

Spirals in Virgo

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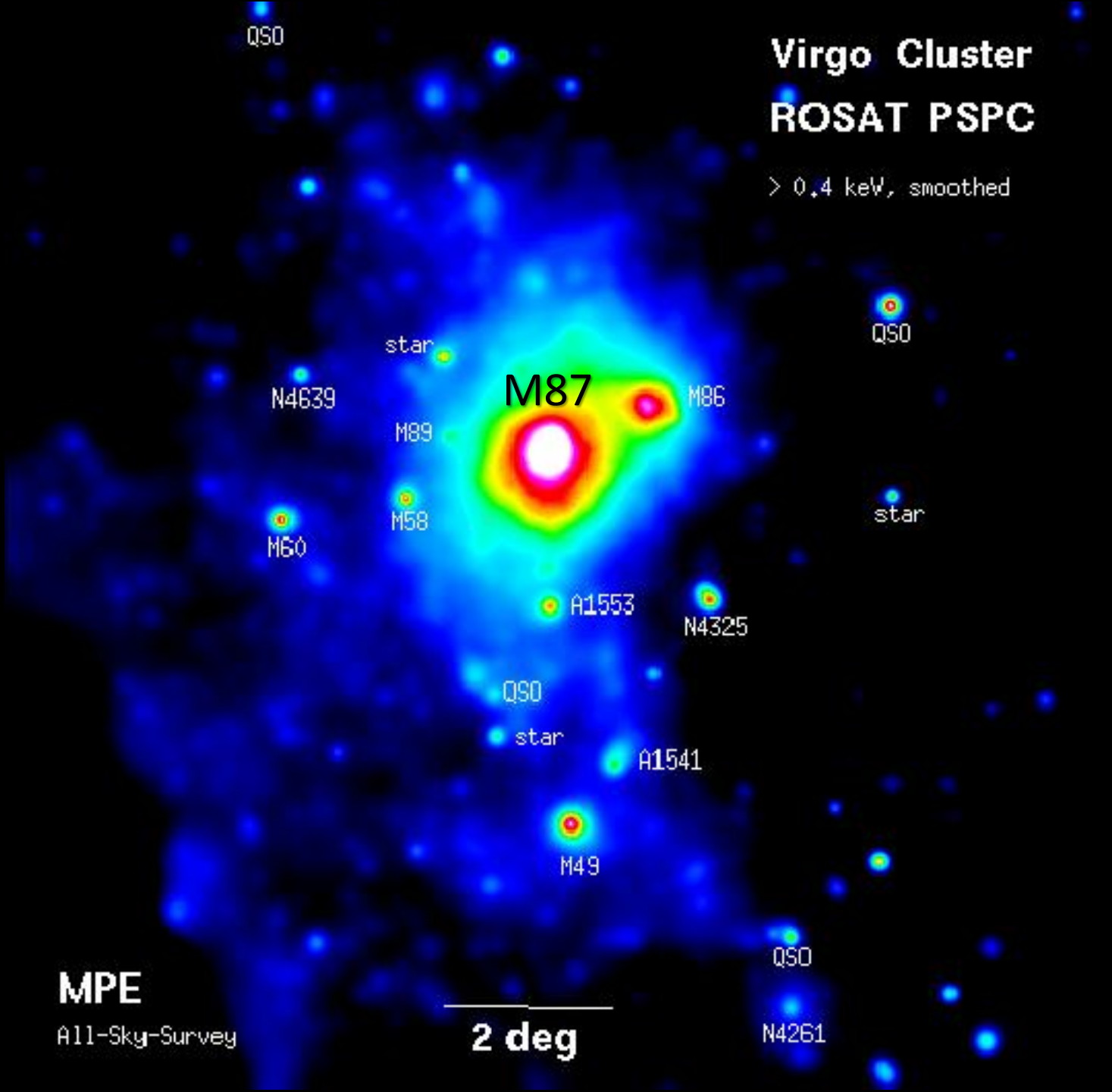
Alessandro Boselli (*LAM Marseille*)

Outline

- **Design features of our survey**
- **Gallery of pretty pictures**
- **Main results: ULXs and nuclear BHs**

