The hunt for short-period black hole companions to Sun-like stars

Matthew Green (he/him)

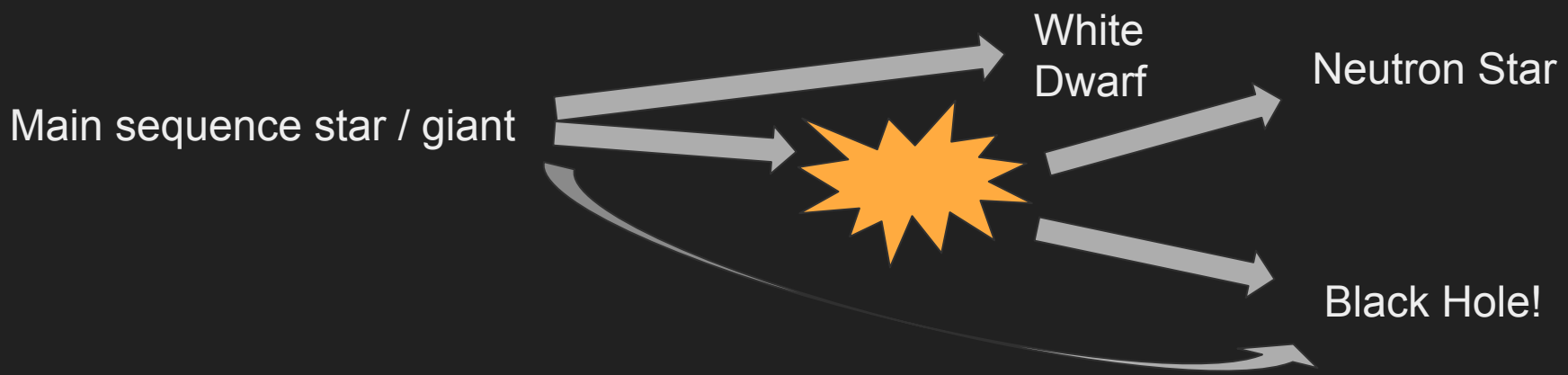
Yoav Ziv, Hans-Walter Rix, Dan Maoz, Tsevi Mazeh, Simchon Faigler, Kareem El-Badry

The hunt for short-period black hole companions to Sun-like stars

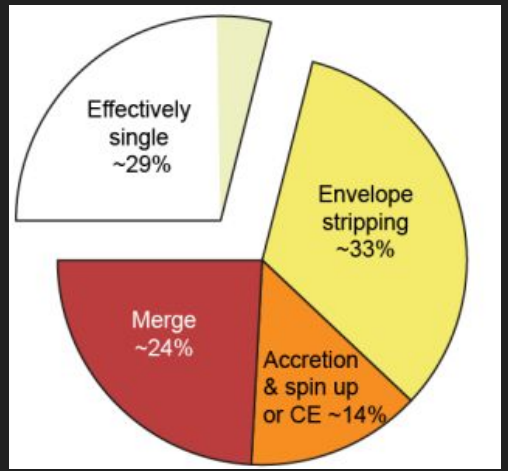
or

“How can I publish my null result?”

Black Holes

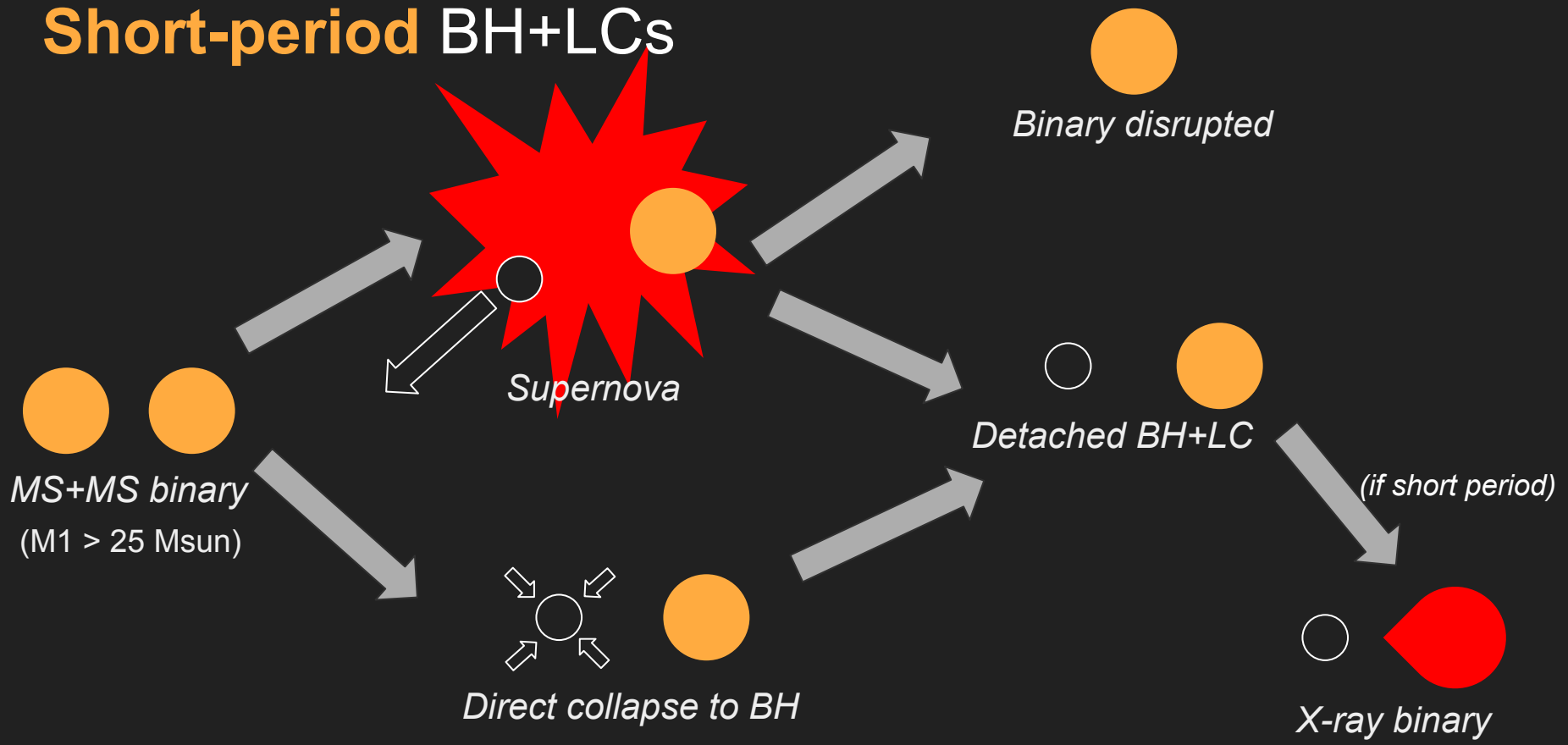


- Should be 10^7-10^8 BHs in Milky Way
- We know ~20-70 in MW, almost all in XRBs
- Very difficult to study when isolated
- Majority should be born in binaries
- How many binaries survive? Estimates vary by factor 10,000 !

