Colibrì

Taking the pulse of Neutron Stars and Black Holes

Jeremy Heyl and Kelsey Hoffman for the Colibrì Team

contact: heyl@phas.ubc.ca

More Information:

www.colibri-telescope.ca

The Colibrì Team:

Jeremy Heyl (PI), Ilaria Caiazzo, Kelsey Hoffman, Sarah Gallagher, Daryl Haggard, Piotr Jasiobedzki, Kostis Michelakis, Neil Rowlands, Samar Safi-Harb, Gregory Sivakoff, Luigi Gallo, Ben Guest, Craig Heinke, Demet Kirmizibayrak, Sharon Morsink, Paul Ripoche, Mario Beaudoin, Dwight Caldwell, Andrew Cumming, Andrea Damascelli, Pinder Dosanjh, Josh Folk, Dennis Gregoris, Karl Jessen, Jagannath Kshtriya, Wolfgang Rau, Bob Rutledge, Ingrid Stairs, and Jeff Young

The First Canadian X-ray Telescope Concept

Colibrì is a proposed X-ray telescope concept designed to unveil the mysteries of neutron stars and black holes. With high spectral and time resolution, and high throughput, *Colibrì* will allow the study of accretion disks and coronae, including reflection and re-emission of radiation by the disk, and observations of isolated and accreting neutron stars.

Colibrì will take advantage of recent advancements in transition-edge sensors (TES) technology to achieve eV-resolution spectroscopy with nanoseconds-precision timing. Combining TES-based detectors with collector optics, *Colibrì* will achieve a high throughput and a large effective area. This concept study is being funded by the Canadian Space Agency (under contract number 9F050-170252/004/MTB).

Science Questions

1) How do accretion disks transport matter?

2) How are relativistic jets launched?

3) What is the structure of spacetime surrounding black holes?

4) What are the masses and radii of neutron stars?

Mission Parameters

- Energy Range: 0.1 - 20 keV
- Energy Resolution: finer than 1 eV at 2 keV (3 eV at 6 keV)
- High throughput: count rates up to 100 kHz
- Timing resolution: better than 1 μs, a factor of fifty smaller than the light-crossing time of a 10 solar-mass black hole
- Total effective area: 2000cm² at 6.4 keV

Neutron Star Science

The neutron star science objectives are the study of accreting and isolated neutron stars to understand the physics of accretion onto the surface and measure properties such as mass, radius and atmospheric composition. The high sensitivity and high-timing resolution of *Colibrì* will allow for detection of reverberation lags in neutron star binaries. Spectral line observations would measure the atmosphere composition and the ratio of M/R. Measurement of the width of the spectral line of a pulsar with known spin period, as in the case of the 61.9 ms PSR J1833-1034, could provide extra constraints on the neutron star's radius (See Test Case Box).

