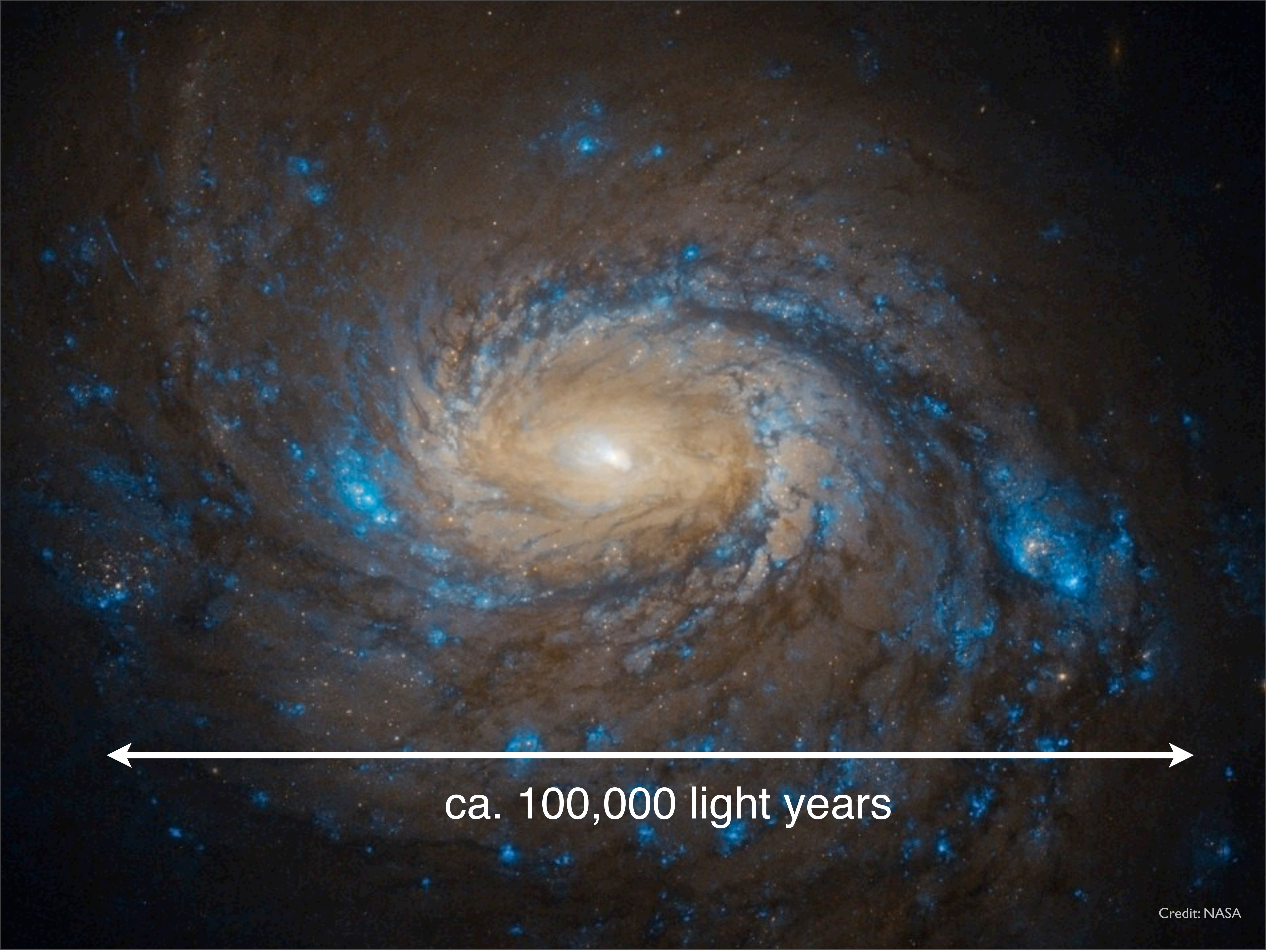
Galaxy-Black Hole Co-Evolution

Kevin Schawinski
Institute for Astronomy
ETH Zurich

@kevinschawinski

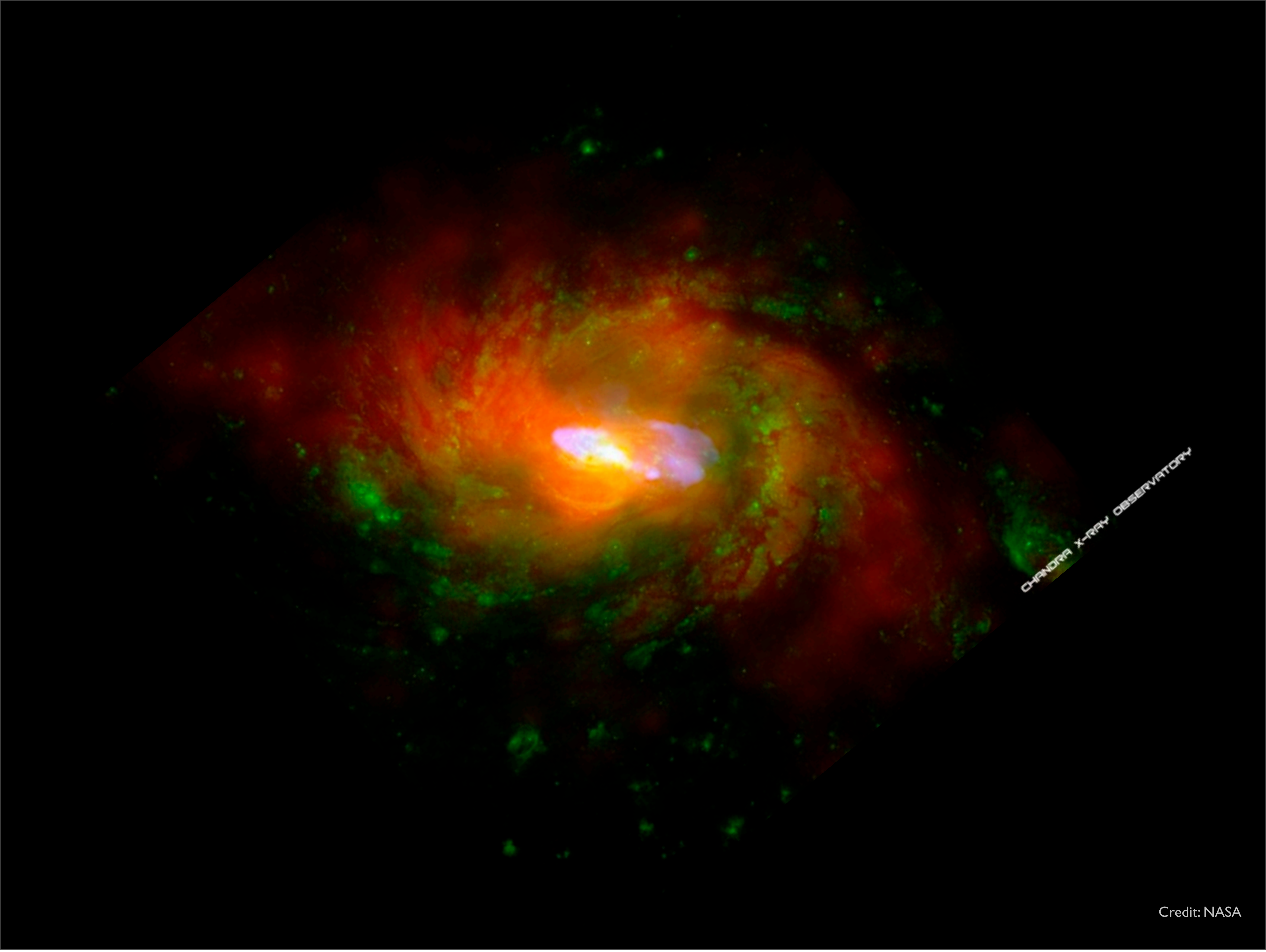
Credit: NASA


Credit: NASA

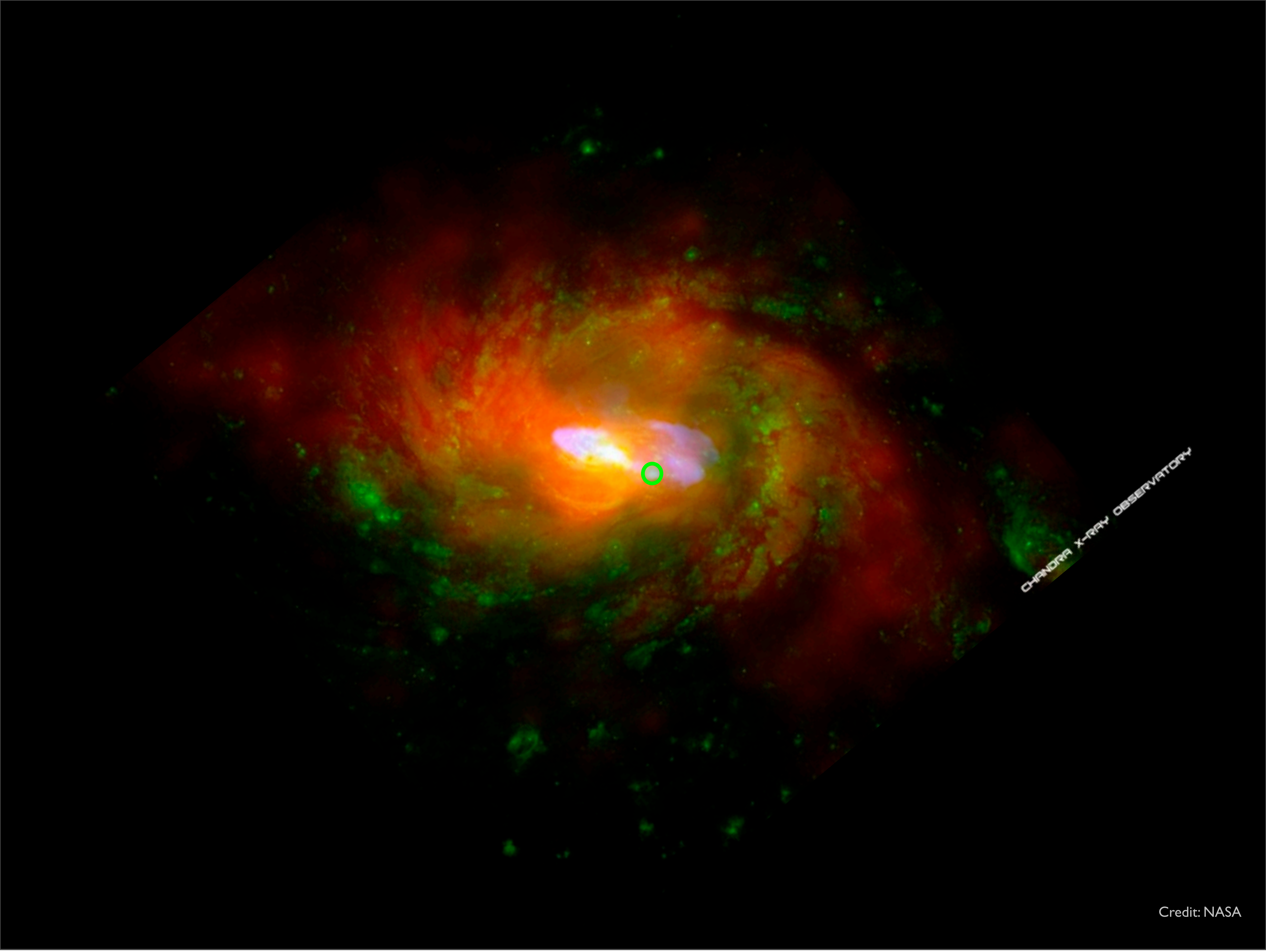

ca. 100,000 light years
Credit: NASA


Credit: NASA

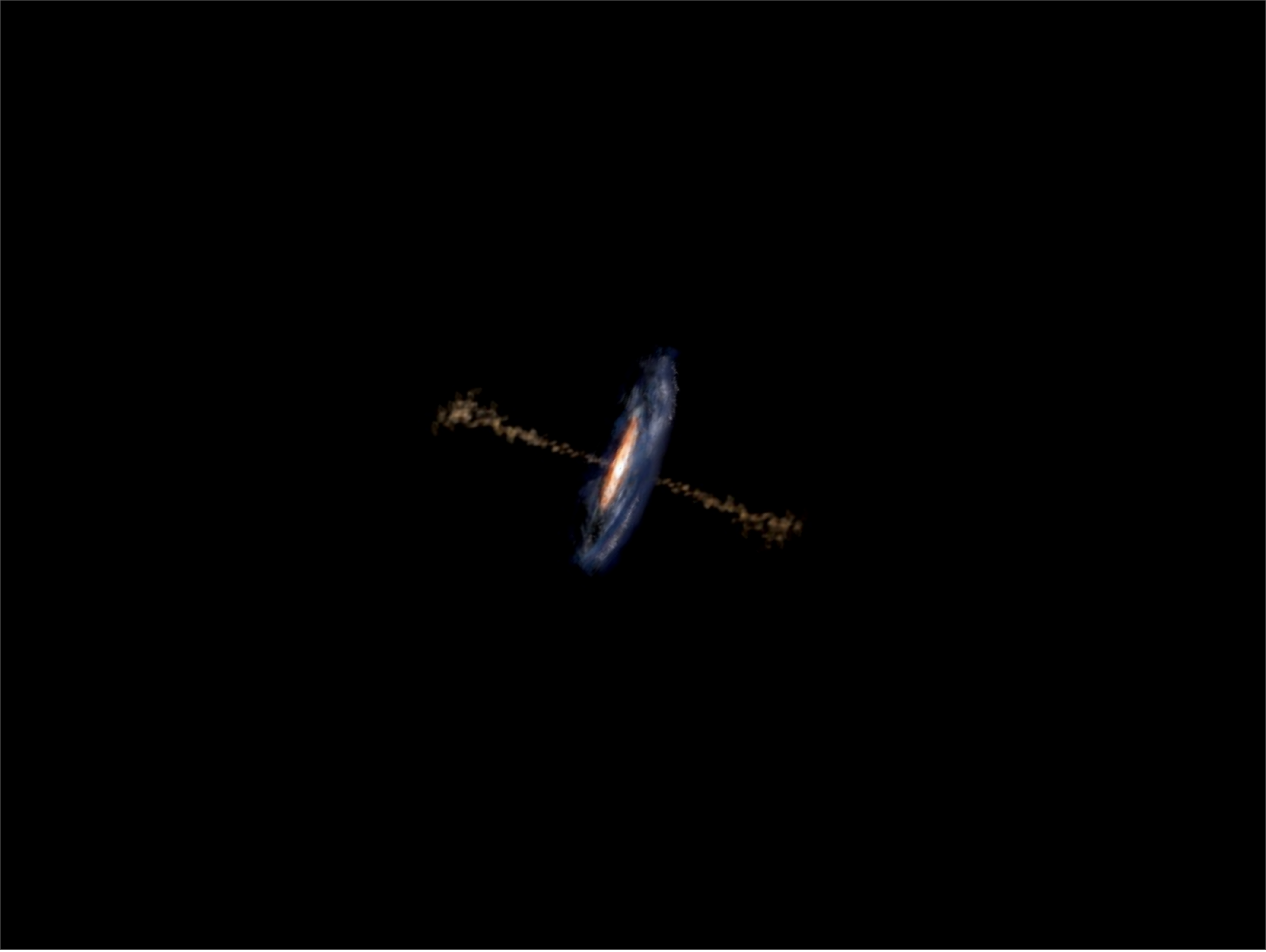

Credit: NASA

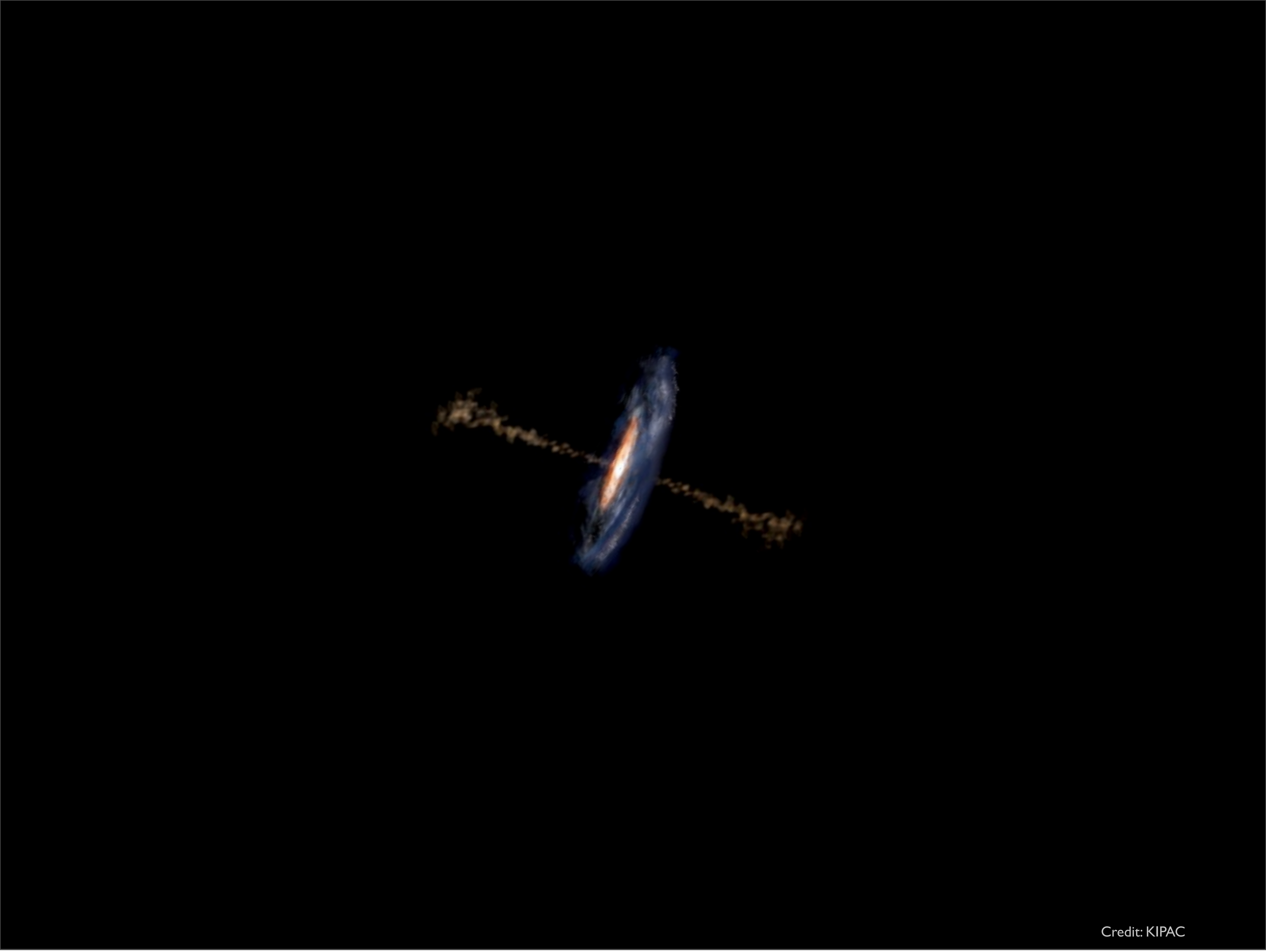


Credit: NASA

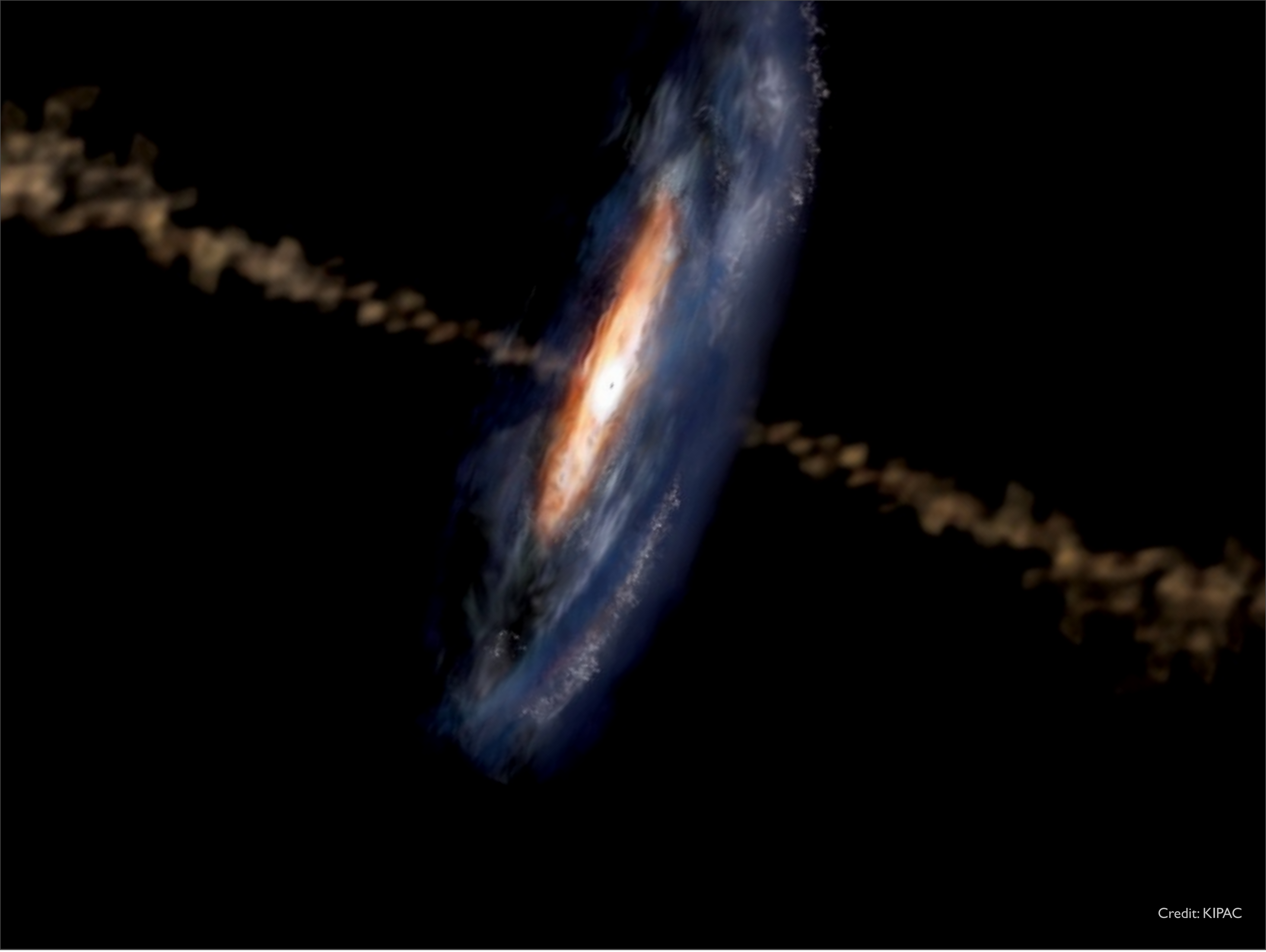


Credit: NASA





Credit: KIPAC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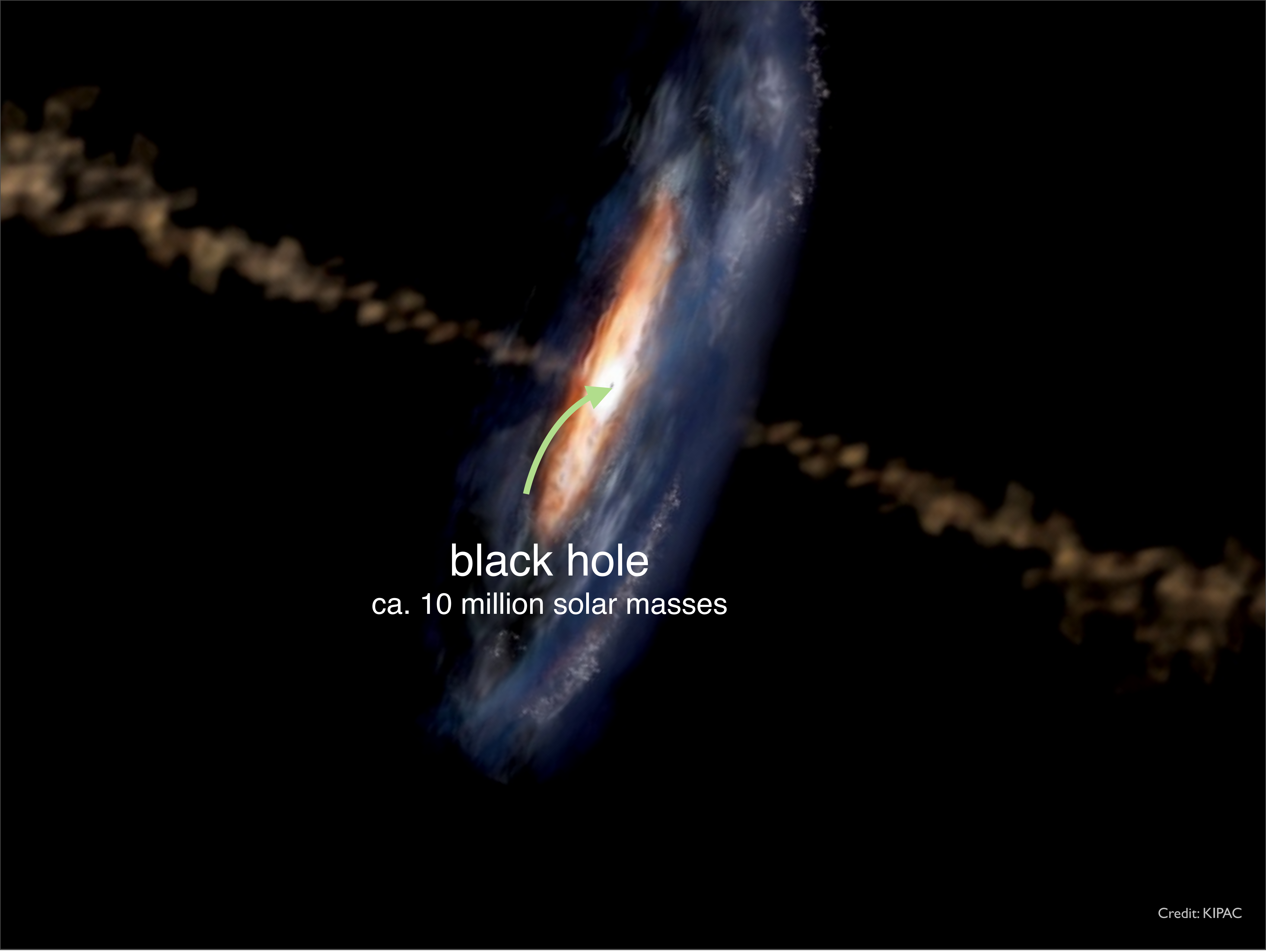
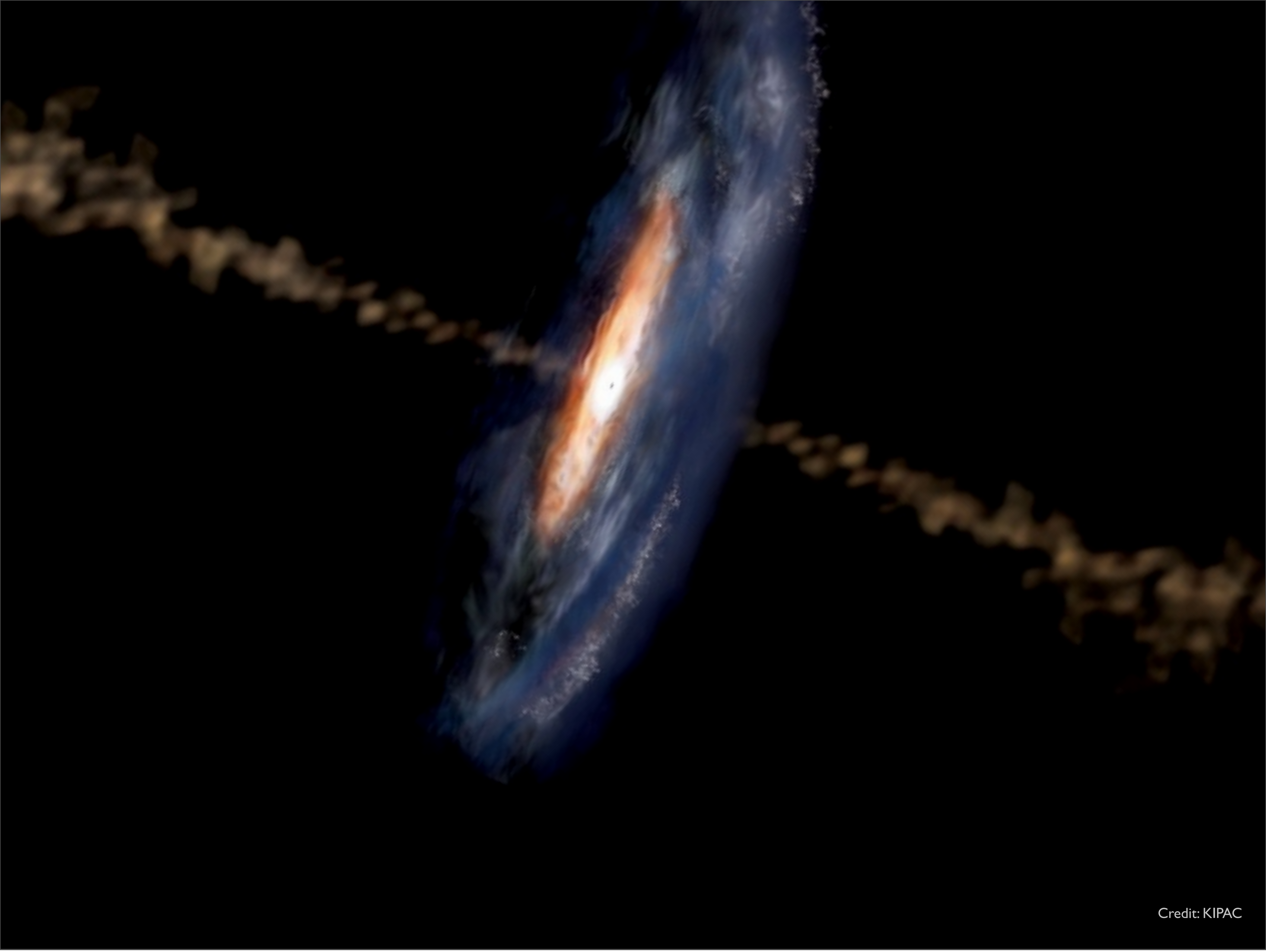

