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## High-energy astrophysics - II. Compact binary stars

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of line brightness) decreases for the highest spin rates. The discs are brightest for a spin rate  $S_0 \sim 0.5$  of the break-up speed, which is in approximate agreement with observations. Without gravity darkening,  $S_0 \sim 0.9$  is predicted. These results are encouraging. Numerical MHD of MTD is in progress. — ALBERT ZIJLSTRA.

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SUMMARY OF THE RAS NAM DISCUSSION MEETING ON

HIGH-ENERGY ASTROPHYSICS — II. COMPACT BINARY STARS

Traditionally, this second high-energy session, this year held on 2004 March 30, focusses on objects within our own Galaxy. It is testament to the rapid expansion of the horizons of stellar astrophysics that much of the session was devoted to discussion of compact binary stars in external galaxies. After some delay caused by an AV technical hitch, we began with a presentation by Dr. Giovanni Miniutti (IoA, Cambridge), which followed on very nicely from the extragalactic work discussed in the preceding session. Dr. Miniutti described observations of broad Fe-line variability in X-ray observations of accreting black holes. He showed that the active galaxy MCG-6-30-15 and galactic black-hole candidate XTE J1650-500 exhibit similar behaviour. He showed that conventional disc-reflection models have difficulty in reproducing the observations. The Fe line is a prominent part of the reflection spectrum, and is powered by reprocessing of the power-law-continuum X-ray flux. Consequently, the Fe line is expected to vary as the power-law-continuum flux varies. This does happen at low values of power-law flux in both MCG-6-30-15 and XTE J1650-500, but in the high state the Fe-line flux remains approximately constant while the power-law flux varies by a factor of five or so. Miniutti & Fabian's model places the source of the power-law continuum off-centre and above the disc, and allows it to move vertically. In this model the intrinsic luminosity of the power-law source remains constant, but the luminosity apparent to an observer changes as the source moves within the deep gravitational potential well. Tracing the reflection-spectrum contribution, including the effects of general-relativistic light bending, can then reproduce both the line shape and flux behaviour of the Fe K line.

The next presentation, by Dr. Tim Roberts (Leicester), focussed on extragalactic black holes of uncertain mass: the ultra-luminous X-ray sources (ULXs) in nearby external galaxies. These objects' luminosities exceed the Eddington limit for a ten-solar-mass black hole, and hence have provoked speculation that they harbour 'intermediate'-mass black holes, *i.e.*, around 100 solar masses. It is more likely, however, that these are black holes with masses consistent with those measured in galactic X-ray binaries; in this case either they appear super-Eddington as a result of anisotropic emission, or they may be truly super-Eddington. The galactic microquasar GRS 1915+105 has super-Eddington intervals, so the ULXs fall within the framework of behaviour already documented within our own Galaxy. Dr. Roberts presented studies of two ULXs. *XMM* observations of a ULX in NCG 55 showed X-ray variability,

including dipping behaviour, which is easily interpreted by analogy with well-studied galactic sources, though the spectrum of this object presented a puzzle. It requires a steep power-law component peaking at lower energies than the disc blackbody, and the other object, NGC 5204 X-1, is amenable to a similar fit. Since the power-law component is generally attributed to inverse-Compton scattering of seed photons from the disc, this is surprising and problematic as there is a lack of soft seed photons. Intriguingly, the spectrum can be fit with a model of an intermediate-mass black-hole accretion disc plus hard power-law spectrum. Better X-ray spectra at energies above 5 keV might discriminate between the two possible interpretations.

Dr. Robin Barnard (Open University) presented results from *XMM* X-ray light curves of the X-ray binaries in M31. Galactic X-ray binaries exhibit two distinct power-density spectra (PDS). At low luminosities variability is strong, the power is roughly constant with frequency at low frequencies, and the PDS shows a break at high frequency, with the power dropping rapidly as frequency increases further. In contrast, at higher luminosity the overall power is lower, and power declines steadily from low frequency to high frequency. A similar behaviour is seen in the low-mass X-ray binary (LMXB) population of M31. Because the M31 sources are all at effectively the same distance, their relative luminosities can be determined much more easily than those of galactic X-ray binaries. Classifying the M31 LMXB observations using the observed flux and PDS, Dr. Barnard found that for each object the PDS exhibits a break only when the source is emitting at lower luminosity. Furthermore, the majority of sources shared the same threshold luminosity, dividing the observations into the two types of variability as characterized by the PDS. This is highly suggestive that these sources are neutron stars all of the same mass, and the transition between low-luminosity and high-luminosity PDS occurs at a given fraction of the Eddington luminosity. Accepting this hypothesis, the eight sources in M31 which exhibit the low-luminosity PDS at significantly higher luminosities are identified as candidate black holes.