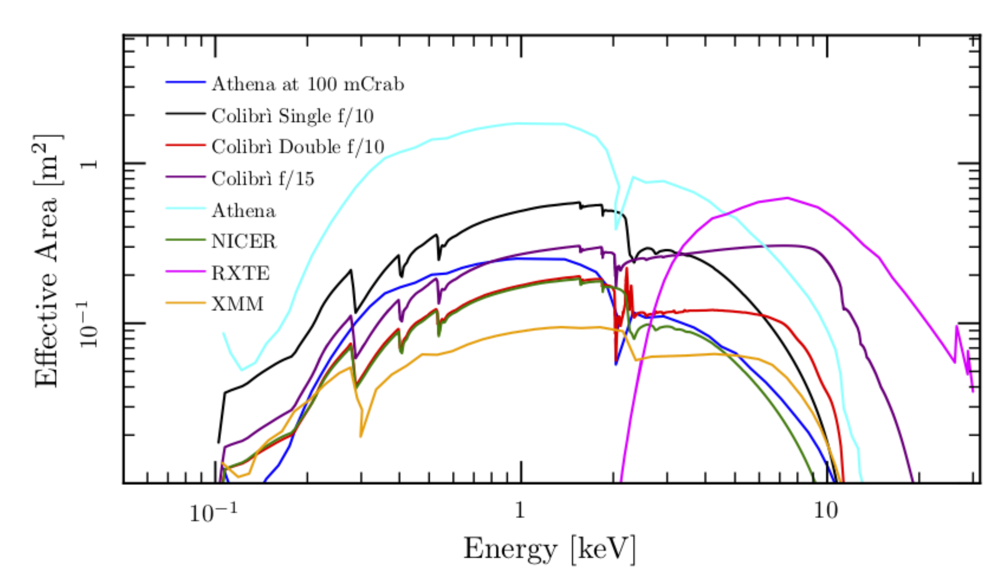
Quasi-Periodic Oscillations

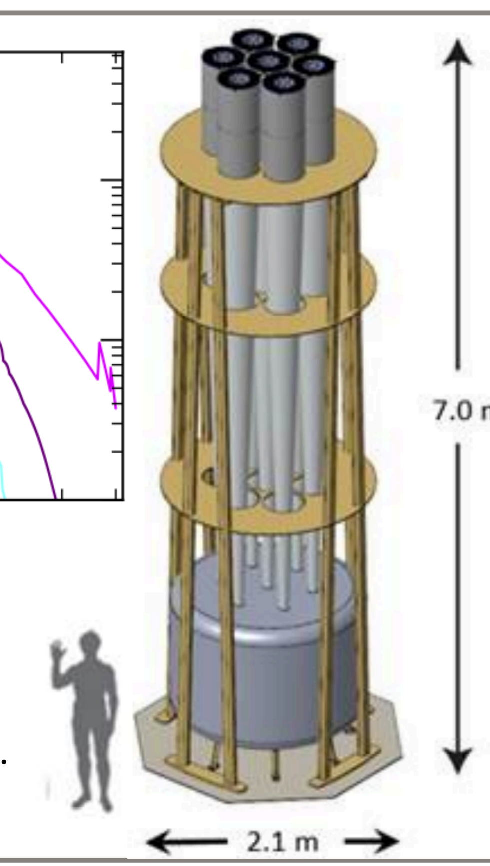
Observations of BHBs with RXTE have driven extraordinary progress in the study of their variability properties. In many of these systems, quasi periodic oscillations (QPOs) were discovered and thought to originate in the inner regions of the accretion disk. The mechanism responsible for QPOs is still debated, but a careful study of their characteristics can lead to a better understanding of the physics of black-hole accretion and of general relativistic effects in the strong field regime.

Observations of the higher-frequency peak of neutron star kHz QPOs would help to place constraints on the mass-radius relationship of neutron stars.

