Dr Robin Barnard

28 Harts Gardens, Guildford, Surrey, GU2 9QB
Telephone: 01483 300398 (Home) 0750 0405553 (Mobile)
Website: http://www.robinbarnard.com
Email: robin.barnard@gmail.com

Professional Profile

Familiar with X-ray observations of M31. World-leading expert in modelling and interpretation of data from evolving stellar X-ray sources. History of innovative research ideas, followed through with logic and rigour. Works well in collaboration or independently. Enthusiastic and patient teacher, with excellent communication skills. Quick to learn.

Scientific Skills and Achievements

- Invented a new method for finding black holes; first two genuine candidates in M31 GCs
- Co-founded the international M31 Large Project Consortium with Wolfgang Pietsch, awarded 1.3 Ms of XMM-Newton observations
- Co-supervised the PhD project of Dr L. Shaw Greening, who conducted a spectral survey of the M31 disc with XMM-Newton.
- Led independent research programme for 7 years
- Developed World-leading techniques in X-ray astronomy
- Identified a possible new breed of black hole binary system: high accretion rate with stable corona
- Found spectral evidence for extended coronae in Ultra-luminous X-ray sources
- Helped identify NGC300 X-1 as a Wolf-Rayet + black hole binary system
- Investigated the artificial variability introduced by combining lightcurves from pn and MOS detectors on XMM-Newton, and identified a solution.
- Created a novel way of estimating the uncertainties in X-ray luminosity functions, even when uncertainties can span several luminosity bins.
- Identified disc precession in M31 dipping binary Bo 158
- Identified the first Z-source candidate in M31
- Wrote doctoral thesis "The spectral evolution during dipping and flaring in low mass X-ray binaries"
- Awarded two month fellowship in Japan, funded by Japanese government
- Expert in statistical analysis of data with uncertainty propagation and null hypothesis testing
- Proficient in variability analysis via power density spectra and lightcurve folding
- Writes custom shell scripts and FORTRAN programs to automate data handling and analysis
- Familiar with the EXOSAT, RXTE, and XMM-Newton satellites
- Have also analysed data from ROSAT, GINGA, ASCA, Beppo-SAX and Chandra
- Expert at analysis with the XMM-Newton SAS and FTOOLS software suites
- Particular expertise in the analysis of X-ray spectra, from static or evolving systems.

Communication Skills and Achievements

- Presented results around the World, at international conferences as well as to the general public
- Wrote a textbook chapter on X-ray astronomy for a new Open University course, to be co-published with Cambridge University Press
- Set exercises and exam questions with model answers for this textbook
- Was panellist on two Chandra Time Allocations Committees

- Have refereed for major astrophysical journals
- Made major contributions to grant proposals that funded his work for seven years
- Taught Open University students of all ages and backgrounds at six residential schools in Mallorca
- Had press release cited World-wide, and translated in to at least 7 foreign languages
- Contributed article to the Open-University/BBC co-production the All Night Star Party in 2003
- Leadership and inspiration
- Providing valuable support as part of a team
- Media interaction
- Building teams to tackle particular tasks
- Eager to accommodate constructive criticism
- Writing proposals for e.g. research grants or telescope time
- Managing/supervising undergraduate and graduate students
- Networking at conferences, etc.

Career Summary

Sep. 2009-present	**THE OPEN UNIVERSITY**	**Visiting fellow**
2001–2009	**THE OPEN UNIVERSITY**	**Postdoctoral research fellow**
1997–2001	**BIRMINGHAM UNIVERSITY**	**Postgraduate student**

Education and Qualifications

PhD (Astrophysics)	University of Birmingham
MPhys (Hons) Physics with Astrophysics (2:i)	University of Manchester

Personal Details

Date of Birth	April 9th 1975
Nationality	British
Driving Licence	Full/Clean
Health	Good; non-smoker
Interests	Travel, photography, cocktail mixing, food from around the World, films

References

REFERENCE 1

Dr Ulrich Kolb
Department of Physics and Astronomy
The Open University
Walton Hall
Milton Keynes
Buckinghamshire
MK7 6AA
UK
email: u.c.kolb@open.ac.uk

REFERENCE 2

Dr Michael Church
Department of Physics and Astronomy
The University of Birmingham
Edgbaston
Birmingham
B15 2TT
UK

email: mjc@star.sr.bham.ac.uk

REFERENCE 3

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Research Interests

In addition to the analysis of Chandra/HST observations of transients, I have several complimentary research interests. Of these, I would concentrate on two: conducting a detailed survey of the ~1200 X-ray sources in the M31 XMM-Newton extended survey, and looking for associations between black hole binaries and globular clusters.

