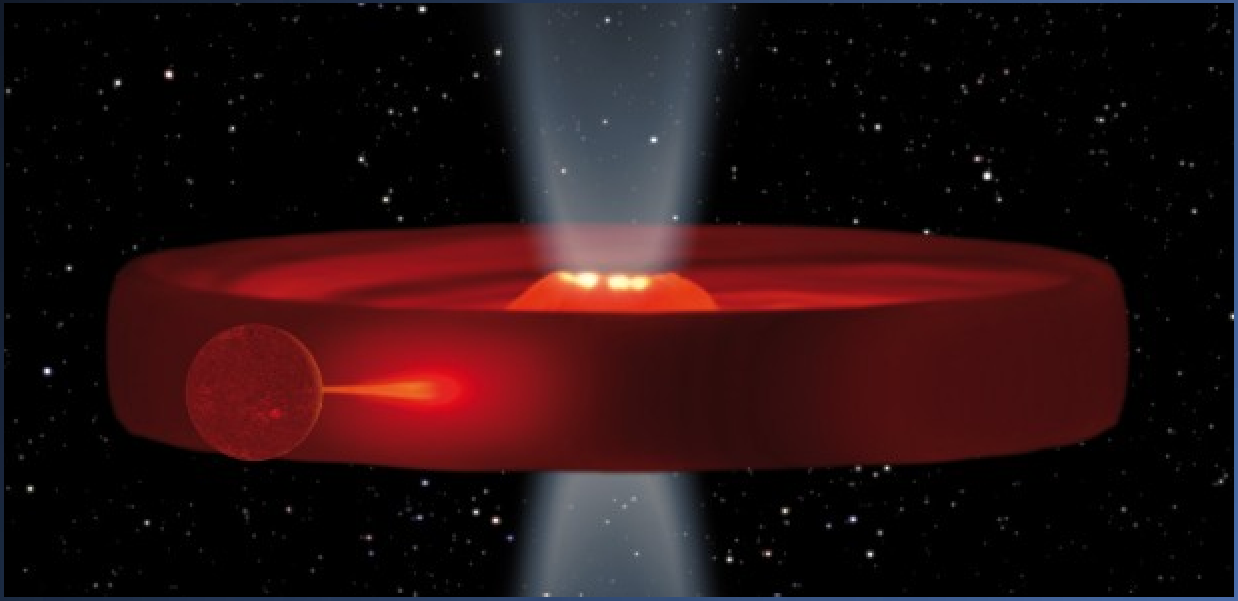
A Catalogue of Galactic BHs in X-ray binaries



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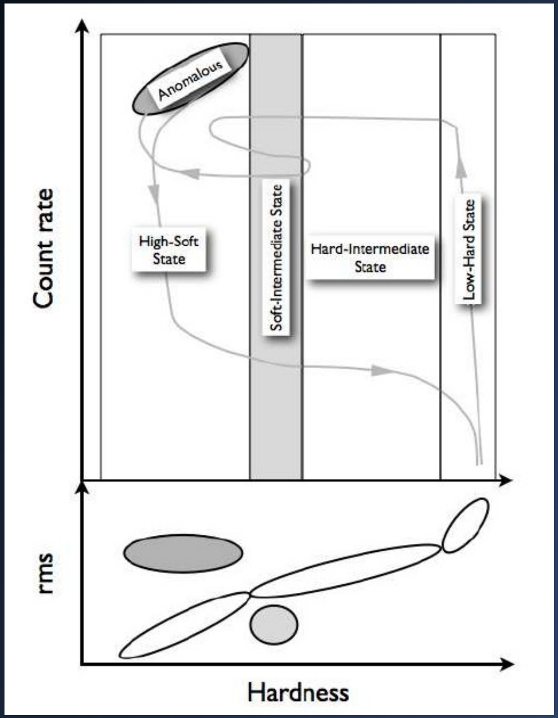
Introduction

BHs are mainly found in X-ray transients – a type of LMXBs

with sporadic outburst episodes and long quiescence states

Despite our efforts, they have been detected only in outbursts in X-rays



Belloni10. See also Belloni+11

BH candidates follow a behaviour in X-rays transiting between states in the outburst.

In quiescence, we can perform dynamical studies if the star is detected:

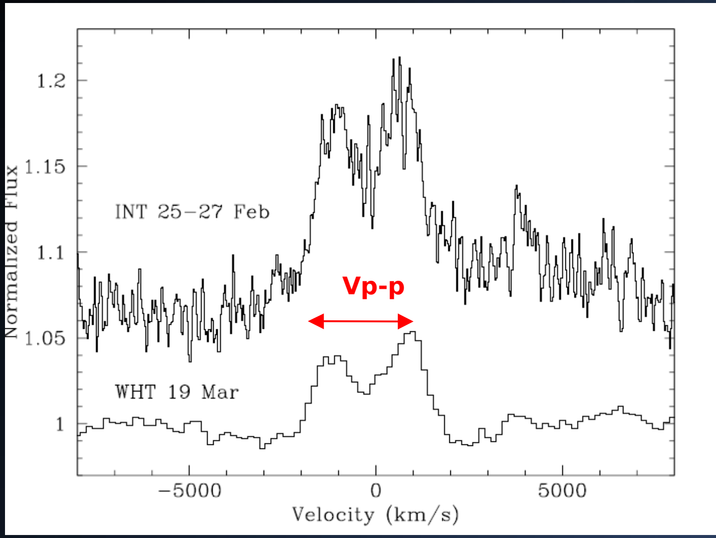
$$P_{ORB}, K_2$$

$$f(M_1), q, i \longrightarrow M_1$$

Dynamically confirmed BHs

At least: $f(M_1) > 3\,M_{sun}$

Swift J1357.2-0933: a VFXT?