Virgo Cluster ROSAT PSPC

> 0.4 keV, smoothed

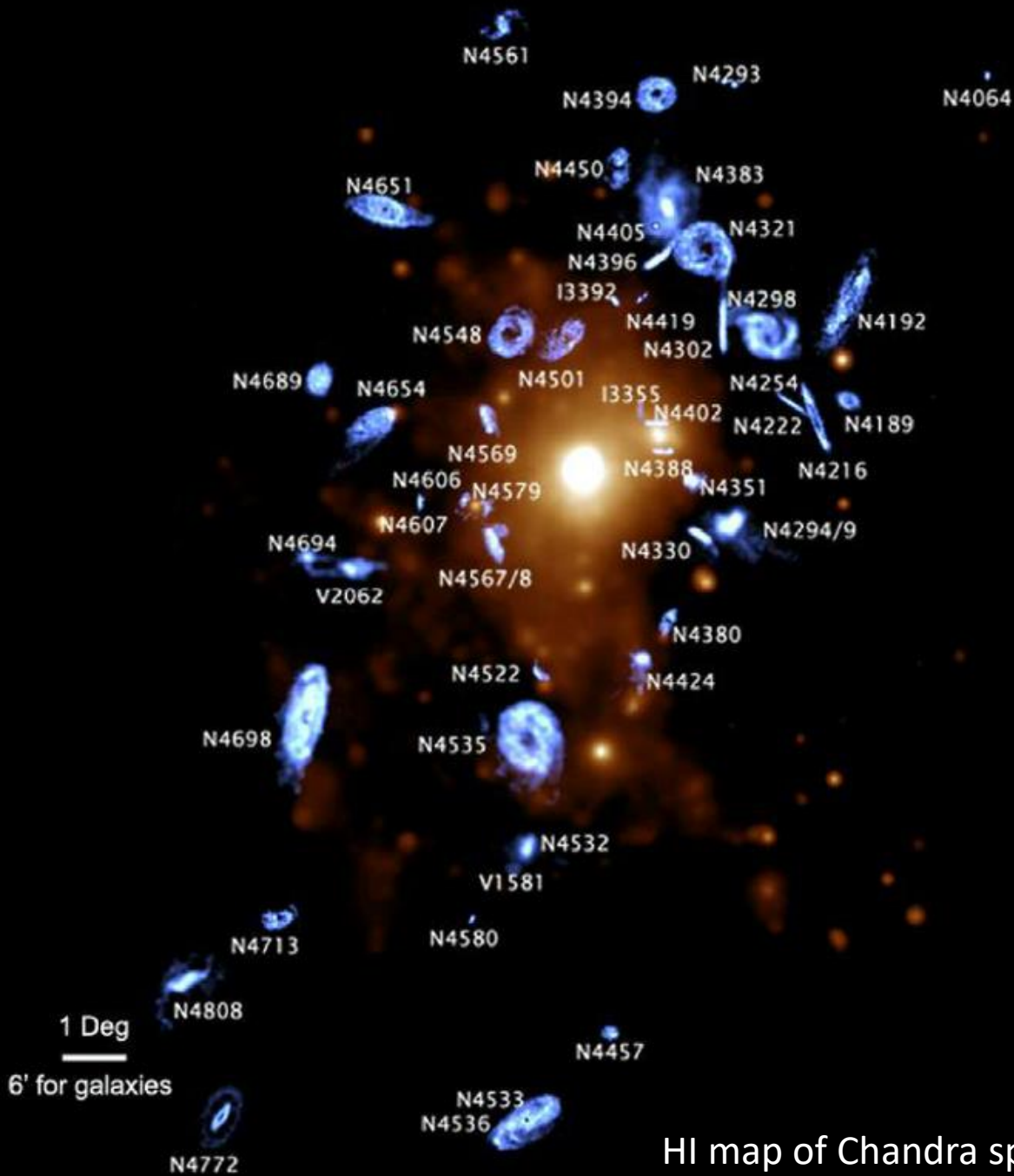


MPE

All-Sky-Survey

2 deg

N4261



HI map of Chandra spirals (Chung et al 2009)

Virgo Ellipticals and Spirals

- **100 early-type galaxies:**
AMUSE survey (Gallo, Treu, Plotkin,...)
Chandra + HST
- **74 spiral galaxies:**
our new survey (various papers in prep.)
Chandra + NGVS

X-rays: Chandra Large Project (PI Soria)

