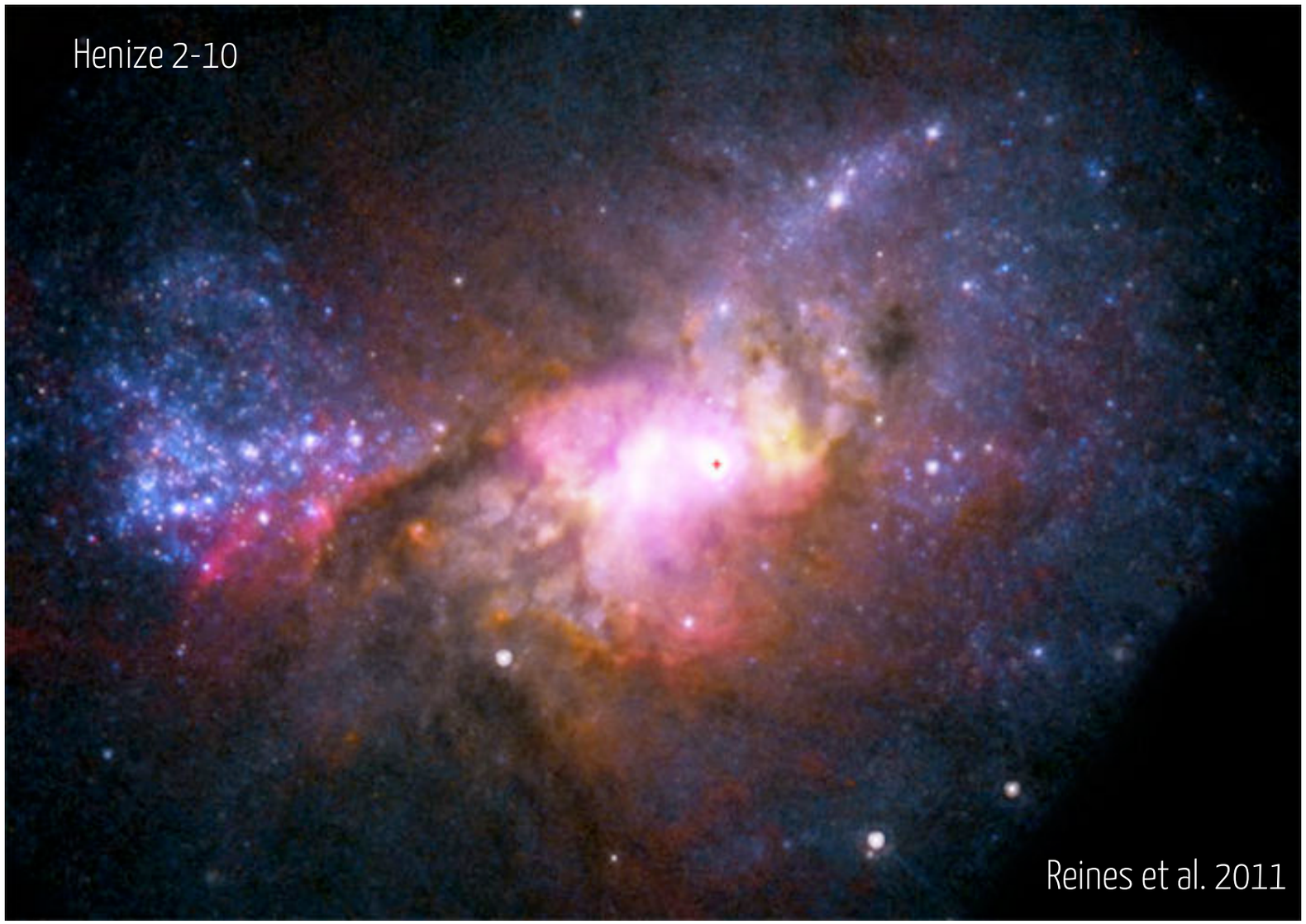
Black Holes 101



Kelly Holley-Bockelmann
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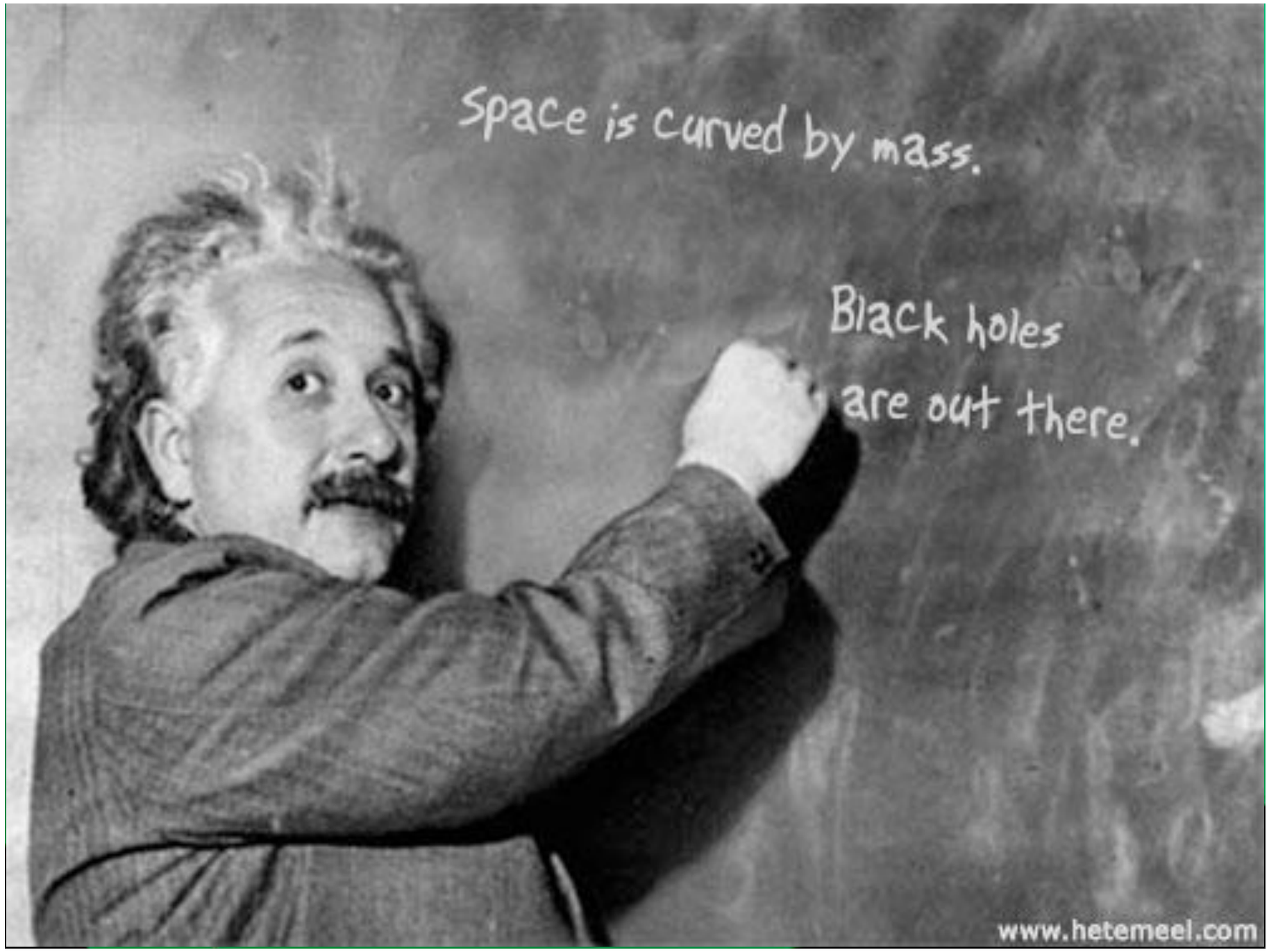
Ask a physicist: what is a black hole?