- **Exploiting the M31 extended survey**

The extended survey consists of 15 separate fields that, together with the pre-existing observations of the central region and disc, cover the entire D_{25} ellipse of M31. Several of these fields required multiple visits, allowing us to detect variations between observations. I have developed proprietary tools (along with Dr Shaw Greening) that obtain lightcurves and spectra for each source in an XMM-Newton observation, measure the variability, and find good fit spectral models with 0.3—10 keV luminosities. I have run these tools on each of the observations; as a result, I have performed automated analysis of ~1200 X-ray sources in these fields.

My role agreed role in the consortium was to look for variability; I have not analysed the spectra, because the spectral analysis was assigned to a PhD student, Holger Stiele, forming a major part of his thesis. He has completed his thesis, but has not done an in-depth spectral survey. Since I have already obtained the data, and acceptable models for most of the X-ray sources, I am in an excellent position to perform such a survey.

As far as I am aware, our previous X-ray spectral surveys of external galaxies are the most detailed available; this is made possible on reasonable time-scales by our scripting tools. As a result, we identified the first high mass X-ray binary (HMXB) candidates in M31, from their X-ray spectra. Wind-accreting HMXBs are expected to exhibit hard power law emission spectra, with photon index ~1. When supervising Dr Shaw Greening's PhD work on the inner disc of M31, I predicted an excess of sources exhibiting HMXB- like spectra in the disc with respect to the central region. We found exactly this excess, allowing us to identify the first candidate high mass X-ray binary systems in M31 (Shaw Greening et al., 2009).

I will combine the results of the XMM-Newton and Chandra observations to produce the most advanced X-ray luminosity functions (XLFs) of M31 to date. In Barnard, Shaw Greening & Kolb (2008), we used a deep XMM-Newton observation of NGC 253 to investigate different methods of estimating XLFs from low photon-count data. We showed that the best results were obtained by grouping the X-ray sources by intensity, modelling the summed emission spectrum for each group, then converting from intensity to flux using that best fit model.

Thanks to the smaller PSF and lower background of Chandra, it can detect an X-ray source from 5 (or possibly even 3) photons; as a result, the Chandra XLFs often extend to lower luminosities than the equivalent XMM XLFs. Modelling the stacked spectra of the faint Chandra sources should result in the most authentic XLFs yet.

I have devised a new method for estimating the uncertainties of XLFs that is effective even when the luminosity limits of a given source span several luminosity bins (Barnard, Clark & Kolb in prep). The method involves generating 1000 normally-distributed random luminosities for each source, based on the 90% confidence limits. We produce binned differential luminosity functions (DLFs) for each iteration, then integrate these to produce binned cumulative luminosity functions (CLFs). We can therefore estimate the standard uncertainties for each luminosity bin of the DLF and CLF. This is important, because uncertainties in CLFs are notoriously difficult to estimate.

- **Searching for associations between black hole binaries and globular clusters**

I have recently identified two black hole candidates in M31 globular clusters (Barnard et al., 2008, 2009), and intend to ascertain how common such associations may be. This will inform theoretical models on the evolution of black hole binaries, and the globular clusters that nurture them.

The incredibly high density of GCs means that XBs are most likely to form there. However, until recently, it was believed that black hole X-ray binaries were ejected from the host GC; this was largely because no-one had found any. For many years this result has shaped the theories on the evolution of GCs and XB formation. The modelling of Kalogera et al. (2004, ApJL, 601, 171) showed that black hole XBs formed by exchange mechanisms could remain, but would have duty cycles of ~0.001 and so would be seen only very rarely. They also showed that BH XBs formed by tidal capture of a main sequence star could also dwell in the host GC; they expected these systems to be bright, persistent X-ray sources, and interpreted the lack of known systems as evidence for tidal disruption of the captured star.

However, the traditional method for identifying black holes in XBs is quite unsuited for GCs, hence it is unsurprising that no associations were found! This method requires that the X-ray source is correctly identified with a donor star; emission lines from the donor exhibit periodic radial velocity shifts that give the mass function, allowing us to ascertain the mass of the accretor. In high density environments such as GCs, it is near impossible to isolate the donor.

