

Basic parameters of the helium-accreting X-ray bursting neutron star in 4U 1820-30

Suleimanov V., Kajava J., Molkov S., Nättilä J., Lutovinov A., Werner K., Poutanen J.
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

© 2017 The Authors Published by Oxford University Press on behalf of the Royal Astronomical Society. The ultracompact low-mass X-ray binary 4U 1820-30 situated in the globular cluster NGC 6624 has an orbital period of only ≈ 11.4 min, which likely implies a white dwarf companion. The observed X-ray bursts demonstrate a photospheric radius expansion phase and therefore are believed to reach the Eddington luminosity, allowing us to estimate the mass and the radius of the neutron star (NS) in this binary. Here, we re-analyse all Rossi X-ray Timing Explorer observations of the system and confirm that almost all the bursts took place during the hard persistent state of the system. This allows us to use the recently developed direct cooling tail method to estimate the NS mass and radius. However, because of the very short, about a second, duration of the cooling tail phases that can be described by the theoretical atmosphere models, the obtained constraints on the NS radius are not very strict. Assuming a pure helium NS atmosphere, we found that the NS radius is in the range 10-12 km, if the NS mass is below $1.7 M_{\odot}$, and in a wider range of 8-12 km for a higher 1.7 - $2.0 M_{\odot}$ NS mass. The method also constrains the distance to the system to be 6.5 ± 0.5 kpc, which is consistent with the distance to the cluster. For the solar composition atmosphere, the NS parameters are in strong contradiction with the generally accepted range of possible NS masses and radii.

<http://dx.doi.org/10.1093/mnras/stx2234>

Keywords

Stars: neutron, X-rays: bursts - X-rays: individual: 4U 1820-30, X-rays: stars

References

- [1] Arnaud K. A., 1996, in Jacoby G. H., Barnes J., eds, ASP Conf. Ser. Vol. 101, ADASS V. Astron. Soc. Pac., San Francisco, p. 17
- [2] Bildsten L., 1998, in Buccheri R., van Paradijs J., Alpar A., eds, NATO Advanced Science Institutes (ASI) Series C Vol. 515, The Many Faces of Neutron Stars. Kluwer Academic Publishers, Dordrecht, p. 419
- [3] Chou Y., Grindlay J. E., 2001, ApJ, 563, 934
- [4] Clark G.W., Li F. K., Canizares C., Hayakawa S., Jernigan G., Lewin W. H. G., 1977, MNRAS, 179, 651
- [5] Costantini E. et al., 2012, A&A, 539, A32
- [6] Cumming A., 2003, ApJ, 595, 1077
- [7] Cumming A., 2004, Nucl. Phys. B, 132, 435
- [8] Damen E., Magnier E., Lewin W. H. G., Tan J., Penninx W., van Paradijs J., 1990, A&A, 237, 103
- [9] Ebisuzaki T., 1987, PASJ, 39, 287

