AGN Disk Channel: Dynamics + Gas

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This is our nearest galactic nucleus:

(Ghez++)

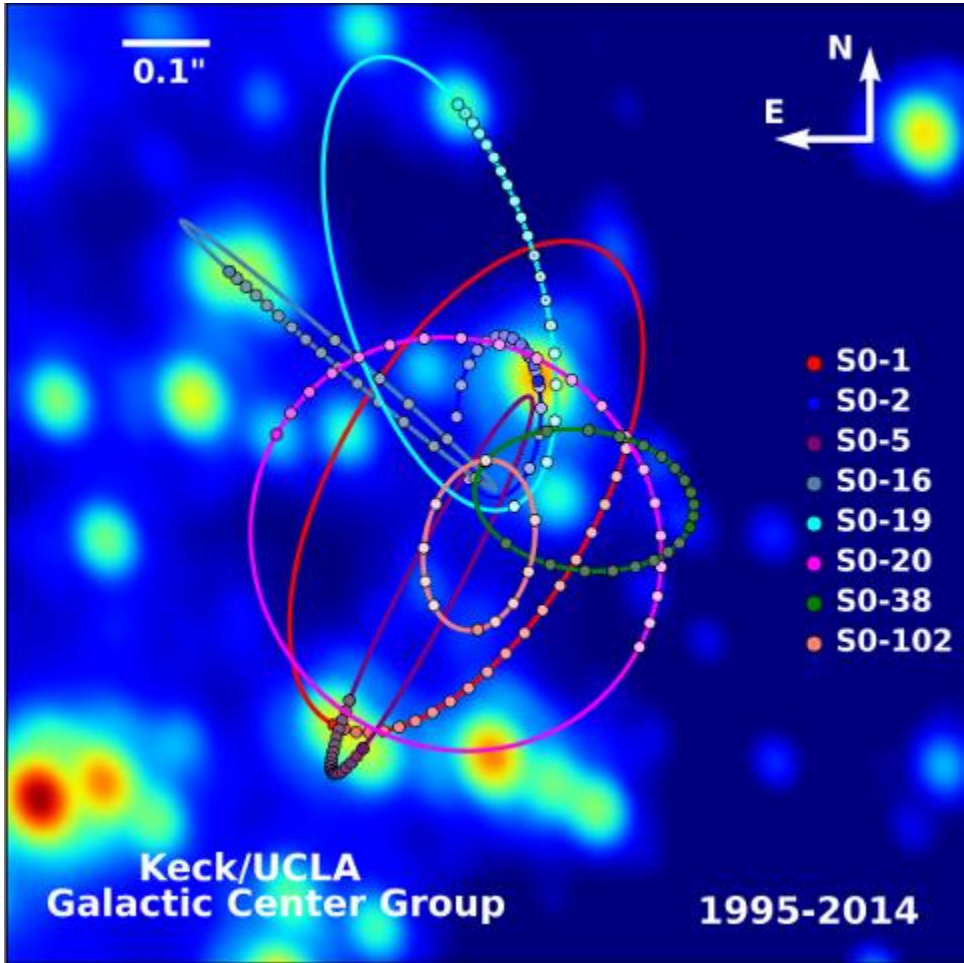
$4x10^6 M_{sun}$

0.1” ~ 10^3AU ~ $10^4 R_S$

N_{sBH}~$2x10^4$ (Hailey++ 2018)

Nuclear Star Clusters (NSCs) common!

