Isolated black holes and neutron stars in the Galaxy

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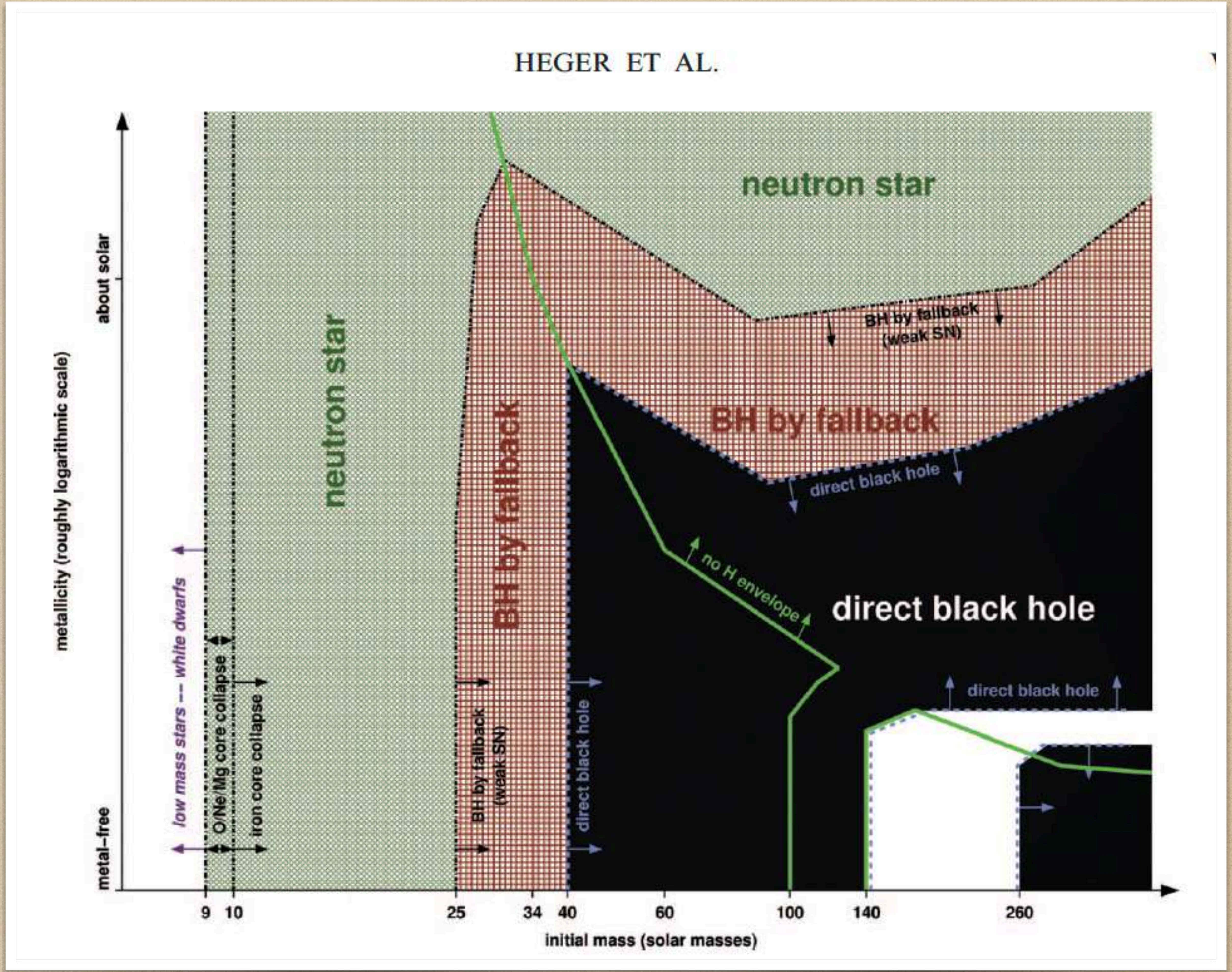
The Fourth National Workshop on the SKA Project
Sharpening the Italian science case for the SKAO
Catania 23/11 - 1/12 2003

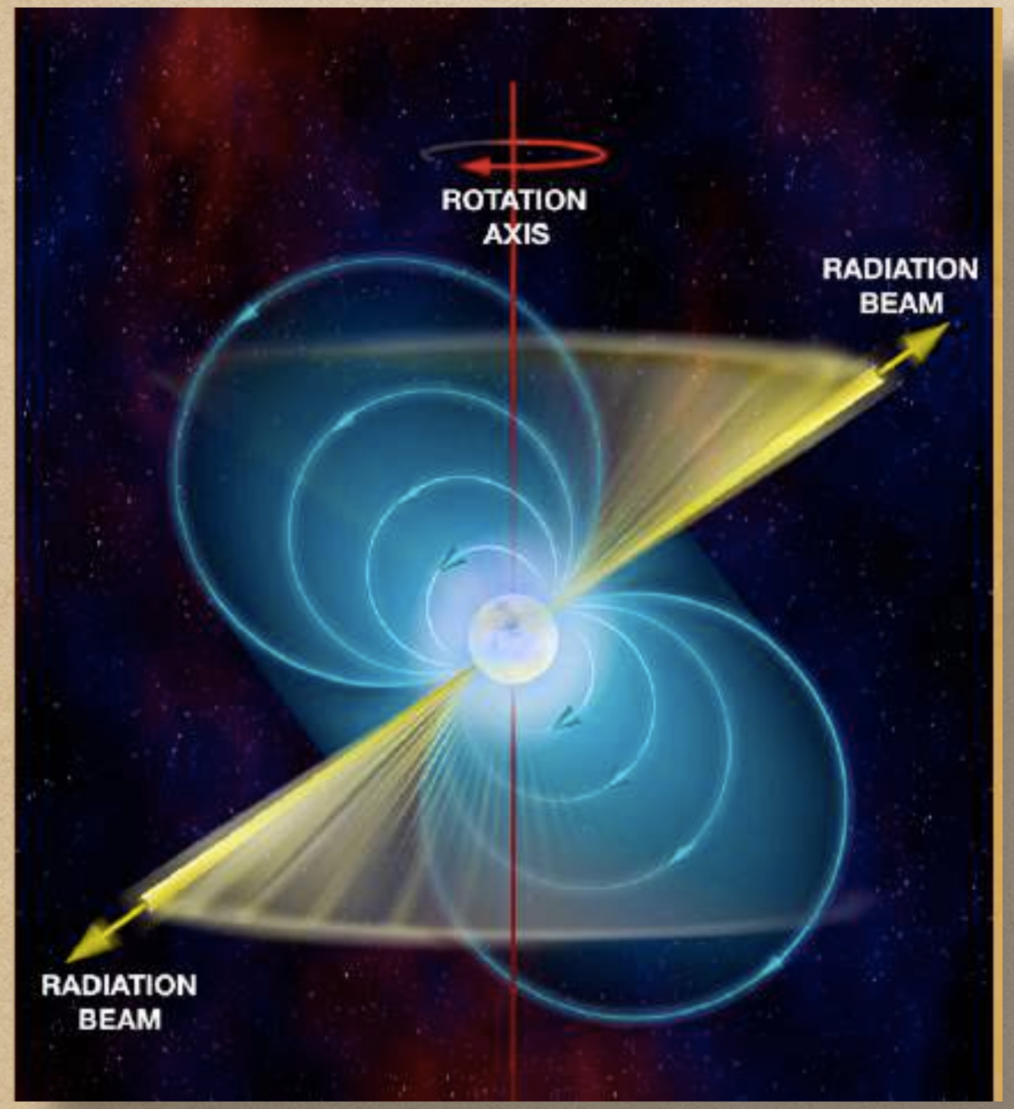
"Dead" stars in the Galaxy

Total number:

10^8-10^{10} NS

10^7-10^9 BH

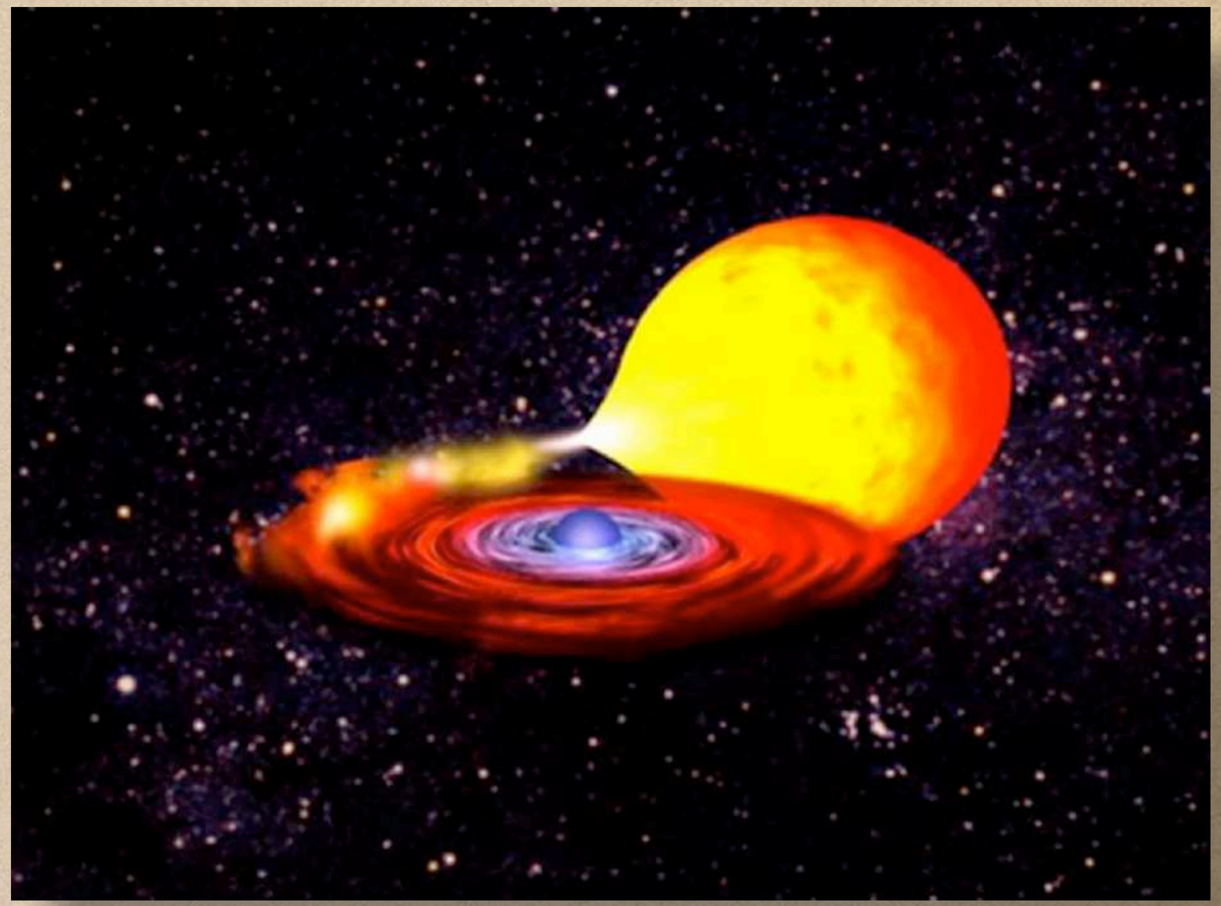


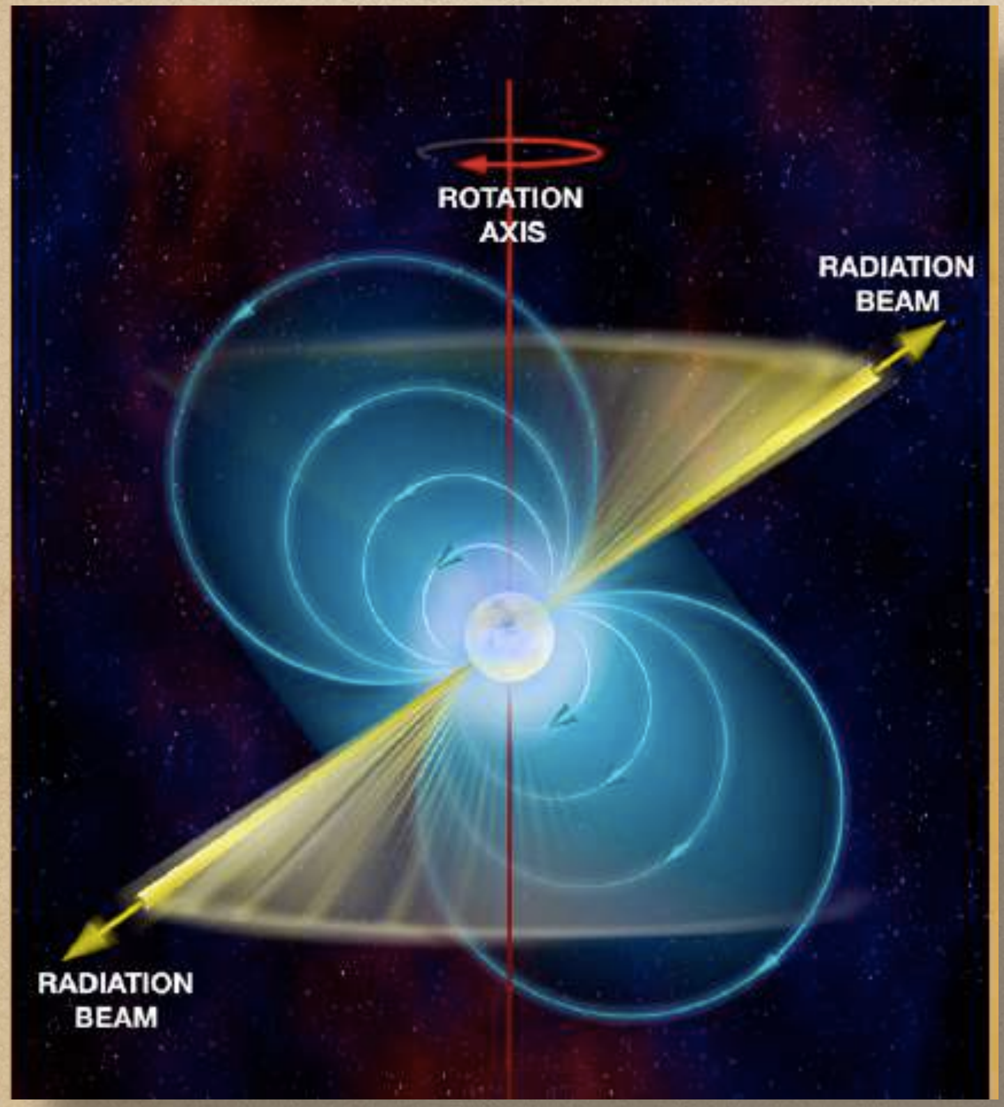


~ 3000 radio and/or gamma-ray pulsars

ROTATION-POWERED NS

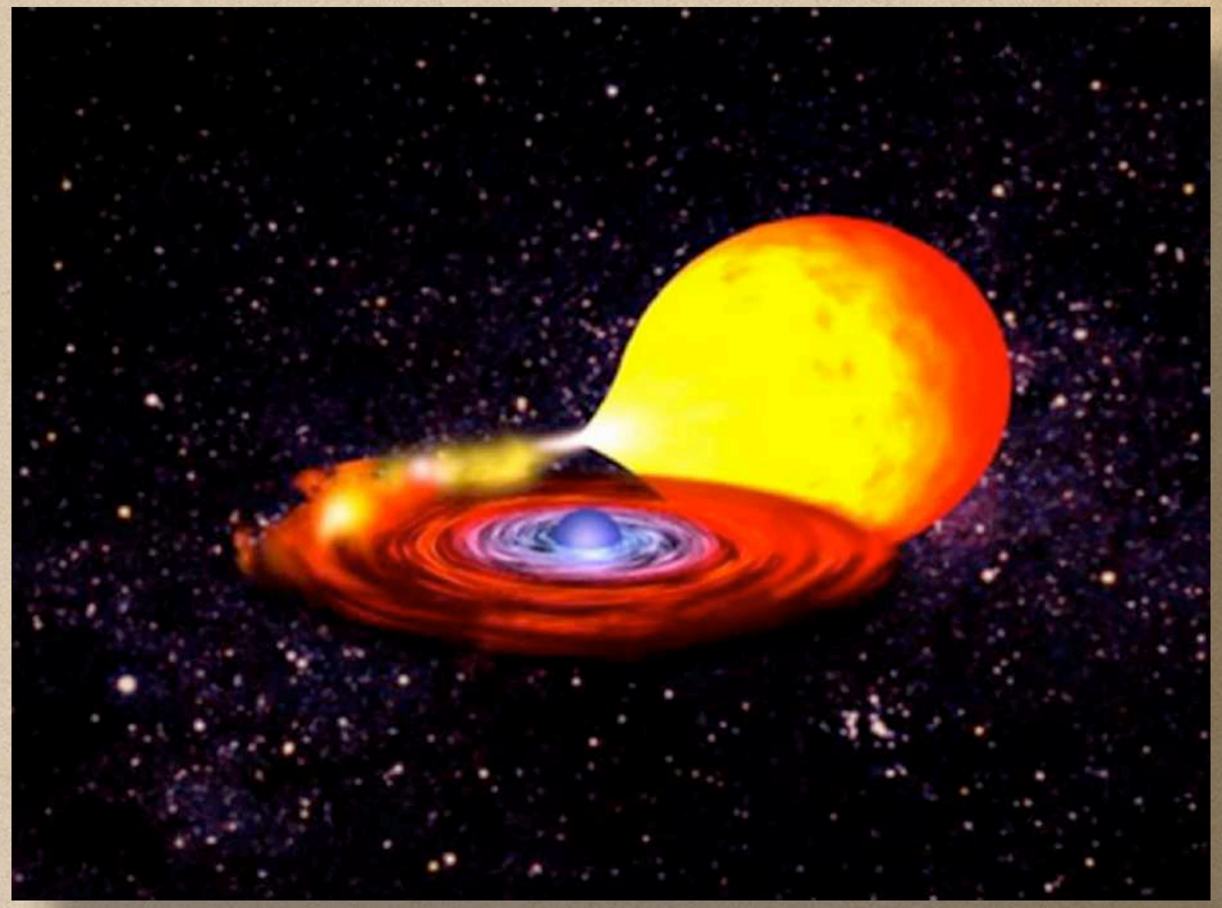
Few hundreds
X-ray binaries
ACCRETION-
POWERED
NS and BH