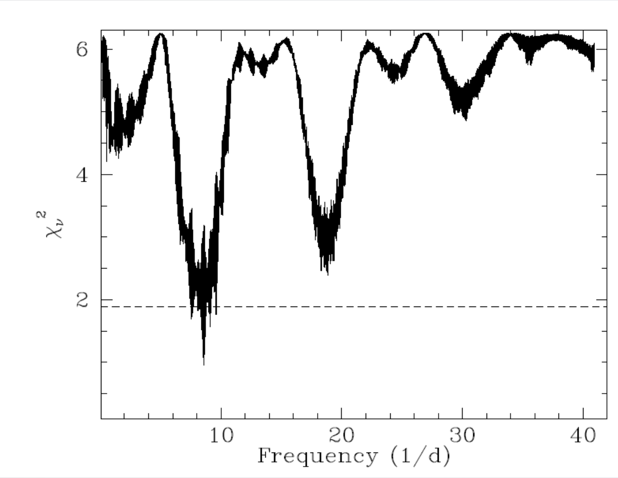


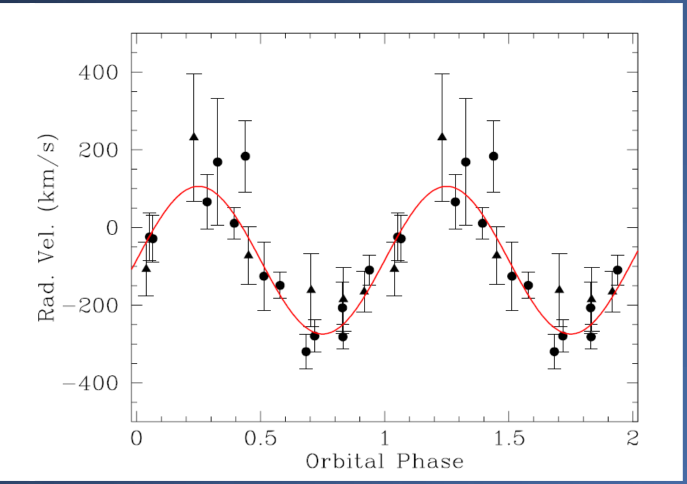
Extremely broad FWHM **Hα: 3300 km/s.**
XTE J1118+480: *FWHM* ~ 2400 km/s,
M_1=8Msun, P=4h, i=68°

Larger disc vel. prompt for: $M_1\uparrow$, $P\downarrow$, $i\uparrow$

(0.5*Vp-p)/K_2 ≅ 1.1 – 1.25 (Orosz+94,95)

Measured: Vp-p= 1790 ± 67 km/s





K_2 ≥ 690 km/s.

+

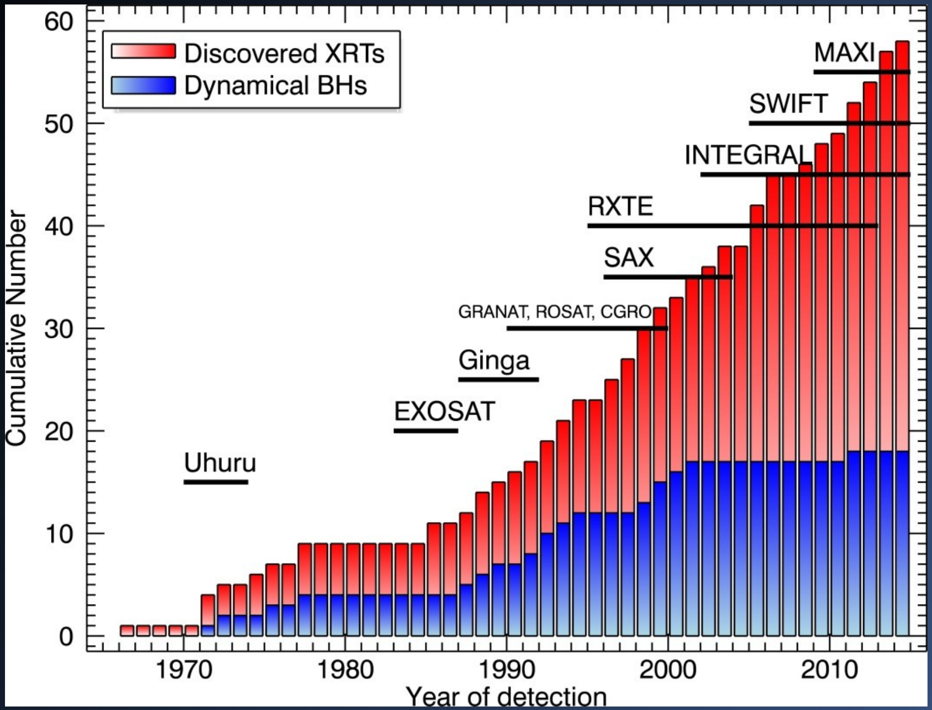
P = 2.8 ± 0.3 h

=

***f(M_1)* > 3 Msun**

Corral-Santana+13 Science

Black Hole Transients (BHTs)



BHTs detected since 1966

Rate of discoveries increased with improvement of X-ray satellites ~1.7 yr^{-1} (since 80's)

In 48 years of X-ray astronomy:

- 58 BH candidates so far (May2014)
- Only **17 dynamically confirmed** (~30% of all BHTs) **+ SwiftJ1357.2-0933**

Main problem is the faintness of the stars in quiescence

The catalogue

Aim:

- Collect all the information available and spread in hundredths of papers and IAUCs/ATels to create a catalogue of BHTs.
- Create a useful and updated reference book
- Analyse all the properties, make statistics and derive some conclusions based on the current sample.