550 ks + archival data

74 spirals with $\text{SFR} > \sim 0.3 M_{\text{sun}}/\text{yr}$

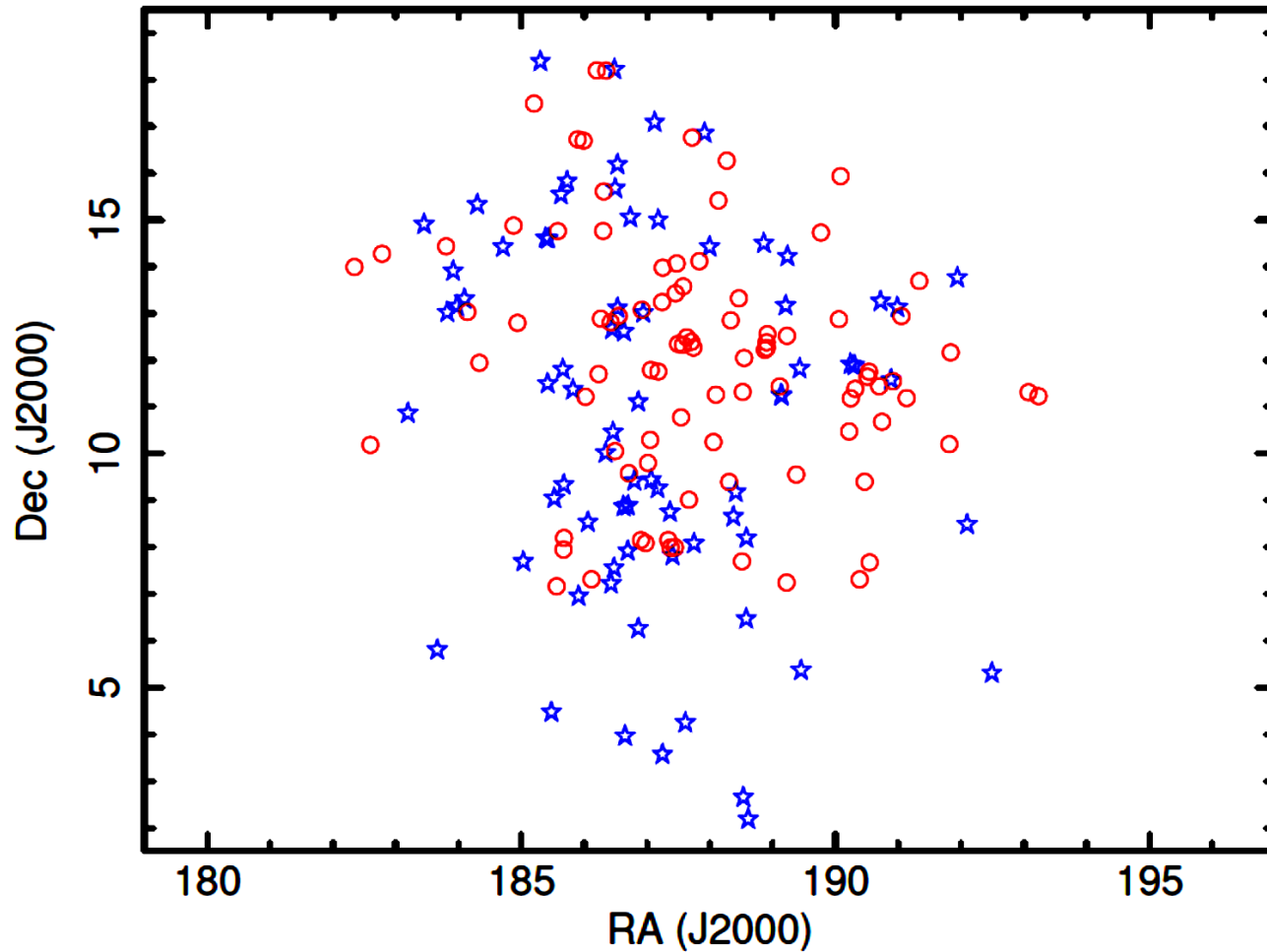
Point-source detection limit $\sim 3E38 \text{ erg/s}$

Optical: Next Generation Virgo Cluster Survey
(Ferrarese, Cote', Lancon, et al)

