

Progress report on the work done in 2003 at the UK Astrophysical Fluids Facility of Leicester University, England, and supported by the European Community "Access to Research Infrastructure action of the Improving Human Potential" Program.

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PROJECT OBJECTIVES:

(no more than 10 lines)

Wlodek Kluzniak and I have noticed that the QPO variability frequencies in the X-ray flux of the BH source GRO J1655-40 are in the 3:2 ratio, and that that rational ratios are a genuine, typical property of QPOs observed in BH and NS sources. Rational ratios suggest that a resonance may be at work here. Working in 2002 at UKAFF, we explored an idea that a parametric resonance affects nearly circular, nearly Keplerian, nearly equatorial plane motion of test particles around a black hole or a neutron star. We numerically constructed a simple model, which reproduces rather well the Sco X-1 observational data. In 2003, we plan to continue this work at UKAFF by considering a much more advanced fluid model of the phenomenon.

MAIN ACHIEVEMENTS AND DIFFICULTIES ENCOUNTERED:

(no more than 20 lines)

No difficulties have been encountered. Several sub-projects have been completed, of which I will mention two most interesting.

01. Mathematical improvements of the theory: We found an exact mathematical formulation of our theory that explains kHz QPOs as a non-linear orbital resonance. Using the multiple-scale method, Paola Rebusco and Jiri Horak found general analytic solution relevant to the astrophysical situation in question. This rather difficult mathematical result has several important consequences, including the one for the "normal branch oscillations" (NBOs) in the Z sources. Until now, the NBOs were thought to be physically distinct from the kHz QPOs. We demonstrated that a low-frequency modulation of the kHz QPOs is a natural consequence of the non-linear relativistic resonance suggested previously by us to explain the properties of the high-frequency twin peaks. Our theory reproduces the 6 Hz NBOs of frequency and amplitude of the kHz QPOs reported by Yu, van der Klis and Jonker.

02. Observed variability from oscillating torus: Michal Bursa developed a supercomputer code to trace off-equatorial plane null geodesics in a general (numerically given) stationary, axially symmetric metric. We used his code to calculate observed variability that is due to strong-field effects (relativistic Doppler and lensing) of almost axially symmetric, oscillating sources. This was never calculated before. For the first time one sees that a very strong luminosity modulation may be achieved in almost axially symmetric situation.

PAPERS PUBLISHED:

01. Gravitating discs around black holes

Topical Review

V Karas, J-M Hure and O Semerak

Classical and Quantum Gravity, **21**, R1-R51 (2004).

astro-ph/0401345

02. Non-linear resonance in the accretion disk of a millisecond pulsar

W.Kluzniak, M.A. Abramowicz, S.Kato, W.H. Lee, N.Stergioulas

Astrophysical Journal Letters, **603**, L89-L92, 2004

astro-ph/0308035

03. Interpreting black hole QPOs

Invited lecture: X-Ray Timing 2003: Rossi and Beyond (Harvard, 2003)

M.A. Abramowicz, W.Kluzniak

In print: "X-Ray Timing 2003: Rossi and Beyond", ed. P. Kaaret, F. K. Lamb, & J. H. Swank (Melville, NY: American Institute of Physics).

astro-ph/0312396

04. The orbital resonance model for twin peak kHz QPOs

M.A. Abramowicz, W.Kluzniak, Z.Stuchlik, G.Torok

In print: Astronomy and Astrophysics

astro-ph/0401464

05. The importance of discovering a 3:2 twin-peak QPO in a ULX or how to solve the puzzle of intermediate mass black holes

M.A. Abramowicz, W.Kluzniak, J.E. McClintock, R.A. Remillard

In print: The Astrophysical Journal Letters

astro-ph/0402012

06. High-frequency QPOs as a problem in physics: non-linear resonance

Presented at: X-Ray Timing 2003: Rossi and Beyond (Harvard, 2003)

W.Kluzniak, M.A. Abramowicz, W.H. Lee

In print: "X-Ray Timing 2003: Rossi and Beyond", ed. P. Kaaret, F. K. Lamb, & J. H. Swank (Melville, NY: American Institute of Physics). astro-ph/0402013

07. Twin peaks kHz QPOs: mathematics of the 3:2 orbital resonance

P. Rebusco

In print: Publications of the Astronomical Society of Japan

astro-ph/0403341

08. The Hartle-Thorne circular geodesics

M.A. Abramowicz, G.J.E. Almergren, W. Kluzniak, A.V. Thampan

Submitted: Classical and Quantum Gravity

gr-qc/0312070

09. Of NBOs and kHz QPOs: a low-frequency modulation in resonant oscillations of relativistic accretion disks

J.Horak, M.A. Abramowicz, V.Karas, W. Kluzniak

Submitted: The Astrophysical Journal Letters

All the papers listed above acknowledge that computations reported in them were performed using the UK Astrophysical Fluids Facility. They also acknowledge the support of the European Community - Access to Research Infrastructure action of the Improving Human Potential Program.

This report was sent to James Gray at UKAFF

A questionnaire about the EU program and the UKAFF facility was taken from:
ftp://ftp.cordis.lu/pub/improving/docs/ari_tac_quest.doc
completed, and sent to Ms. Brigitte Sambain of the European Commission in Brussels