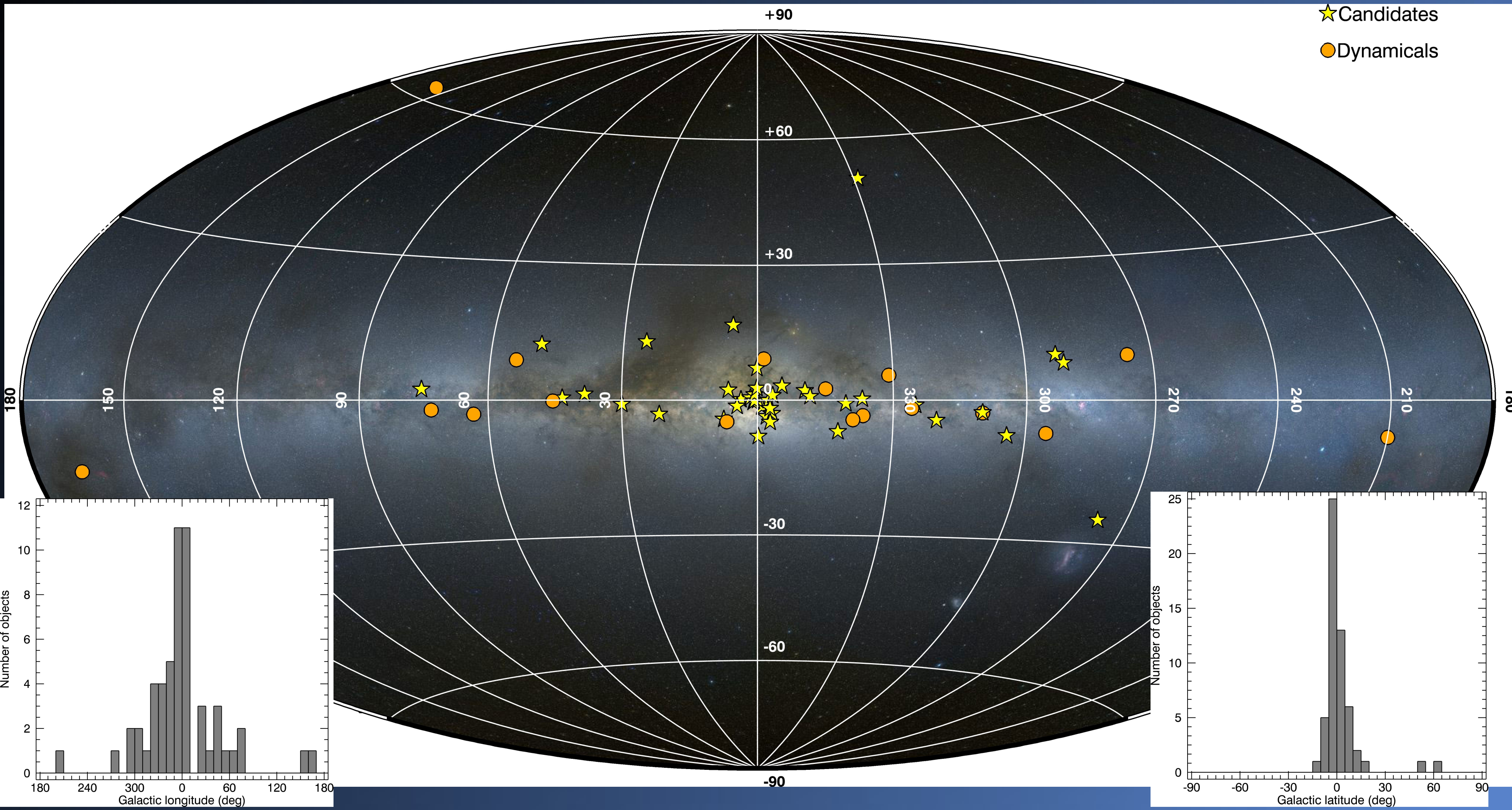
The on-line version:

Main characteristics + dedicated page on each target with extended information: magnitudes, dynamical parameters, references, links, finding charts, etc...

www.astro.puc.cl/~jcorral/BHTcat

Distribution in the Galaxy

Most of XRTs lie in the Plane and bulge. Only a few are in the halo.



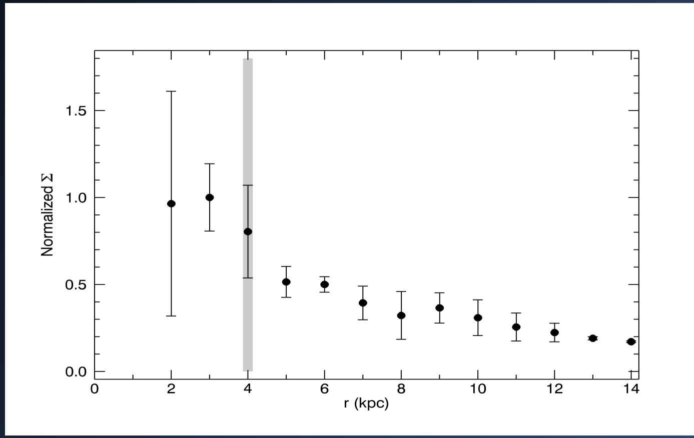
Corral-Santana+14, in prep.