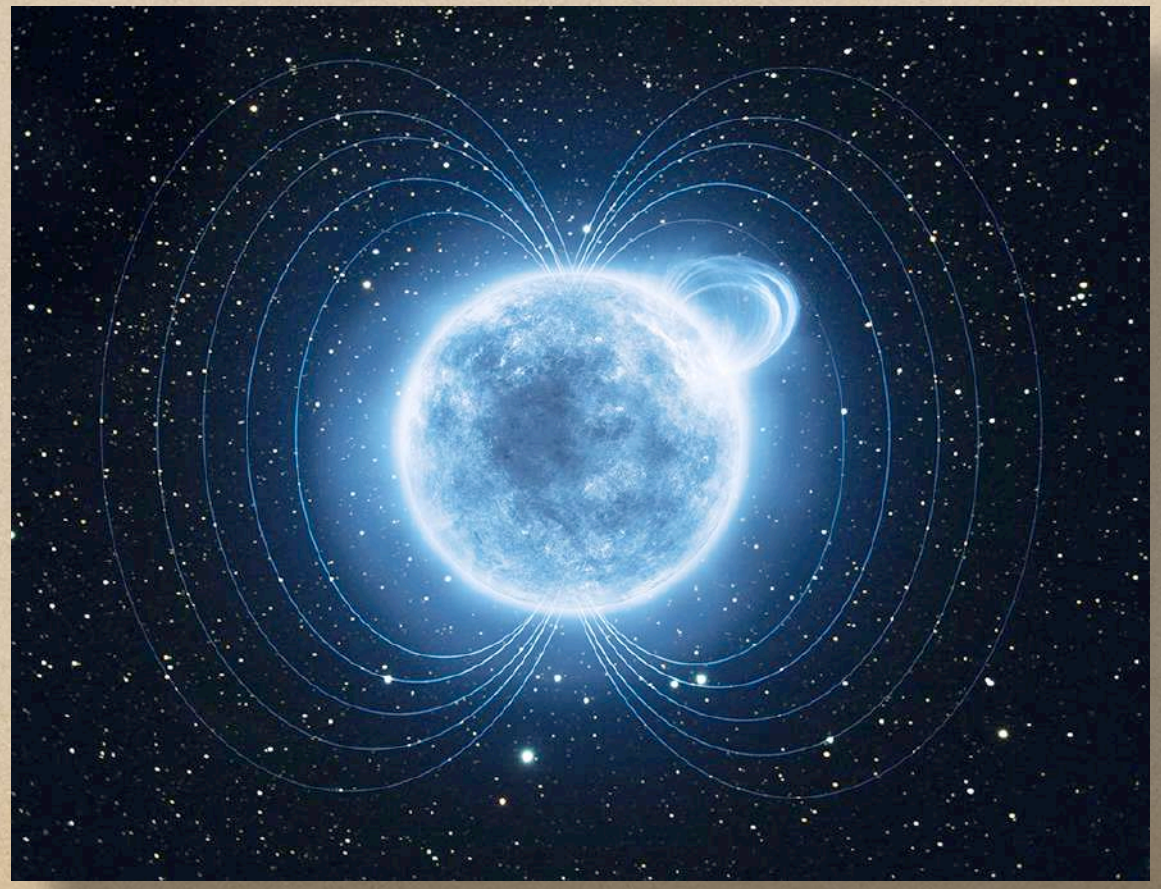




~ 3000 radio and/or gamma-ray pulsars
ROTATION-POWERED
(NS)

Few hundreds
X-ray binaries
ACCRETION-POWERED
(NS, BH)



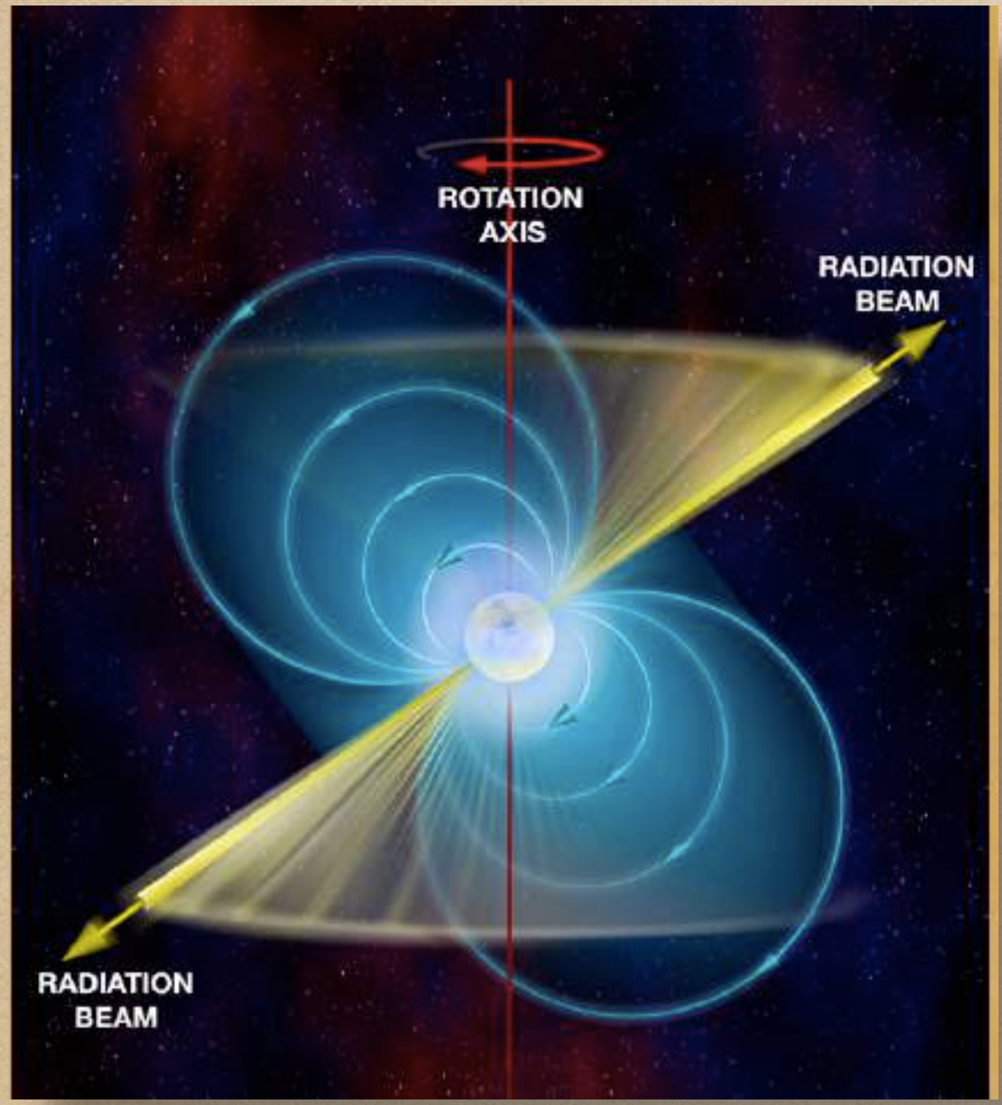


Few tens
MAGNETICALLY-POWERED / THERMALLY EMITTING (NS)