black hole
ca. 10 million solar masses
Credit: KIPAC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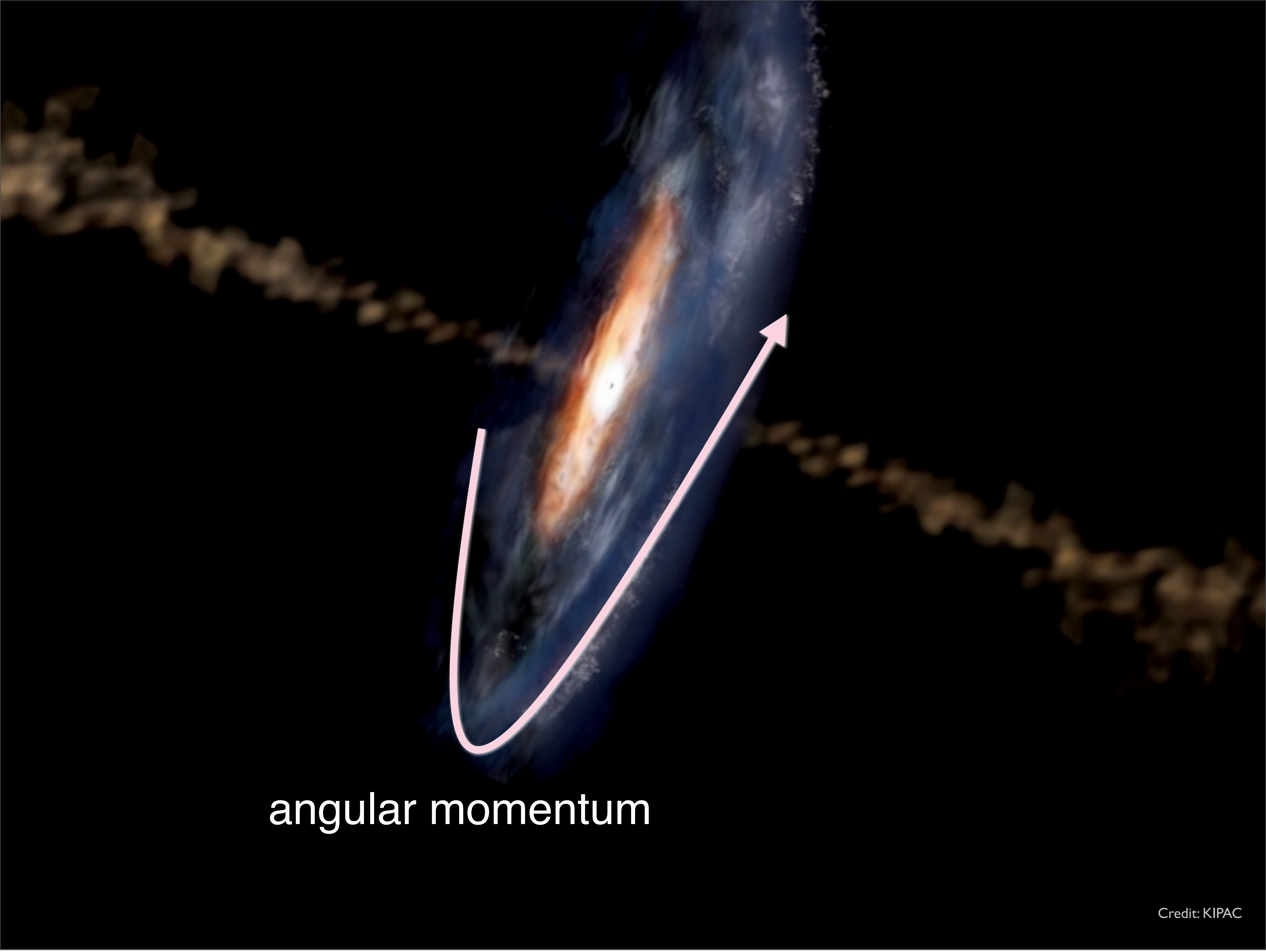
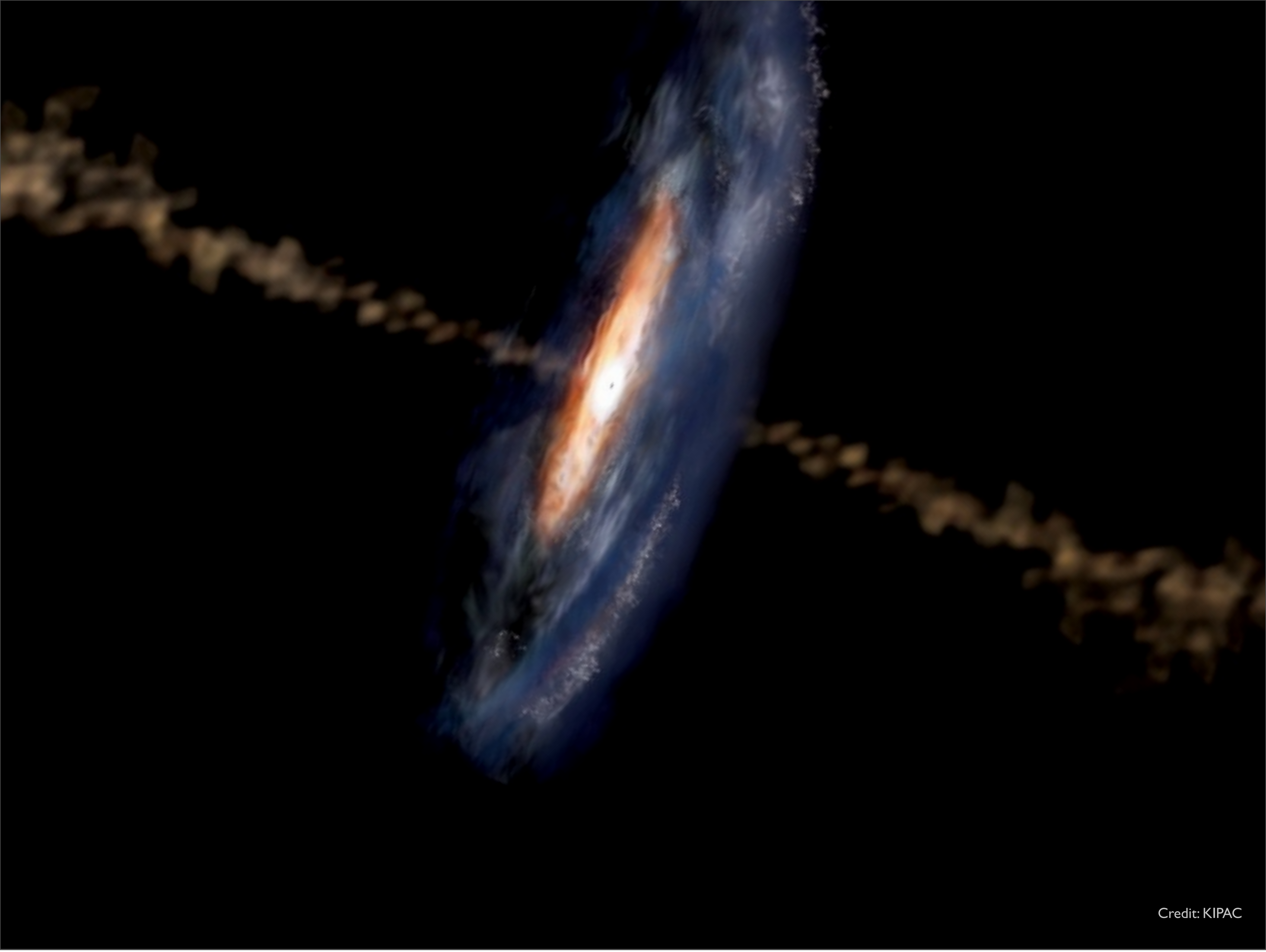

angular momentum
Credit: KIPAC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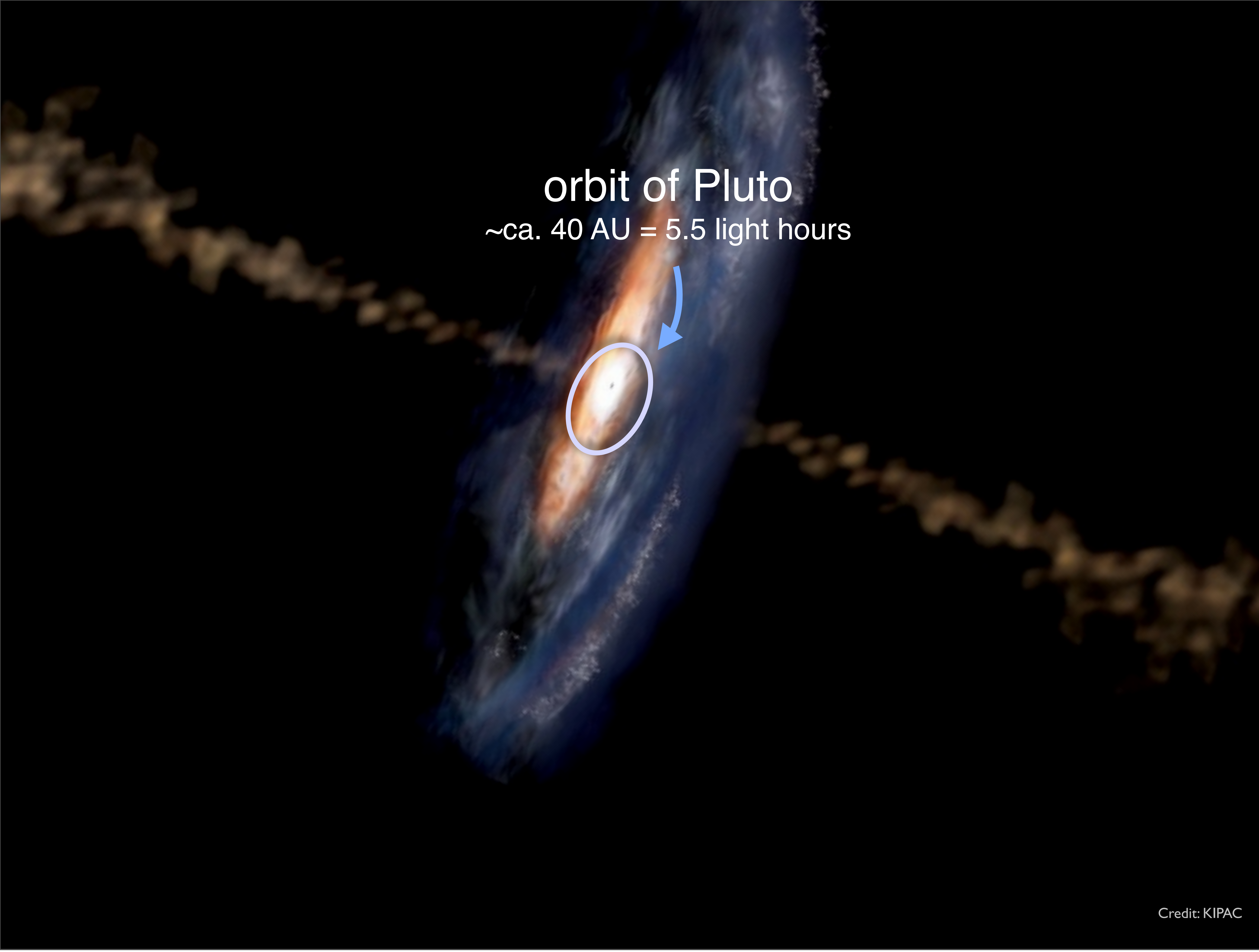
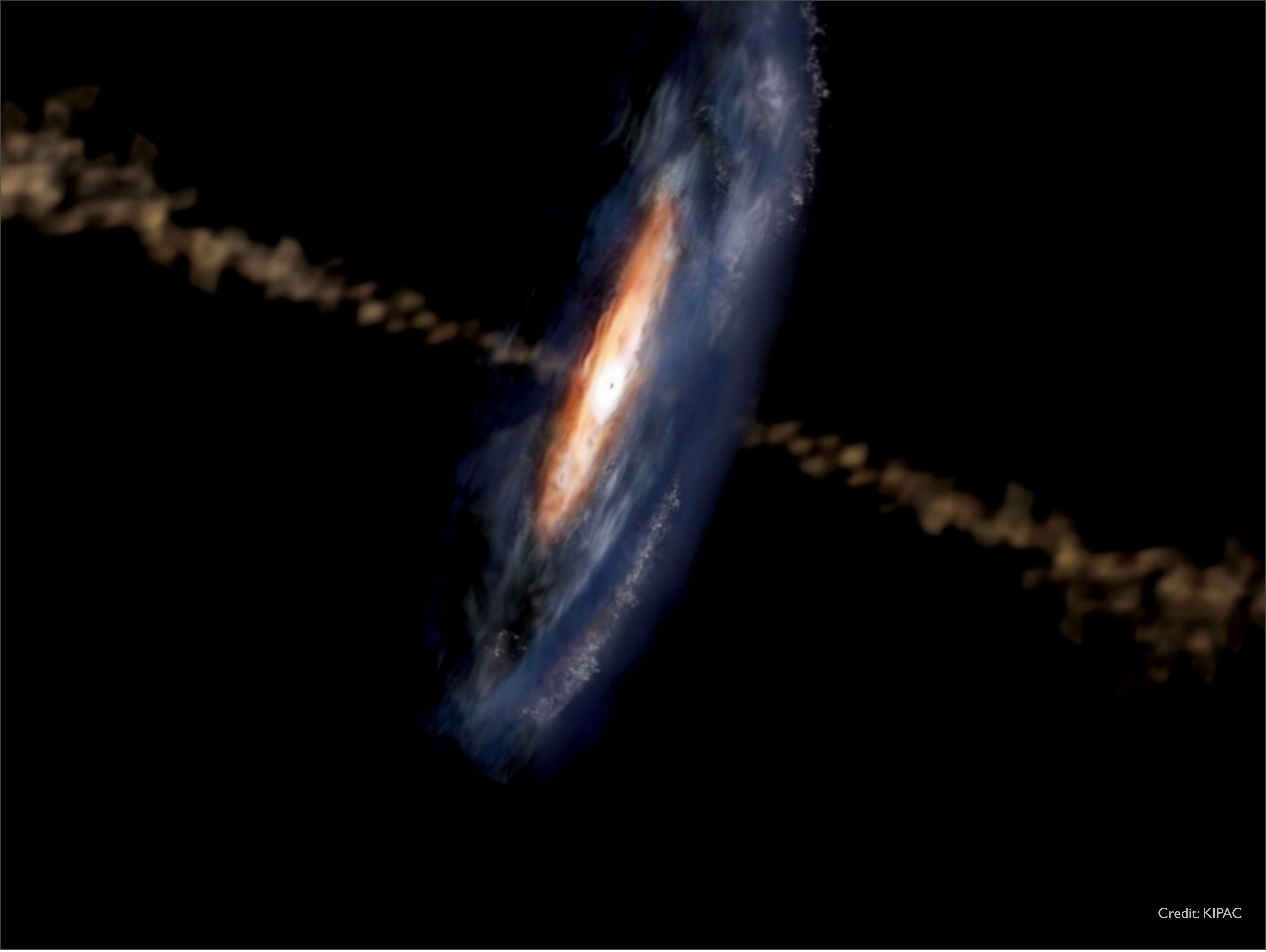

orbit of Pluto
~ca. 40 AU = 5.5 light hours
Credit: KIPAC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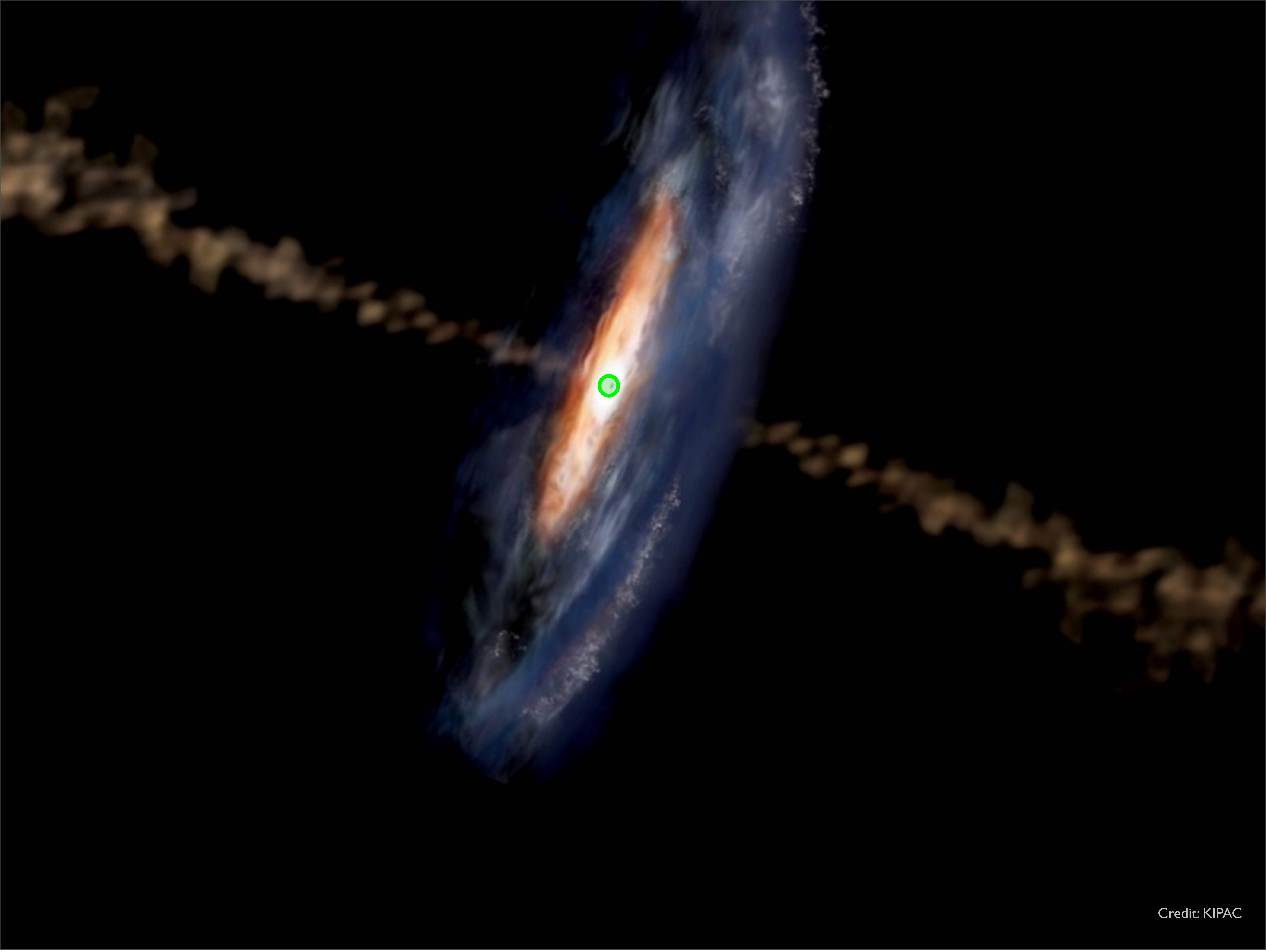
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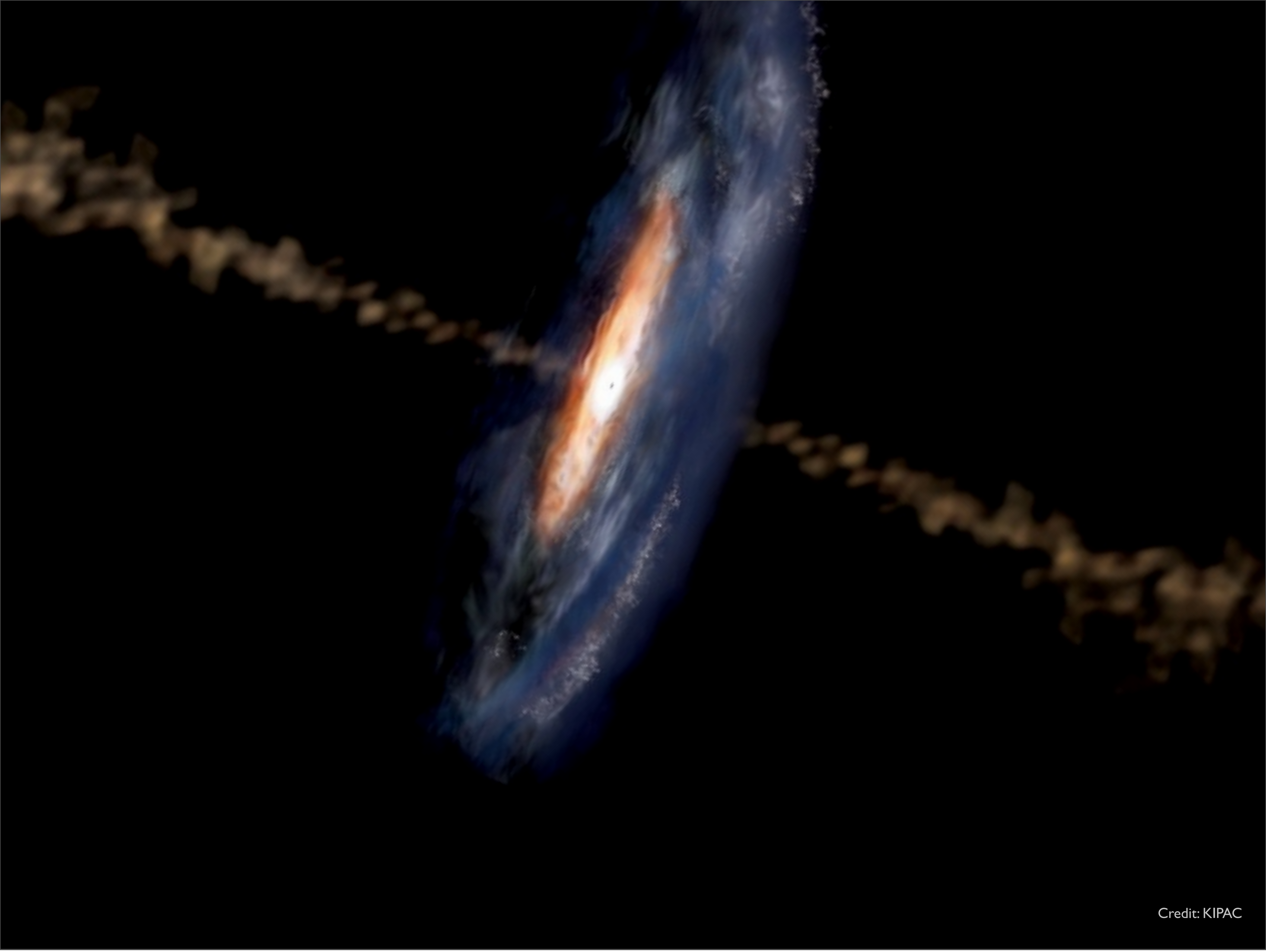
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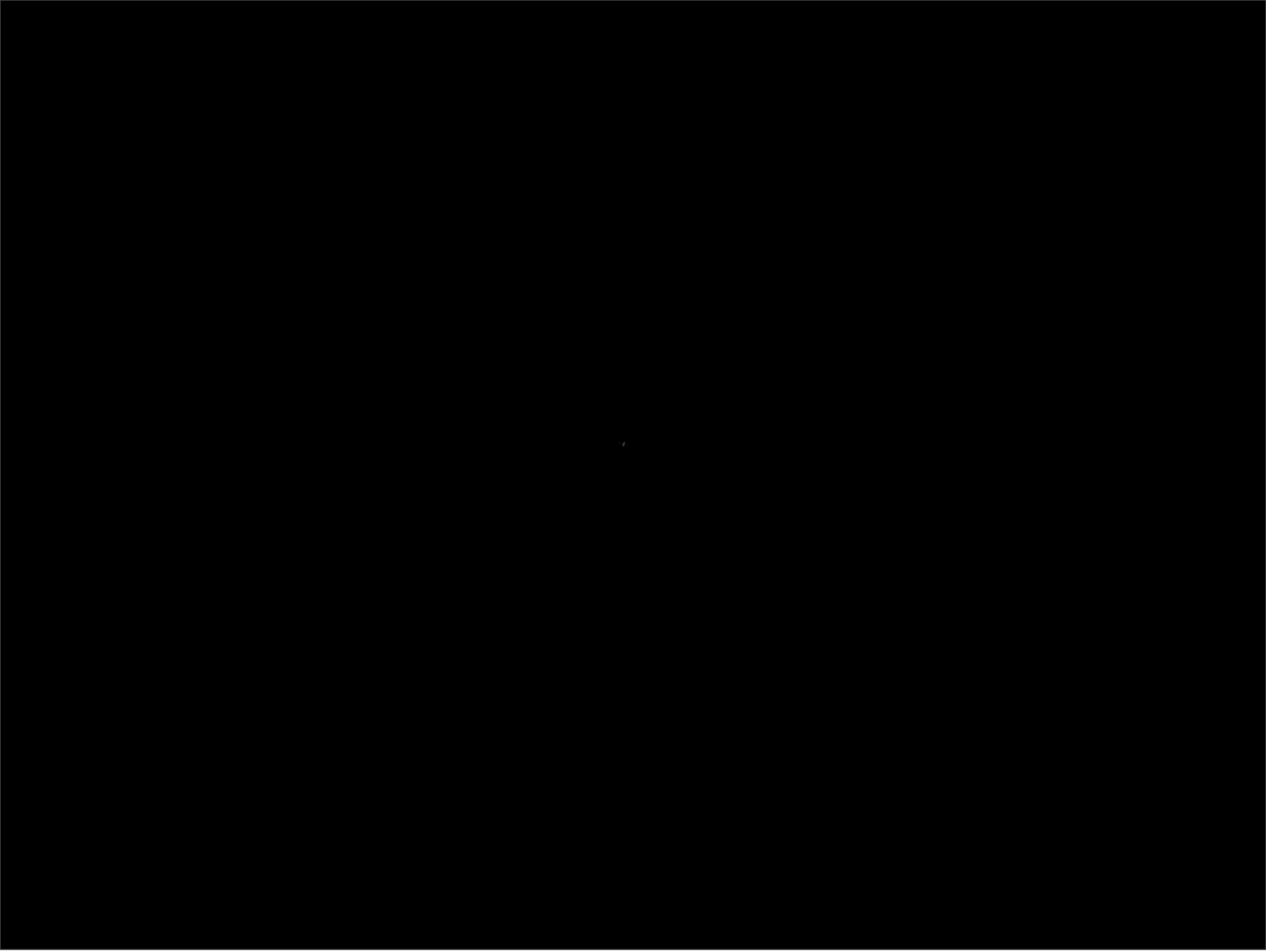
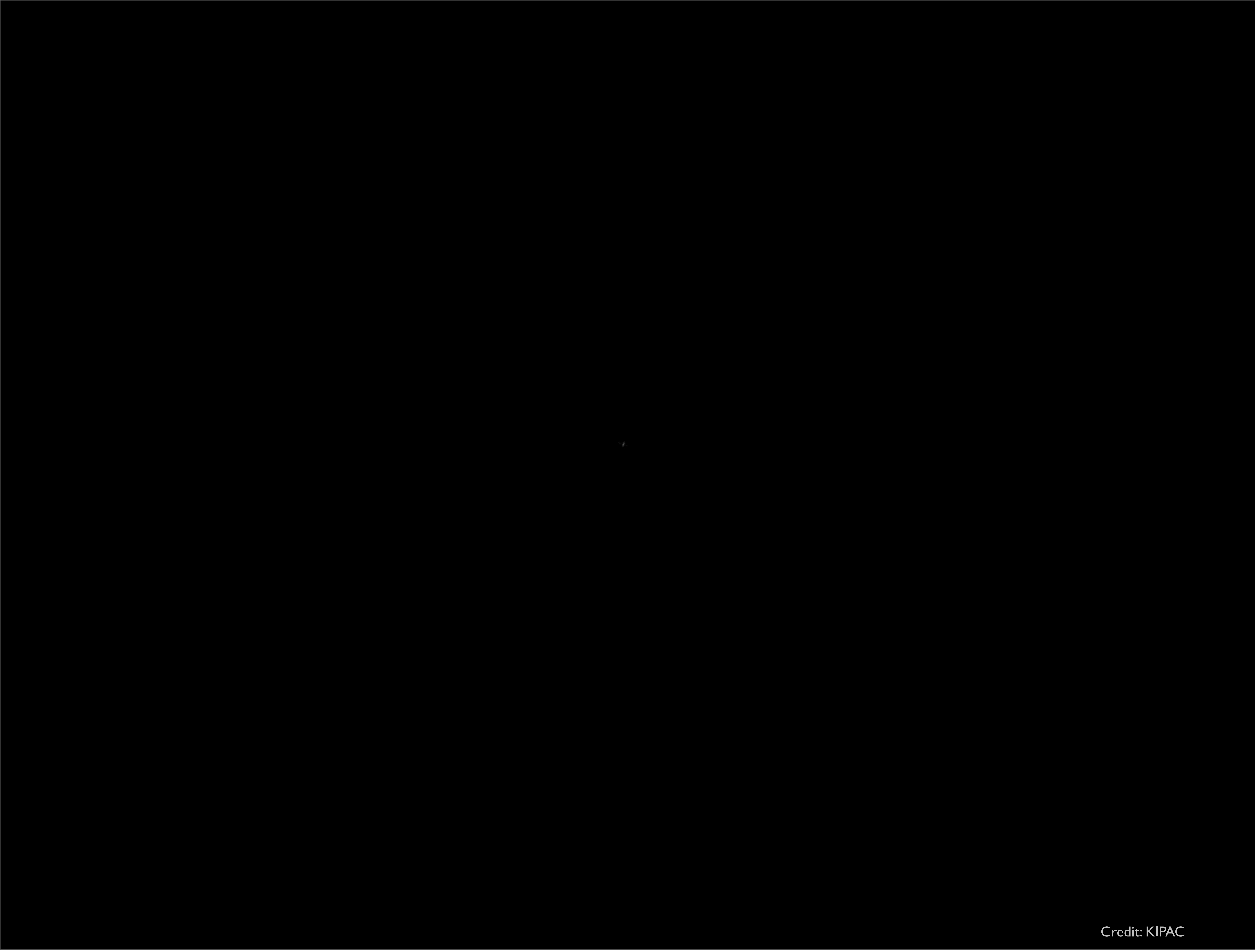
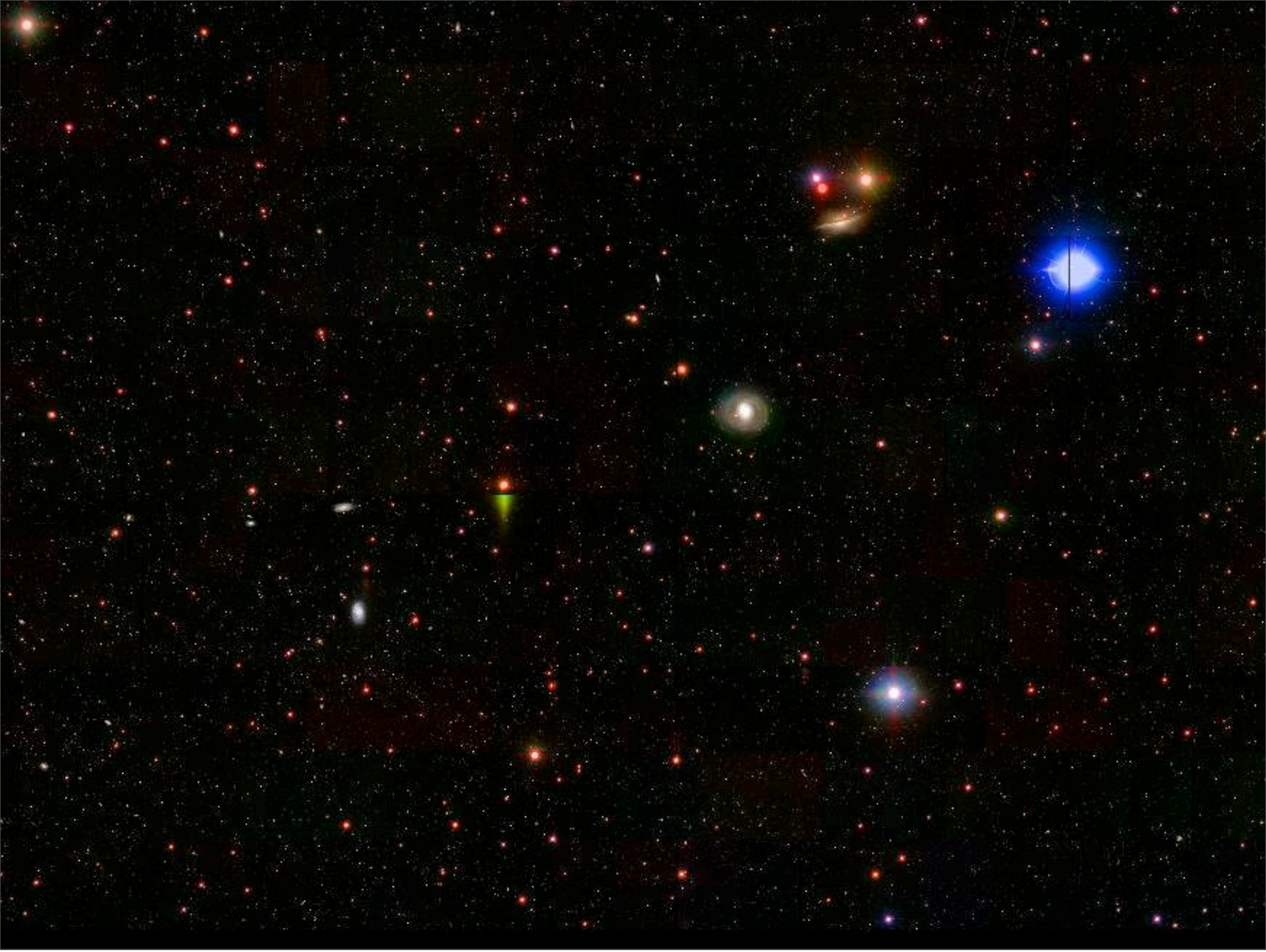