Radial distribution

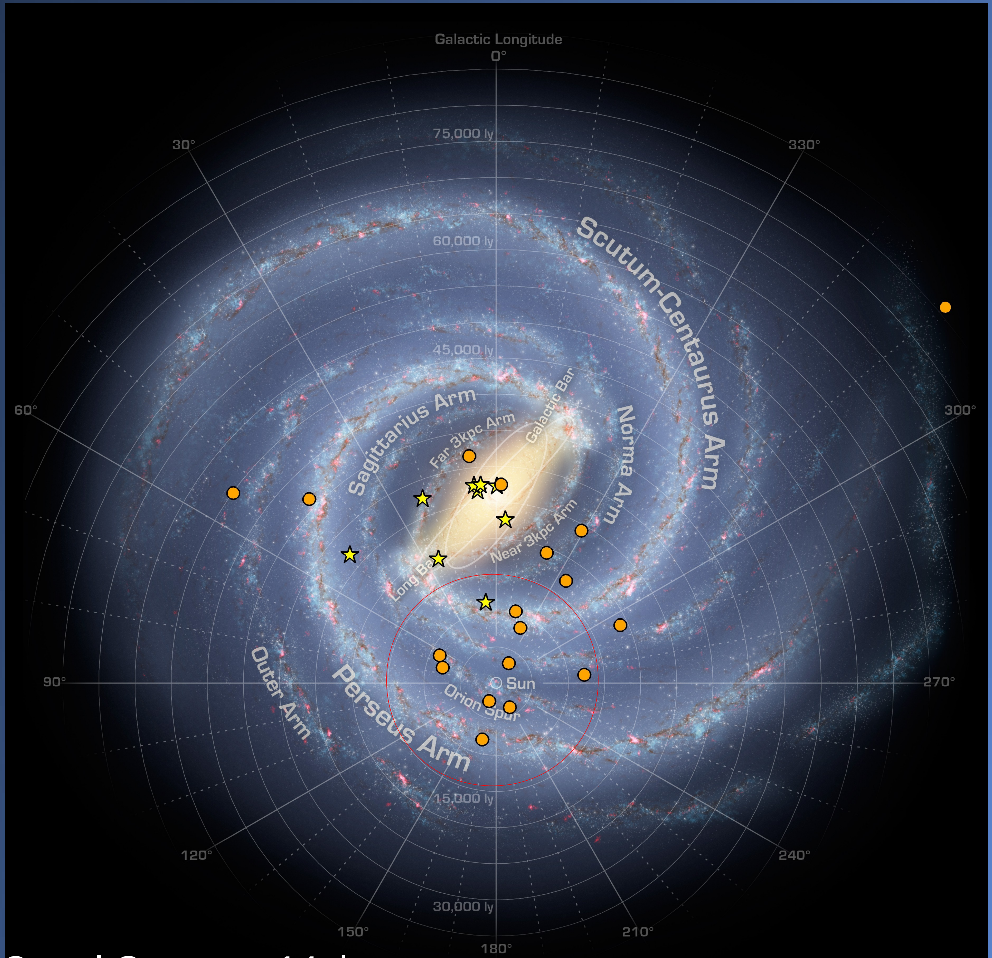
~55% of BHTs with known or estimated distances are within 4.5 kpc

Therefore, IS extinction is a severe limitation to dynamical confirmation.

The sample is complete up to **4kpc**, i.e. it's a good representation of dormant population



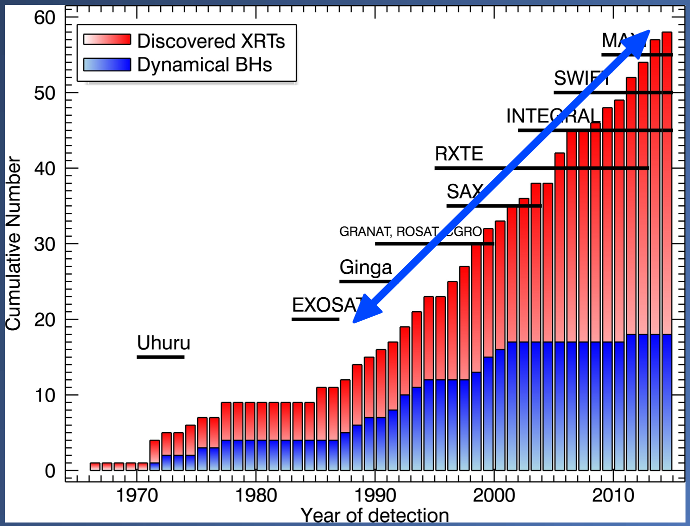
From analysis of vertical distribution (z), we can estimate the number of BHTs in the Galaxy (Duerbeck83)



Corral-Santana+14, in prep.

Number of BHTs in the Galaxy

There are 10 objects with r<4kpc discovered since the rate of discoveries became constant (~1988)



If we assume that their vertical distribution follows the same function than the stellar one:

$$\rho^*(z) = \rho_0^* \exp\left(\frac{-|z|}{z_0}\right) \ (\mathrm{kpc}^{-3}\ \mathrm{yr}^{-1})$$

And a lot of assumptions:

- The mean outburst recurrence period is 100 yr (White&van Paradijs96)
- The solar vertical distribution can be extrapolated to other parts of the Galaxy (which is not true! since ~30% of the luminosity mass is in the bulge)
- There is no radial dependence

The derived lower limit of BHTs in the Galaxy is **~1000**

Consistent with previous determinations (Tanaka92, White&van Paradijs96 and Romani98) but lower than the 10^4 predicted using population-synthesis models (Kiel&Hurley06 or Yungelson+06)