104 square degrees observed with CFHT Megaprime

Point-source detection limit $g' \sim 25.7 \text{ ABmag}$

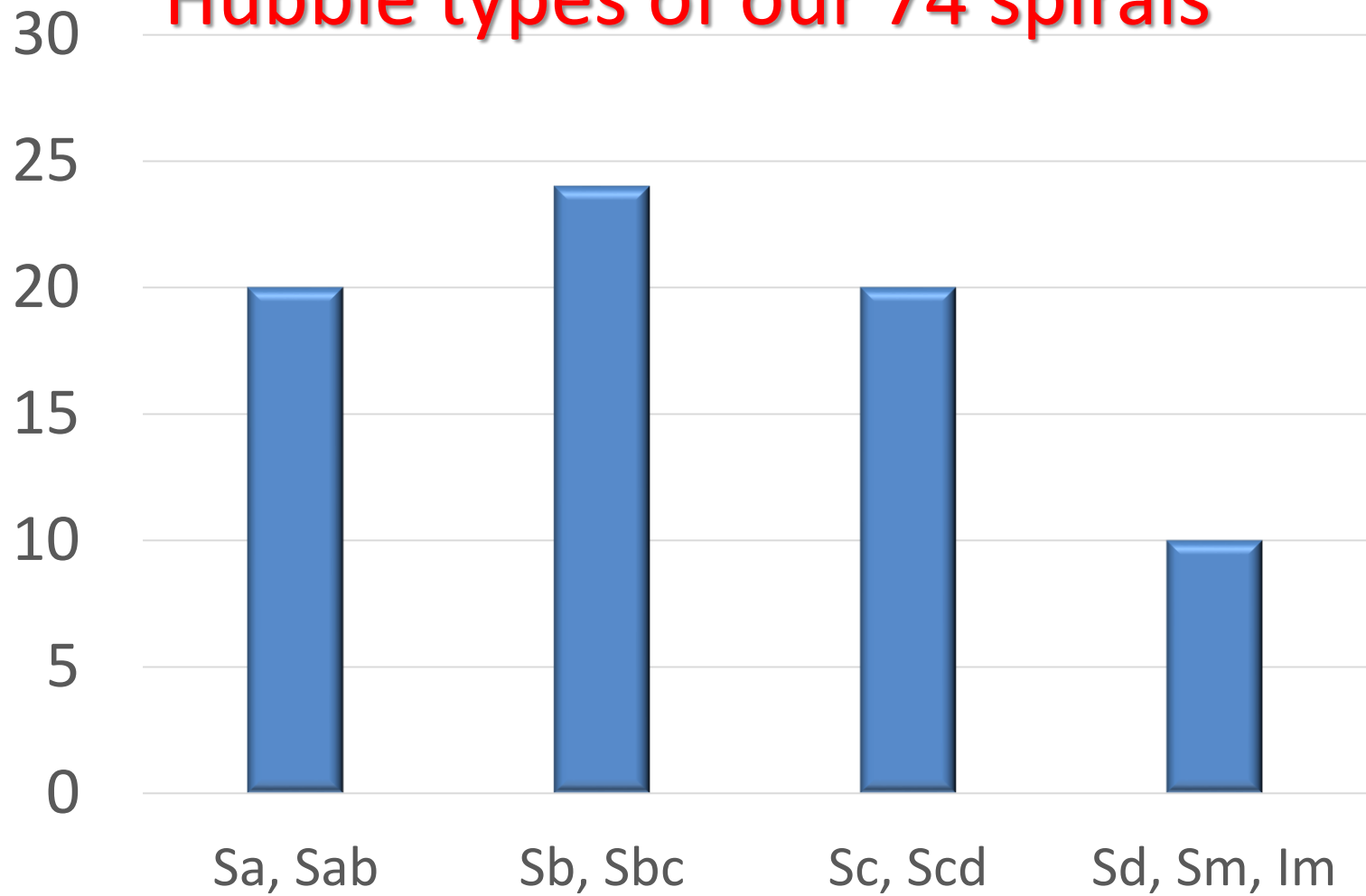
Virgo Ellipticals and Spirals



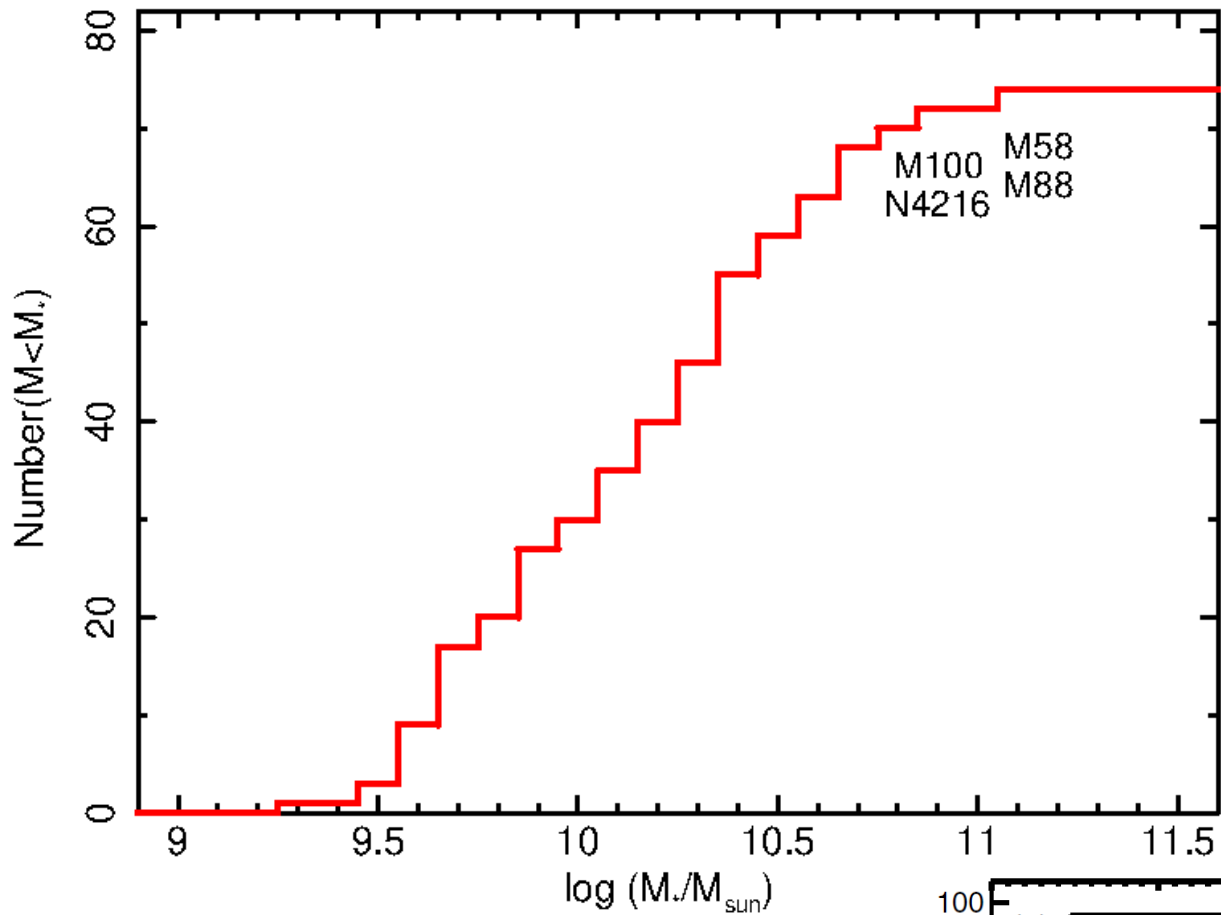
Red = elliptical galaxies in the AMUSE survey

