High Mass X-ray Binaries Across The Space Satellites

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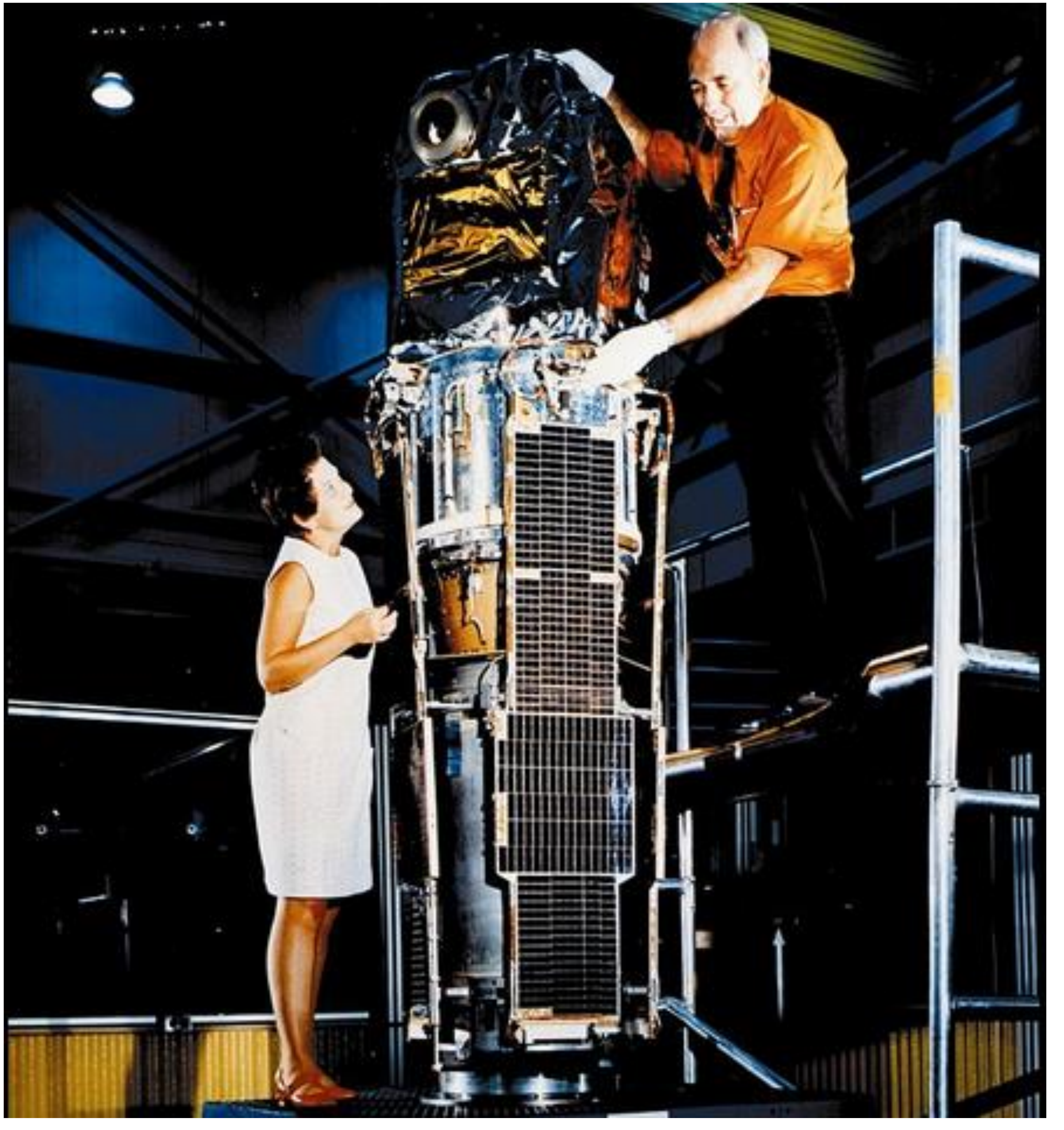
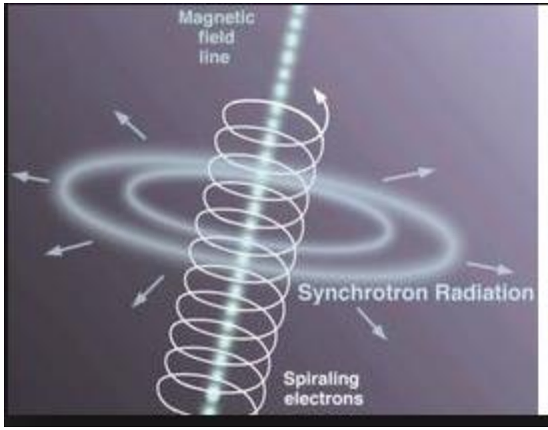
Introduction