Dynamical parameters

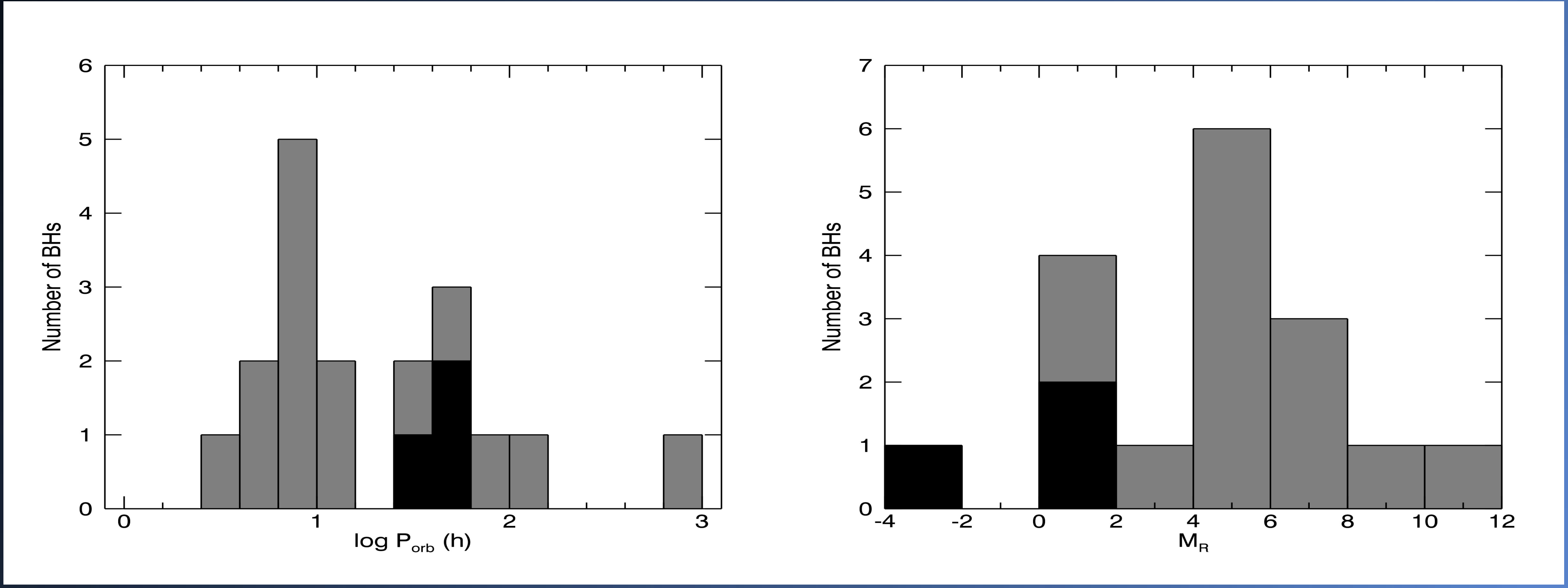
NAME	Spectral type	P_{orb} (h)	K_2 (km/s)	$f(M_1)$ ($M_\odot$)	M_1 ($M_\odot$)	q	i (°)	$v_{rot} \sin i$ (km/s)
Swift J1357.2–0933†	M4–M6	2.8 ± 0.3	> 690	≥ 3.0		≤ 0.06	~ 90	
XTE J1650–500	K4V	7.69 ± 0.02	435 ± 30	2.7 ± 0.6	≤ 7.3	> 0.1	50 ± 3	
XTE J1118+480	K5V	4.08 ± 0.003	709 ± 1	6.27 ± 0.04	8.53 ± 0.60	0.04 ± 0.01	68 ± 2	96^{+3}_{-11}
XTE J1859+226	K5V?	6.58 ± 0.05	541 ± 70	4.5 ± 0.6	> 5.42		< 70	
V4641 Sgr	B9III	67.60 ± 0.01	211 ± 3	2.7 ± 0.1	6.4 ± 0.6	0.45 ± 0.04	72 ± 4	100.9 ± 0.8
XTE J1550–564	G8–K4IV	37.00880 ± 0.00006	363 ± 6	7.65 ± 0.38	9.1 ± 0.6	≈ 0.03	75 ± 4	55 ± 5
GRO J1655–40	F6IV	62.91 ± 0.003	215 ± 2	2.73 ± 0.09	6.7 ± 1.2	0.42 ± 0.03	70 ± 2	87^{+8}_{-4}
N. Vel 93	K7–M0V	6.84492 ± 0.00002	475 ± 6	3.2 ± 0.1	~ 4.4	0.14 ± 0.01	37–80	50–100
GRS 1915+105	K1–5III	812 ± 4	126 ± 1	7.02 ± 0.17	10.1 ± 0.6	0.042 ± 0.024	70 ± 2	21 ± 4
GRO J0422+32	M0–5V	5.094 ± 0.002	378 ± 16	1.19 ± 0.02	3.95 ± 0.95	0.12 ± 0.08	45 ± 2	90^{+22}_{-27}
N. Mus 91	K3–5V	10.40 ± 0.01	406 ± 7	3.01 ± 0.15	6.95 ± 0.6	0.13 ± 0.04	54 ± 1.5	106 ± 13
V404 Cyg	K0IV (±1)	155.31 ± 0.02	208.5 ± 0.7	6.08 ± 0.06	12 ± 2	0.067 ± 0.005	55 ± 4	39 ± 1
GS 2000+251	K3–6V	8.25809 ± 0.00005	520 ± 16	5.01 ± 0.12	9 ± 2	0.042 ± 0.012	66 ± 8	86 ± 8
BW Cir	G5III	61.07 ± 0.002	279 ± 5	5.73 ± 0.29	$\geq 7.6 \pm 0.7$	$0.12^{+0.03}_{-0.04}$	≤ 79	69 ± 8
N. Oph 77	K3–7V	12.51 ± 0.03	447 ± 3	4.86 ± 0.13	6.5 ± 1.5	< 0.053		
A0620–00	K4V	7.7523372 ± 0.0000002	433 ± 3	2.76 ± 0.01	6.6 ± 0.3	0.067 ± 0.004	51 ± 1	
GX 339-4		42.14 ± 0.01	317 ± 10	5.8 ± 0.5	$\gtrsim 6$	≤ 0.125		
4U 1543–475	A2V	26.9 ± 0.2	124 ± 4	0.22 ± 0.06	5.0 ± 2.5	0.25–0.31	30 ± 6	

Statistical analysis of the observational and dynamical parameters of the sample:

- Inclinations: none eclipsing although 20% expected for a random distribution – hidden from view (Narayan&McClintock05)
- Swift J1357.2-0933 may be the first edge-on BH (Corral-Santana+13). But Armas Padilla+13 presented an alternative explanation.

