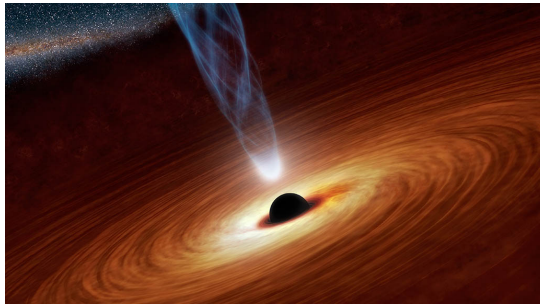
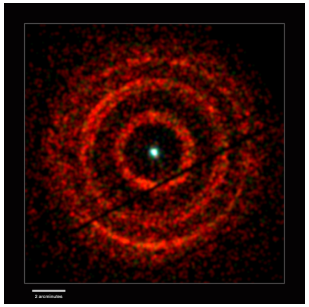
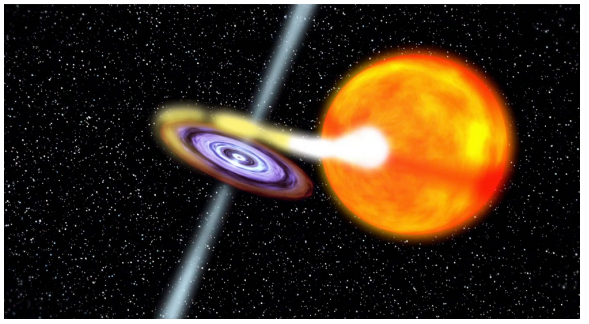




Observational Aspects of Accreting Black Holes: Overview

John Tomsick

Space Sciences Laboratory/UC Berkeley

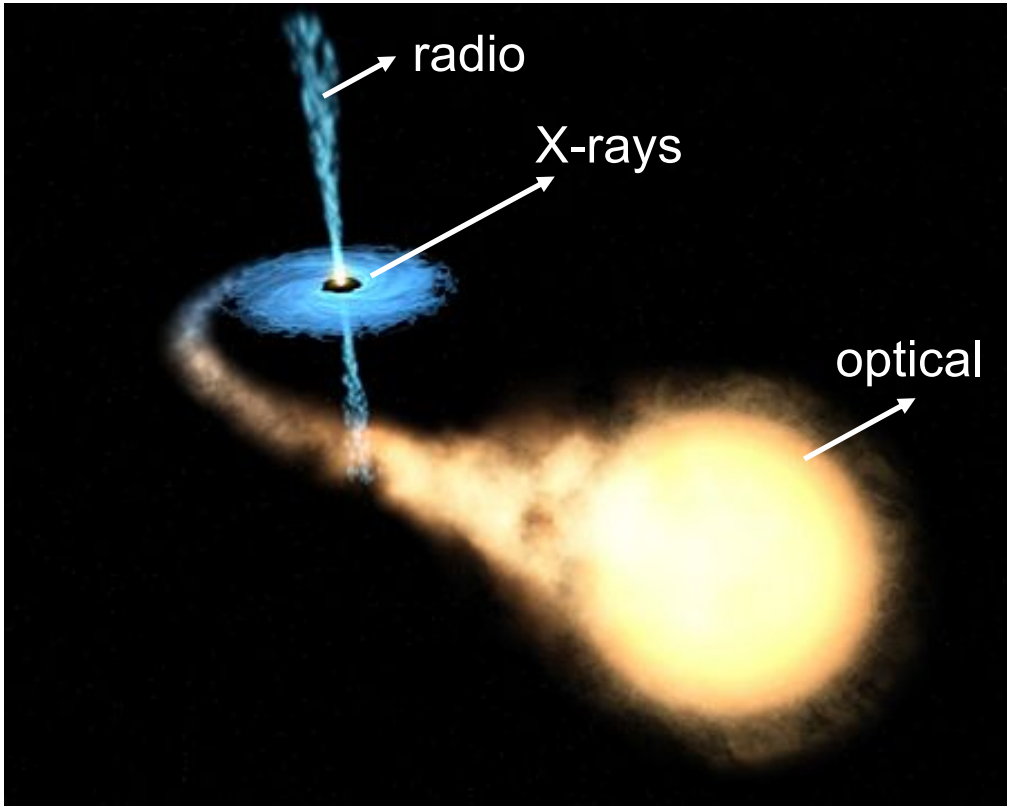
September 2018

X-ray satellite missions that I've used

Mission Name	Dates	Energy Range
RXTE	1995-2012	2-60 keV (PCA)
Chandra	1999-now	0.3-10 keV
XMM-Newton	1999-now	0.3-12 keV
INTEGRAL	2002-now	15-400 keV (IBIS)
Swift	2004-now	0.5-10 keV (XRT)
Suzaku	2005-2015	0.5-300 keV
NuSTAR	2012-now	3-79 keV

- We also need to observe at other wavelengths (radio, optical, etc.) to get the complete picture.