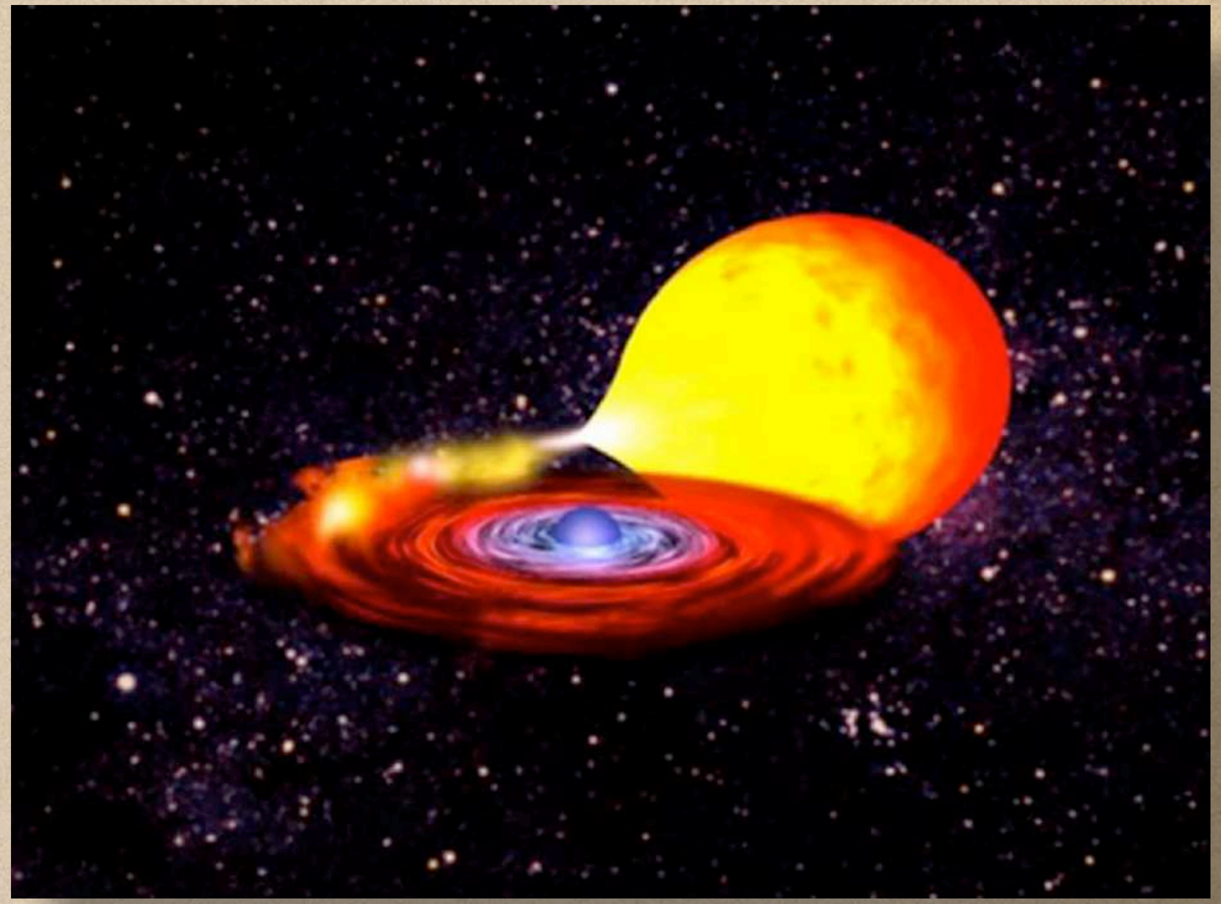
"Dead" stars in the Galaxy

Total number:	Observed
10^8-10^{10} NS	~ 3000-4000 NS
10^7-10^9 BH	≲20 confirmed + ≲ 30 candidate

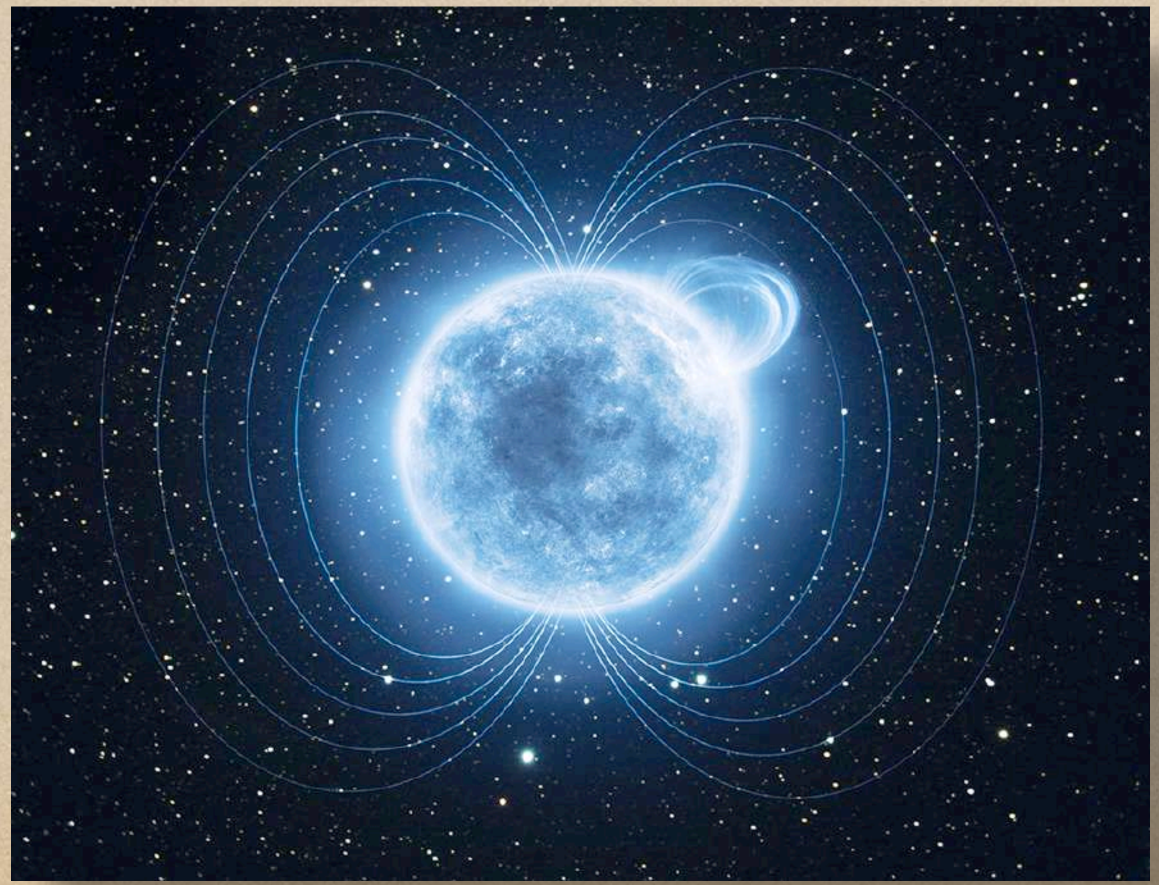
Selection effects



Beaming,
Age,
L=L(P,B),
…



Evolution,
Age,
Orbital separation,
…



Age,
Absorption,
….

"Dead" stars in the Galaxy

Observed << Expected

- different emission processes (age dependent)
- selection effects in observations

Binary wrt isolated

Most massive stars are binary (disruption / formation)

Other ways to look for stellar remnants

Other ways to look for stellar remnants - 1

"Invisible" companions of (single-lined spectroscopic) binaries

SOVIET ASTRONOMY—AJ VOL. 10, NO. 2 SEPTEMBER-OCTOBER, 1

COLLAPSED STARS IN BINARY SYSTEMS

O. Kh. Guseinov and Ya. B. Zel'dovich

Translated from Astronomicheskii Zhurnal, Vol. 43, No. 2,
pp. 313-315, March-April, 1966
Original article submitted October 18, 1965

A method for detecting collapsed stars which are members of spectroscopic binary syster
is proposed. Several pairs are selected from among the spectroscopic binary systems wi
invisible companions, in which one may suppose that their components are collapsed stars

—> a few candidates found:

2MASS J05215658+4359220 Thompson+2019 Science
—> 83 d orbit, M 3.3[-0.7,+2.8] —> BH or massive NS

In **NGC 3201** globular cluster. Giesers+ 2018; 167 d orbit, M>4.36 M_sun

GIRAFFE (2M04123153+6738486) Jayasinghe+2022
stripped giant with presumed BH companion, but then shown to be a giant

UNICORN (V723 Mon) Similar to GIRAFFE,
El-Badry+2022 both are stripped giants with subgiant companions

GAIA BH1 El-Badry+2022 —> Sun like G star + 9.6 M_sun BH in 186 d orbit, d=480 pc

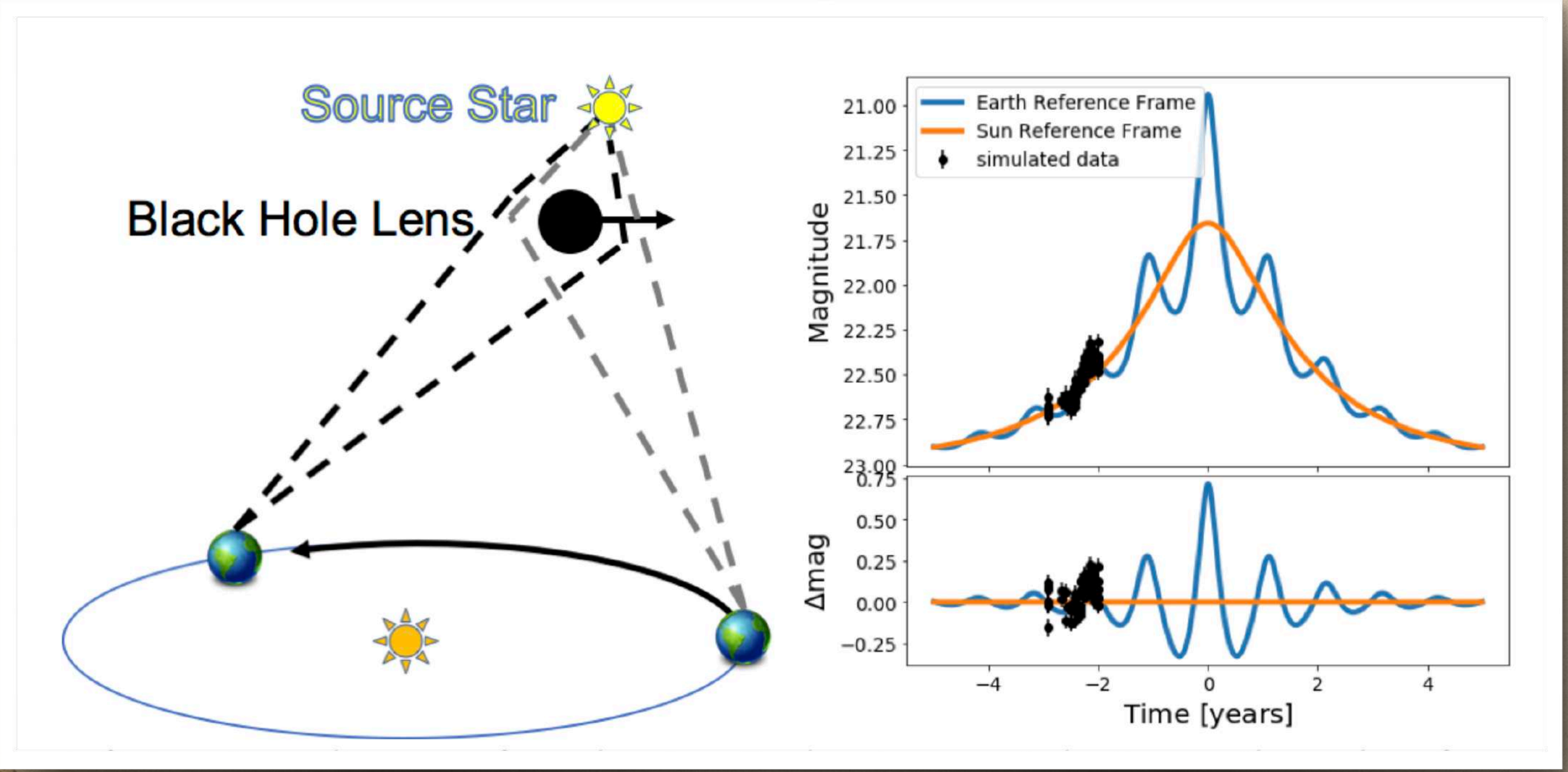
2MASS J15274848+3536572 Lin+2022
—> Main seq K star, Porb=6.14 hr, with NS companion, d=118 pc