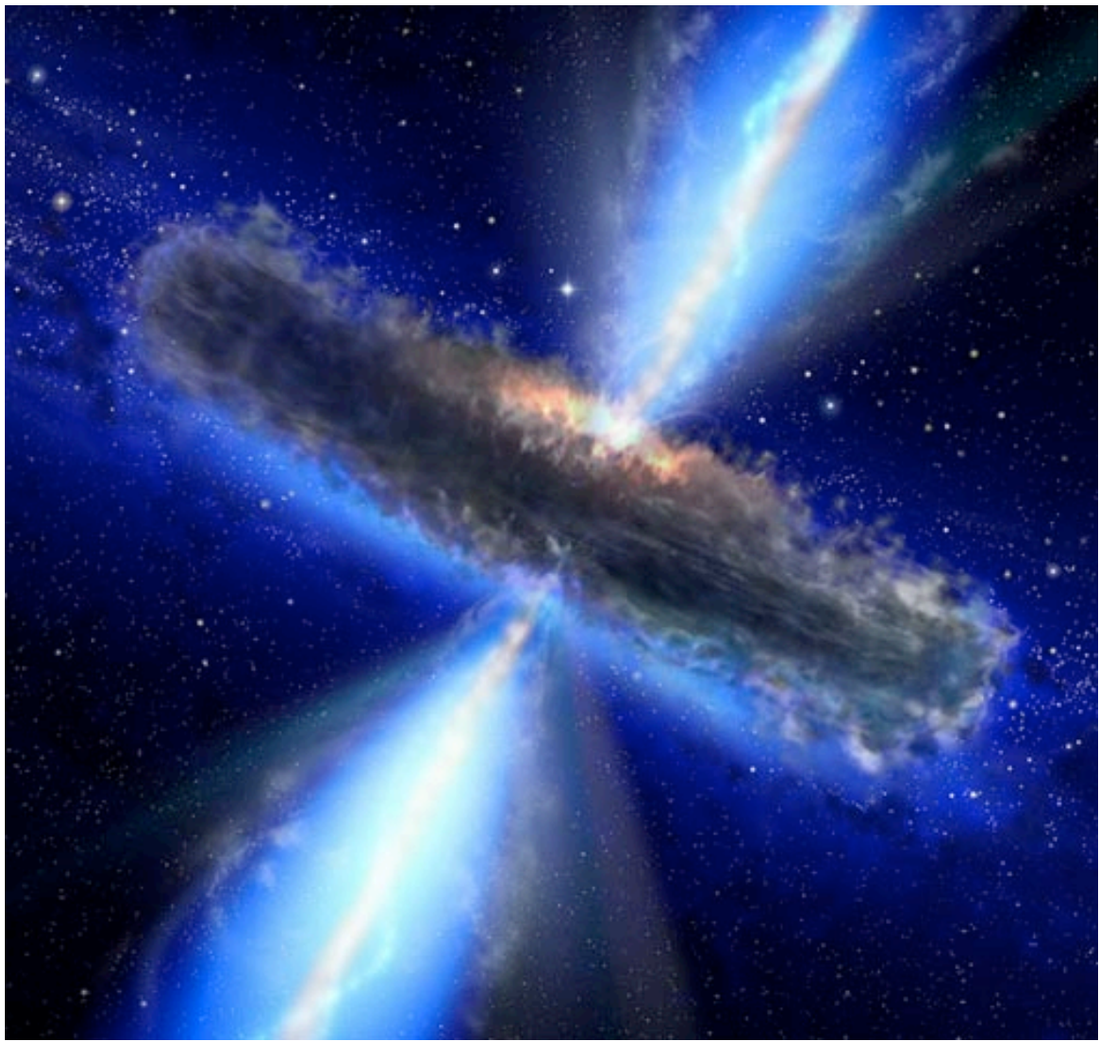


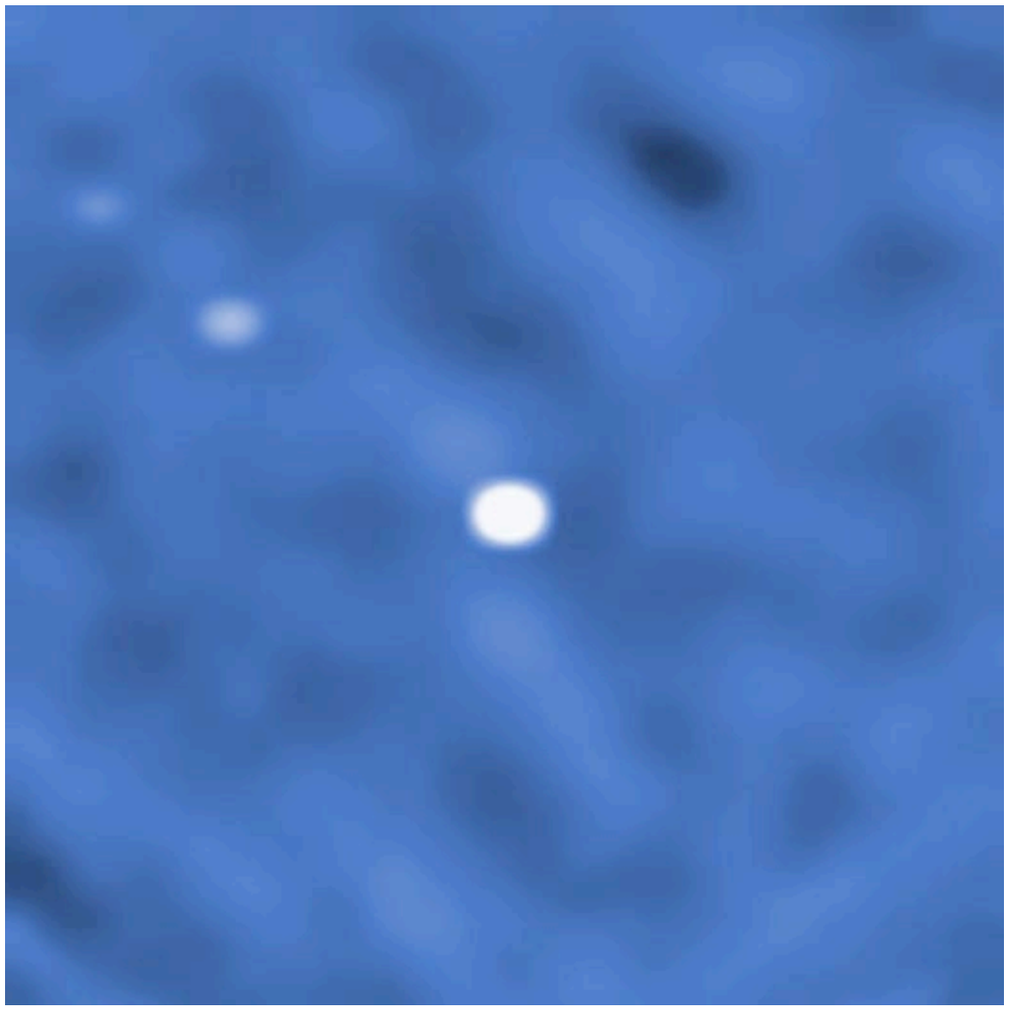
A black hole is an infinite curvature in spacetime

Text

Merging black holes radiate away mass — making an enormous gravitational wave in spacetime

Ask an astronomer: what is a black hole?





Gas that falls into a black hole heats up and emits high energy photons, is entrained by magnetic fields in a jet.

AGN UNIFICATION

BLAZAR

RADIO LOUD QUASAR

RADIO GALAXY

GAS CLOUDS IN "NARROW LINE REGION"

SUPERMASSIVE BLACK HOLE

ACCRETION DISC

SEYFERT II

SEYFERT I

DUSTY GAS CALLED A "TORUS"

"BROAD LINE REGION"

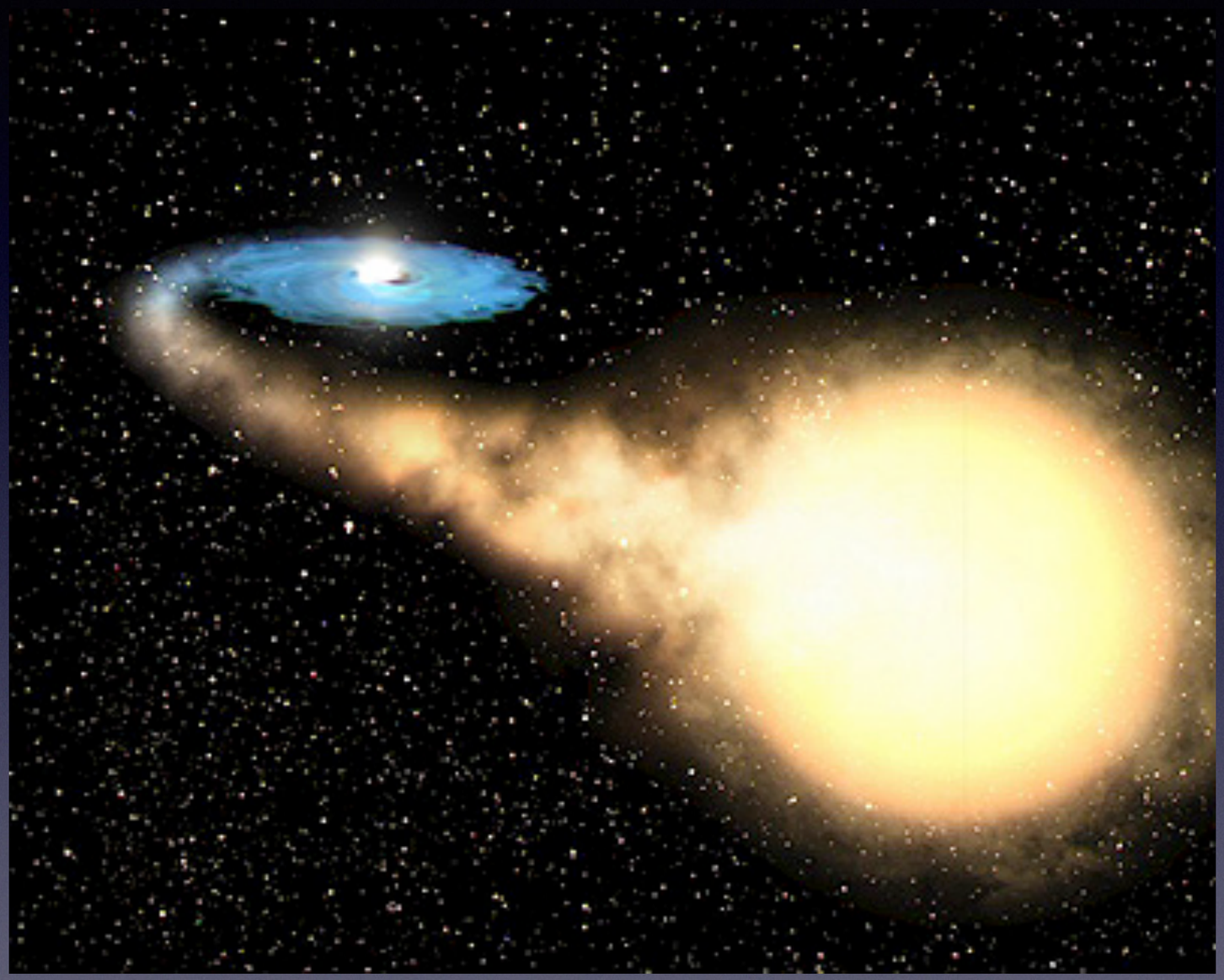
KEY

STUFF

WHAT AN OBSERVER SEES

Brian Jackson, @astrotweeps

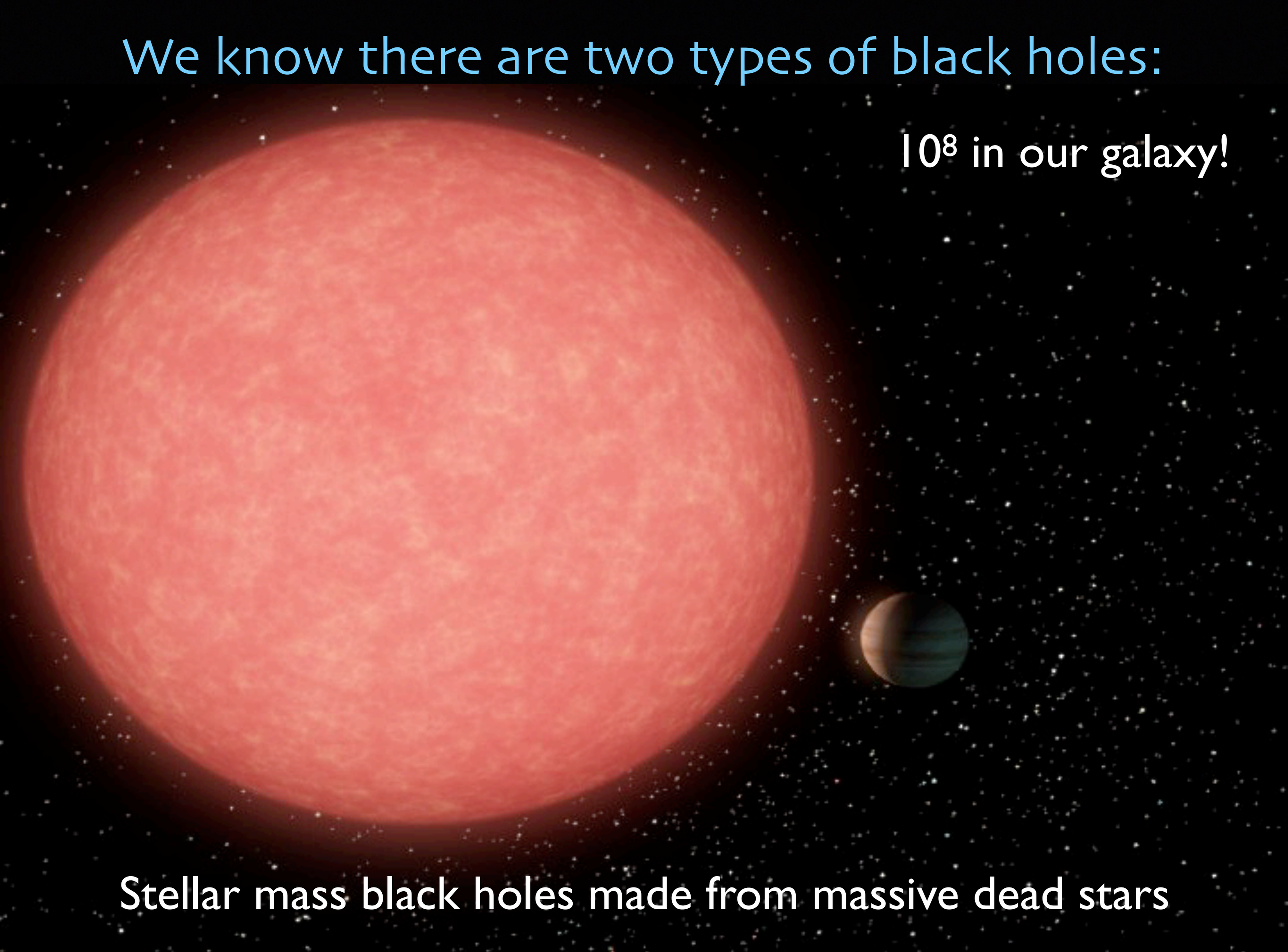
We know there are two types of black holes:



Stellar mass black holes made from massive dead stars

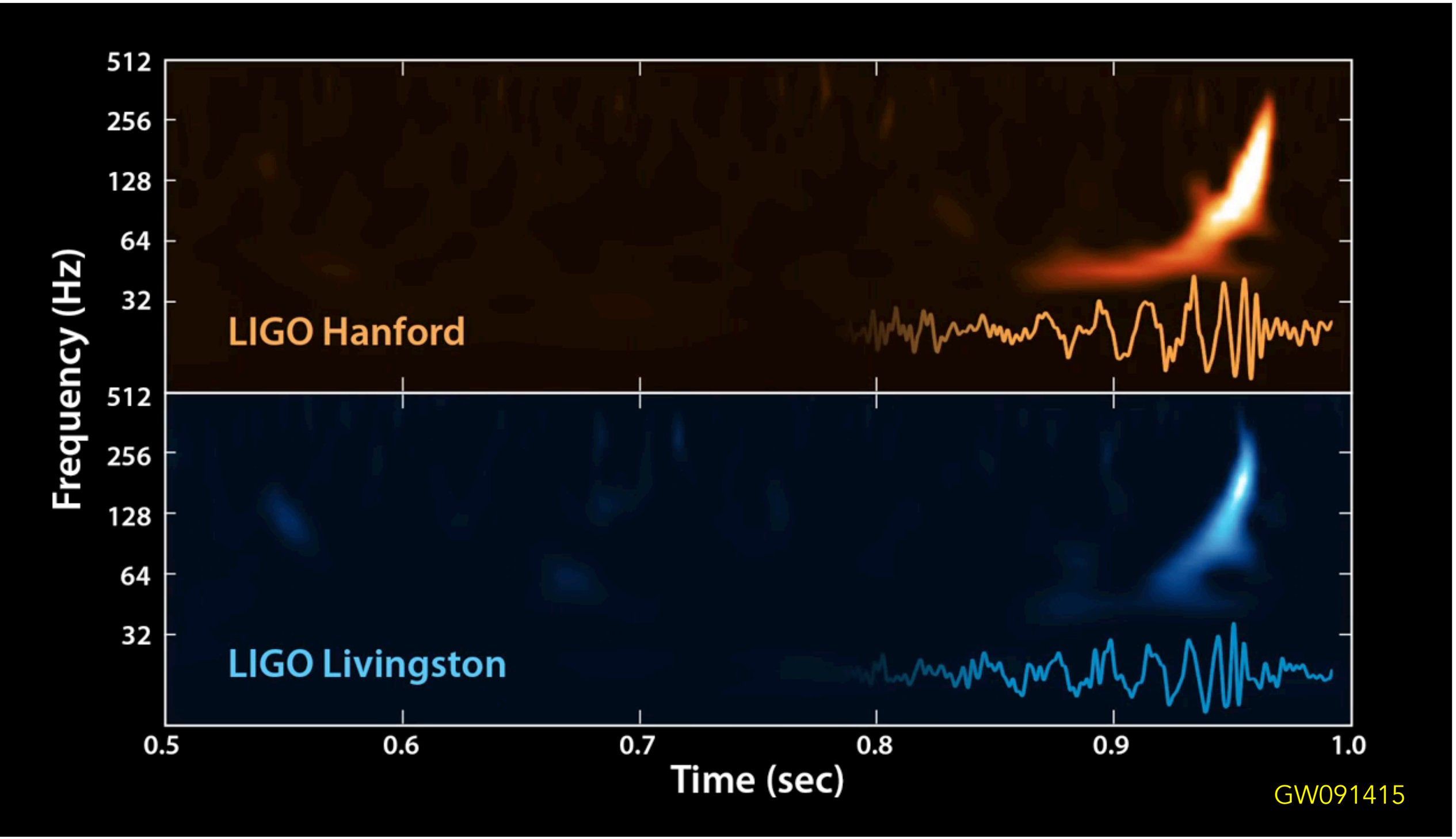
We know there are two types of black holes:

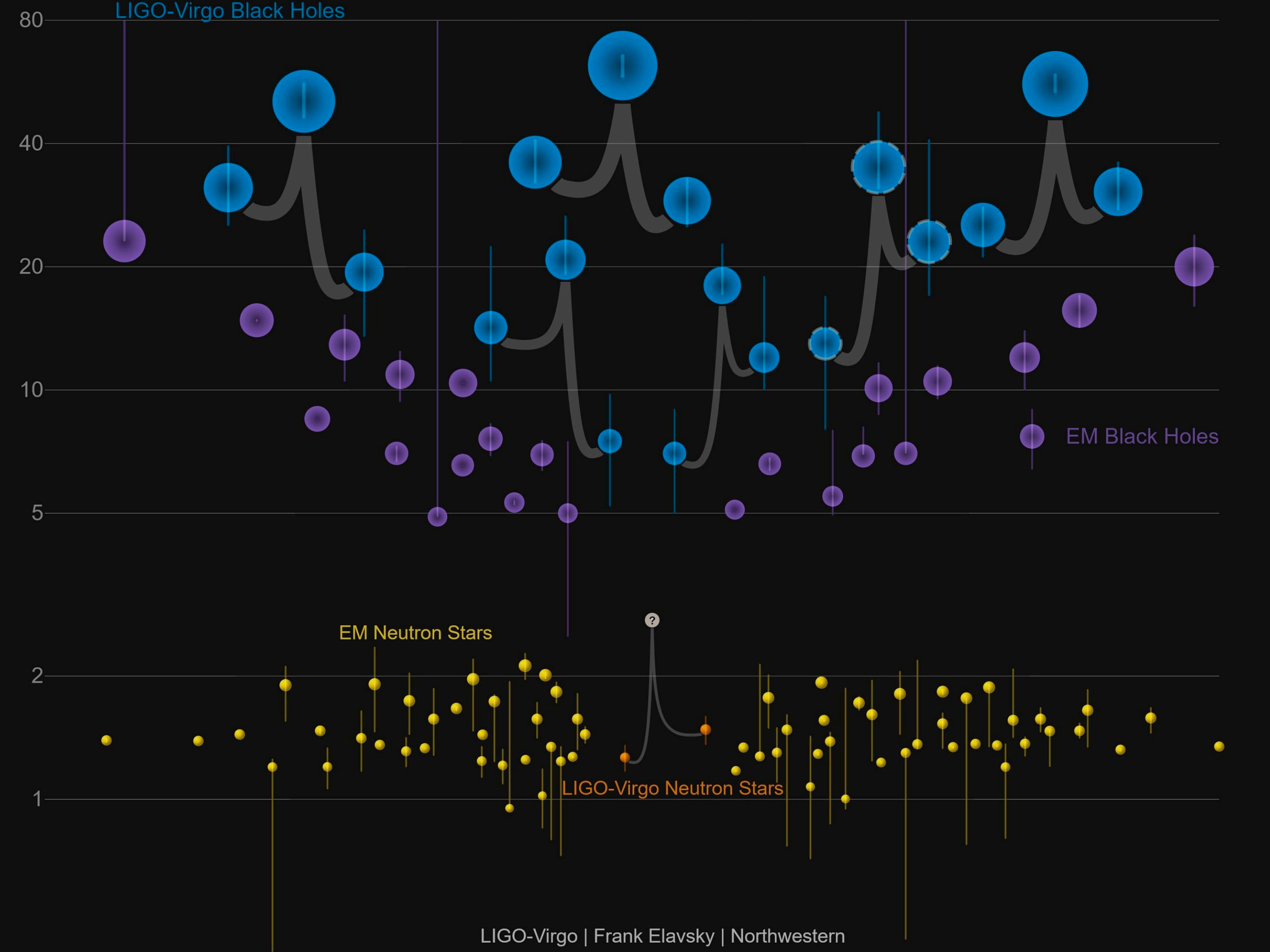
10^8 in our galaxy!



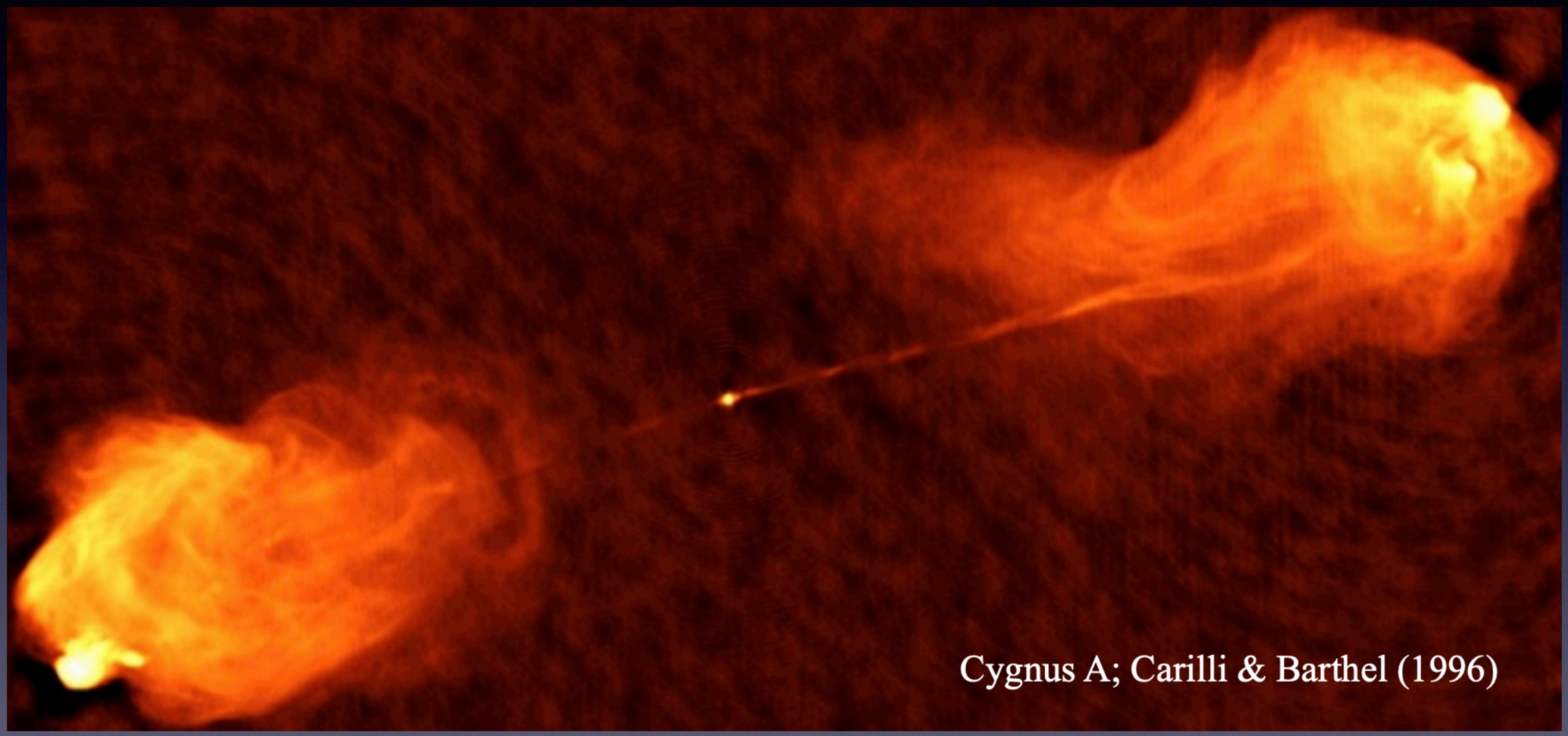
Stellar mass black holes made from massive dead stars

The chirp heard around the world




LIGO-Virgo Black Holes
80
40
20
10
5
EM Black Holes
EM Neutron Stars
2
1
LIGO-Virgo Neutron Stars
?
LIGO-Virgo | Frank Elavsky | Northwestern

We know there are two types of black holes.



