How do accretion disks transport matter?

- How are relativistic jets launched?
- What is the structure of spacetime surrounding black holes?
- What are the masses and radii of neutron stars?

ission Parameters

- nergy Range: 0.1 10 keV
- nergy Resolution: finer than 1 eV at 2 keV (3 eV at 6 keV)
- ligh throughput: count rates up to 100 kHz
- iming resolution: better than 1 μ s, matching the innermost bit period for a 10 solar-mass black hole
- otal effective area: 2000cm² at 6.4 keV

eutron Star Science

Case: Neutron Star Spectral Lines

tellite found evidence for weak and narrow absorption lines vered pulsar PSR J1833-1034 in the supernova remnant at 4.2345 keV and 9.296 keV. The upper figure shows the line detected with it 4.2345keV from PSR J1833-1034 (blue) compared to simulations for Colibri 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 Colibri. Colibri will allow for the search of narrow spectral lines from a diversity of isolated and accretion powered pulsars, including nursing magnetars and XRBs.

Blue line: Hitomi detection of line at 4.2345keV of PSR J1833-1034 4.1 4.2 4.4 4.3 Energy (keV) Reverbergation Mapping Reverbergation Mapping In both neutron stars and black holes, X-may a uasi-Periodie Oscillations DA'S Blue line: Hitomi detection of line at 9.296keV of PSR J1833-1034 n the inner he mecha egi of t accretion p t accr on d · O 11 deba e<mark>d, b</mark> t a careful study is st of the ion wi acc car to ette inde the of d hote sequent nes, relativist s in 1 chole acc<mark>reti</mark>o nd of ne stron<mark>g fi</mark> rener liffe nt 1 he bin ion hig nsit cy peak of star kH POs equ Colib ll enab 9.15 92 9.25 9.3 9.45 Enerav (keV) **UBC** UNIVERSITY UNIVERSITY OF SAINT MARY'S UNIVERSITY SINCE 1802



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<u>of</u> Manitoba Stewart Blusson Quantum Matter Institute

THE UNIVERSITY OF BRITISH COLUMBIA

Western

TRIUMF Honeywell MDA

Black Hole

The science objectives of Colibri include the stu accretion disk physics and the effects of strong 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 "nohair" 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 nformation about the inner region of the accretion isk, within a few gravitational radii from the hole, ncoded in the fast variability of its spectrum. In articular, the emission from the accretion flow very lose to accreting compact objects presents highrecision diagnostics of their spacetime, including ation mapping and quasi-periodic oscillations. urthermore, variability in the X-ray emission from ompact objects also carries information on

Colibri: Take Home Message

High-Time Resolution High-Spectral Resolution High-Throughput

Transition Edge Sensor (TES) Detectors in Space

The Colibri Team

Jeremy Heyl, UBC



Principle Investigator

Daryl Haggard, McGill



Mission Planning Lead

Ilaria Caiazzo, UBC



Project Scientist

Kelsey Hoffman, Bishop's



Project Manager

Samar Safi-Harb, Manitoba



Neutron Star WG Lead

Sarah Gallagher, Western



Black Holes WG Lead

The Colibrì Team

Gregory Sivakoff, Alberta



Coordinated Observations Lead

Kostis Michelakis, SBQMI, UBC



Detectors

Neil Rowlands, Honeywell



Payload

Piotr Jasiobedzki, MDA



Satellite

The Colibrì Team

Principal Investigator:

Jeremy Heyl, University of British Columbia

Project Scientist:

Ilaria Caiazzo, University of British Columbia

Project Manager:

Kelsey Hoffman, Bishop's University

Working Group Leads:

Black Holes - Sarah Gallagher, Western University

Neutron Stars - Samar Safi-Harb, University of Manitoba

Mission Planning Lead:

Daryl Haggard, McGill University

Coordinated Observations Lead:

Gregory Sivakoff, University of Alberta

Detector Technical Lead:

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Detector Technical Team members:

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Josh Folk, SBQMI, University of British Columbia