M_{SMBH} changes dynamics



A (different) cartoon AGN

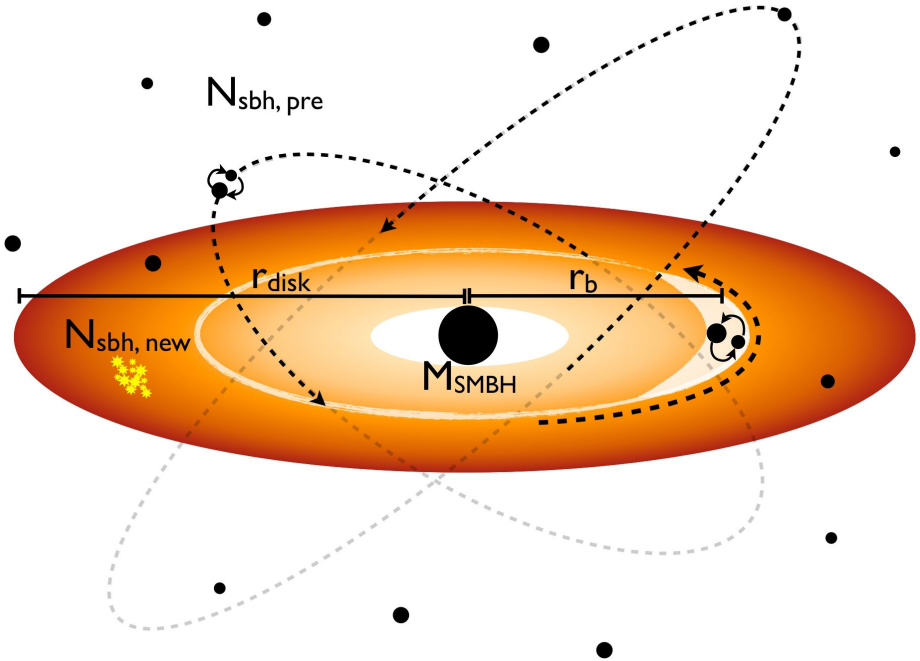


Image credit: O'Dowd

BBH mergers

~~Planet~~ BH migration torques

Type I, non-gap opening

$q<10^{-4}$

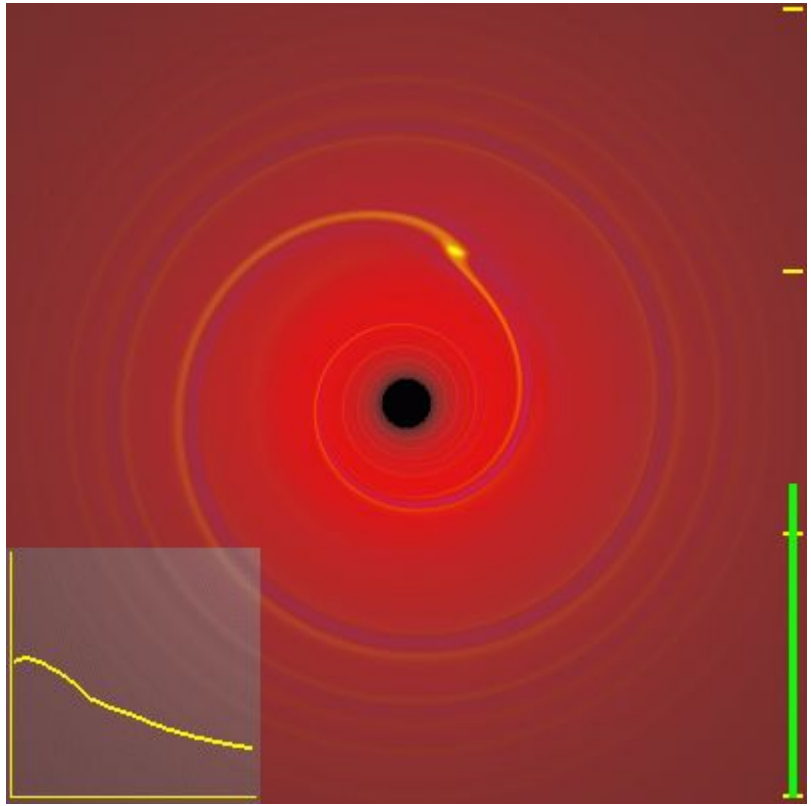
Rate ~ $M_{migrator}$

McKernan, Ford, Lyra, Perets **2012**

Low v_{rel}, binary hardening, build IMBH

McKernan, Ford, Kocsis, Lyra, Winter **2014**

Observational consequences (incl. for LIGO)



