SEARCHING FOR EXOPLANETS IN EXTREME ENVIRONMENTS VIA DIRECT IMAGING

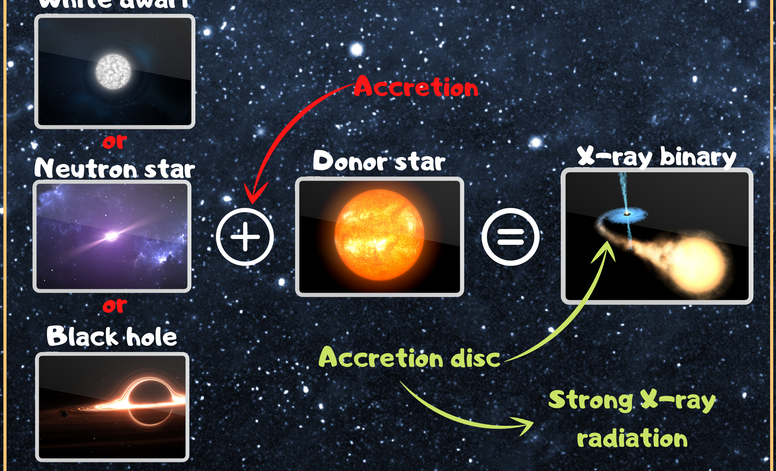
M. PRASOW-ÉMOND (1,2), J. HLAVACEK-LARRONDO (1), K. FOGARTY (3,5), J. RAMEAU (4), L.-S. GUITÉ (1), D. MAWET (5), D. LAFRENIÈRE (1) *ET AL.*

(1) Université de Montréal, (2) iREx, (3) NASA AMES, (4) Université de Grenoble, (5) California Institute of Technology

Overview

As part of a pilot study aiming to explore the immediate environments of X-ray binaries, we obtained NIRC2 observations taken with the W. M. Keck Observatory of a dozen X-ray binaries from 2017 to 2020. These consist of the first high-contrast images of X-ray binaries, enabling us to search for companions (exoplanets, brown dwarfs, and stars) in these extreme environments and potentially completely redefine our comprehension of these binary systems.

X-Ray Binaries



X-ray binaries are unique laboratories for studying astronomical objects and phenomena under extreme conditions

Observations

Build a sample of X-ray binaries that are close and young enough to observe them via direct imaging (19 X-ray binaries).

Prepare for high-contrast imaging (combination of coronagraphy, angular differential imaging, and observational techniques).

Choose filters in the near-infrared, as this is the wavelenght interval for which exoplanets are the brightest.

Use the instrument NIRC2 on the W. M. Keck Observatory, with its vortex coronagraph (6).

2017-2018: Observations for 7 X-ray binaries
2020: Observations for 9 X-ray binaries (2 reobserved)

See Fig. 1 and 2 for the images of the X-ray binaries for which we detected candidate companions. Those are also the first high-contrast images of X-ray binaries ever taken.

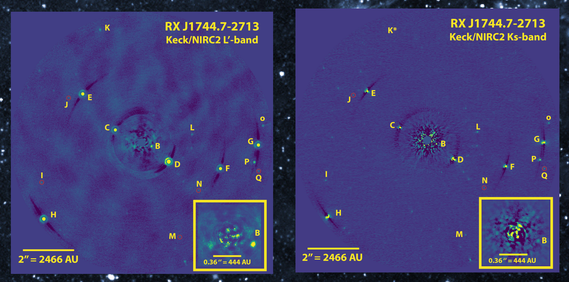


Fig. 1: High-contrast images of RX J1744.7-2713 (two bands)

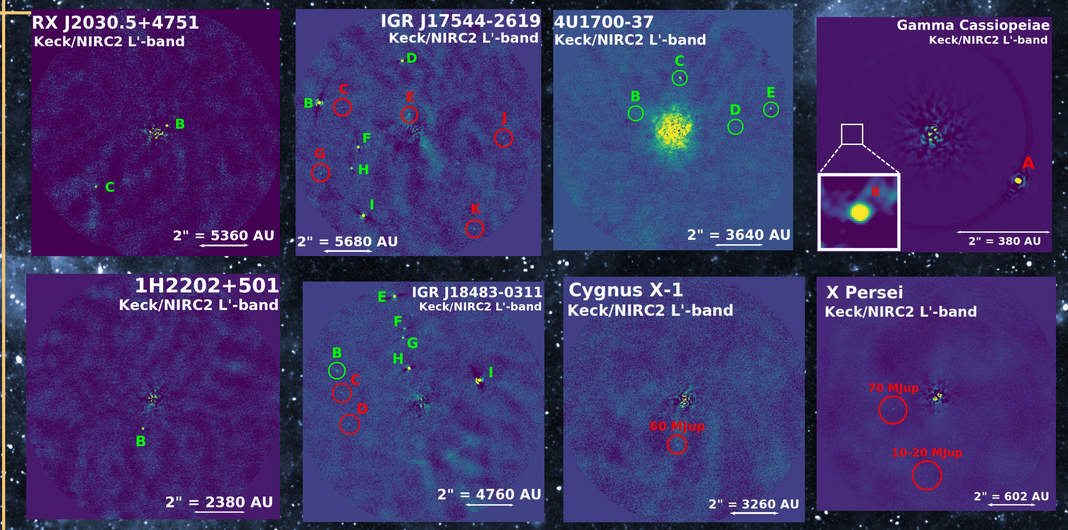


Fig. 2: High-contrast images of the other X-ray binaries for which we detected candidate companions

Some methods to determine the nature of the detections

They could be...

Background stars or Bounded companions

1. **Astrometry** — By taking follow-up observations several days/months/years apart, we can study the proper motion of the objects and therefore conclude if they are bound or not.
2. **Color-magnitude diagram** — If observations in two different bands are available, we can construct a color-magnitude diagram to determine if their color and magnitude are coherent with stars or exoplanets using evolutionary models.
3. **Background probability** — Using 3D models of the sky (e.g. TRILEGAL {7}) we can estimate the expected number of sources in a certain area. Depending on the number of sources, we can calculate the probability of finding a source with the same magnitude of a detected candidate.
4. **More observations** — In order to study an object more in depth and to add constraints, we can propose for additional observations, such as spectroscopic analysis, other bands, etc.

We thus decided to explore the environment of X-ray binaries via direct imaging in order to search for companions orbiting around them.

Sub-Stellar Companions

Exoplanets and Brown dwarfs

Some arguments that motivated the project

1. The first exoplanets were discovered around pulsars in the 90s (e.g. {1}), which means that sub-stellar companions can exist in extreme environments.
2. Studies indicate that they can exist in a variety of environments: from the ones that orbit exceedingly close to their host star (e.g. {2}) to those found excessively far (e.g. {3}).
3. Recently, it was argued that X-ray binaries could host planetary systems {4}, detectable via transit spectroscopy.
4. However, those systems are more likely to harbour wide orbit planets because of planet-star/planet-planet interactions that would push away the companions {5}.

References

{1} Wolszczan & Frail (1992)
{2} Seager & Sasselov (1998)
{3} Naud et al. (2014)
{4} Imara et al. (2018)
{5} Bonavita et al. (2016)
{6} Mawet et al. (2005)
{7} Girardi et al. (2005)

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Journée étudiante du centenaire du département de physique de l'Université de Montréal

myriam.prasow-emond@umontreal.ca