Supermassive black holes (SMBHs) lurking at galaxy centers

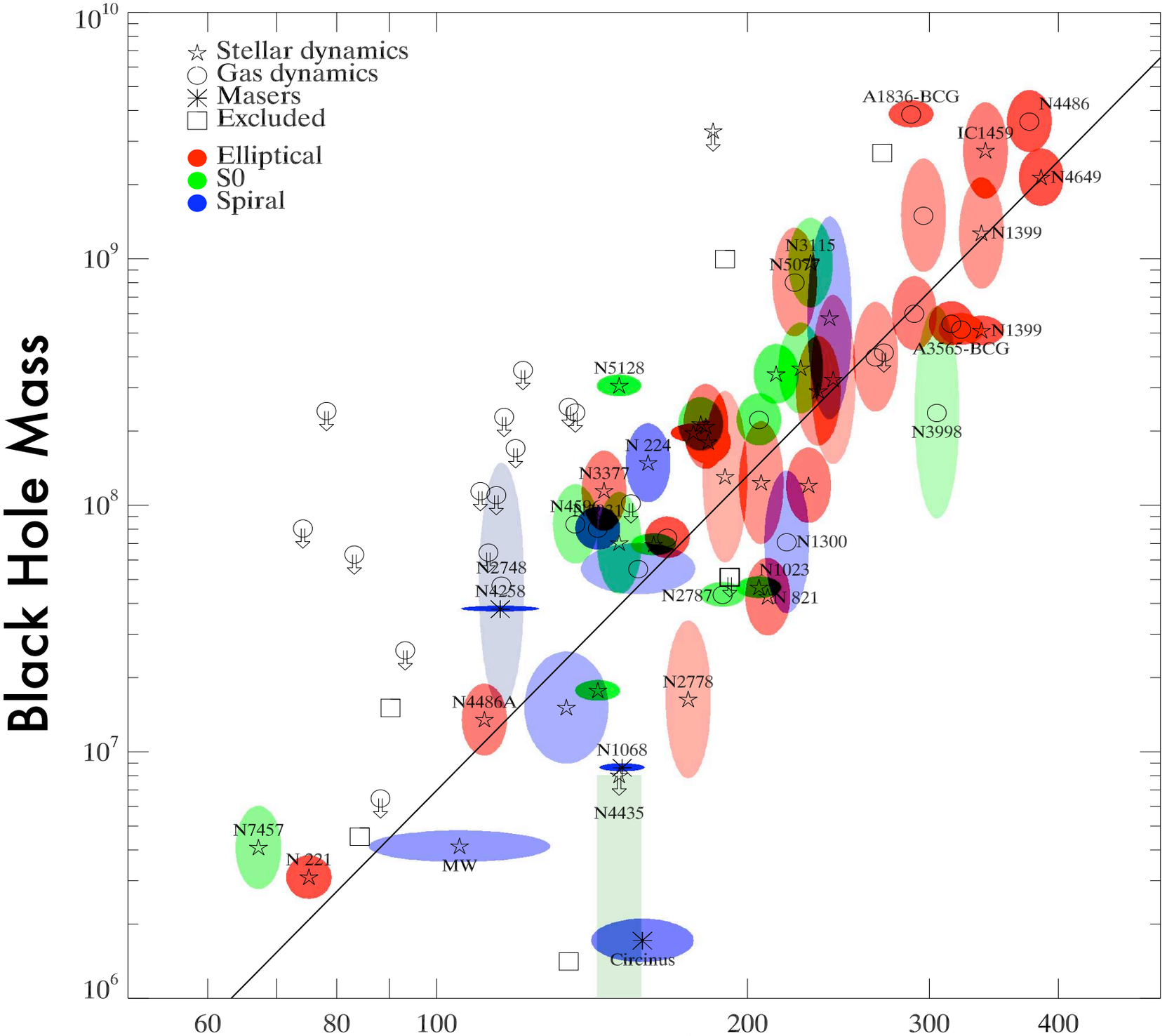
Are there other types of black holes?

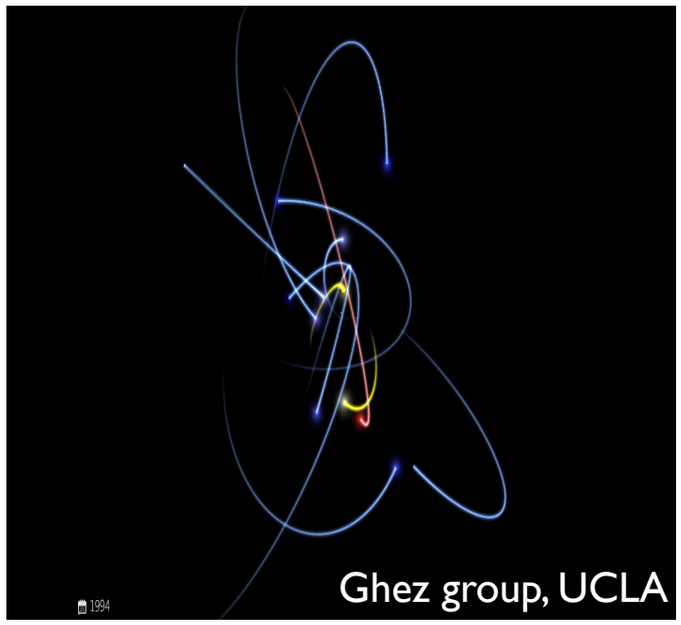
Evidence of an intermediate mass black hole --- in the outskirts of a galaxy

Farrell et al. 2009; 2012

>500 $M_\odot$, with stellar shroud!

A black hole and its galaxy co-evolve when they should be decoupled!





$R_{sch}=2\,G\,M/c^2=O(10^{-6})$ pc

$R_{infl}=G\,M/\sigma_0^2=O(10^{0})$ pc

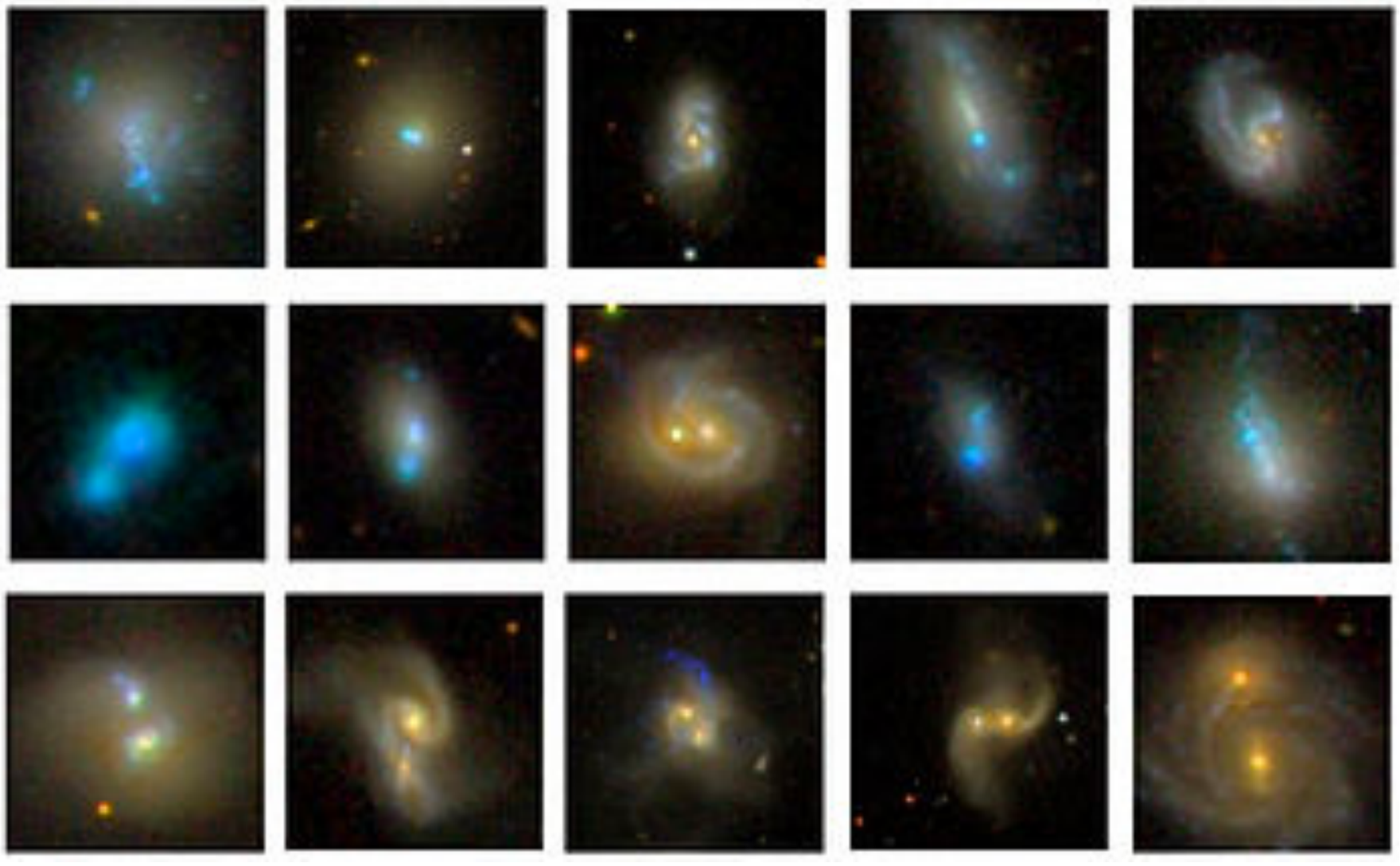
$R_e=O(10^{3})$ pc

Gultekin et al 2009 -- see also Gebhardt et al 2000; Ferrarese & Merritt 2000: McConnell+Ma 2013, and work is on-going…

Prevailing paradigm:
galaxy mergers fuel black holes + black hole feedback regulates galaxy star formation