My method allows us to identify black hole XBs from their X-ray properties alone; hence it is far more likely to find GC black hole binaries. This method was first developed in Barnard et al. (2003, Paper 16), but fully realised in Barnard et al. (2008, Paper 5). In summary, black hole and neutron star LMXBs exhibit remarkably similar X-ray properties (variability and emission spectra) at low accretion rates, but distinctly different properties at higher accretion rates; however, Gladstone et al. (2007, MNRAS, 378. 13) showed that neutron star LMXBs only exhibit low state behaviour at 0.01—1000 keV luminosities less than 10% of the Eddington limit. The largest known neutron stars have masses ~2 M_{Sun}; hence, X-ray binaries that exhibit low state behaviour at 0.01—100 keV luminosities >>$3x10^{37}$ erg s^{-1} may be classified as black hole candidates (BHCs).

Initial identifications of BHCs (Papers 13 & 16) were contaminated by an artefact introduced by the XMM-Newton analysis software (Barnard et al, 2007, Paper 9). This artefact also compromised the results of several other groups. Using a corrected method, I have found two genuine black hole candidates; remarkably, both are associated with GCs in M31 : Bo45 (Paper 5) and Bo 144 (Paper 3). Furthermore, both appear to be persistently bright over the last 20—30 years; hence, they are consistent with theoretical predictions for LMXBs formed by tidal capture of a main sequence star.

I will exploit the complementary abilities of XMM-Newton and Chandra to maximise the scientific return; The exquisite spatial resolution of Chandra will be used to resolve multiple sources and possibly position the X-ray source within the GC, while the superb sensitivity of XMM-Newton will be used to identify low state characteristics. In the first instance, I will start with M31, as I have first-look data products for ~2000 X-ray sources from the extended survey. Where we go from there would be up for discussion. My method is only sensitive to the subset of BHCs that exhibit low state behaviour at high luminosities, and we must account for this when estimating the frequency of GC BH binaries.

Publications (copies available at www.robinbarnard.com)

(A) Public outreach

Barnard, R., 2003, OU/BBC All night star party 2003 website
http://www.open2.net/starparty/extreme_p1.htm ``Extreme Astronomy"

(B) Publications in refereed journals

1 Crowther, P.A., Barnard, R., Carpano, S., Clark, J.S., Dhillon, V.S., Pollock, A.M.T, MNRAS accepted
"NGC300 X-1 is a Wolf-Rayet/Black Hole binary"

2 Barnard, R., 2010, MNRAS accepted
"In-depth studies of the NGC253 ULXs with XMM-Newton: remarkable variability in ULX1 and evidence for extended coronae"

3 Barnard, R. & Kolb, U., 2009, MNRAS, 397, L92
"A second black hole candidate in a M31 globular cluster is identified with XMM-Newton"

4 Shaw Greening, L., Barnard, R., Kolb, U., Tonkin, C., Osborne, J.P., 2009, A&A, 495, 733
"An X-ray spectral survey of the disc of M31 with XMM-Newton"

5 Barnard, R., Stiele, H., Hatzidimitriou, D., et al., 2008, ApJ, 689, 1215
"New XMM-Newton analysis of three bright X-ray sources in M31 globular clusters, including a new black hole candidate"

6 Barnard, R. Clark, J.S. Kolb, U., 2008, A&A, 488, 679, highlighted paper
"NGC300 X-1 and IC10 X-1: a new breed of black hole binary?"

7 Barnard, R., Shaw Greening, L., Kolb. U., 2008, MNRAS, 388, 849
"A multi-coloured survey of NGC 253 with XMM-Newton: testing the methods used for creating luminosity functions from low-count data"

8 Ofek, E.O., Muno, M., Quimby, R. et al., 2008, ApJ, 681, 1464
"GRB 070201: A Possible Soft Gamma-Ray Repeater in M31"

9 Barnard, R., Trudolyubov, S., Haswell C.A., Kolb, U. et al., A&A 469, 875
"On the artificial nature of aperiodic variability in XMM-Newton observations of M 31 X-ray sources and the ultra-luminous source NGC 4559 ULX-7"

10 Barnard, R., Foulkes, S. B., Haswell, C. A., Kolb, U., Osborne, J. P., Murray, J. R., 2006, MNRAS, 366, 287
"Discovery of disc precession in the M 31 dipping X-ray binary Bo 158"

11 Mukai, K., Still, M., Corbet, R. H. D., Kuntz, KD, Barnard, R., 2005, ApJ, 634, 1085
"The X-ray properties of M101 ULX-1 = CXOKM101J140332.74+542102"