Jeff Young, SBQMI, University of British Columbia

Pinder Dosanjh, SBQMI, University of British Columbia

Mario Beaudoin, SBQMI, University of British Columbia

Andrea Damascelli, SBQMI Director, University of British Columbia

Karl Jessen, SBQMI, University of British Columbia

Science Payload Technical Lead:

Neil Rowlands, Honeywell Aerospace

Science Payload Mechanical/Thermal Engineering Lead:

Dwight Caldwell, Honeywell Aerospace

Satellite Technical Lead:

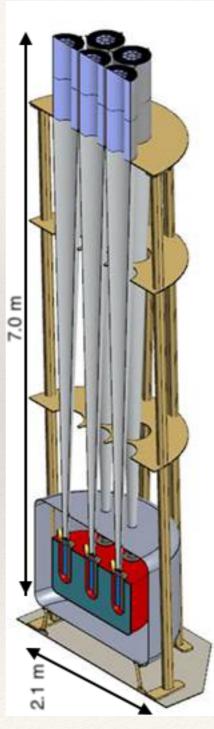
Dr. Piotr Jasiobedzki, MacDonald Dettwiler Satellite Technical Team members: Dennis Gregoris, MacDonald Dettwiler Jagannath Kshtriya, MacDonald Dettwiler Science Working Group Members: Luigi Gallo, St. Mary's University Sharon Morsink, University of Alberta Demet Kırmızıbayrak, University of British Columbia Paul Ripoche, University of British Columbia Andrew Cumming, McGill University Craig Heinke, University of Alberta Ingrid Stairs, University of British Columbia Bob Rutledge, McGill University Benson Guest, University of Manitoba

Colibri Mission Overview

- * High-time resolution, high-spectral resolution and high throughput
- Science questions:
 - 1. Does general relativity apply in the strong gravity regime? Is spacetime around black holes well described by the Kerr metric?
 - 2. Can we better understand the physics of accretion? How do accretion disks lose angular momentum? What is the mechanism behind winds? How are jets launched?
 - 3. How does matter behave in extreme environments in terms of density, gravity and magnetic fields? What is the physics of ultra-dense matter? What are the masses, radii and atmospheric composition of neutron stars?
- Current Status: 18-month concept study (September 2018 February 2020)

Colibri Mission Specs

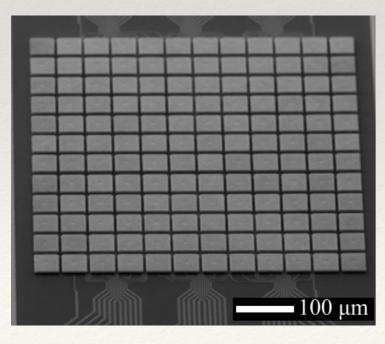
- * Energy Range: 0.5 20 keV
- Energy Resolution: 2 5 eV
- Timing Resolution: 250 ns
- * Effective Area: 3000 cm²
- * Count Rate: >100 kHz
- Orbit: Sun Synchronous,
 500-800km
- * Mission Lifetime: 5 years
- Ground Ops: X-band, CSA
 Sat-Ops/ NRCan



- * Focal Length: 4.9 m
- * Number of Arrays: 7
- * Foils per Array: 30
- * Coating: Iridium
- Detectors: TESBolometers
- * Bath Temp: 70 mK
- * Tc = 100 mK

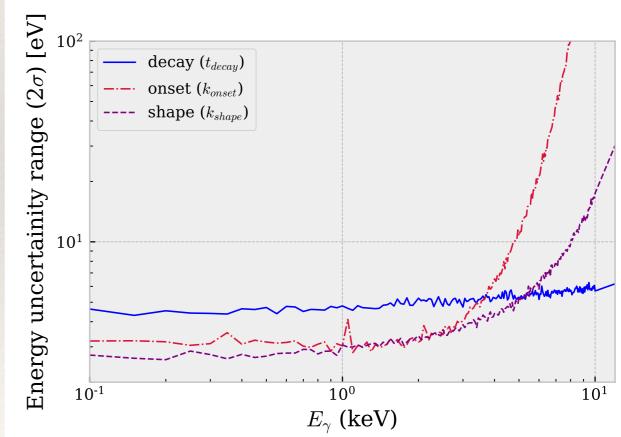
Colibri: TES Detectors

- Transition Edge Sensors: high energy resolution and sensitivity
- Canadian TES detector
 development to be at Stewart
 Blusson Quantum Matter
 Institute at UBC