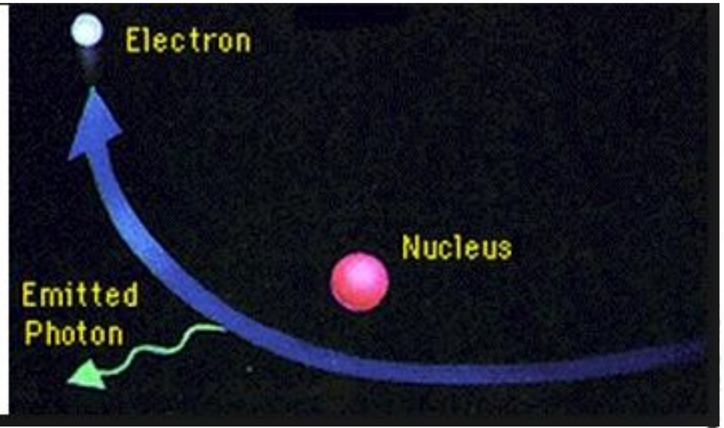
- Small Astronomy Satellite (SAS) is the first Explorer satellite launched in 1958.
- Observational features of cyclotron resonance scattering detected through absorption lines in the spectra of magnetized accreting NSs.
- They form due to resonant scattering processes with **electrons** which are quantized in energy levels perpendicular to the magnetic field.
- Providing the **direct observation for the cyclotron features and calculate the magnetic field** (≥ 10^10-12 G) from electrons, protons.
- Since the first detection of a cyclotron line in the X-ray source
- Her X-1 by UHURU satellite in 1979, **36 sources have been discovered by many space satellites.**

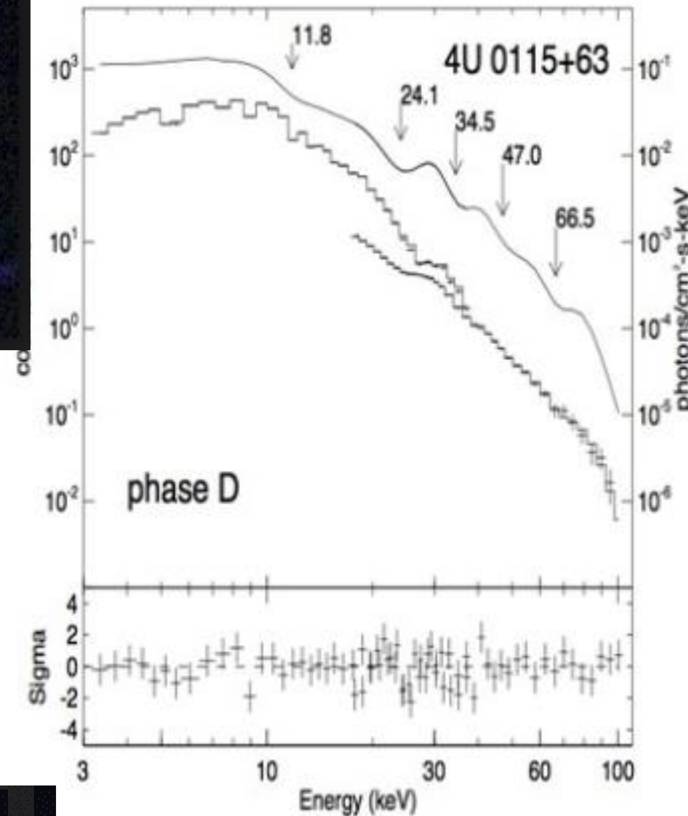


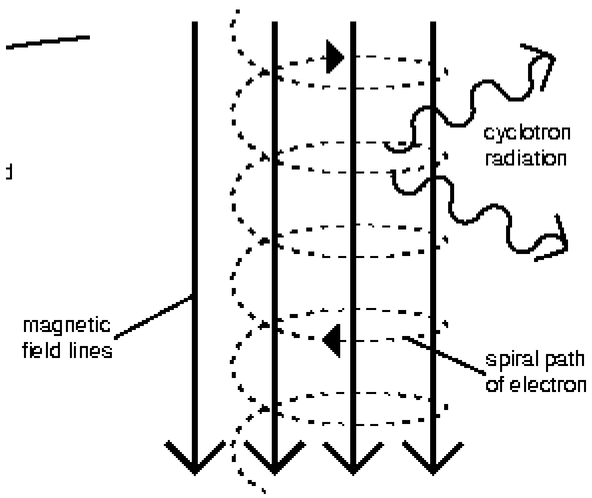
Marjorie Townsend discusses the X-ray Explorer Satellite's performance with Bruno Rossi at NASA's Goddard Space Flight Center.

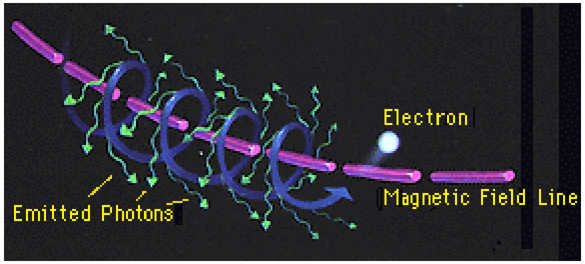
cyclotron radiation where electrons emit photons as they spiral around the magnetic field lines, resulting in a stable, non-oscillating shock.











