X-ray Spectroscopy of an outburst from the candidate black-hole binary Swift J1753.7-2544

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Abstract

Low-mass X-ray binaries (LMXB), in which a compact object (a neutron star or black hole) accretes material from a star similar to our Sun, are often seen to undergo transient outbursts, with a dramatic and rapid rise in X-ray luminosity followed by slower fading to quiescence. In 2013, the Swift satellite observed such an outburst from a previously undetected black-hole-candidate LMXB, subsequently named Swift J1753.7-2544. Here we report our X-ray spectral analysis of this source from archival data, in order to trace the changing state of the inner accretion disk and compact object.

We have used fifteen Swift-XRT observations to constrain physically motivated models for the source emission (as well as validating see procedures by testing for badness-of-fit some alternate models we know should be inappropriate for this object). Standard X-ray analysis techniques were used to determine statistical errors, to assess the time-evolution of model-parameters, and to compute the total flux from the source at each stage in the outburst and subsequent fading. We have also analyzed archival images from the Chandra X-ray telescope, both to place an upper limit on the flux from Swift J1753.7-2544, and to compute the total flux from the object. Standard X-ray analysis techniques were used to determine statistical errors, to assess the time-evolution of model-parameters, and to compute the total flux from the source at each stage in the outburst and subsequent fading.

1. Context

A special class of binary stars is the X-ray binaries (XRB), consisting of a relatively normal star and a collapsed star (a white dwarf, neutron star, or black hole). When they are close enough together, matter is transferred from the more normal star to the collapsed remnant, often settling into an accretion disk, and powering strong X-ray emission. Low-mass X-ray binaries, including Swift J1753.7-2544, tend to exhibit long periods of quiescence punctuated by episodic strong outbursts, during which the X-ray flux increases by several orders of magnitude.

2. Choosing Models to fit Spectral Data

To determine which model “best” fits our data, we chose a model spectrum using the software XSPEC and fitted it to our data. A “fit statistic” is then computed and we were able to judge whether or not the model spectrum “fits” the data. Once a “best-fit” model is obtained, we can test the chosen model to see if it passes the “goodness-of-fit” test. Having applied a range of physical models to our data, we chose the Power law and Black Body as the models that best fit our data. Figure 2 (below) shows both the Power Law and Black Body models, respectively, at 56354.51 MJD.

When we plot the fitted flux from our model to each spectrum, we indeed see the characteristic fast rise followed by slow decay - see Figure 3A. We also saw a correlation between the photon flux and column density, as seen in Figure 3B.

3. Time evolution of parameters

After selecting suitable models to fit our data, we collected the model parameter values and their uncertainties, for all the observations in our dataset. Choosing a particular parameter, we assembled its values over the history of the measurements, and plotted its time evolution. An X-ray outburst is thought to be caused by a sudden dramatic increase of mass accretion onto the compact object. During this time, the photon flux is expected to rise rapidly, followed by a steady decay, eventually returning to pre-outburst level.

4. What about spatial contamination?

Is our source itself visible near the middle? Might our 1D data of Swift J1753.7-2544 be contaminated by another object within the field of view?

To attempt to answer this question, we are examining a 0.3-12 keV X-ray image of Swift J1753.7-2544 that was taken with the Chandra X-ray telescope (Figure 4B, bottom-right). This image was taken on 2013 March 16, which was 51 days after the outburst was detected by Swift. The green rectangle on the figure displays the extraction region used for the SWIFT-XRT data, which corresponds to one arm of the “X” shape in the top figure. At present, we find no evidence that any additional point sources contaminate our data – so that our spectra really are dominated by Swift J1753.7-2544.

5. Status and Plans

4A, top-right). The point source itself is visible near the middle.

At present, indications are that Swift J1753.7-2544 appears to be reasonably typical for LMXBs in outburst, although some puzzling features of the spectra still require interpretation. For example, we might be seeing complications due to X-ray scattering off the interstellar medium, although analysis is still in progress.

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7. References