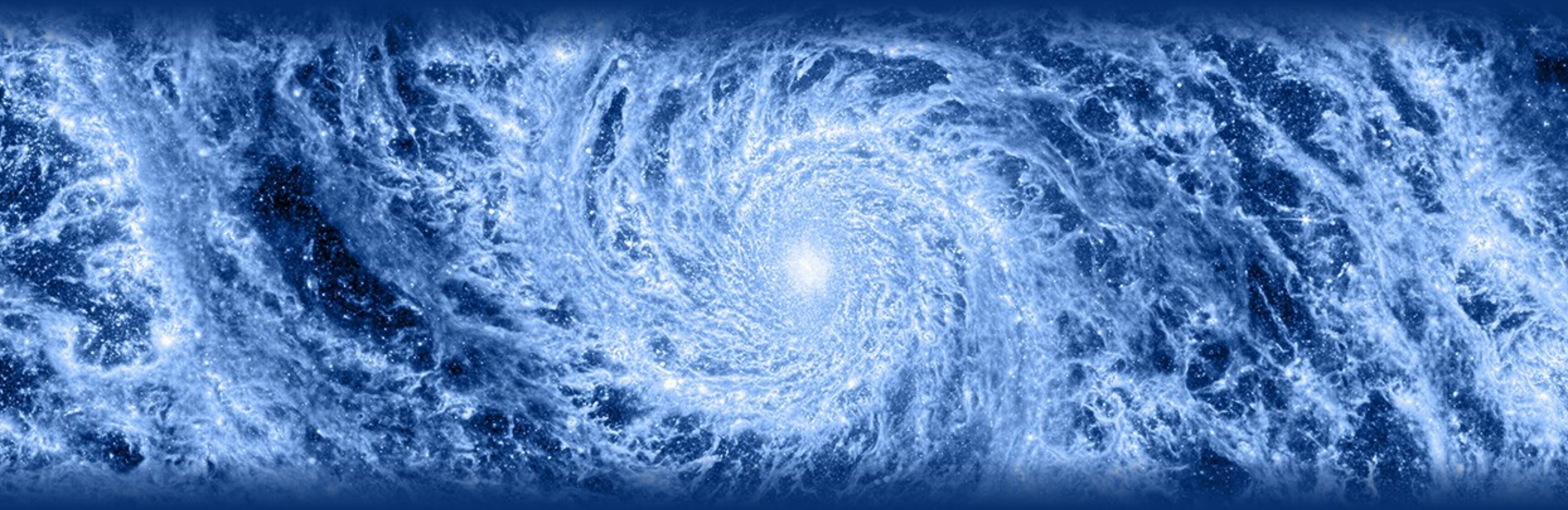
Galaxies

Prof. Benedikt Diemer



Chapter 9 • Black holes and AGN feedback

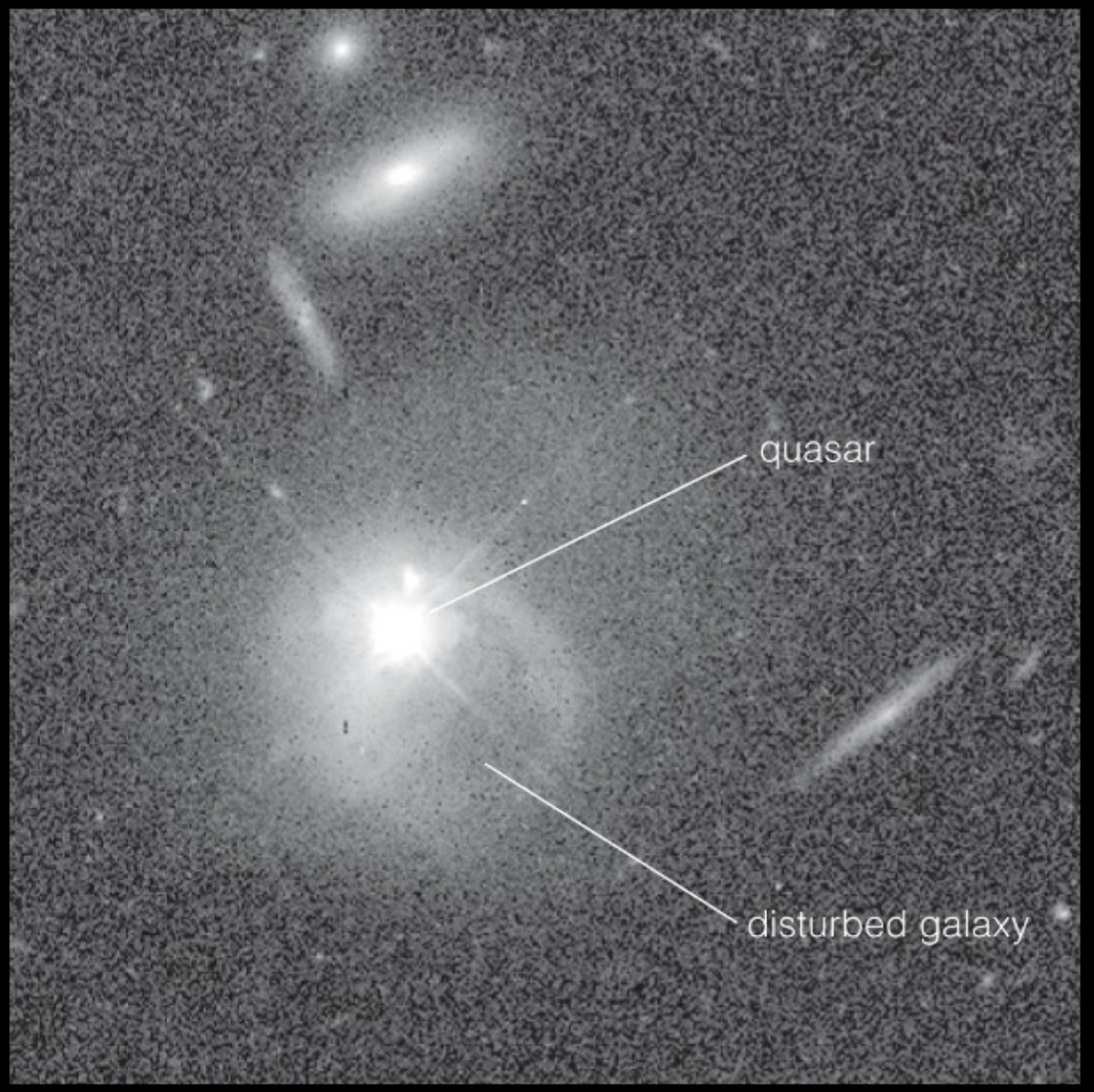
§9.1 • The unified model of AGN

Quasars

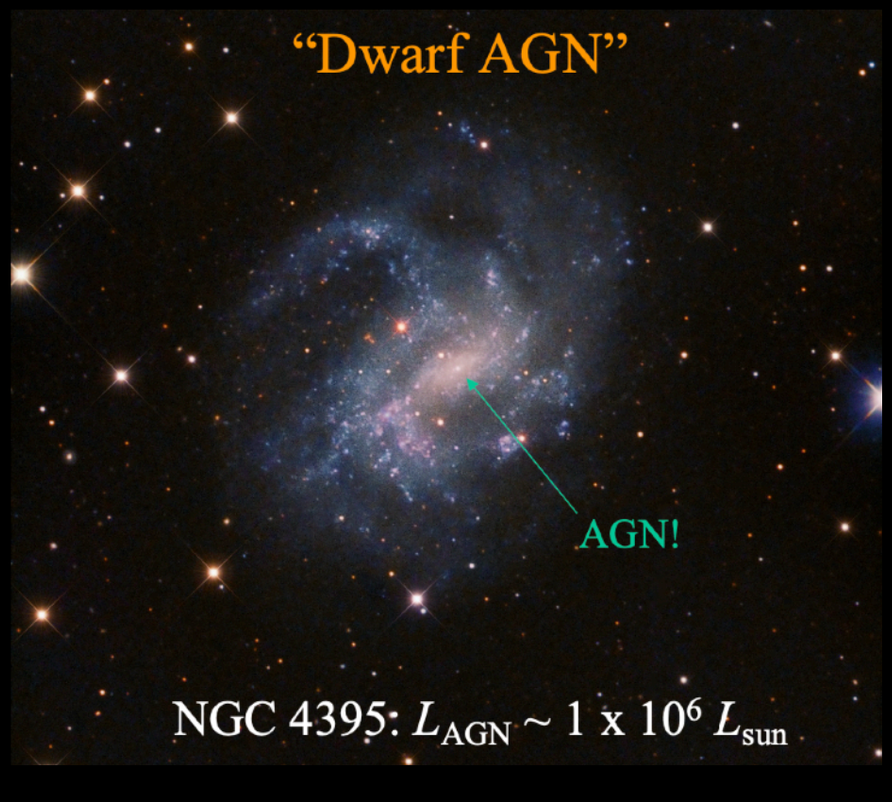
NGC 1068

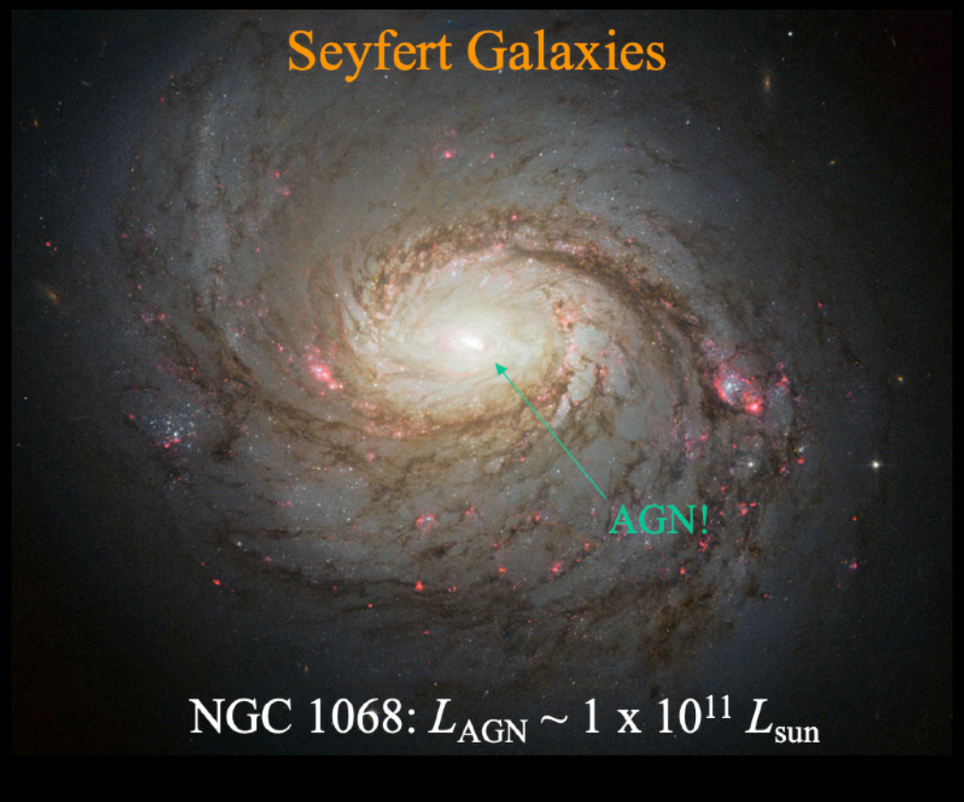
Quasars

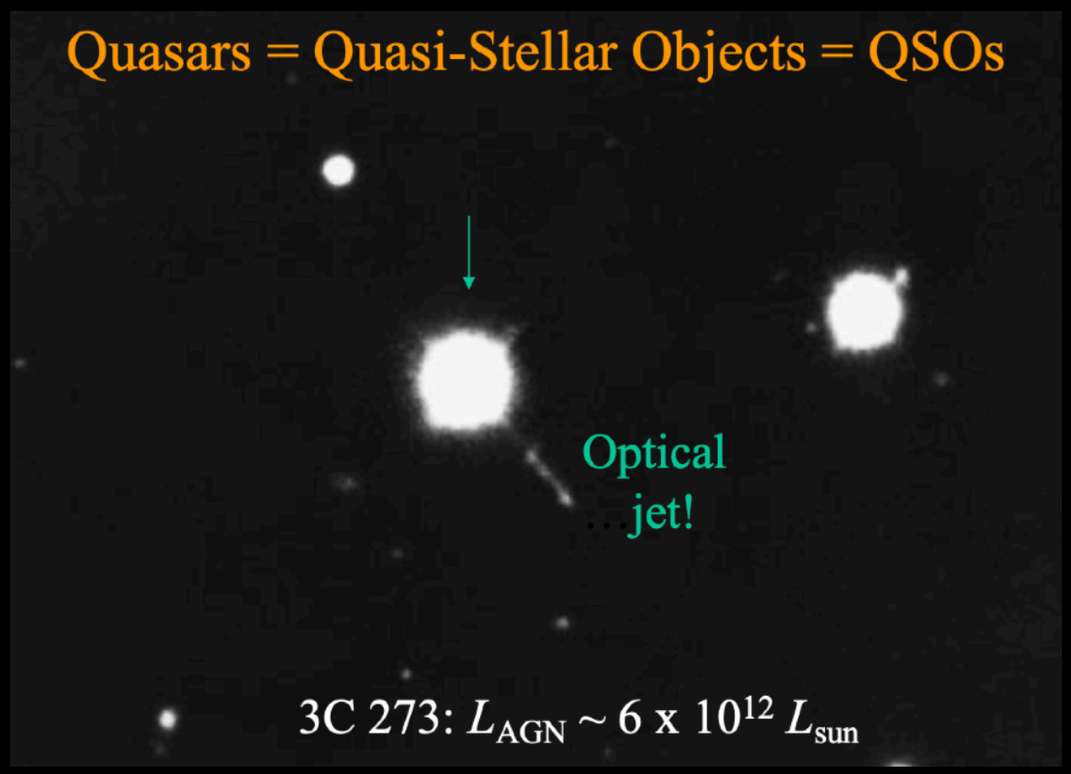
- For historic reasons, particularly powerful AGN are sometimes called quasars
- The name means “quasi-stellar objects” and alludes to the fact that they look just like a point, or a star
- Quasars can be 100 times brighter than the MW