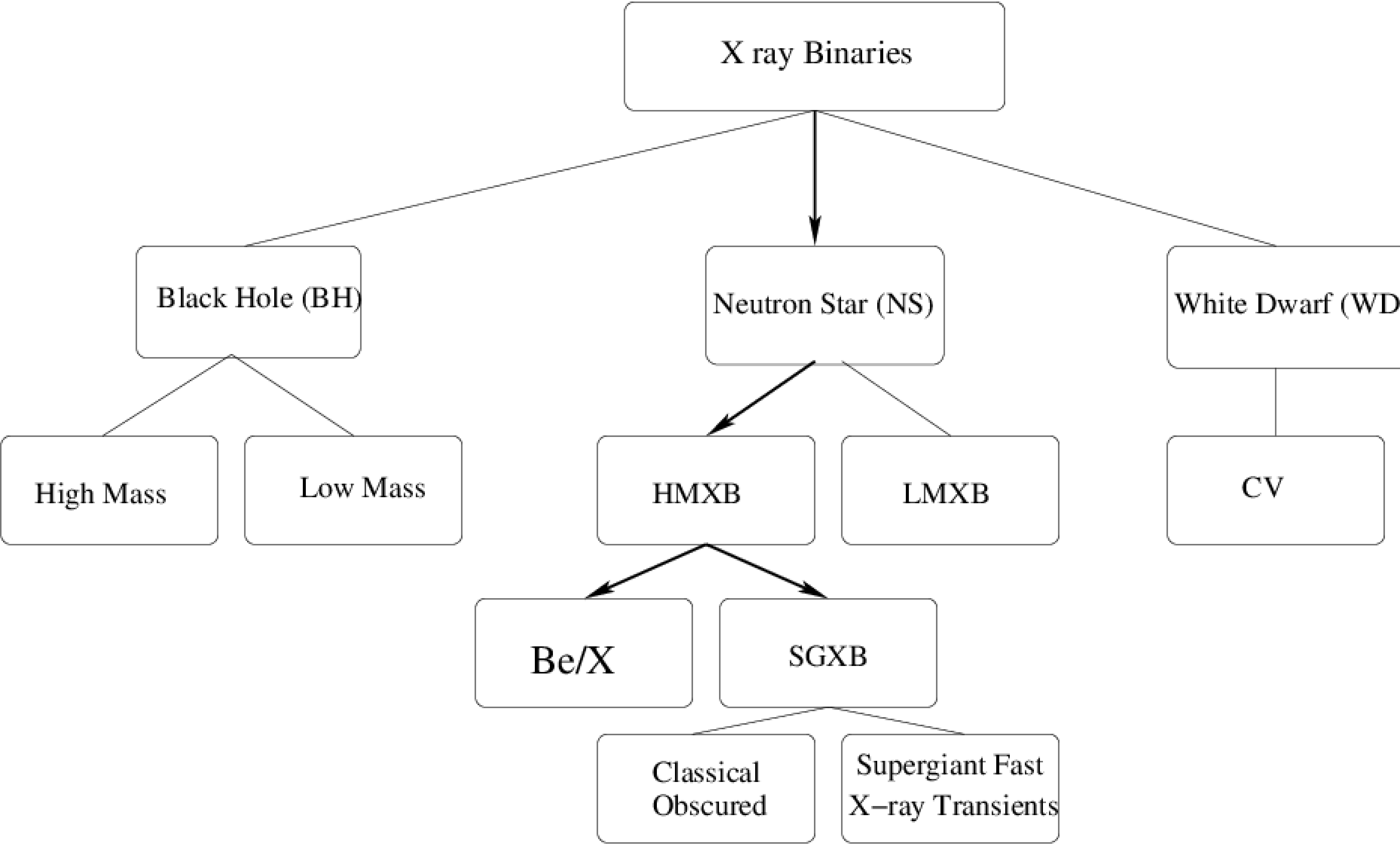
List x-ray space satellites

- X-Ray observations are made from a near-space environment on sounding rockets or high-altitude balloons.

Name	Launch	
Ariel 5	1974	
Ariel 6	1979	
ASCA	1993	
ATHENA	—	Under development
AGILE	2007	
Apollo Telescope Mount	1973	Part of Skylab, ope
Arcus	—	Proposal
ALEXIS	1993	
ANS	1974	
Astrosat	2015	
BeppoSAX	1996	
BBXRT	1990	
Compton Gamma Ray Observatory	1991	
Chandra X-ray Observatory	1999	

Constellation-X Observatory	—	2008 proposal
Copernicus	1972	
Cos-B	1975	
DXS	1993	
Einstein Observatory	1978	originally *HEAO-2*
EXOSAT	1983	
Fermi	2008	
Ginga	1987	
Granat	1989	
Gravity and Extreme Magnetism	—	2012 proposal
Hakucho	1979	
Hard X-ray Modulation Telescope	2017	
HEAO-1	1977	
HEAO 3	1979	
High Energy Transient Explorer	1996	
Hinode	2006	
Hinotori	1981	Originally *ASTRO-A*
Hitomi	2016	Originally *ASTRO-H*
IXPE	—	Under development

INTEGRAL	2002	
International X-ray Observatory	—	2012 proposal
LOFT	—	Proposal
MAXI	2009	
Neil Gehrels Swift Observatory	2004	Originally *Swift Gamm*
NICER	2017	
NuSTAR	2012	
OAO-1	1966	
ORBIS	—	Under development
OSO 7	1971	
OSO 8	1975	
RHESSI	2002	
ROSAT	1990	
RXTE	1995	
SAS-3	1975	
SVOM	—	Proposal
Spektr-RG	—	Under development
Suzaku	2005	
Tenma	1983	
Uhuru	1970	