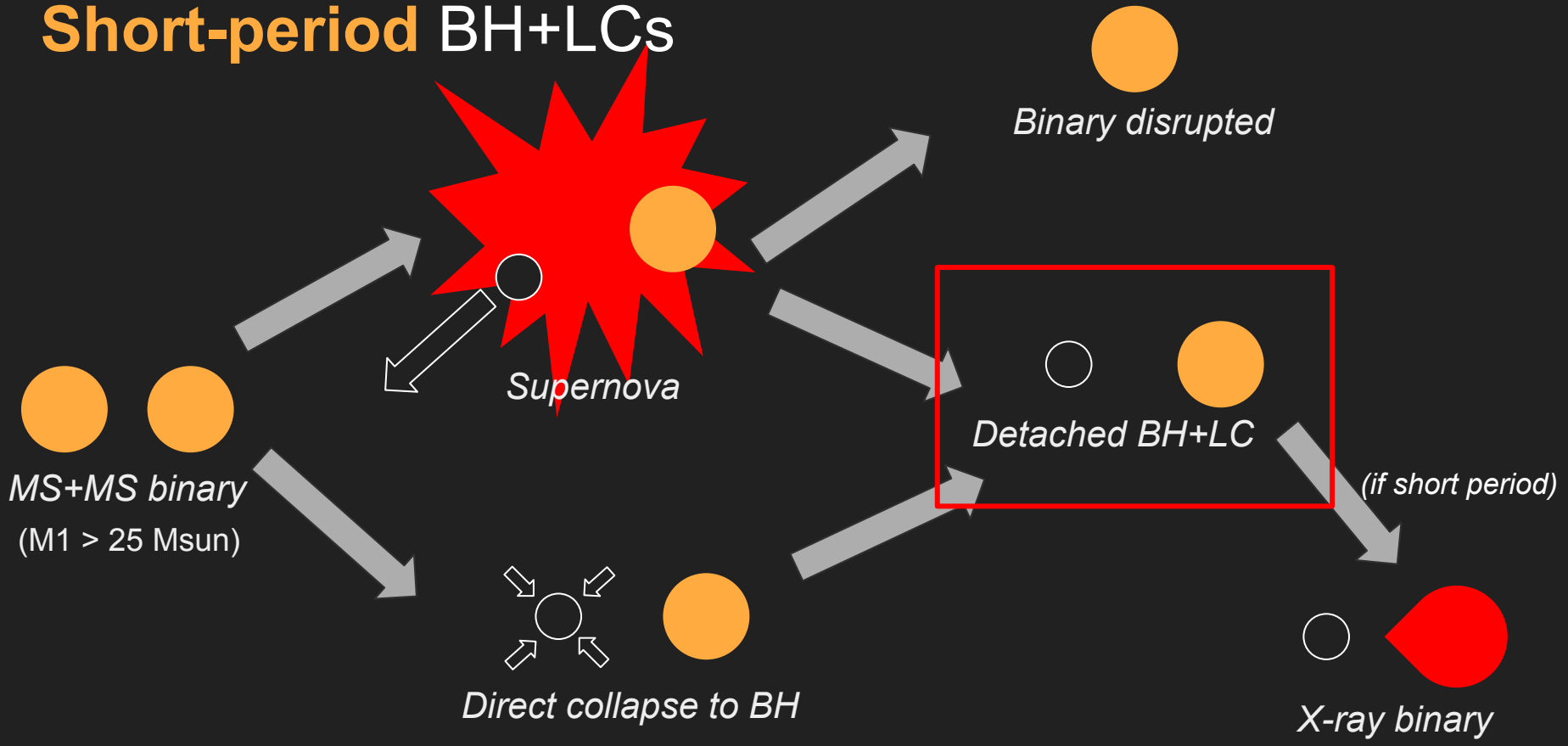


Sana+ 2012

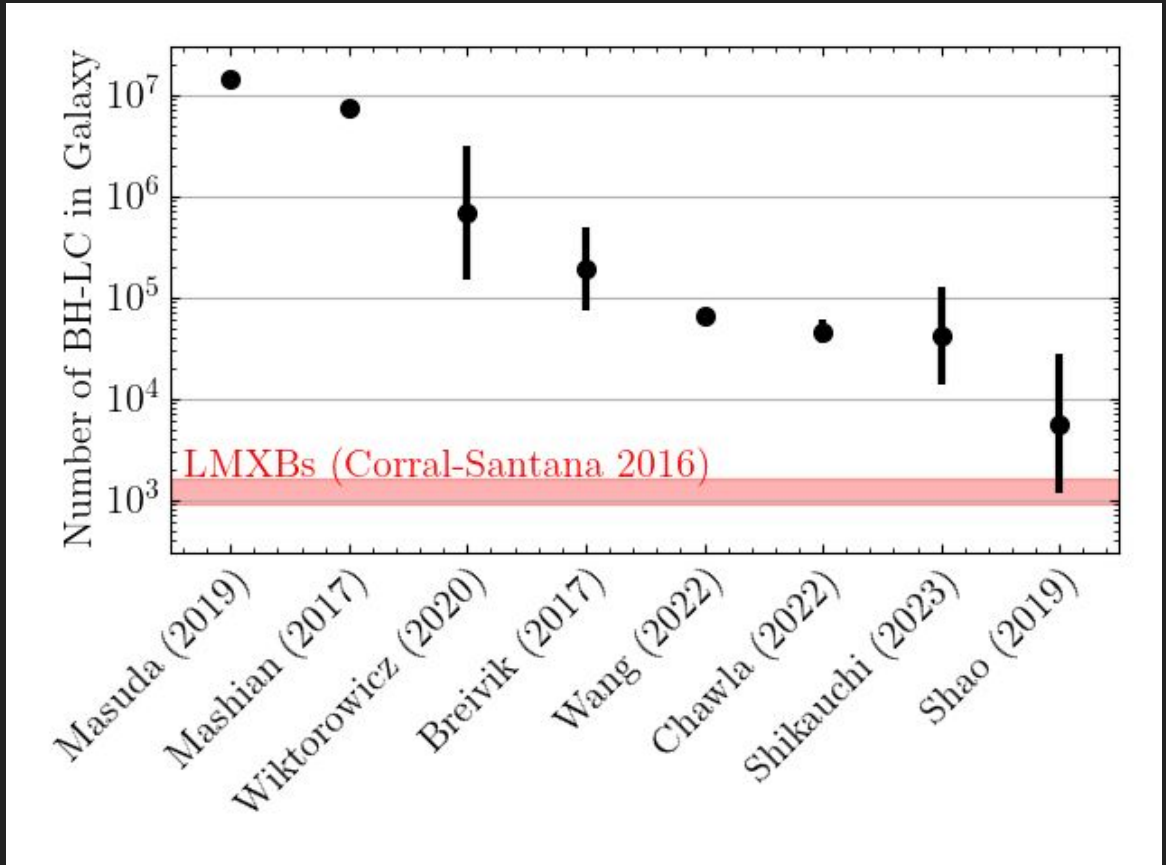
Short-period BH+LCs



Short-period BH+LCs



How many non-accreting BH+MS binaries are there?



Gaia Data Release 3

Special issue

Gaia Data Release 3

Ellipsoidal variables with possible black hole or neutron star secondaries★

R. Gomel[1], T. Mazeh[1], S. Faigler[1], D. Bashi[1], L. Eyer[2], L. Rimoldini[3], M. Audard[2], N. Mowlavi[2,3], B. Holl[2], G. Jevardat[3], K. Nienartowicz[3], I. Lecoeur[3], and L. Wyrzykowski[4]

Unicorns and giraffes in the binary zoo: stripped giants with subgiant companions

Kareem El-Badry[1,2,3★] Rhys Seeburger[3] Tharindu Jayasinghe,[4] Hans-Walter Rix,[3] Silvia Almada,[3] Charlie Conroy,[1] Adrian M. Price-Whelan[5] and Kevin Burdge[6,7]

HIGH MASS FUNCTION ELLIPSOIDAL VARIABLES IN THE GAIA FOCUSED PRODUCT RELEASE: SEARCHING FOR BLACK HOLE CANDIDATES IN THE BINARY ZOO

D. M. Rowan[1,2], Todd A. Thompson[1,2,3], T. Jayasinghe[4], C. S. Kochanek[1,2], and K. Z. Stanek[1,2]
[1]Department of Astronomy, The Ohio State University, 140 West 18th Avenue, Columbus, OH, 43210, USA

A Sun-like star orbiting a black hole

Kareem El-Badry[1,2,3★] Hans-Walter Rix,[3] Eliot Quataert[4] Andrew W. Howard,[5] Howard Isaacson,[6,7] Jim Fuller[5] Keith Hawkins[8] Katelyn Breivik,[9] Kaze W. K. Wong,[9] Antonio C. Rodriguez,[5] Charlie Conroy,[1] Sahar Shahaf[10] Tsevi Mazeh[11] Frédéric Arenou,[12] Kevin B. Burdge[13] Dolev Bashi[11] Simchon Faigler,[11] Daniel R. Weisz[6] Rhys Seeburger[3] Silvia Almada Monter[3] and Jennifer Wojno[3]
