EXPLORING THE INTEGRAL ARCHIVE

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Period Determination of HMXBs

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ABSTRACT

INTEGRAL, the International Gamma Ray Astrophysics Laboratory, is a satellite launched in 2002. Containing four primary instruments, INTEGRAL looks at sources in energy ranges approximately between 5 keV and 10 MeV, from hard X-rays to Gamma rays.

The INTEGRAL archive contains data for many sources that have not been fully explored. This project focuses on a sample of High Mass X-ray Binary sources thought to have eclipses. Lomb-Scarge spectral analysis and Phase Dispersion Minimisation are both used to find periodicities in the light curves of these sources.

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1 INTRODUCTION

1.1 THE INTEGRAL SATELLITE

INTEGRAL, the International Gamma Ray Astrophysics Laboratory, is a satellite launched in 2002. Containing four primary instruments, INTEGRAL looks at sources in energy ranges approximately between 5 keV and 10 MeV, from hard X-rays to Gamma rays. The mission was launched by ESA, with support from NASA and the Russian Space Agency. The satellite was placed into a highly elliptical orbit around the Earth, with an orbital period 72 hours. This allows the instruments significant time making observations above the Earthś radiation belts, which would otherwise contribute to the noise of the signal. The satellite has been in operation for over ten years, providing some of the best observations available to astrophysicists.

1.2 IBIS/ISGRI

IBIS, the Imager on-board the INTEGRAL Satellite, provides the majority of the data used in this project. The instrument has two sets of detecting tiles placed one above the other, the first to detect hard X-rays and low energy gamma photons, the second to detect higher energy gamma photons. This project focussed on observations in X-rays, which utilises the lower range of light frequency sensitivity of IBIS from the first detector, ISGRI, INTEGRAL Soft Gamma Ray Imager.

The designs of ISGRI and PICsIT, its higher energy counterpart, are very similar. ISGRI uses an array of Cadmium Telluride tiles in a 128 by 128 array, and PICsIT has an array of Caesium Iodide tiles arranged 64 by 64. Using this dual detector design, IBIS is sensitive between 20 keV to 10 MeV. One additional benefit of this setup is that photons which register in both layers can be identified, which allows an improvement in the signal to noise ratio by discounting those unlikely to have come from a target source.

1.3 OTHER INSTRUMENTS ON-BOARD INTEGRAL

The Spectrometer on INTEGRAL, abbreviated SPI, is used to provide information on the energy incoming photons that IBIS cannot. SPI has an energy resolution of 2.2 keV at 1.33 MeV, approximately 0.2%, whilst INTEGRAL has a spectral resolution of between 8% to 10%. SPI uses a hexagonal arrangement of 19 germanium tiles, cooled down to 85 K. INTEGRAL is also equipped with two additional X-ray imagers, called the Joint European X-Ray Monitor, or JEM-X. The two imagers are identical, and use a gas scintillator detector to measure photons in the 3 - 35 keV region. Finally, INTEGRAL is also equipped with an optical telescope, called the Optical Monitoring Camera, OMC, to provide measurements in tandem with the other instrumentation.

1.4 CODED MASKS

X-rays cannot be focused using conventional optical lenses, so the high energy instruments on-board INTEGRAL all make use of coded masks to form an image. Coded masks use a pattern of transparent and opaque elements in front of the sensor, and could be considered a sophisticated pinhole camera. Light entering a pinhole camera casts an image on the sensor, but greatly the pinhole greatly reduces the amount of light that can enter. Most coded masks have approximately two thirds of the mask opaque. As expected, light entering through a coded mask does not create an image, but creates a shadow based on the arrangement of the opaque and transparent elements. This shadow is the combination of all the images formed from each element.

The design of a coded mask allows the usage of mathematical algorithms applied to the sensor output, to construct an image, a process called deconvolution. Furthermore the design of coded masks is such that a source in the instrument's field of view will cast a unique shadow based on the orientation to the instrument. This means that multiple sources in the field of view can be separated, at a very fine angular resolution for an instrument of its type.