TES array for X-ray detection from Lee et al. 2015

- On-board pulse processing -Sample every 5 microseconds
- Use of Linear filters (Paul Ripoche, Graduate student at UBC)



Colibri Science Goals

Black Holes

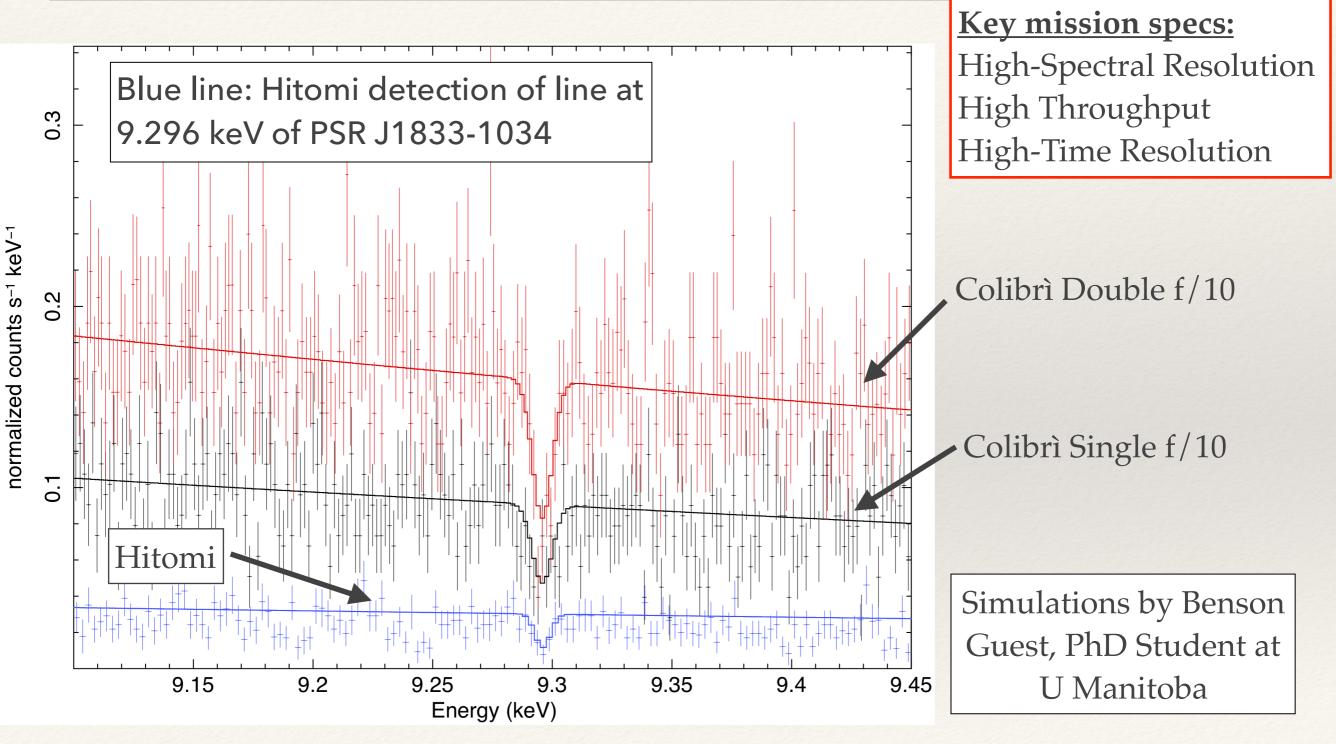
- Reverberation mapping: Test
 GR, measure BH Mass
- Quasi Periodic Oscillations
- Warm/Hot Intergalactic
 Medium
- * High Velocity Hot Outflows