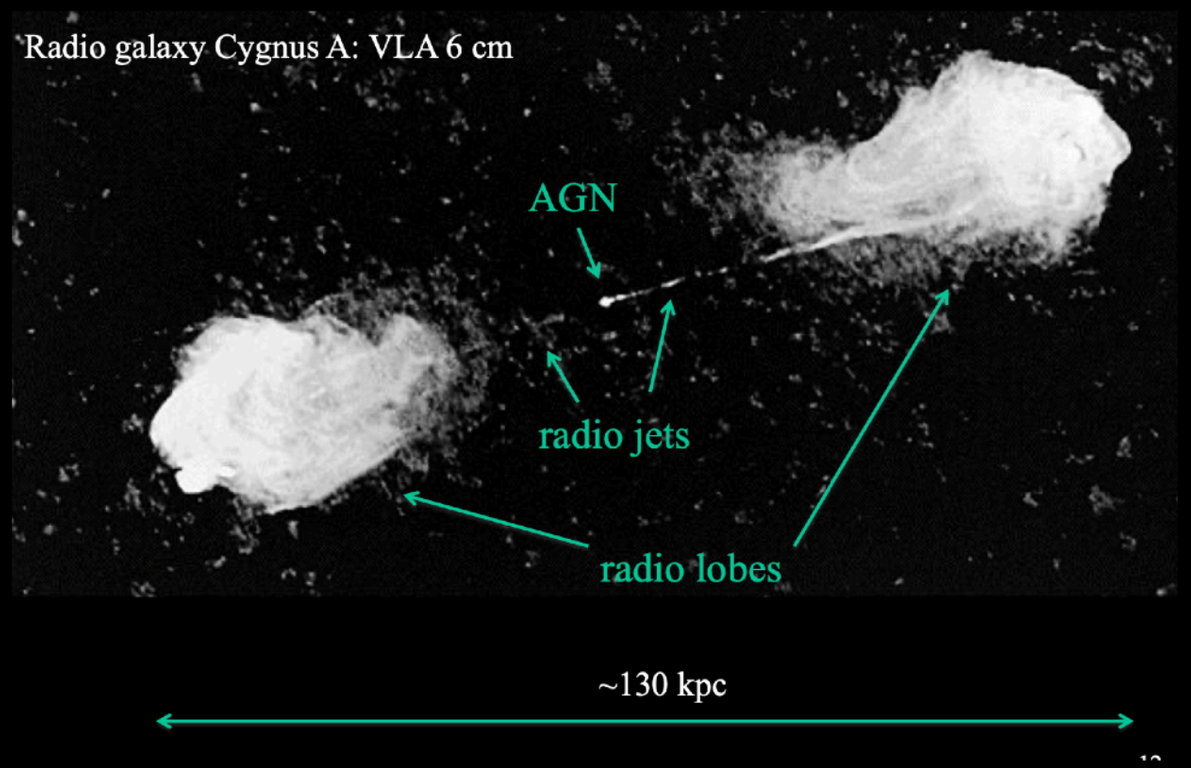


AGN diversity



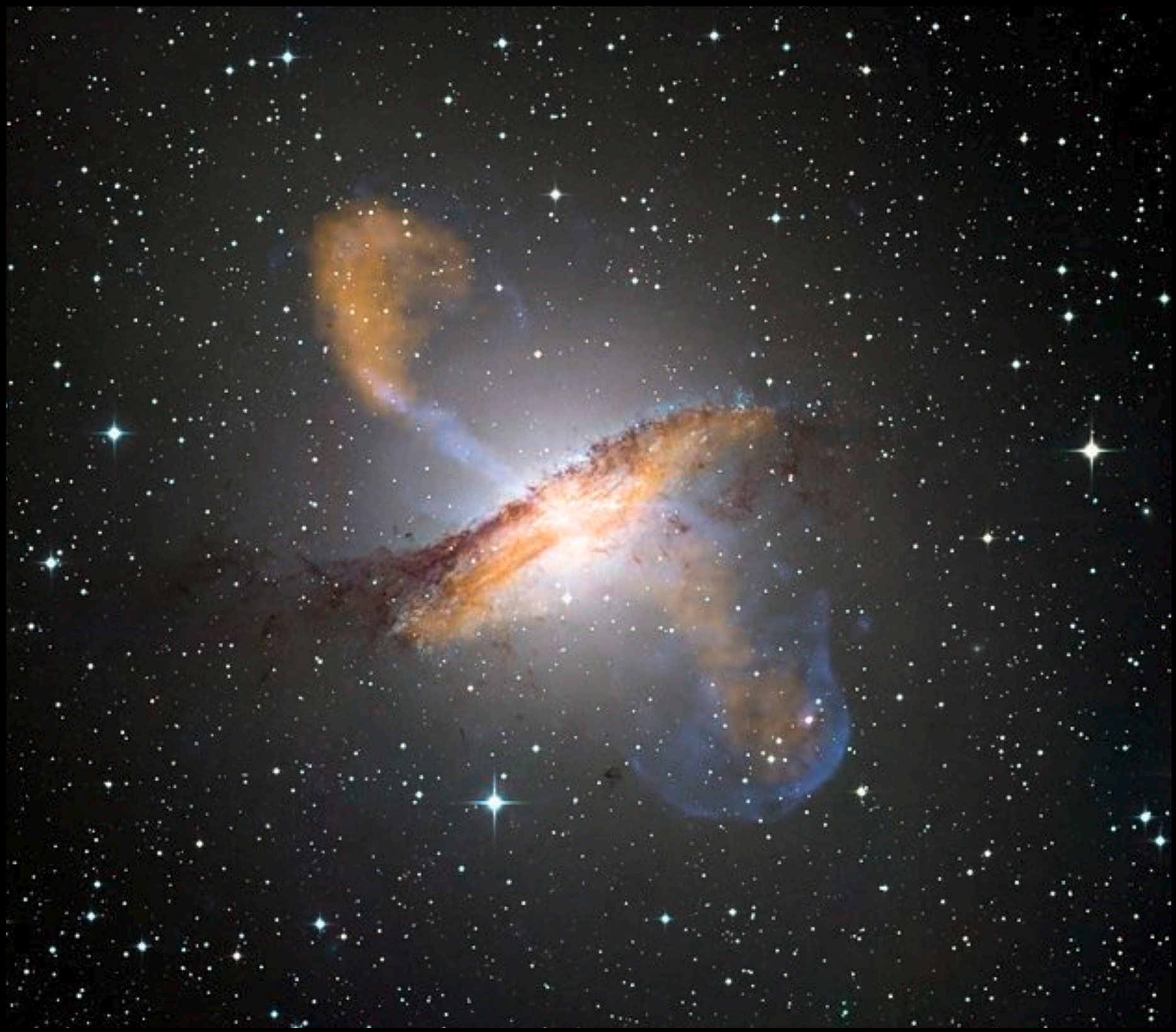






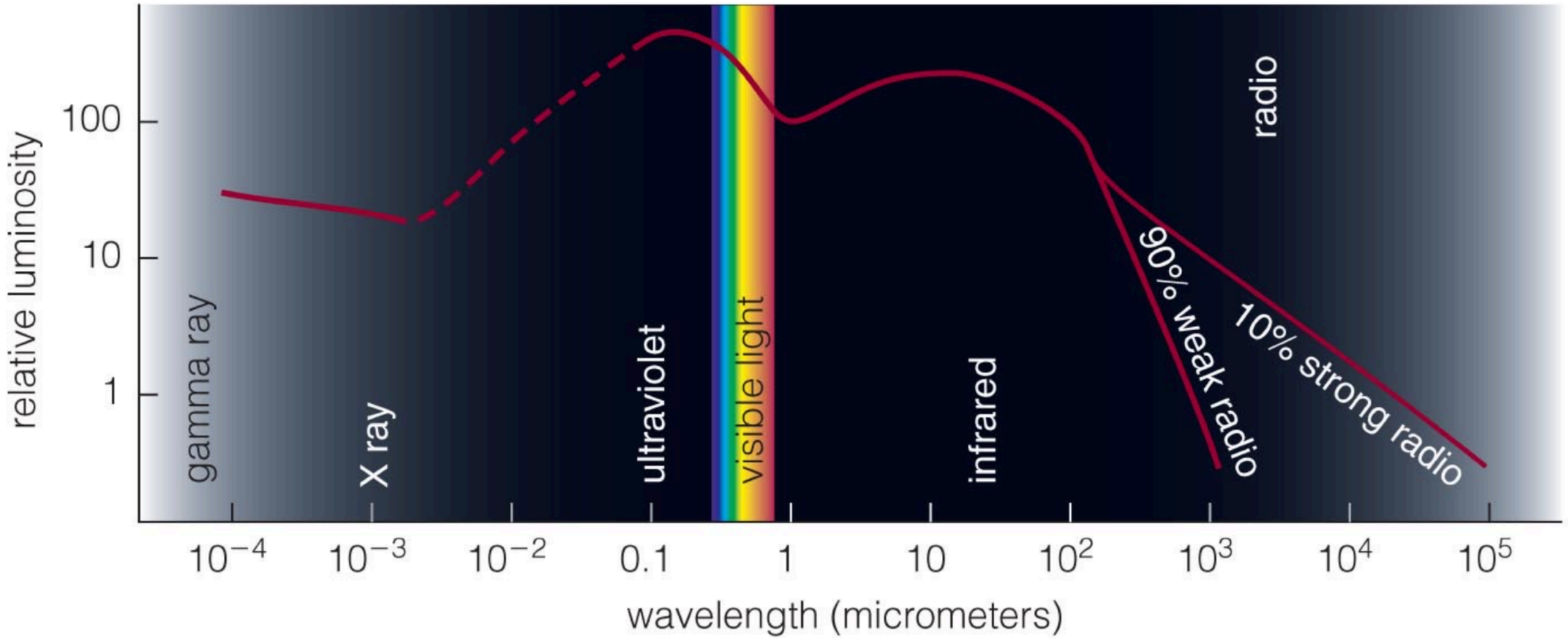
Slide adapted from Sylvain Veilleux

Active Galactic Nuclei (AGN)

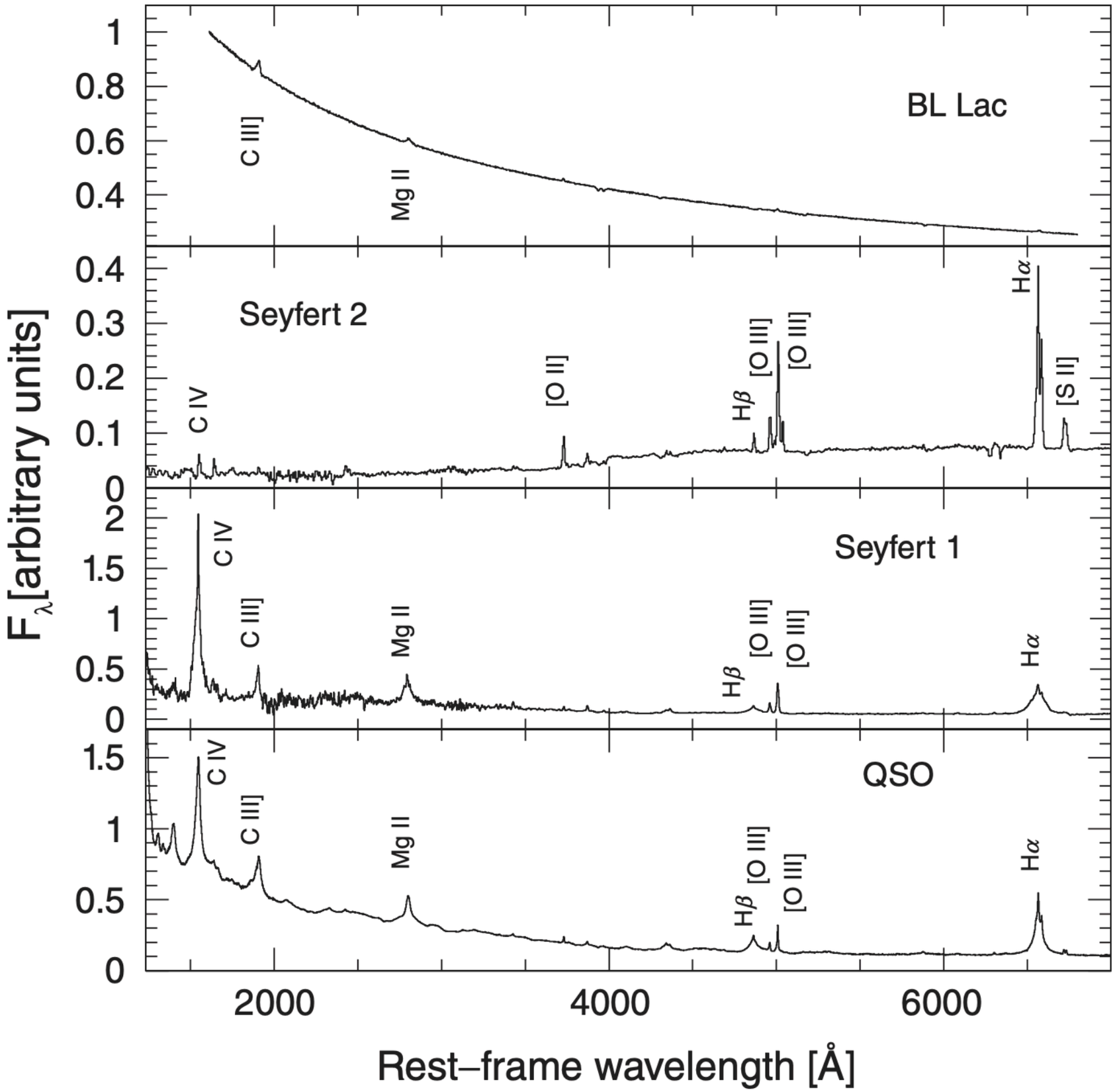


Centaurus A • ESO / NASA / MPIfR

AGN spectrum



AGN spectra



CFN §3.6

AGN classes

table 27-2 Properties of Active Galactic Nuclei (AGNs)