Distribution of confirmed BHTs

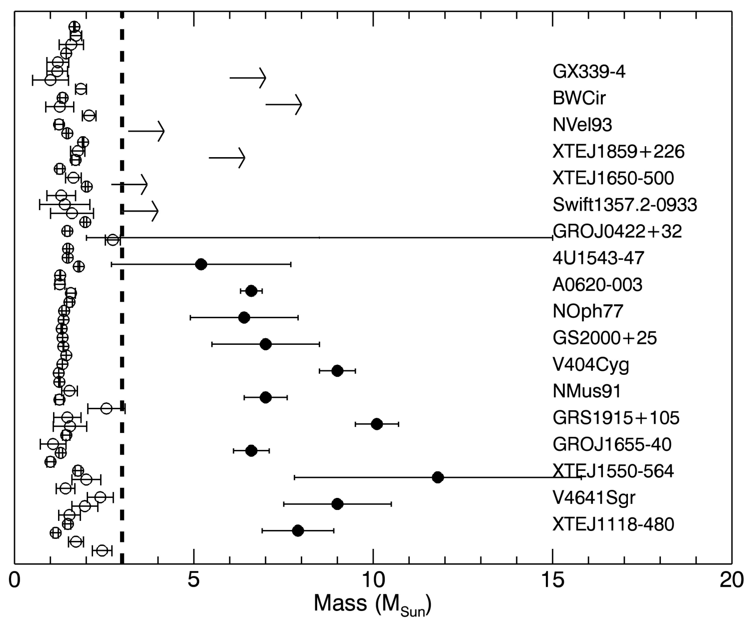
- Bimodal period distribution with major peak at 6-10h and gap at 15h (bifurcation period; Menou+1999) due to evolutionary paths.
- Distribution M_R shows peak at ~4-6 (in agreement with MS K-type)
- Note the 3 IMXBs: GROJ1655, V4641Sgr and 4U1543-475 (in black)



Corral-Santana+14, in prep.

Mass distribution

- Uncertainties in the mass of 20-30% due to the low accuracy in the inclination
- Mass distribution should be smooth by correlation with masses of progenitors stars



Corral-Santana+14, in prep.

- There seems to be a gap at 2-5Msun.
- The existence of the gap is probably real (Ozel+10, Farr+11)

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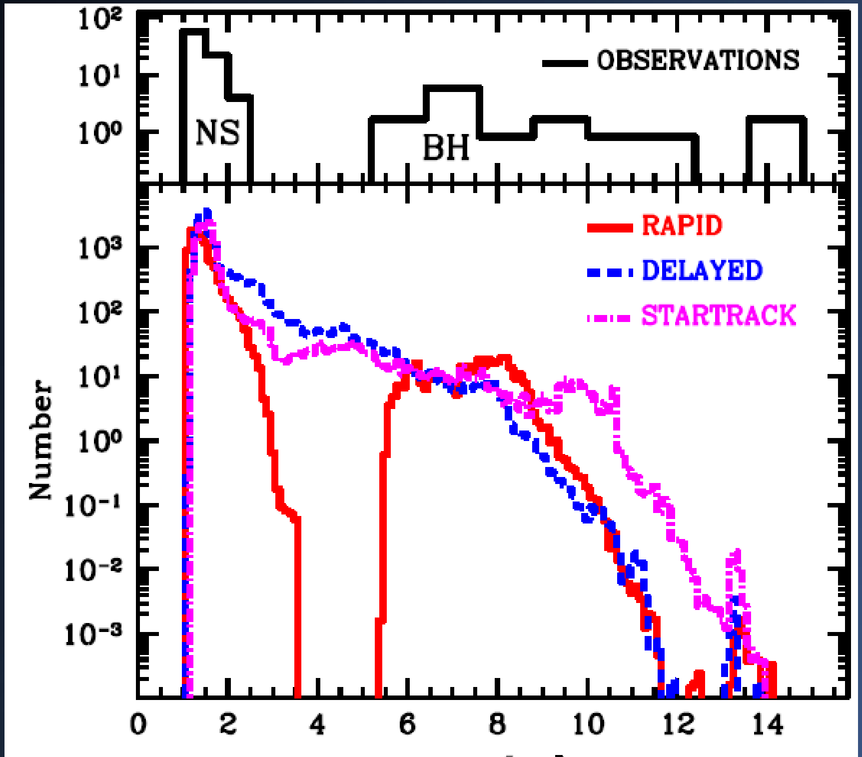


Belczynski+2012

- There seems to be a gap at 2-5Msun.
- The existence of the gap is probably real (Ozel+10, Farr+11)
- However some SN models with hydrodinamic simulations can reproduce the gap (Belzynski+12)
- But poor statistics and possible systematic errors in inclination.

