1975JAVSO...4....2L

X-RAY STARS AND QUASARS: VARIABLES THAT NEED WATCHING*

by

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INTRODUCTION

As we all know so well, Astronomy is now regarded as the most glamorous of the physical sciences. Discoveries made during the last 10-20 years from space and with radio telescopes are primarily responsible for the tremendously exciting developments which have put astronomy into the limelight. The three most fascinating objects discovered recently are quasars, pulsars and X-ray sources (which in turn probably contain neutron stars and black holes). An increasing number of these fantastic sources are within the range of 6-inch telescopes, and this report is intended to draw the attention of the AAVSO to some of these sources and discuss why they are so very important to our fuller (but never complete!) understanding of their properties.

X-RAY SOURCES

The most complete listing of X-ray sources now available is the "Third Uhuru Catalogue of X-ray Sources" (Giacconi et al., Astrophysical Journal Supplement No. 237, 1974), and interested AAVSOers will find it indispensable. One hundred sixty-one objects are tabulated, complete with positions and, when known, the optical identifications. Approximately a dozen more sources have been discovered since the 3U catalog, and I will describe one of these in a moment. First, let me pick out some of the Uhuru sources which very definitely need frequent monitoring and let me briefly explain why. Incidentally, if your Swahili is rusty, Uhuru means freedom and is the name of the satellite in which were mounted X-ray telescopes built by American Science and Engineering personnel.

Scorpius X-1, the most intense X-ray source of all (and first discovered), is identified with a binary star system that varies irregularly from 12^m to 14^m and periodically with an amplitude of about $0\overset{m}{.}25$**. The periodic variation (18.9 hours) is almost completely masked by the irregular flaring. The reasons why Sco X-1 is so important are (1) the possibility that it may become a nova, and (2) the recent rapid general decrease in brightness. Harvard plates show that for the past nine years, its average brightness has been fading at a rate of about $0\overset{m}{.}1$ every three years. Perhaps this is the lull before the nova storm. (See Fig. 1 for the light curve of Sco X-1).

* Based on an address given to the AAVSO meeting in Atlanta, Georgia, May 23, 1975.

** All magnitudes given in this paper will be on the V or visual system.

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X Persei has long been on the AAVSO observing list, and has been known as a variable star for almost a century. It fluctuates irregularly from $6^{m}.0$ to $6^{m}.8$. The cause of the variation is not known, and astronomers are eager to compare its spectrum carefully at maximum and minimum light to find out why. Also there is a good possibility that one member of this spectroscopic binary system is a black hole. Since only one other black hole is known (probably) to exist, X Per should receive much added attention.

Cygnus X-2. Much like Sco X-1 except that it varies irregularly between 14^{m} and 18^{m}. We believe it has a periodic fluctuation also (22.1 hours), but more observations of all sorts are needed to understand this X-ray source better.

HZ Herculis. Known as a variable since the late 1930s, this binary is responsible for the source Her X-1. Currently, it varies from about $13^{m}.0$ to $14^{m}.5$ every 1.700 days due to the so-called reflection effect (actually an X-ray excitation effect for HZ Her). More interestingly (to AAVSOers), it "turns off" every 10-20 years for a few years. That is, it stays near minimum brightness (about $m_v = 14.5$) continuously until it "turns on" again. The last time it turned off was 1949; therefore, we are overdue for the next turning off. Please help us to watch for the next turn off.

A0537+27. This X-ray source, named after its coordinates, was unknown before April, 1975, when it presumably turned on and was discovered by a British X-ray satellite. It is tentatively identified with a peculiar 9^{m} B-star with emission lines in its spectrum. Harvard photographs show that it varies with a full range of approximately 1^{m}, and X-ray observations have revealed a 104 second flickering. Much more is to be learned about this newest X-ray source which promises to be most interesting.

PULSARS

I will say just a few words about pulsars since only one (the remnant star of the Crab Nebula, itself an X-ray source) pulsates conspicuously in visible light. However three other X-ray sources do show pulsing (HZ Her and the systems associated with Centaurus X-3 and Vela X-1), but at very low levels of intensity. No other pulsars have yet been detected optically. Some day, when we witness another bright supernova like the Crab progenitor (and we are overdue), we should have another pulsar visible. If an AAVSOer is the lucky one to spot it first, please call me collect at once.