[1]Center for Astrophysics | Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA

Search for dormant black holes in the OGLE data

M. Kapusta[1], P. Mróz[2]

A red giant orbiting a black hole

Kareem El-Badry[1,2,3,4★] Hans-Walter Rix,[3] Yvette Cendes,[1] Antonio C. Rodriguez,[4] Charlie Conroy,[1] Eliot Quataert[5] Keith Hawkins[6] Eleonora Zari,[3] Melissa Hobson,[3] Katelyn Breivik,[7] Arne Rau,[8] Edo Berger,[1] Sahar Shahaf[9] Rhys Seeburger[3] Kevin B. Burdge[10] David W. Latham,[1] Lars A. Buchhave[11] Allyson Bieryla,[1] Dolev Bashi[12] Tsevi Mazeh[12] and Simchon Faigler[12]

Search for dormant black holes in ellipsoidal variables – III. The OGLE BULGE short-period sample

Roy Gomel,[1★] Simchon Faigler,[1] Tsevi Mazeh[1] and Michał Pawlak[2]
[1]School of Physics and Astronomy, Tel Aviv University, Tel Aviv 6997801, Israel

Identifying quiescent compact objects in massive Galactic single-lined spectroscopic binaries★

L. Mahy[1], H. Sana[2], T. Shenar[3], K. Sen[4,5], N. Langer[4,5], P. Marchant[2], M. Abdul-Masih[6], G. Banyard[2], J. Bodensteiner[7], D. M. Bowman[2], K. Dsilva[2], M. Fabry[2], C. Hawcroft[2], S. Janssens[2], T. Van Reeth[2], and C. Eldridge[8]