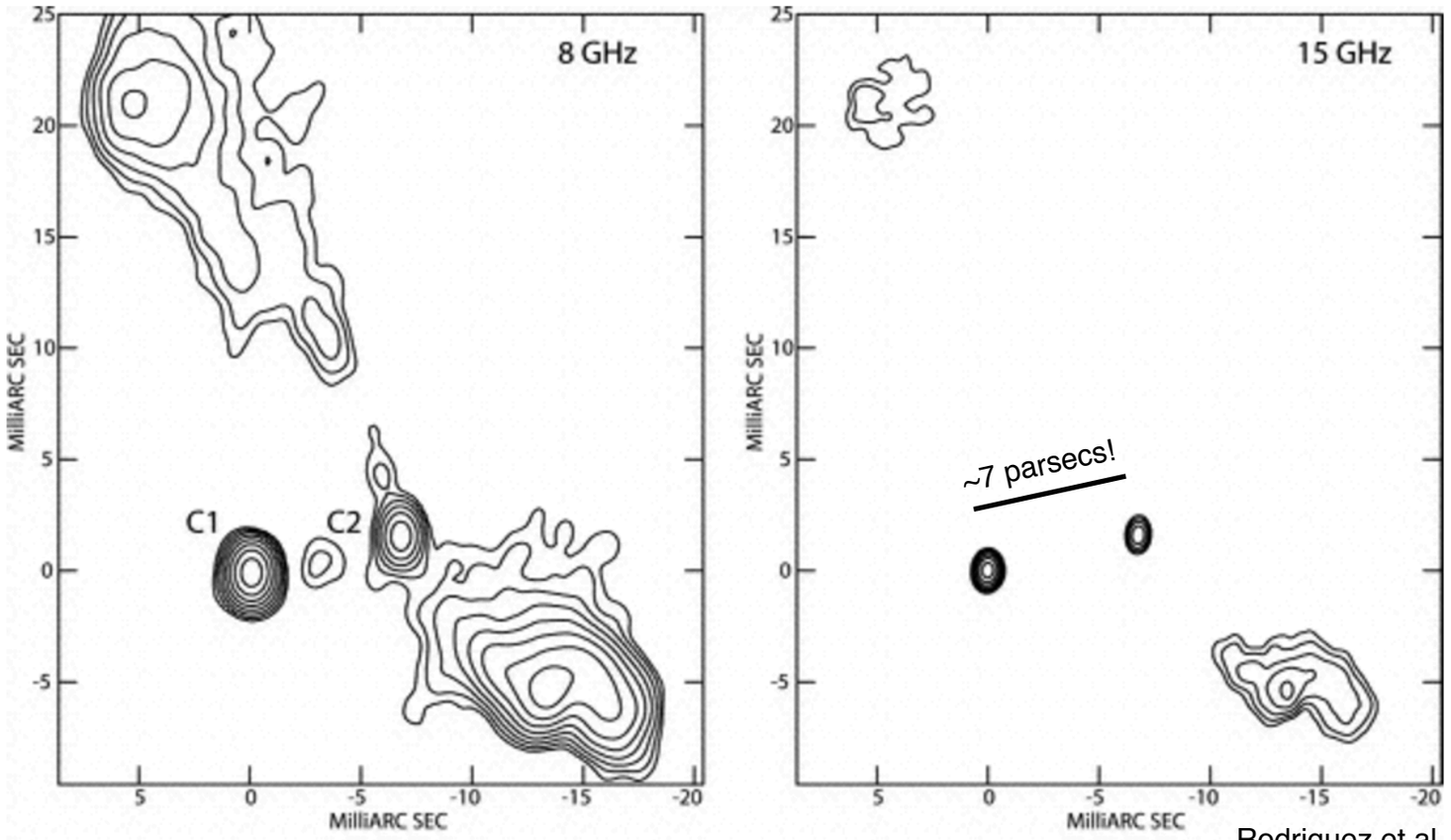
Renaud et al. 2019

While there are certainly dual AGN,



Mezuca et al. 2014

...there are (arguably) no known binary black holes



Rodriguez et al. 2006

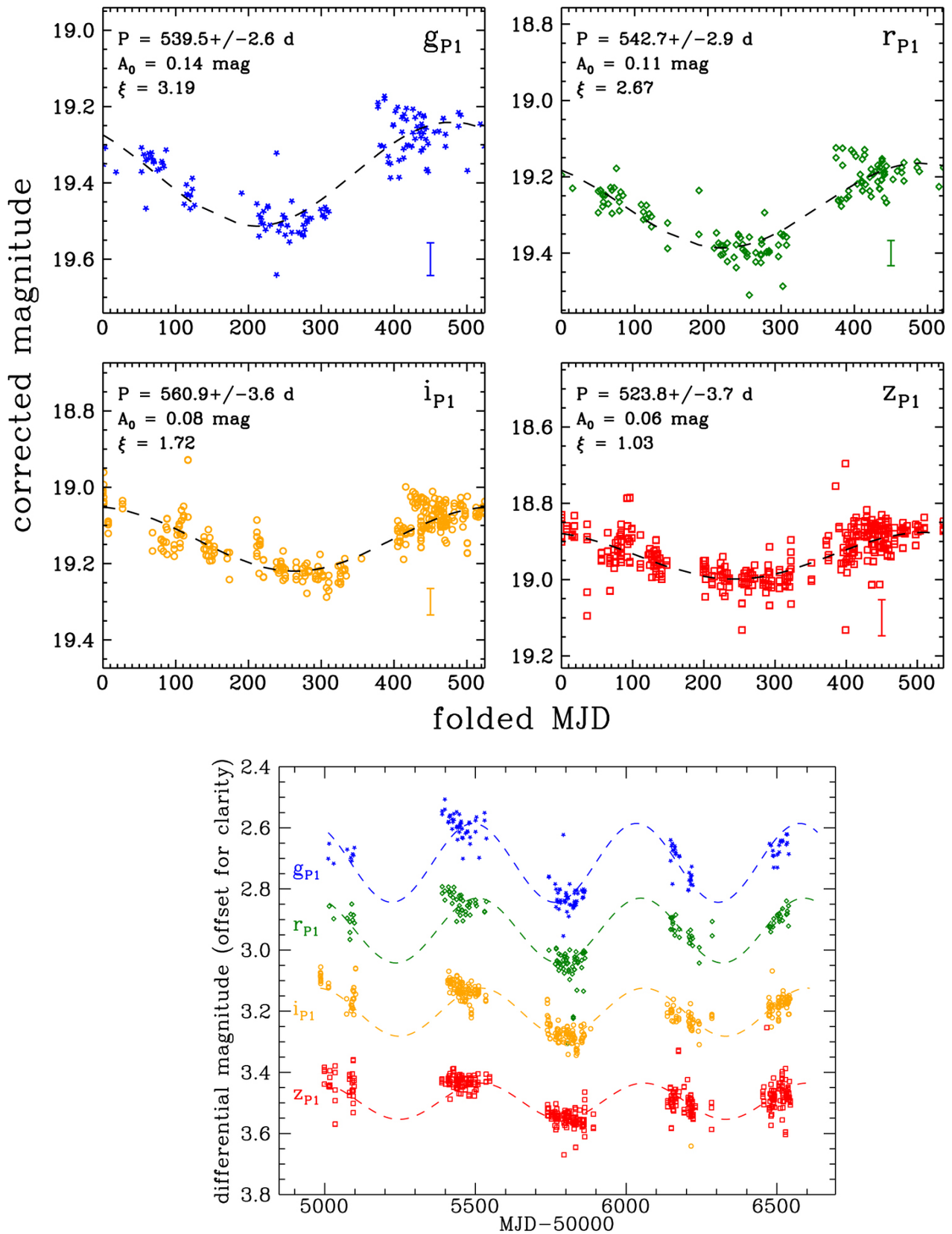
Radio very long baseline interferometric search of ~3100 AGN, only 1 found to be consistent with a binary black hole

Burke-Spolaor 2011

Stay tuned! Time-domain astronomy will help here...

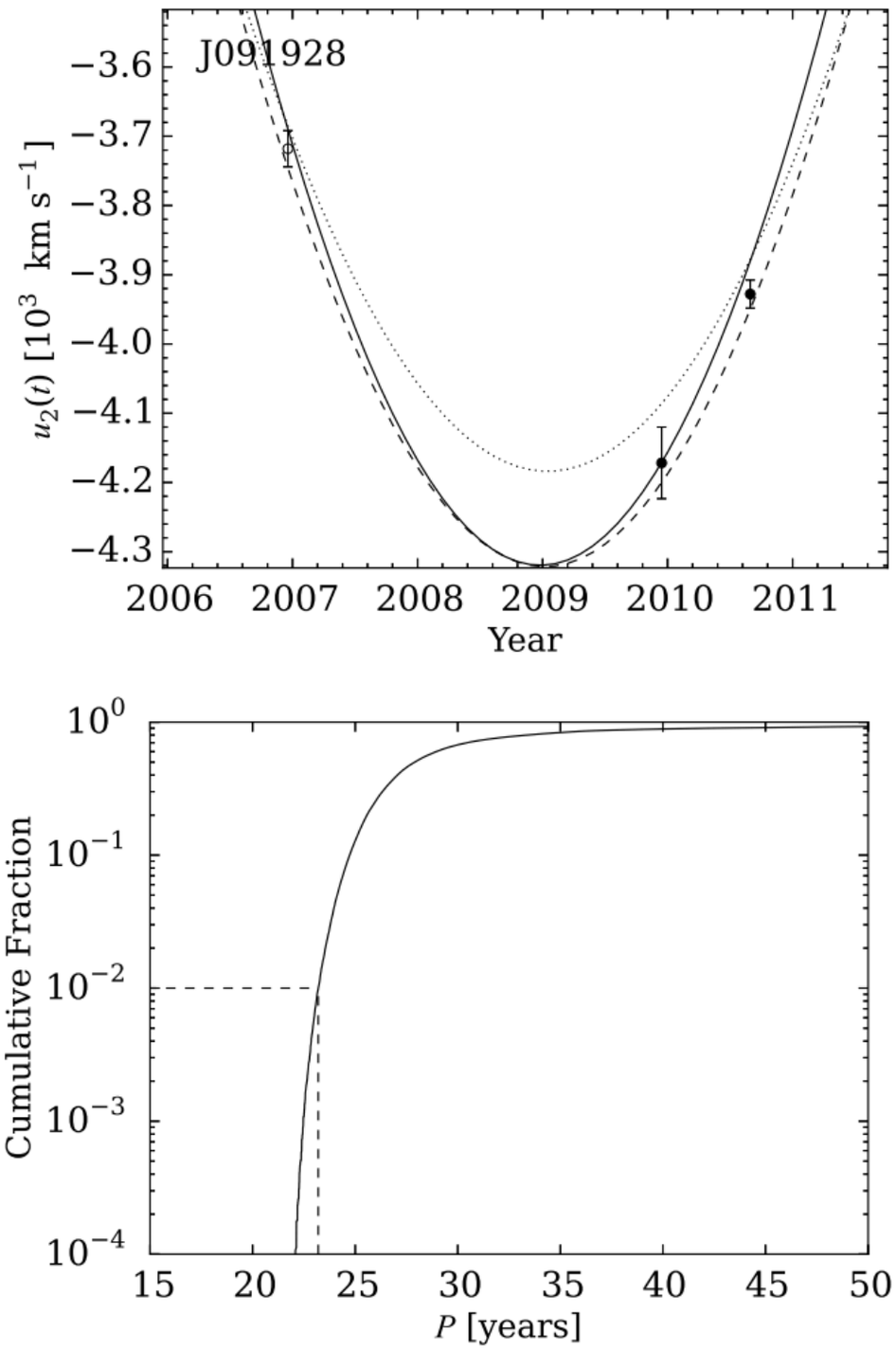
Pan-Starrs PSO J334.2028+01.4075

Periodicity caused by 542+/- 15 day orbit of a 10^{10} solar mass binary at 0.05<q<0.25 @ z=2.06 — separation of ~10 R_S!!



Liu et al. 2015

Looking for the radial motion of the spectral lines in quasars, there are ~3 good BBH candidates

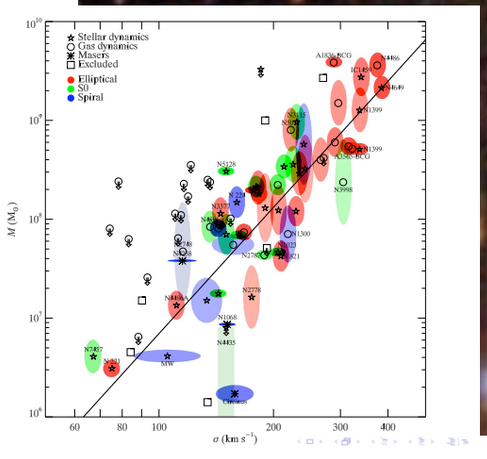


Stay tuned: By 2028, LSST should find ~10^4 BBH candidates

Runnoe et al. 2017

Rule-breaker: Unassuming galaxy with 17 billion solar mass black hole!

NGC 1277

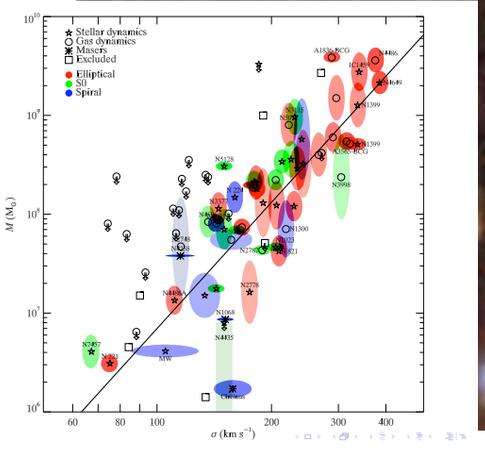


van den Bosch et al. 2012

Perseus cluster

Rule-breaker: Unassuming galaxy with ~~17~~ billion solar mass black hole!

Stay tuned! MASSIVE Sur



Heinze 2-10 is dwarf with a million solar mass black hole

and there are SMBHs in bulgeless galaxies, too!