QUASARS

A group of us at Harvard are using old plates to derive historical light curves for the 231 quasi-stellar objects (QSOs or quasars) brighter than 18^{m}. Most are variable, and some spectacularly so. Seven are known to become brighter than $12^{m}.5$ and are listed in Tables 1 and 2. If quasars are as far away as their red-shifts imply, some of these can become extremely luminous in absolute terms. For example, our own galaxy, which is itself quite luminous as ordinary spiral galaxies go, has an absolute visual magnitude, M_v, of about -20, whereas we now know several QSOs that can reach M_v of greater than -30. In other words, if one of these quasars were placed at the standard distance of 10 parsecs = 32.6

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light years from the earth, it could outshine the sun by more than 3 magnitudes -- it would be more than 15 times as bright. Table 1 also gives the red-shifts of these objects, their recessional velocities in units of the fraction of the speed of light, the distance these red shifts imply, and the corresponding peak absolute magnitude. Nothing is known in the entire universe which becomes more luminous than these objects. Table 2 lists quasi stellar objects for which reliable red-shifts cannot be measured. These objects show rapid variations of brightness, as much as $1^{m}.5$/day. Fig. 2 shows the light curve of the quasar 3C 279.

The obvious question is: How do QSOs get so bright? The outbursts can be of very short duration -- less than a month -- and rise-times can be as short as a day or two. The implication of this rapid variability is that the dimensions of the quasar eruption must be less than a few light days (the diameter of Pluto's orbit is about half a light day) -- extremely small for something so luminous. Several ways of releasing so much energy so quickly have been conjectured. One is to have nearly simultaneous outbursts of about a million ordinary supernovae -- hardly a likely event, it would seem. Another is the total annihilation of about one solar mass per outburst, with a corresponding transformation to radiant energy as given by $E = mc^2$. The collision of a normal star with another star made of anti-matter could do this quite easily although calculations show that star-anti-star collisions are inefficient in producing radiant energy. They are better at producing neutrinos, which are virtually undetectable.

Desparately needed are spectra taken during and shortly after one of these gigantic explosions. An early warning system that would carry the news of a bright outburst quickly from observer to AAVSO Headquarters to the spectroscopists could help us out of our embarrasment of not knowing what causes the most spectacular explosion known to man.

In conclusion, I am happy to report that finding charts of a number of X-ray systems and quasars will soon be readied for interested AAVSO members. I hope we have many requests from them and that soon Janet Mattei will be flooded with observations. And don't forget the special supernova request!

Most of the Harvard research described above was supported by the National Science Foundation to which I am very grateful.

TABLE 1

A SAMPLING OF BRIGHT QUASARS

Desig.	α (1950)	δ (1950)	Peak m_v	$z^{(1)}$	$v/c^{(2)}$	Distance(3) (10^9 l.y.)	M_{bol}(4)
3C 273	12 26 33	+02 19.7	11.7	0.16	0.15	2.3	-27.7
3C 279	12 53 36	-05 31.1	11.0	0.54	0.41	6.2	-31.3
OQ 172(5)	14 42 51	+10 11.2	18.0	3.53	0.91	13.7	-30.0
1510-08	15 10 09	-08 54.8	11.6	0.36	0.30	4.5	-29.7
3C 323.1	15 45 32	+21 01.7	14.6	0.26	0.23	3.5	-26.0
2134+00	21 34 04	+00 28.2	14.5	1.94	0.79	11.9	-31.3
3C 454.3	22 51 29	+15 52.9	14.3	0.86	0.55	8.3	-29.2

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Notes to Table 1:

(1) $z = \Delta\lambda/\lambda_o$ = red-shift/(wave length emitted at rest).

(2) v/c = recession velocity in units of the speed of light. Corrected for the effects of relativity by the expression

$$v/c = \{(1+z)^2 - 1)\}/\{(1+z)^2 + 1\}.$$

(3) Distances are computed from the Hubble law expressed as,

$$\text{Distance} = v/H,$$

with H = 19.9 km sec^{-1} $\text{megalightyear}^{-1}$.

(4) Computed from the assumption $M_v = M_{bol}$ and the relativistic expression,

$$M_v = m_v - 43.33 - 5 \log z - 1.086(1-q_o)z,$$

with $q_o = 0.5$.

(5) This object has the largest red-shift yet measured. The Lyman-alpha line of hydrogen, with a rest wave length of 1216 angstroms, appears at about 5500 angstroms in its spectrum.

TABLE 2

BL LACERTAE AND OTHER PECULIAR RADIO SOURCES

Desig.	Other Name	α (1950)	δ (1950)	Peak m_v	z	Distance (10^9 l.y.)
0537-44		05 37 20	-44 06.7	12.3		
0851+20	OJ+287	08 51 57	+20 18.0	12.0		
1101+38		11 01 41	+38 28.7	11.4		
1219+28	W Com	12 19 01	+28 30.4	12.9		
2200+42	BL Lac	22 00 39	+42 02.1	12.3	0.07?	1.0

Note to Table 2:

The first four objects have featureless spectra and therefore Doppler red-shifts cannot be determined. They are referred to as BL Lacertae objects. The questioned red-shift for BL Lac itself refers to the fuzziness surrounding this QSO. There is no guarantee that the two are connected.