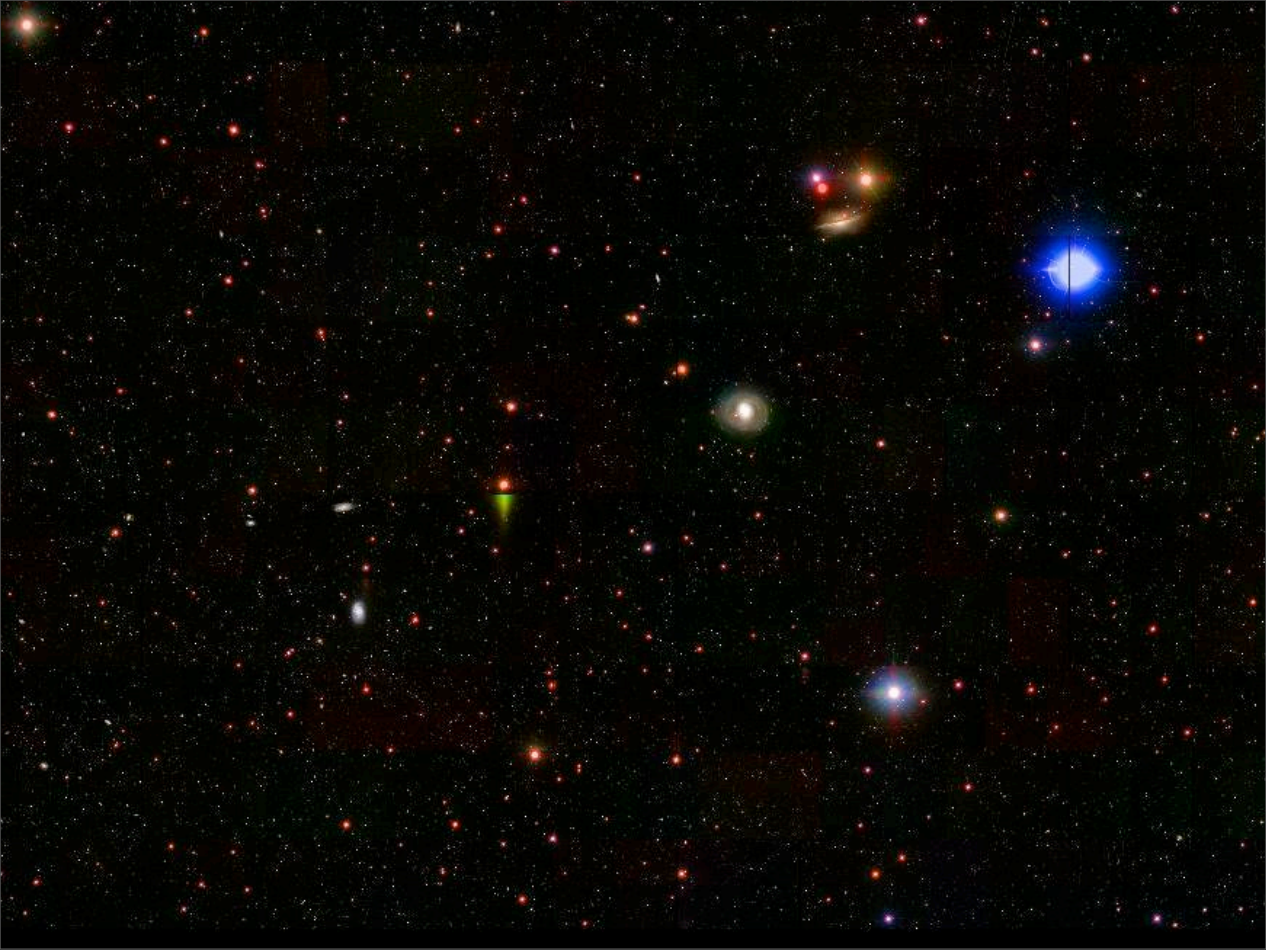


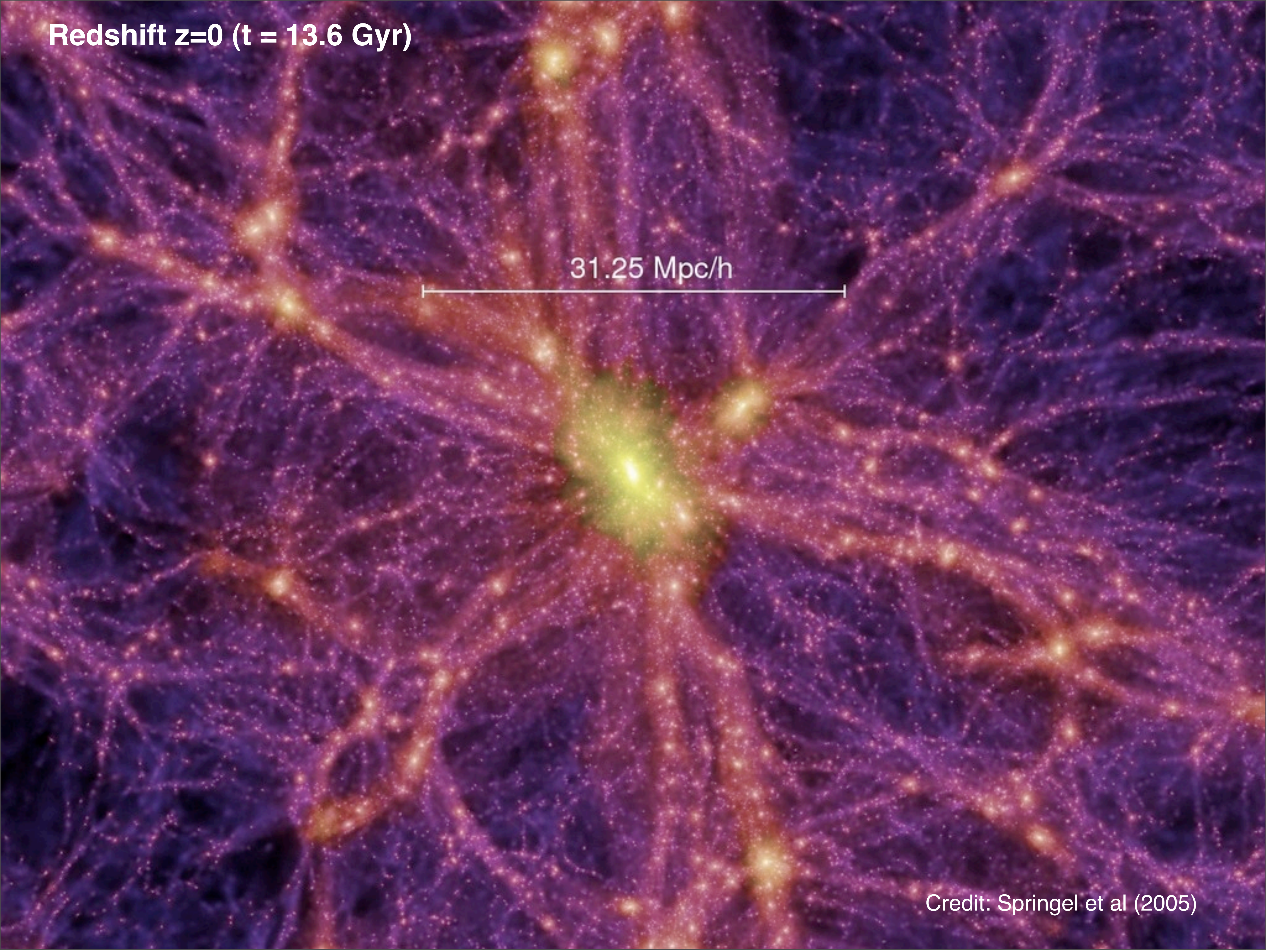
Credit: KIPAC

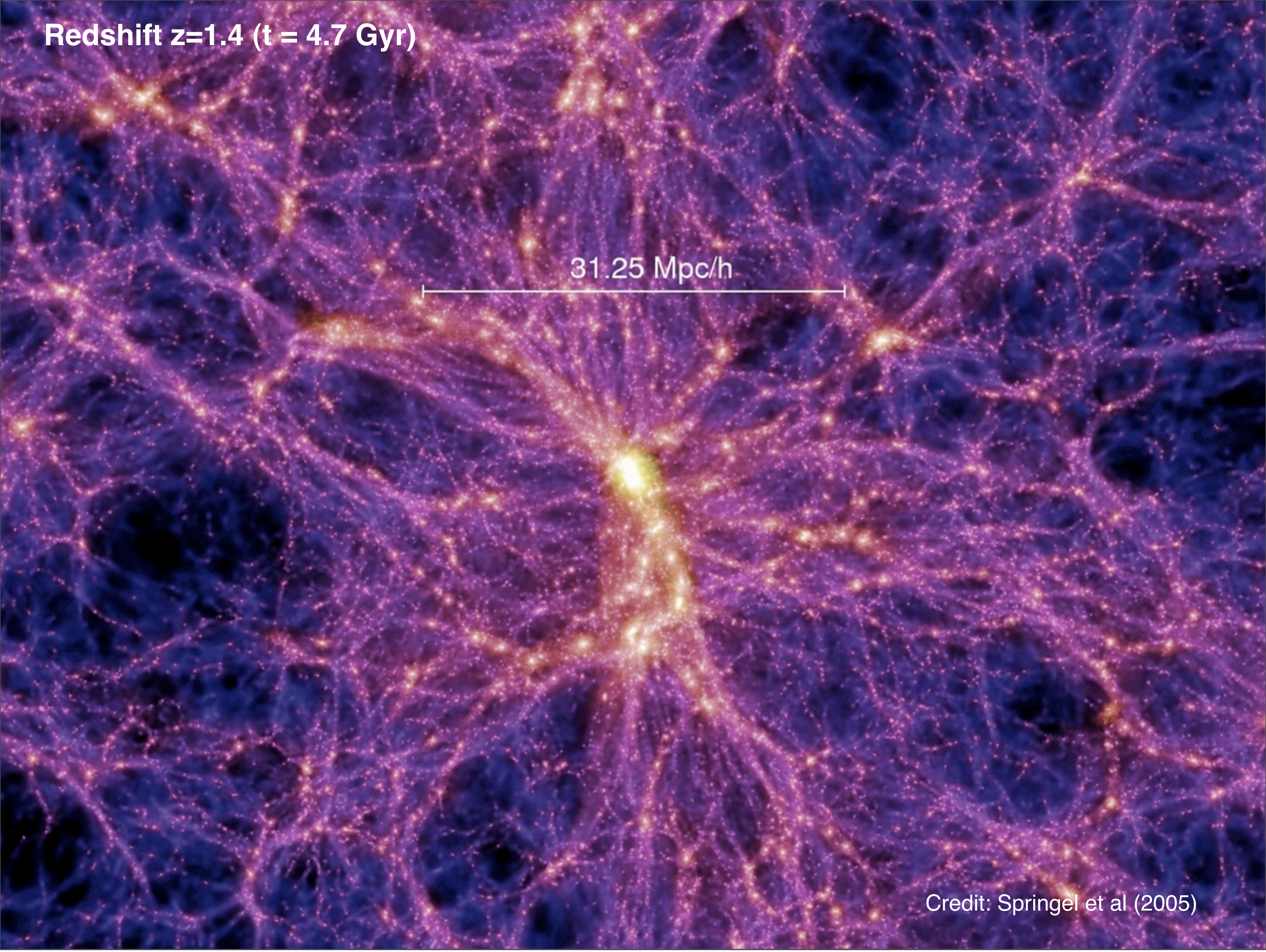

Credit: NASA

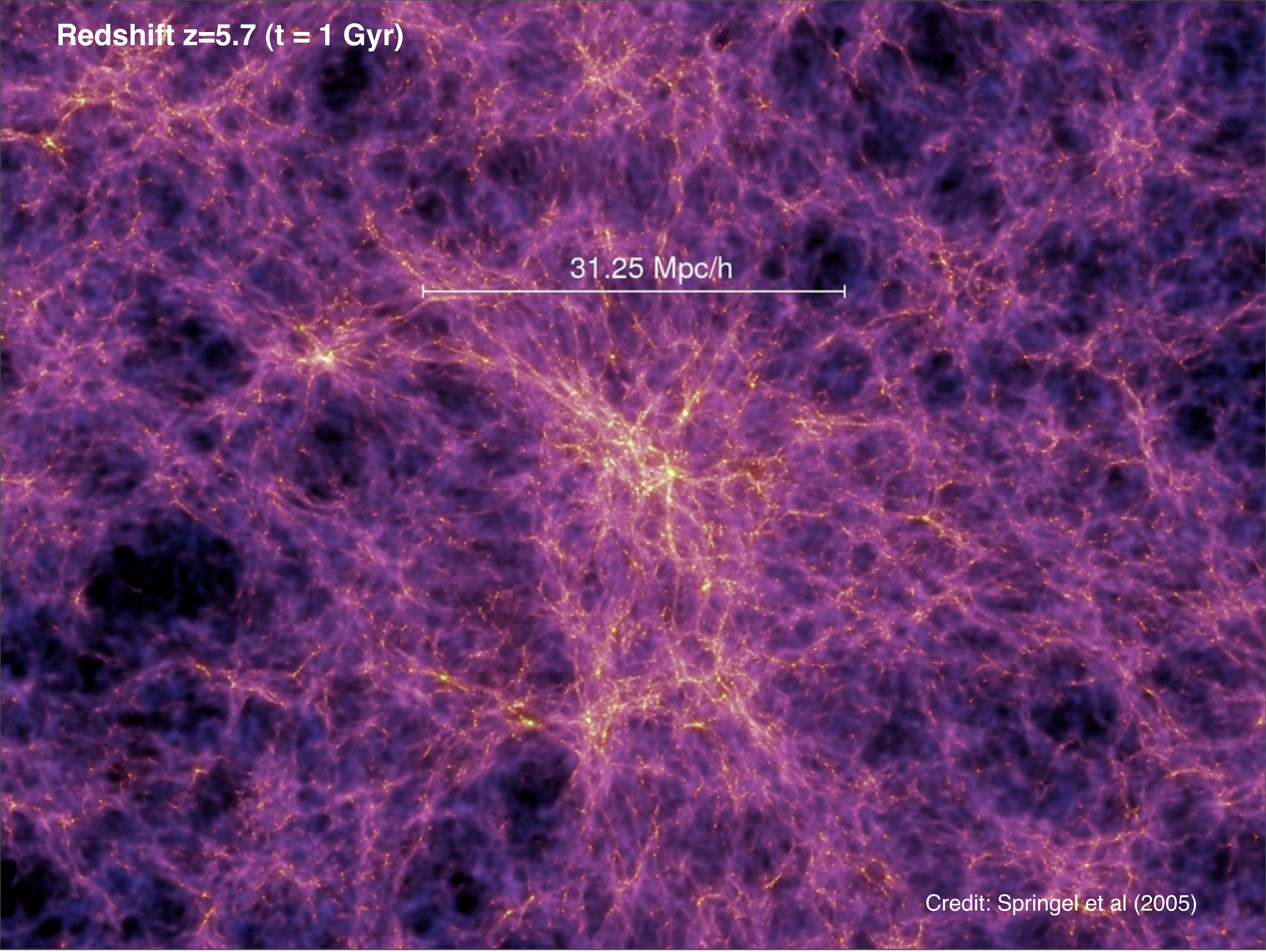
Credit: KIPAC

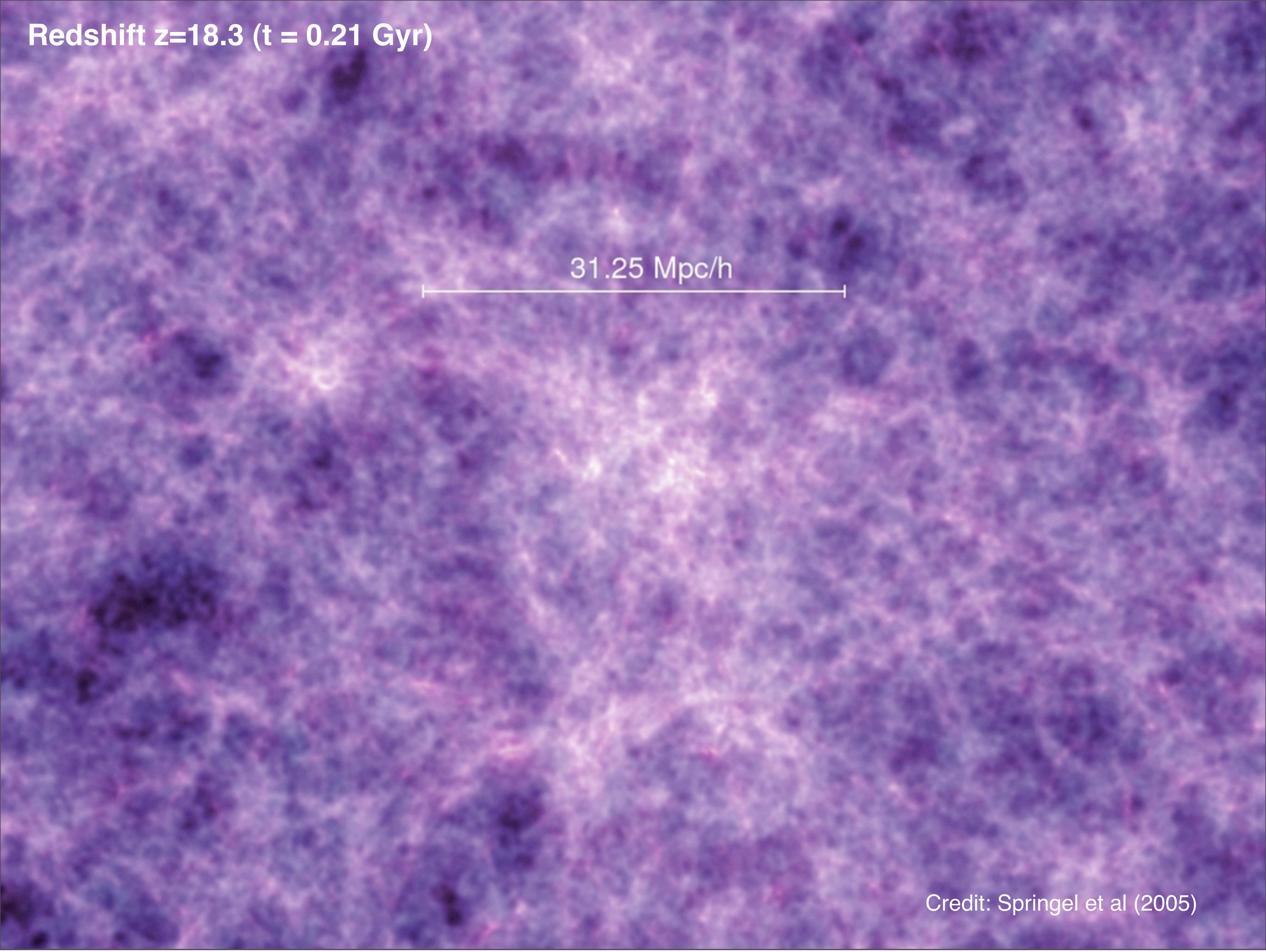





Redshift z=0 (t = 13.6 Gyr)
31.25 Mpc/h
Credit: Springel et al (2005)


Redshift z=1.4 (t = 4.7 Gyr)
31.25 Mpc/h
Credit: Springel et al (2005)


Redshift z=5.7 (t = 1 Gyr)
31.25 Mpc/h
Credit: Springel et al (2005)


Redshift z=18.3 (t = 0.21 Gyr)
31.25 Mpc/h
Credit: Springel et al (2005)

gas+astrophysics = gastrophysics

e.g. White & Rees (1978)

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Dark matter haloes collapse under gravity

e.g. White & Rees (1978)

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Baryonic matter (gas) collapses to disks
due to angular momentum

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Galaxies “form”
(rather, become visible due to stars emitting light)
and grow due to mergers and accretion

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(rather, become visible due to stars emitting light)
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“Feedback” somehow regualtes this process
(Supernovas, schwarze Löcher)

e.g. White & Rees (1978)

Cold Gas
(logT < 4.5 K)

Warm Gas
(4.5 log T < 5.5 K)

Hot Gas (log t
> 5.5 K)

Stars

Credit: Richard Bower and the EAGLE collaboration (Durham University)

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(logT < 4.5 K)