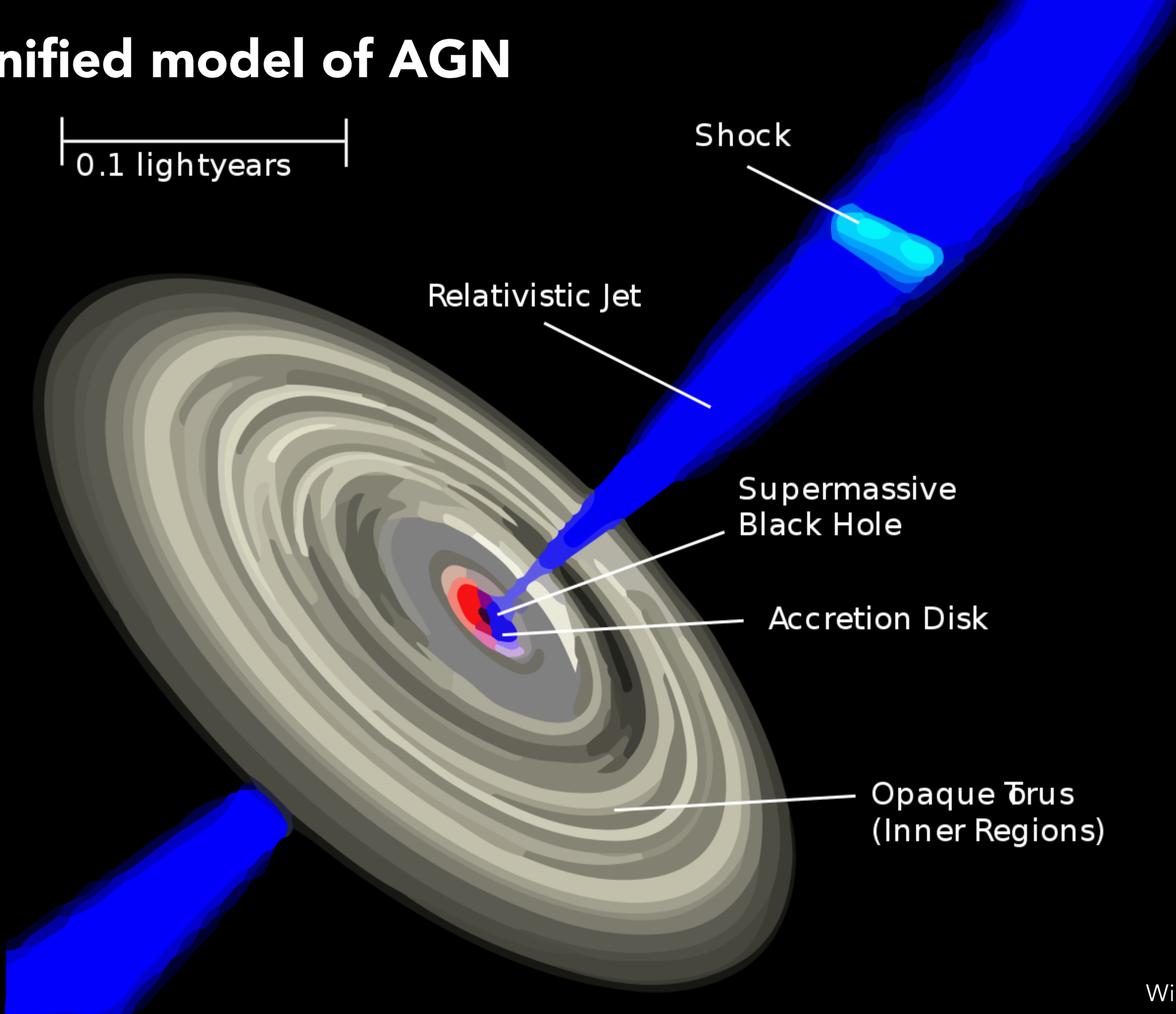
Object	Found in which type of galaxy	Strength of radio emission	Type of emission lines in spectrum	Luminosity (watts)	Luminosity (Milky Way Galaxy = 1)
Blazar	Elliptical	Strong	Weak (compared to synchrotron emission)	10^{38} to 10^{42}	10 to 10^{5}
Radio-loud quasar	Elliptical	Strong	Broad	10^{38} to 10^{42}	10 to 10^{5}
Radio galaxy	Elliptical	Strong	Narrow	10^{36} to 10^{38}	0.1 to 10
Radio-quiet quasar	Spiral or elliptical	Weak	Broad	10^{38} to 10^{42}	10 to 10^{5}
Seyfert 1	Spiral	Weak	Broad	10^{36} to 10^{38}	0.1 to 10
Seyfert 2	Spiral	Weak	Narrow	10^{36} to 10^{38}	0.1 to 10

Table by Tommaso Treu

$M_{\mathrm{BH}} \approx 10^8 M_\odot$

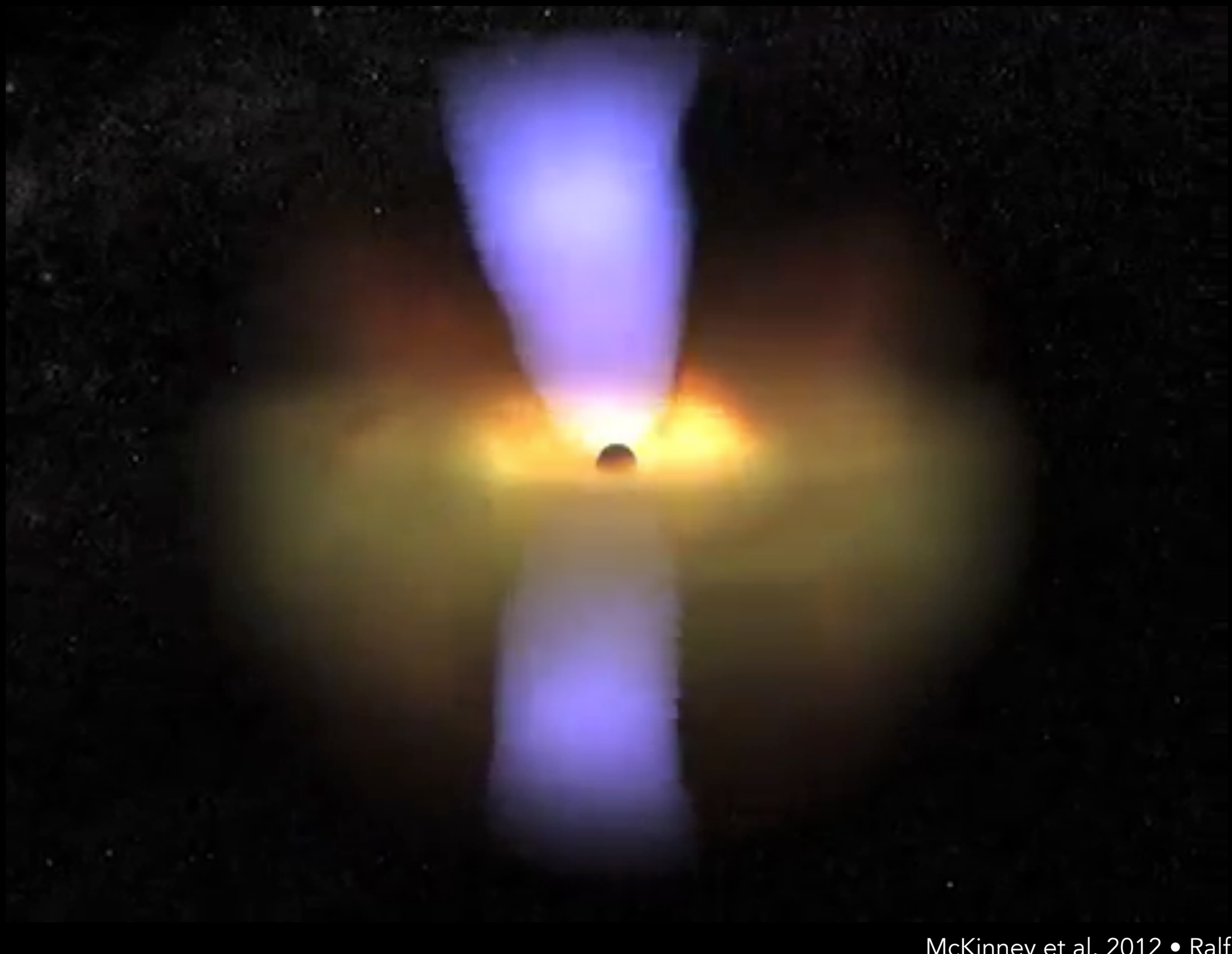
Interstellar

Unified model of AGN



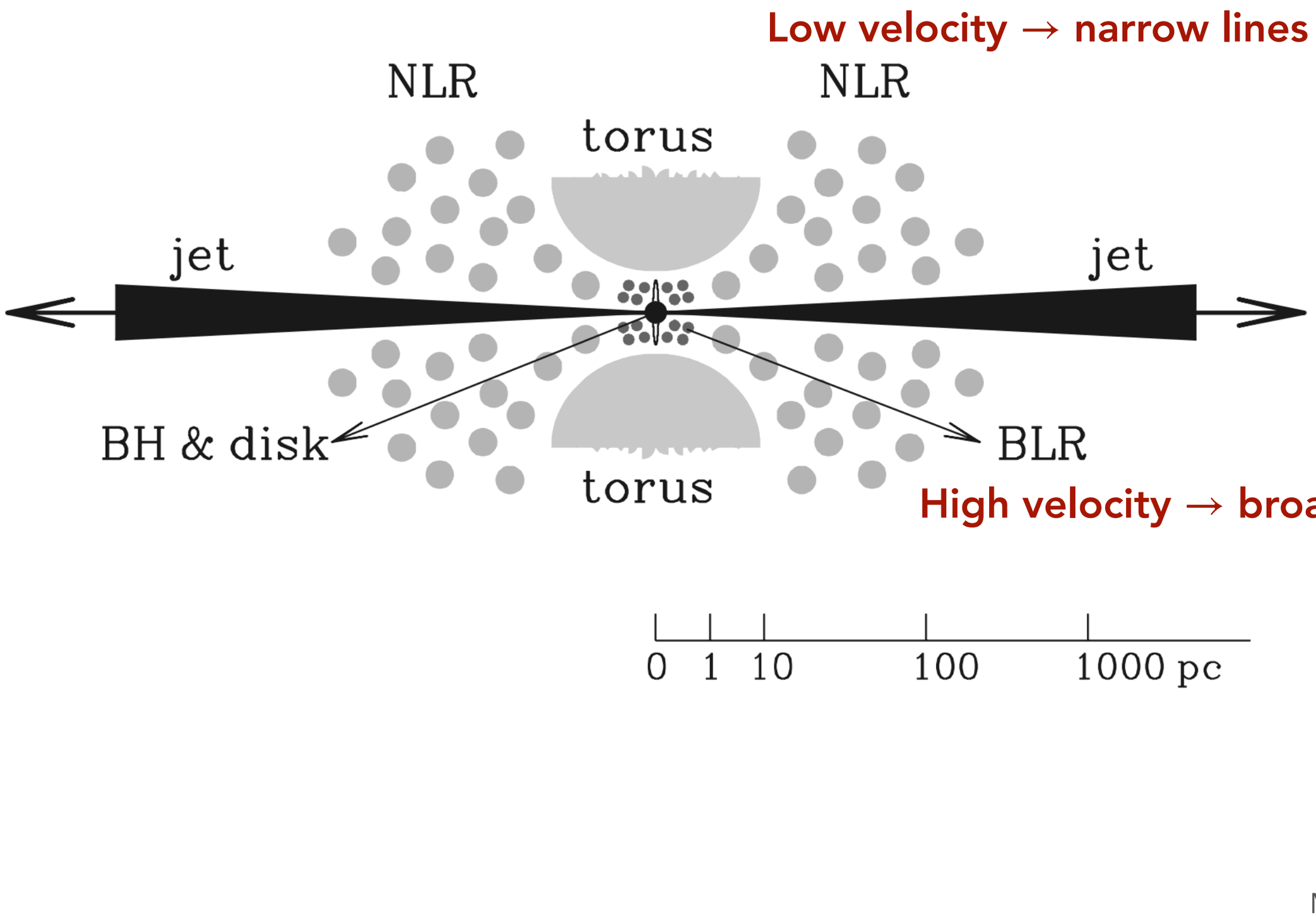
Wikipedia

Active Galactic Nucleus (simulation)