2 THEORETICAL BACKGROUND

2.1 X-RAY BINARIES

X-ray astronomy was confined to the study of our own Sun until the discovery of the first extra-solar in 1962 by Giacconi et. al. An X-ray detector was mounted in the head of a rocket, and launched into a high parabolic arc. The experimental team had discovered what would later be designated Scorpius X-1. Initially this discovery, and the discovery of other similar X-ray sources was puzzling to astronomers, who could account for how these stars were very luminous in X-rays, yet dim in optical wavelengths. If these were stars similar to our own, they should be significantly brighter in optical telescopes.

2.2 UHURU/SAS-A

The Uhuru/SAS-A satellite was the first mission to offer the insight that led to the modern field of X-ray astronomy. Operating in the X-ray band, it detected eclipses in the lightcurves of two sources, Her X-1 and Cen X-3. Whilst both sources have their differences, this result indicated that the systems are binary. Furthermore the orbital period and profile of the eclipses suggested that the stars were orbiting very close together. This then implied that the two stars could be interacting, with the possibility of mass transfer between the two. Also, one of the objects had to be compact. In the case of Her X-1 and Cen X-3, the compact object is a neutron star. We now understand that mass is transferred from a donor star to the compact object, accreting onto it. The initial mystery of how these sources were so luminous in X-rays is solved when one considers the energy transfer that is possible as the accreting material exchanges it's gravitational potential energy for heat.

2.3 MASS TRANSFER AND THE ROCHE LOBE

X-ray Binary stars are broadly divided into two categories, those of a high mass companion star, and those of a low mass companion star.

2.3.1 *High Mass X-ray Binaries*

High Mass X-ray Binaries, HXMBs, have their mass transfer from donor star to compact object driven by a powerful stellar wind. Typically the donor star is an O or B type. The compact object accretes by simple infall as it ploughs through the relatively dense stellar wind. HMXBs do have accretion disks, but tend to be smaller than those of low mass systems.

2.3.2 *Low Mass X-ray Binaries*

Conversely, Low Mass X-ray Binaries, LMXBs, have donor stars that are not sufficiently large or luminous to drive a powerful stellar wind. Thus the compact object has to accrete by a different mechanism. Consider the Binary system in a co-rotating frame of reference, such that the two stars appear stationary. Taking account of both centrifugal force and gravitational potential, the Roche Lobe is the local minimum or potential well where matter is gravitationally bound. Some stars extent is greater than their Roche Lobe, which allows matter to be transferred to the compact object by flowing over the L1 Lagrangian point. LXMBs tend to exhibit larger accretion disks than HMXBs and, due to the dynamics of the mass transfer, form a "figure of eight" shape.

2.4 CLASSES OF HXMB

This project focusses on a sample of HMXBs, which astrophysicists subdivide into three broad categories.

2.4.1 *SGXBs*

SGXBs, Supergiant X-ray Binaries have compact objects that spend their orbit in the strong stellar wind of an OB Supergiant. They are typically the most luminous subclass of HXMBs, often showing short drops in the X-ray flux observed where the compact object is eclipsed by its donor companion. Whilst the orbital eccentricity of the accreting object is lower than the other classes of HMXB, variations in the X-ray flux observed is affected by the orbital period of the accreting object, as it moves closer and further away from the supergiant.

2.4.2 *BeXBs*

Be star X-ray Binaries are, as the name suggests, associated with spectral type Be donor stars. Of significance to the behaviour of the X-ray flux is the fact that Be stars typically form equatorial disks of matter. This is thought to be aided by the tendency for Be stars to rotate rapidly. Furthermore, BeXB systems tend to have the neutron star in an eccentric orbit. As a result, the X-ray luminosity of these systems increases rapidly as the neutron star approaches it's periastron, when it intersects with this equatorial region of material surrounding the Be star, and is relatively quiet for the rest of its orbit.

2.4.3 *SFXTs*

Finally, Superfast X-ray Transients are a class that share common features with both SGXBs and BeXBs. SFXTs show outbursts similar BeXBs, but on a shorter timescale, and in addition are associated with the OB supergiants. One proposed explanation to explain the extremely short lived outbursts of these sources compared to the classical and persistent SGXBs is that the wind of these stars is inhomogeneous, and that the outbursts are caused by sudden accretion onto the neutron star as it moves through a "clumpy" patch of solar wind. This may not a be totally sufficient explanation, since SFXTs exhibit some eccentricity in the orbit of the neutron star, and it is thought that it may be a combination of these factors that leads to the large and short outbursts.