HD96670. Gomez+Grindlay2021 O-type + 6.2 Msun BH, Porb=5.3 d,

24 NS and/or BH candidates from GAIA astrometry Andrews+ 2022
Masses in 1.35-2.7 M_sun range

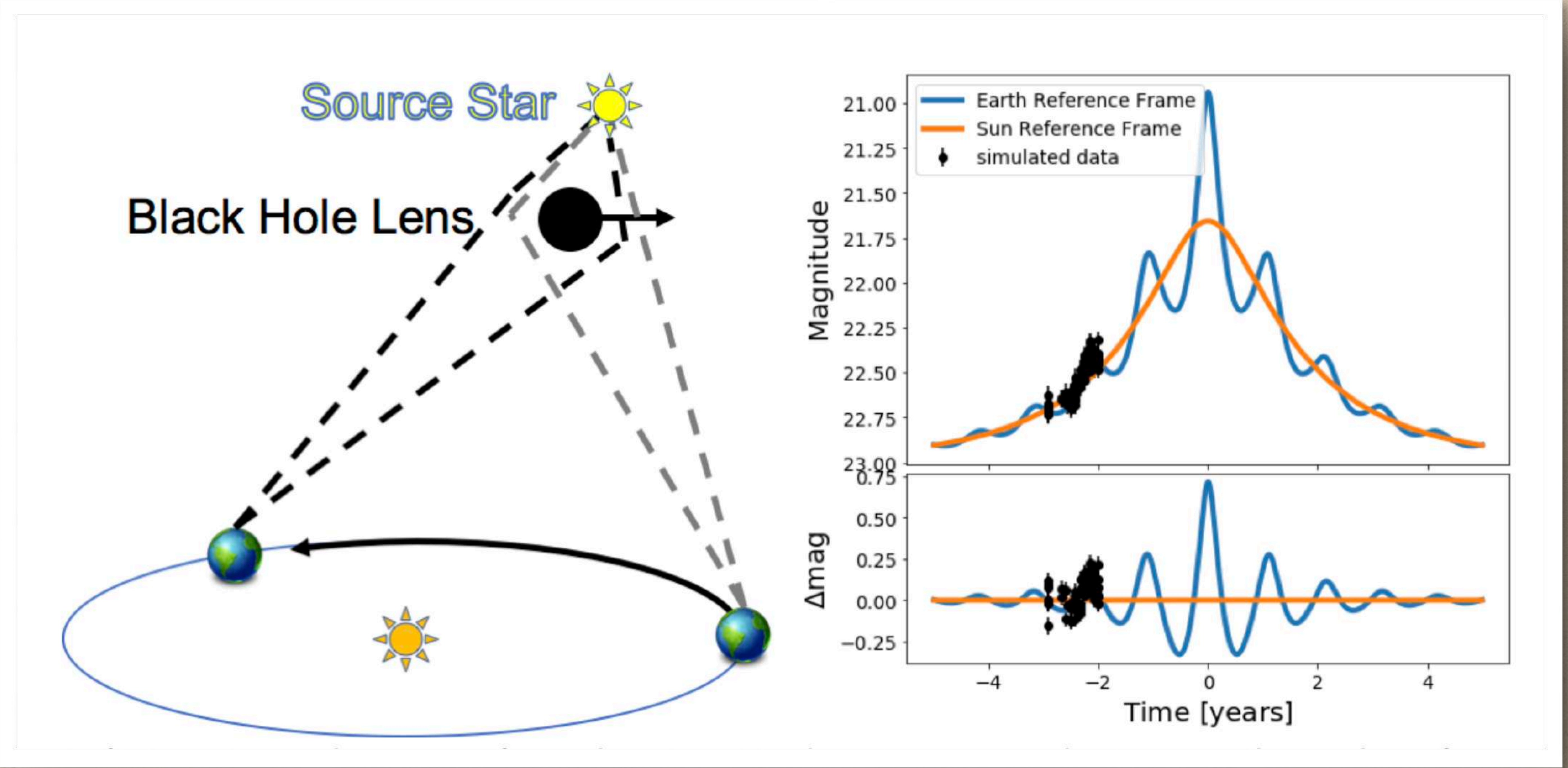
Other ways to look for stellar remnants - 2

Parallactic Gravitational Microlensing



Other ways to look for stellar remnants

Astrometric Parallactic Gravitational Microlensing



$$\hat{t} = \frac{2R_E}{v_\perp} = \frac{4}{v_\perp c}\sqrt{\frac{GMD_l(D_s - D_l)}{D_s}}$$

degeneracy between lens mass, relative velocities and distances is solved

"Astrometric Parallactic" Microlensing

One confirmed isolated BH

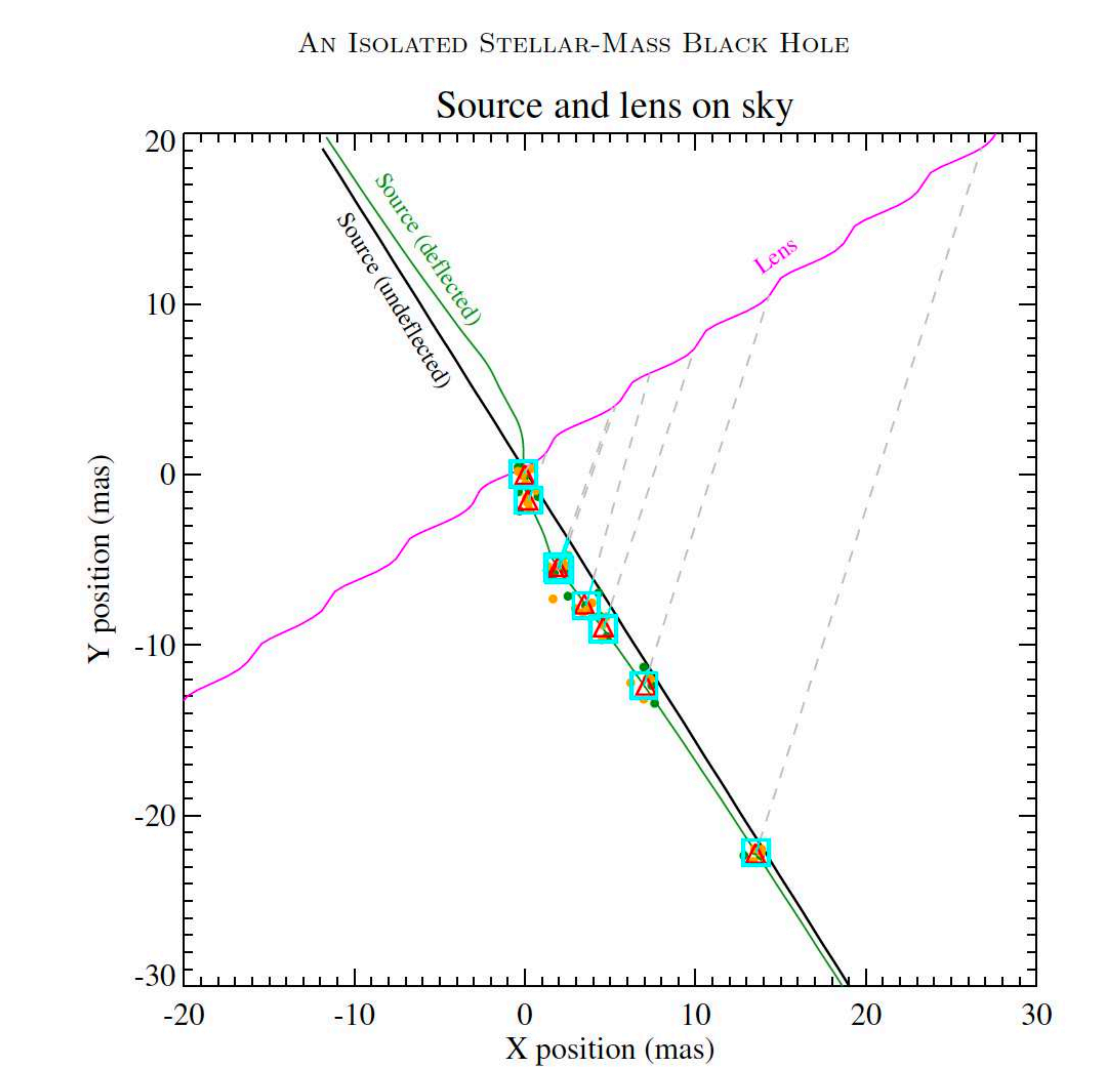
+ several candidates (BH , NS)