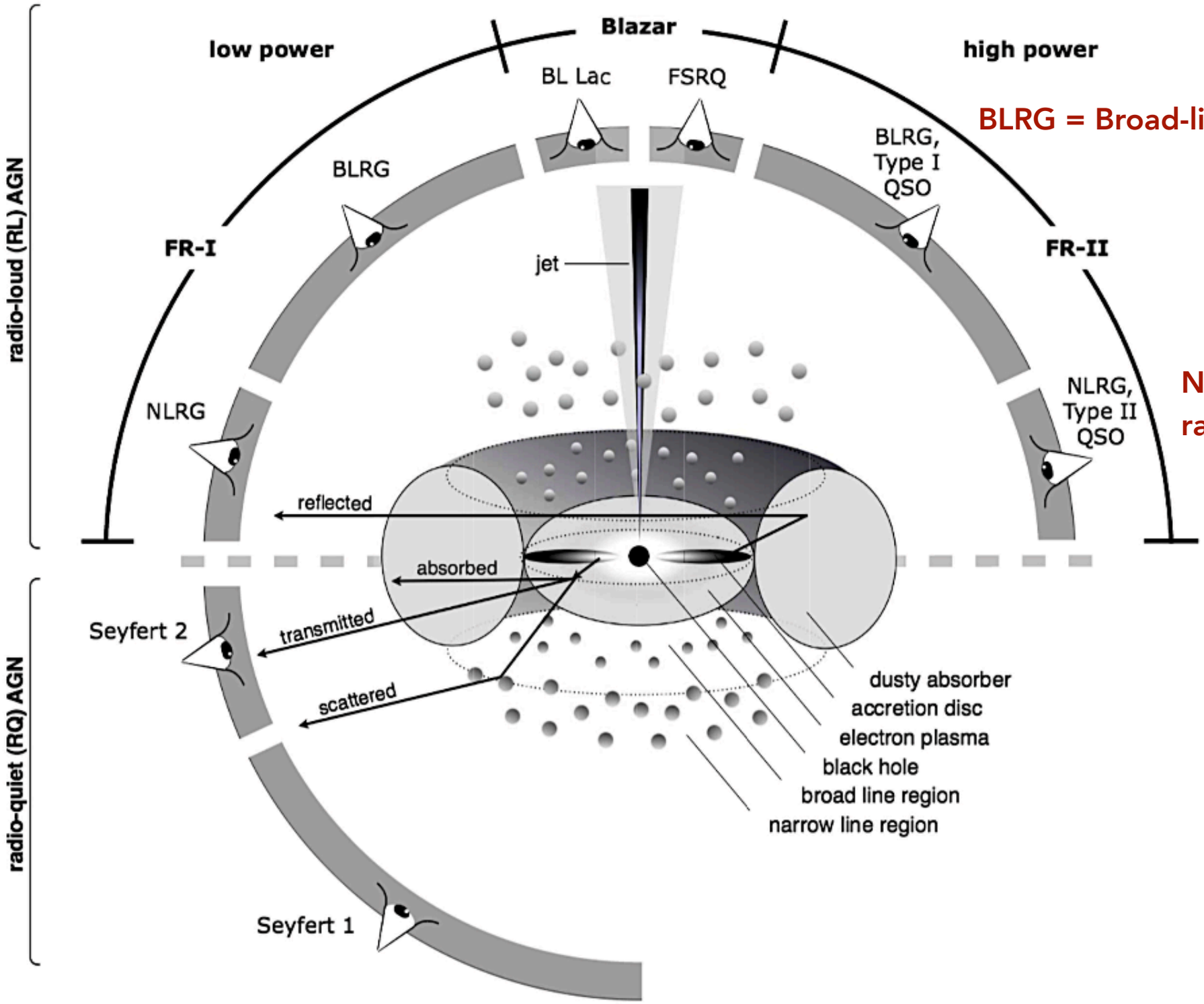
McKinney et al. 2012 • Ralf Kaehler

Unified model of AGN



MBW §14.2

Unified model of AGN



BLRG = Broad-line radio galaxy

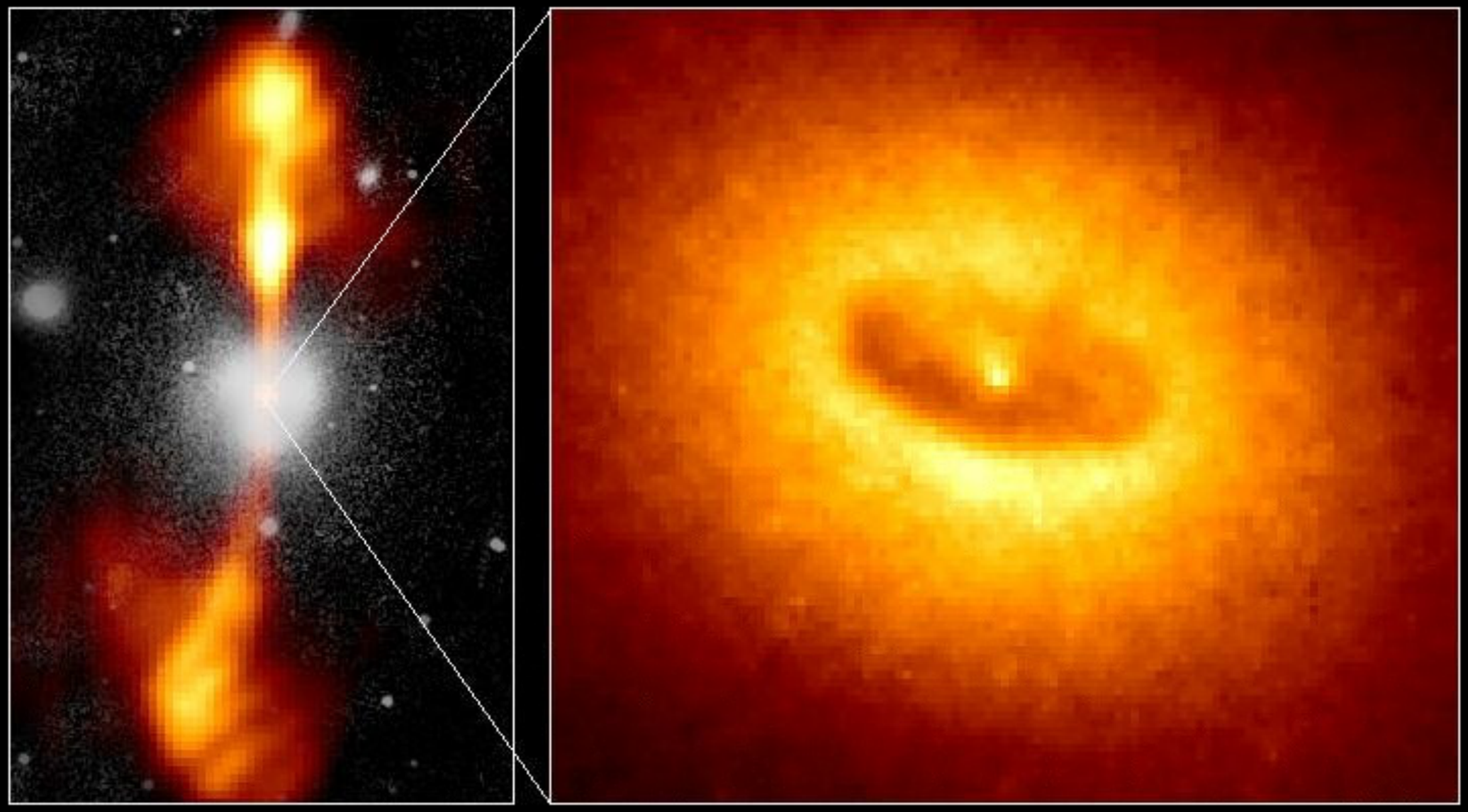
NLRG = Narrow-line radio galaxy

Beckmann & Shrader 2012

NGC 4261

Radio/optical

HST

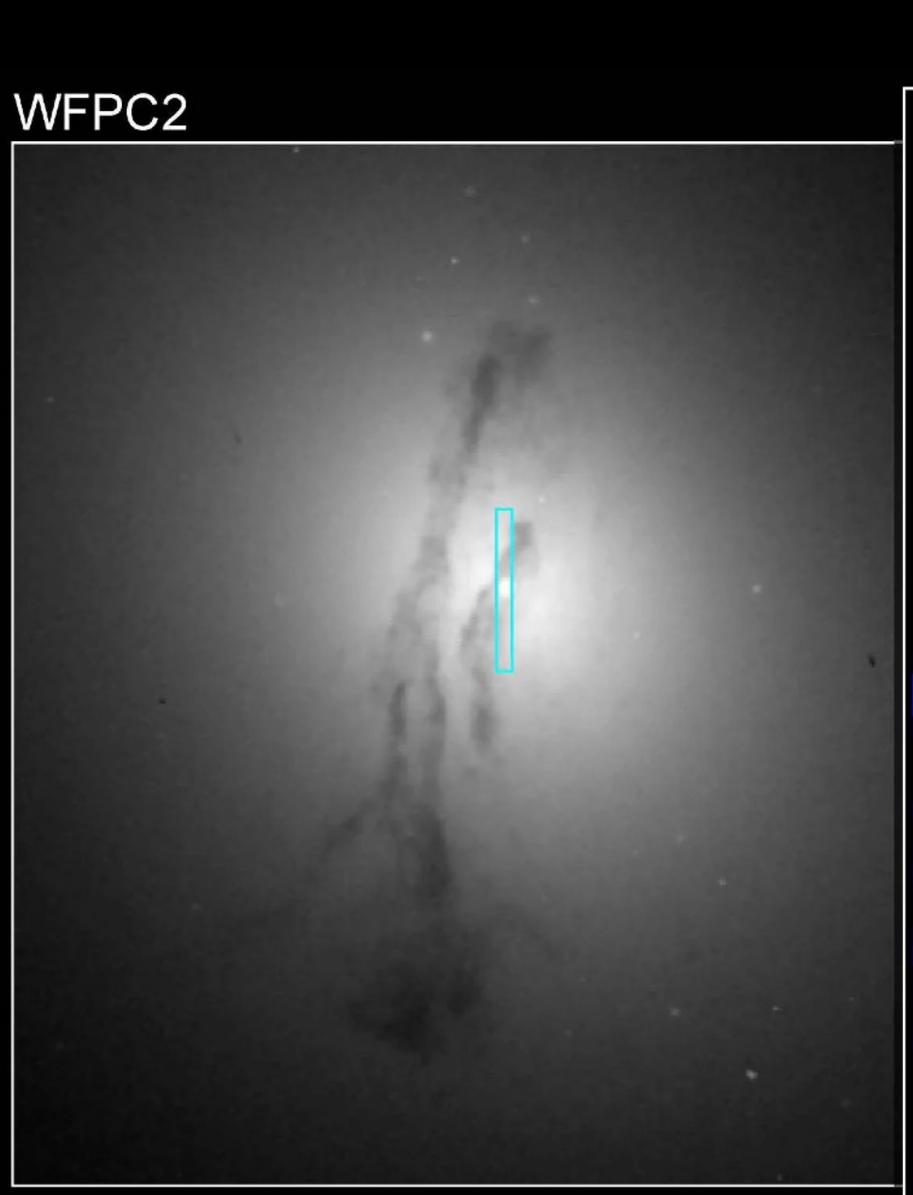


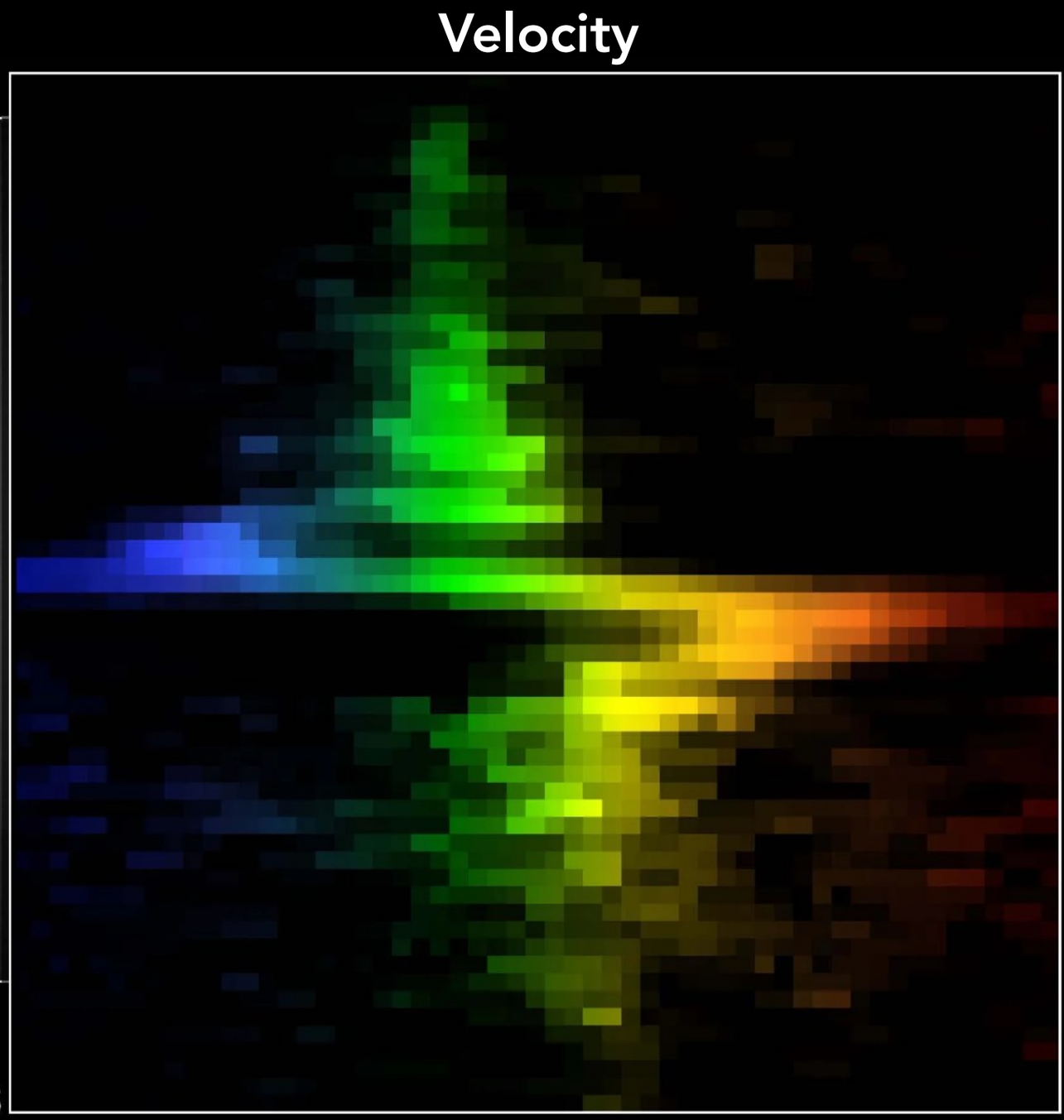
30,000 pc

120 pc

Slide adapted from Sylvain Veilleux

M84

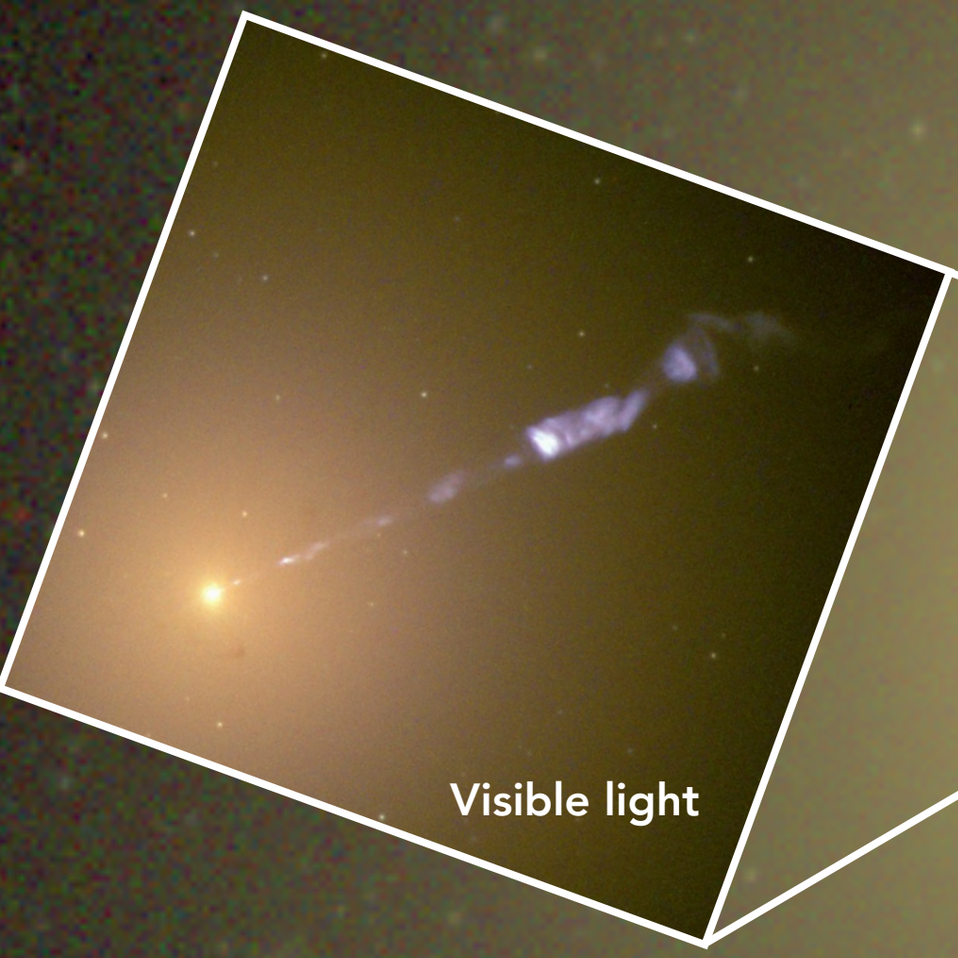


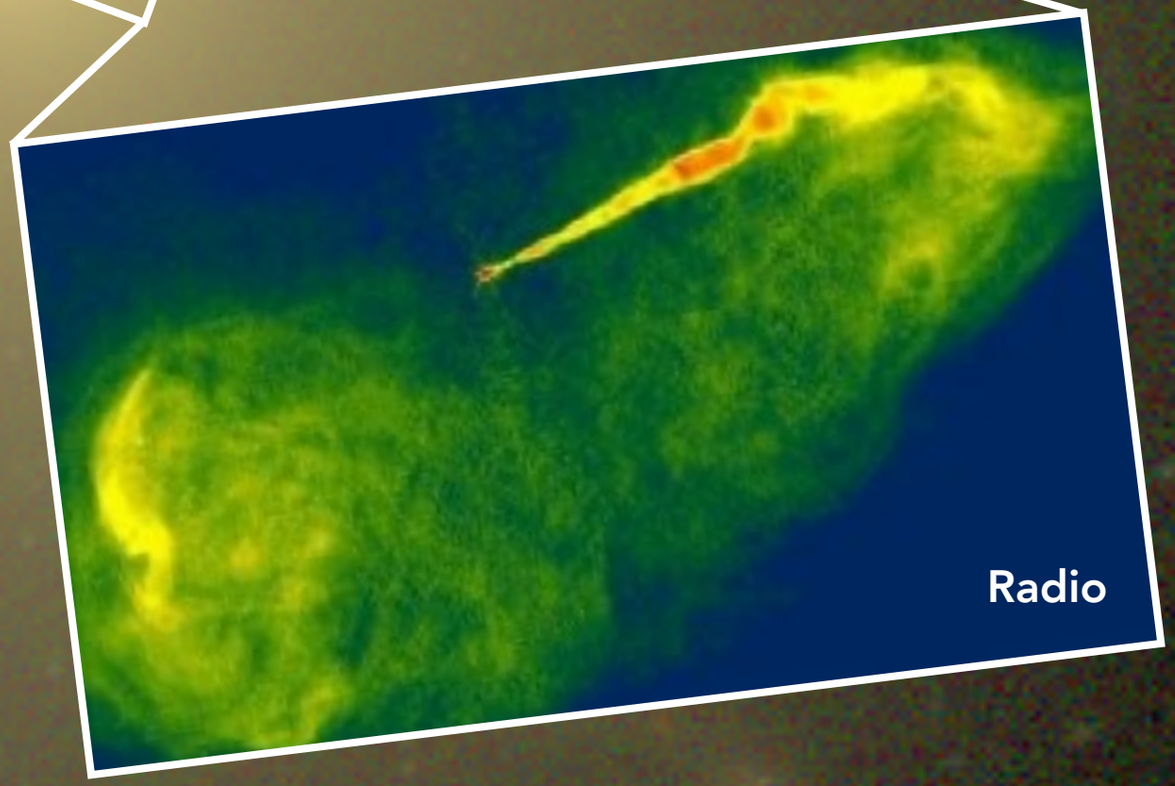


Slide adapted from Sylvain Veilleux