Colibrì the Instrument

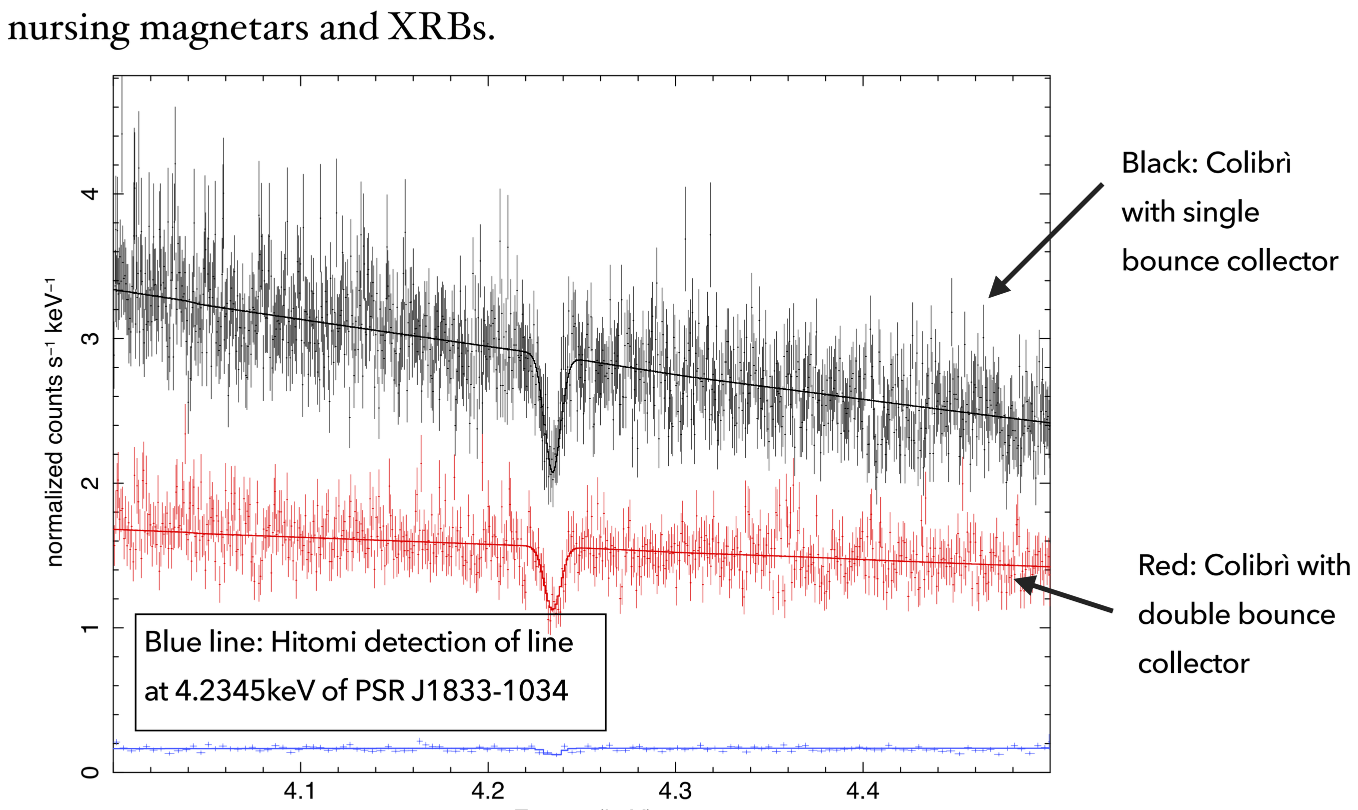
The *Colibrì* concept is based on multiple aperture non-imaging X-ray collectors similar to NICER but with cryogenically cooled transition edge detectors for high energy resolution and sensitivity. *Colibrì* aims to achieve an energy resolution finer than 1eV at 2 keV, and count rates up to 100kHz, in an energy range of 0.5-20 keV. The timing of *Colibrì* aims to be better than 1μs, a factor of fifty smaller than the light-crossing time of a 10 solar-mass black hole. The total effective area of *Colibrì* is to be at least 2000 cm² at 6.4 keV. Optics concepts are currently being investigated in order to increase the effective area, for example a single-bounce vs. double-bounce collector. A comparison of the effective area anticipated for *Colibrì* as compared to other X-ray instruments is shown on the right.