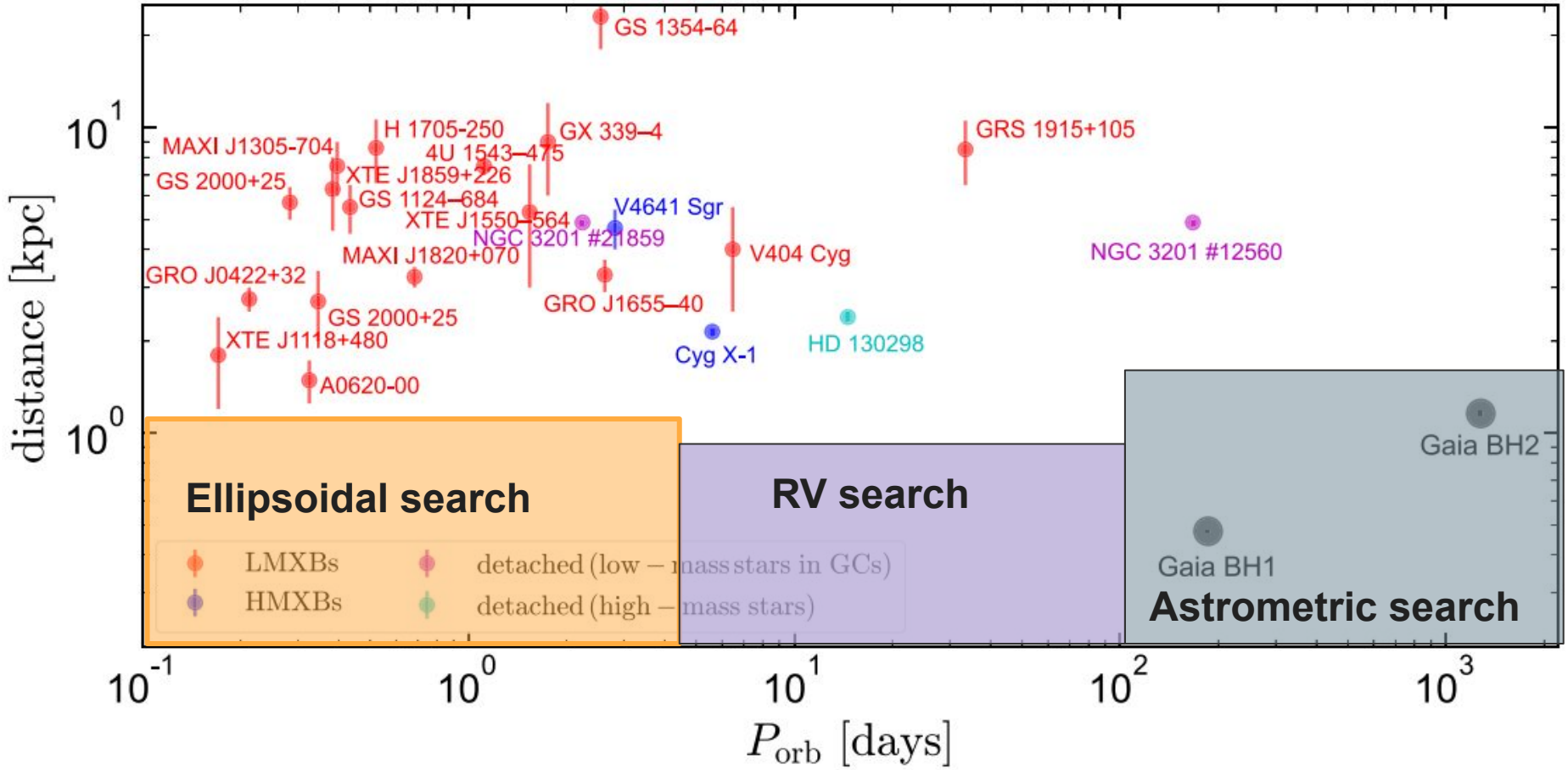
Triage of the *Gaia* DR3 astrometric orbits – I. A sample of binaries with probable compact companions

S. Shahaf[1★] D. Bashi[2] T. Mazeh[2] S. Faigler,[2] F. Arenou,[3] K. El-Badry[4,5,6] and H. W. Rix[6]
[1]Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot 7610001, Israel

So are BH+LC binaries just difficult to find?

Or are they really very rare?

… Can we set an upper limit on the population density?