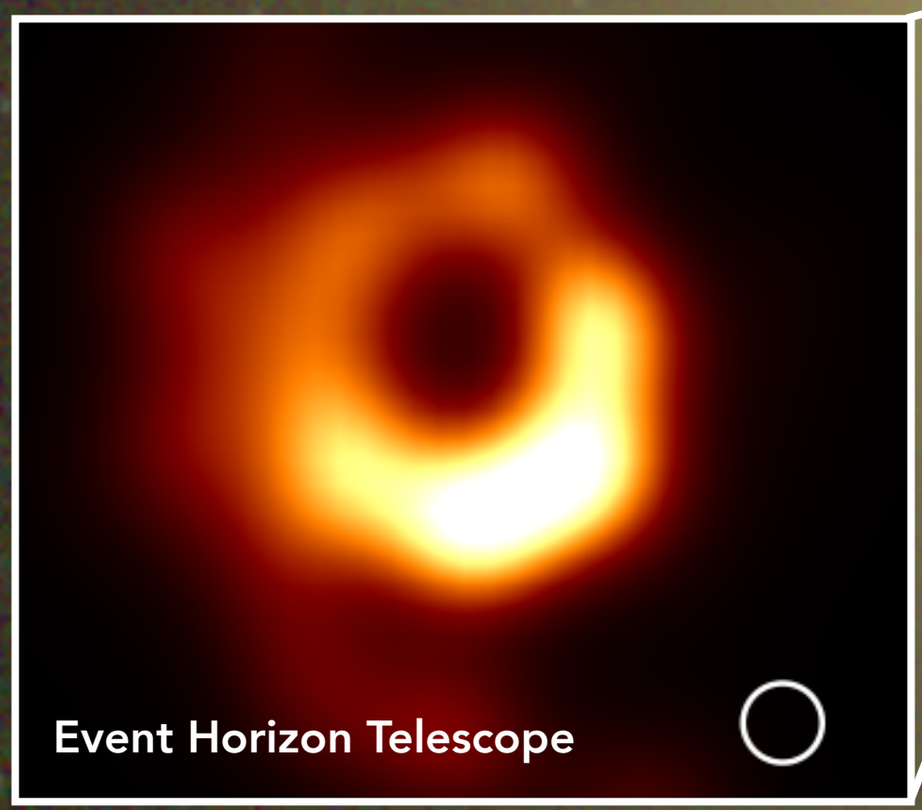
The AGN in M87

The AGN in M87

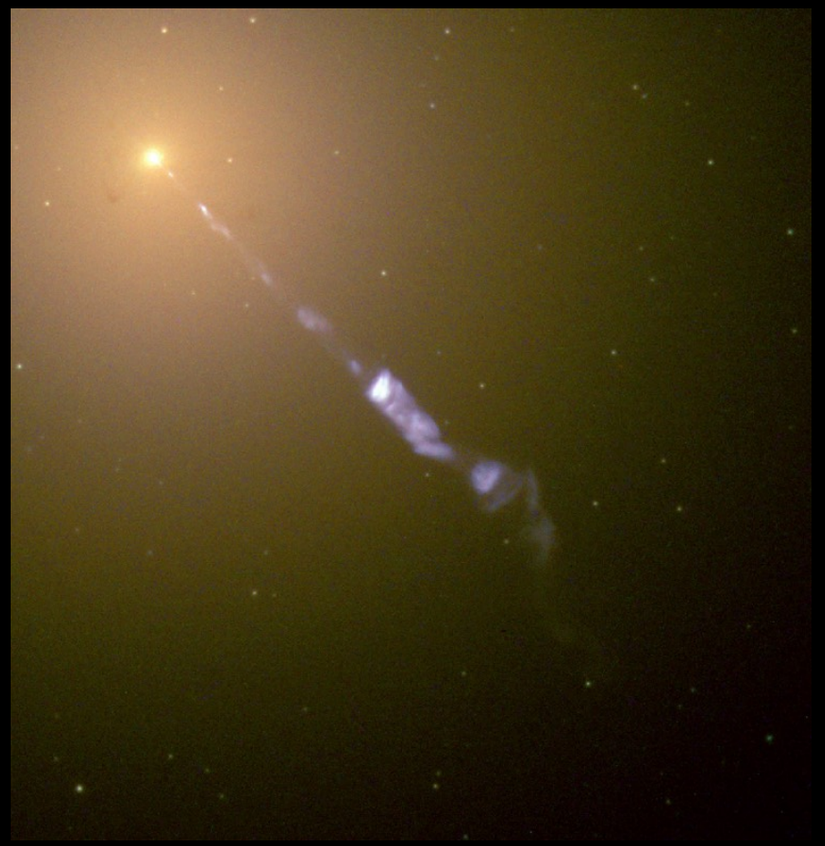




The AGN in M87

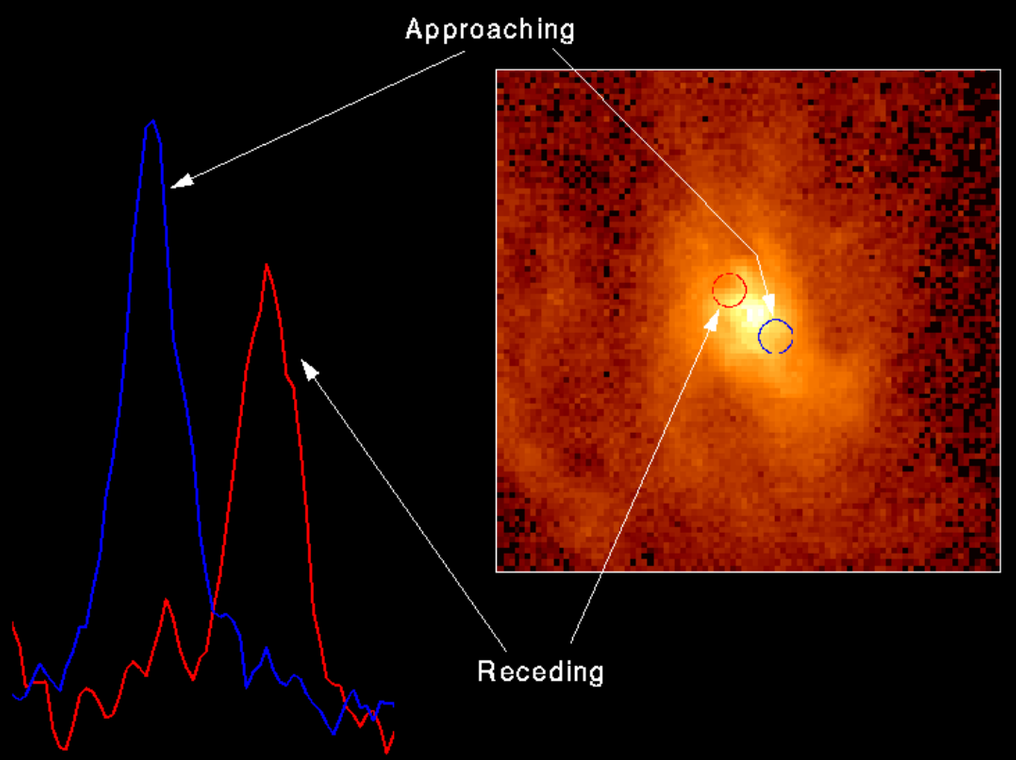


The AGN in M87



Visible light (HST)

- Jet moves with at least 90% of the speed of light
- Need a 6 billion solar mass black hole to explain gas disk velocities (and other observations)

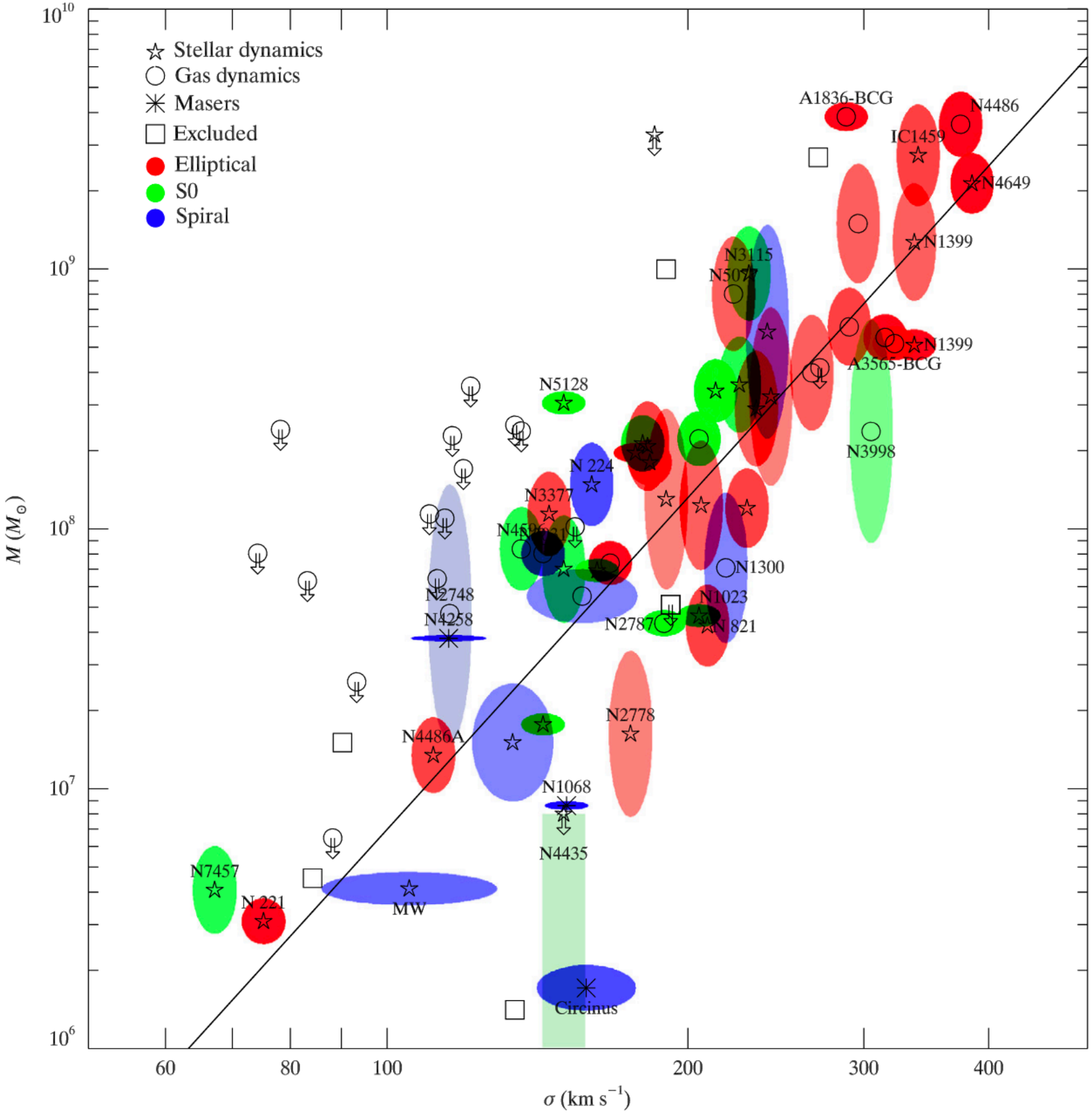


Abundance of AGN

Type of object	Number density [Mpc^{-3}]
Field galaxies	10^{-1}
Luminous spirals	10^{-2}
Seyfert galaxies	10^{-4}
Radio galaxies	10^{-6}
QSOs	10^{-7}
Radio-loud quasars	10^{-9}