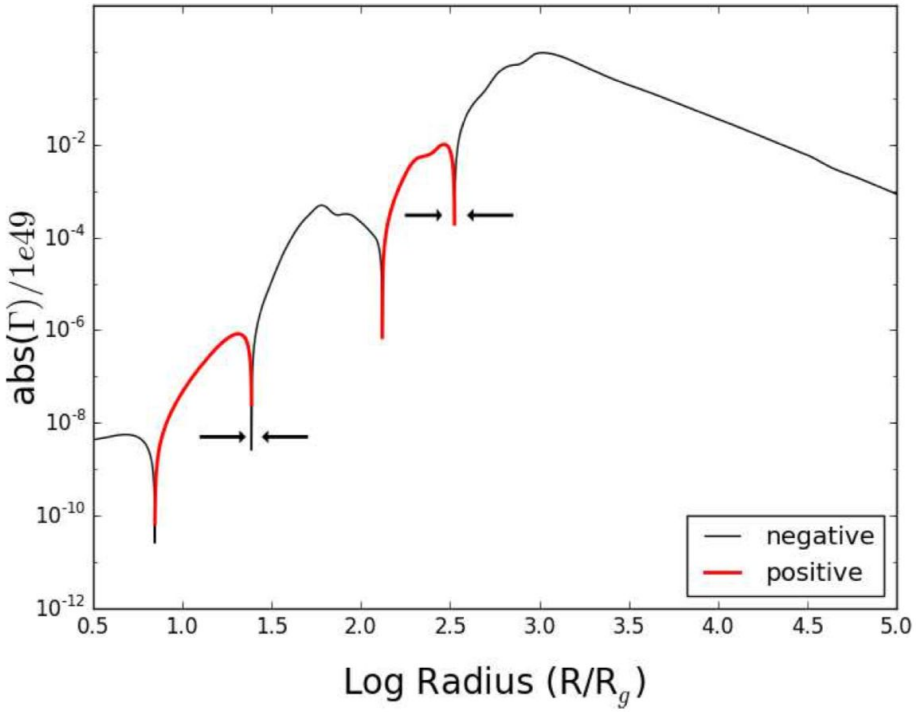
Armitage 2005

Migration can go both directions

Migration traps: likely but

- Requires dΣ/dr sufficiently large
- Secondary effect from dT/dr

Important consequences!



Bellovary, MacLow, McKernan, Ford 2016

Distinctive/unique AGN channel predictions

Mass merger hierarchies (IMBH; >100Msun via mergers)

Upper & lower BH mass gap fill in

2 populations:

- Bulk disk mergers (80-90%)
- Trap mergers (10-20%)

High mass ratio BH-NS mergers (q~0.1 typically)