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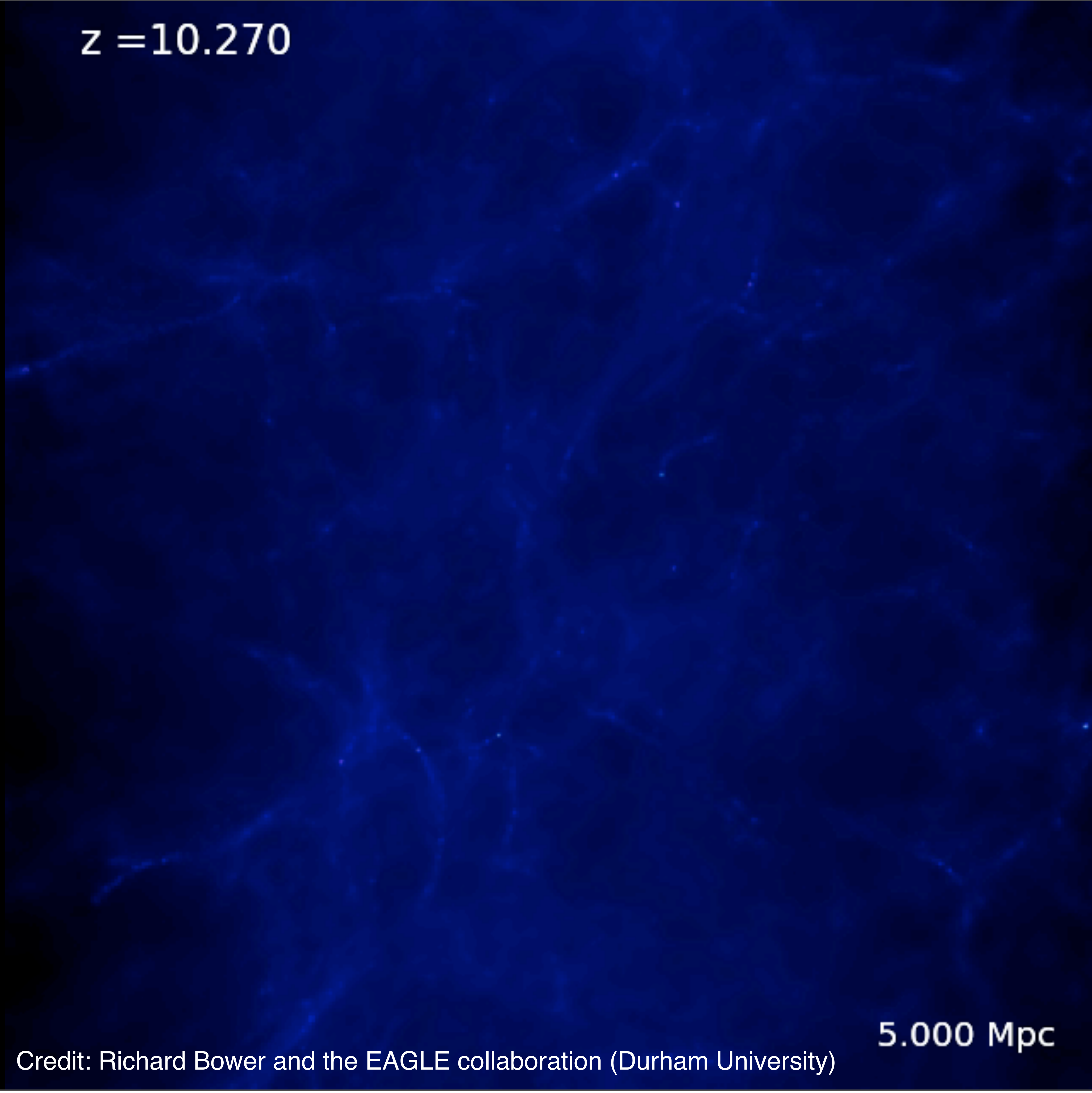

Credit: Richard Bower and the EAGLE collaboration (Durham University)

Energy liberated by a black hole growing via accretion

$$E_{bh} \sim \eta_{acc} M_{bh} c^2$$

Credit: ESA

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Gravitational binding energy of a galaxy

$$E_{grav} \sim 3GM^2/5R$$
$$\sim M_{bulge} \sigma^2$$

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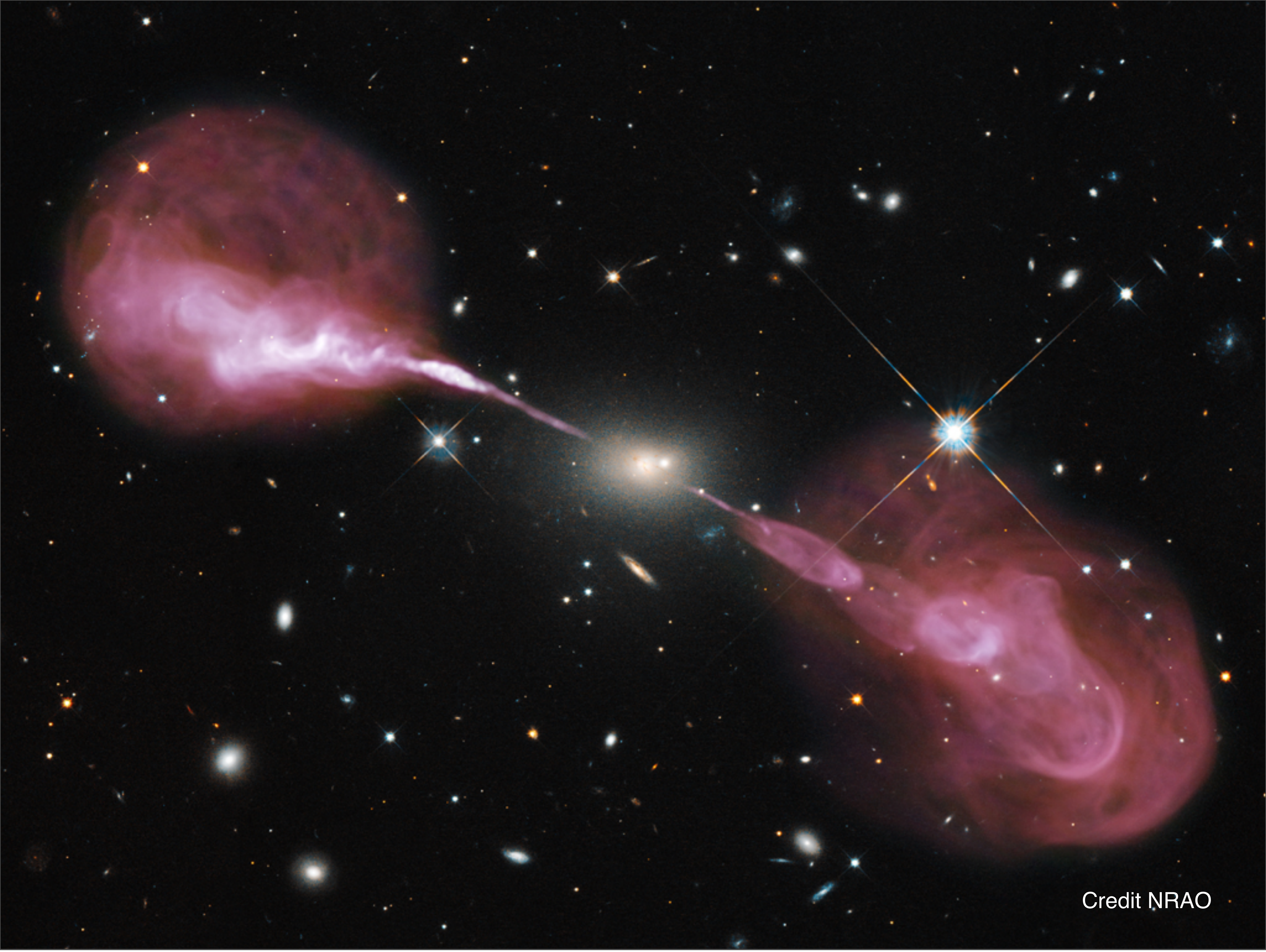
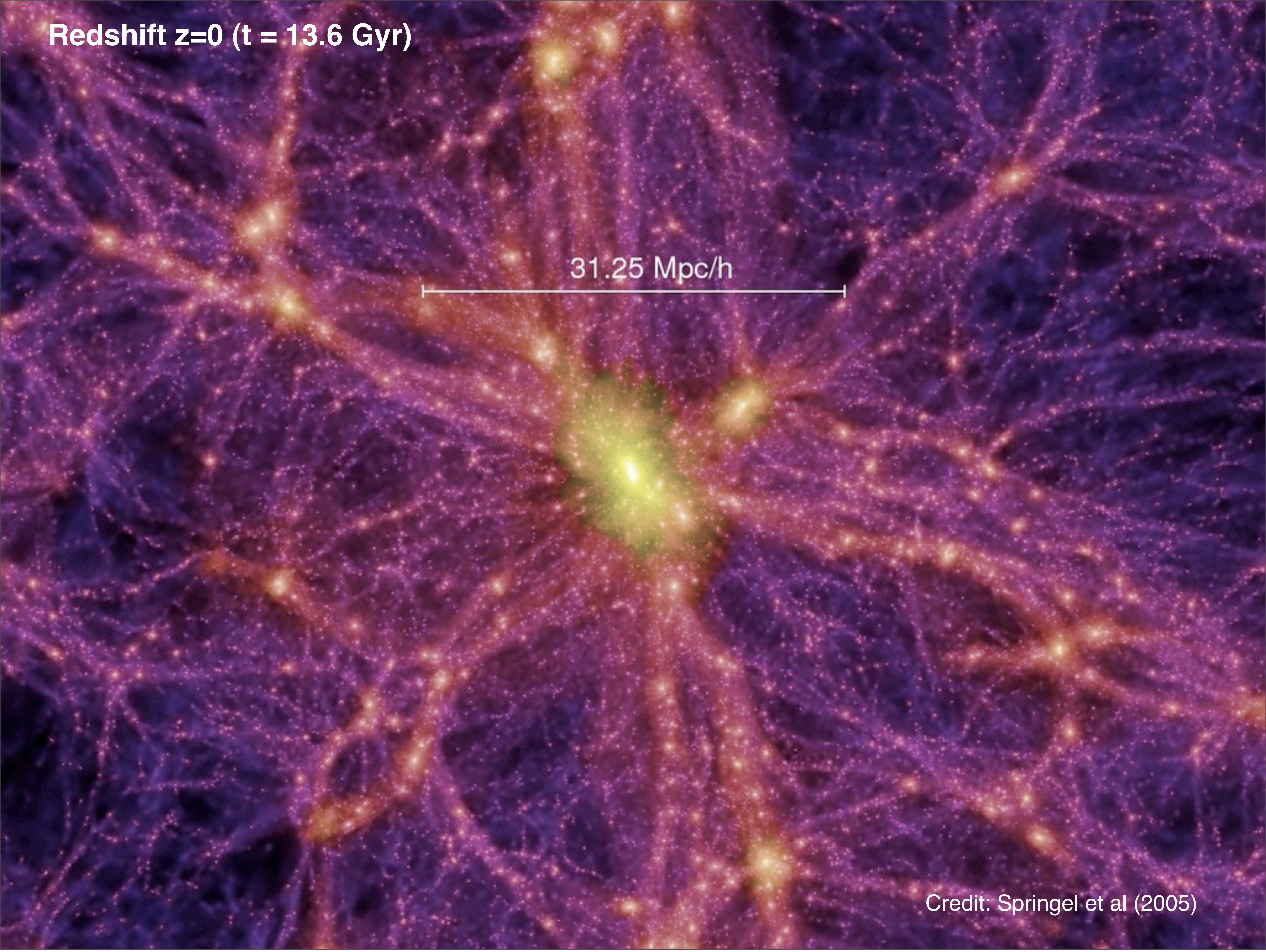
$$E_{bh} \gg E_{grav}$$


Credit NRAO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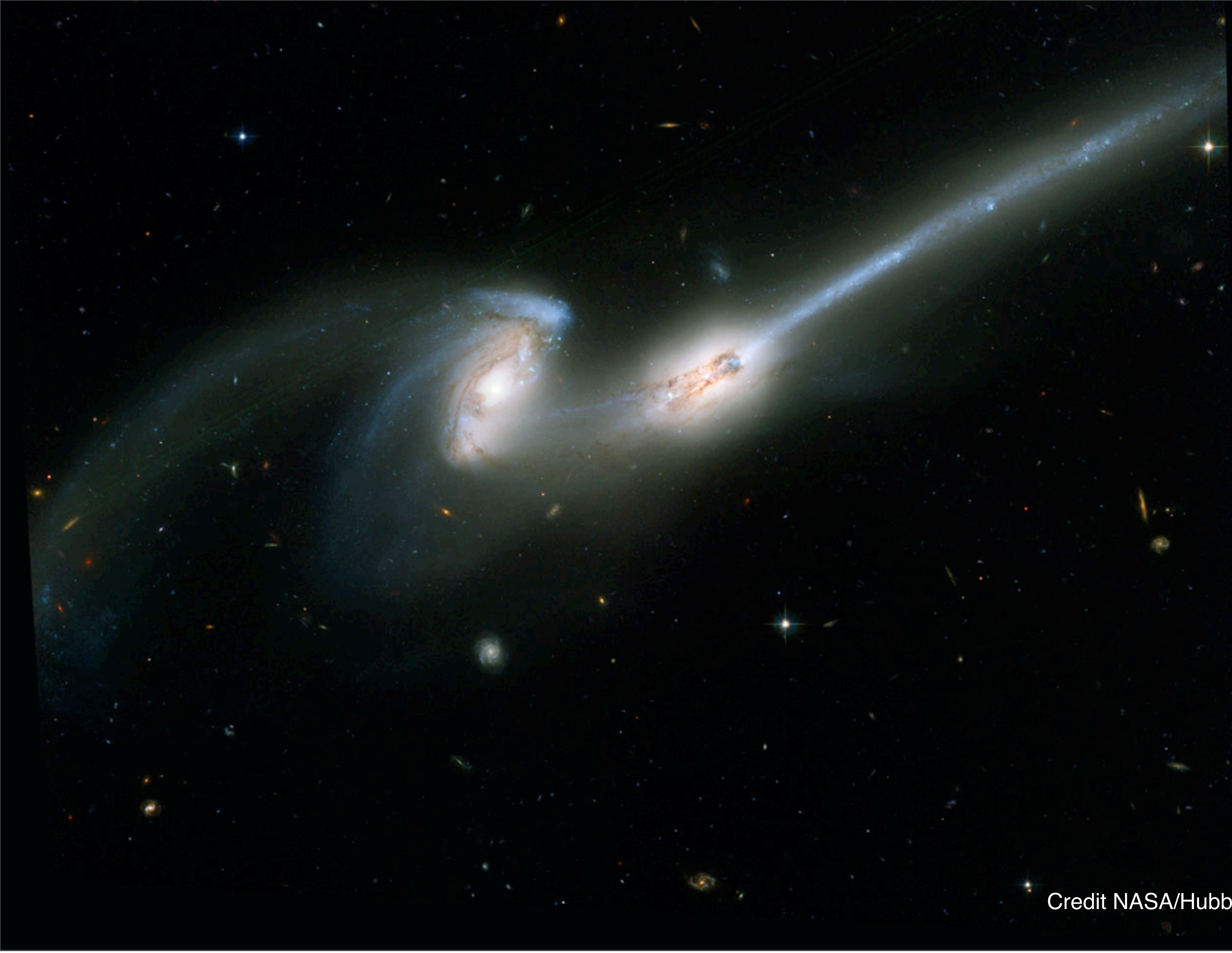

Credit NASA/Hubble

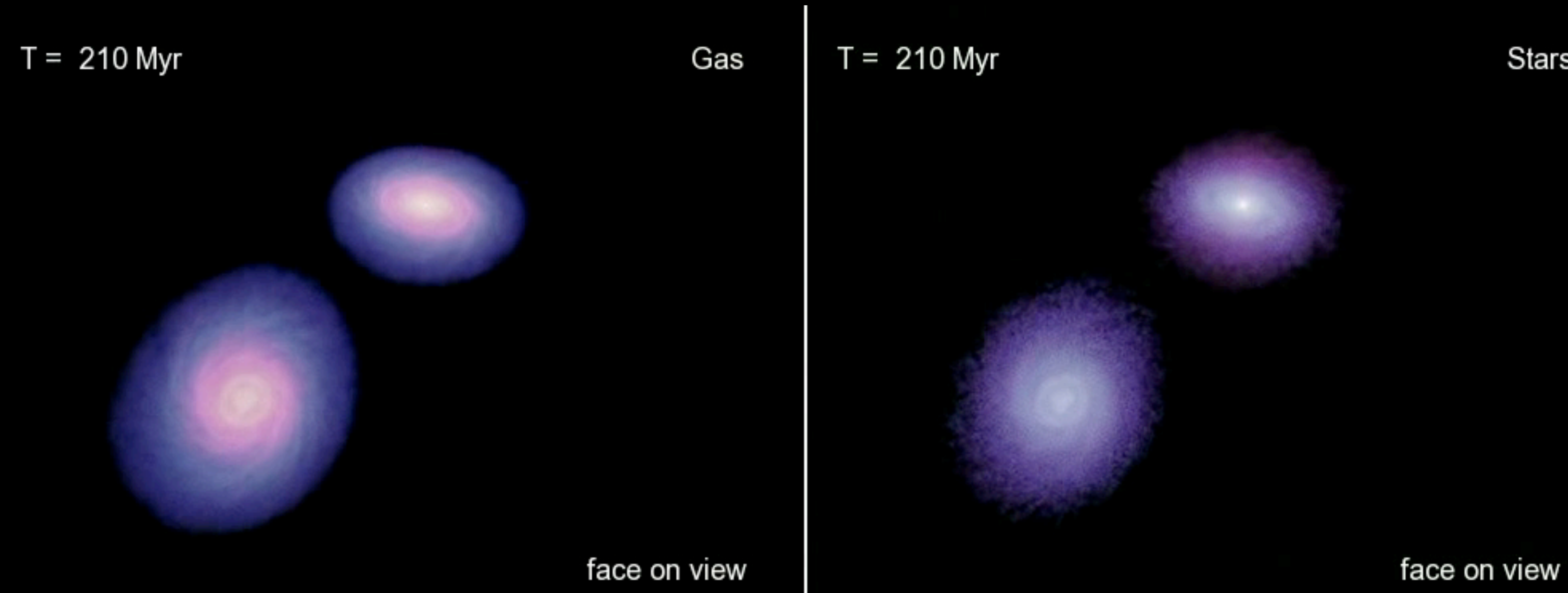
Gas
(blue=cool, red=hot)

Stars
(blue=young, red=old)

Credit Phil Hopkis (Caltech)

Gas
(blue=cool, red=hot)

Stars
(blue=young, red=old)



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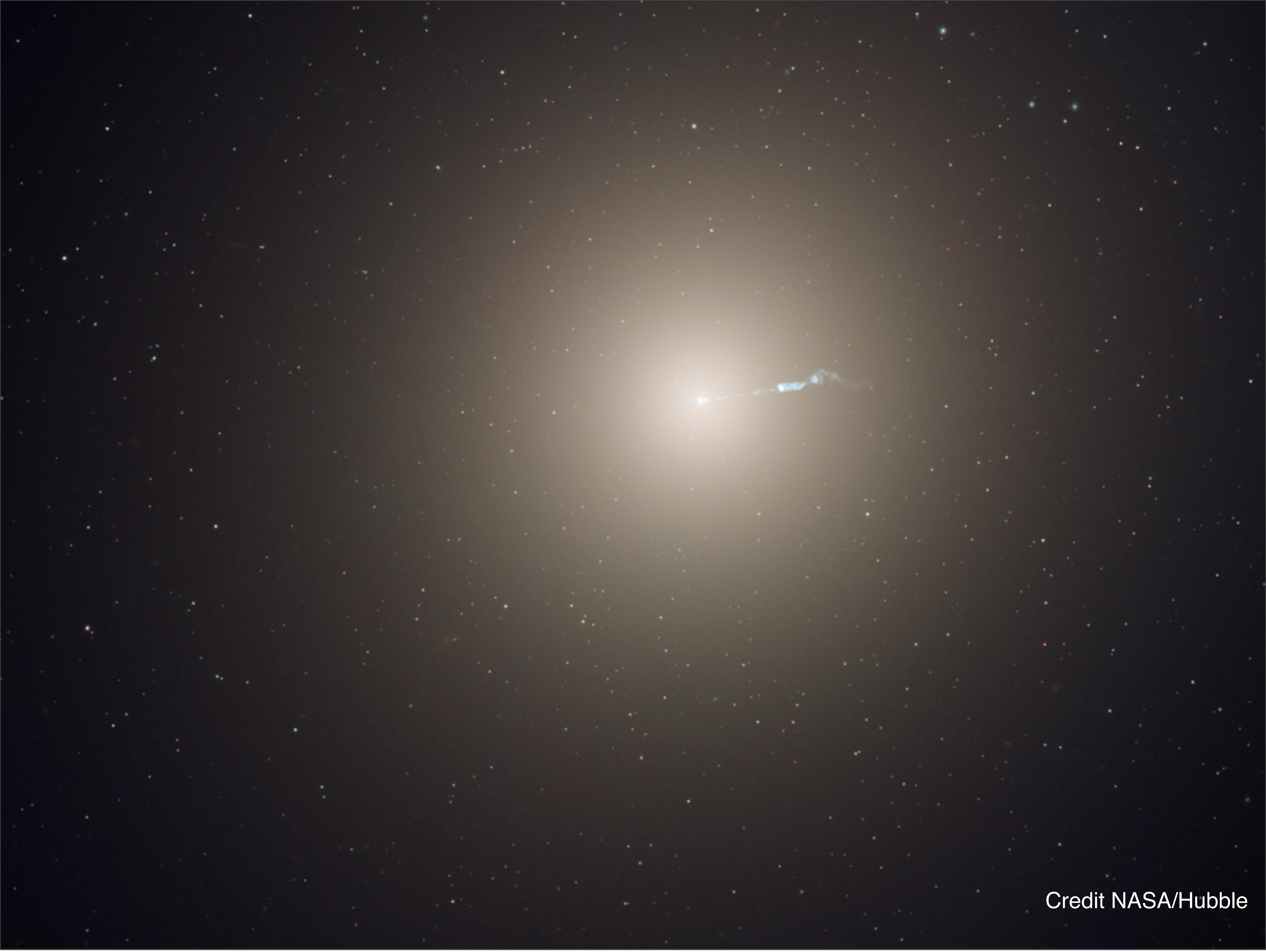
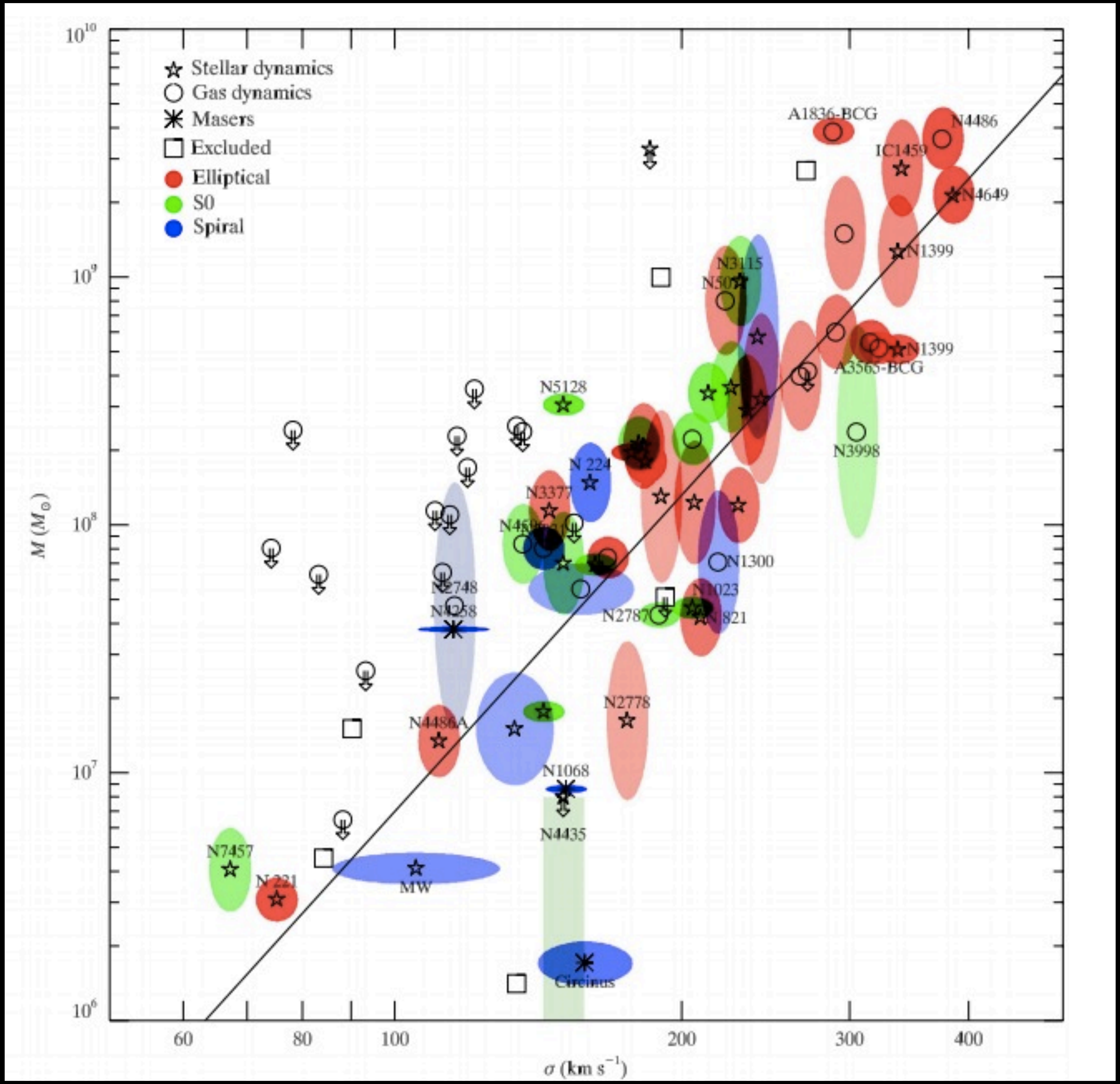
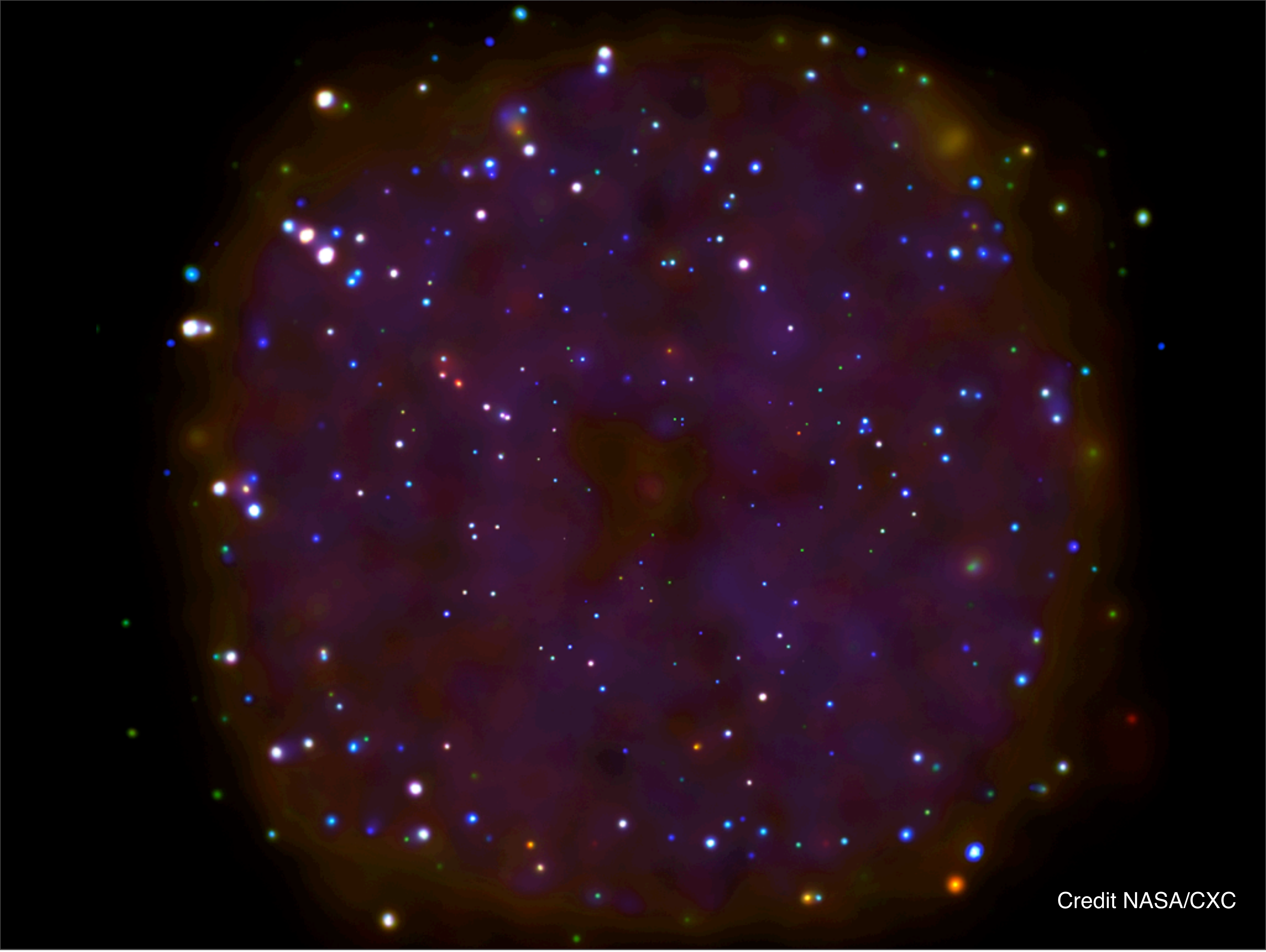