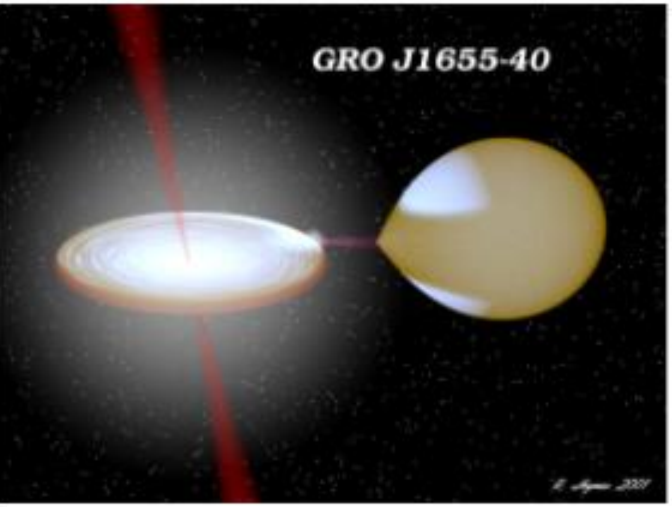

X ray Binaries
Black Hole (BH)
Neutron Star (NS)
White Dwarf (WD)
High Mass
Low Mass
HMXB
LMXB
CV
Be/X
SGXB
Classical
Obscured
Supergiant Fast
X−ray Transients

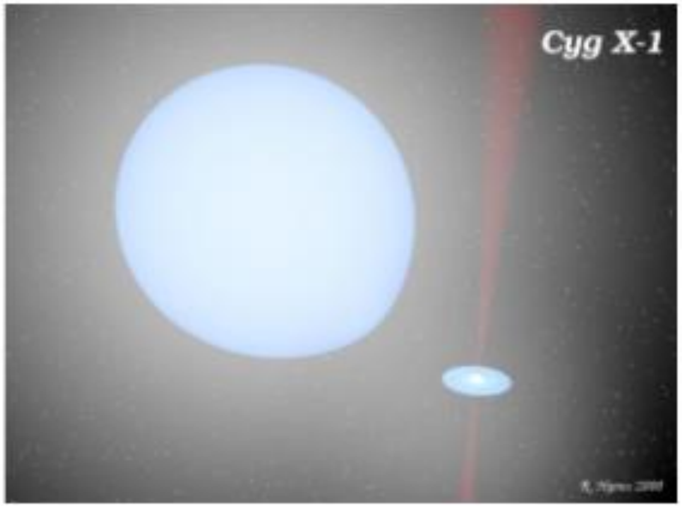
Magnetic fields in Neutron Stars

- **HMXB**- Accretion mainly via stellar wind ;

mainly NS with high B (~ 10^11-10^13 G) having a harder spectra;

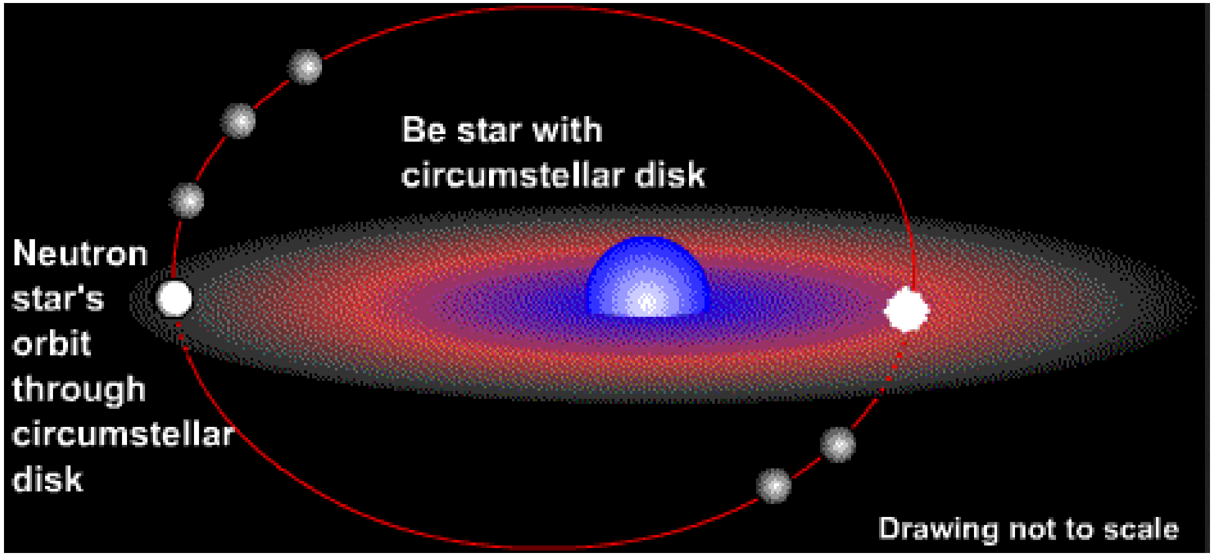
- **LMXB**- Accretion via Roche-lobe overflow; BH transients; NS LMXBs- weaker B field (10^9-10^11 G) spectra softer mainly from the accretion disk & the surface; exhibit variability