See WP 036 for more details, Talk by Ilaria Caiazzo at UBC Town Hall (Nov 26)

Neutron Stars

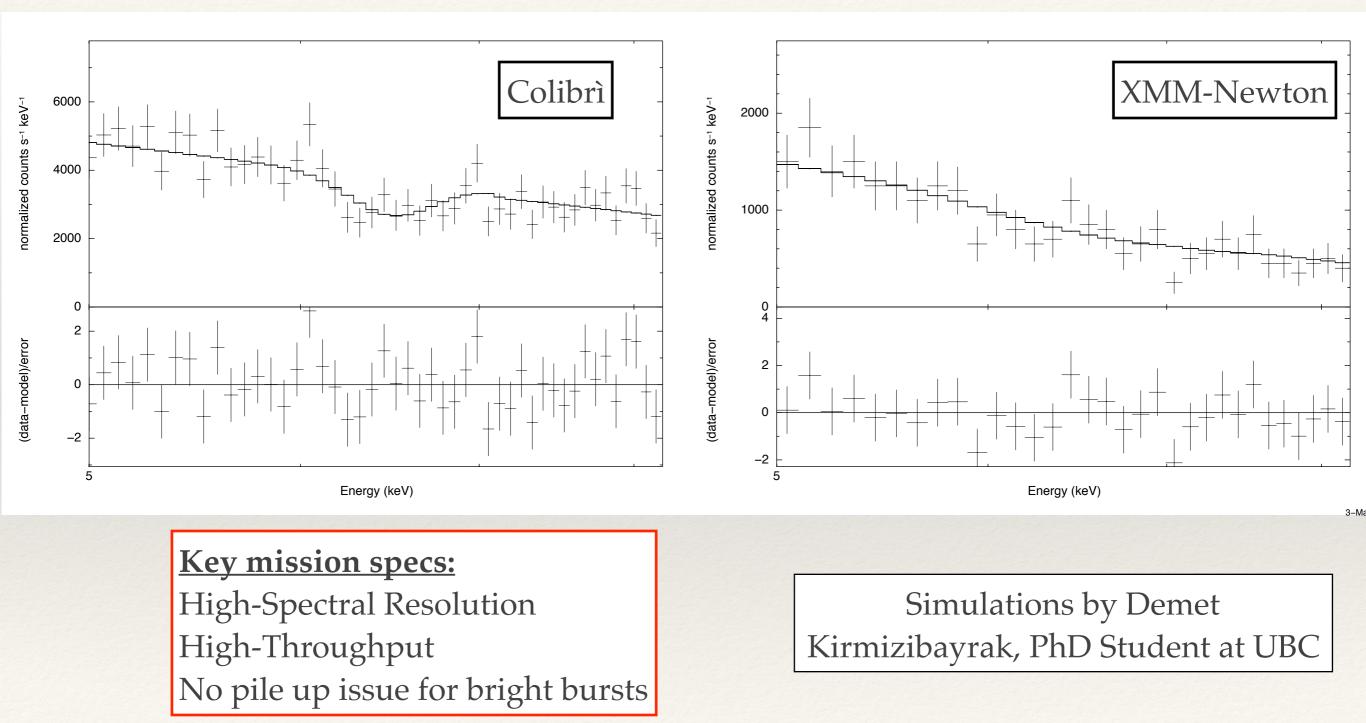
- Lines/Spectroscopy: Isolated and Accreting
- Magnetar Spectral Lines
- Accretion Disk Winds
- Quasi Periodic Oscillations
- Thermonuclear bursts
- * Mass & Radius of Neutron Stars