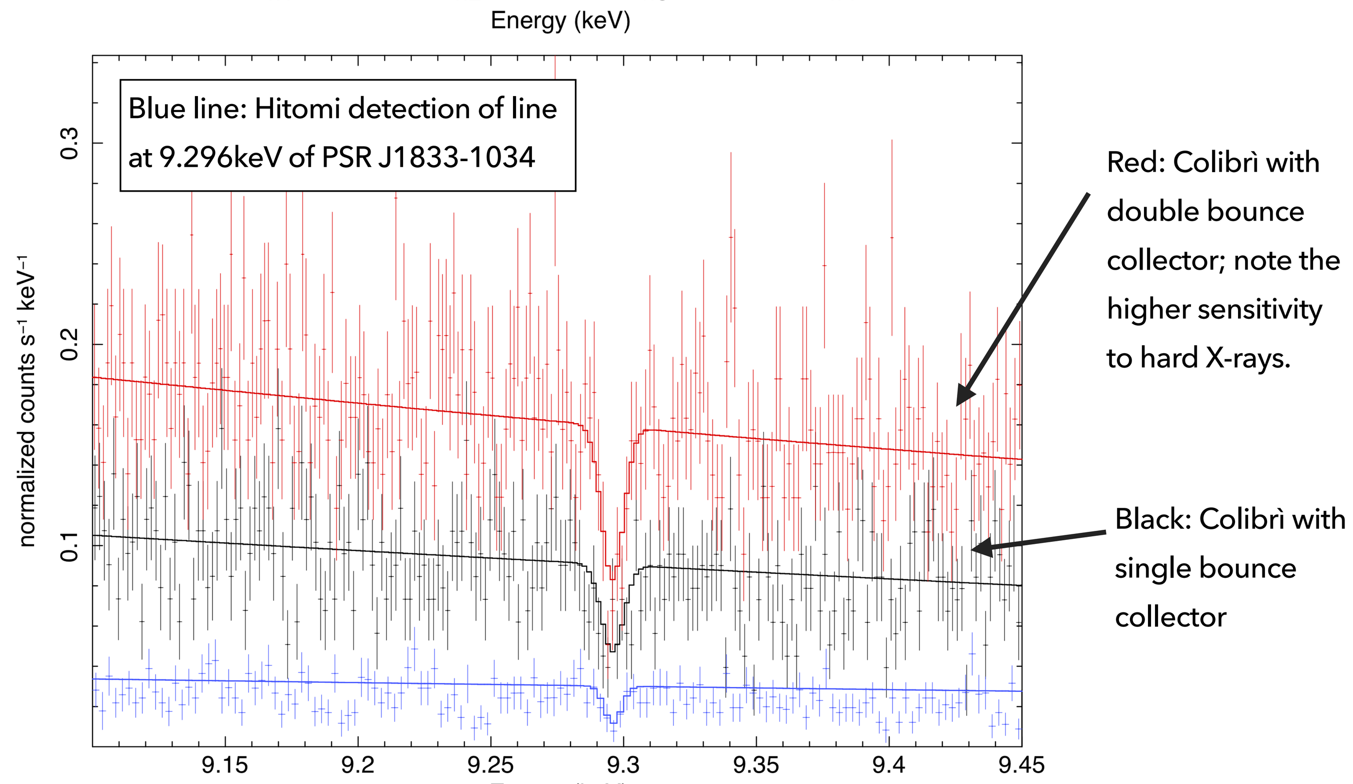




Test Case: Neutron Star Spectral Lines

Recently the Hitomi satellite found evidence for weak and narrow absorption lines from the rotational-powered pulsar PSR J1833-1034 in the supernova remnant G21.5-0.9 at 4.2345 keV and 9.296 keV. The upper figure shows the line detected with Hitomi at 4.2345keV from PSR J1833-1034 (blue) compared to simulations for *Colibrì* for the same observing time with two mirror configurations: single-bounce collector (black) with three times the geometric area of NICER and double-bounce collector (red) with the same geometric area as NICER. The lower figure is the comparison of the Hitomi detection of the line at 9.296keV to the same simulations using the two different mirror configurations of *Colibrì*. *Colibrì* will allow for the search of narrow spectral lines from a diversity of isolated and accretion powered pulsars, including nursing magnetars and XRBs.





Black Hole Science

The science objectives of *Colibrì* include the study of accretion disk physics and the effects of strong-field gravity around black holes, as well as probing the spacetime around black holes and putting constraints on different theories of gravity.

One of the most subtle consequences of GR is the "no-hair" theorem, for which black holes can be fully characterized by their mass, angular momentum and charge. The only way to test this theorem is to probe the spacetime very close to the hole. Fortunately, the X-ray emission of accreting black holes carries information about the inner region of the accretion disk, within a few gravitational radii from the hole, encoded in the fast variability of its spectrum. In particular, the emission from the accretion flow very close to accreting compact objects presents high-precision diagnostics of their spacetime, including reverberation mapping and quasi-periodic oscillations. Furthermore, variability in the X-ray emission from accreting compact objects also carries information on the accretion processes themselves.

Reverberation Mapping

In both neutron stars and black holes, X-ray emission from outside the disk (coming from the neutron star's surface or from a glowing corona above the black hole) can be reflected by the disk into our line of sight. By correlating the primary emission with the reflected one we can map the accretion disk: as more distant regions of the accretion disk will be illuminated in subsequent times, photons of different energy will present different time delays.

The combination of high sensitivity and high timing resolution of *Colibrì* will enable the detection of reverberation lags for neutron star binaries.

UBC · Université Bishop's University · Western · University of Manitoba · University of Alberta · McGill University · Saint Mary's University Since 1802 · Queen's University · CSA ASC · Stewart Blusson Quantum Matter Institute, The University of British Columbia · TRIUMF · Honeywell · MDA