Blue = spiral galaxies in our survey

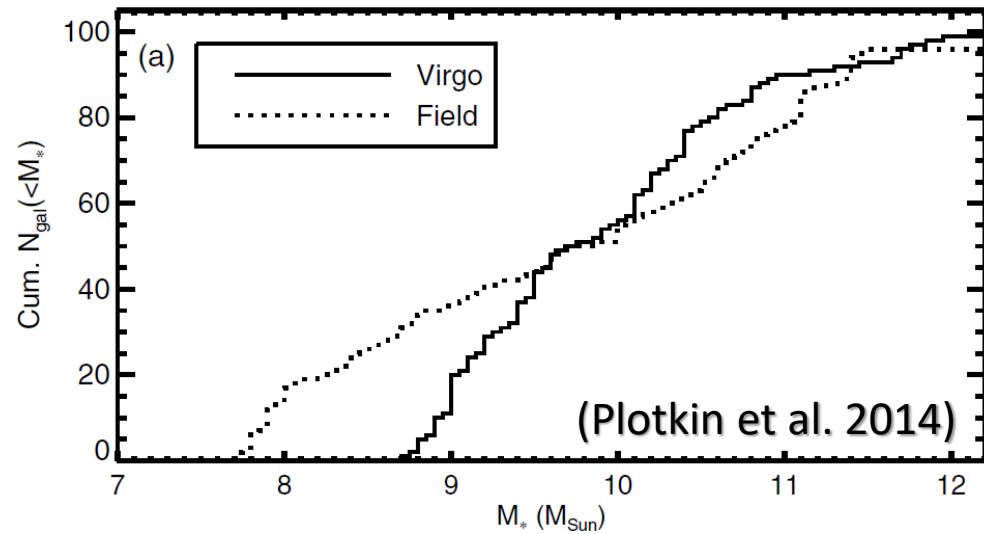
Hubble types of our 74 spirals



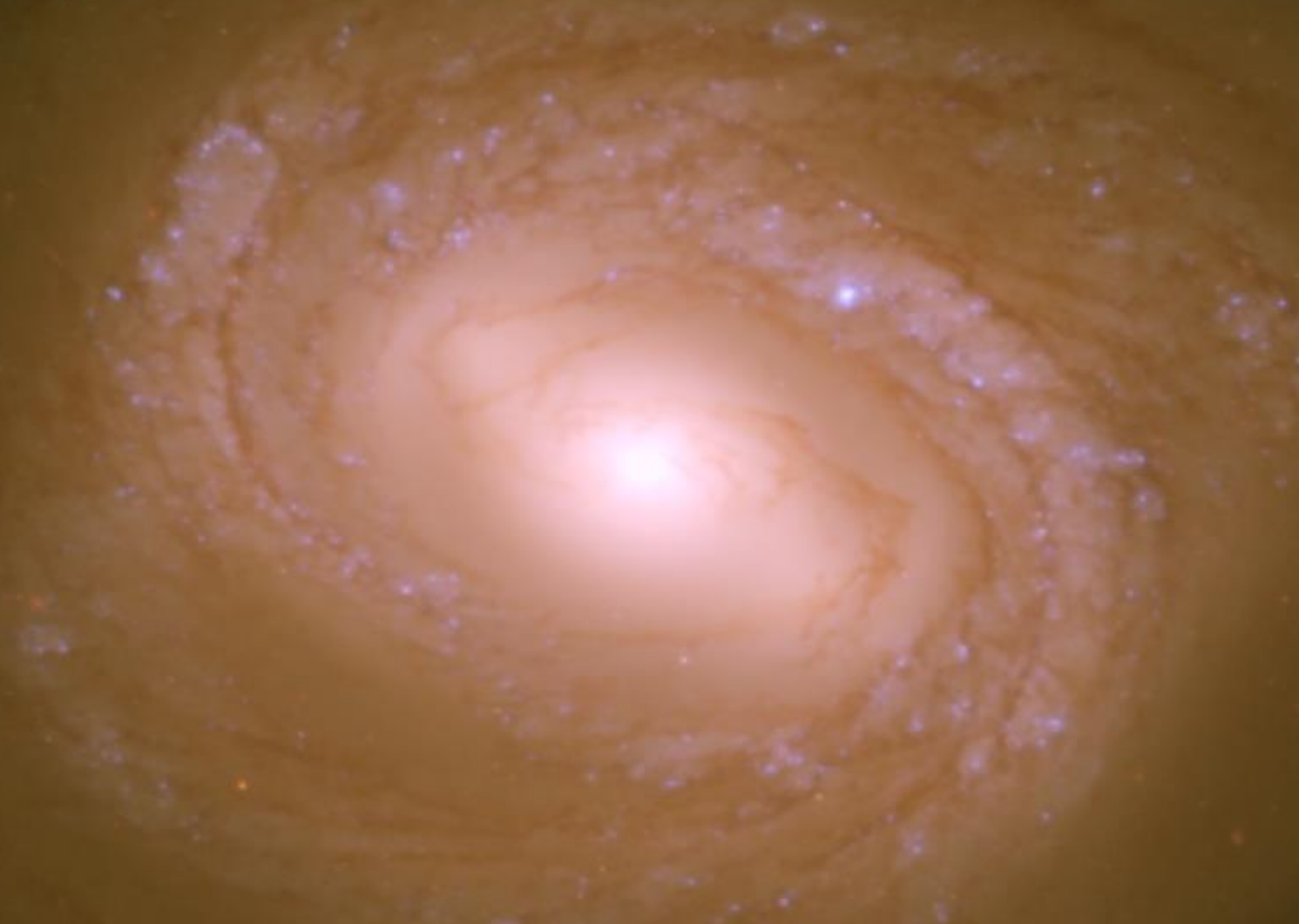
Mass distribution of the 74 spirals



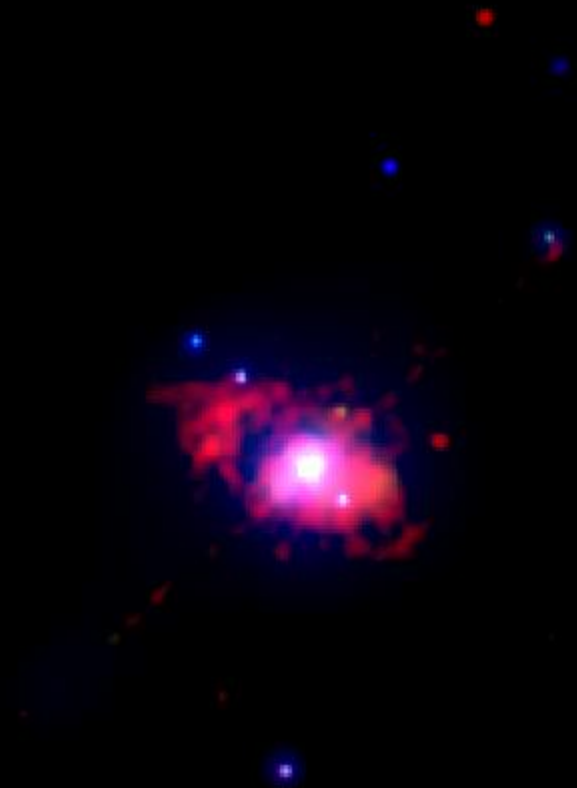
Comparison with the mass distribution of the E galaxies in the AMUSE sample