- [10] Galloway D. K., Muno M. P., Hartman J. M., Psaltis D., Chakrabarty D., 2008, *ApJS*, 179, 360
- [11] García F., Zhang G., Méndez M., 2013, *MNRAS*, 429, 3266
- [12] Gilfanov M., Revnivtsev M., Molkov S., 2003, *A&A*, 410, 217
- [13] Grindlay J., Gursky H., Schnopper H., Parsignault D. R., Heise J., Brinkman A. C., Schrijver J., 1976, *ApJ*, 205, L127
- [14] Güver T., Wroblewski P., Camarota L., Özel F., 2010, *ApJ*, 719, 1807
- [15] Haberl F., Stella L., White N. E., Gottwald M., Priedhorsky W. C., 1987, *ApJ*, 314, 266
- [16] Haensel P., Potekhin A. Y., Yakovlev D. G., 2007, *Astrophysics and Space Science Library Vol. 326, Neutron Stars 1: Equation of State and Structure*. Springer, New York
- [17] Heasley J. N., Janes K. A., Zinn R., Demarque P., Da Costa G. S., Christian C. A., 2000, *AJ*, 120, 879
- [18] Iben I. Jr., Tutukov A. V., 1991, *ApJ*, 370, 615
- [19] in't Zand J. J. M., Weinberg N. N., 2010, *A&A*, 520, A81
- [20] in't Zand J. J. M., Homan J., Keek L., Palmer D. M., 2012, *A&A*, 547, A47
- [21] Inogamov N. A., Sunyaev R. A., 2010, *Astron. Lett.*, 36, 848
- [22] Ji L. et al., 2013, *MNRAS*, 432, 2773
- [23] Ji L., Zhang S., Chen Y., Zhang S.-N., Torres D. F., Kretschmar P., Li J., 2014, *ApJ*, 791, L39
- [24] Kajava J. J. E. et al., 2014, *MNRAS*, 445, 4218
- [25] Kajava J. J. E., Nätttilä J., Poutanen J., Cumming A., Suleimanov V., Kuulkers E., 2017, *MNRAS*, 464, L6
- [26] Kúsmierek K., Madej J., Kuulkers E., 2011, *MNRAS*, 415, 3344
- [27] Kuulkers E., den Hartog P. R., in't Zand J. J. M., Verbunt F. W. M., Harris W. E., Cocchi M., 2003, *A&A*, 399, 663
- [28] Lapidus I. I., Sunyaev R. A., Titarchuk L. G., 1986, *Sov. Astron. Lett.*, 12, 383
- [29] Lattimer J. M., Prakash M., 2007, *Phys. Rep.*, 442, 109
- [30] Lattimer J. M., Prakash M., 2016, *Phys. Rep.*, 621, 127
- [31] Lattimer J. M., Steiner A. W., 2014, *ApJ*, 784, 123
- [32] Lewin W. H. G., van Paradijs J., Taam R. E., 1993, *Space Sci. Rev.*, 62, 223
- [33] London R. A., Howard W. M., Taam R. E., 1984, *ApJ*, 287, L27
- [34] London R. A., Taam R. E., Howard W. M., 1986, *ApJ*, 306, 170
- [35] Madej J., 1991, *ApJ*, 376, 161
- [36] Nätttilä J., Suleimanov V. F., Kajava J. J. E., Poutanen J., 2015, *A&A*, 581, A83
- [37] Nätttilä J., Steiner A. W., Kajava J. J. E., Suleimanov V. F., Poutanen J., 2016, *A&A*, 591, A25
- [38] Özel F., 2006, *Nature*, 441, 1115
- [39] Özel F., Psaltis D., Güver T., Baym G., Heinke C., Guillot S., 2016, *ApJ*, 820, 28
- [40] Paczynski B., Anderson N., 1986, *ApJ*, 302, 1
- [41] Pavlov G. G., Shibanov I. A., Zavlin V. E., 1991, *MNRAS*, 253, 193
- [42] Poutanen J., Nätttilä J., Kajava J. J. E., Latvala O.-M., Galloway D. K., Kuulkers E., Suleimanov V. F., 2014, *MNRAS*, 442, 3777
- [43] Postnov K. A., Shakura N. I., 1987, *Sov. Astr. Lett.*, 13, 122
- [44] Priedhorsky W., Terrell J., 1984, *ApJ*, 284, L17
- [45] Rappaport S., Ma C. P., Joss P. C., Nelson L. A., 1987, *ApJ*, 322, 842
- [46] Rauch T., Suleimanov V., Werner K., 2008, *A&A*, 490, 1127
- [47] Revnivtsev M. G., Suleimanov V. F., Poutanen J., 2013, *MNRAS*, 434, 2355
- [48] Shaposhnikov N., Titarchuk L., 2004, *ApJ*, 606, L57
- [49] Steiner A. W., Lattimer J. M., Brown E. F., 2010, *ApJ*, 722, 33
- [50] Stella L., Priedhorsky W., White N. E., 1987, *ApJ*, 312, L17
- [51] Strohmayer T., Bildsten L., 2006, in Lewin W., van der Klis M., eds, *Compact stellar X-ray sources*, Cambridge Astrophysics Series, No. 39. Cambridge Univ. Press, Cambridge, p. 113
- [52] Strohmayer T. E., Brown E. F., 2002, *ApJ*, 566, 1045
- [53] Suleimanov V., Poutanen J., Werner K., 2011a, *A&A*, 527, A139
- [54] Suleimanov V., Poutanen J., Revnivtsev M., Werner K., 2011b, *ApJ*, 742, 122
- [55] Suleimanov V., Poutanen J., Werner K., 2012, *A&A*, 545, A120
- [56] Suleimanov V. F., Poutanen J., Klochkov D., Werner K., 2016, *Eur. Phys. J. A*, 52, 20
- [57] Suleimanov V. F., Poutanen J., Nätttilä J., Kajava J. J. E., Revnivtsev M. G., Werner K., 2017, *MNRAS*, 466, 906

- [58] Vacca W. D., Lewin W. H. G., van Paradijs J., 1986, MNRAS, 220, 339
- [59] van Paradijs J., Lewin W. H. G., 1987, A&A, 172, L20
- [60] van Paradijs J., Dotani T., Tanaka Y., Tsuru T., 1990, PASJ, 42, 633
- [61] Weinberg N. N., Bildsten L., Schatz H., 2006, ApJ, 639, 1018
- [62] Worpel H., Galloway D. K., Price D. J., 2013, ApJ, 772, 94
- [63] Worpel H., Galloway D. K., Price D. J., 2015, ApJ, 801, 60
- [64] Zamfir M., Cumming A., Galloway D. K., 2012, ApJ, 749, 69
- [65] Zdziarski A. A., Wen L., Gierliński M., 2007, MNRAS, 377, 1006