ACCRETING MILLISECOND X-RAY PULSARS (AMXPS)

Astrophysics of Interacting Binary Stars

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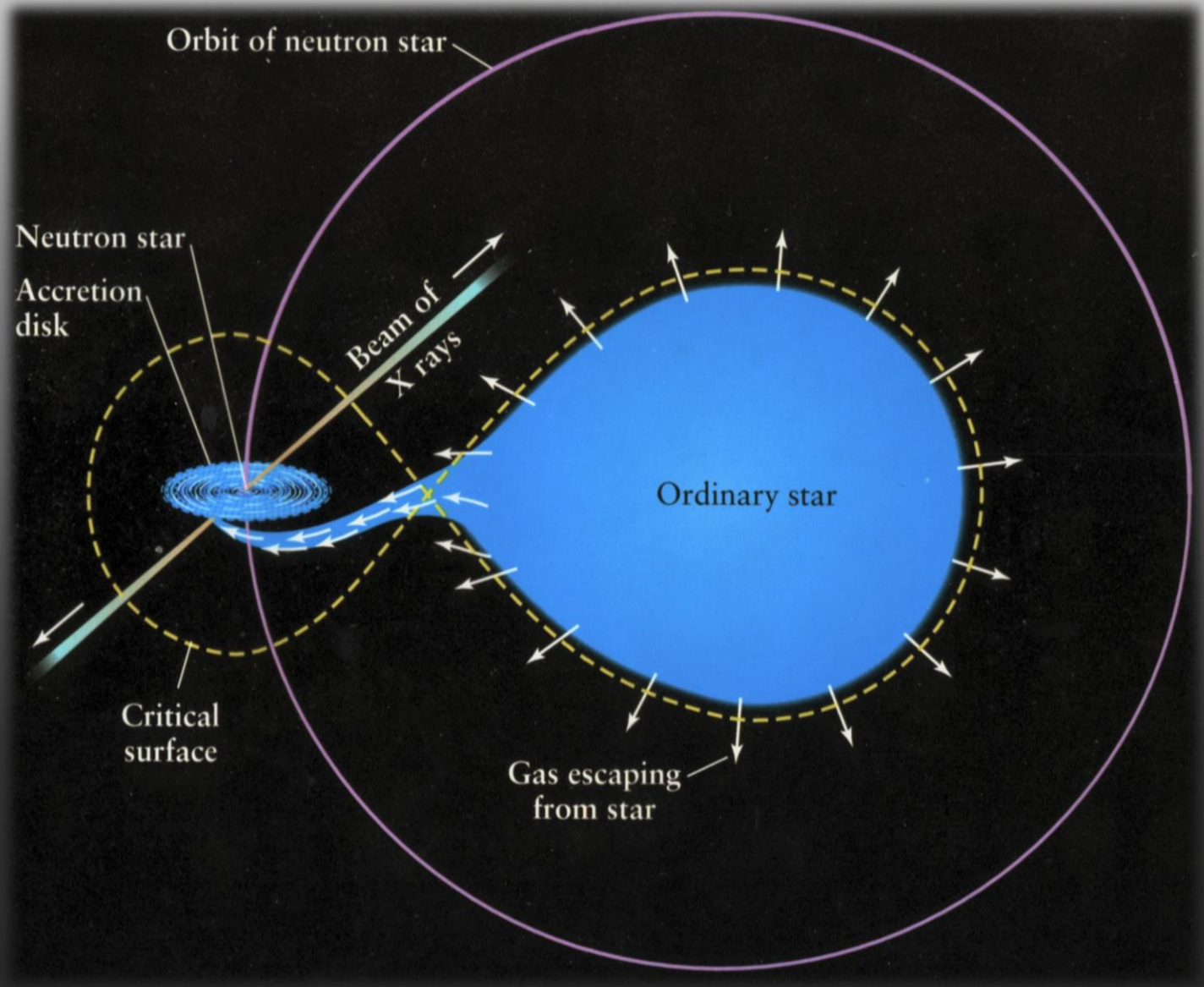
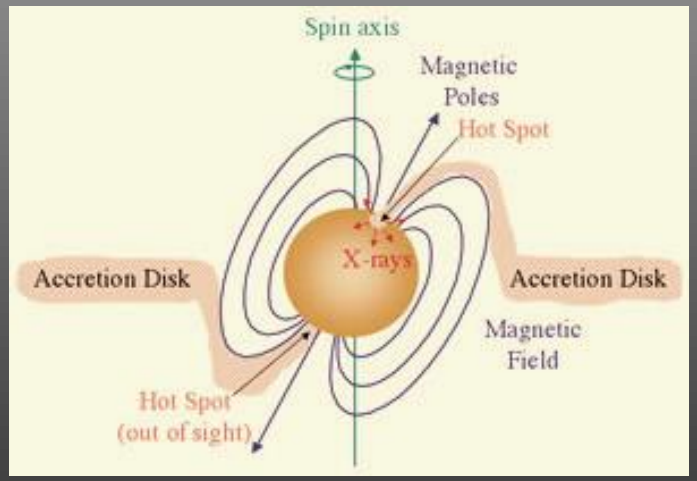
GENERAL ILLUSTRATION OF AMXP SYSTEM