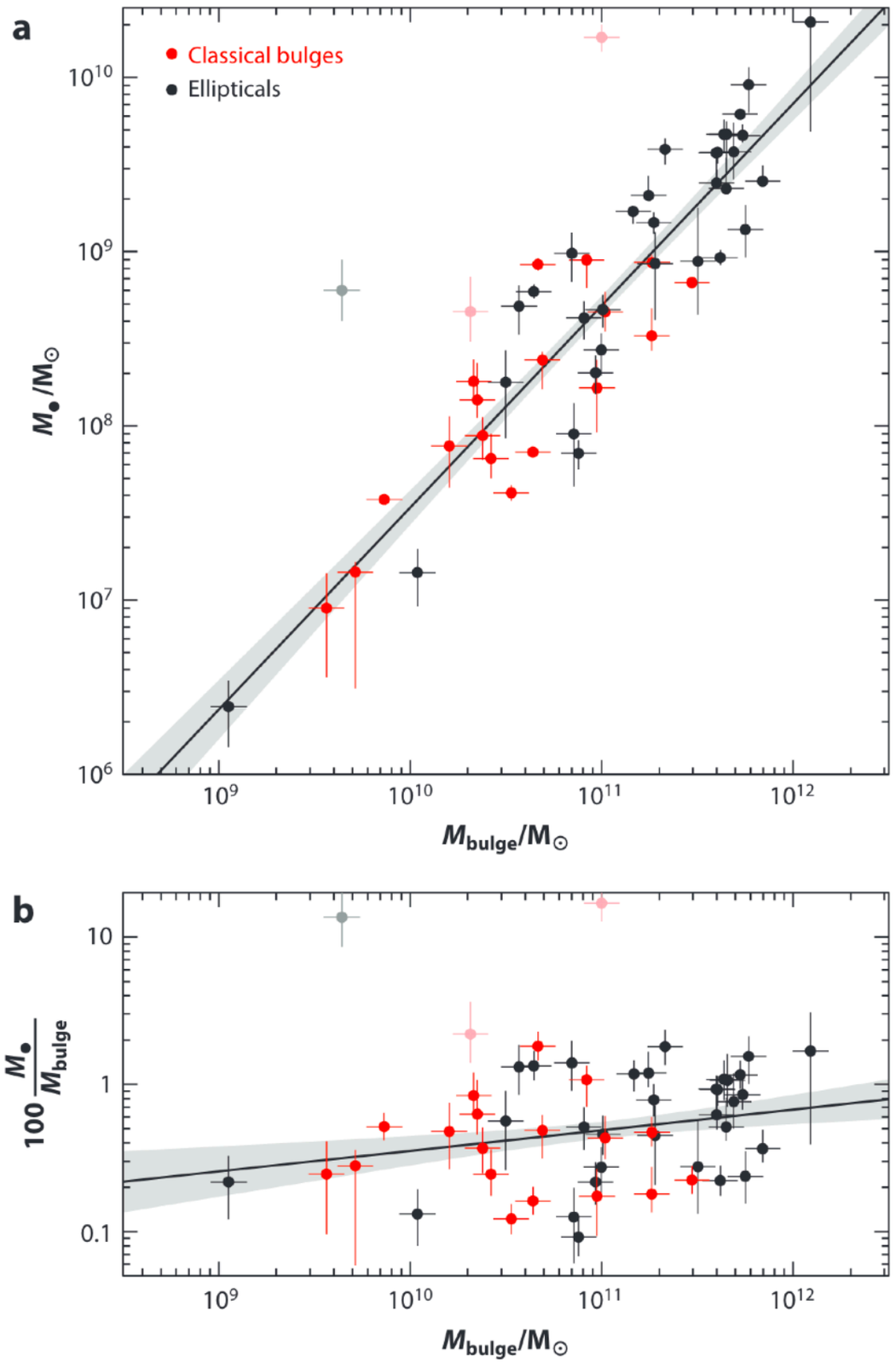
§9.2 • The growth of black holes

The bulge-black hole relation



Gültekin et al. 2009

The bulge-black hole relation



Kormendy & Ho 2013

z =10.0

$M_{BH} = 10^5 M_\odot$
$M_{BH} = 10^6 M_\odot$
$M_{BH} = 10^7 M_\odot$
$M_{BH} = 10^8 M_\odot$
$M_{BH} = 10^9 M_\odot$

6 Mpc/h

z = 7.5

6 Mpc/h

z = 6.5

6 Mpc/h

z = 4.0

6 Mpc/h

z = 3.0

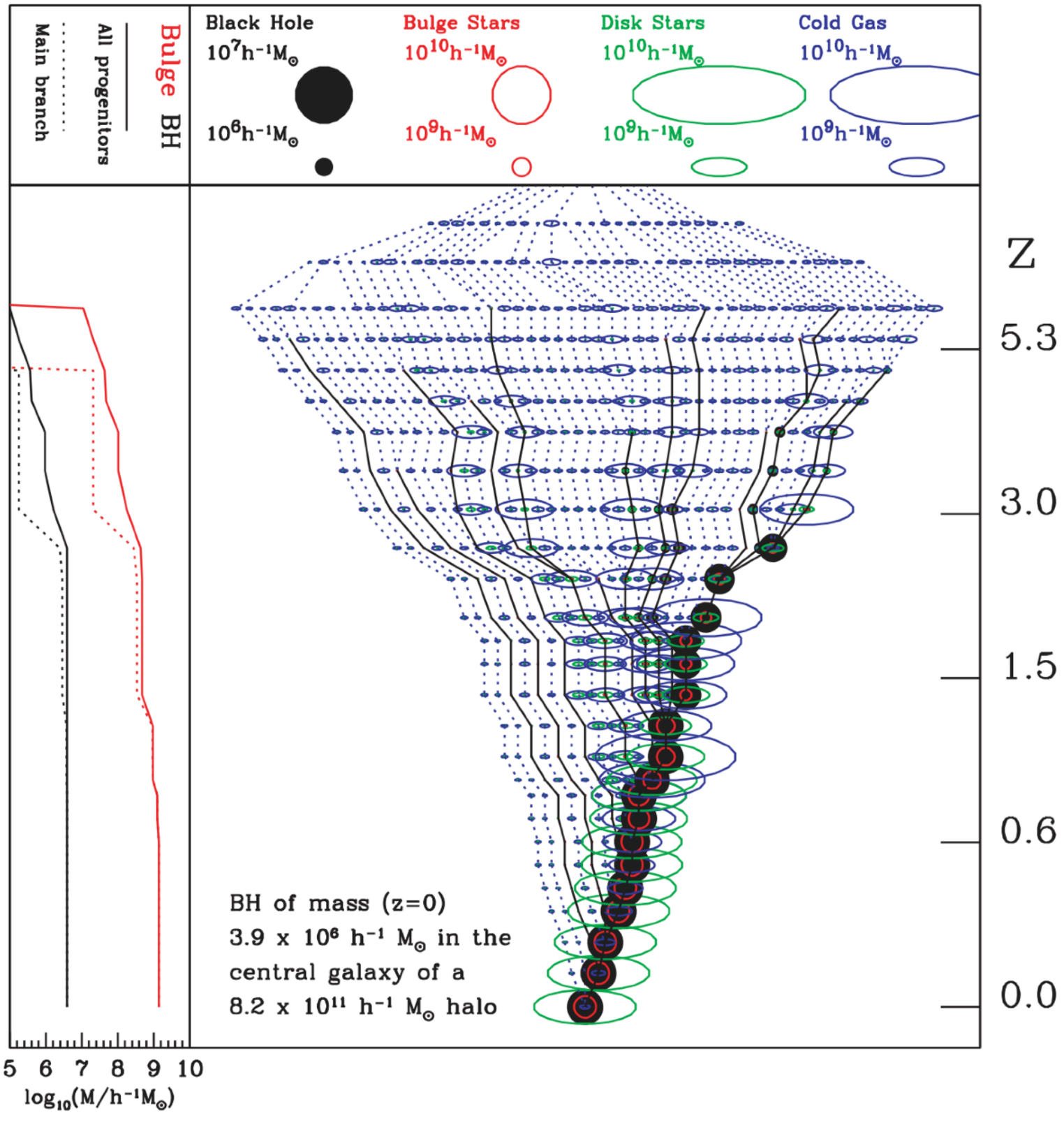
6 Mpc/h

z = 2.0

6 Mpc/h

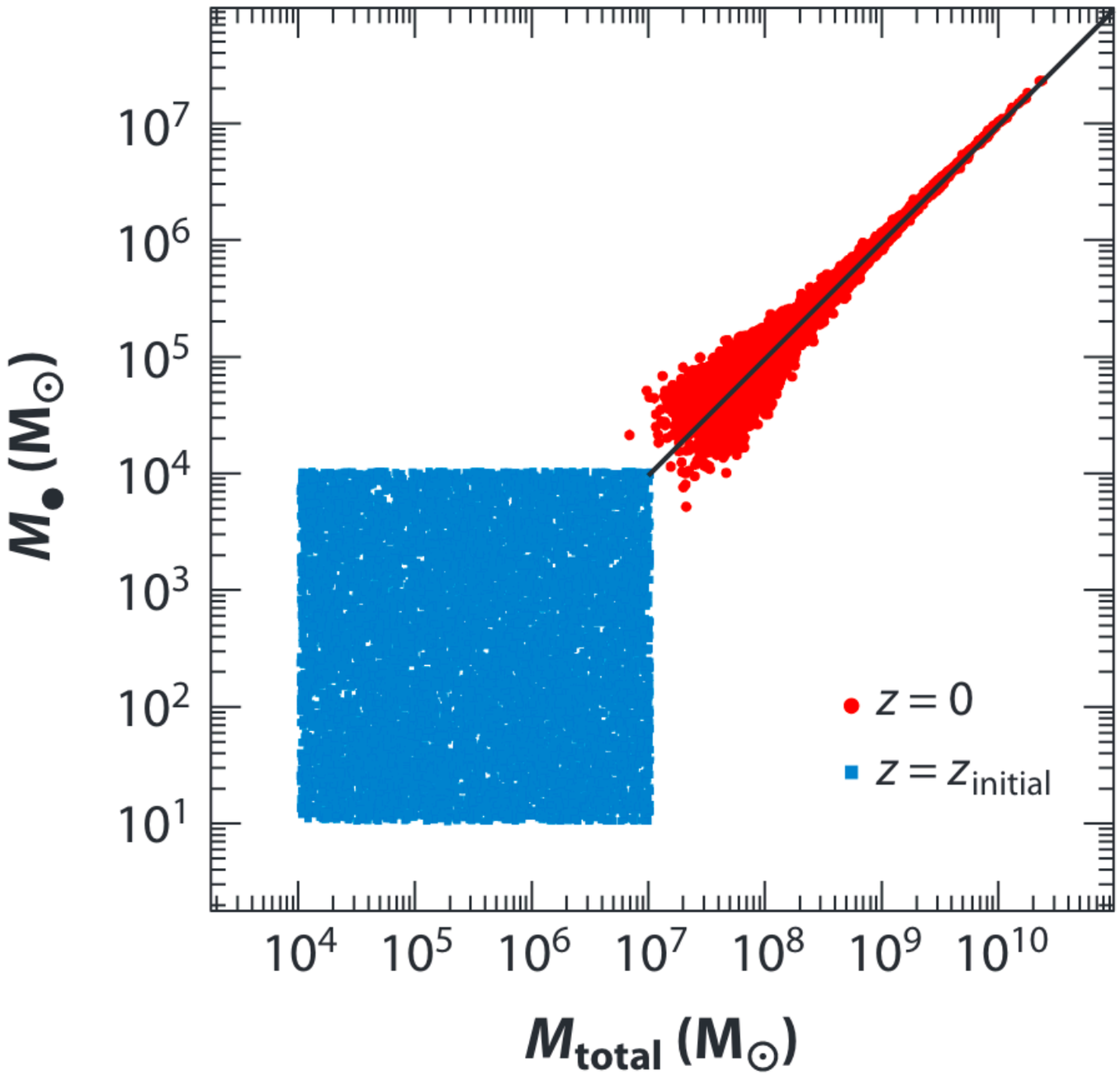
Simulation & Visualization by Tiziana di Matteo