Reines et al. 2011

Sommers et al. 2012

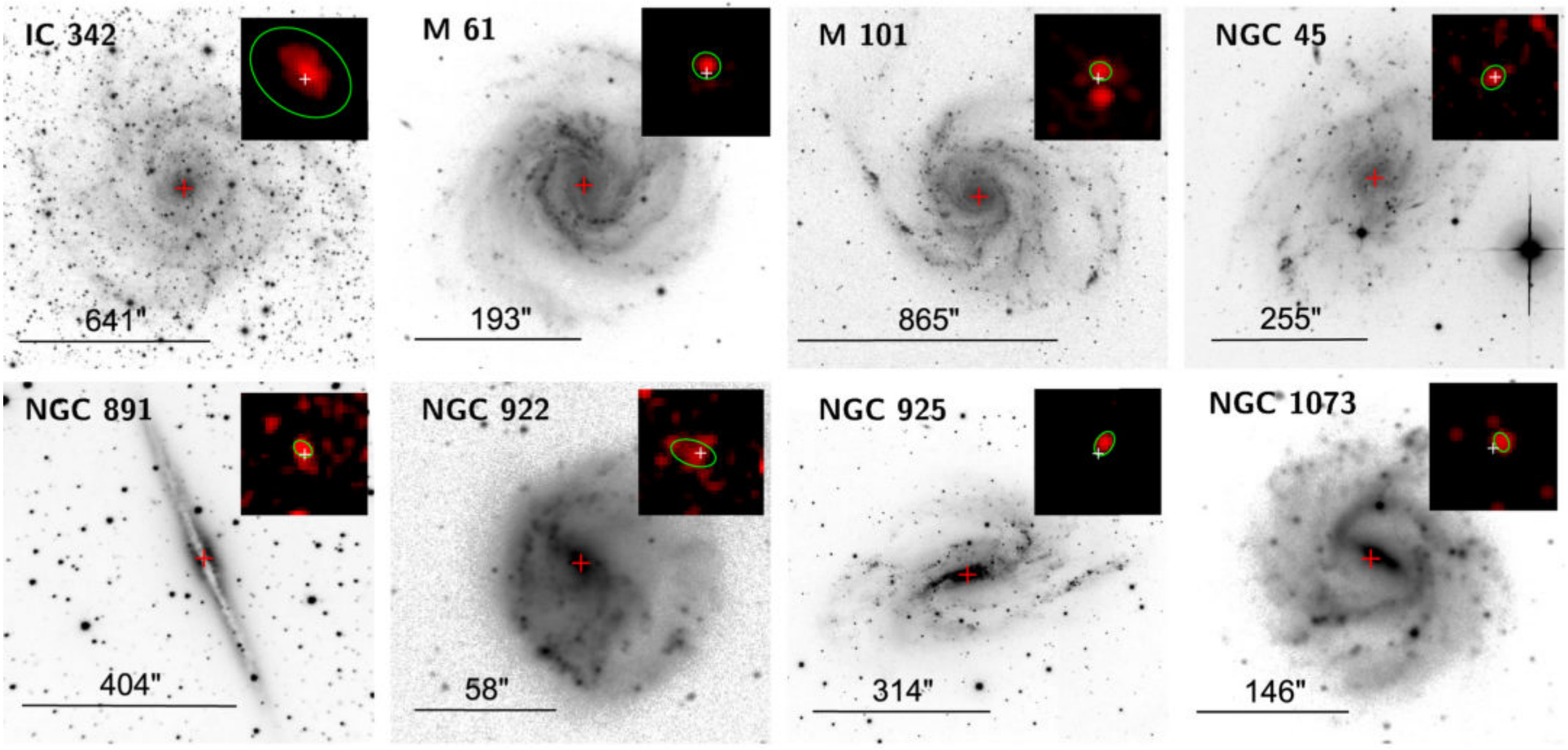
Satyapal et al. 2014

...and in low surface brightness galaxies, like Malin 1...

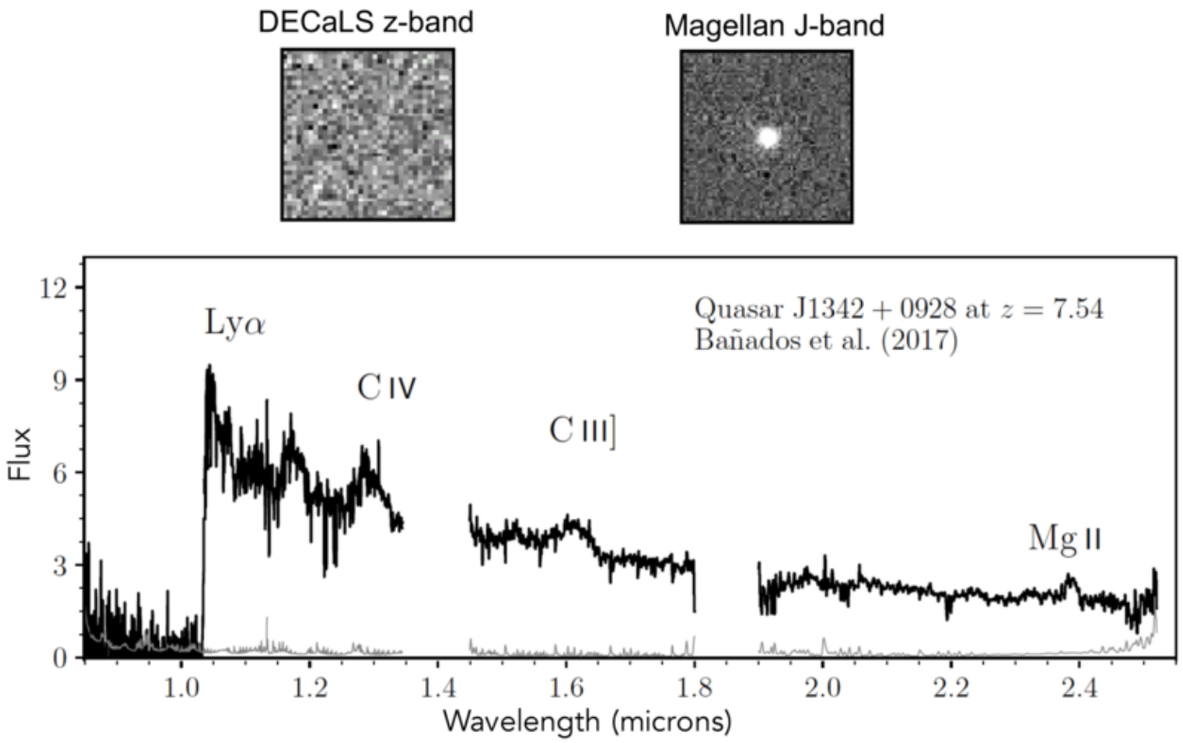
Subramanian et al. 2015

Warning: viral masses — assume lin
width maps to velocity for Keplerian
motion

Chandra reveals new SMBHs with <10^6 solar masses in disky galaxies

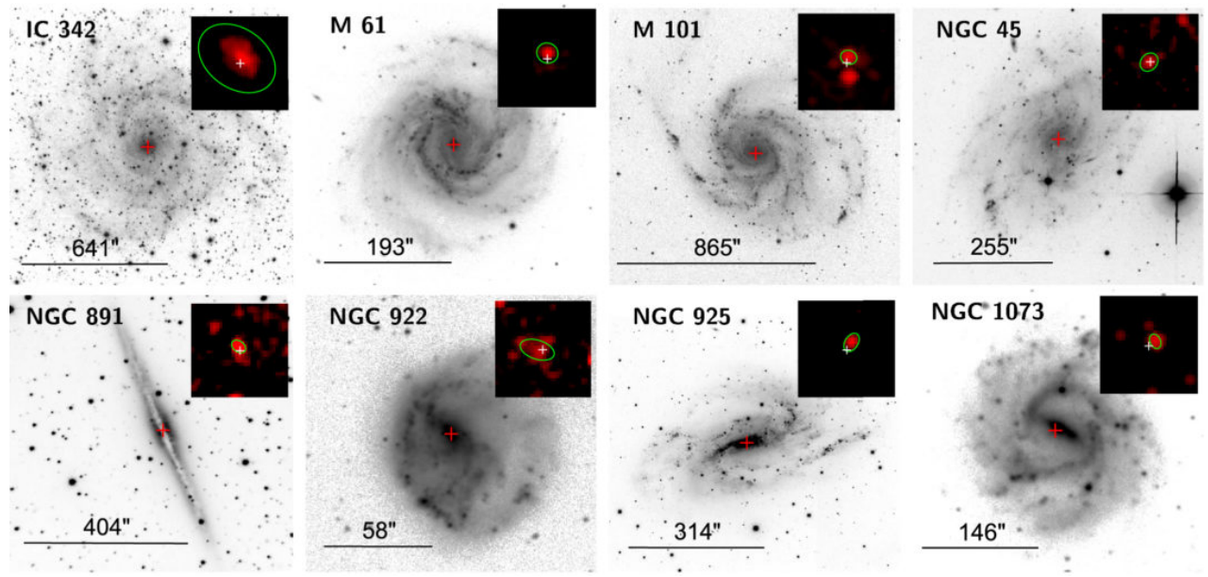


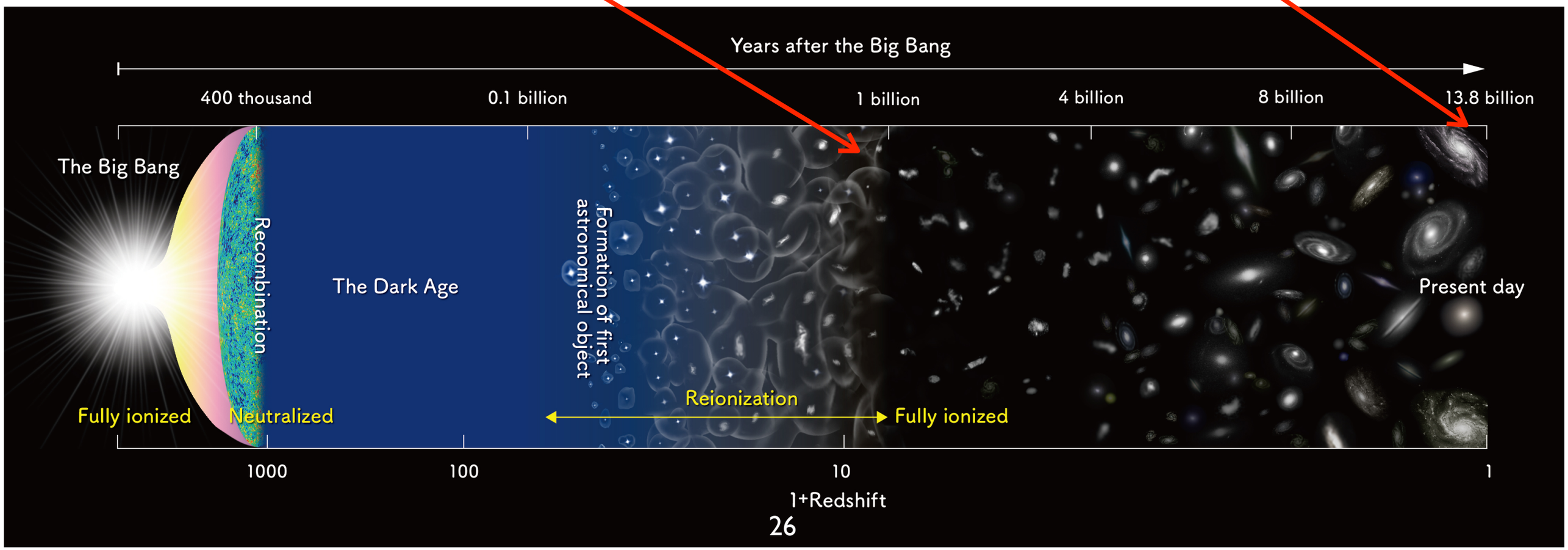
She et al 2017 — 21% of disky galaxies host SMBHs like these.



8x10⁸ M⊙ Black Hole!