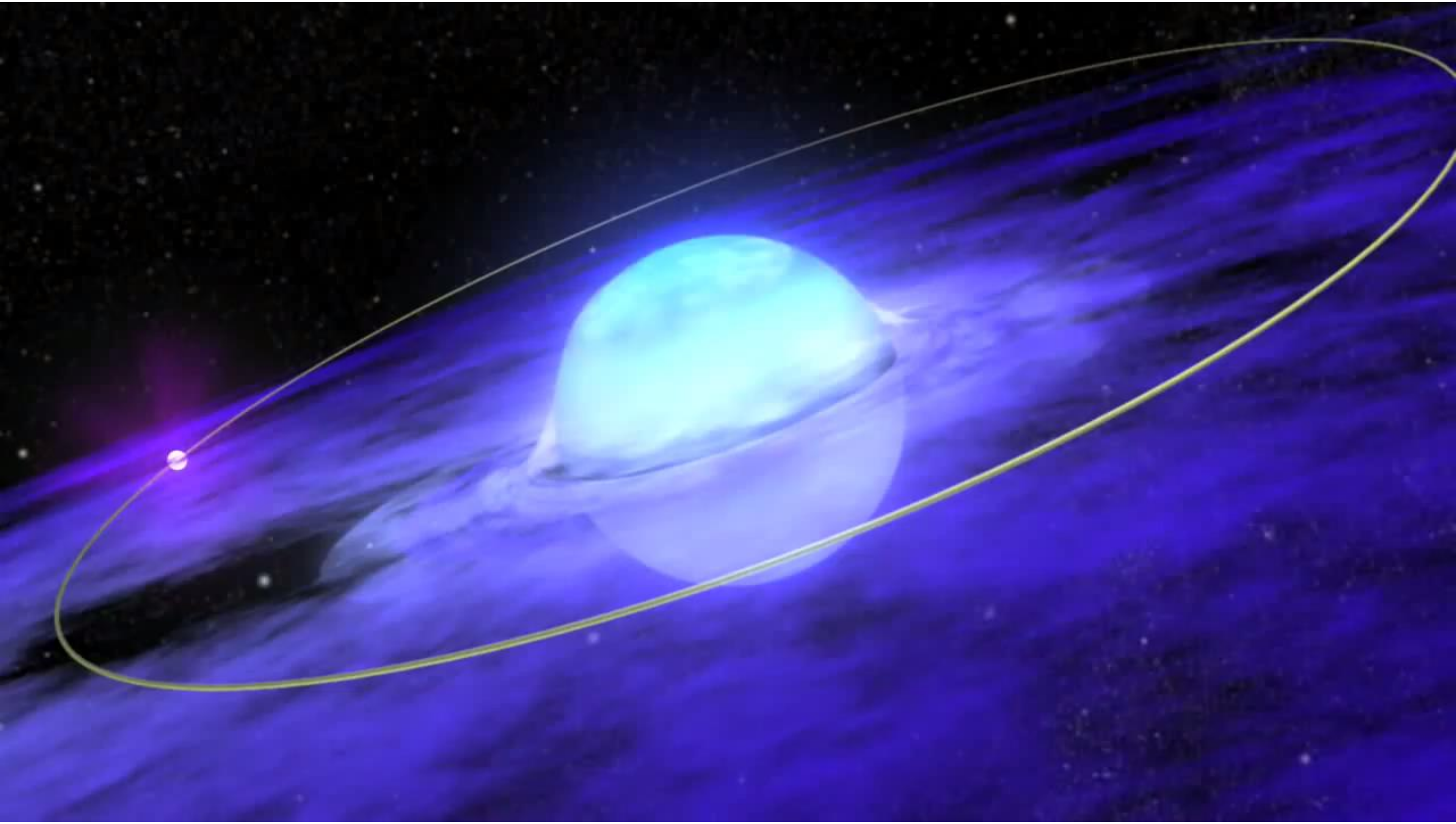




Low mass X-ray binaries
- Roche lobe overflow
- low mass companions
- old NSs
- accretion driven by an accretion disc

High mass X-ray binaries
- Wind fed accretion
- high mass companions
- young NSs
- a disc not always can form





HMXBs classifications

- **Be X-ray binaries** (a type B star with emission lines) form by far largest class of identified HMXBs (van den Heuvel 2004) in the Galaxy (~> % 80), P_orb ~15 d to several years, and with relatively low mass companions (~ 8 to 20M$\odot$). **Transient** X-ray sources.

- **Supergiant** (SG) companion i.e. Cen X-1 and Vela X-1, only about a dozen known members, with short orbital periods (< 11 days) and the companions are very massive (~ 18 to over 40M$\odot$).