Spectral Features: PSR J1833-1034

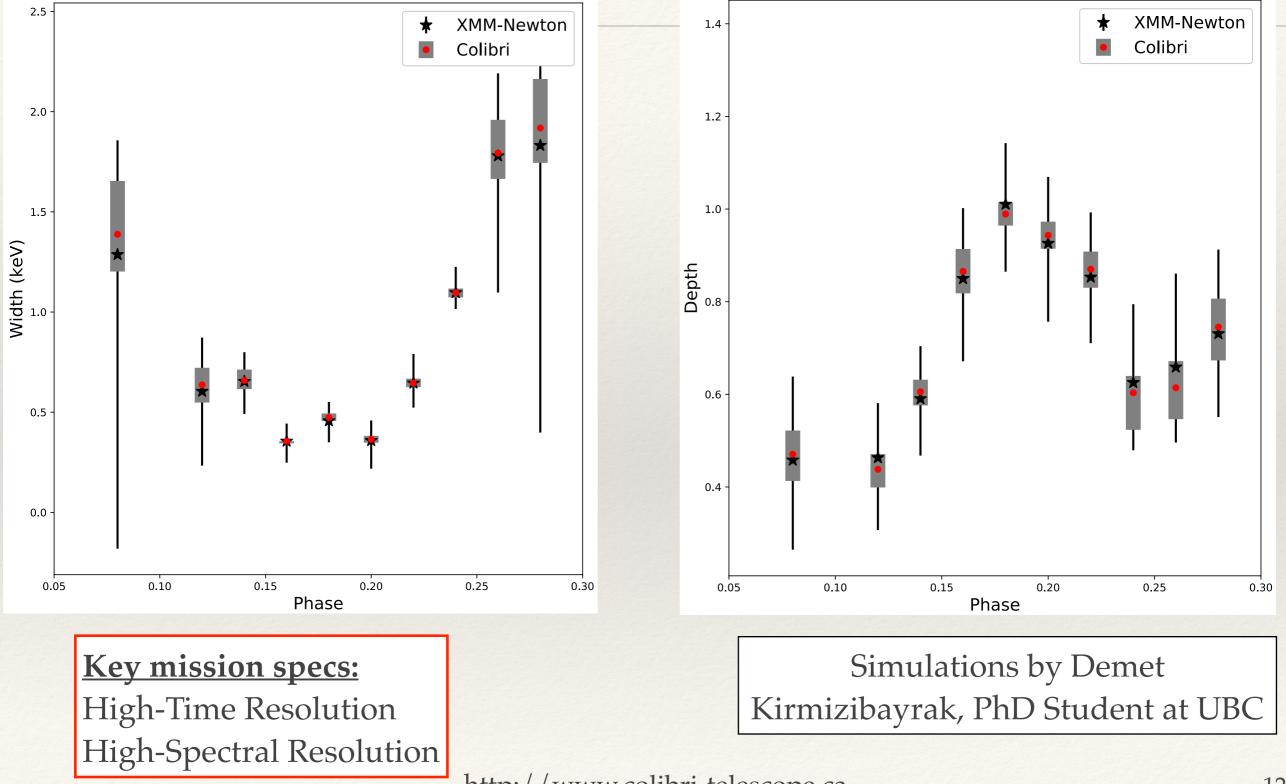


http://www.colibri-telescope.ca

Magnetar Outbursts: SGR 1900+14



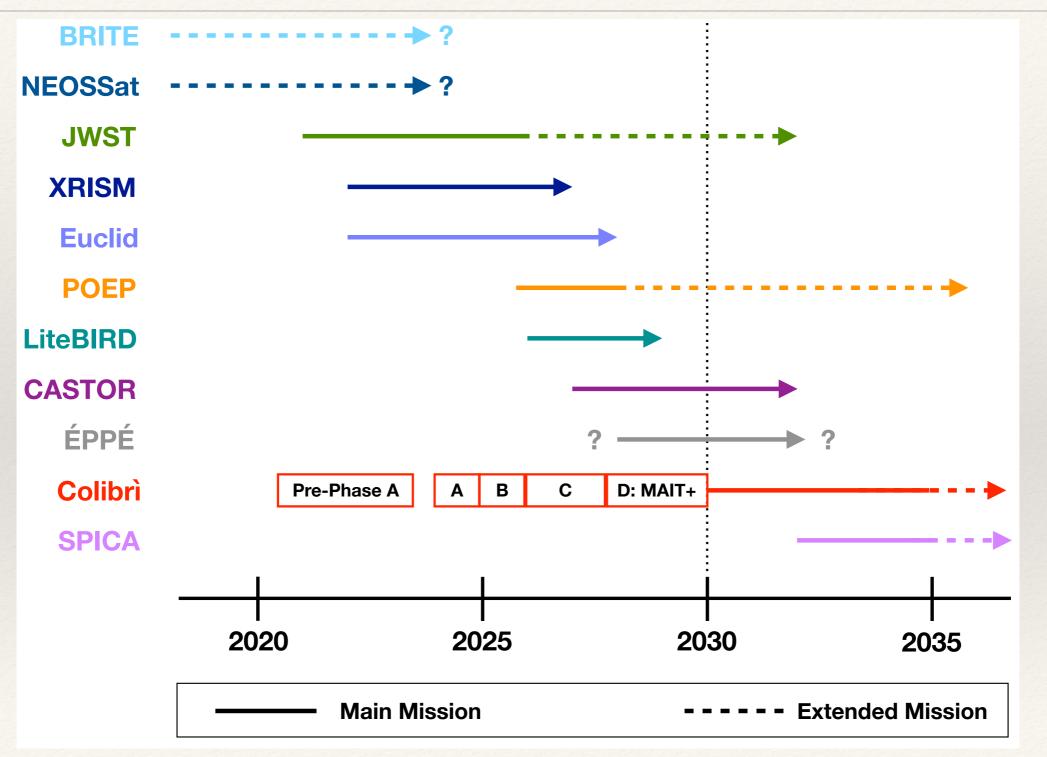
SGR 0418+5729 Phase Resolved Spectroscopy



Colibri: Training and Retention

- * HQP Training:
 - Student involvement has already been instrumental for the progress of the study
 - Preparation of the next generation of leaders