OGLE 11-462

(Lam+ 2022, Sahu+ 2022, Mroz+ 2022)

$7.88 \pm 0.82\, M_\odot$

1.49 ± 0.12 kpc



Other ways to look for stellar remnants - 3

Accretion from Interstellar Medium

THE EFFECT OF INTERSTELLAR MATTER ON CLIMATIC VARIATION

By F. HOYLE and R. A. LYTTLETON

Received 19 April 1939

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Accretion from Interstellar Medium

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$$\dot{M} = 4\pi n m_p \frac{(GM)^2}{(V^2 + c_s^2)^{3/2}} \lambda \quad \mathrm{g\ s^{-1}}.$$

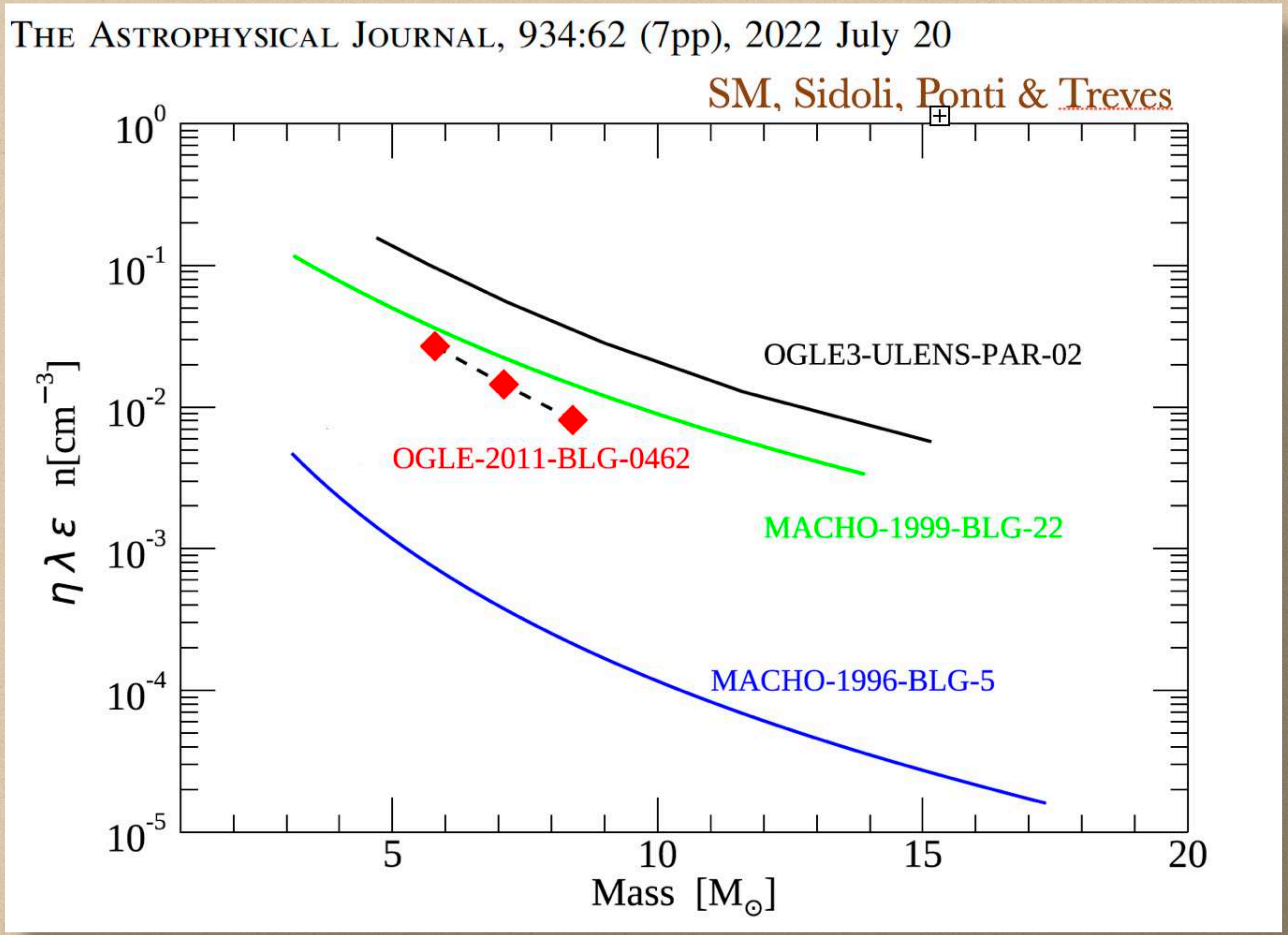
$$L \equiv \frac{GM\dot{M}}{R_{\rm ns}} = 2.46\ 10^{31} \left(\frac{n}{1\ \mathrm{H\ cm^{-3}}}\right)\left(\frac{10\ \mathrm{km\ s^{-1}}}{v}\right)^3 \mathrm{erg\ s^{-1}}$$

Accretion from Interstellar Medium

NS —> Searches unsuccessful (velocity, absorption)

(e.g. Treves & Colpi 91, Blaes & Madau 93, Schwope+ 99, Perna+03, ...)

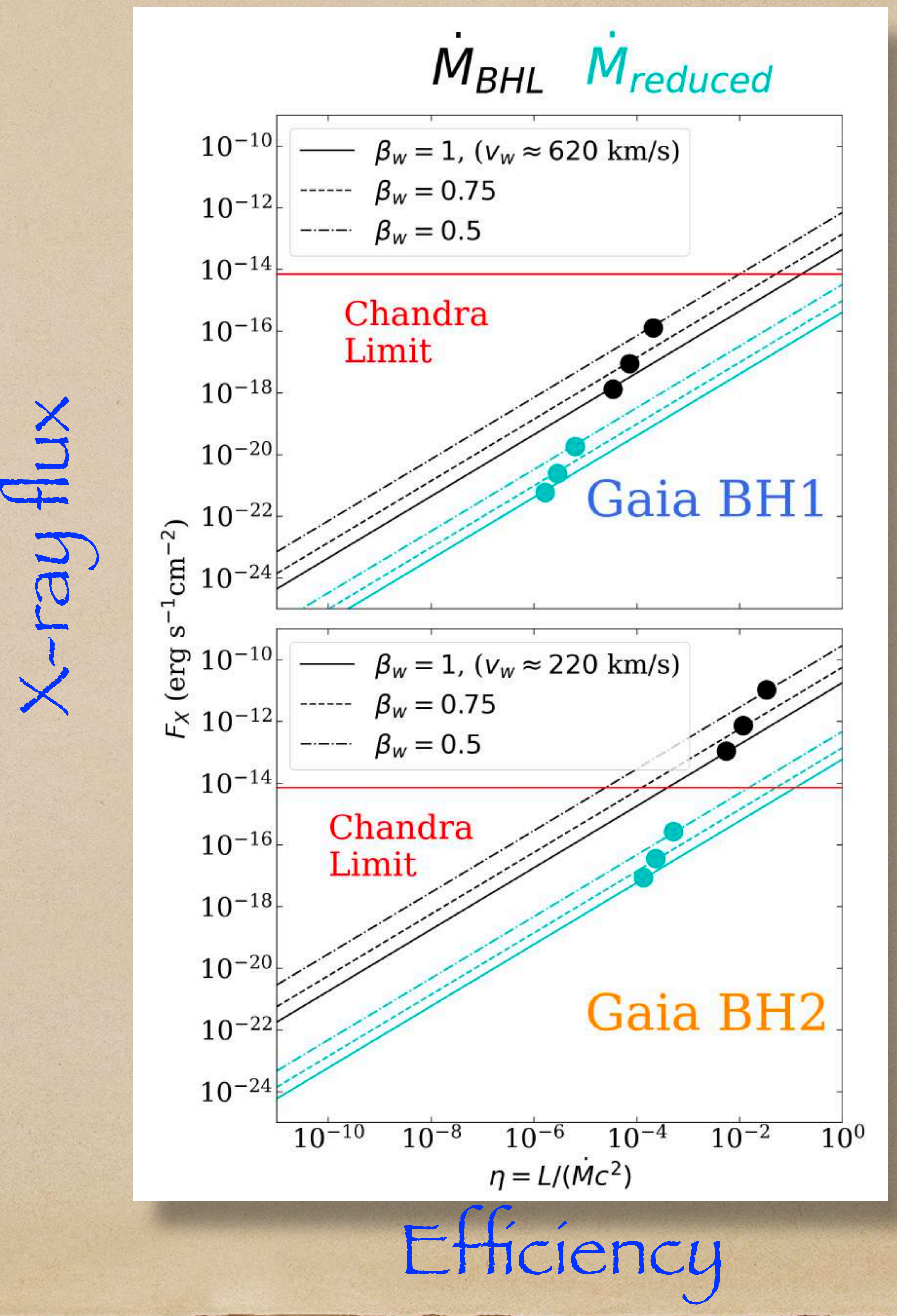
Constraints from X-ray observations of isolated BH found with gravitational microlensing