12 Williams, B. F., Barnard, R. Garcia, M. R. et al., 2005, ApJ, 634, 365
"A potential supernova remnant/X-ray binary association in M31"

13 Barnard, R., Kolb, U., Osborne, J. P., 2004, A&A, 423, 147
"Identifying a black hole transient in M 31 with XMM-Newton and Chandra"

14 Barnard, R., Kolb, U., Osborne, J. P., 2003, A&A, 411, 553
"Tracing a Z-track in the M 31 X-ray binary RX J0042.6+4115"

15 Barnard, R., Church, M. J., Bałucińska-Church, M., 2003, A&A, 405, 237
"Physical changes during Z-track movement in Sco X-1 on the flaring branch"

16 Barnard, R., Osborne, J. P., Kolb, U., Borozdin, K. N., 2003, A&A, 405, 505
"RX J0042.3+4115: A stellar mass black hole binary identified in M 31"

17 Barnard, R., Bałucińska-Church, M., Church, M. J., Smale, A. P., 2001, A&A, 380, 494
"A study of spectral evolution during dipping in XB 1323-619 with Rossi-XTE and Beppo-SAX"

18 Bałucińska-Church, M., Barnard, R., Church, M. J, Smale, A. P., 2001, A&A, 378, 847
"Neutron star black body contraction during flaring in X 1624-490"

19 Bałucińska-Church, M., Church, M. J., Charles, P. A., et al., 2000, MNRAS, 311, 868
"The distribution of X-ray dips with orbital phase in Cygnus X-1"

(C) Publicly Available Conference Proceedings

20 Barnard, R., Shaw Greening, L., Kolb, U., Proceedings "X-rays from Nearby Galaxies" 4-7 September 2007 (arXiv:0710.4893)
"A multi-coloured survey of NGC 253 with XMM-Newton"

21 Stiele, H., Pietsch, W., Haberl, F., et al., 2007, Proceedings "X-rays from Nearby Galaxies" 4-7 September 2007 (arXiv:0711.3696v1)

22 Barnard, R., Trudolyubov, S., Haswell C.A., et al., 2007, AIPC, 924, 691
"Artificial variability in XMM-Newton observations of X-ray sources: M31 as a test case"

23 Barnard, R., Foulkes, S.B., Haswell, C.A., et al., Proceedings 'The X-ray Universe 2005' San Lorenzo de El Escorial (Madrid, Spain) 26-30 September 2005, astro-ph/0511067
"Discovery and modelling of disc precession in the M31 X-ray binary Bo 158?**"**

24 Shaw Greening, L., Tonkin, C., Barnard, R., Kolb, U., Osborne, J. P., Proceedings IAU230: 'Populations of High Energy Sources in Galaxies', 14-19 August 2005, Dublin, Eds E.J.A. Meurs and G. Fabbiano, astro-ph/0509583
"Cumulative luminosity functions of the X-ray point source population in M31"

25 Barnard, R., Shaw Greening, L., Tonkin, C., Kolb, U., Osborne, J. P., Proceedings IAU230: 'Populations of High Energy Sources in Galaxies', 14-19 August 2005, Dublin, Eds E.J.A. Meurs and G. Fabbiano, astro-ph/0509533
"XMM-Newton reveals ~100 new LMXBs in M31 from variability studies"

26 Barnard, R., Osborne, J. P., Kolb, U., Haswell, C. A., 2004, AIP Conference Proceedings `Interacting binaries: Accretion, evolution and outcomes' (Cefalu, July 4—1 2004), 797, 219
"Black hole hunting in the Andromeda Galaxy"

27 Barnard, R., 2004, Proc. `IAU colloquium 194: Compact binaries in the Galaxy and Beyond', RevMexAA, (Serie de Conferencias), 20, 71-72
"Big game hunting in the Andromeda Galaxy: Identifying and weighing black holes in low mass X-ray binaries"

28 Osborne, J. P., Priedhorsky, W., Barnard, R., et al., 2002, Proc. Symposium `New visions of the X-ray universe in the XMM-Newton and Chandra era' 26--30 November 2001, ESTEC, The Netherlands, ESA SP-488

“The XMM-Newton survey of M 31”

29 Barnard, R., Kolb, U., Osborne, J. P., 2002,Proc. Symposium `New visions of the
X-ray universe in the XMM-Newton and Chandra era' 26--30 November 2001, ESTEC,
The Netherlands, ESA SP-488
“XMM-Newton observations of variability in the X-ray binaries of M 31: flares, dips and a burst”