The Chandra View of X-ray Binaries

Saeqa Dil Vrtilek
Harvard-Smithsonian Center for Astrophysics
• Why X-ray Binaries?

• Spatial
  XRB Luminosity Functions
  X-ray Scattering Halos

• Spectral
  Elements and Abundances
  X-ray line velocities

• Future
  Astro-E2
  Constellation-X
  X-ray polarimetry
  X-ray interferometry?
A Low Mass X-Ray Binary: 4U 1820–30

X-Ray Emission: BURSTS

X-Rays

Accretion Disk

Neutron Star

White Dwarf

130,000 km

1,200 km/sec

Earth

SUN
Why are X-ray Binaries interesting?

- Most efficient energy release mechanism known
- Behavior of matter under extreme conditions
- Endpoints of stellar evolution
- Most nearby, easily studied example of accretion process
What remains to be understood?

- The mass-transfer process: fundamental driver behind the most energetic phenomena in the Universe
- Angular momentum transfer/disk structure
- Equation of state of neutron stars
- Formation process of compact objects
- Origin and evolution of binary systems
47 Tuc: X-ray color-magnitude

Grindlay et al. 2001
XRBs in Globular Clusters

Pooley et al 2003; Heinke et al 2003
X-ray Halos: GX13+1

ROSAT

ACIS-I

Smith 2000
Halo Scattering Geometry

\[ h_{\text{max}} = 1 - e^{-\alpha} \]

\[ \alpha = \frac{id / \pi \sigma_{\text{eff}}^2 / \lambda}{1 + \frac{1}{2} \Delta \lambda_{\text{eff}}^2 / \lambda} \]
X-ray Halo

Yao et al 2003
X-ray Halo: Cygnus X-1

ACIS/HETG in CC

Yao et al 2003
X-ray Halo: 4U1538-52

ACIS-I

Clark 2004
X-ray Halo: 4U1538-52

Clark 2004
M 31: Chandra view!

Chandra ACIS-I

Garcia et al 2000
Elliptical Galaxy NGC 4697

Sarazin, Irwin, & Bergman 2000
S0 Galaxy NGC 1553

Blanton, Sarazin, & Irwin 2001
Colliding galaxies NGC 4038/39 ("the Antennae")

Fabbiano, Zezas, & Murray
CXB Contribution to XLF

Sarazin et al 2001

Kong et al 2002

Gilfanov 2003
“Universal” XLFs of HM and LM XBs

Gilfanov 2004
LMXB XLFs: Stellar Mass Indicators

Gilfanov 2004
HMXBs: Star Formation Rate Indicators

Gilfanov 2004
$L_X$-SFR and $L_X$-$M_*$

Grimm et al 2003; Gilfanov 2004
The Chandra View

- Spectral

Elements and Abundances
X-ray line velocities
Cyg X-3 with ASCA SIS

Liedahl & Paerels 1996
Cyg X-3 with Chandra HETG

Paerels et al 2000
Circinus X-1

BeppoSAX

laria et al 2002
Circinus X-1: X-ray P-Cygni!

ACIS/HETG

Schulz et al 2000
Time variability of a P Cygni Line

Time step: 1

X-ray P Cygni Line from Highly Ionized Silicon

Relative Flux

Wavelength (Å)

Brandt & Schulz 2000
SS433 with HETG
SS433 with HETG

SS433 Model

Relativistic Fe Lines

Miller et al 2003
Cyg X-1 with HETG

Feng, Tennant, & Zhang 2003
Black Hole Event Horizons

Neutron Star X-ray Nova

Black Hole X-ray Nova
Black hole event horizon

Kong et al. 2002
Garcia et al. 2001
Jets: XTE J1550-564

Corbel et al 2002

ACIS/HETG
XTE J1550-564 Time Lapse

NASA/CXC
Jet Model XTE J1550-564

Tregillis, Jones, and Ryu 2002
Effective area and resolution

constellation.gsfc.nasa.gov/science/design/effective_area.html
The Contribution of the Reflection Spectrum from an Accretion Disk

- Disk reflection plus direct component
- Inclination = 0°, 60°, 85°
- AXAF/XMM energy band
- Constellation energy band

constellation.gsfc.nasa.gov/science/example/bh.html
Vela X-1 Si K with Con X

constellation.gsfc.nasa.gov/science/example_science/endpoints.html
An Efficient X-ray Polarimeter

Costa et al 2001
Going out of Focus.

You've got very good eyesight.
Angular Resolution

Spectrum Coverage: Setting the Whole Picture

Angular Resolution: Seeing the Details

Vrtilek et al 2000
Still a ways to go!

Chris Madden cartoons
Cyg X-3 with BeppoSAX
X-ray Pulsar 4U1538-52

BeppoSAX

Robba et al 2001
Cyg X-3 with Chandra HETG

Paerels et al 2000
Cyg X-1 with ACIS/HETG

Schulz et al 2000
Cyg X-1 with HETG in CC mode

Miller et al 2002