http://w3.phys.nthu.edu.tw/~hkchang/ga1/ch12-02.htm

BINARY SYSTEM

- Subgroup of Low-mass X-ray Binary (LMXB)
- Many systems found from the Globular Clusters
- Millisecond X-ray pulsar (Accretor)
  - Recycling scenario (Spun up during LMXB)
    - Spin frequencies ≥ 100 Hz (Distribution cutoff ≈ 700 Hz)
  - Relatively weak magnetic field ($10^8 - 10^9\ Gauss$)
  - Accretion powered
  - Spin up and spin down due torques



https://astronomy.swin.edu.au/cosmos/

BINARY SYSTEM

- Donor Star
  - $\mathrm{M} \leq M_{sun}$
    - Very low mass preferred (almost always $\mathrm{M} < 0.2 M_{sun}$)

- Mass transfer through the first lagrangian point
  - Matter channeled onto the magnetic poles causing X-ray pulsation
  - Eventually matter builds onto neutron star causing X-ray outburst
    - Outburst luminosities are usually faint (below 10% of Eddington limit)

BINARY SYSTEM

- Transient system
  - Outbursts and quiescence
- Can show burst oscillations (mechanism not well known)
  - Presumed to develop from asymmetric temperature distribution on the NS surface
  - Seen at frequencies close to spin frequency
  - Not observed in every outburst
- Orbital periods range between 40 min to 19 h

BINARY SYSTEM

- Can be re-activated as a radio pulsar (rare)
  - IGR J18245–2452
    - Shown AMXP and radio millisecond pulsar phase

- System behaviour varies
  - X-ray outburst typically lasts from 2 days to less than 3 months
  - Most systems shown only 1 outburst since discovery

  - Intermitten millisecond X-ray pulsars
    - Emits pulsations sporadicly during outbursts
      - Accreting matter might weaken the magnetic field by orders of magnitude

FIRST AMXP

- **SAX J1808.4−3658**
  - First discovered in 1996 by BeppoSax satellite during outburst
  - In 1998 X-ray pulsation observed by NASA's Rossi X-ray Timing Explorer (RXTE)
    - Mission duration: 1995 – 2012
  - Binary system: Neutron star and brown dwarf
    - 401 Hz Spin frequency
    - Spends most of the time in the quiescence
      - X-ray Luminosity ≈ $10^{31}\ \frac{ergs}{s}$
      - Outburst X-ray luminosity ≈ $10^{36}\ - 10^{37}\ \frac{ergs}{s}$
  - X-ray burst oscillations, quasi-periodic oscillations and coherent X-ray pulsation
- So far, only 20 AMXPs have been discovered (small group)

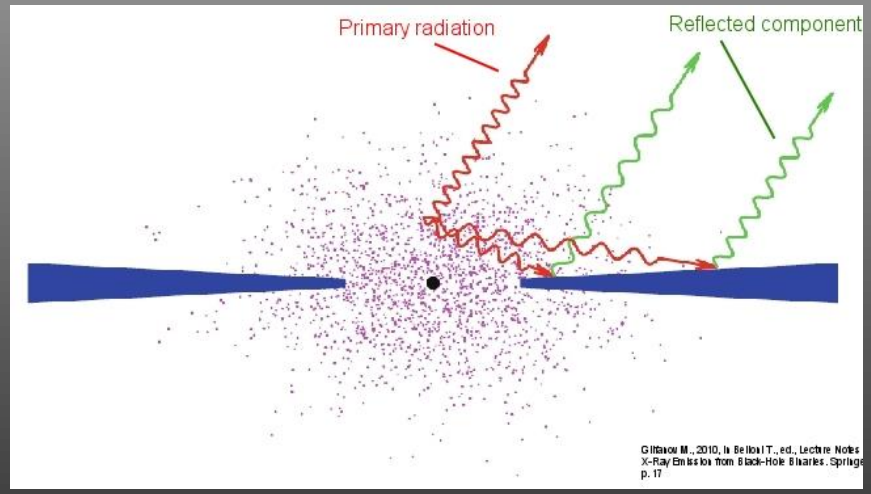
DETECTION

- AMXPs systems are detected using X-ray satellites
  - Earth's atmosphere absorbs radiation

- Used X-ray satellites (and telescope)
  - Rossi X-ray Timing Explorer (RXTE)(Decommissioned)
  - Neil Gehrels *Swift* Observatory (SWIFT) (ongoing)
  - The Neutron Star Interior Composition Explorer (NICER)(ongoing)
    - Telescope on the International Space Station (ISS)
  - XMM-Newton (ongoing)
  - INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL)(ongoing)
  - Nuclear Spectroscopic Telescope Array (NuSTAR)(ongoing)
  - Chandra X-ray Observatory (CXO) (ongoing)