- HQP Retention:
 - * Science office staff positions (R6 of WP: 64)
- Continued mission development also supports the Space Sector

Colibri and the Canadian Landscape



Colibri: Next Steps

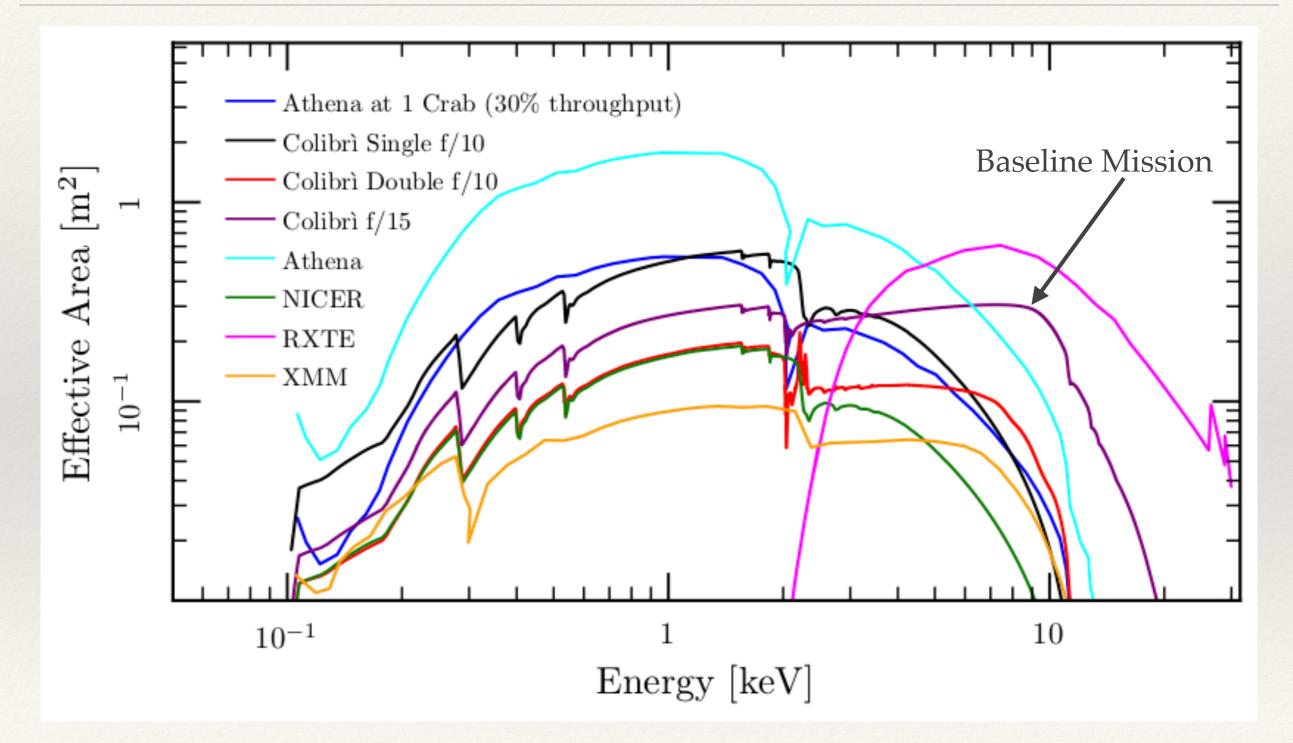
- * FAST Recently submitted, will increase SRL
- * SMS Validate Science requirements, increase SRL
 - Develop secondary science goals
- * STDP Increase TRL of Canadian made TES detectors