Constraints from X-ray observations of BH found in wide binaries

X-ray upper limits —> accretion rate << Bondi-Hoyle

Rodriguez+ 2023



Accretion from Interstellar Medium

NS —> Searches unsuccessful (velocity, absorption)

(e.g. Treves & Colpi 91, Blaes & Madau 93, Schwope+ 99, Perna+03, ...)

BH —> UL on candidates found with microlensing (isolated) or dynamically (binaries) confirm low efficiency at low Mdot

(Mereghetti+22, Rodriguez+23)

Other ways to look for stellar remnants - 4

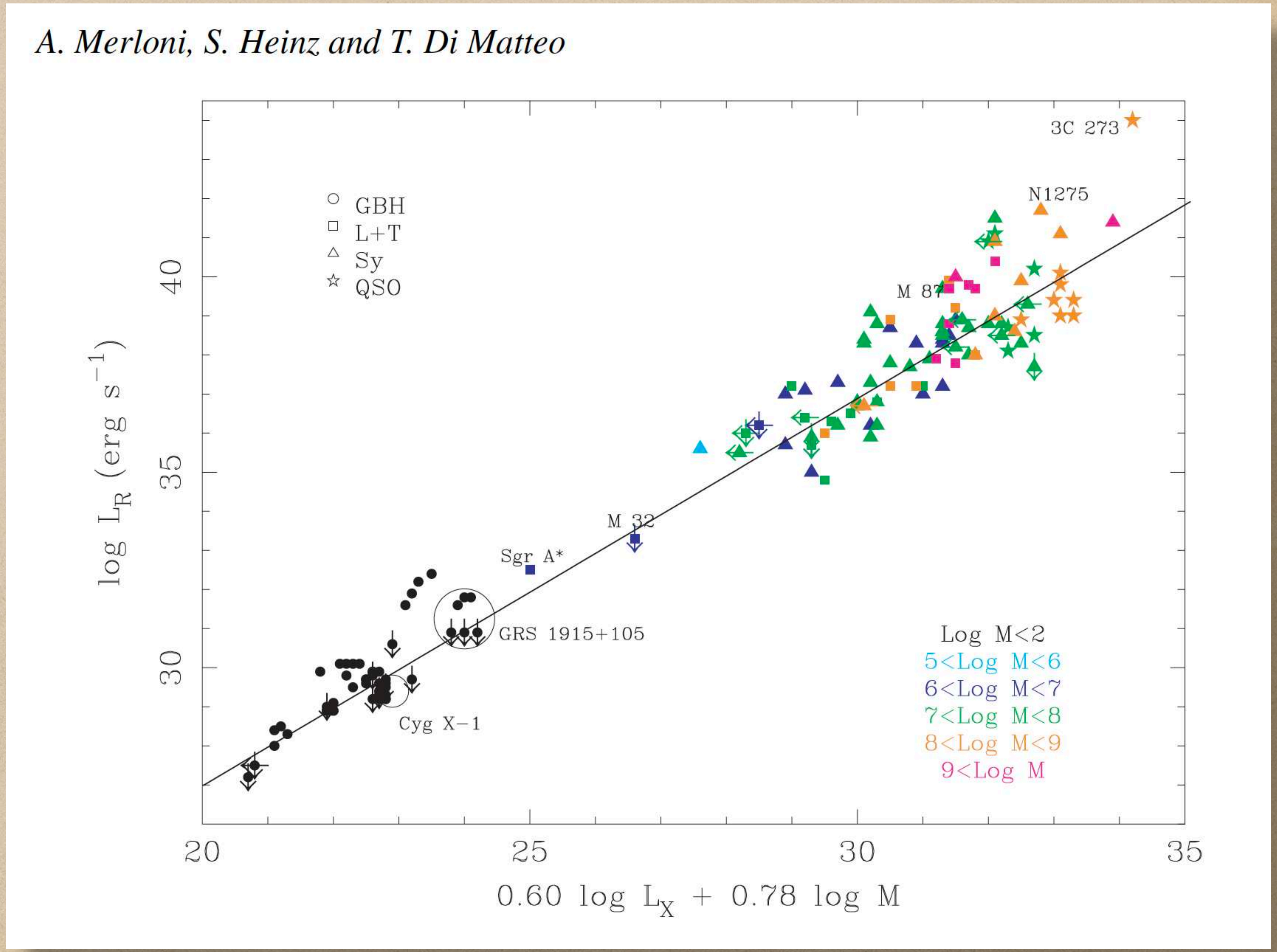
$L_{RADIO} \propto L_X^b$

b~0.6-0.7

(Corbel+06,07; Gallo+06,..)

At low accretion rate radio searches are more sensitive than X-ray ones

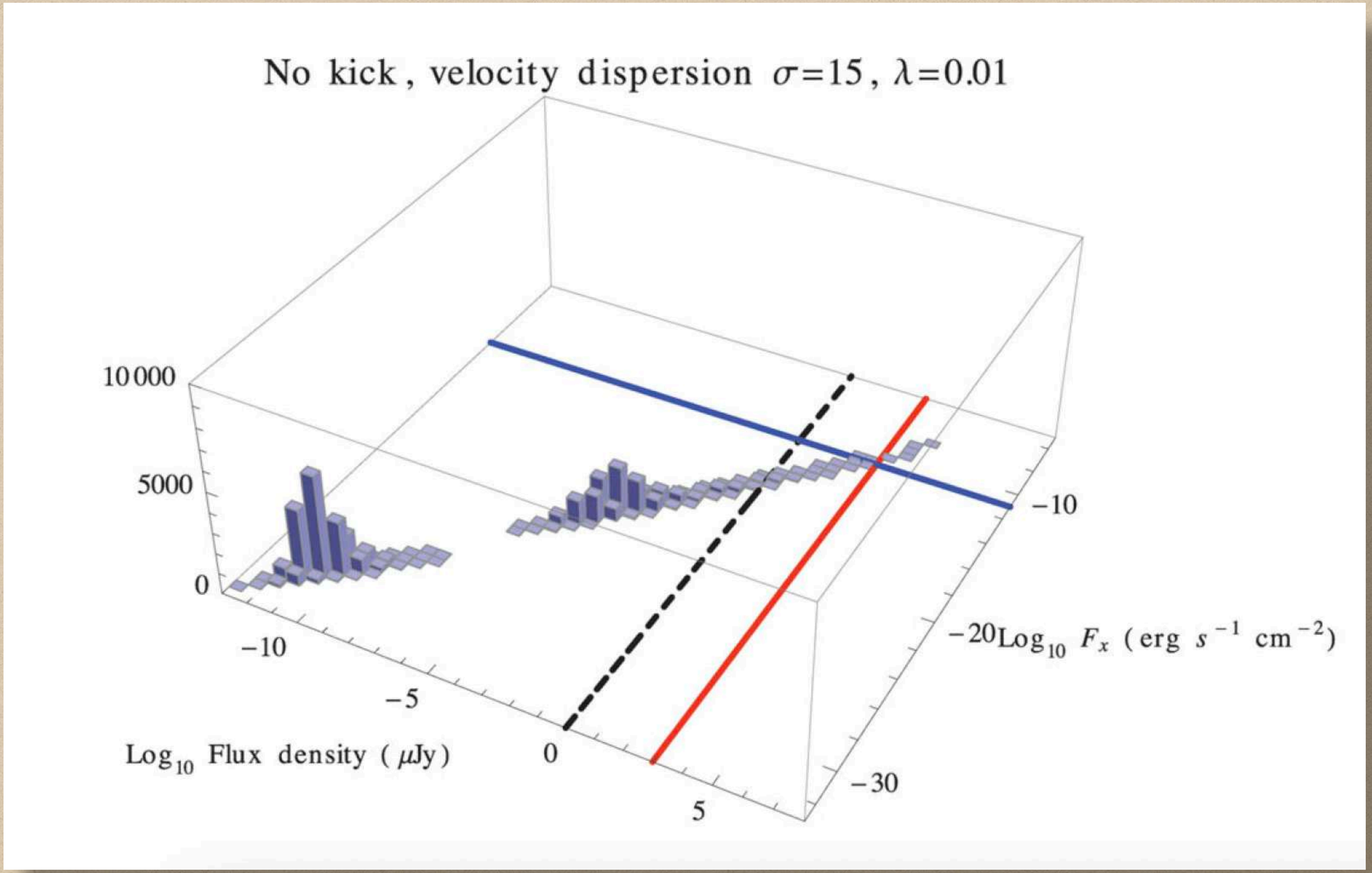
(Maccarone 2005)