Credit NASA/Hubble

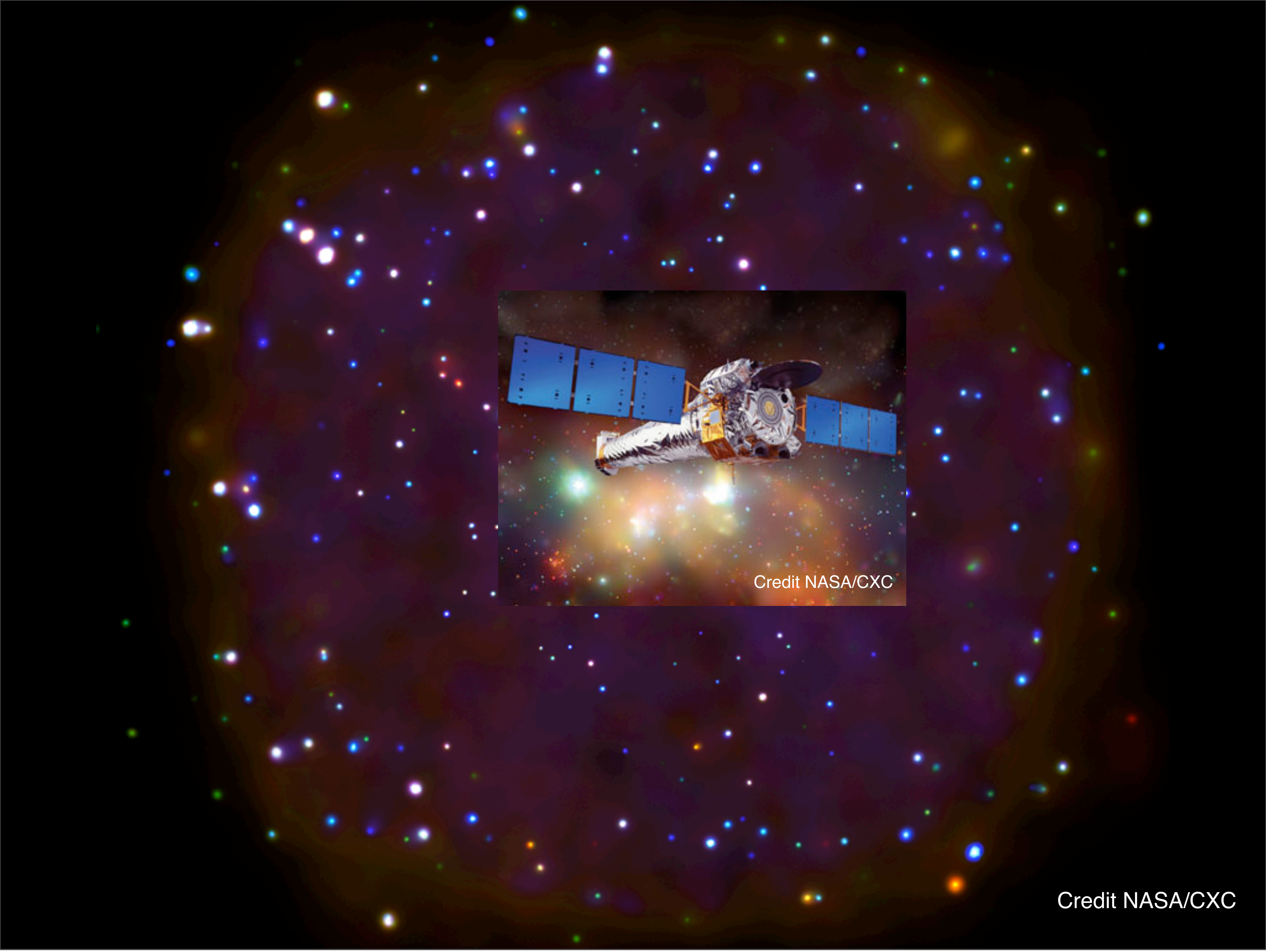
Black hole mass (solar masses)



Velocity dispersion of the bulge (km/s)

from: Gultekin+2009; see also: Gehbartd+2000; Ferrarese & Merritt 2000


Credit NASA/CXC


Credit NASA/CXC
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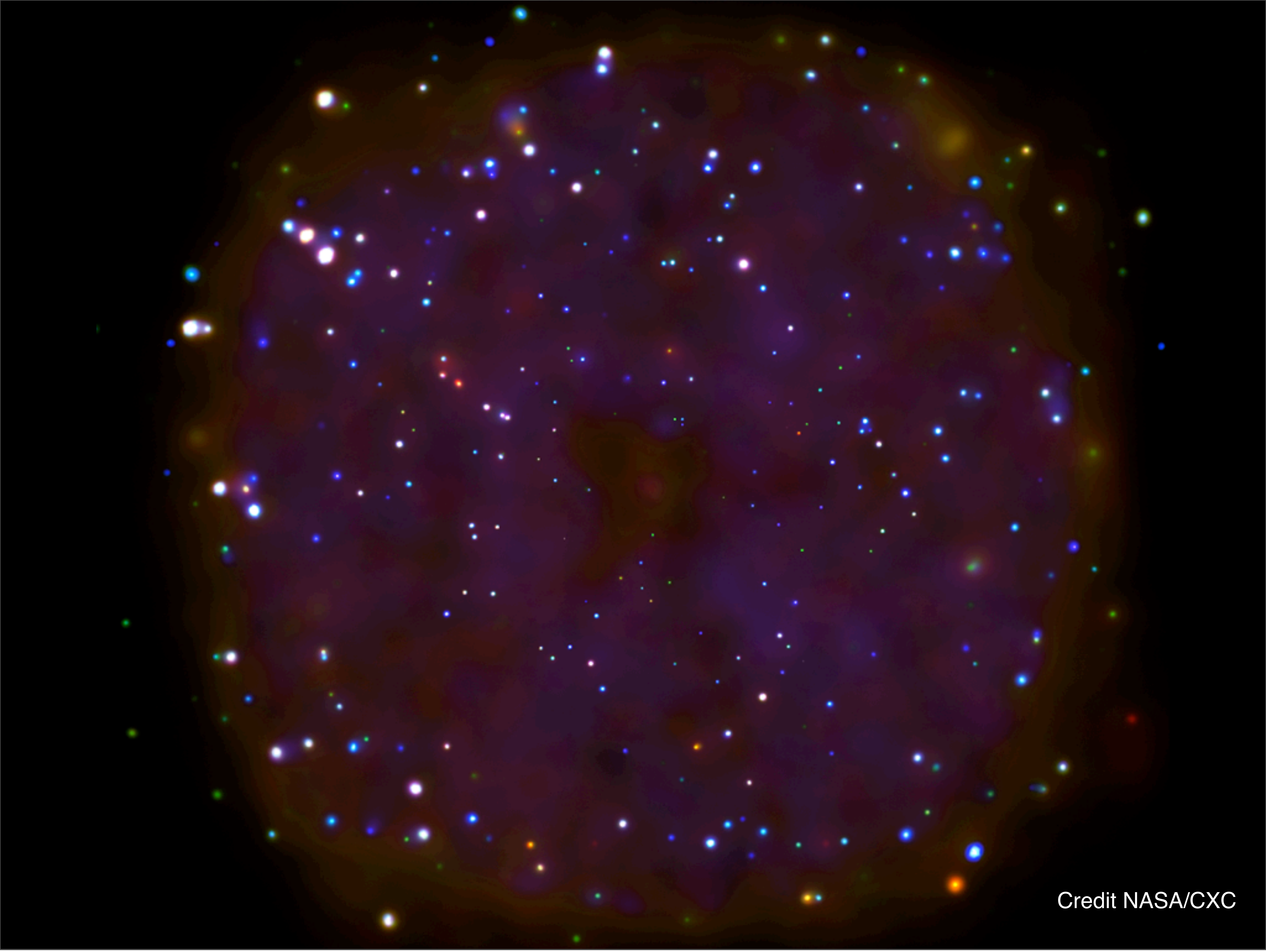

Credit NASA/CXC

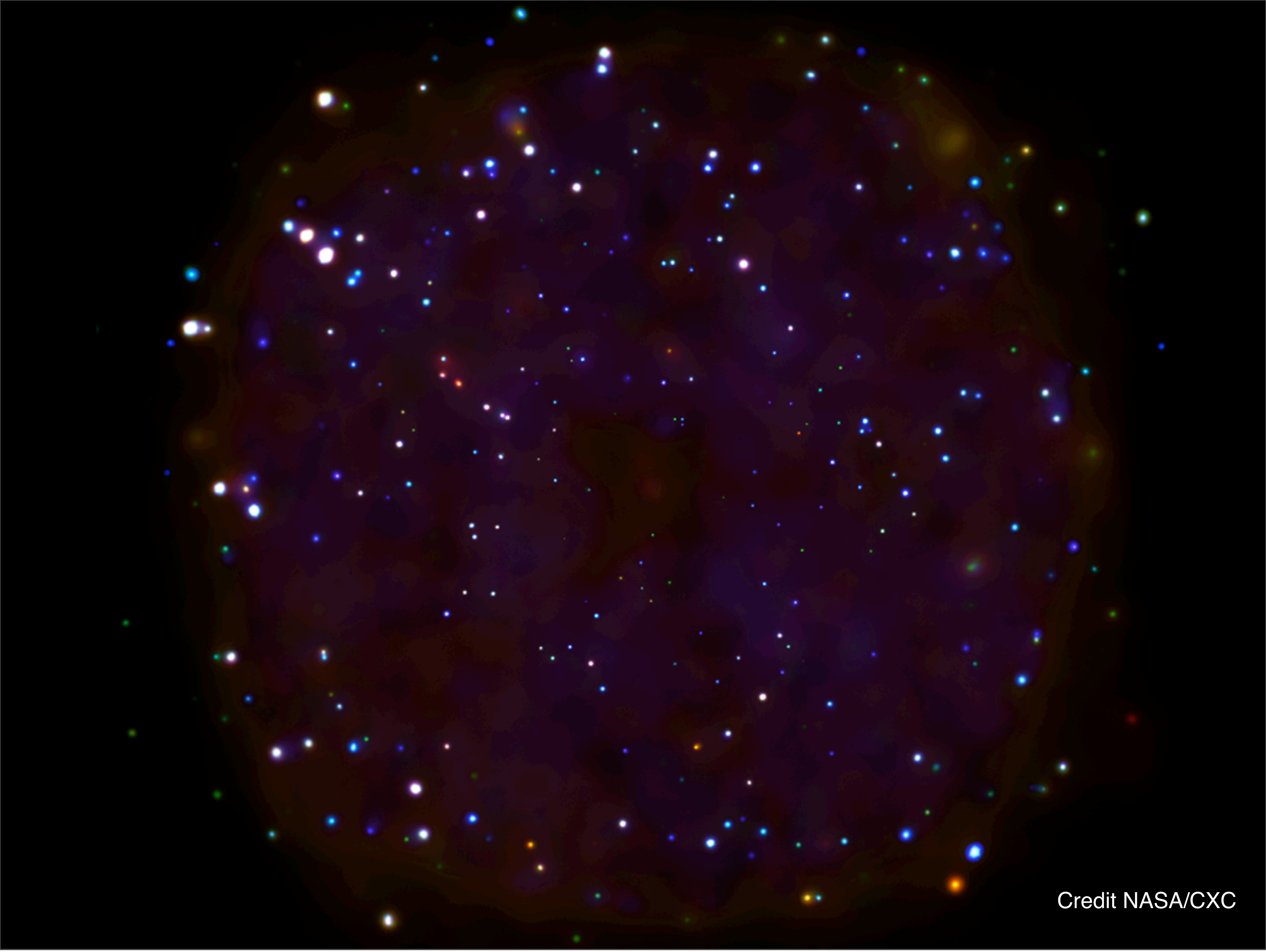
In what kind of galaxies to black holes grow?

What effect does this growth have
on the evolution of the host galaxy?

1. Is the hypothesis correct that black holes grow in galaxy collisions?

2. Can we observe the effect of “feedback” directly”

3. Woher kommen denn die schwarzen Löcher in den Zentren von Galaxien?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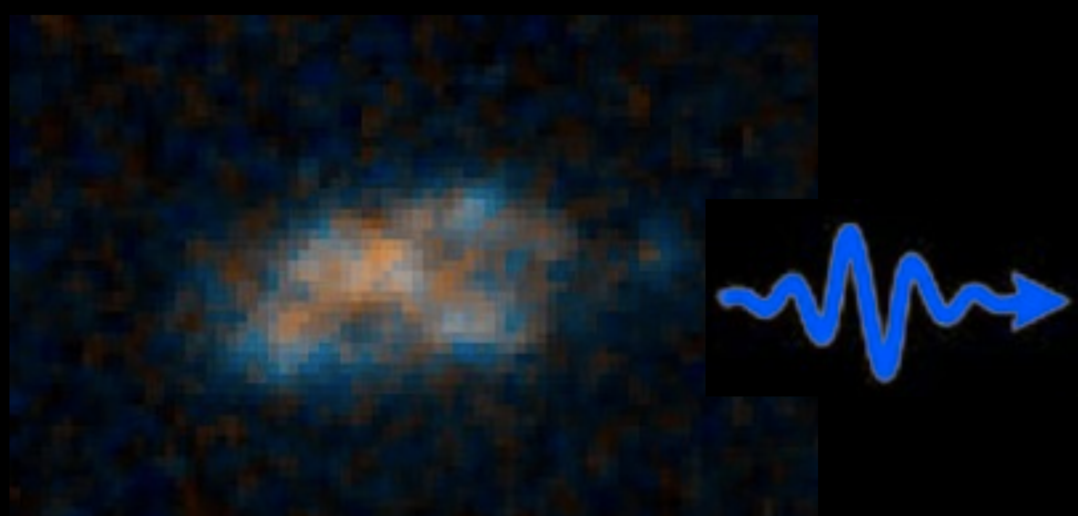
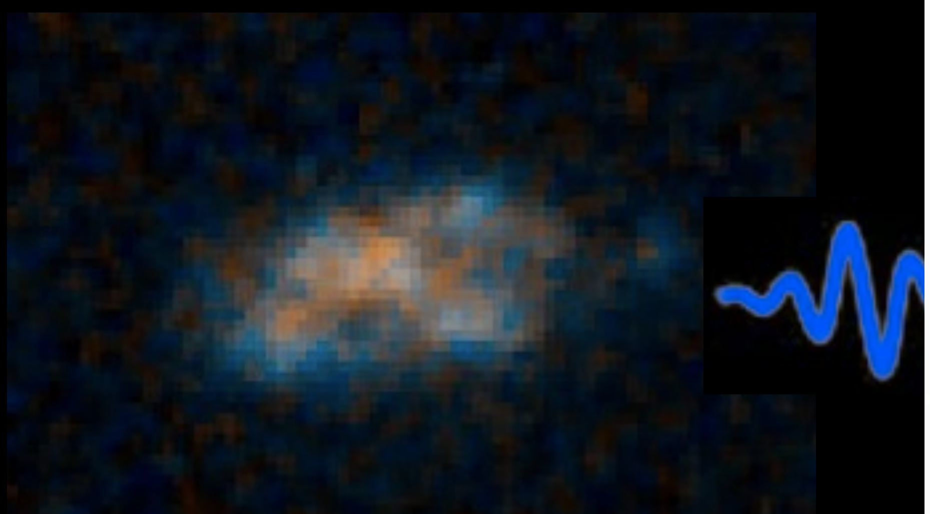
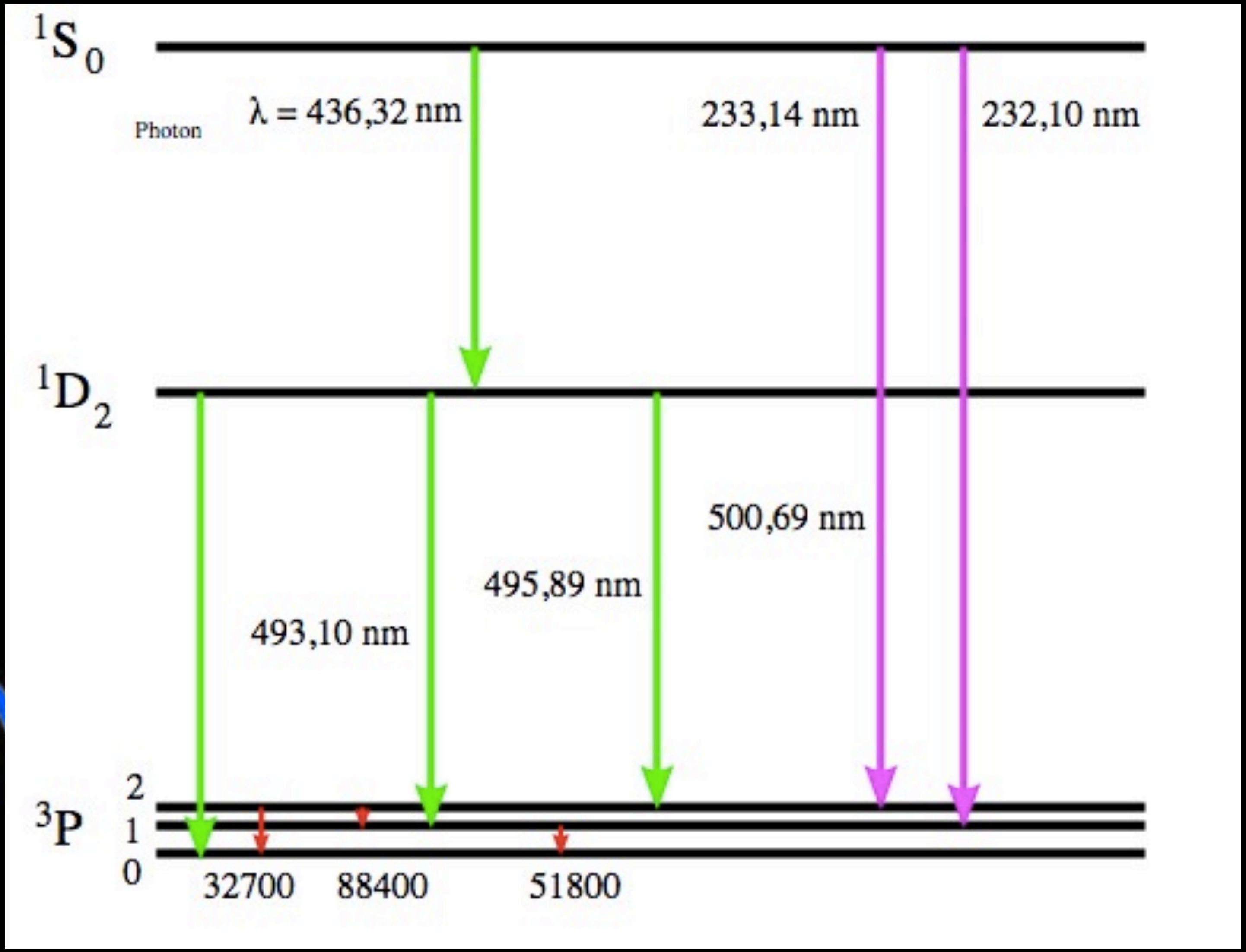
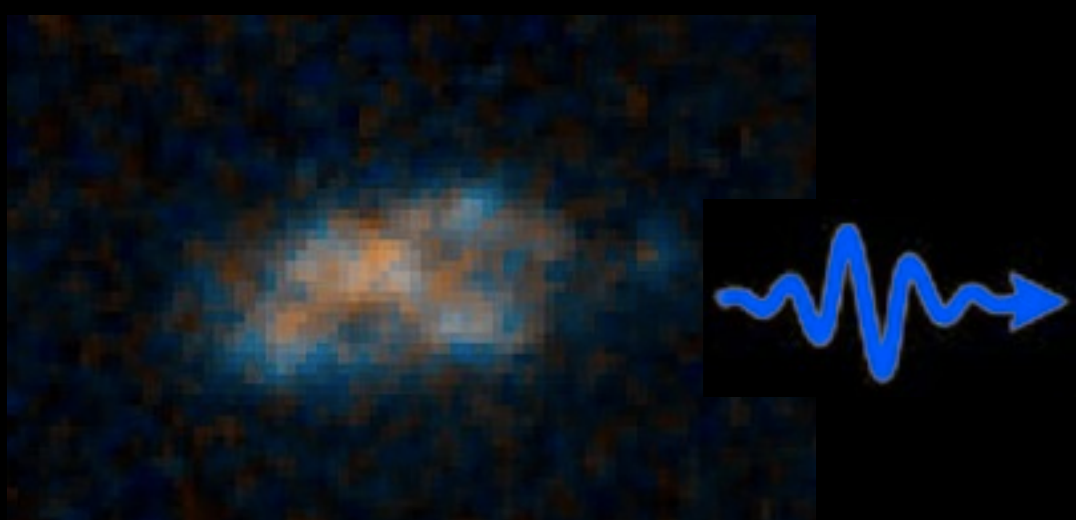
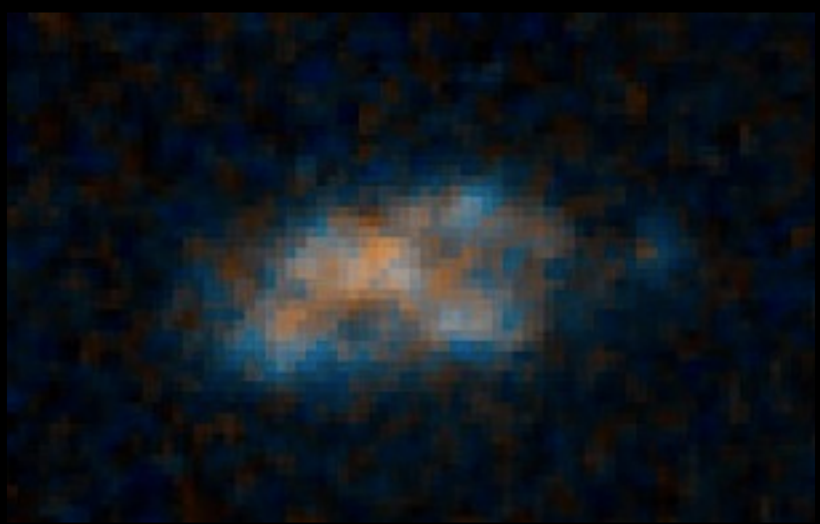






$^1S_0$
Photon
λ = 436,32 nm
233,14 nm
232,10 nm
$^1D_2$
500,69 nm
495,89 nm
493,10 nm
2
^3P
1
0
32700
88400
51800





