investigated six of them. The results of the search for variability which are given in Table I are negative. Further observations are in progress; in the next few months we plan to investigate six more DC-dwarfs.

6. BL Lac-Type Objects

The second type of objects under investigation, BL Lac-type objects, are optical stellar-like sources with non-thermal spectra and without lines. They are also intensive radio sources, especially in centimeter and millimeter ranges. BL Lac objects essentially change their luminosity on a time-scale of the order of months, days and sometimes even hours. Their nature is unknown. Probably, they are all a variety of rapidly variable QSO's whose continuum radiation is much stronger than the line emission. However, another possibility is not excluded; namely, that at least some BL Lac objects are within our Galaxy and that they are, for example, massive black or white holes. In that case their radiation will be of a fluctuating character in micro- and milliseconds ranges.

Unfortunately, due to technical reasons, the quality of our recorded data of BL Lac itself turned out to be low. But we have succeeded in observing OJ 287, which is a more typical BL Lac-type object than BL Lac itself.

It is seen from Table II that fluctuations are absent either in micro-, milli-, or second rages. The result seems to indicate for the optical radiating region of OJ 287 dimensions $>10^{10}$ cm; i.e. the object is neither a black nor a white hole with a mass of several dozens or hundreds of solar masses. Of course, we have just the same result for the brightest QSO 3C 273.

7. X-Ray Sources

Table II gives the results of a search for optical variability in the stars identified

TABLE II

Object	Number of sets	Time range	Limit on the amplitude of variability
OJ 287	2	10^{-5} to 10s	0.06
3C 273	1	10^{-4} to 1s	0.02
Sco X-1	1	10^{-4} to 1s	0.02
Cyg X-1	7	10^{-4} to 3s	0.02
HZ Her	3	10^{-5} to 50s	0.05

with binary X-ray sources in the Northern Hemisphere. Theoretical models of such objects were described earlier in this symposium.

We investigated especially carefully Cyg X-1, the system almost definitely containing a black hole. No manifestations of optical variability of the object were observed in any set of observations. This is probably explained by the high luminosity of the ordinary companion which is of an order of magnitude greater than that of the X-ray source in all ranges.

From this viewpoint the system Her X-1, where the luminosity of the optical star is much less, seems more promising. We began to observe this object a month ago and at present the long-term memory of our computer stores about 20×10^6 bits of information on it. Only a small part of the data has by now been analyzed. The analysis has shown that at the corresponding moments of time the variability of HZ Her in the range from 10^{-5} up to 50 s did not surpass 5%.

The analysis of the data accumulated is now in progress, and in a fortnight a new observational set of MANIA programmes will begin.

The maniacs hope for luck.

P.S. The detailed description of the experiment (theory, procedure of observations and data processing, results and discussion) is now in press in *Commun. SAO U.S.S.R.*

References

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