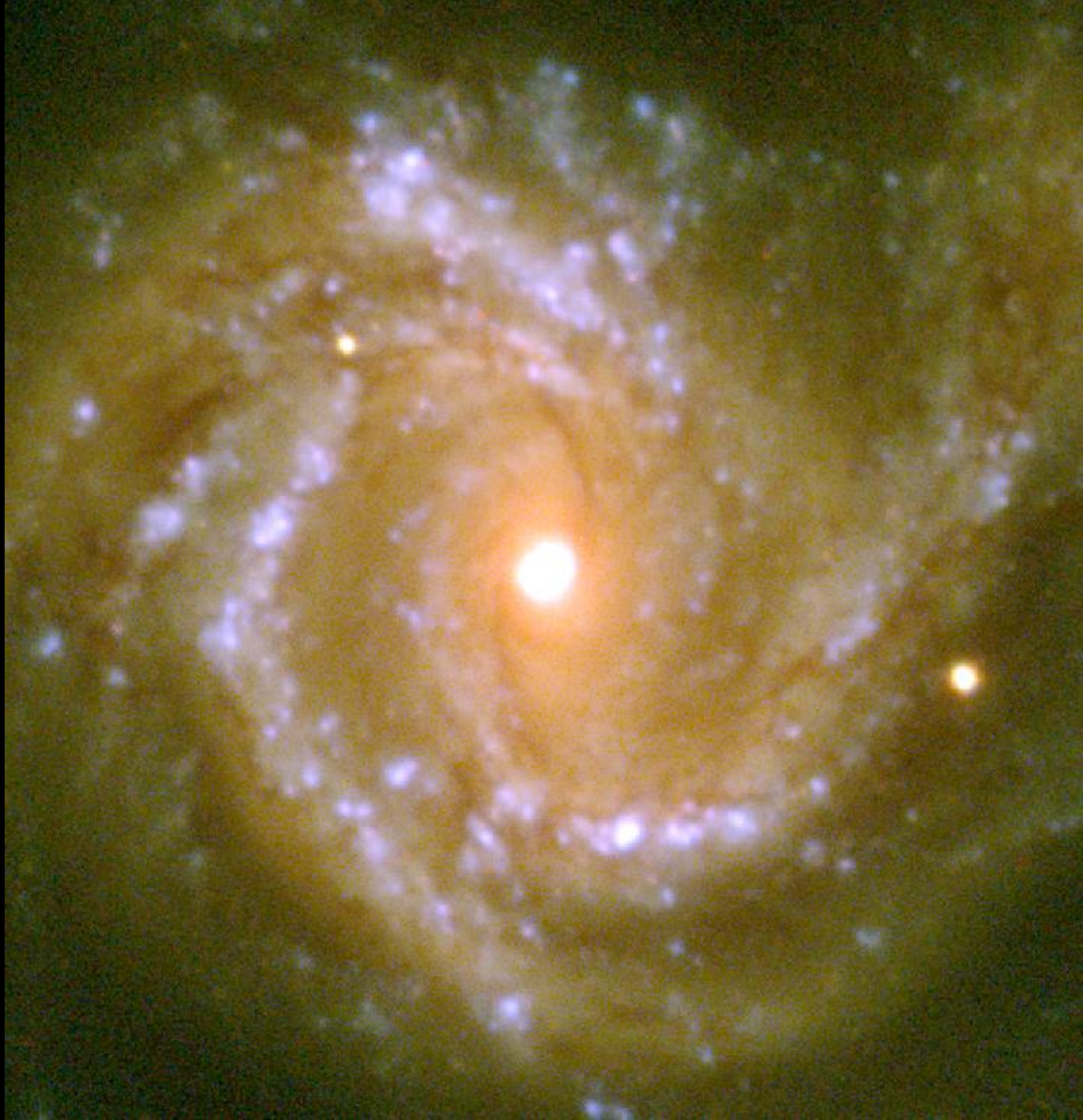
M58



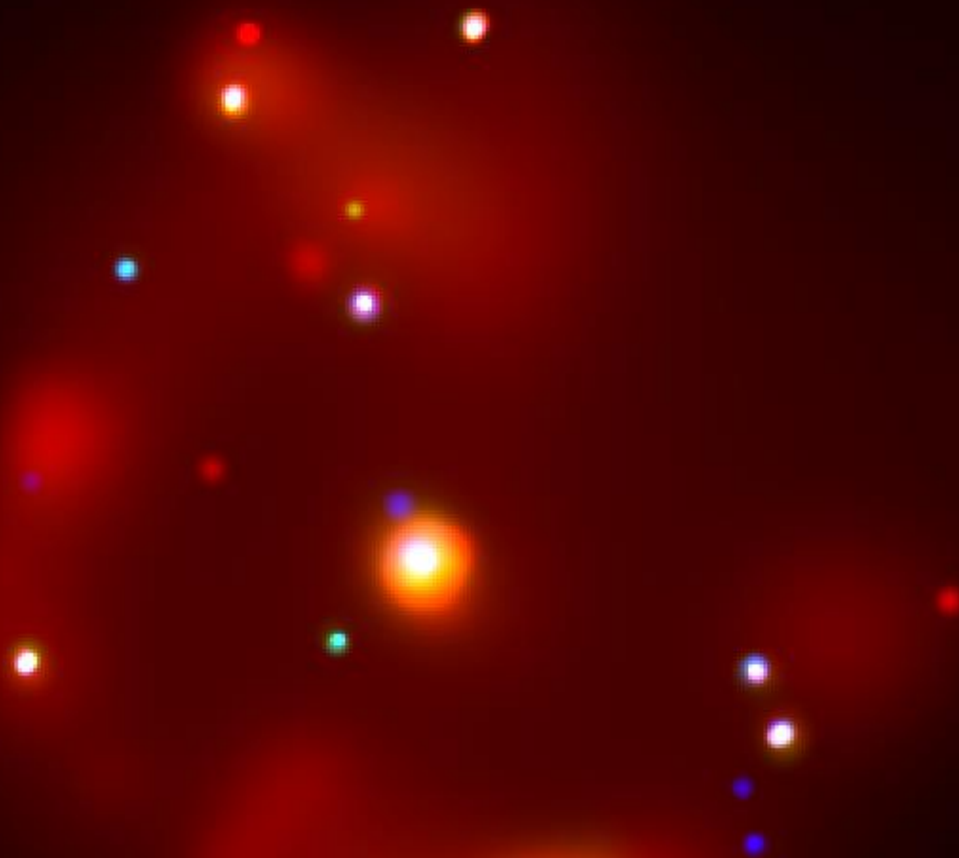