Credit: NASA

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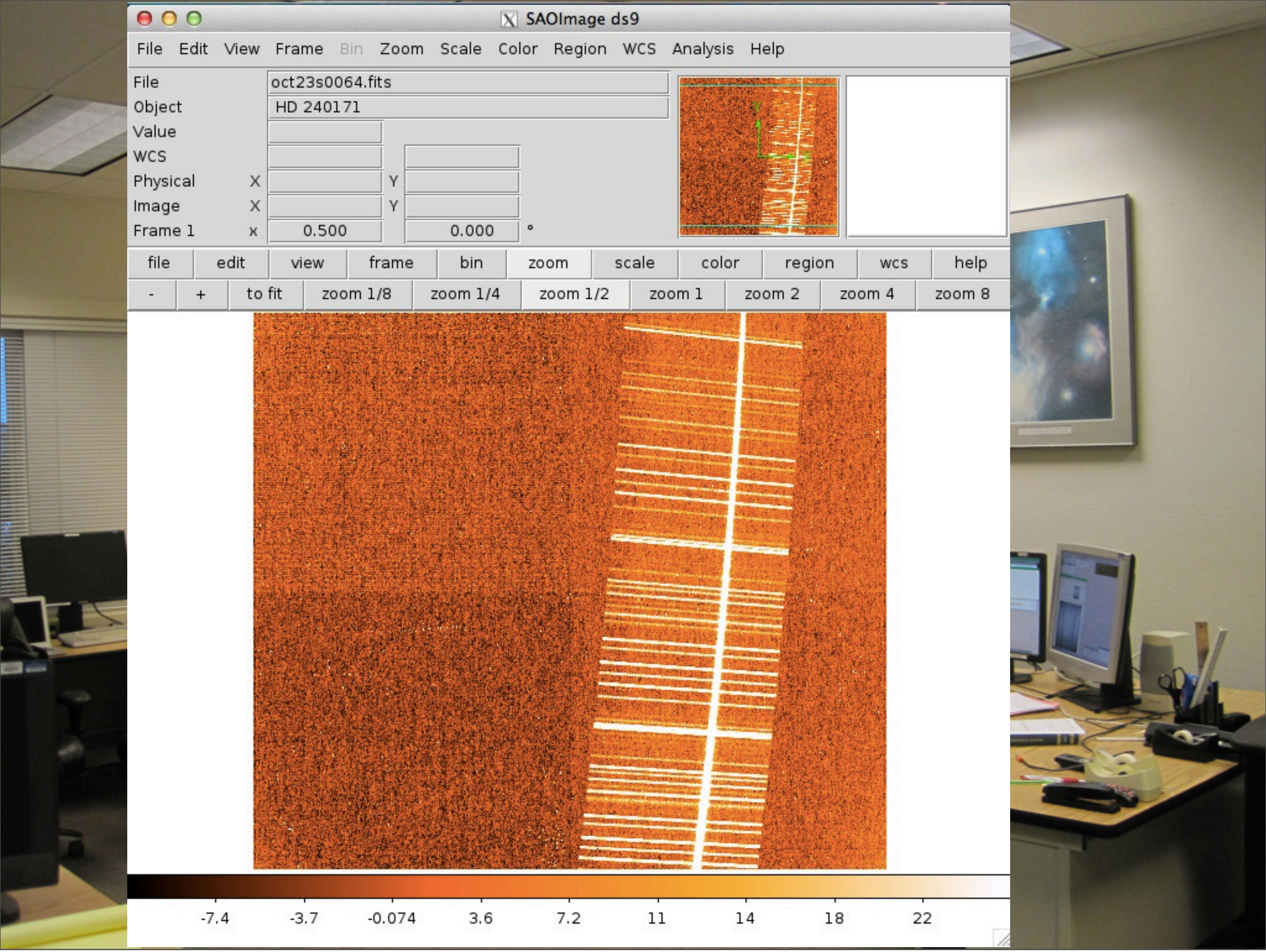
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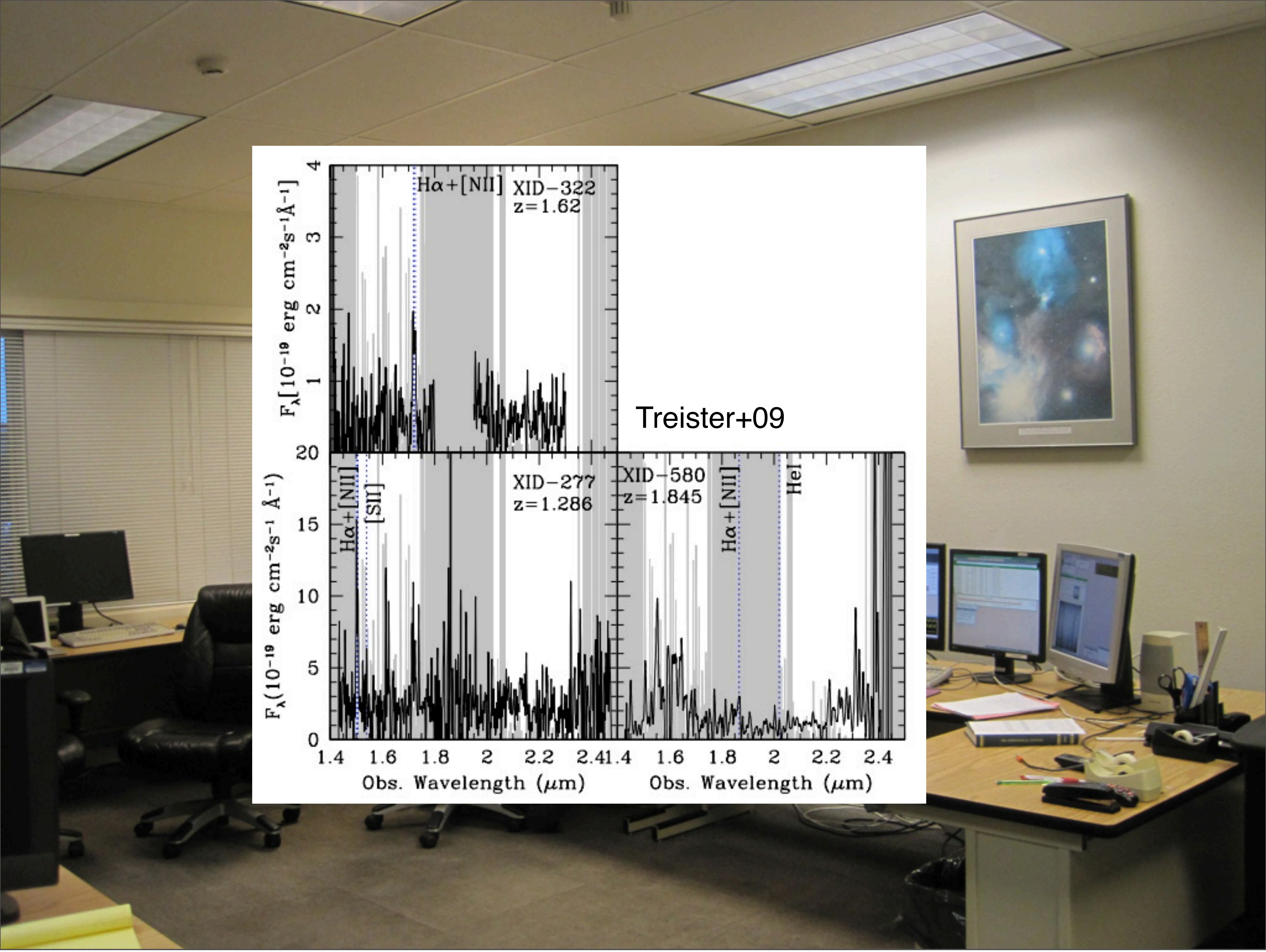
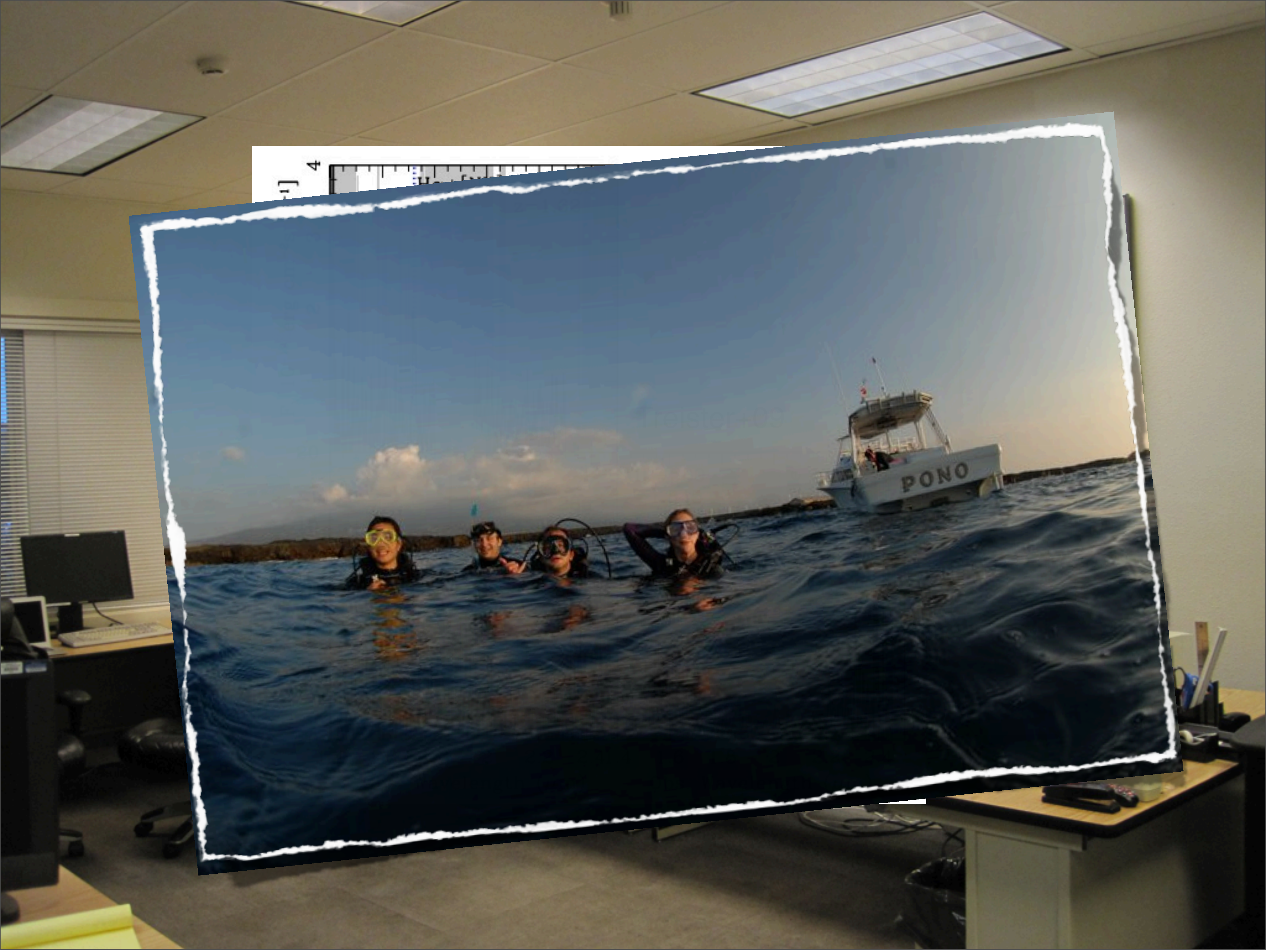
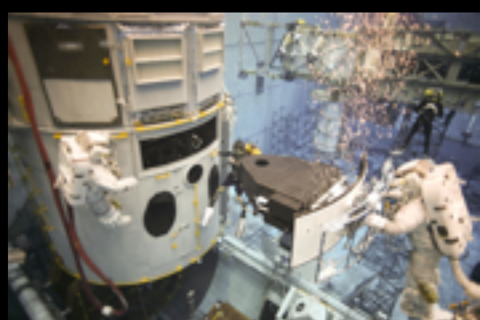
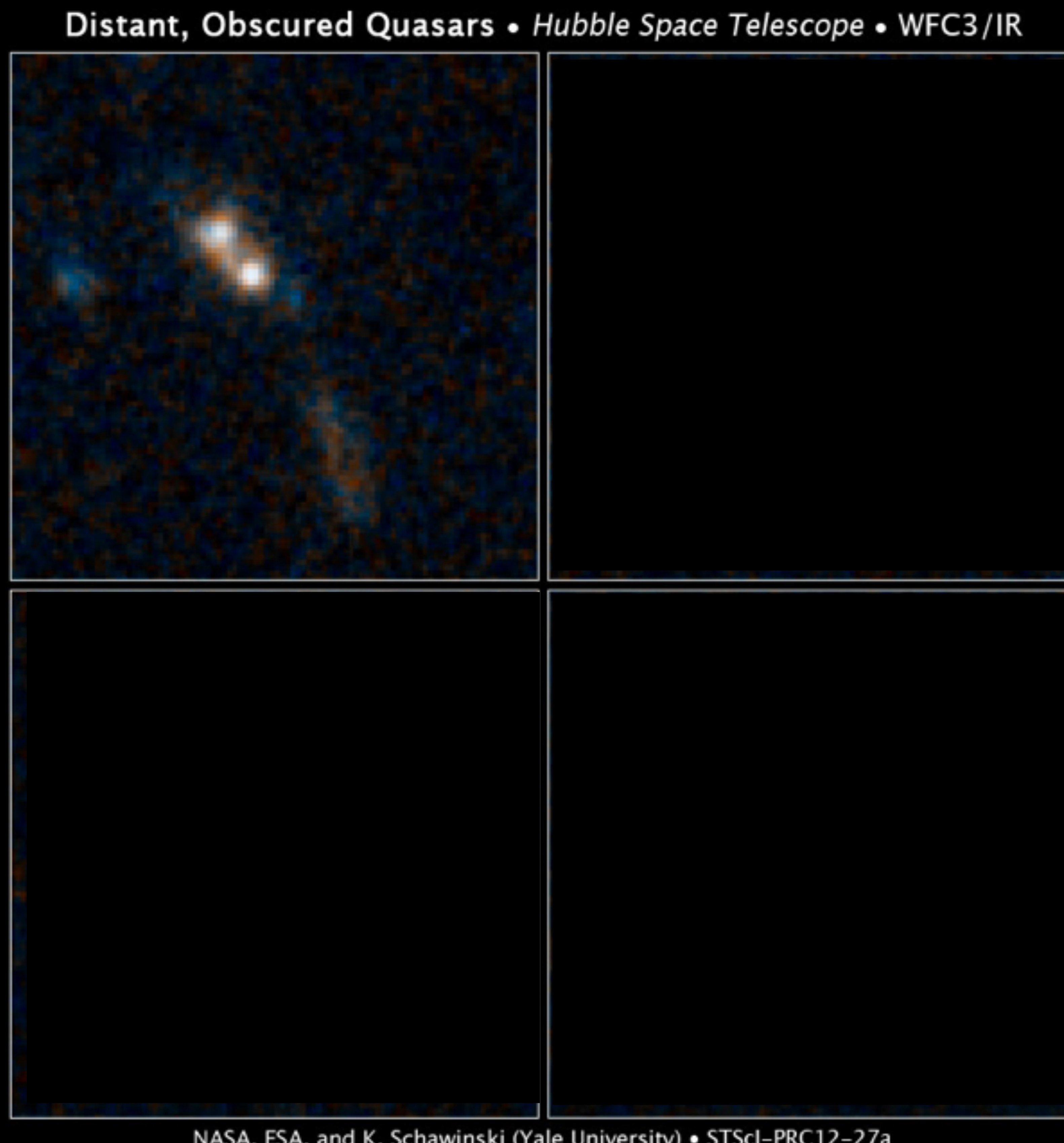

Hα+[NII]
XID−322
z=1.62
Fλ[10⁻¹⁹ erg cm⁻²s⁻¹Å⁻¹]
Treister+09
XID−277
z=1.286
Hα+[NII]
[SII]
Fλ(10⁻¹⁹ erg cm⁻²s⁻¹ Å⁻¹)
XID−580
z=1.845
Hα+[NII]
HeI
Obs. Wavelength (μm)
Obs. Wavelength (μm)


PONO

Normal Quasars

z~2, ca. 3 Billion years after the Big Bang





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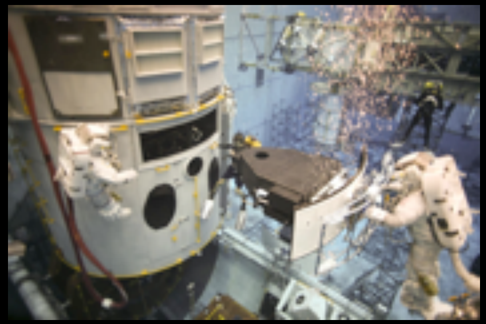

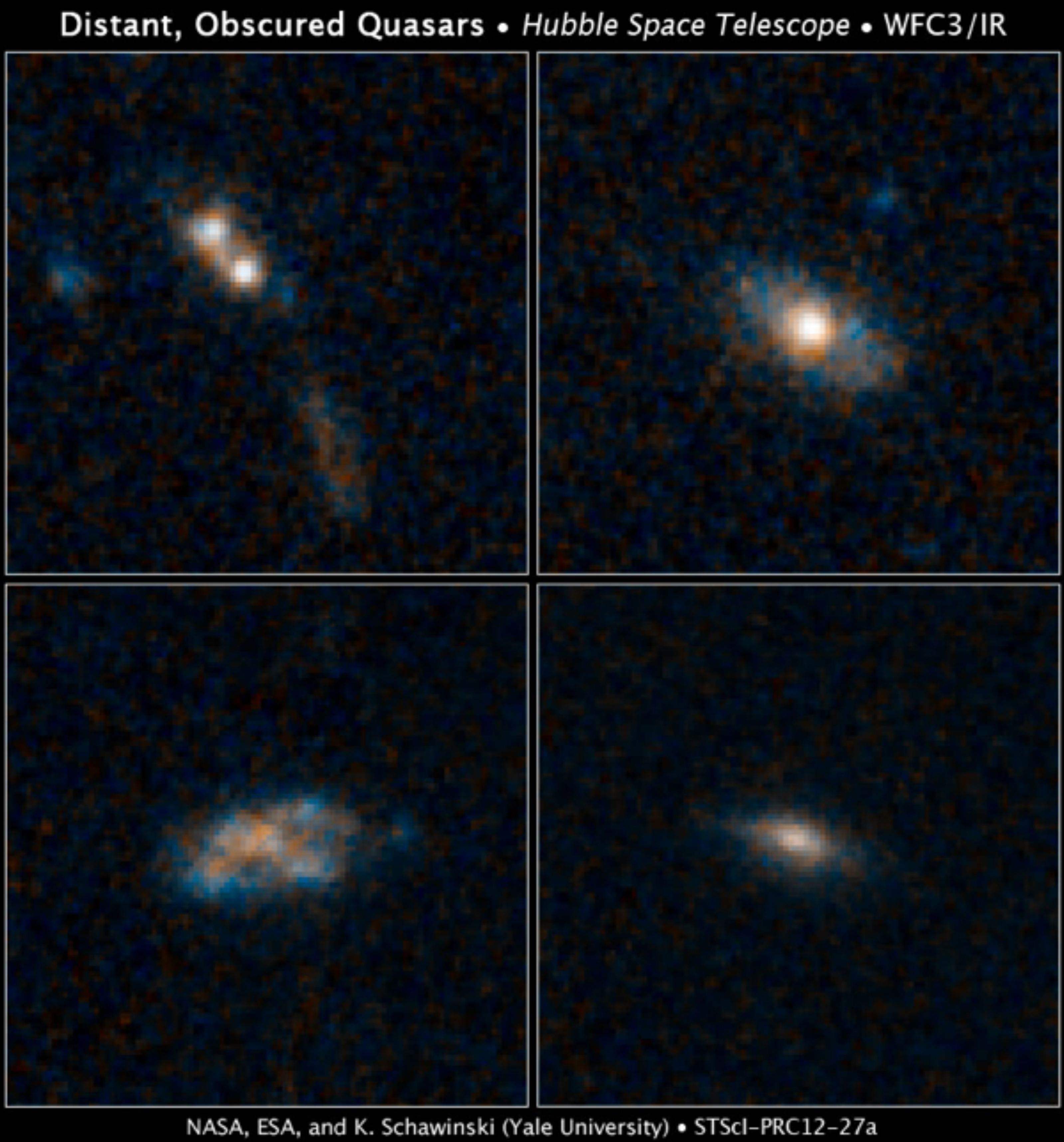

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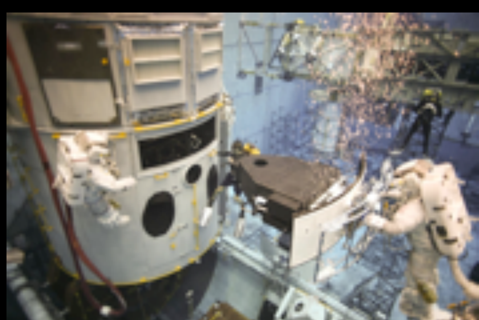

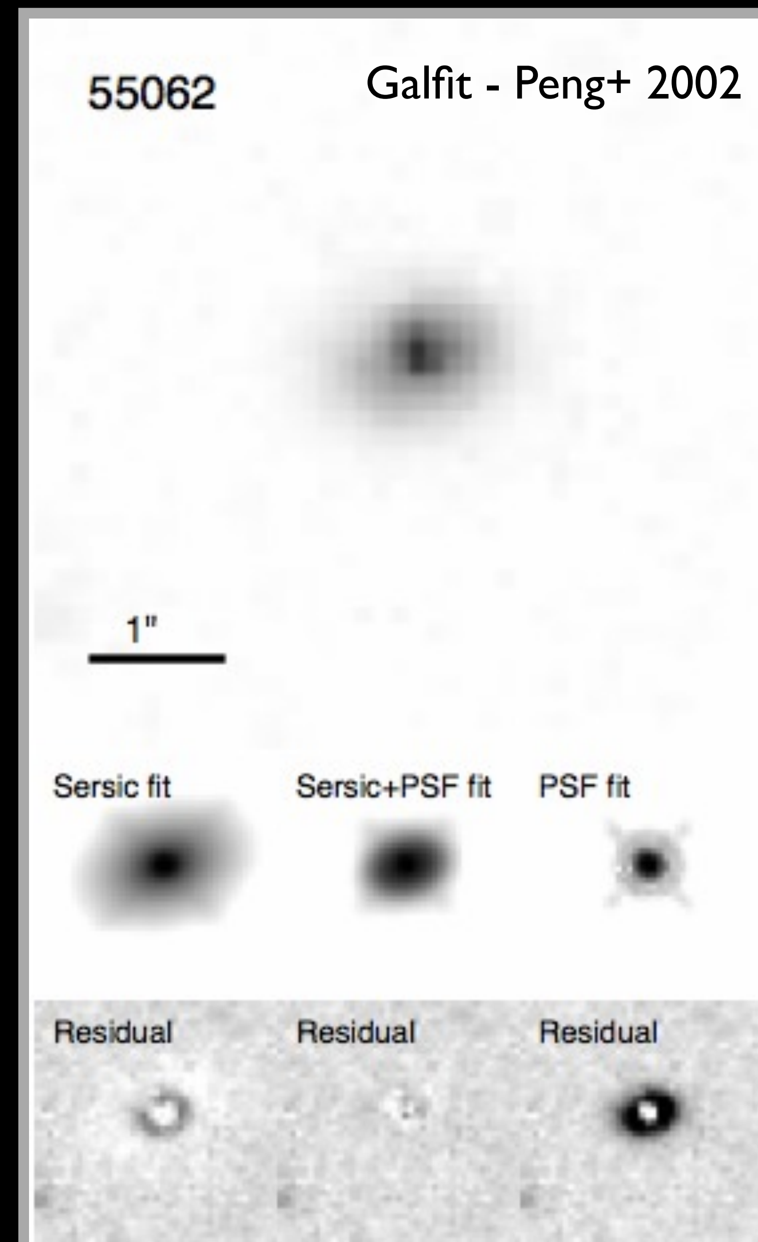

The Brightest Quasars in the Universe

z~0.5-2, ca. 3-9 Billion years after the Big Bang

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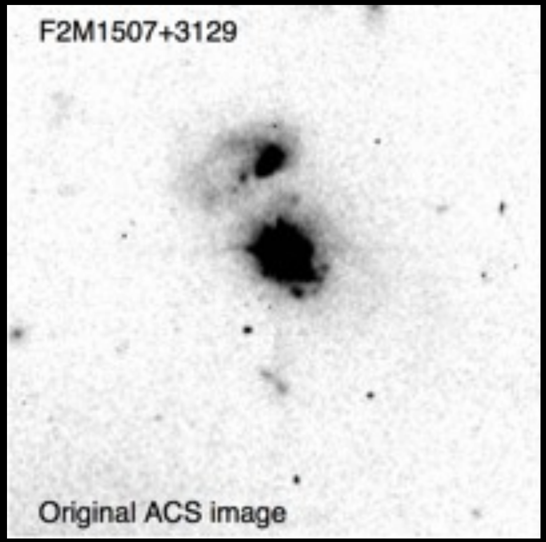

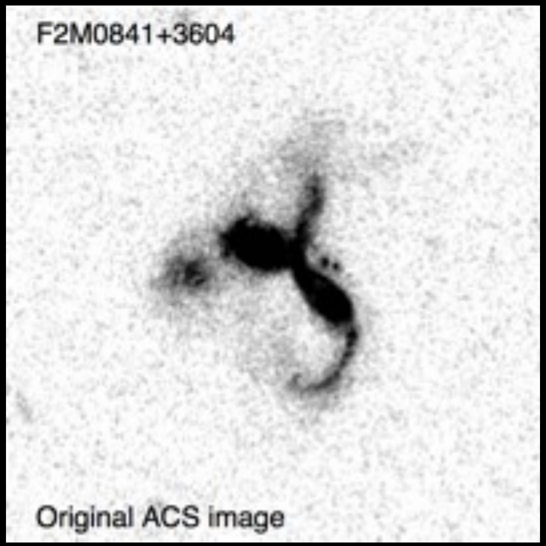

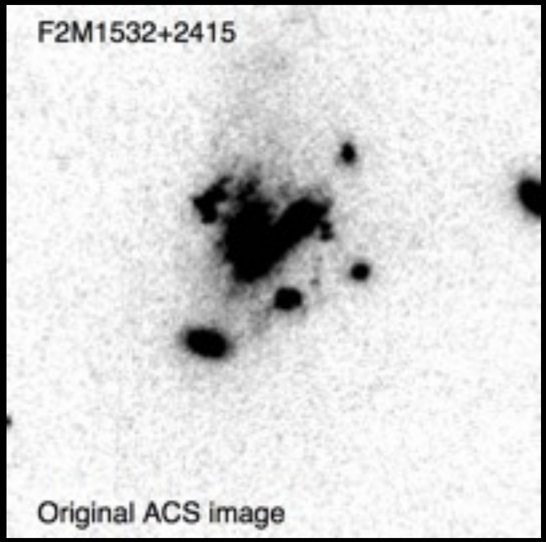

Hubble images of low-z “red” quasars
Urrutia+07

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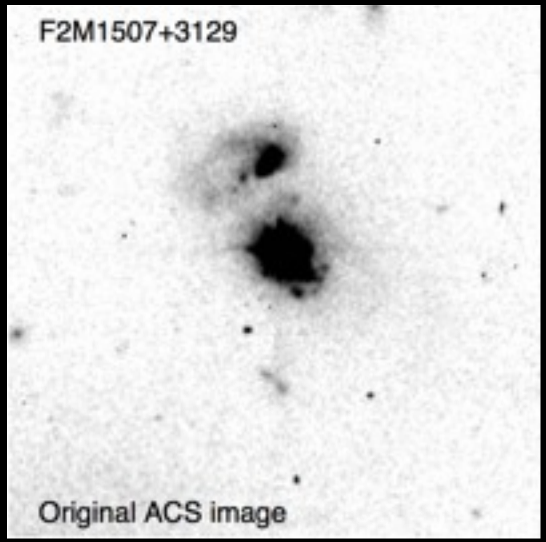
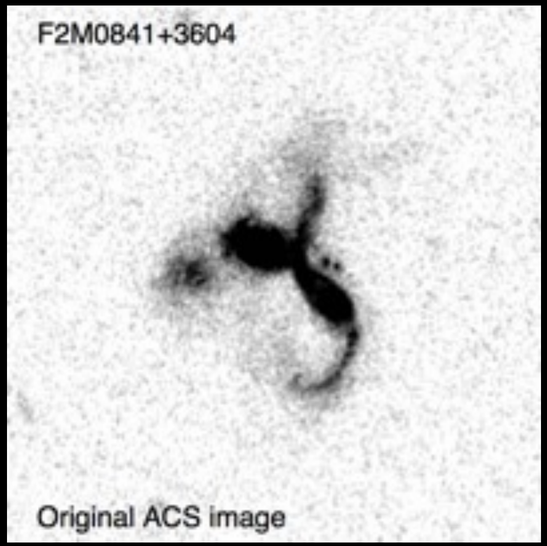
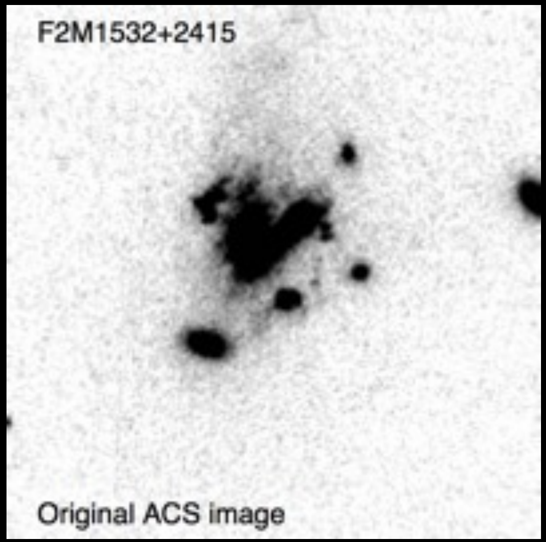
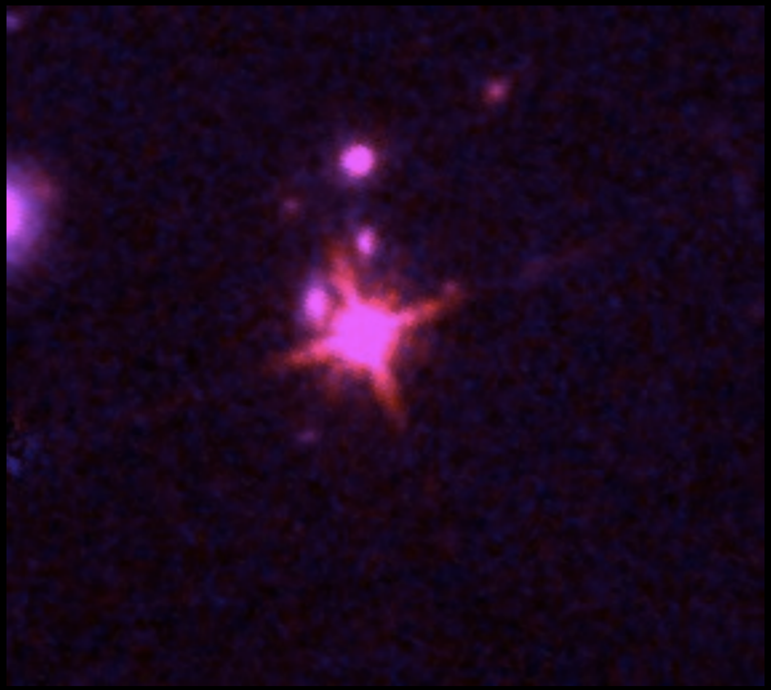




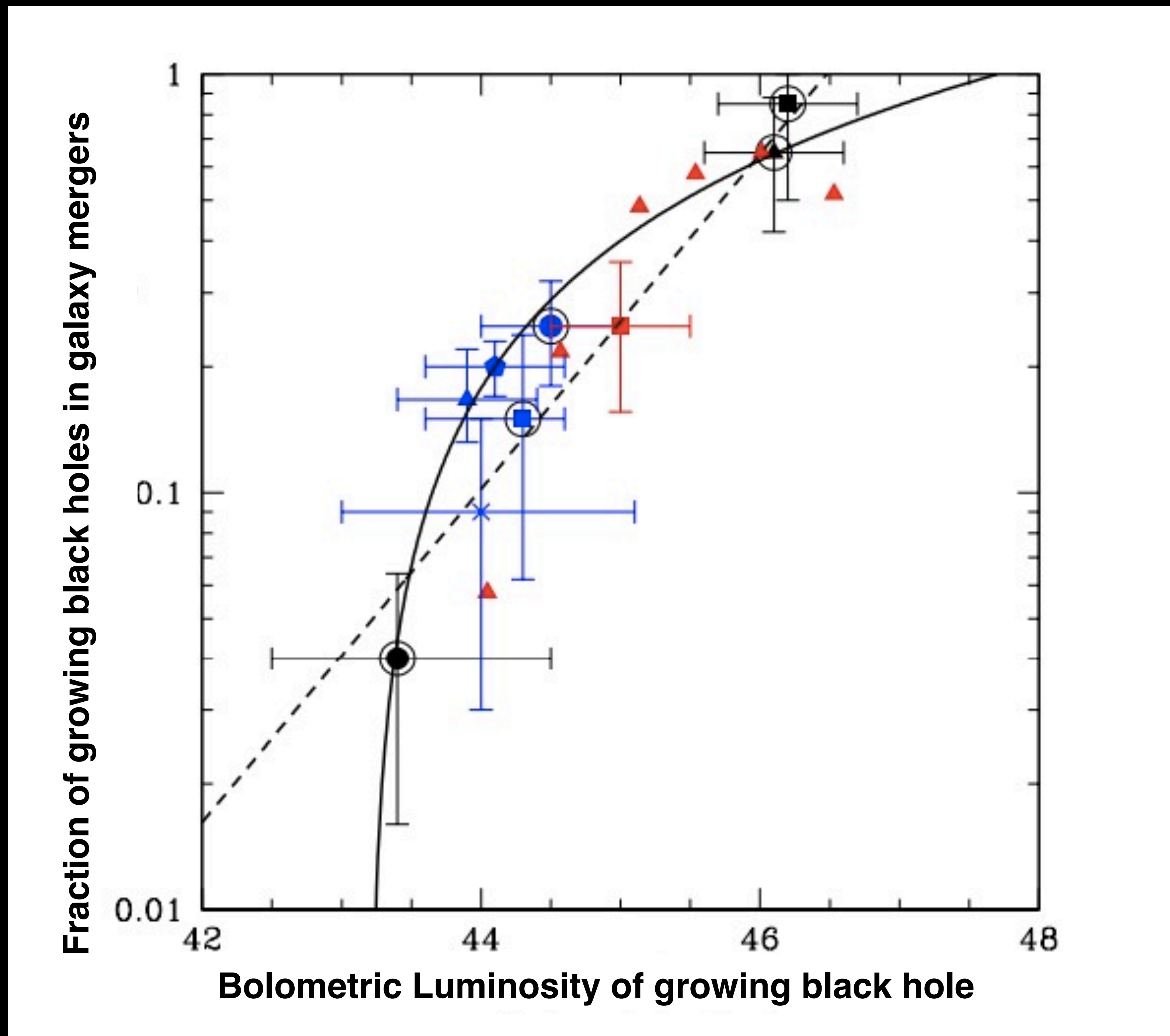




Hubble images of low-z “red” quasars
Urrutia+07

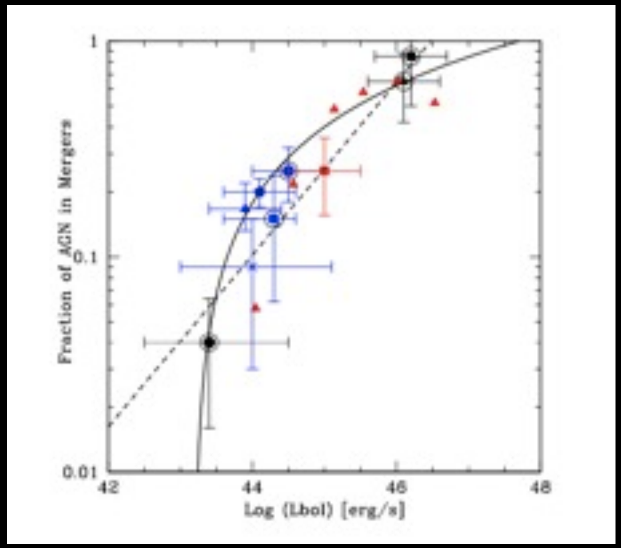
Hubble images of high-z “red” quasars

Are black hole growth episodes triggered by galaxy mergers?