Soon-to-be-Dr. Will Clarkson (Open University) discussed an unusual X-ray binary within our own Galaxy, posing the question, "how old is Cir X-1?" Cir X-1 has an eccentric orbit, with the periodic outbursts typical of high-mass X-ray binary (HMXB) transients, which are young systems harbouring massive donor stars in which the orbit has not (yet) been circularized by tidal forces. Cir X-1's detailed X-ray properties, *i.e.*, type-I X-ray bursts and quasi-periodic oscillations, resemble those of LMXBs, and these properties are thought to require a neutron star with a weak magnetic field. LMXBs are found preferentially in old stellar populations, and neutron-star magnetic fields are thought to decay with age, implying an old neutron star in Cir X-1. Since Cir X-1 suffers strong interstellar extinction, Clarkson and collaborators attempted to detect the mass-donor star in the infrared with *AAT-IRIS2* snapshot spectra at apastron and just after periastron. Unfortunately, this work has so far been inconclusive, with no CO bandheads detected and significant IR contamination from the accretion flow. *RXTE* light curves were used to update the ephemeris, and implied that there is rapid dynamical evolution and an orbital eccentricity  $> 0.6$ , both reinforcing the interpretation as a young system. This implies young neutron stars can appear to have weak magnetic fields, possibly as a result of rapid field decay, or a screening effect by the accretion flow.

Dr. Joern Wilms (Warwick) began his presentation with an overview of the

capabilities of *INTEGRAL*, noting that the combination of *INTEGRAL* and *RXTE* makes broadband spectroscopy from 2–500 keV possible. Clearly this might provide the capability required to discriminate between the intermediate black-hole and super-Eddington interpretations of ULXs discussed earlier by Dr. Roberts; unfortunately, the ULXs are too faint to allow this with the current satellites. Dr. Wilms discussed his extensive observations of Cyg X-1: during *INTEGRAL*'s performance verification he obtained 1.5 months (yes, months!) of observation of Cyg X-1 during autumn 2002, which was accompanied by five long visits by *RXTE* to provide calibration. The spectra cover two and a half decades in photon energy, which clearly provides strong constraints on any model. As expected, the Cyg X-1 data were consistent with a Comptonization model. An alternative model involving synchrotron and synchrotron-self-Compton emission from a jet also fits the spectrum at energies exceeding 10 keV. One of the three *INTEGRAL* instruments does not yet have a finalized calibration. Once this is achieved, further progress in pinning down the astrophysics underlying the X-ray emission from Cyg X-1 and other systems is expected.

The final speaker was Dr. Koji Mukai (NASA/GSFC & USRA), whose subject was *Chandra* observations of AM Herculis, a cataclysmic variable with a strongly magnetic white-dwarf accretor. Dr. Mukai thus had the most nearby object of the session, but compensated for this by travelling the farthest to attend the meeting and interpreting his spectra using models developed for extragalactic contexts. He showed that *Chandra*/*HETG* spectra of CVs are rich in detail, with emission lines of multiply-ionized species superimposed on continuum emission. Broadly the spectra fall into two types: non-magnetic CVs and EX Hya show thermal multiple-temperature spectra, and are well-reproduced by models developed for cooling flows in clusters of galaxies; and three CVs with weakly magnetic white dwarfs showed hard continua and weak iron L-shell emission lines, which could be reasonably well-matched by photoionization models. AM Her is shown to belong to this second group. Furthermore, its hard continuum and the higher-energy lines can be modelled with a cooling-flow model with differential partial-covering absorbers. At the lowest energies, additional emission lines are necessary, presumably due to photoionization.

Because of the AV problems, the session overran considerably but we had enough time to consume the caffeinated beverages so crucial to NAM. — CAROLE HASWELL.

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#### SUMMARY OF THE RAS NAM DISCUSSION MEETING ON

#### HIGH-ENERGY ASTROPHYSICS — V. GAMMA-RAY BURSTS

This discussion meeting, held on 2004 March 31, began with Davide Lazzati (IoA, Cambridge) reviewing developments since the discovery of gamma-ray-burst (GRB) afterglows just six years ago. Optical spectra showed GRBs to be at cosmological distances, leading to apparent explosion energies equivalent to a solar rest mass. However, the maximum energy of the non-thermal gamma-ray spectrum being above the electron-positron pair-production limit required