The halo-black hole relation



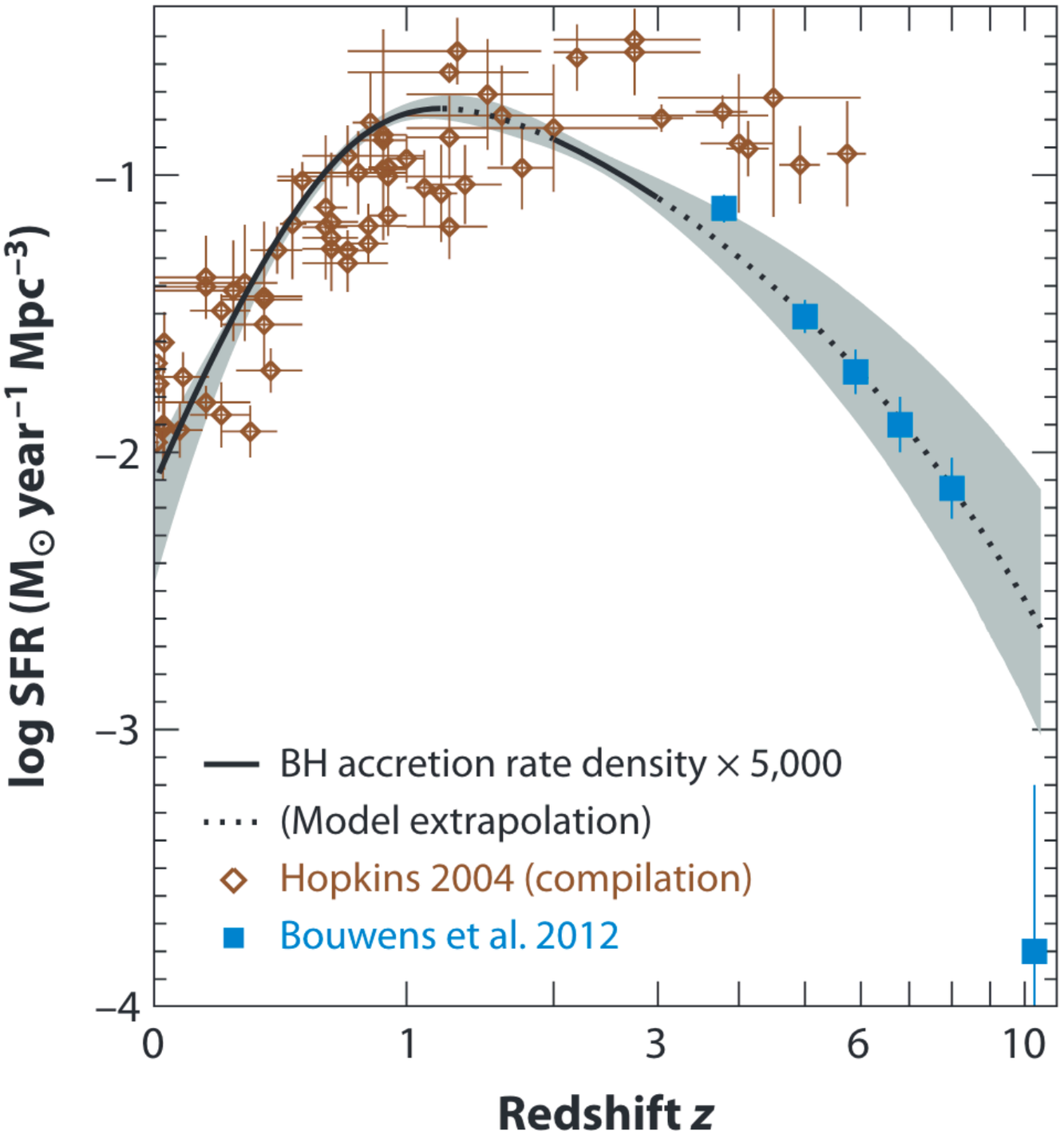
Malbon et al. 2007

The halo-black hole relation



Kormendy & Ho 2013

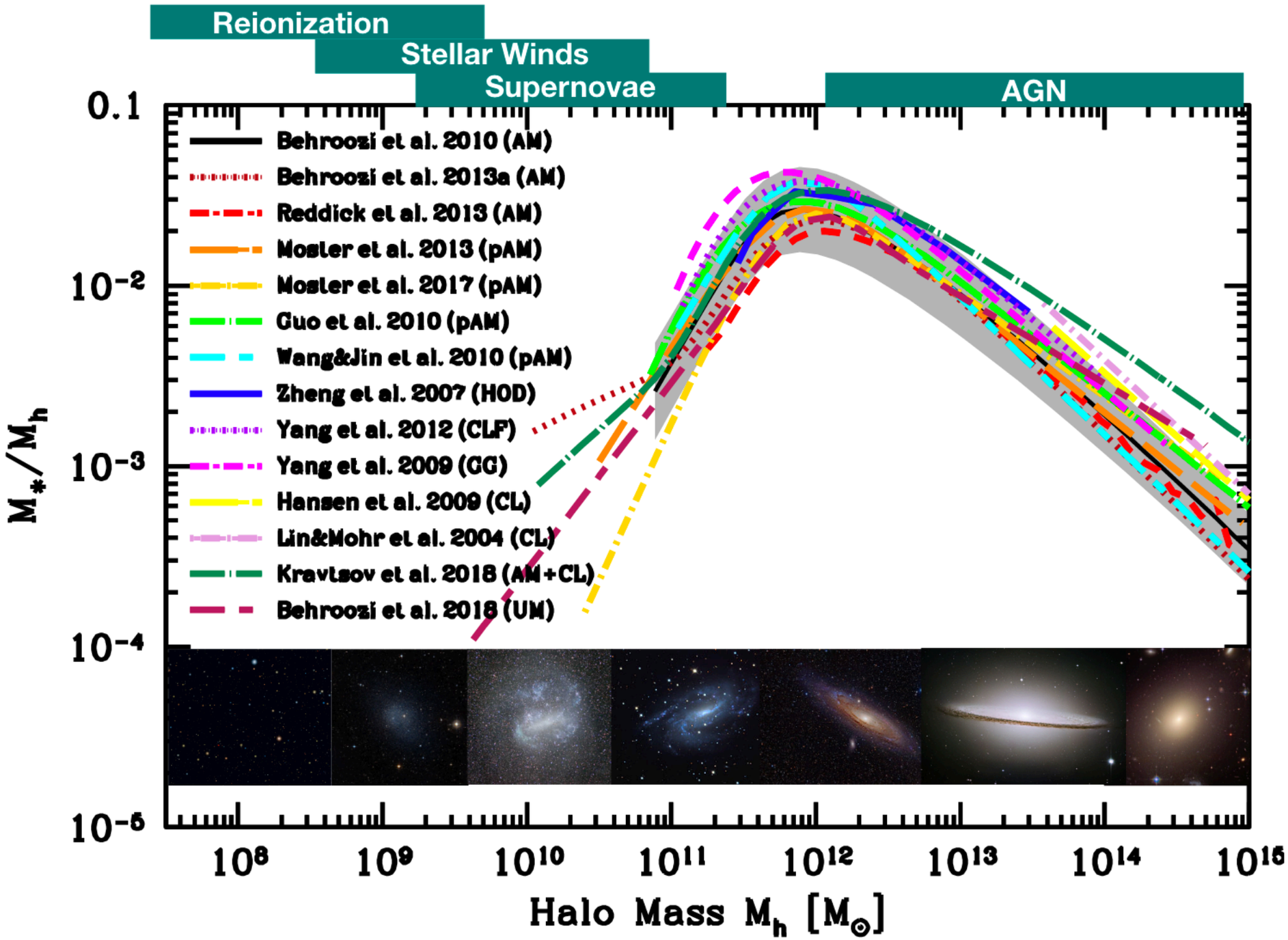
Cosmological growth of BH population



Kormendy & Ho 2013

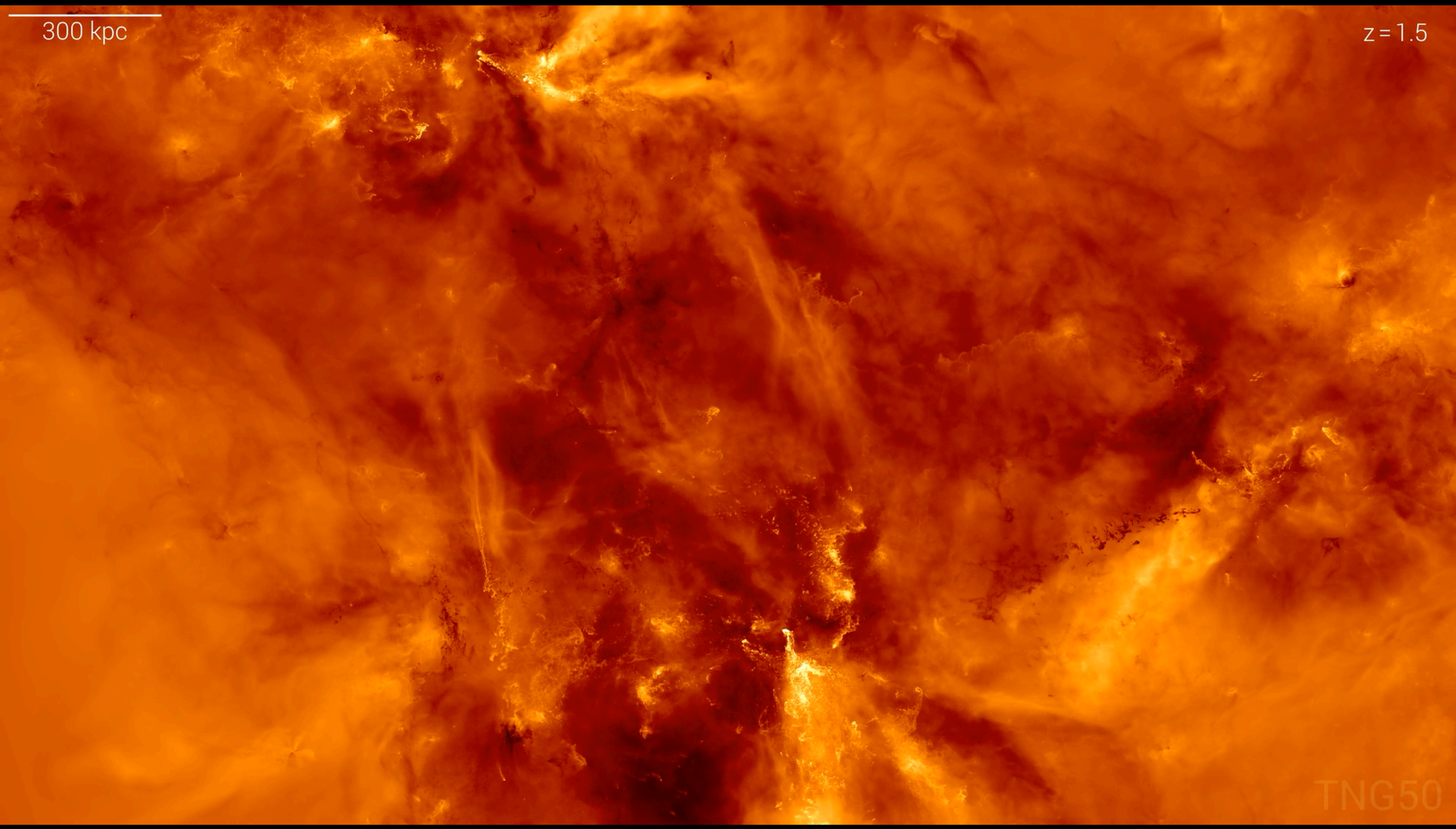
§9.3 • AGN feedback

AGN feedback impact on the SHMR



Wechler & Tinker 2018

Gas flows around forming galaxies (simulation)

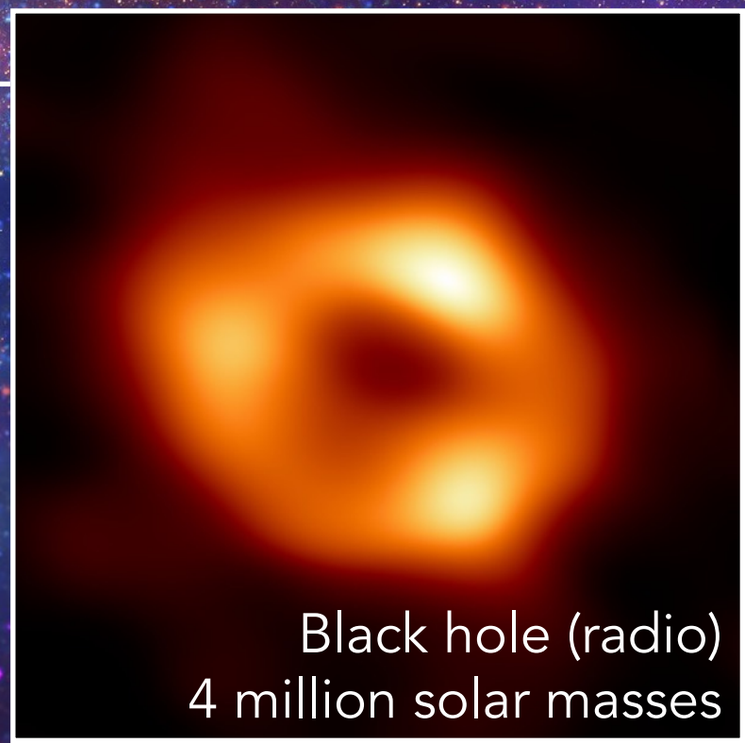


Illustris TNG50 Simulation • Pillepich et al. 2019 • Nelson et al. 2019 • movie page

The Galactic Center

About 200 ly

Infrared (yellow/red) and X-rays (blue/purple)



Black hole (radio)
4 million solar masses

Recap: Stars around the central black hole

1995.5

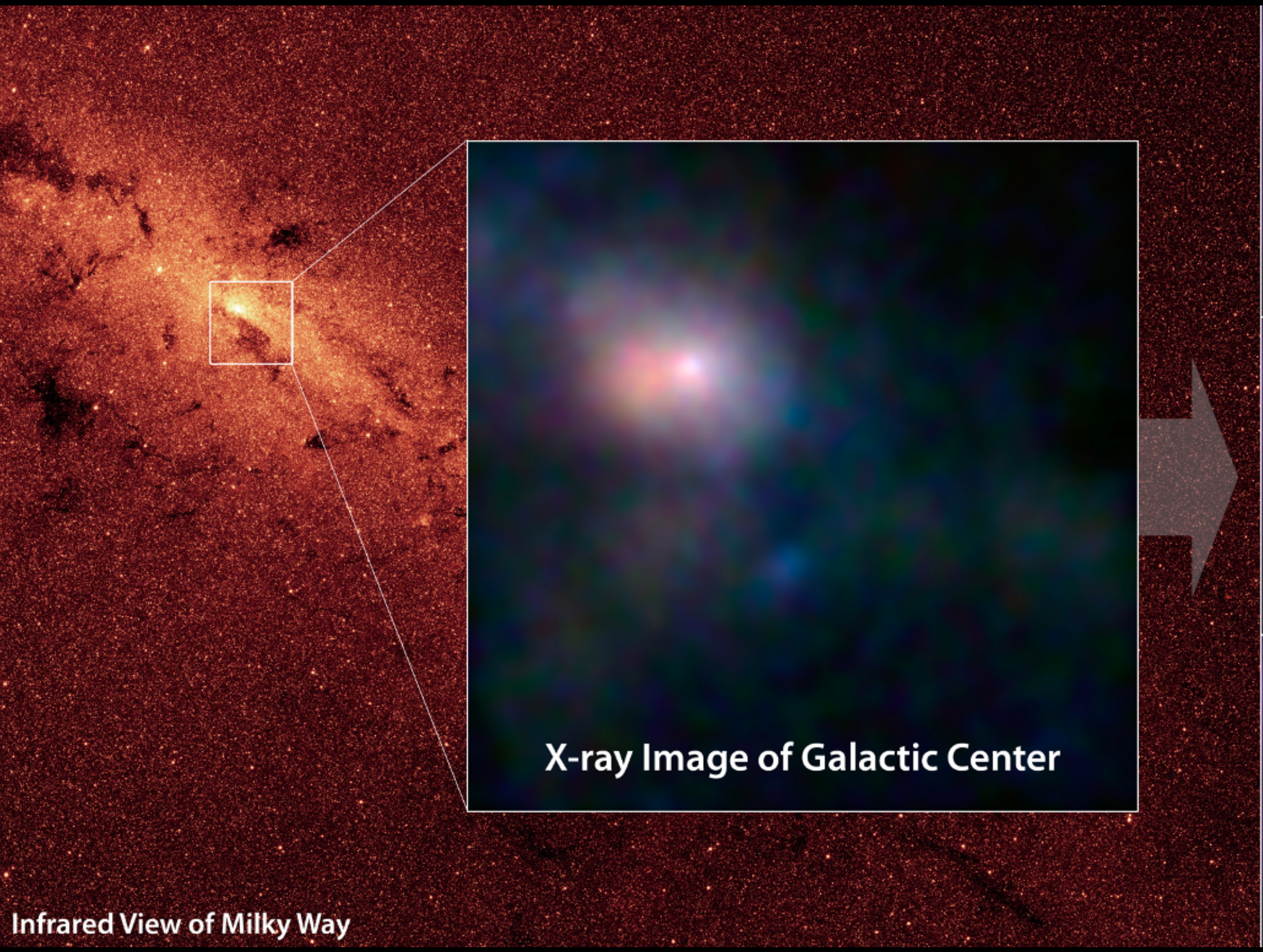
S0-16
S0-2
S0-53
S0-3
S0-7
S0-1
S0-26
S0-40
S0-38
S0-19
S0-102
S0-37
S0-45
S0-4
S0-49
S0-17
S0-20
S0-5
S0-30