Possible EM counterparts

Populations: MC results

If GW190521 is a trap merger

15mergers/trap/Myr

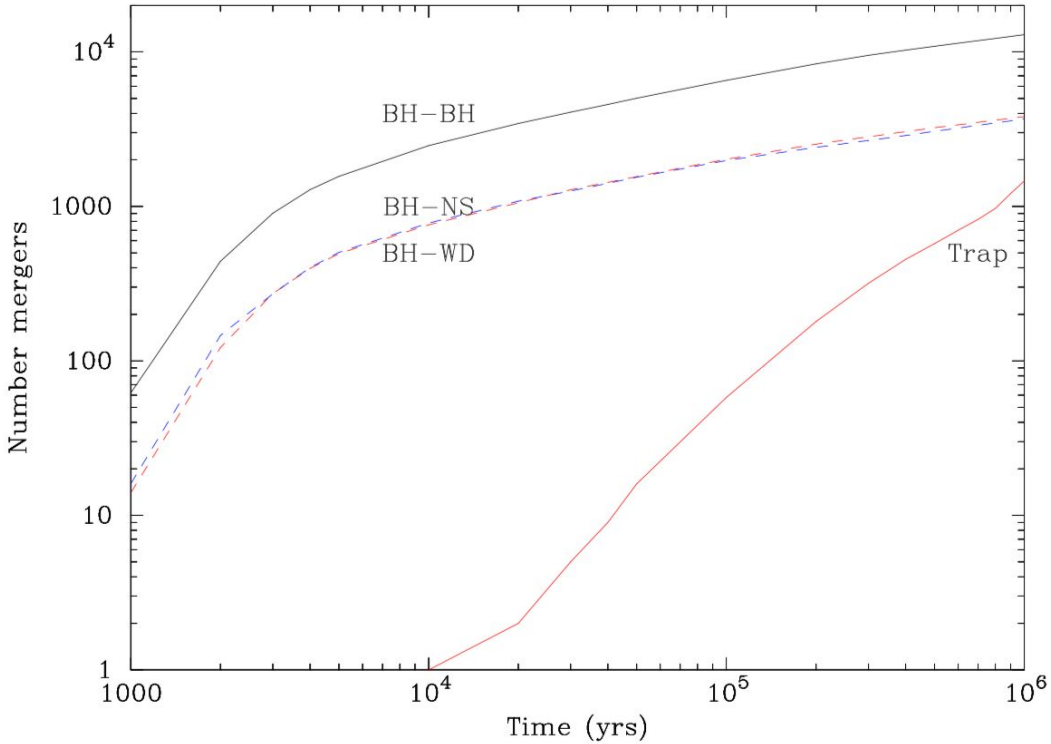
If 1% of galaxies=AGN

40k AGN Gpc^{-3}

0.6 trap mergers Gpc^{-3} yr^{-1}

~6 Gpc^{-3} yr^{-1} from same channel

For 100 AGN



McKernan, Ford & O'Shaughnessy 2020

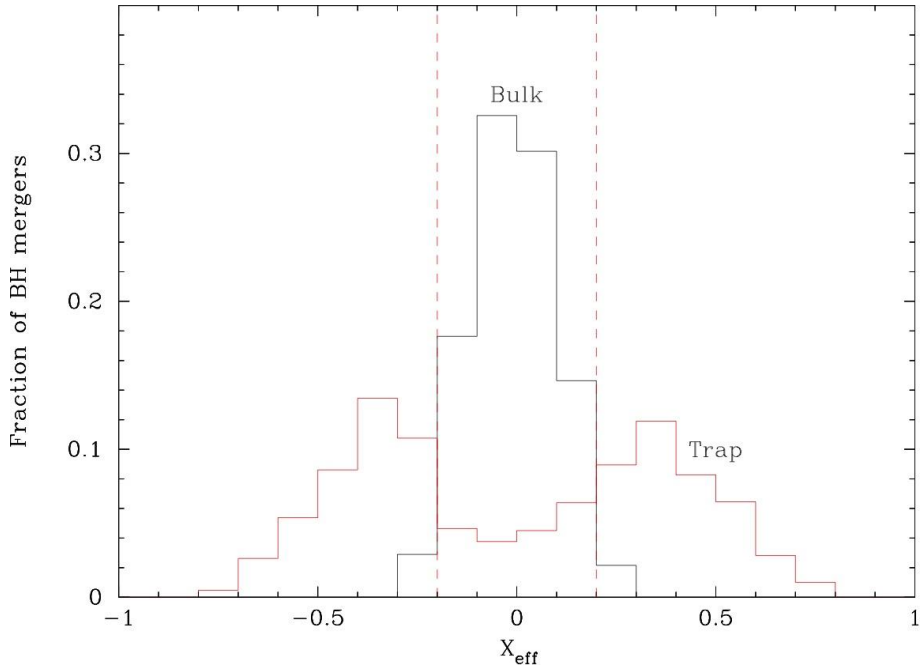
Populations: MC results

Most mergers in **bulk** disk (80-90%)

- q~0.6+/-0.3
- χ_{eff} centered on 0, width depends on natal spin
- 80-90% 1g-1g