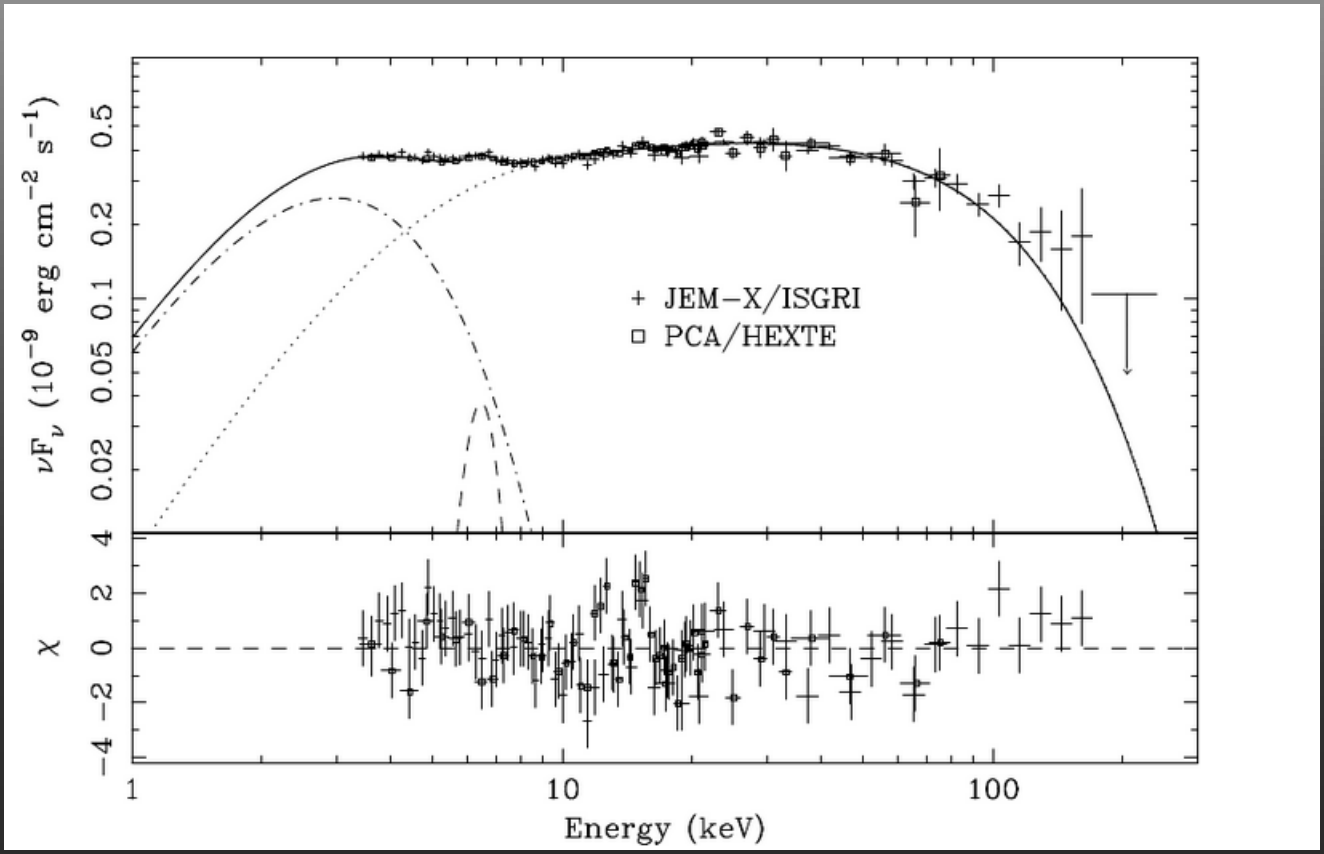
OBSERVATION

- Spectral properties
  - No transition between hard and soft spectral state
    - AMPXs are seen as hard X-ray transients
  - Moderate/high resolution instruments
    - Broad-band spectral analysis
    - Reflection features
      - Iron line at 6.4 – 6.7 keV
  - Modeling of spectral features may give information about physical parameters
    - Ionization state of matter in the inner disk
    - System inclination respect to the line of sight
    - Truncated inner disk radius (due magnetic field)
    - Emitting outer radius



Credit: Gilfanov M., 2010, Lecture Notes in Physics, Vol. 794, Springer-Verlag, Berlin, p. 17

SPECTRUM



- Simultaneous PCA, JEM-X, HEXTE and ISGRI spectrum of HETE J1900.1-2455
- Dot-dashed curve is disk blackbody model, dotted curve comps(comptonization) model, dashed curve gaussian line and total spectrum solid curve.
- Lower shows the residuals between the model and the data.

OPEN QUESTIONS

- Why do not majority of LMXBs show no pulsation?
  - Several models to describe
    - Magnetic field screening
    - Smearing from optically thick corona
    - Gravitational light bending
- Why is there not more of radio pulsation in X-ray quiescence? (AMXP and LMXB)

REFERENCES

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- A. Patruno, A. L. Watts, Accreting Millisecond X-Ray Pulsars, 2013
- D. Altamirano et al., Type I X-ray bursts and burst oscillations in the accreting millisecondX-ray pulsar IGR J17511−3057, 2010
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