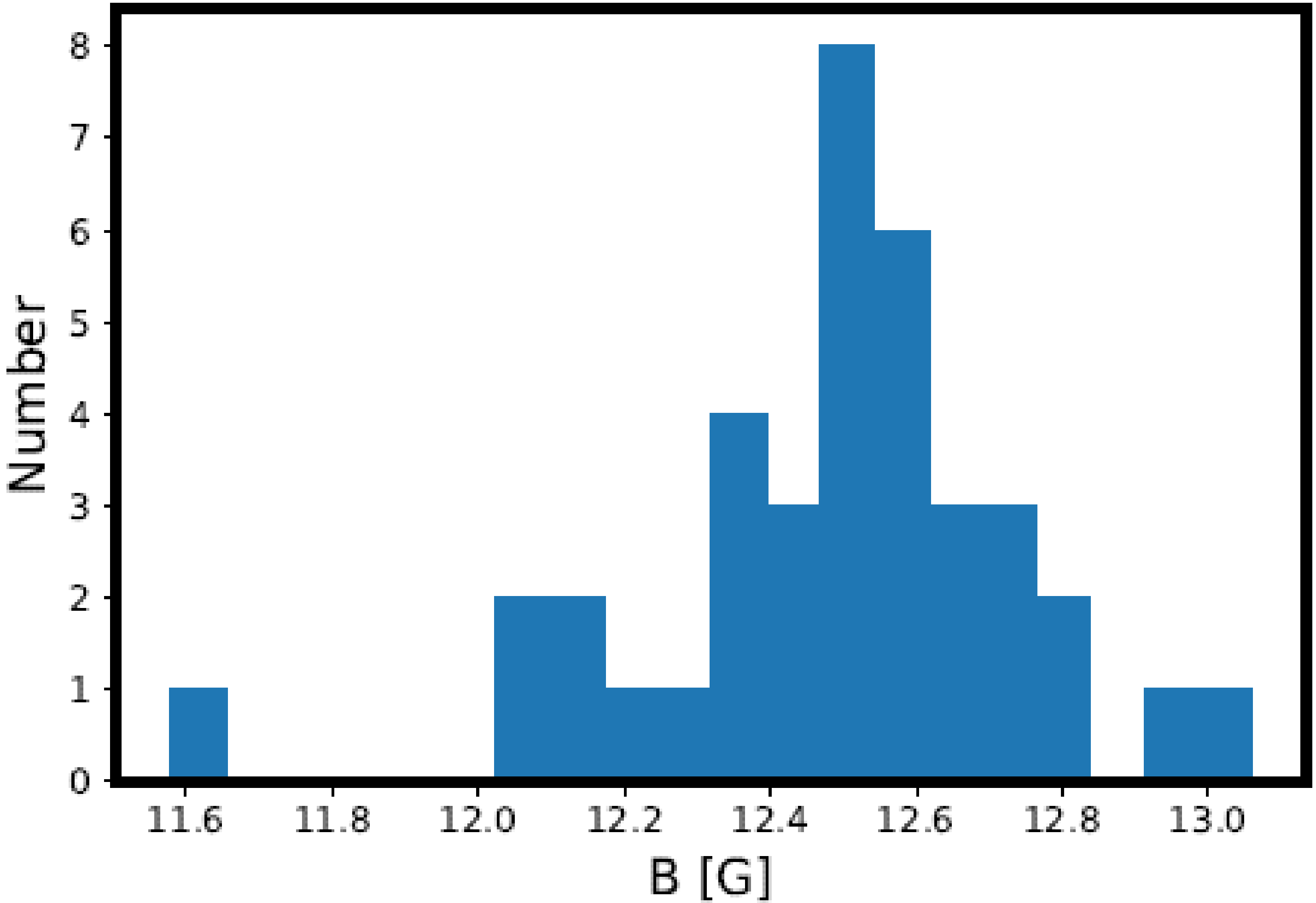
  Persistent X-ray emission,

Objectives…

- Our aim is to use several X-ray spectra of HMXBs, in particular the detection of **cyclotron lines**, to study the P_spin, P_orb, M_dot, and B-field of the NSs to obtain clues about the evolution of HMXBs.
- Derive unknown parameters of HMXBs, such as wind velocity, wind mass loss rate and T_eff. These parameters influence significantly on the model of wind-fed binary systems and can be constrained the effects on binary evolution

Table 1: List of observational parameters of all known of HMXBs with cyclotron resonant scattering features