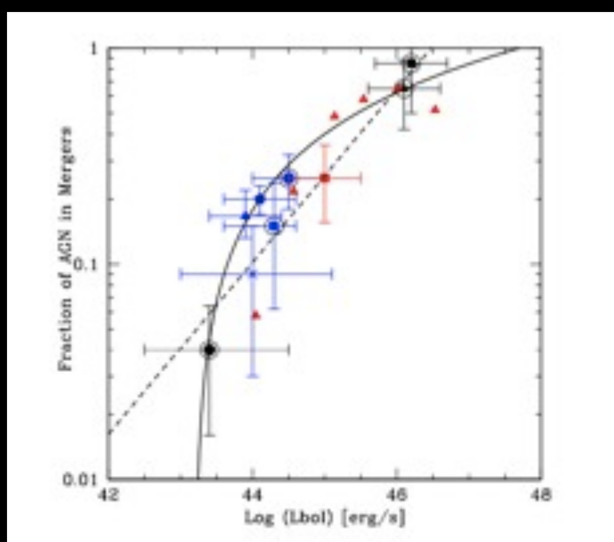


Treister, Schawinski, Simmons & Urry 2013

How and where do black holes grow?



How and where do black holes grow?



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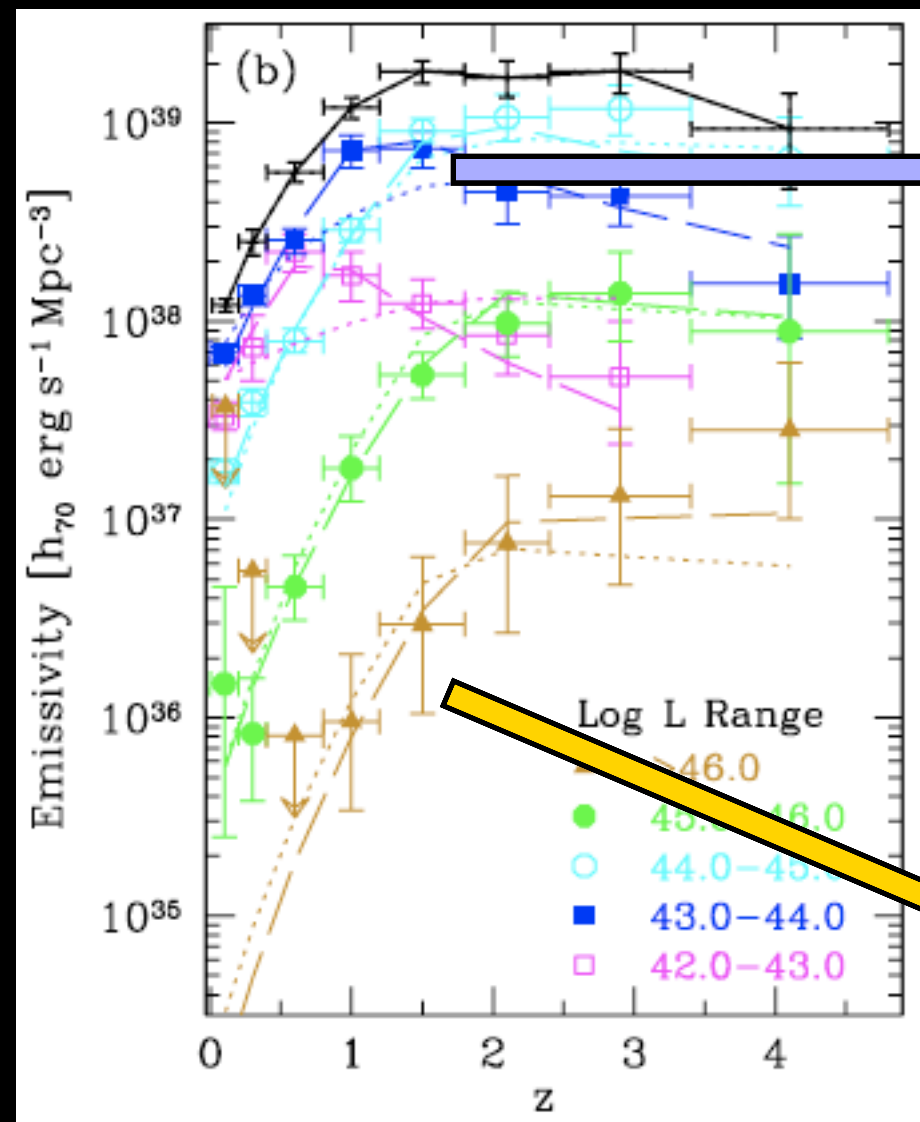
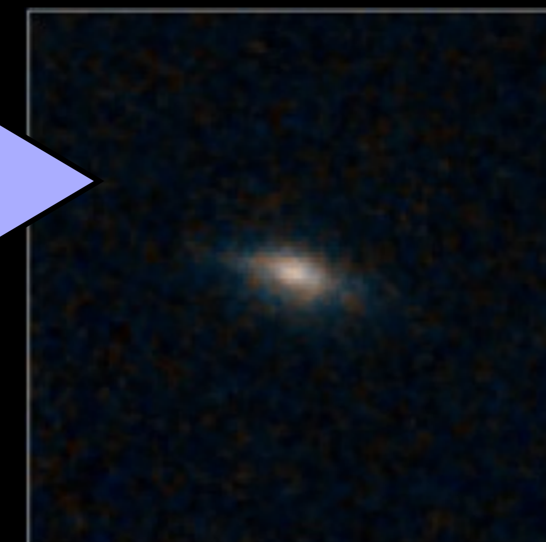
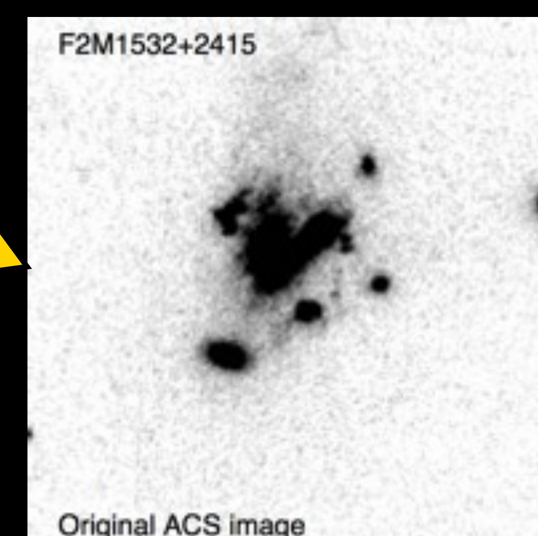


Hasinger+2005





How and where do black holes grow?

“normal” growing black holes

90% by space density
50% of mass accreted

the brightest quasars in the universe

10% by space density
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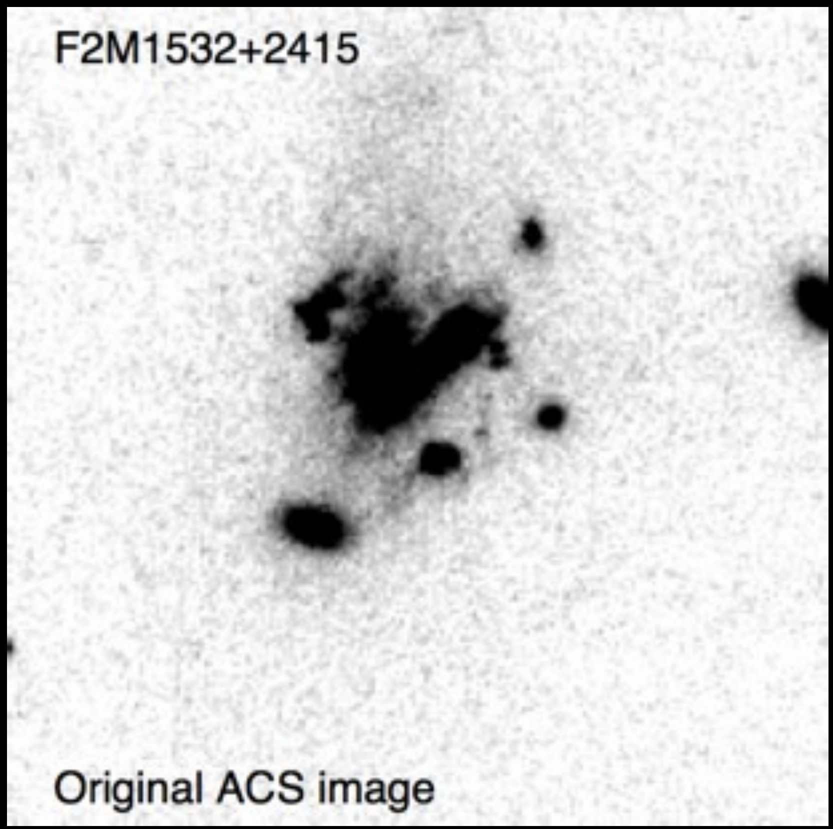

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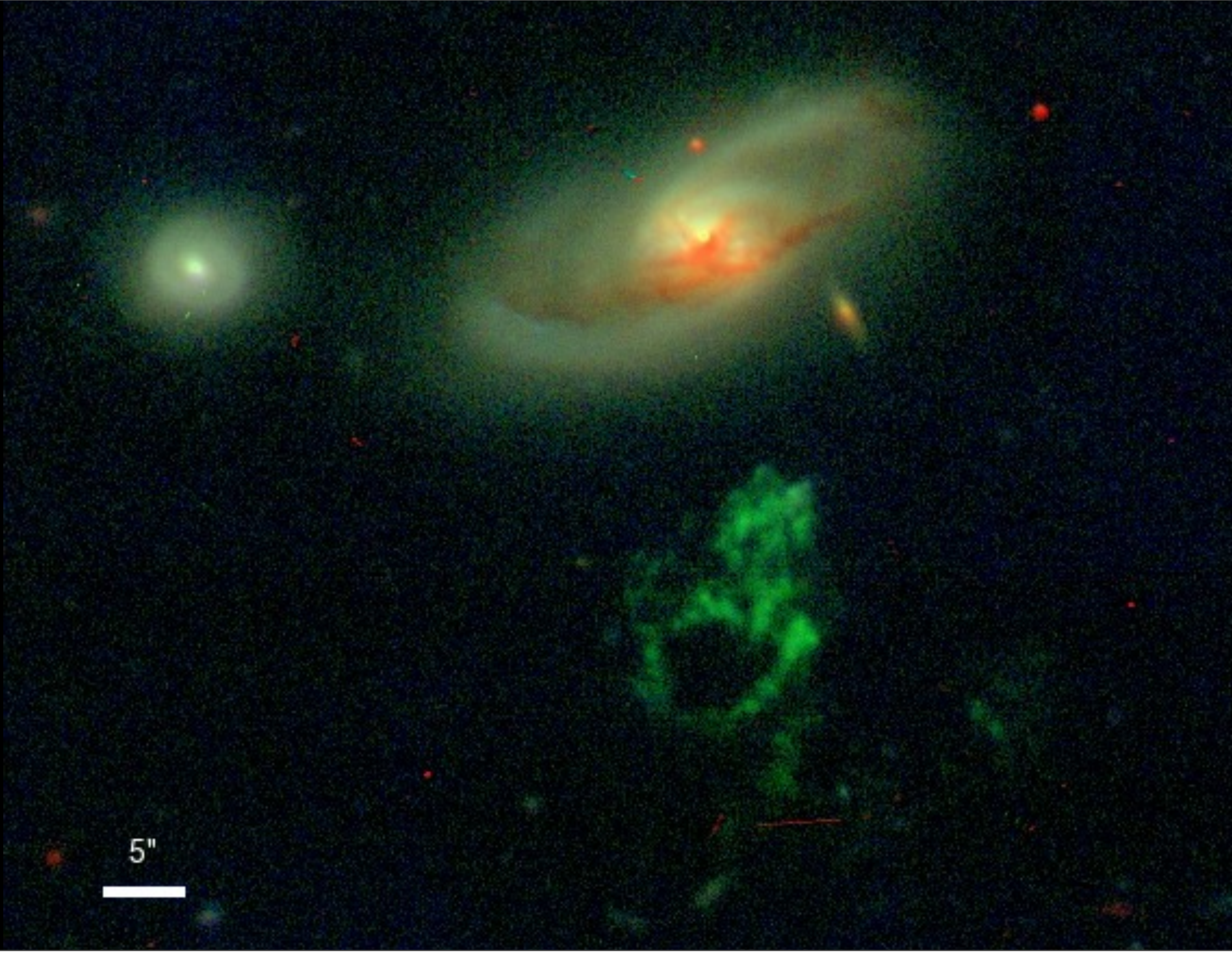
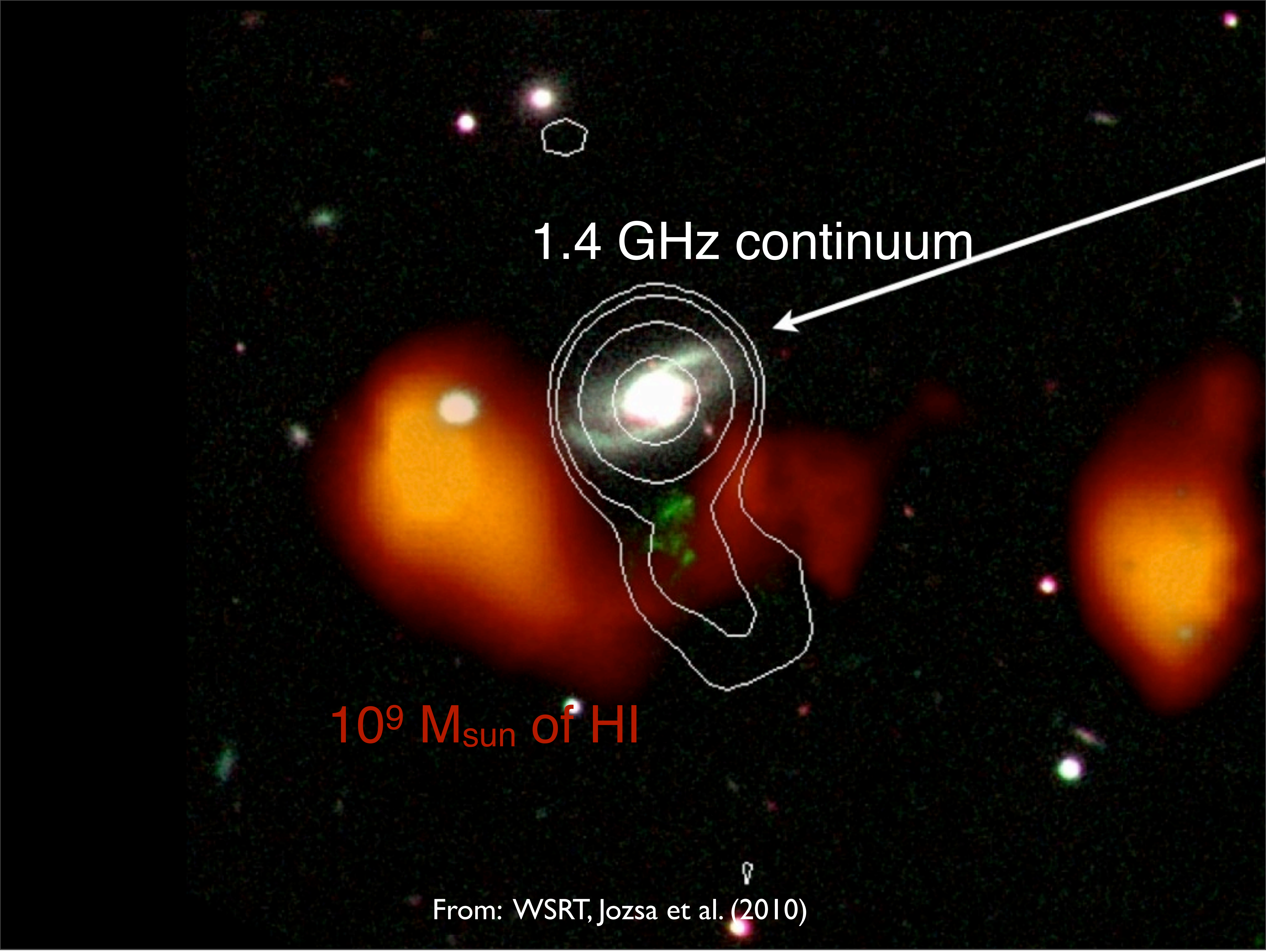
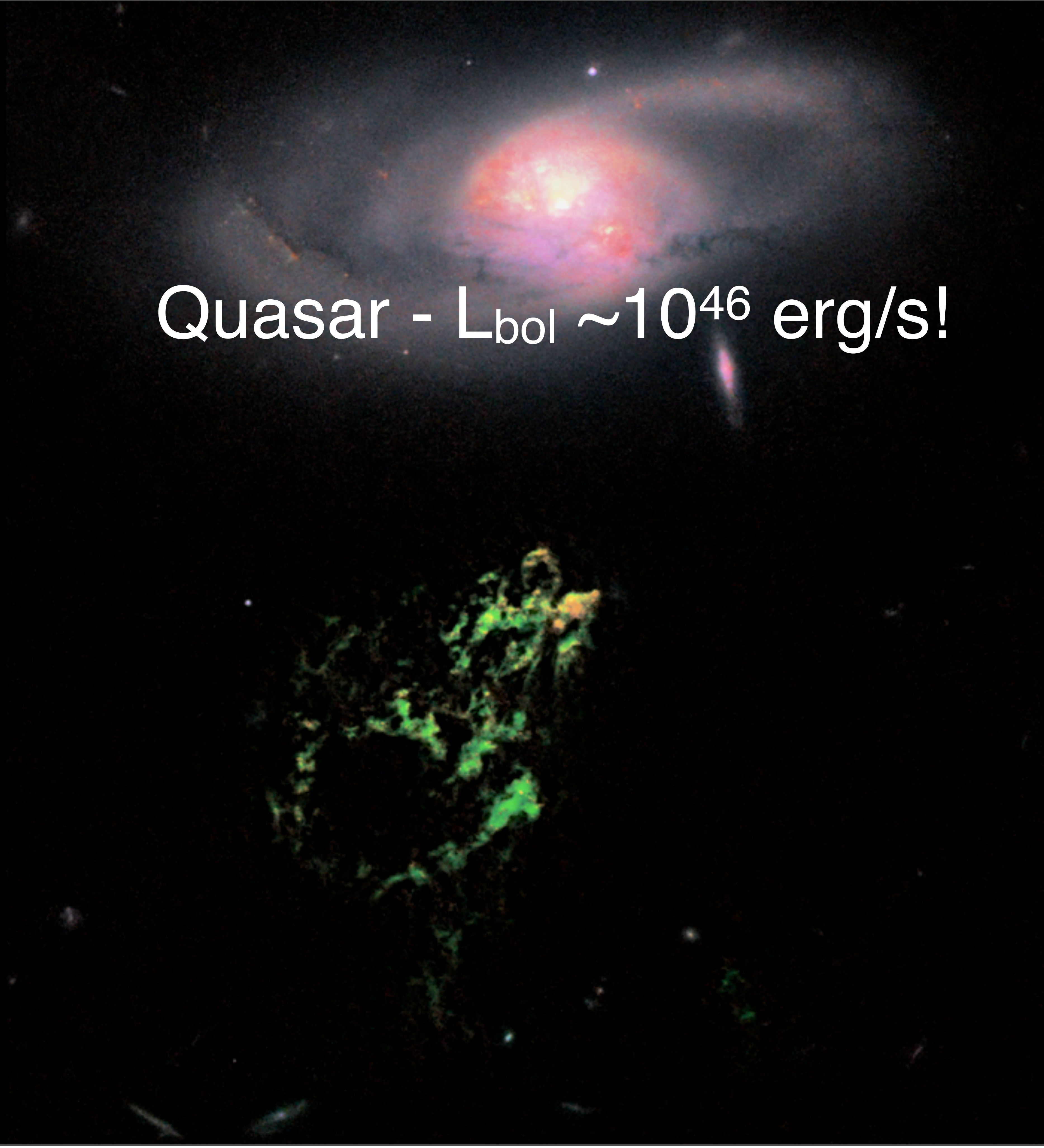
Discovered by citizen scientist Hanny van Arkel in 2007


5"


1.4 GHz continuum
10^9 M_{sun} of HI
From: WSRT, Jozsa et al. (2010)



Quasar - L_{bol} ~10^{46} erg/s!

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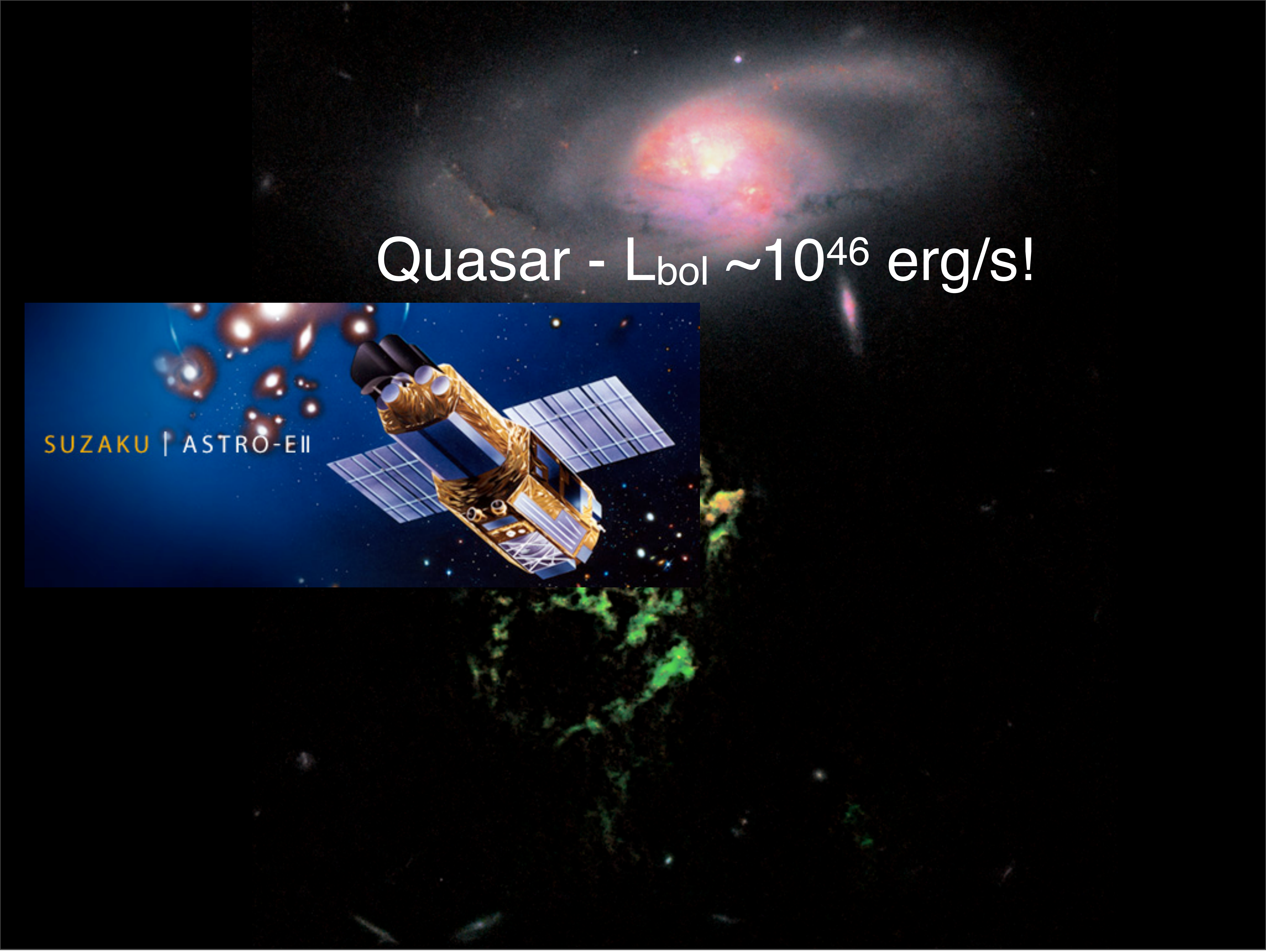