SKA will detect isolated BH / NS accreting at low rates from the ISM (or from weak stellar winds in wide binaries)

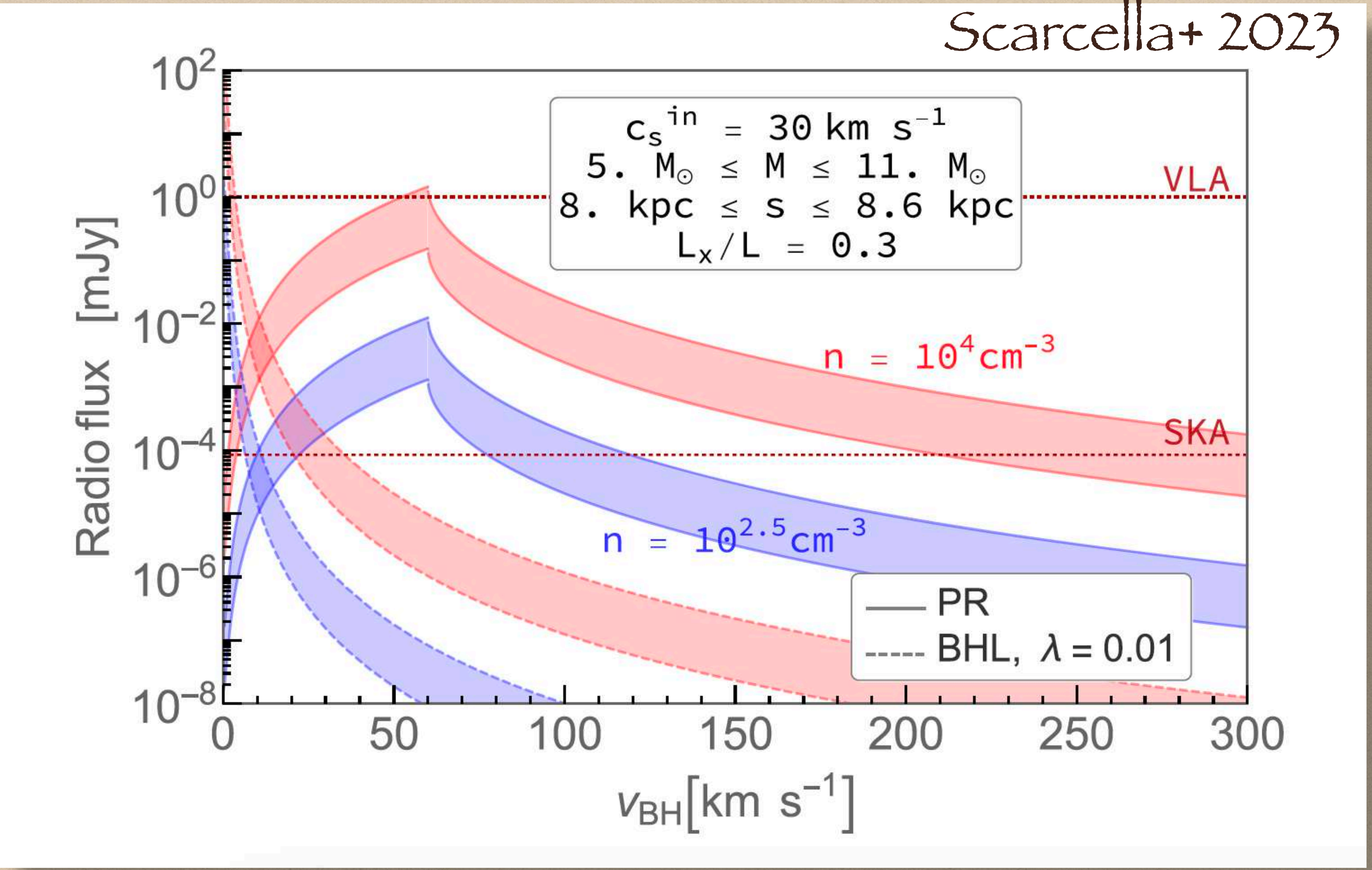
Simulations of nearby population (35,000 BH at <250 pc)

Fender+ 2013



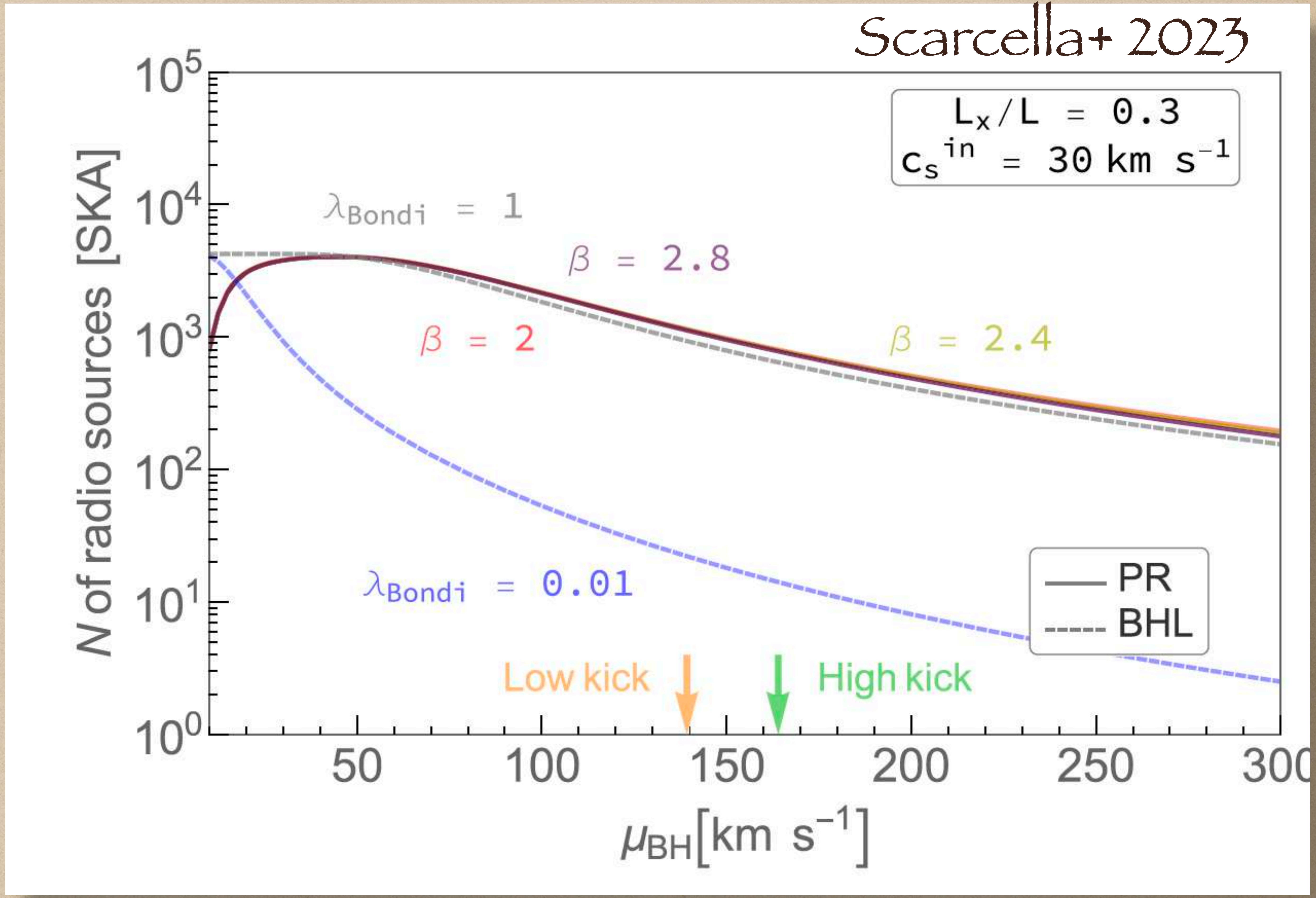
Several hundreds above 1 μJy (for optimistic assumptions)

Simulations of Central Molecular Zone (75,000 BH)



Simulations of Central Molecular Zone (75,000 BH)

A few thousands
above 85 nJy
(1.4 GHz, ~1000 hr)



CONCLUSIONS

- Our current view of NS / BH population is limited and biased
- SKA will improve this by detecting isolated BH / NS accreting at low rates from the ISM (or from weak stellar winds in wide binaries)

CONCLUSIONS

- Our current view of NS / BH population is limited and biased

- SKA will improve this by detecting isolated BH / NS accreting at low rates from the ISM (or from weak stellar winds in wide binaries)

- Sensitivity and wide field of view —> more efficient than X-rays

- Open questions:
    - How many ?
    - How to find and recognise them ?
      (high proper motion / multifrequency / ...?...)