Object	$P_{\rm spin}$ (s)	$P_{\rm orbit}$ (d)	$E_{\rm cyc}$ (keV)	$B(1+z)^{-1}$ (10^{12}G)	B (10^{12}G)	L_x (10^{35} erg s^{-1})	Distance (kpc)	Type
4U 0115+63	3.6	24.3	15±0.15	1.3	1.7	700	7	Transient/ Be 1,
4U 1907+09	439	8.37	18.8±0.4	1.6	2.1	35	4	Persistent/ SG5,
4U 1538−52	529	3.73	$21.4^{+0.9}_{-2.4}$	1.8	2.4	5.1	4.5	Persistent/SG 6,
Vela X-1	283	8.96	$54^{+0.5}_{-1.1}$	4.7	6	60	1.9	Persistent/ SG1
Cen X-3	4.8	2.09	$30.4^{+0.3}_{-0.4}$	2.6	3.4	24.5	8	Persistent/ SG6,
V0332+53	4.37	34.25	$30^{+0.2}_{-0.2}$	2.6	3.4	25	7	Transient/ Be 1
Cep X-4	66.3	20.85	$30.7^{+1.8}_{-1.9}$	2.6	3.4	60	3.8	Transient/ SG 1
A 0535+26	105	111	50±0.7	4.3	5.6	80	2	Transient/ Be 3,
GX 301−2	690	41.5	$42.4^{+3.8}_{-2.5}$	3.6	4.7	31.5	1.8	Persistent/ Be 6,
LMC X-4†	13.5	1.4	100±2.1	8.6	11.2	1500	50	Persistent/ SG1
4U 0352+309	837	250	$28.6^{+1.5}_{-1.7}$	2.5	3.2	0.42	0.95	Persistent/ Be 6,
OAO1657-415†	37.7	10.4	36	3.1	4	48.7	6.4	Persistent/ SG3
J1946+274	15.83	169.2	$36.2^{+0.5}_{-0.7}$	3.1	4	300	9.5	Transient/SG 6,
MXB 0656−072	160.4	56.2	$32.8^{+0.5}_{-0.4}$	2.8	3.7	130	3.9	Transient/SG 3
GX 304−1	275.46	132.5	$53.7^{+0.7}_{-0.6}$	4.6	6	45	2.4	Transient/Be 3
J16493-4348†	1069	6.78	33±4	2.8	3.7	6.8	6-26	Persistent/SG 3
GS 1843+00	29.5	55	20±0.45	1.7	2.2	30	10	Transient/Be 4
1A1118-61	408	580	$55.1^{+1.6}_{-1.5}$	4.8	6	37	5	Transient/Be 4
J1008-57	93.5	247.8	79	7.6	300	9.9	5	Transient/Be 4
EXO 2030+375†	41.7	46	11.44±0.02	1	1.3	100	7.1	Transient/Be 3
J1626.6-5156	15	132	10	0.9	1.1	1.7	15	Transient/Be 4
4U 1700-377	–	3.4	37	3.2	4.1	13	1.9	Persistent/SG 3
J01583+6713	469	561	35.3 ± 1.6	3	4	4	6.4	Transient/Be 5
4U 2206+54	5500	19.11	29.6 ± 2.8	2.6	3.3	0.85	3	Persistent/Be 5
2S 0114+65	9700	11.6	22	1.9	2.5	6.6	7.2	Persistent/SG 5
J1739-302†	–	51.5	30	2.6	3.4	42	2.3	Transient/SG 5
J18483-0311†	21	18.6	3.3	0.3	0.4	0.22	3	Transient/SG 5
J0440.9+4431	205	155	32	2.8	3.6	20	3.3	Persistent/Be 6
J1409 - 619	506	233	44±3	3.8	4.9	0.7	14.1	Transient/Be 6
J18462-0223	997	–	30±7	2.6	3.4	16	6	Transient/SG 6
J18179-1621	11.82	20-50	$20.8^{+1.4}_{-1.8}$	1.8	2.3	100	8	Transient/Be 6
J17544-261	71.5	4.9	17	1.1	1.45	300	3.6	Transient/SG 6
2S 1553-542	9.27	30.6	23.5±0.4	2.1	2.7	760	20	Transient/Be 6
4U 1909+07	604	4.4	44	3.8	4.9	28	7	Transient/SG 6
J16393-4643	904	4.2	$29.3^{+1.1}_{-1.3}$	2.6	3.3	20	25	Persistent/SG 6
J054134.7-68	61.6	80	10	0.9	1.2	3000		Persistent/Be 6
KS 1947+300	1808	41.5	12.5	1.1	1.4	3000	0.03	Transient/Be 7
IGR J18027-201	140	4.6	23	2	2.6	30		Persistent/SG 7
SMC X-2	2.4	18.6	27	2.3	3.1	5500		Transient/Be ?
J0520.5-69	8	24	31.5	2.7	3300	3.6		Transient/Be 7


Number
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13.0
B [G]

Observational Data…

- Space telescopes

- Ginga, RXTE, BASTE, INTEGRAL, SWIFT, EXOSAT, Suzuku and **HXMT…**

We need to consider some observational biases**1)** to strong magnetic field prevents accretion onto NS and we could not observe such systems as bright X-ray sources.

2) More observational data is needed.

3) Besides such possibility of biases, this concentration around *B* ≈ 10^12G will draw a lot of interests and promote further studies of NS magnetic field