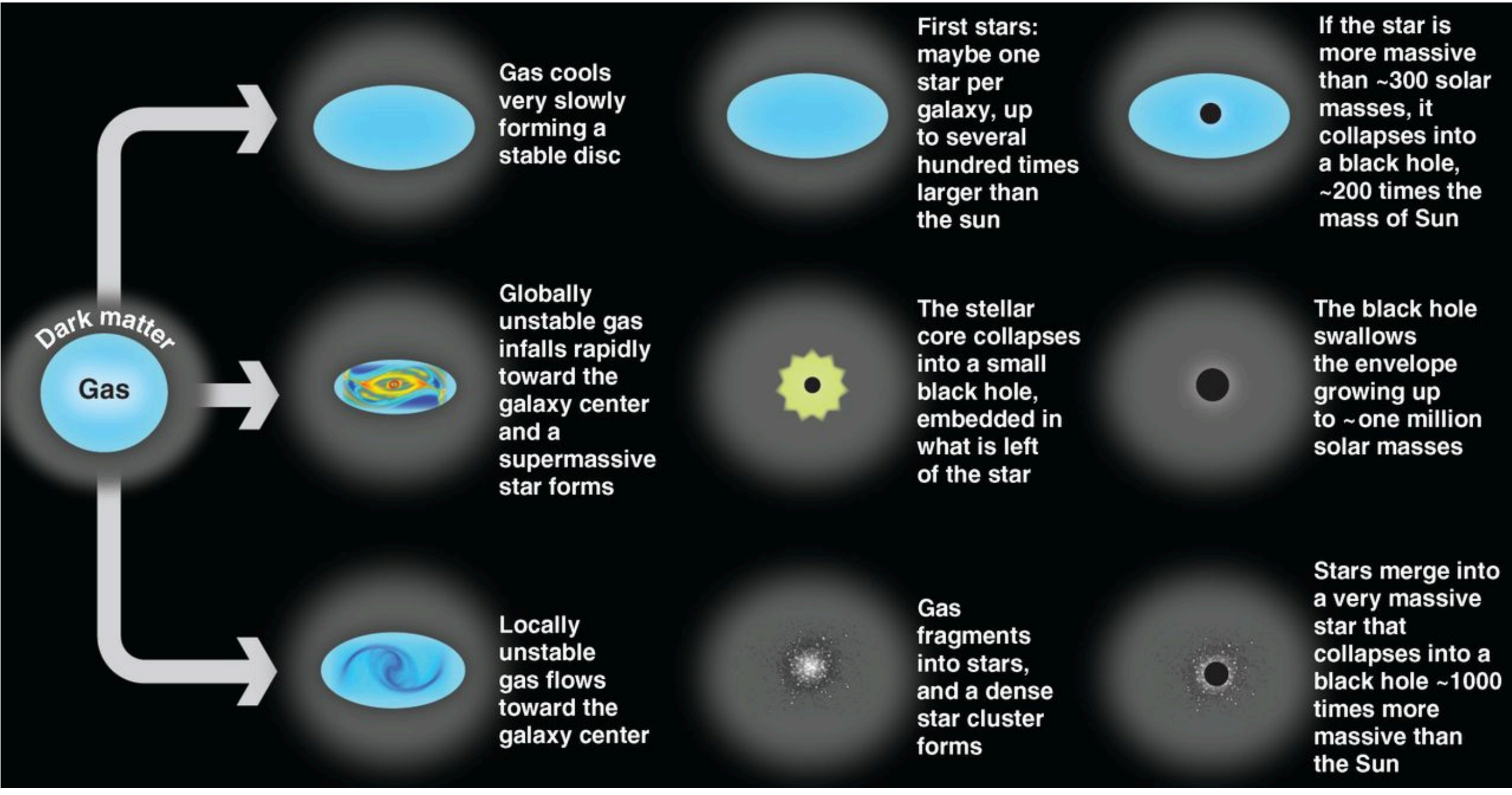
~10⁶ — 10⁹ M⊙ Black Holes





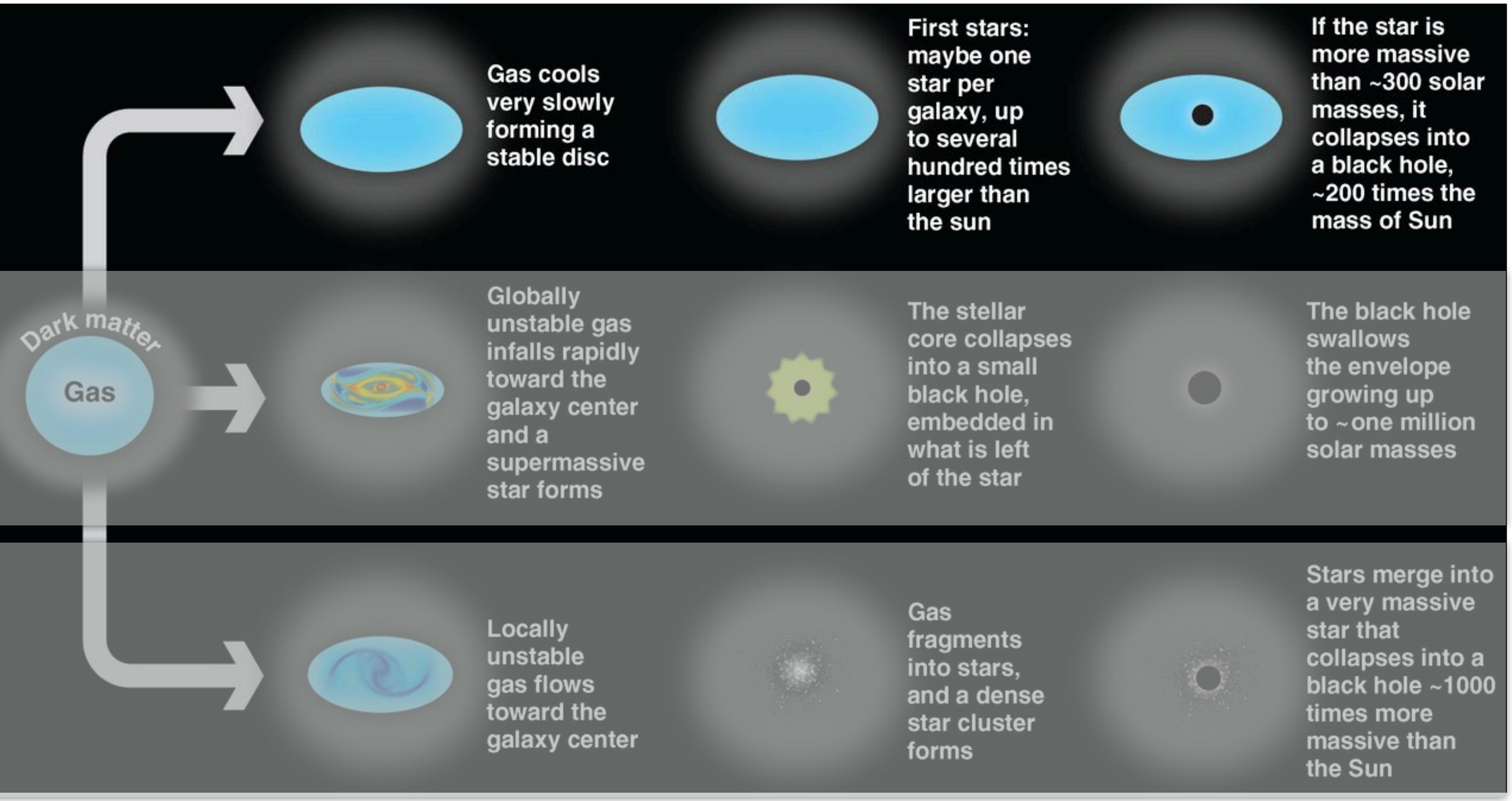
How are supermassive black holes born and how can gigantic ones be in place so soon after the Big Bang?