Trap mergers 10-20%

- q~0.1+/-0.1
- χ_{eff} bimodal
- Often ng-2g, ng-3g; n>20 possible



McKernan, Ford, O'Shaughnessy, Wysocki 2020

GW190412 (q~0.3) and GW190814 (q~0.1): entirely comfortable

EM Counterparts

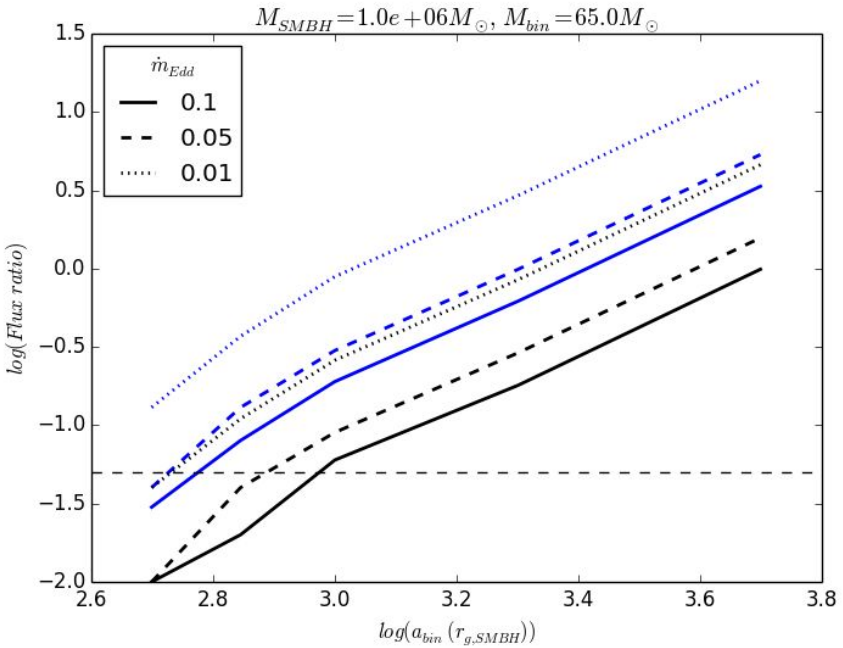
Black holes… are black

But if there's gas…

AGN=really bright

But maybe tap the kick energy?

Let's go look



McKernan, Ford, Bartos++2019

Notorious B.I.G.

ZTF19abanrhr

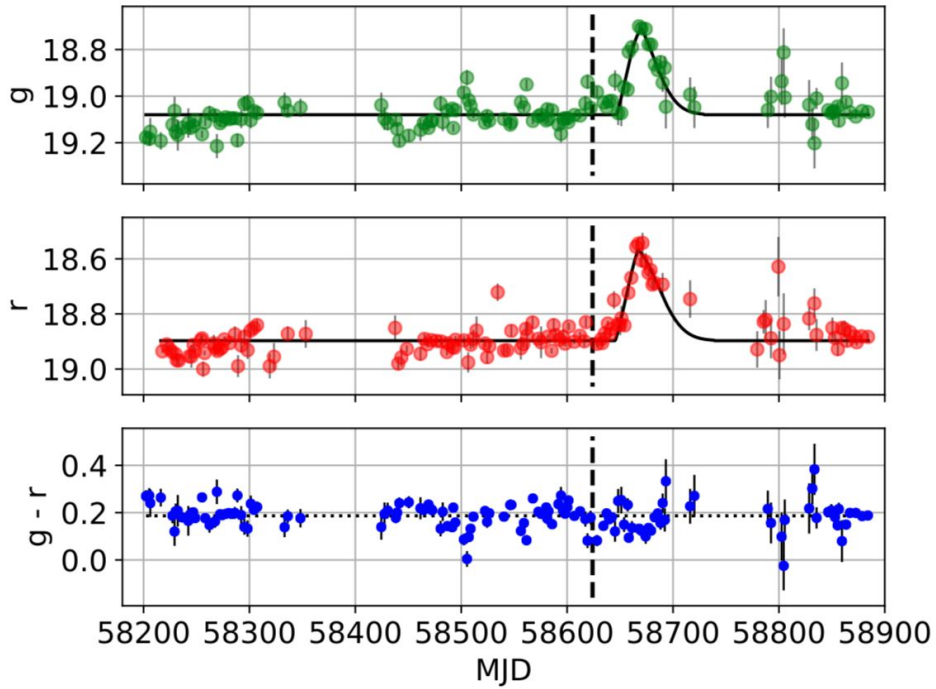
Candidate counterpart to GW190521

In the LIGO error volume (yes, still)

Not a SN, TDE or microlensing

Very unusual flare for this AGN

Very unusual flare for ***any*** AGN



Graham, Ford, McKernan, Ross, Stern++2020

AGN channel, end of part 1

Potential for unequal mass ratios due to migration torques

χ_{eff} may look very similar to standard dynamics (see Zoltan for more!)

Migration traps make many generations possible (but don’t dominate rate)

EM counterparts (candidate!)

- But ask Imre about statistical method (Bartos++2018)

More details available

Multiple groups w/overlapping collaborators: Haiman, Bartos, Groebner & Ishibashi

NSC vs disk dynamics (2+1): Leigh, Geller, McKernan, Ford++2018

Rates/AGN implications: McKernan++2018, Ford & McKernan 2019

3-d N-body w/migration: Secunda++2019, Secunda++ (with Adorno) 2020a

Retrograde orbiters: Secunda++2020b

Disk capture: Fabj, Nasim, Caban++2020, Nasim++2021 (in prep)

Gas torque modifications w/2 migrators: Mejia++2021 (in prep)