A Catalogue of Galactic Black Holes in X-ray Binaries

Updated: June 2014 - v0.5

ID#	YEAR	NAME	RA	DEC	l	b	Mout	Mqui	E(B-V)	d	z	Sp.Ty.	Porb	K2	f(M)	M1	q	i	v sini
			J2000	J2000	deg	deg	mag	mag	mag	kpc	kpc		h	km/s	Msun	Msun		deg	km/s
34	2001	XTEJ1650-500	16 50 00.98	-49 57 43.60	336.7182	-03.4270		R~20.2	1.19	2.6±0.7	-0.15	K4V	7.6	435±30	2.7±0.6	≤7.3±0	>0.1	50±3	
33	2000	XTEJ1118+480	11 18 10.85	48 02 12.90	157.6607	62.3206	V=12.9	R=19	0.011	1.72±0.1	1.52	K7V	4.08	709±7	6.3±0.2	8.53±0.6	0.04±0.01	68±2	
32	1999	XTEJ1859+226	18 58 41.58	22 39 29.40	054.0461	08.6076	R~15	R=22.4	0.491	11-14	1.6-2.1	K5V	6.56	541±70	4.5±0.6	>5.42		<70	
31	1999	SAXJ1819.3-2525	18 19 21.58	-25 24 25.10	006.7740	-04.7891	V~8?	R~13.5?	0.32	6.2±0.7	-0.82	B9III	67.6	211±3	2.7±0.1	6.4±0.6	0.45±0.08	72±4	100.9±0.8
30	1998	XTEJ2012+381	20 12 37.71	38 11 01.10	075.3883	02.2471	R=19.9		1.9-										
29	1998	XTEJ1748-288	17 48 05.06	-28 28 25.80	000.6756	-00.2220			HIGH										
28	1998	XTEJ1550-564	15 50 58.78	-56 28 35.00	325.8825	-01.8269	V=16.6	V=22	1.604	~5.3	~-0.17	G8-K4IV	37	361±18	6.86±0.71	10±2	0.09-0.15	73.1±2.3	
27	1997	XTEJ1755-324	17 55 28.60	-32 28 39.00	358.0393	-03.6314			1.105										
26	1997	GRS1737-31	17 40 09.00	-31 02 24.00	357.5880	-00.0990			HIGH										
25	1996	GRS1739-278	17 42 40.03	-27 44 52.70	000.6721	01.1758		R=20.5	2-										
24	1996	XTEJ1856+053	18 56 42.92	05 18 34.30	038.2690	01.2720	Ks=16.4		>5										
23	1994	GRS1730-312	17 33 32.00	-31 12 16.00	356.6877	01.0065			>5										
22	1994	GROJ1655-40	16 54 00.14	-39 50 44.90	344.9819	02.4560		V=17.3	1.2	3.2±0.2	0.13	F6IV	62.9	215±2	2.73±0.09	6.7±1.2	0.39±0.05	70±2	26±3
21	1993	GRS1716-249	17 19 36.93	-25 01 03.43	000.1423	06.9909	V=16.3	R≥20	0.9	2.4±0.4	0.29								
20	1993	GRO1009-45	10 13 35.60	-45 04 35.31	275.8773	09.3439	V=13.8		0.193	3.8±0.3	0.62	K7-8V	6.844944(3)	475±6	3.2±0.1	~4.4	0.14±0.01	~78	
19	1992	GRS1915+105	19 15 11.55	10 56 44.80	045.3656	-00.2194		I=23.4	9.6	≤11.2±0.8	≤-0.04	K1-5III	804	140±15	9.5±3	14±4	0.058±0.033	70±2	
18	1992	GROJ0422+42	04 21 42.79	32 54 35.80	165.8790	-11.9108	R=12.6	R=20.9	0.24	2.5±0.3	-0.54	M2V	5.094±0.002	378±16	1.19±0.02	3.95±0.95	0.12±0.08	45±2	90±^22-27
17	1991	GRS1124-684	11 26 26.65	-68 40 32.83	295.3005	-07.0726	V=13.3	R=19.9	0.3	5.9±0.3	-0.72	K3-5V	10.4±0.01	406±7	3.01±0.15	6.95±0.6	0.09-0.17	54±1.5	106±13
16	1990	GRS1758-258	18 01 12.40	-25 44 36.10	004.5077	-01.3610		K=13.6	3.2										
15	1989	GS2023+338	20 24 03.82	33 52 01.90	073.1188	-02.0914	V=12.7	R=16.4	1.3	2.39±0.14	-0.08	K0IV(+-1)	155.314	208.5±0.7	6.08±0.06	12±2	0.055-0.064	55±4	39±1
14	1988	GS1734-275	17 36 02.00	-27 25 41.00	000.1608	02.5906			1.478										
13	1988	GS2000+251	20 02 49.58	25 14 11.30	063.3666	-02.9989	B=17.5	R=21.2	1.5	2.7±0.7	-0.14	K3-6V	8.3	520±16	5.01±0.12	10±4	0.042±0.012	61±14	86±8
12	1987	GS1354-64	13 58 09.73	-64 44 05.22	309.9774	-02.7797	V=16.9	R=22	1	~25	~-1.21	G5III	61.1	279±5	5.73±0.29	≥7.6±0.7	0.08-0.15	≤79	69±8
11	1985	EXO1846-031	18 49 16.91	-03 03 52.70	029.9585	-00.9177		I>22	17										
10	1985	SLX1746-331	17 49 48.94	-33 12 11.60	356.8069	-02.7797			1.416										
9	1977	H1705-250	17 08 14.58	-25 05 29.00	358.5874	09.0569	V~16	R=20.8	0.472	8.6±2.1	1.35	K3-7V	12.5	447±3	4.86±0.13	5.6-8.3	<0.053		
8	1977	H1743-322	17 46 15.61	-32 13 59.90	357.2552	-01.8330	R=21.9		3.478										
7	1975	A0620-003	06 22 44.54	00 20 44.40	209.3382	-06.2225	V=11.2	R=17.4	0.39	1.16±0.11	-0.13	K4V	7.8	433±3	2.72±0.06	11±2	0.05-0.07	40±3	
6	1974	A1524-617	15 28 17.20	-61 52 58.50	320.3191	-04.4272	B=17.5	R=22.7	0.697										
5	1972	J1659-487	17 02 49.44	-48 47 22.60	338.9393	-04.3264	V=15.5	R~20.1	0.911	>6	>-0.4	GIV	42.1	317±10	5.8±0.5	≥7	≤0.125		
4	1971	4U1755-338	17 58 40.04	-33 48 26.80	357.2155	-04.8724	V=18.5	R>21.5	0.696										
3	1971	4U1630-472	16 34 03.02	-47 22 56.70	336.9217	00.2545			HIGH										
2	1971	4U1543-475	15 47 08.70	-47 42 50.70	330.9266	05.3626	V=14.9	R~16.2?	0.5	7.5±0.5	0.71	A2V	26.9	124±4	0.22±0.06	5±2.5	0.25-0.31	30±6	
1	1966	Cen-X-2	13 58 00.00	-64 42 00.00	310.0000	-02.7000			1.324										

www.astro.puc.cl/~jcorral/BHTcat - available soon. Save in bookmarks!