The Colibri Mission

- Canada's First Flagship X-ray telescope
- * Builds on CSA's investment in Hitomi and XRISM
- Study the laws of the Physics of the Extreme
- Combination of high-time resolution, high-spectral resolution and high throughput
- Development of TES detectors in Canada
- Opportunities for HQP training throughout development and mission operations
- Job Creation: Through HQP retention via science office, grow the detector industry in Canada, support Canadian space sector — Build a robust and experienced workforce in the Space Sciences
- * In order to continue the development through 2020-2030, build capacity through a space program and support in the LRP report is required

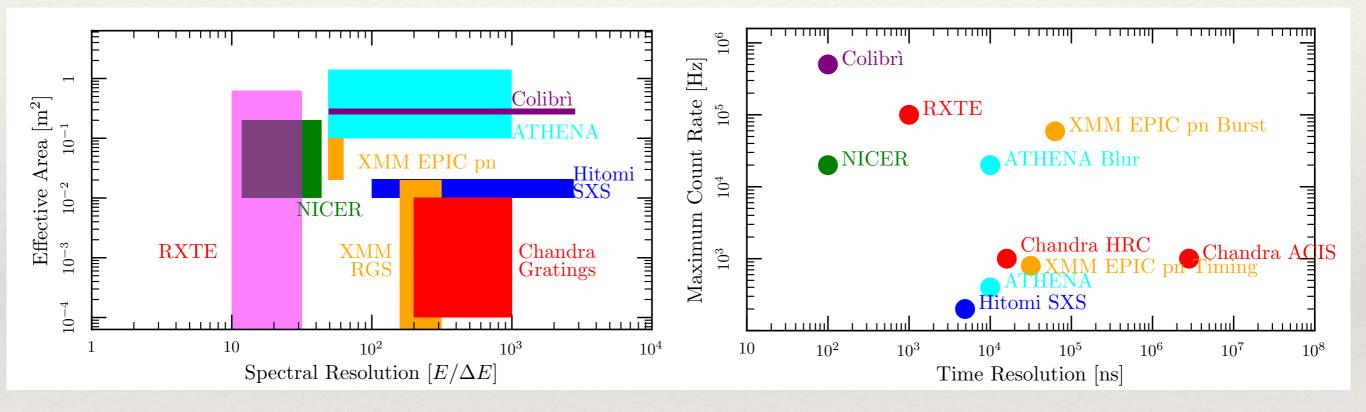
Back up slides

Colibri Effective Collecting Area



http://www.colibri-telescope.ca

Comparison to other X-ray Missions



Spectral Features: PSR J1833-1034