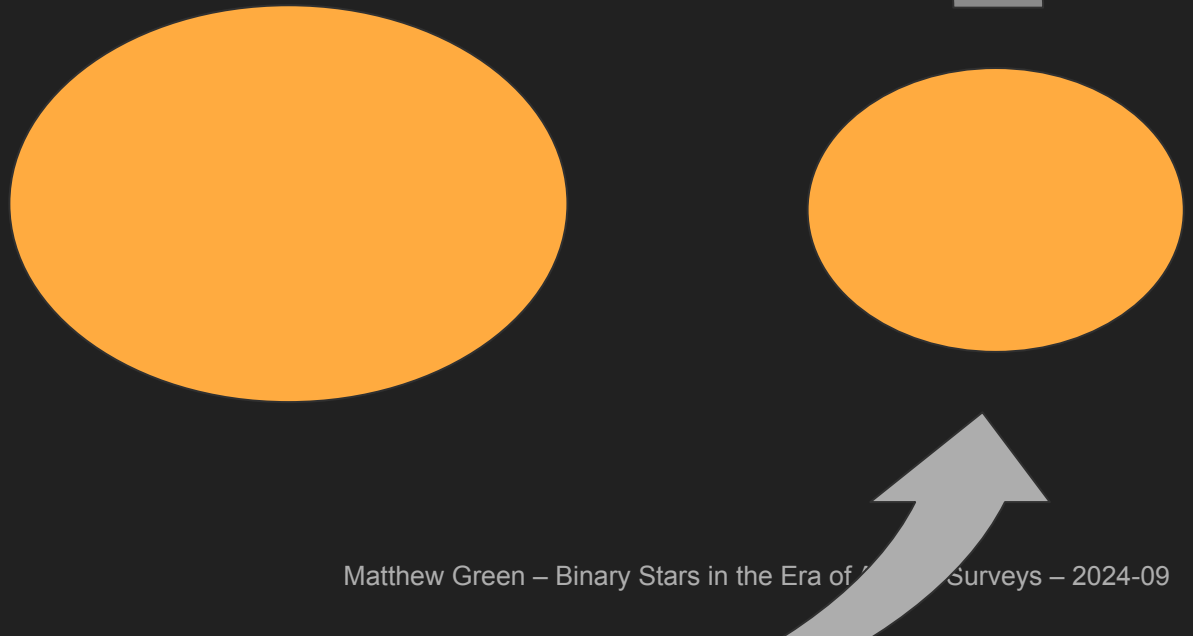


El-Badry+ 2023

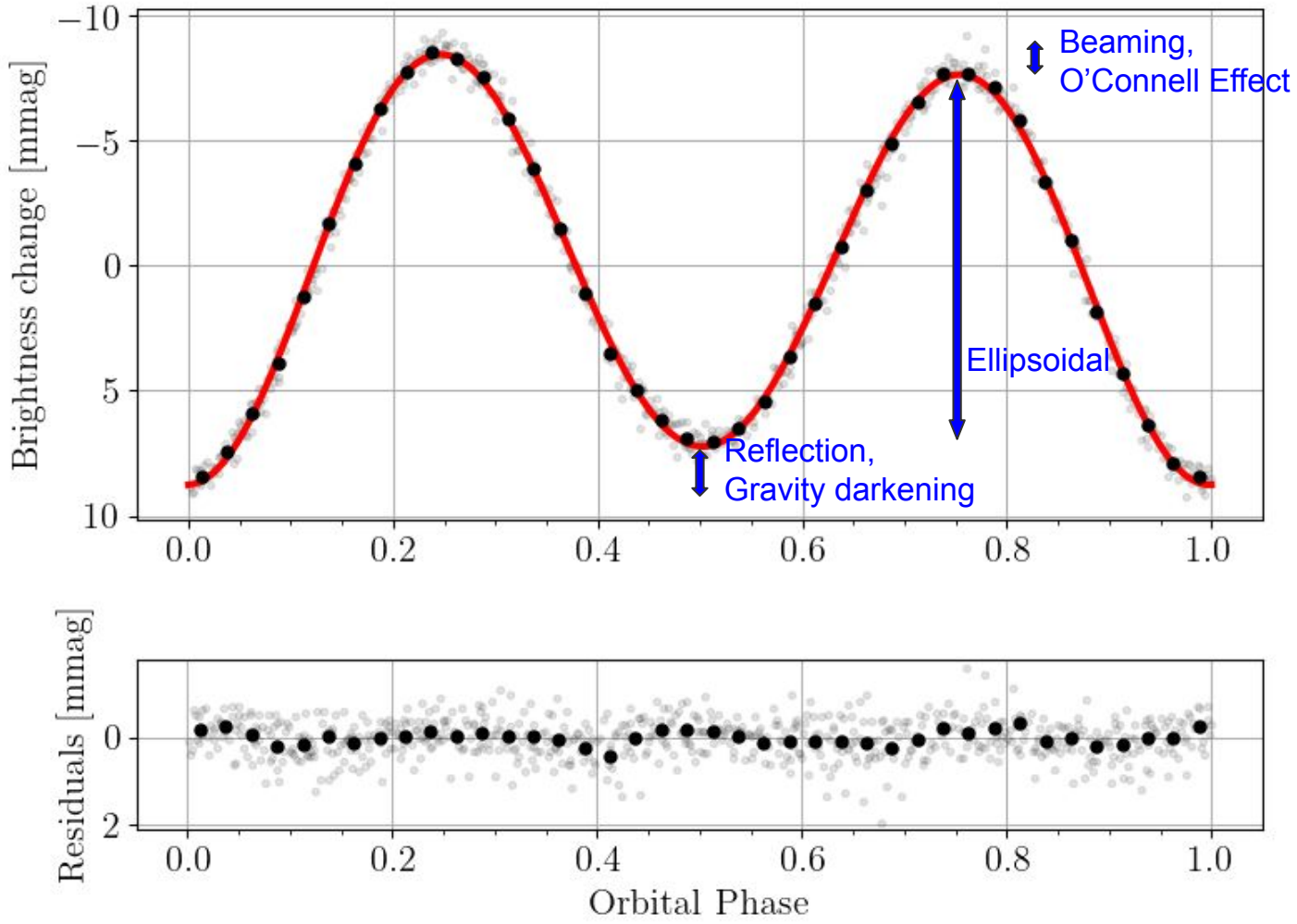
Ellipsoidal binaries

Target selection

Ellipsoidal modulation



TIC 115471382



BEER =

BEaming
Ellipsoidal modulation
Reflection

Faigler et al. (2011,2013,2015a,b)

15,000 ellipsoidal binaries from TESS

4.5 million MS stars

First two years of TESS

Whole sky

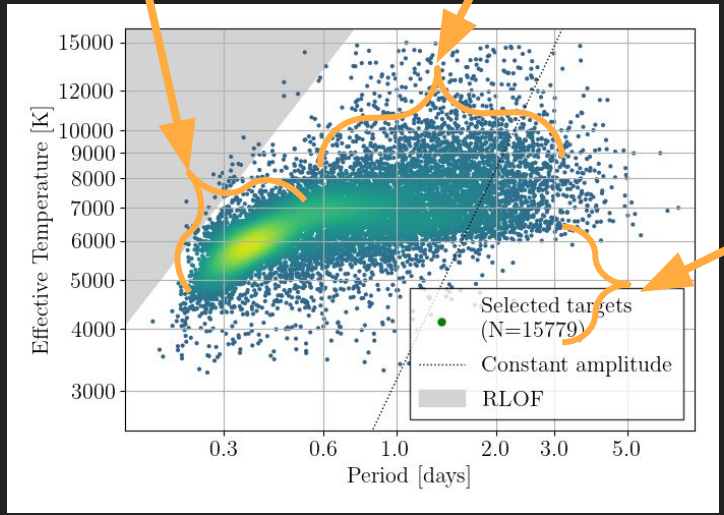
1+ month coverage

30-min cadence

QLP reduction, *T < 13.5*

Contact binaries (FGK-type)

Detached binaries (AF-type)