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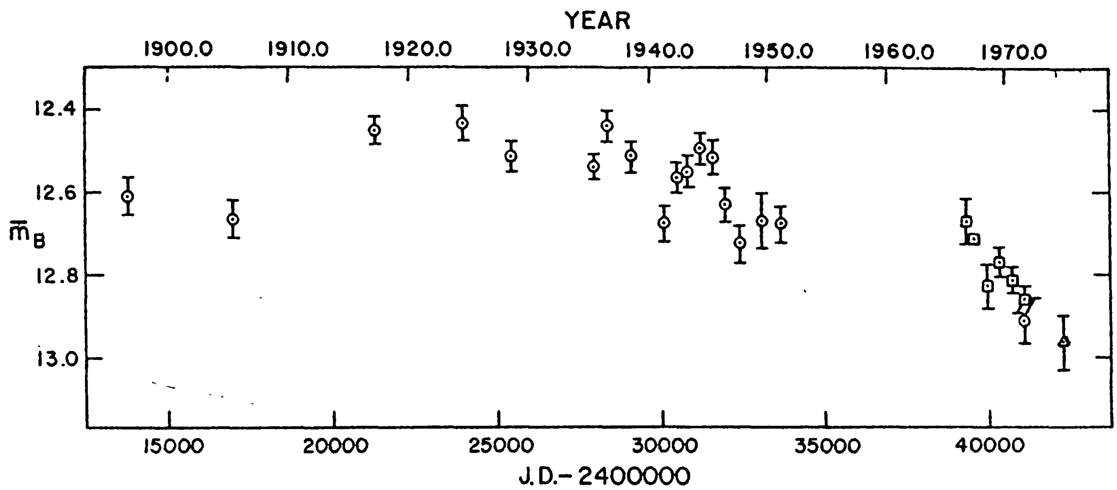

Figure 1. The historical light curve of Scorpius X-1, as derived mainly from Harvard photographs by Elaine Gottlieb, E. L. Wright and the author. Here are plotted the average photographic (blue) magnitudes of the star system associated with the strongest X-ray source in the sky. The squares (after JD 2435900) are recent photoelectric magnitude determinations. The big question here is will Sco X-1 continue to fade?

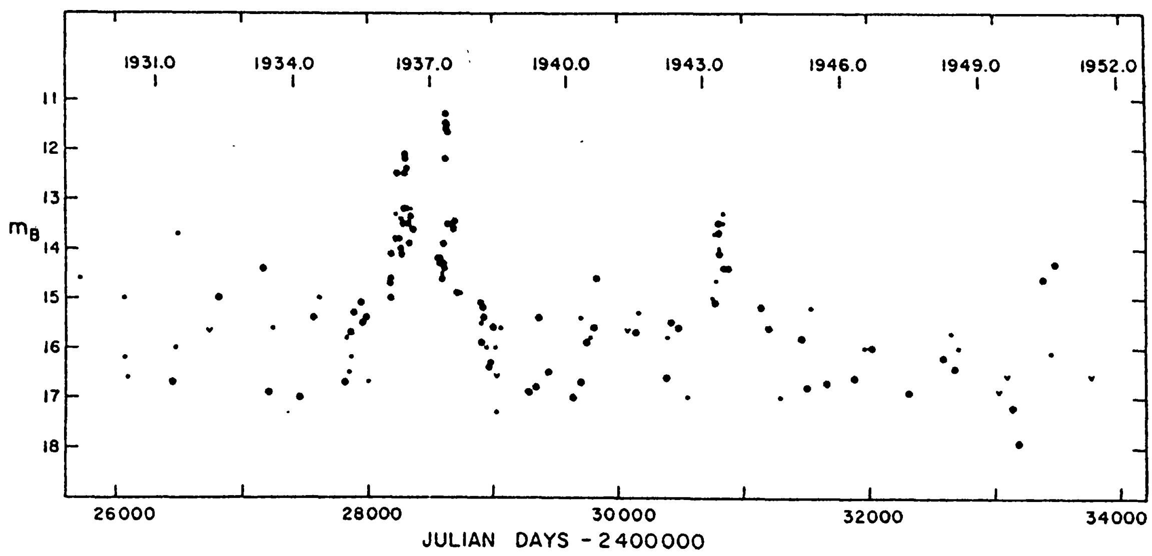

Figure 2. The historical light curve of the quasar 3C 279, as derived from Harvard photographs by Lola J. Eachus and the author. The blue photographic magnitudes plotted here show several large outbursts. At its peak in 1937, 3C 279 was possibly the most luminous object in the entire universe.

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