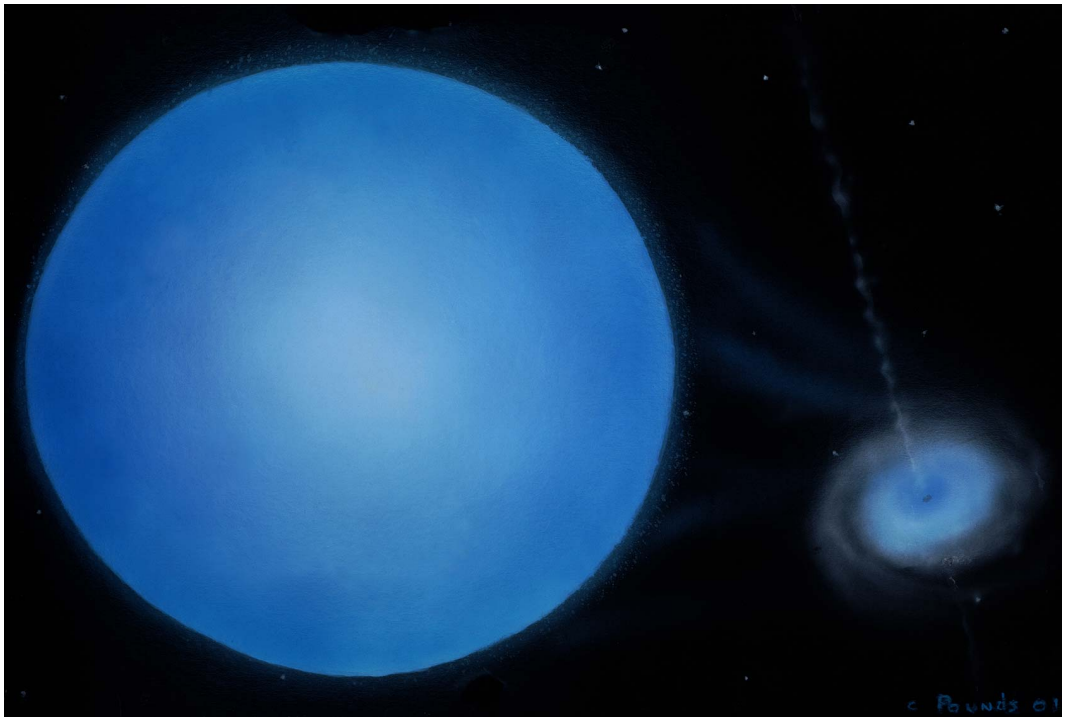
Low-mass X-ray binaries (LMXBs)



Companion: Optical dominates
Inner Disk: X-rays dominate
Outer Jet: Radio dominates

- Companion star
  - Always produces a low level of optical emission
- Accretion disk
  - Emits from infrared to optical to X-rays
  - For transients, X-rays can vary from 10^{30} to 10^{39} erg/s
- Jet
  - Emits in the radio, infrared, and optical
  - The base of the jet may also emit in the X-rays

High-mass X-ray binaries (HMXBs)



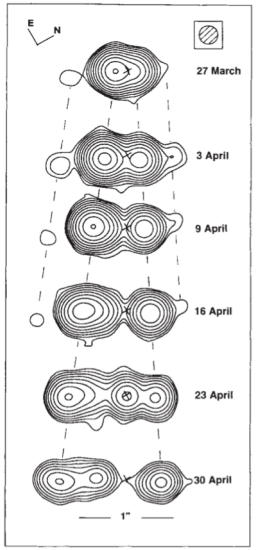
- HMXBs with black hole accretors are fairly rare
- Cyg X-1 is the best-studied example in the Milky Way Galaxy

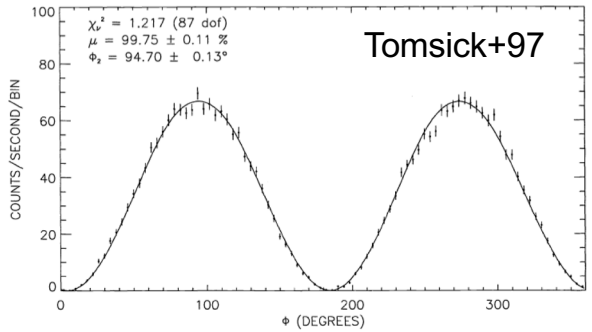
- Companion star
  - Dominates in the optical
- Accretion disk
  - X-ray luminosity typically 10^{37} erg/s for Cyg X-1
- Jet
  - Same as LMXBs

Observational tools

- Light curves (source intensity vs. time)
- Energy spectra (source intensity vs. energy)
- Power spectra (variability amplitude vs. frequency)
  - Basic tool of X-ray timing
- Imaging (binary separations are too small, $<10^{-4}$ arcsec)
  - Can see jets in the radio bandpass (radio interferometry) →
  - There are a few examples of X-ray jets (Chandra, 10”-30”)
- Astrometry (positions of sources)
  - Parallax distance measurements
  - Orbital motion detection rare but becoming possible
- Polarization (modulation curve) →
  - Modulation curves used for X-rays and gamma-rays
  - Other techniques used for optical and radio

Shows radio images at 6 different times (Mirabel & Rodriguez 1994)





Topics to be discussed

- The Spin Rates of Black Holes
  - X-ray energy spectra (mostly NuSTAR)
  - Gravitational waves (LIGO and Virgo for BH-BH mergers)
- Multiwavelength Observations
  - Especially optical and radio
- High-Energy Polarization Measurements
  - Past (OSO-8), Present (INTEGRAL, COSI, PoGO+), and Prospects for the Future (IXPE)
- X-ray Timing
  - RXTE, AstroSat, NICER, STROBE-X