Data for the Mystery Object Exercise

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1 Introduction

This file contains the combined observational data for the in-class role-playing exercise on identifying the mystery object. Students must ask for a particular observation, and only then should be given the relevant data. Students will frequently ask for other data: you will have to make these results up, using your knowledge of the answer below.

1.1 The Answer

The object is a M-giant in a circular orbit around a massive black hole. The orbit is edge on, and the M-giant is therefore eclipsing the black hole. The black hole is a strong and constant X-ray source. Both black hole and M-giant are falling in towards our galaxy at 130 km/s.

Students should be able to work this much out in around 2 hours. The radial velocity vs. time plot gives them the mass, and the eclipse entry and exit times give them an upper limit on the X-ray source size (which forces this object to be a black hole).

I chose to leave some unsolved enigmas in the data, which the students may or may not find. This is to give good students a sense of the open-ended nature of science, and to show them that interesting things they cannot explain are good, not bad (as is the case in most undergraduate assignments). The origin of this whole system is one such enigma. Another concerns the X-ray emission mechanism. The energy budget for the X-ray source is fine; it can be powered by the stellar wind. However, the upper limit on the X-ray source size is far smaller than either the black body size needed to radiate this luminosity, or the Schwarzschild radius of the black hole. This can be used to lead into a discussion of relativistic beaming and non-thermal emission mechanisms.

2 X-ray Image

2.1 Lecturer Notes

If students ask for an X-ray image, tell them that ROSAT will have observed this part of the sky, and that they have to talk to the people at the Max
Planck Institut to get it, and that they will have to be very humble. If they choose to do this, tell them that they get no response, but that a week later, the following IAU circular is released.

Alternatively, if none of the students think of making X-ray observations, release this circular as a bonus surprise at an appropriate moment to all the groups.

2.2 Data
IAU Circular Number 23443

New, Very Strong X-ray Source Discovered.

W. Brinkmann, of the Max Planck Institut fuer Extraterrestriche Physik, Garching bei Muenchen

The Roentgen Sattelit (ROSAT) identified an extremely powerful X-ray source at coordinates 21:39:15.3 -44:33:56.2, with errors in both coordinates of 15". The source was detected during a 4000 ksec exposure with the PSPC camera, taken as part of a survey for QSOs within the Hawkins field.

The source has a temperature of 1.0E6 K (measured from the ratio of hard-to-soft X-rays), and an estimated total (bolometric) flux of 5.0E-6 W/m2, making it one of the most powerful X-ray point sources ever detected. The source is not spatially resolved, placing an upper limit on its size of 12".

The source was not detected in a subsequent 30sec exposure, four days later. The observations have a (3 sigma) sensitivity limit of 1.35E-9 W/m2. We therefore conclude that the source is variable over timescales of days.

This source was not detected during the ROSAT all-sky survey of 1993: this region was scanned 4 times during the survey, with exposures of 10-40 sec.

No further information is available at this time.
3 Radio Data

3.1 Lecturer Notes

This is included primarily as a red herring.

3.2 Data
Radio Observations of SF2139

Australia Telescope Compact Array:
24 hours total observations, in configuration C.

13cm: detected, flux = 0.23 mJy
20cm: detected, flux = 0.27 mJy

No 21cm line emission was detected.
1 Jk (Jansky) = 1.0E-26 W/m2/Hz

Source subtends less that 5'' and no variability (at the 5% level) was detected.
4 X-ray Monitoring

4.1 Lecturer Notes

Two forms of monitoring data are included. The first is on timescales of 10 minutes (from ASCA), and covers 5 ksec. The second, using RXTE only covers 1.5 ksec, but has 5 sec resolution. The group will need to know the phase of the source to see anything interesting in the latter.

4.2 Data
X-ray Monitoring Data: 10 second exposures at 10 minute intervals, from the ASCA Satellite
X-ray Monitoring Data: 5 second exposures at 5 sec intervals, from the RXTE Satellite
5 Imaging

5.1 Lecturer Notes
The AAT, ROSAT and HST/NICMOS images are red herrings. They can be used to place upper limits on the proper motion, when compared against UK Schmidt discovery images taken 14 years earlier.

5.2 Data
ROSAT soft X-ray image of the star. Position can be determined to an accuracy of 5 arcsec.
Hubble Space Telescope image of the star. Lines indicate SF2139. Image taken with the NICMOS camera, at a wavelength of 1.6μm. The position of the star can be measured to an accuracy of 0.02 arcsec.
Anglo-Australian Telescope image of the star. Lines indicate SF2139. Image taken with the Prime Focus Imager, equipped with the MIT/LL CCD detector, through an R-band filter.
6 Time-Resolved Spectroscopy

6.1 Lecturer Notes

This exists at a variety of scales: the two high time resolution plots match the two X-ray plots, and so could be used as simultaneous observations.

6.2 Data
Radial Velocity vs. Time for the Star SF2139. An allowance has been made for the effect of the orbit of the Earth around the sun, and of the Sun around the galactic centre: velocities are thus galactocentric. Positive velocities indicate motion away from the Milky Way.
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