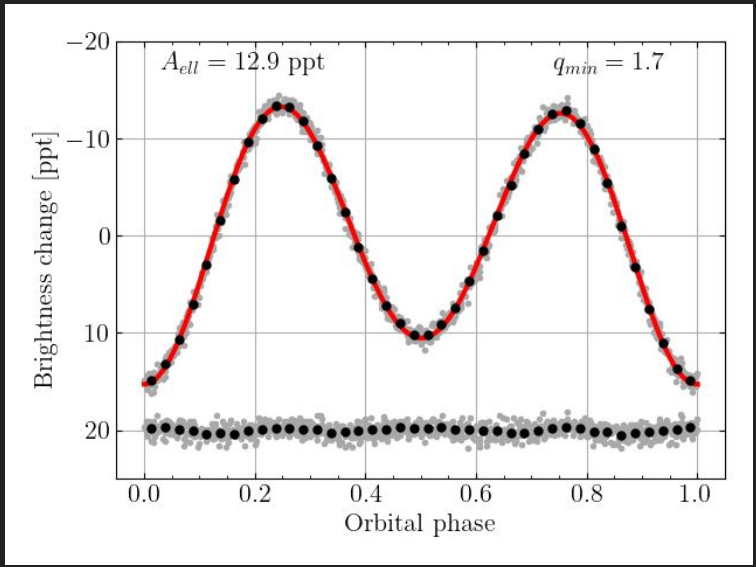


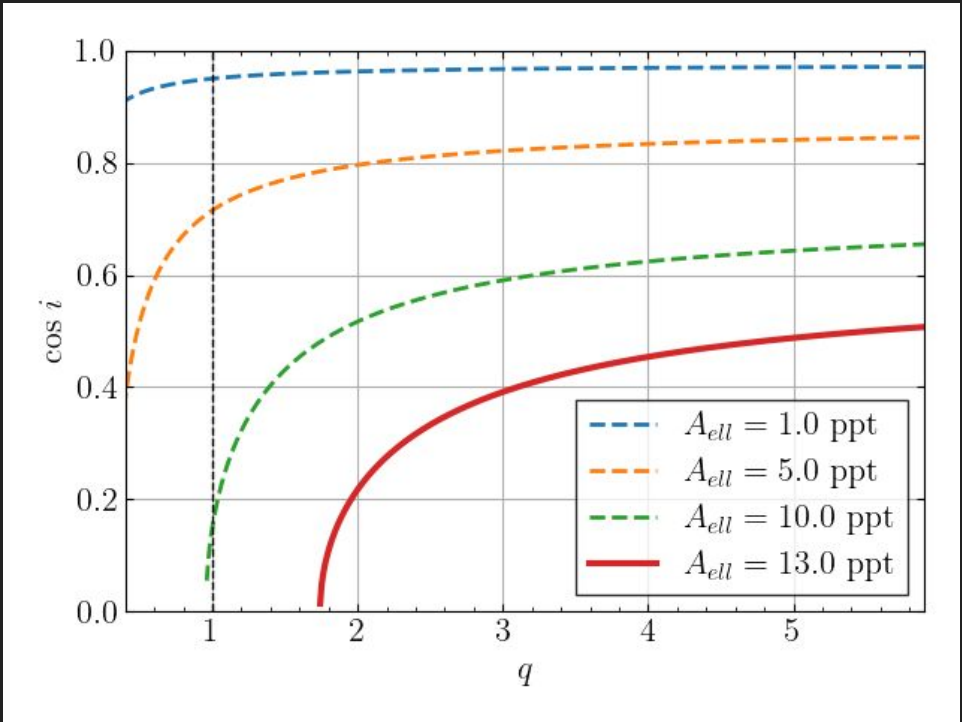
No detached GK binaries?

Green+ 2023

How to look for black holes?

Can calculate qmin based on measured ellipsoidal amplitude





Green+ in prep

How to look for black holes?

Can calculate qmin based on measured ellipsoidal amplitude

BUT!!!

The derived qmin assumes:

1) Reliable M1 and R1
2) Binary is (semi-)detached

Needs spectroscopic follow-up to confirm

Follow-up of candidates finds that all (so far) are contaminants!

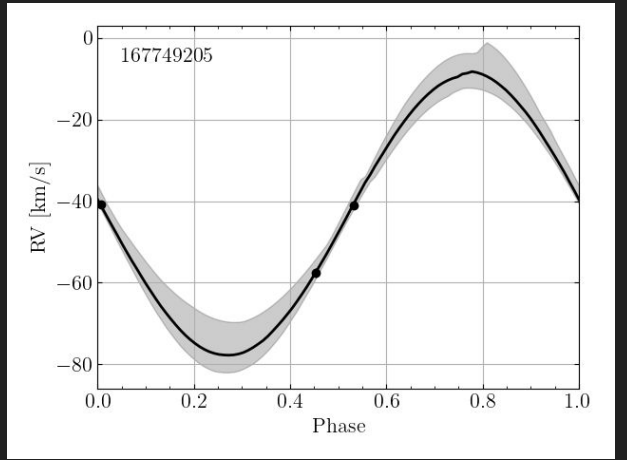
Follow-up

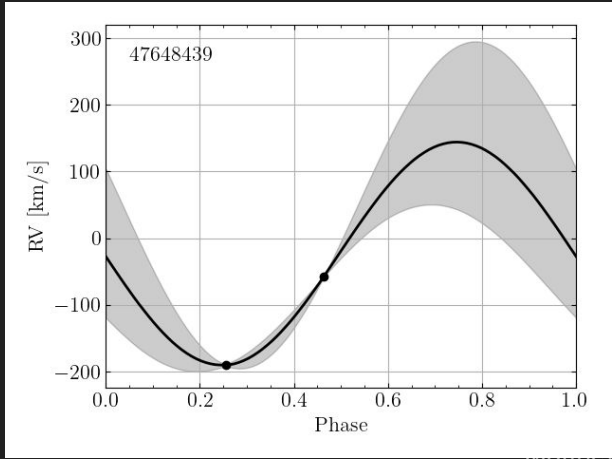
Our candidates

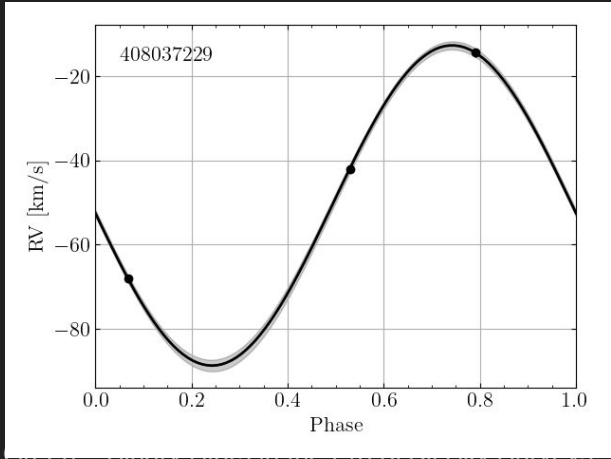
From 4 million TESS stars:

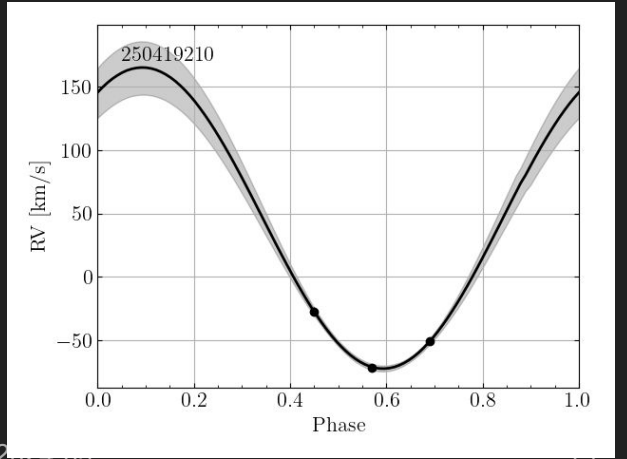
15000 binary systems *(Green+ 2023)*

450 BH-LC candidates







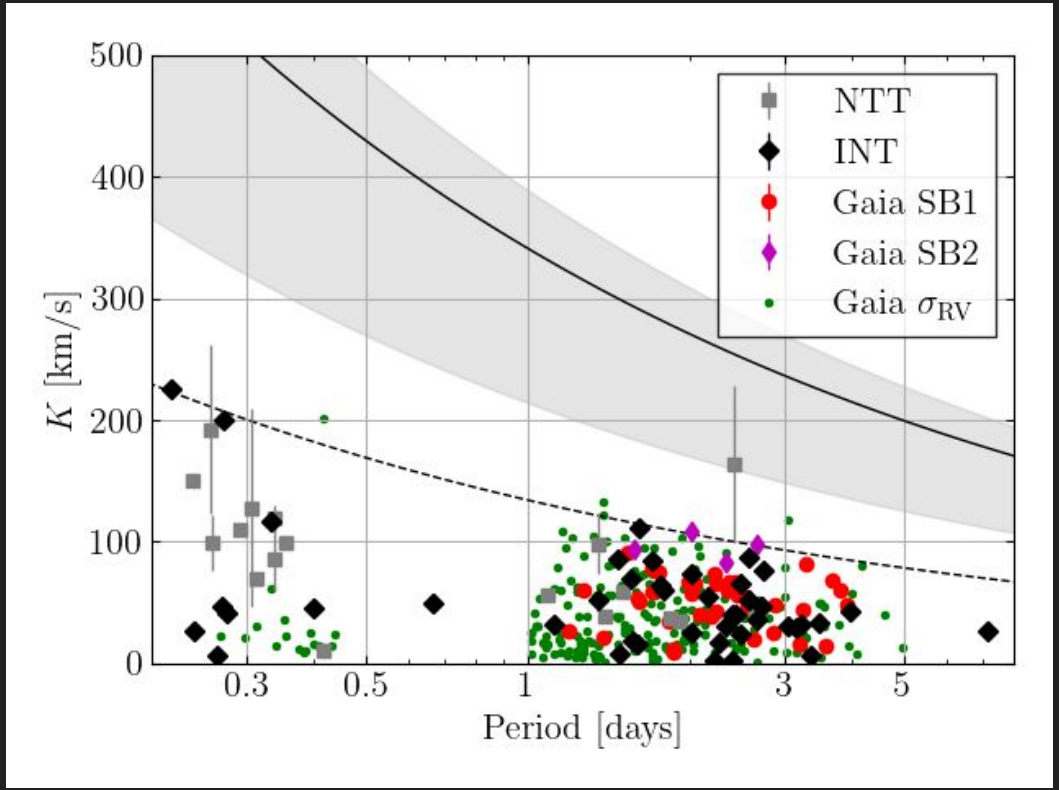


From 450 candidates …

Approx 60 followed up by us

+ 200 from *Gaia*

=> No detection so far



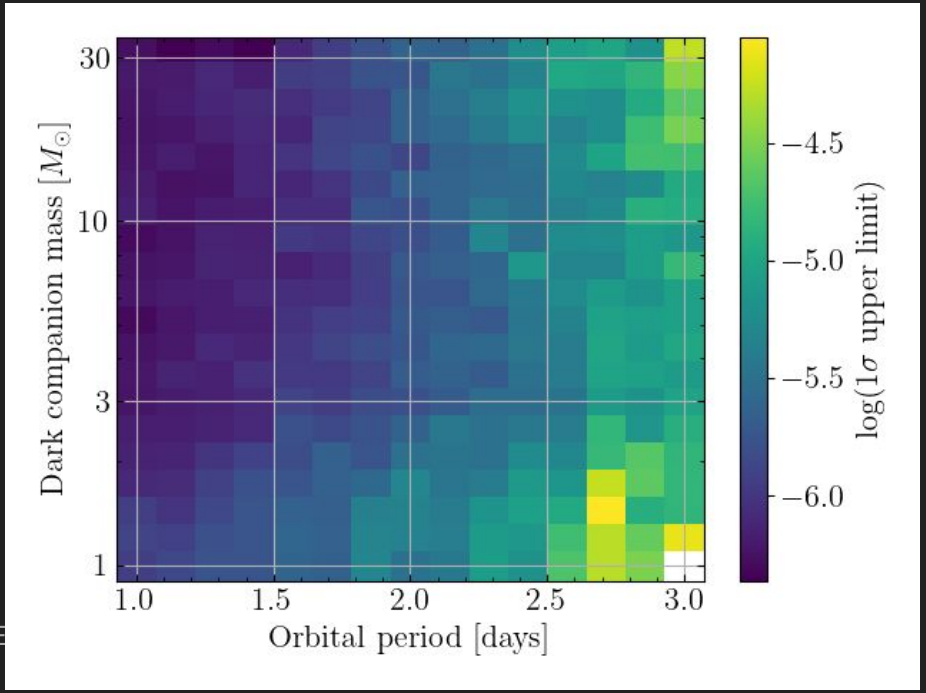
Green+ in prep

Injection-recovery tests

Flat TESS lightcurve + predicted ellipsoidal signal (Porb, M1, M2, cos i)

Is it recovered?