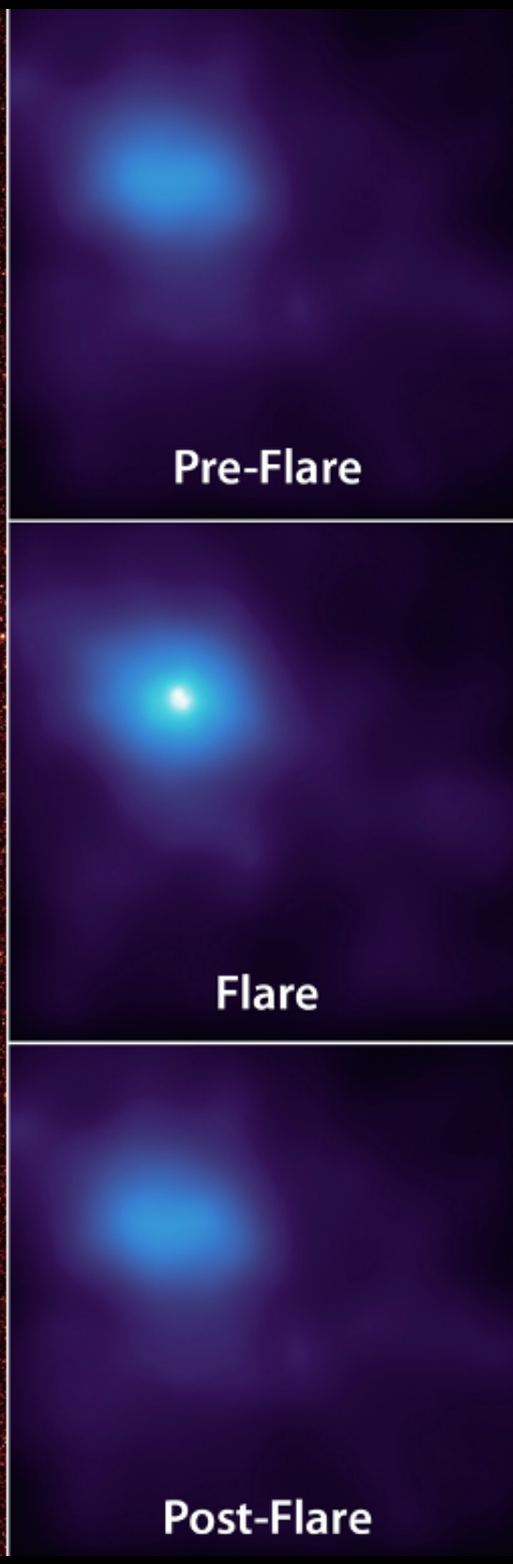
0.1"

UCLA Galactic
nter Group

Andrea Ghez / UCLA Galactic Center Group

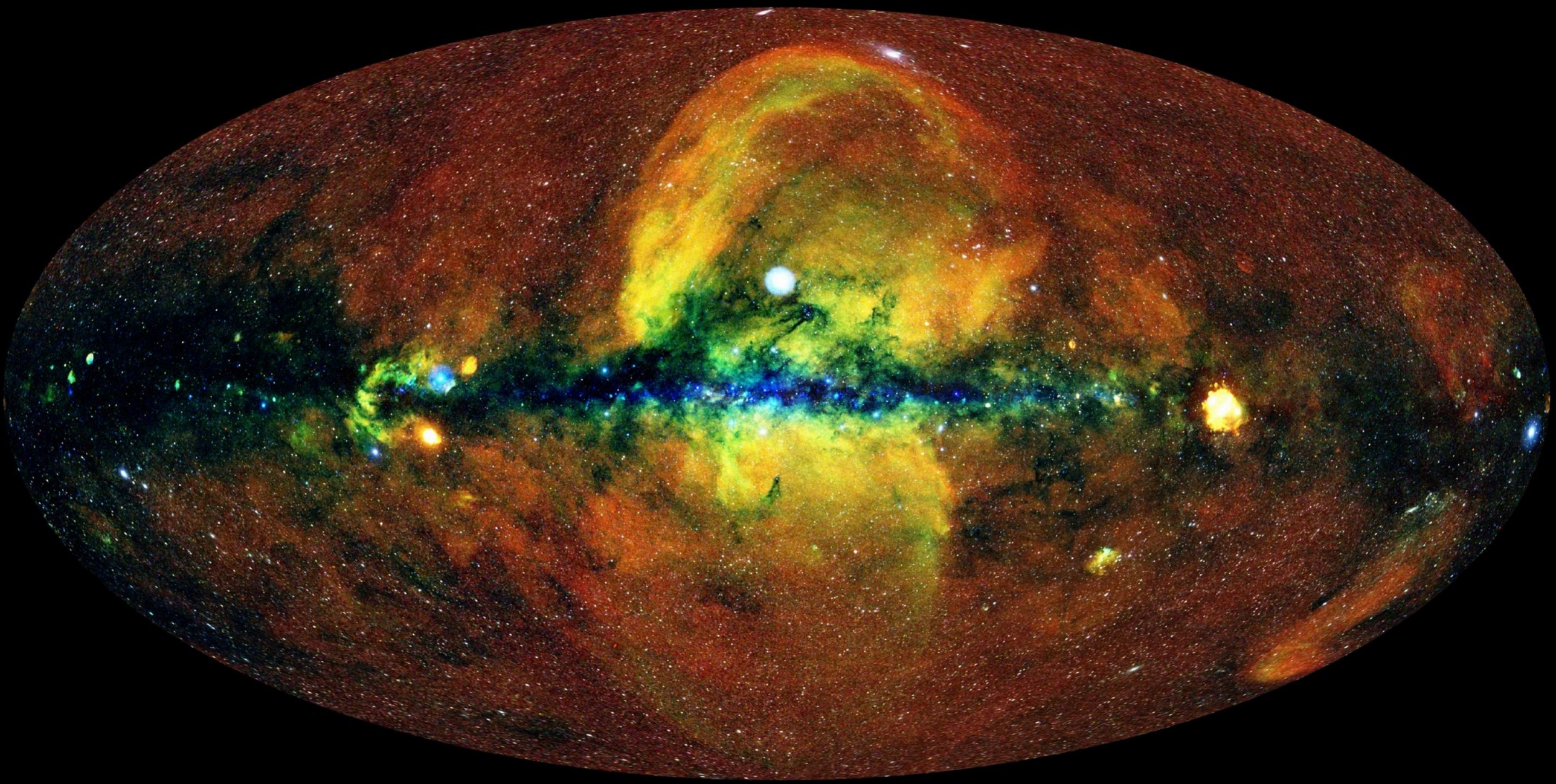
The Galactic Center





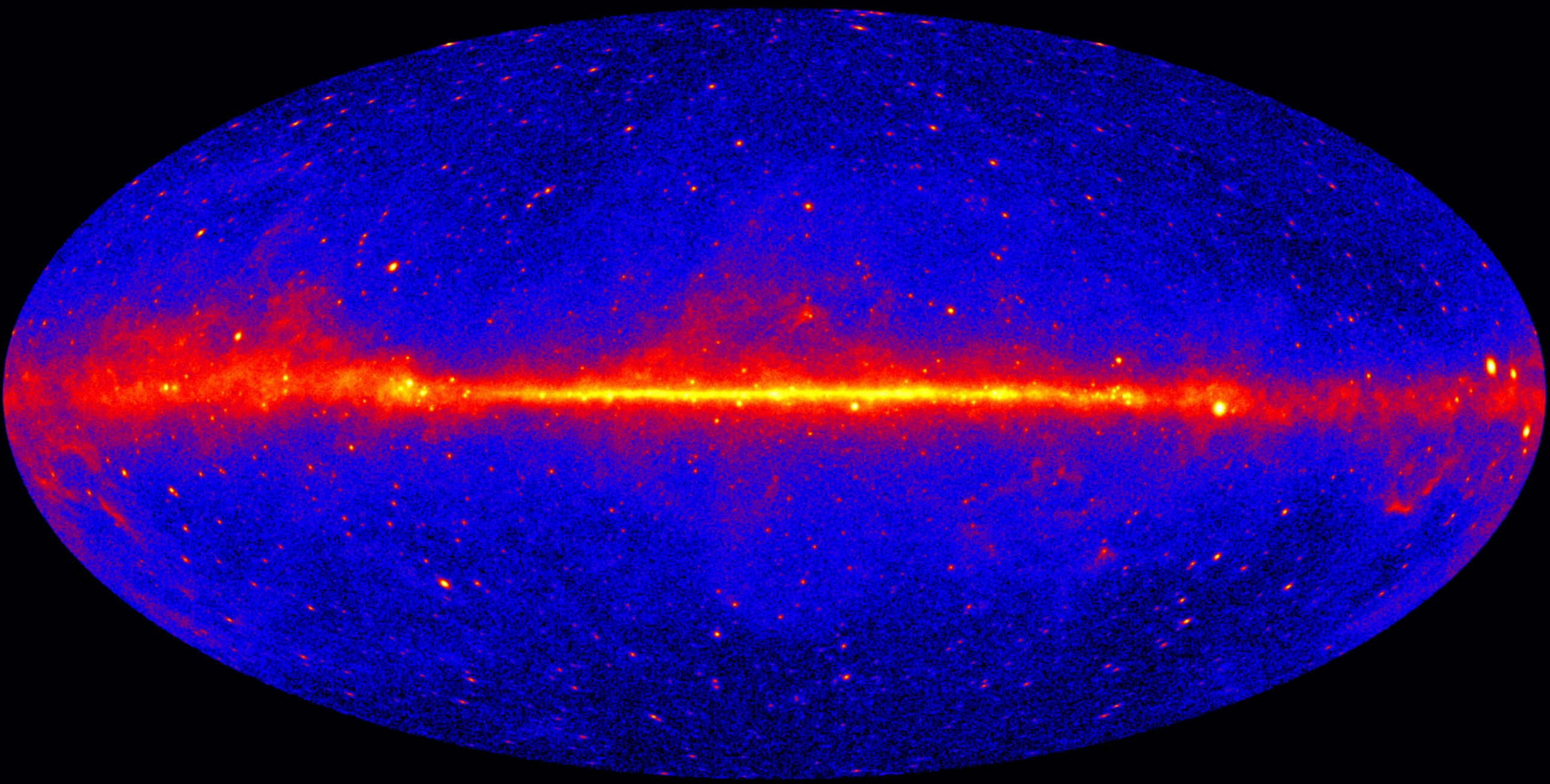
Slide adapted from Sylvain Veilleux

0.5-4 nm / X-rays / very hot gas



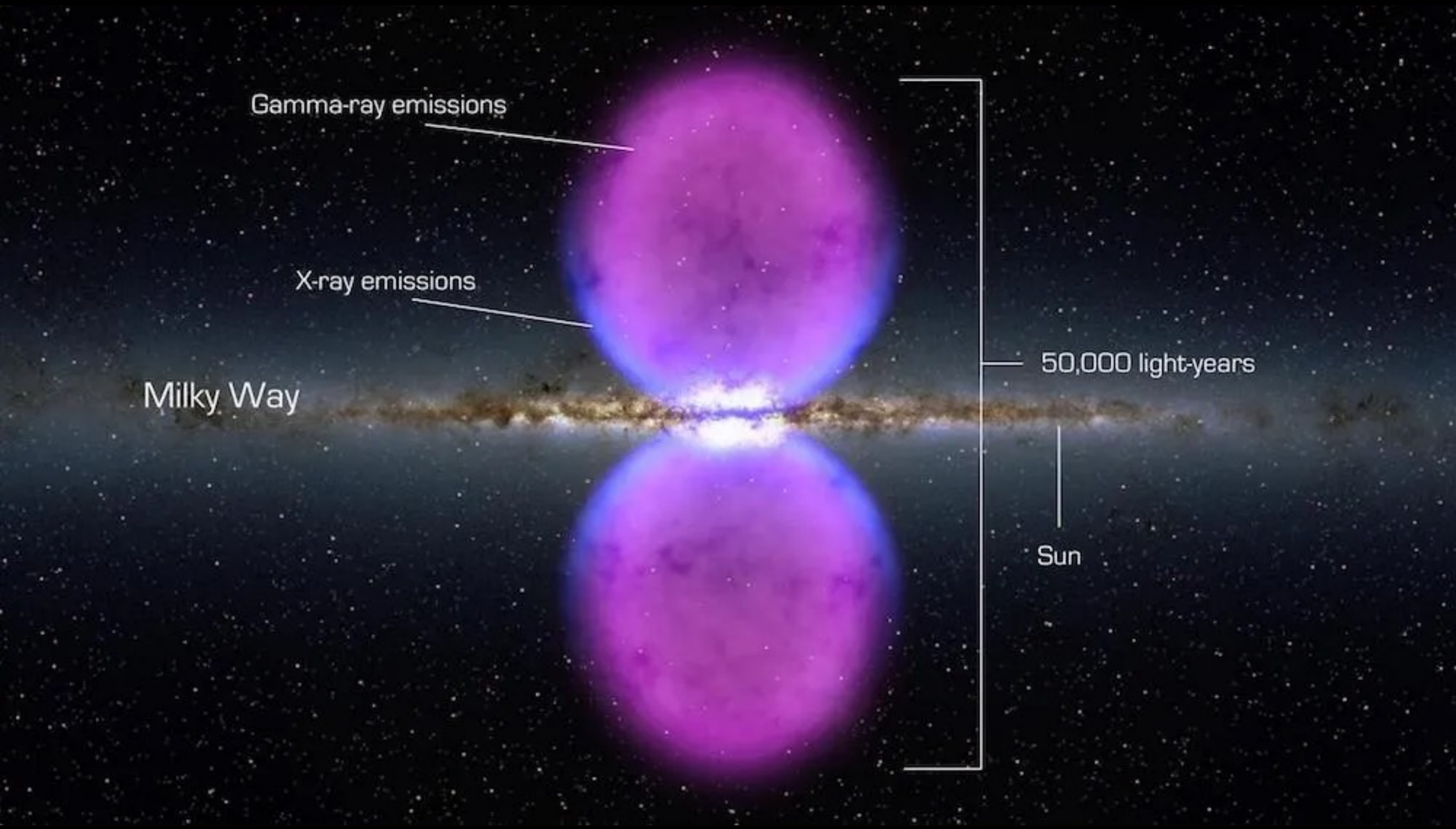
XRG satellite / eROSITA / MPE

below 10^{-15} m / γ-rays / energetic point sources



Fermi satellite

The Fermi bubbles



Artist's rendition (NASA)

Reading

- CFN §3.6, §8.8
- MvdBW §14