GS1354-64 (BW Cir)

ID#: 12

RA J2000(hms)	**DEC J2000(dms)**	
13 58 09.73	-64 44 05.22	Kitamoto+1990

Gal. long (deg)	**Gal. lat. (deg)**
309.9774	-02.77966

Year of discovery: 1987 Makino1987

DYNAMICAL PARAMETERS

Description	**Parameter**	**Value**	**Reference**
Spectral type		~G5 IV	Casares+2009
Distance	d (kpc)	~25	Casares+2009
Galactic height	z (kpc)	~-1.21	Casares+2009
E(B-V)	E(B-V)	1.0	Casares+2009
Orbital period	Porb (h)	61.1	Casares+2009
Star's radial vel.	K_2 (km/s)	279±5	Casares+2004
Mass function	$f(M_1)$ [Msun]	5.73±0.29	Casares+2004
Mass ratio	$q=M_2/M_1$	$0.12^{+0.03}_{-0.04}$	Casares+2004
Inclination	i (deg)	<79	Casares+2009
Rotational broadening	Vrot sini (km/s)	69±8	Casares+2009

OBSERVATIONAL PARAMETERS

Parameter	**Value**	**Reference**
Flux (erg/s/cm^2) [band keV]	2.9x10-9 [1-10]	Makino1989 Kitamoto+1990
B (mag)		
V (mag)	16.9 o 22.14 q	Pedersen+1987 Casares+2009
R (mag)	20.4 q 20.65 q 20.5 q	Casares+2004 Casares+2009 Martin95
I (mag)	19.73 q	Casares+2009

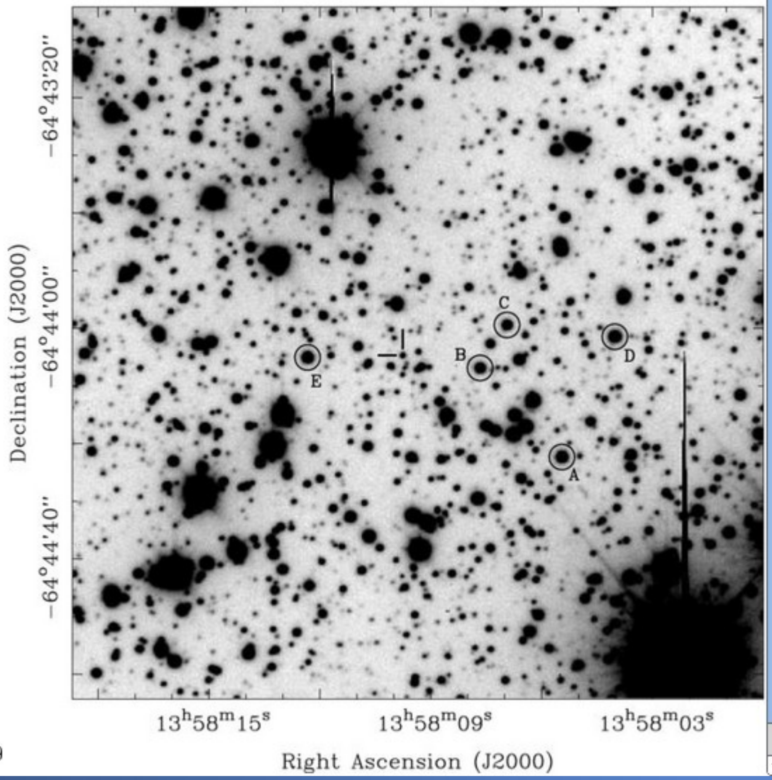
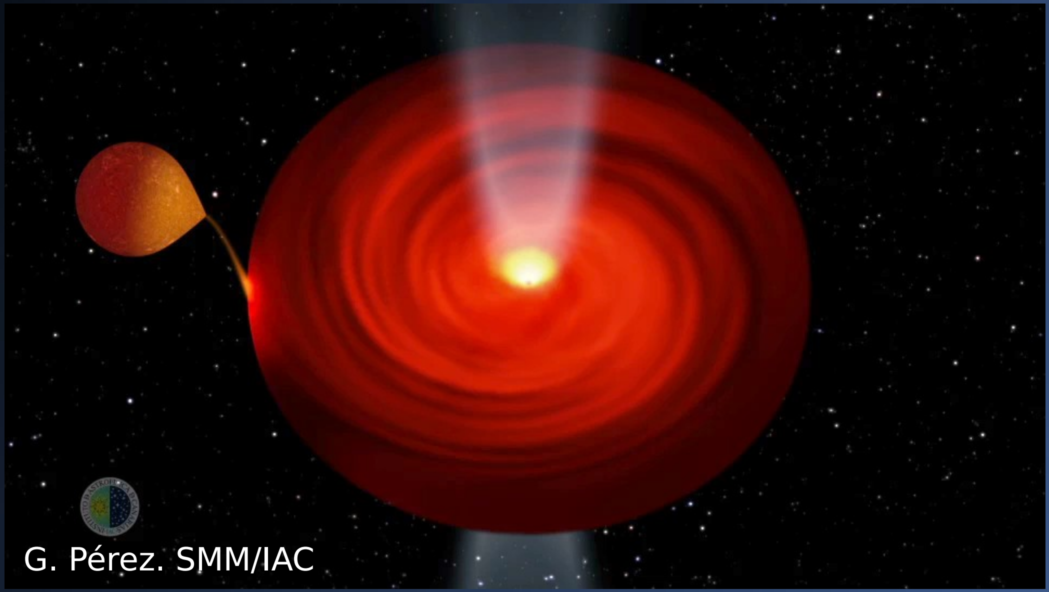


Image from Casares+2009

Magnitude notes:

www.astro.puc.cl/~jcorral/BHTcat - available soon. Save in bookmarks!

Comments, suggestions, new data, new discoveries, ...
jcorral@astro.puc.cl



Thank you