Forming a black hole: let me count (some of) the ways



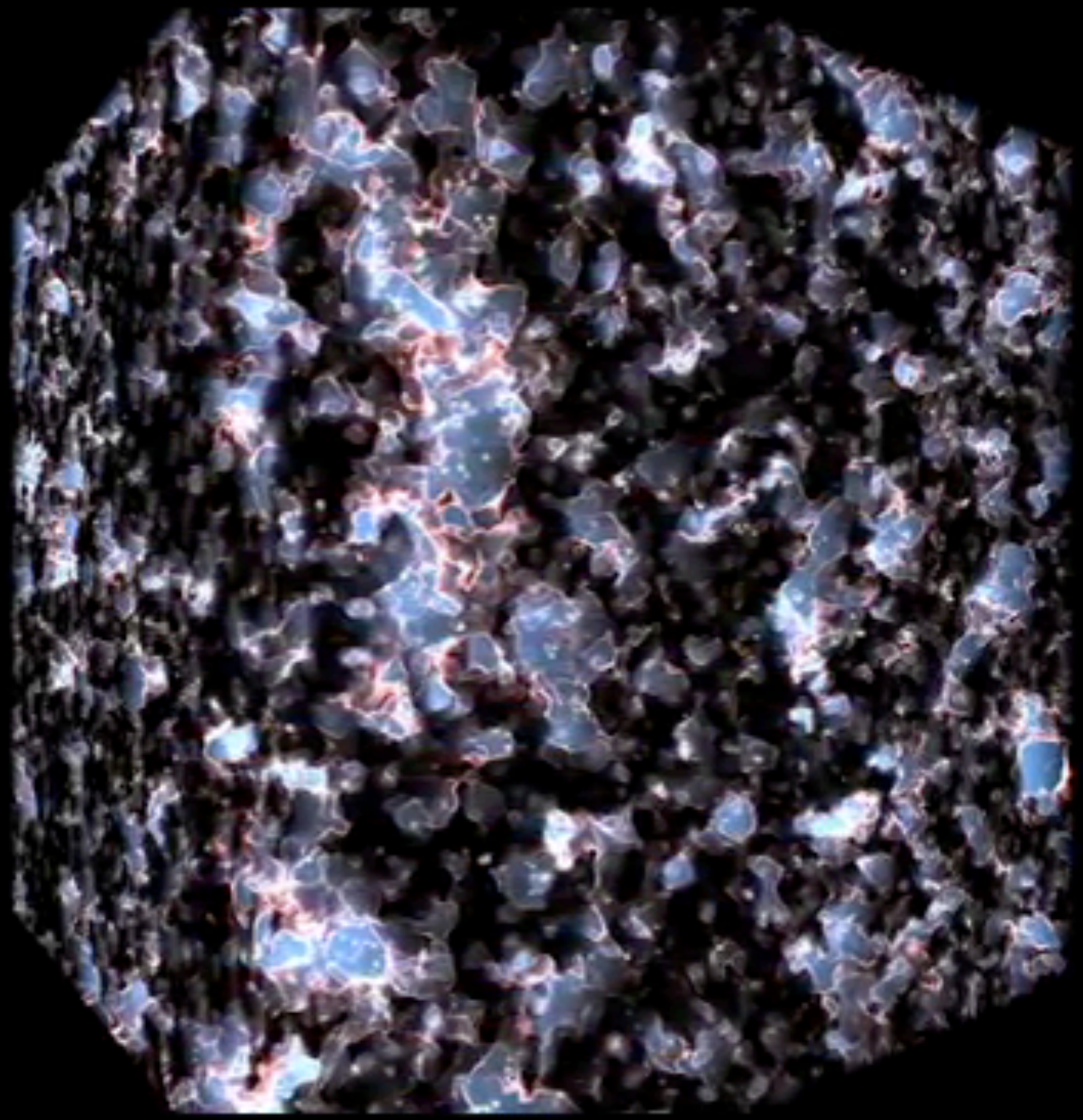
From excellent Volonteri review

One channel: Light seeds from the first generation of stars



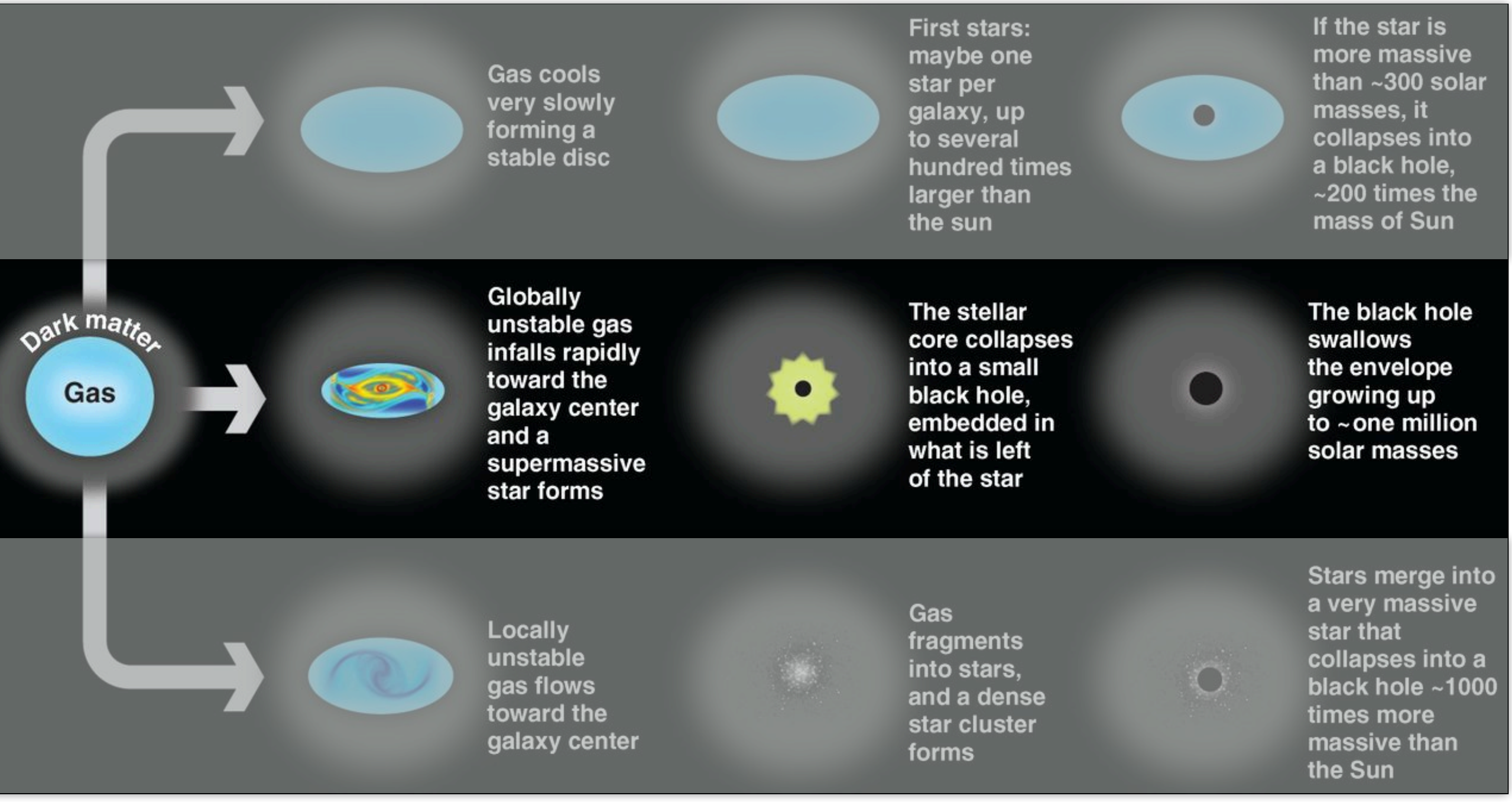
From excellent Volonteri review

These first stars help heat and reionize the universe. The remnants are 10-100$M_\odot$ seed black holes



Credits: Simulation: Marcelo Alvarez, Tom Abel; Visualization: Ralf Kaehler

One channel: Heavy seeds from directly collapsing black holes



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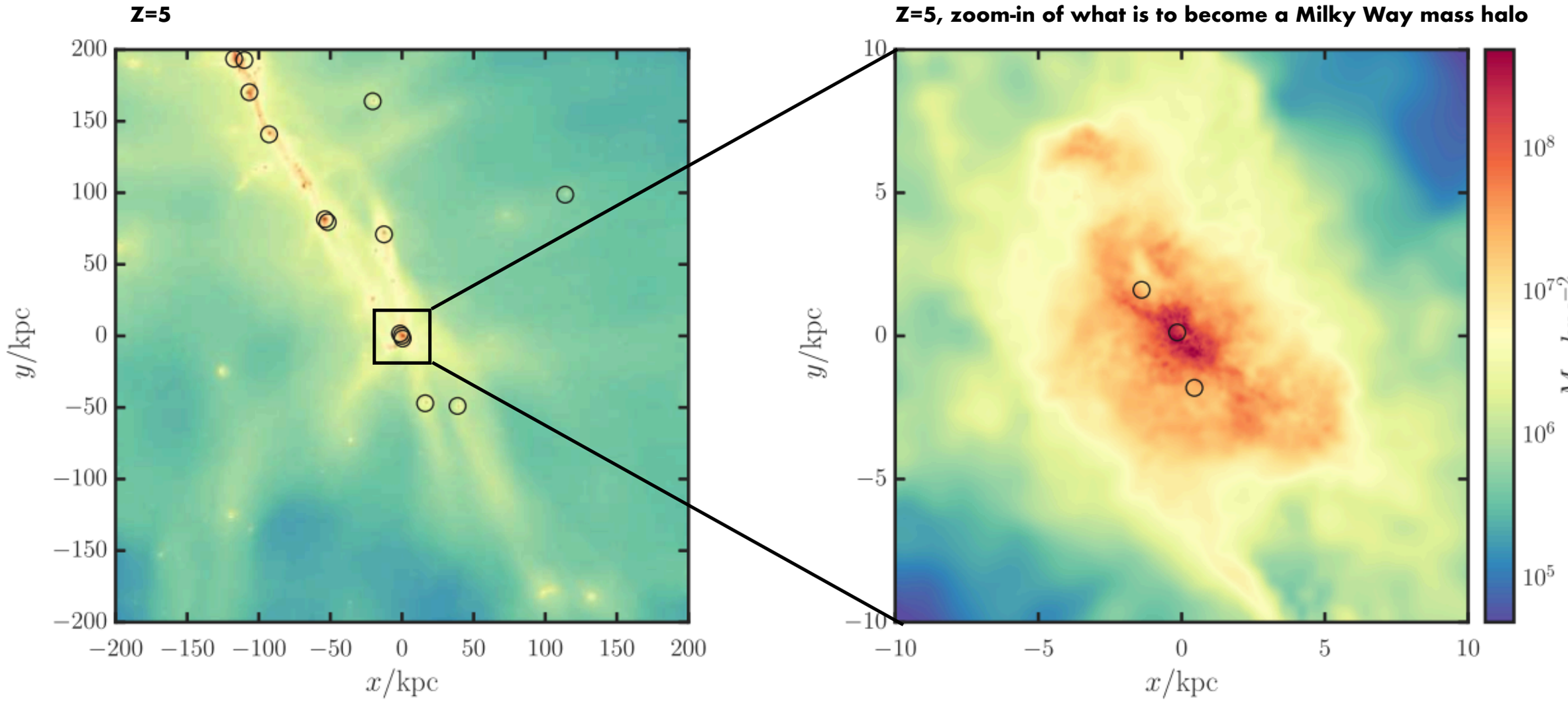
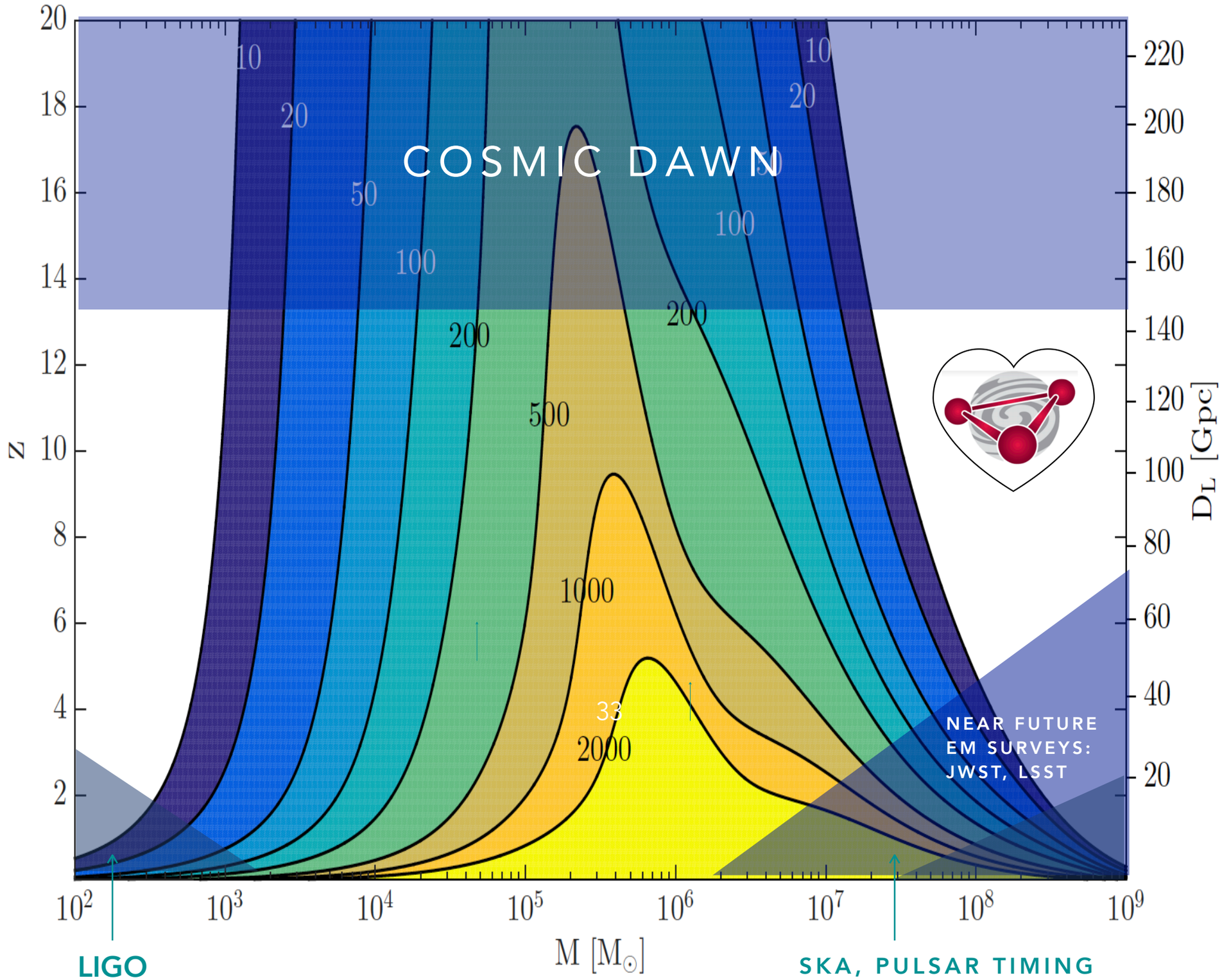


Cosmological Hydrodynamical Simulations of Direct Collapse Black Hole Formation

Dunn, Bellovary, KHB, Christensen, Quinn 2018

Gravitational Waves will get the only* direct view of seed formation and black hole early growth!



It's a wonderful era to be an astronomer!

We need to get robust SMBH masses and pin down SMBH binaries

We need to know the real SMBH-galaxy correlation

We don't know how black holes are born or how they grow

We don't understand SMBH accretion and feedback

We need to understand SMBH dynamics

Spin! We aren't thinking enough about spin!