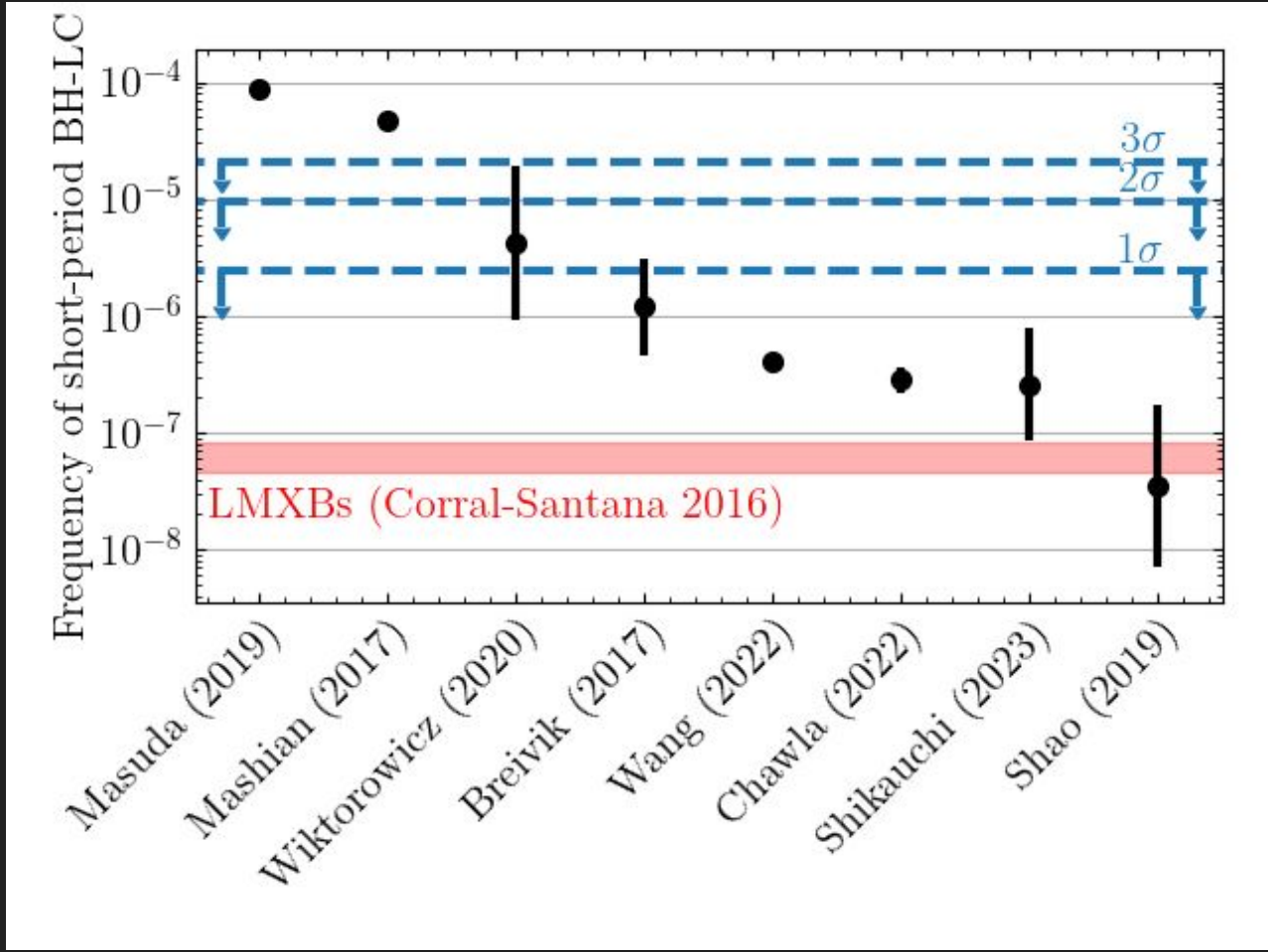
Two-dimensional upper limits



Overall

So far we can exclude the most optimistic models

The only observational constraint on the non-accreting BH+MS population at short Porb so far



Green+ in prep

How to look for the next black hole?

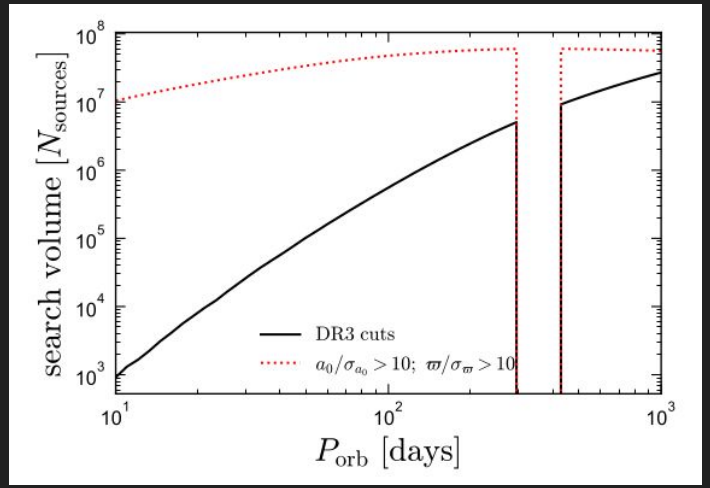
Now, comparable search volume to *Gaia* astrometry

After DR4, astrometry will dominate

For short periods, ellipsoidal still the best method

But needs ~10-100x more target stars

Green+ (in prep)



El-Badry+ (2023)

Summary

Short-period BH companions exist around less than one in 10^6 stars

Enough to rule out “optimistic” models ($10^{4\text{-}5}$) but not pessimistic models ($10^{7\text{-}8}$)

Comparable to upper limit on long-period systems from astrometry

Black holes are difficult to find

Thank you for listening!

mjgreenastro@gmail.com *https://arxiv.org/abs/2211.06194*