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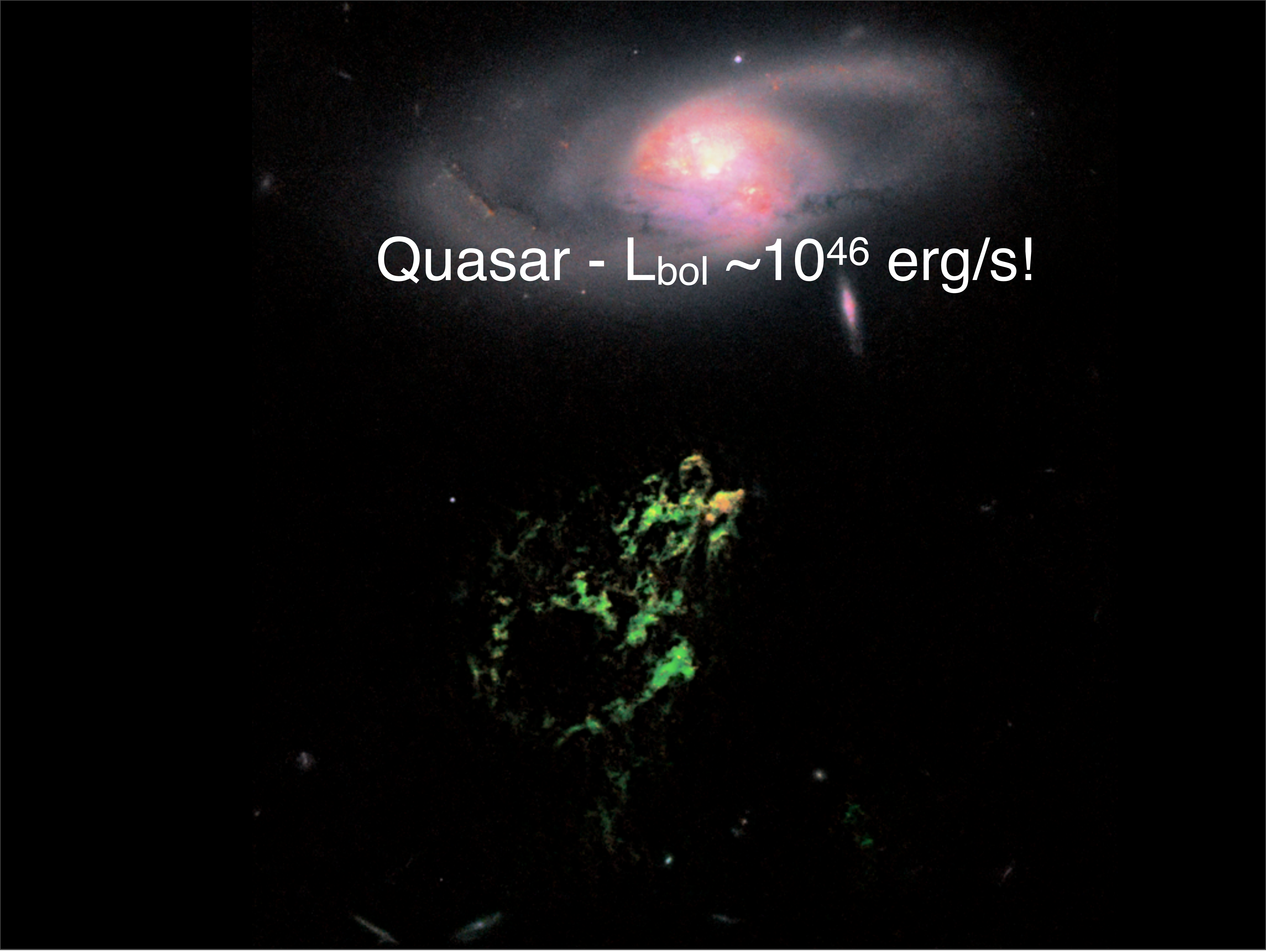
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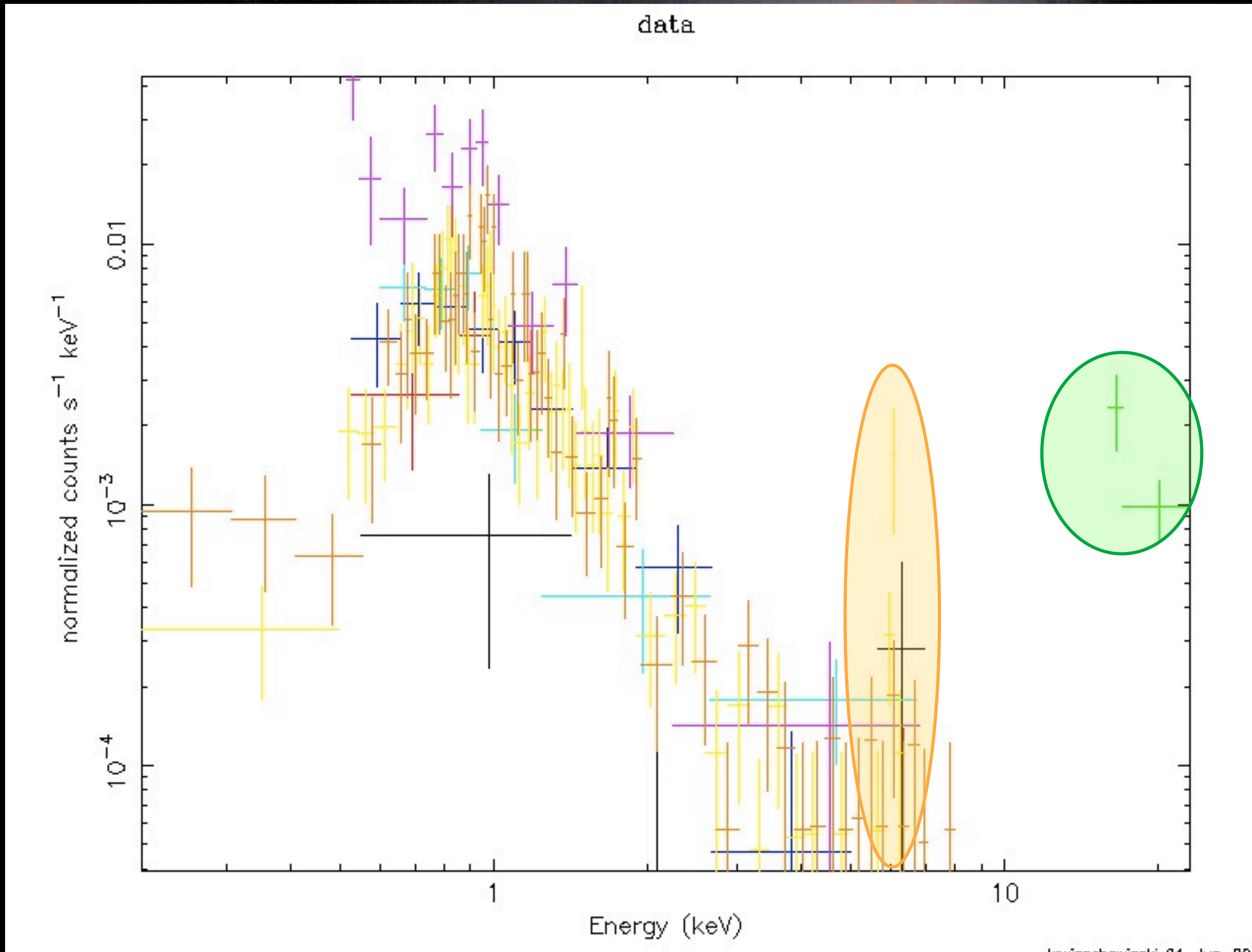
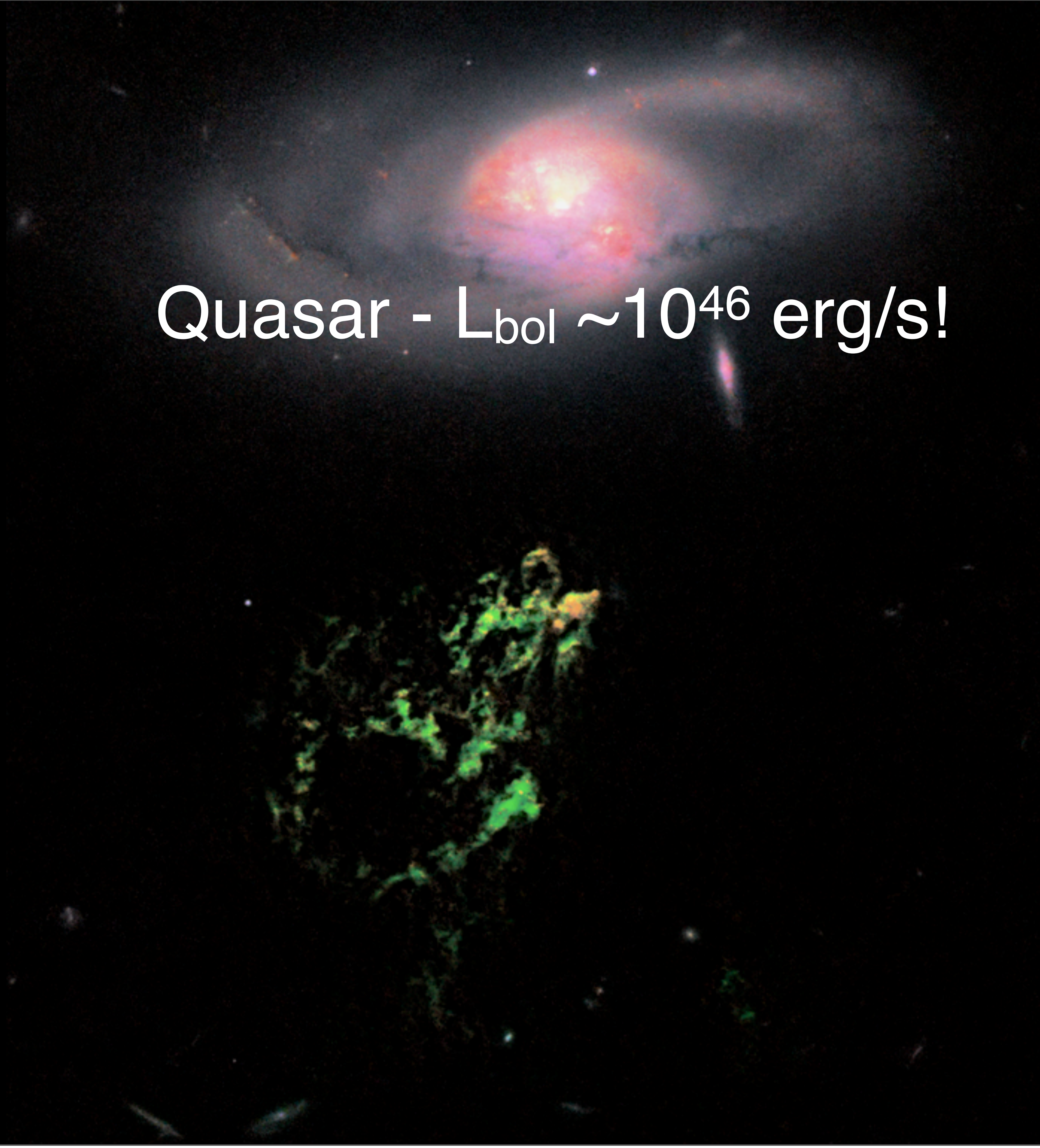

data
normalized counts s^{-1} keV^{-1}
0.01
10^{-3}
10^{-4}
1
10
Energy (keV)
kevinschawinski 24–Jun–201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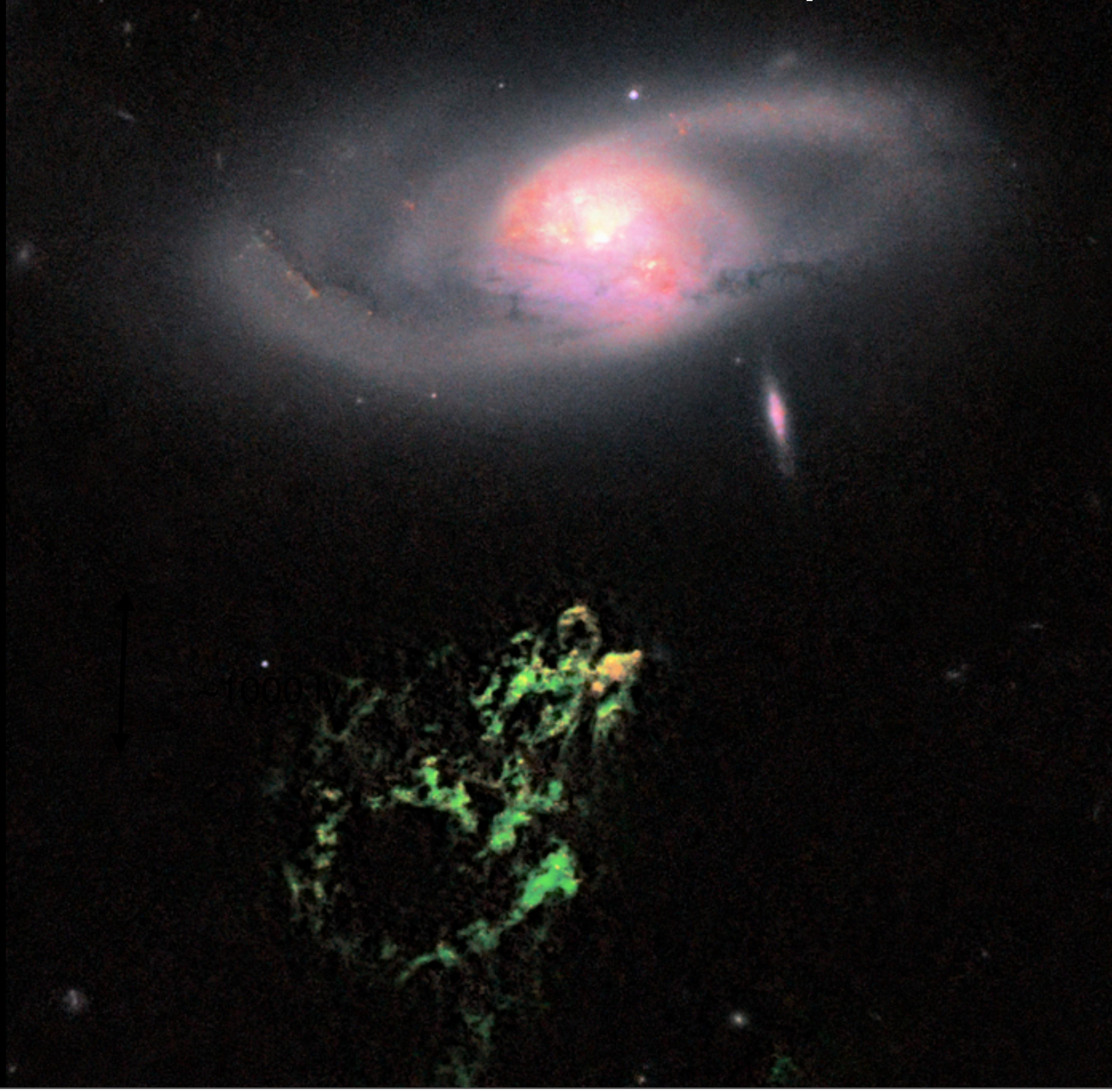
A better view of the heart of a quasar



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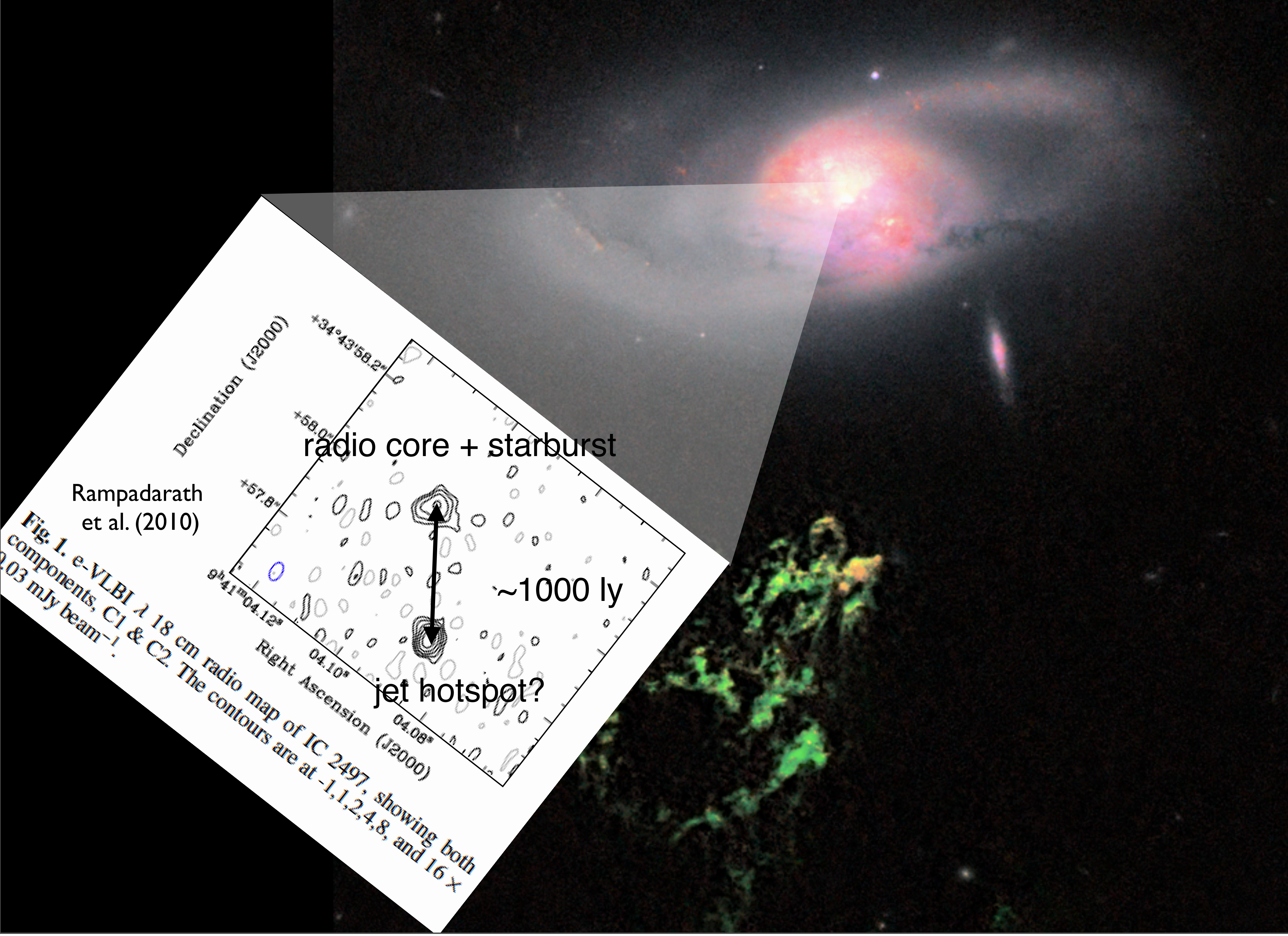

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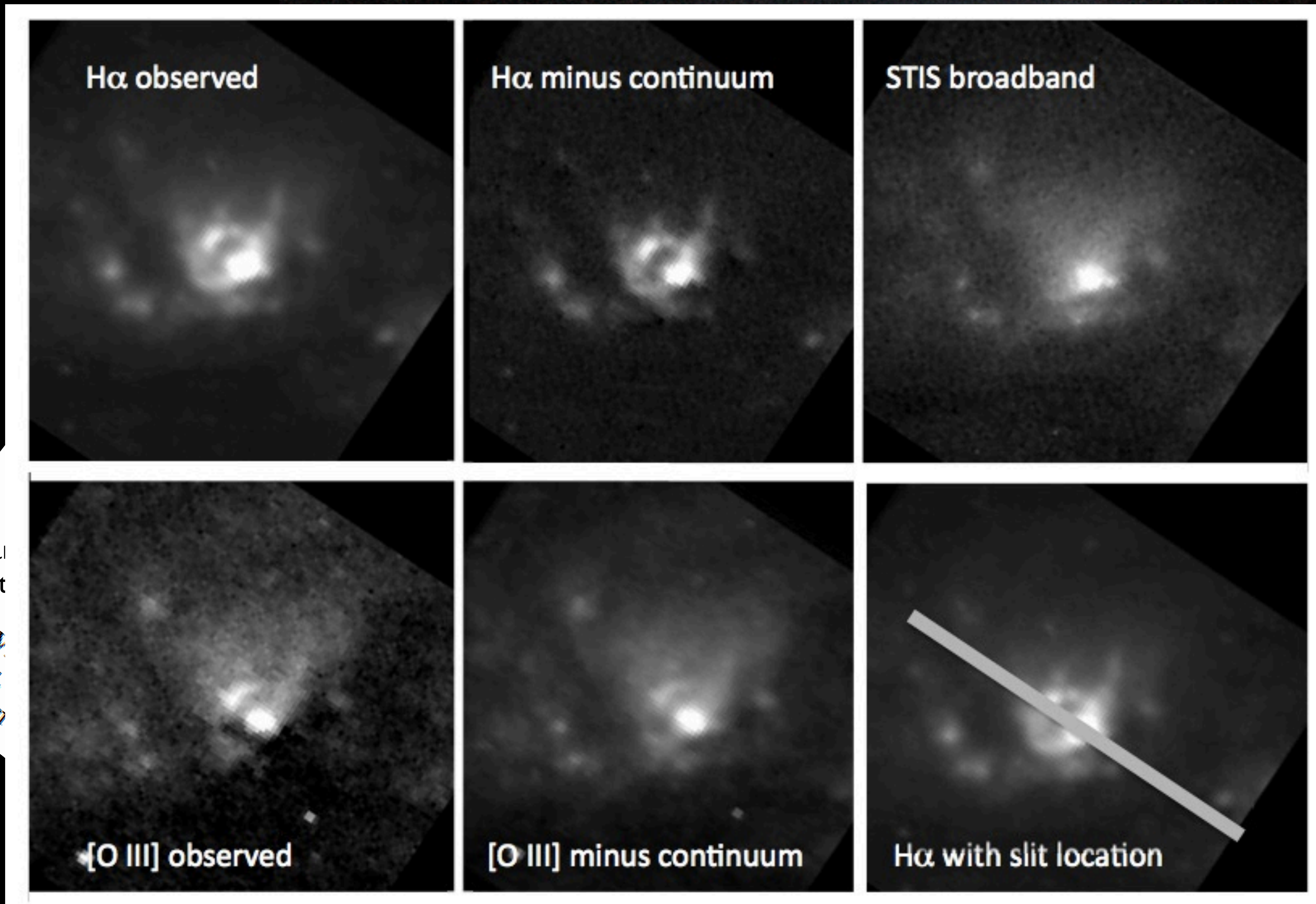
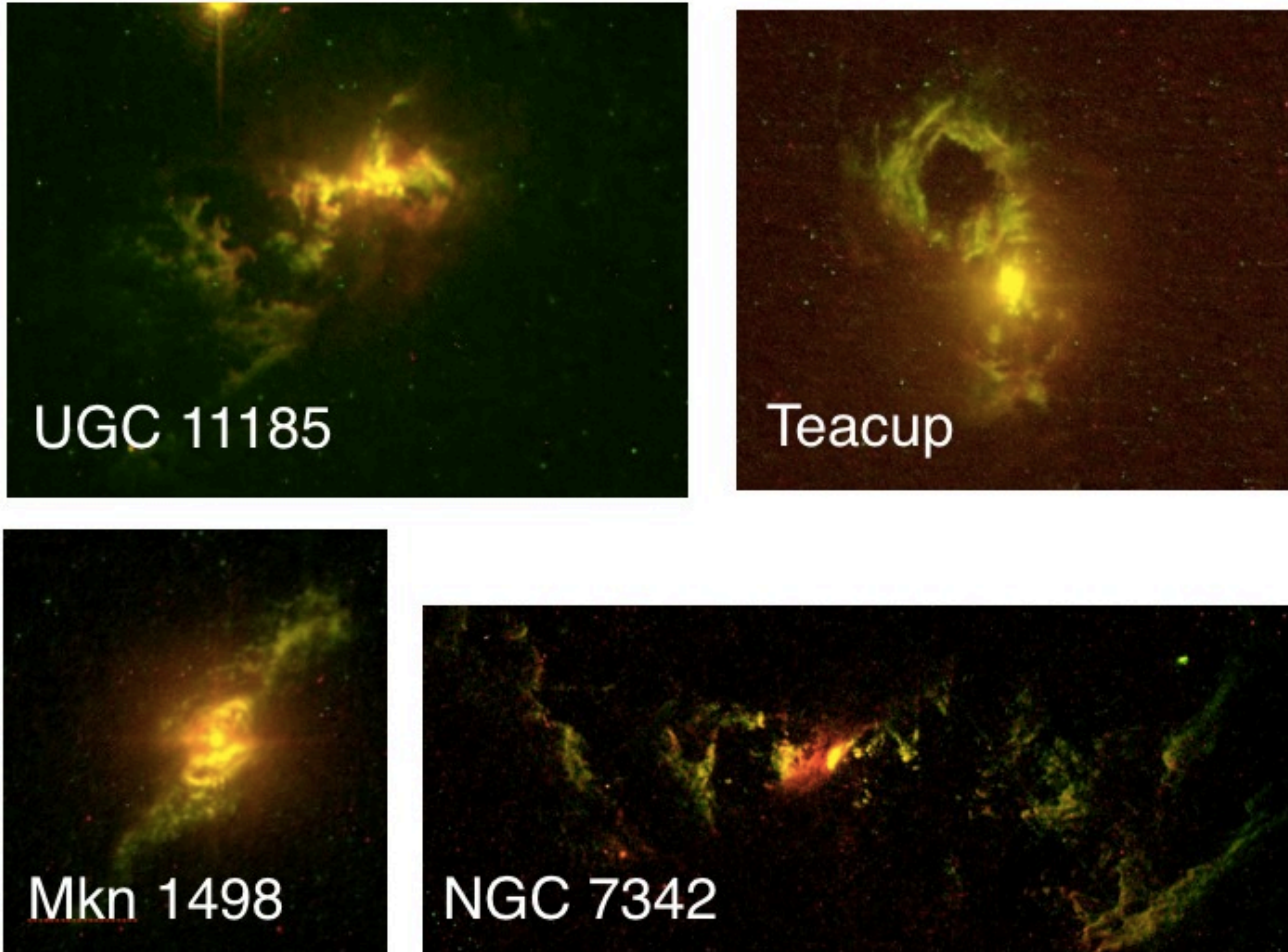



UGC 11185
Teacup
Mkn 1498
NGC 7342

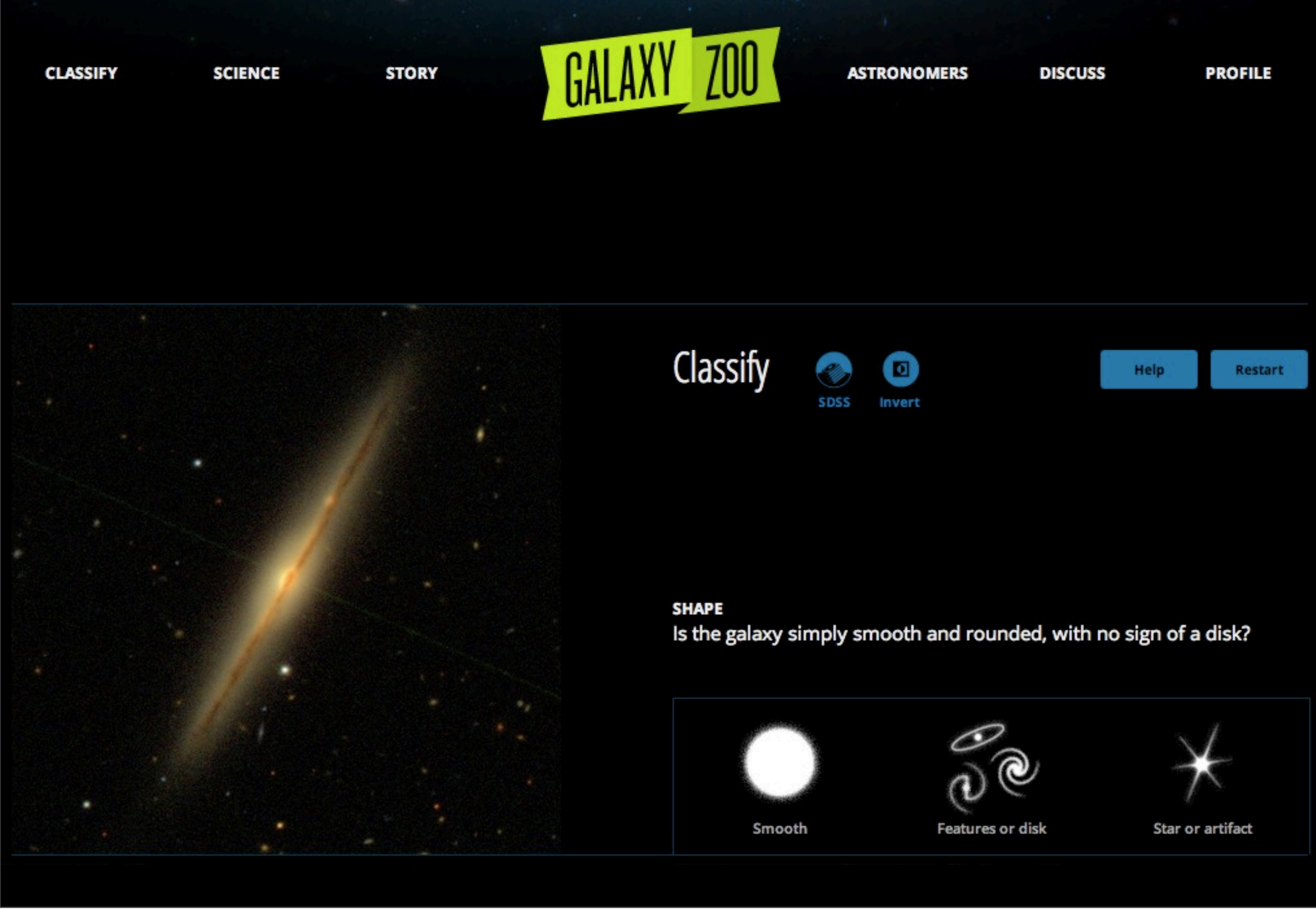
Galaxy-Black Hole Co-evolution

Accreting black holes may regulate galaxy evolution and shape the galaxy population

We don't really know how this works, but we'd love to know.

http://www.galaxyzoo.org

quench.galaxyzoo.org



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Maths, more maths, physics, chemistry at A level (UK)
Also: be a computer geek!

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Faculty:
ETH Zurich (Switzerland)
Also: get students to do work as admin takes over???