M58



M61



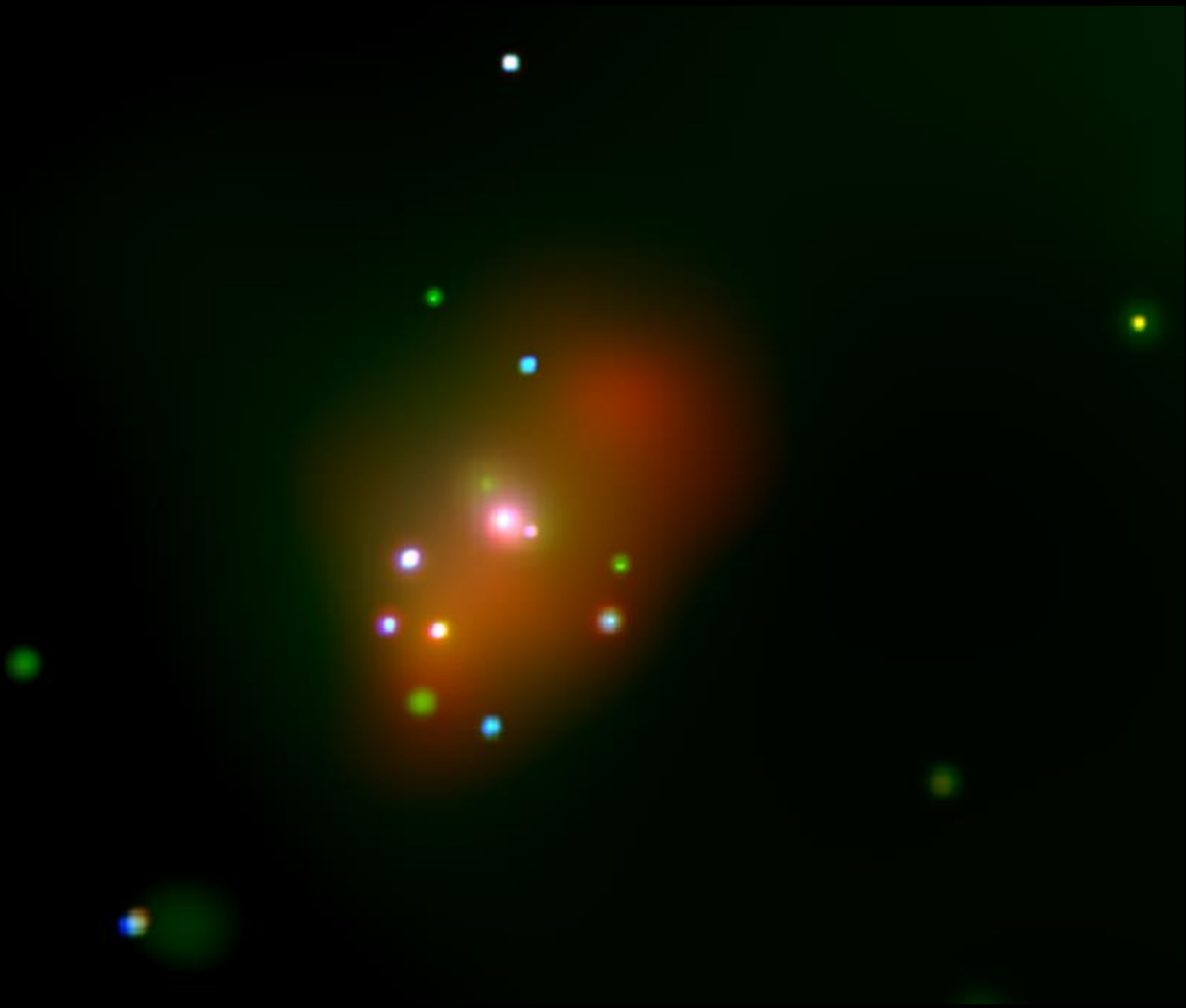