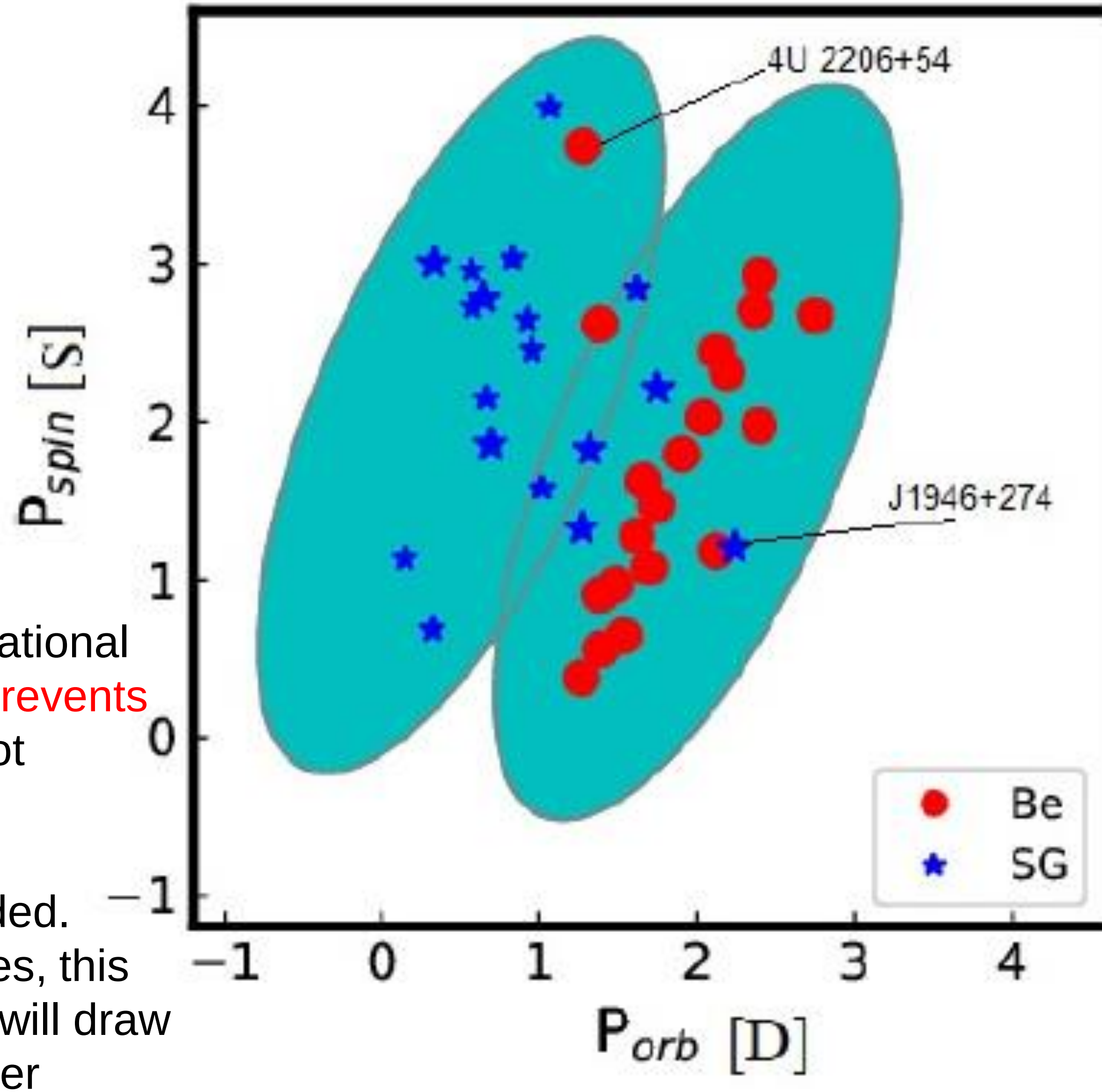

Table 2: The following table provides a sample of the all known harmonic cyclotron line features of HMXBs.

Object	E_{cyc} (keV)	Reference
4U 0115+63	15, 24, 36, 48,62	1,2,3,4
4U 1907+09	18.8, 40	5,6,7
Vela X-1	24, 54	8,9,10
V0332+53	30, 51, 74	11,12,13,14
A 0535+26	50, 100	10,15,16
J1626.6-5156	10, 18	17,18
EXO 2030+375	11, 63	3,19
J1739-302	30, 60	20
Her X-1	36, 73	21,22,23,24
4U 1538-52	22, 47	25,26,27,28
1A1118-61	55, 110	28,29,30
J01583+6713	35, 67	31
4U 2206+54	30, 60	32,33
2S 0114+65	22, 44	34,35
J1409 619	44,73, 128	36
Cep X-4	30.7, 45	37

$$En = \frac{m_e c^2}{sin^2\theta} \sqrt{(}1 + 2n(\frac{B}{B_{crit}})sin^2\theta) - 1$$

$$E_{\rm cyc} = 11.6 B_{12} (1 + z)^{-1}$$

For more detailed information *please see*

- Shigeyuki KARINO, Kenji NAKAMURA and **Ali TAANI**, Stellar wind accretion and accretion disk formation: applications to neutron star high mass X-ray binaries, Publications of the Astronomical Society of Japan (ACCEPTED).
- **Ali Taani**, Shigeyuki Karino, Liming Song, Mashhoor Al-Wardat, Awni Khasawneh and Mohammad Mardini, On the possibility of disk-fed formation in supergiant high-mass X-ray binaries, Research in Astronomy and Astrophysics, Vol. 19, 12
- **A. Taani,** S Karino, L Song, C. M. Zhang, S Chaty, A New Set of Parameters of High-Mass X-ray Binaries Found with their Cyclotron Lines. (to be submitted).
- **A. Taani**, S. Karino, L. Song, M. Al-Wardat, A. Khasawneh, M. Mardini and H. Al-Naimiy, On the wind accretion model of GX 301-2, Journal of Physics: Conference Series (under review).

Thank you for your Attention