M61



M88



M88



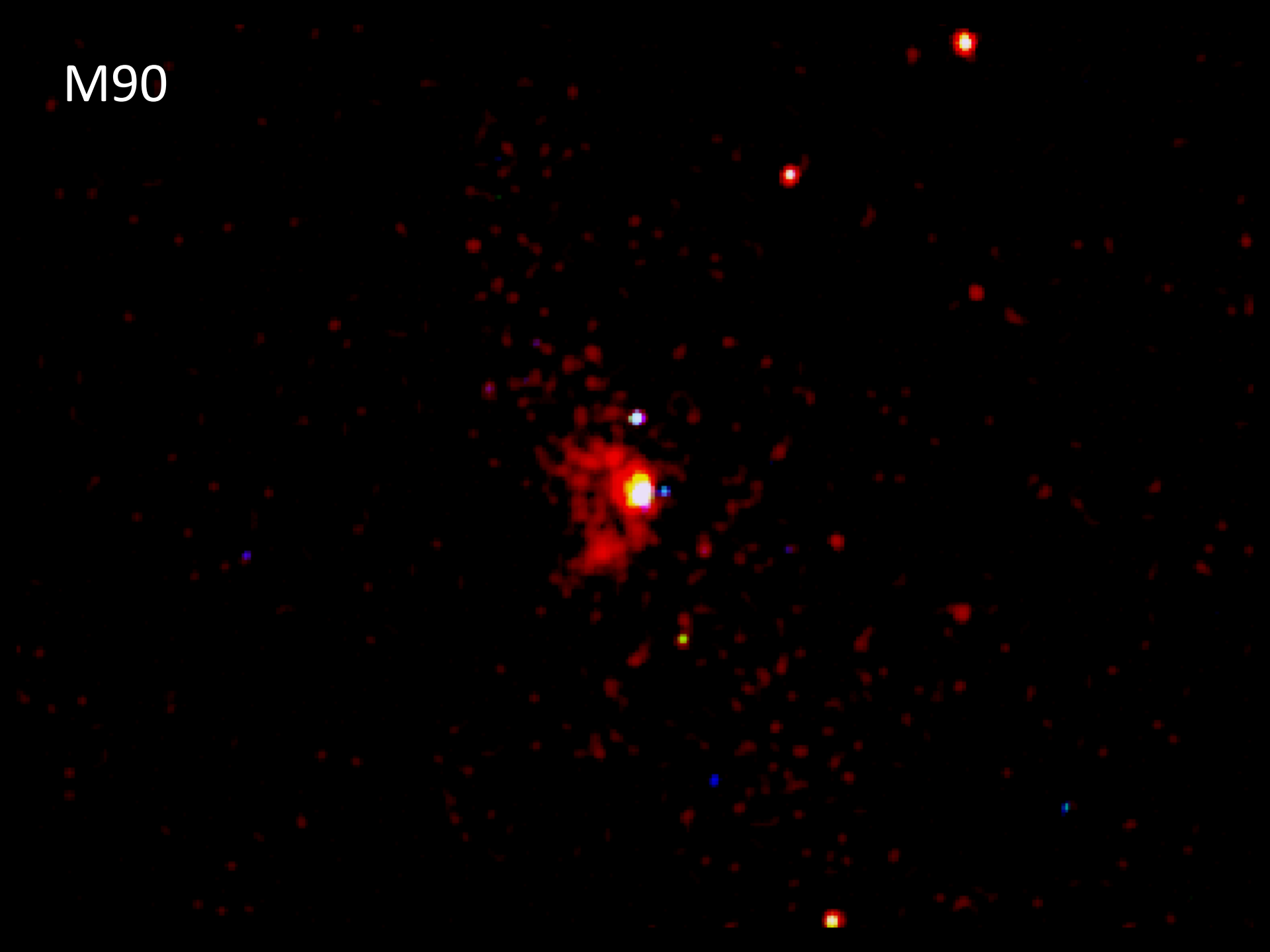
M90



M90



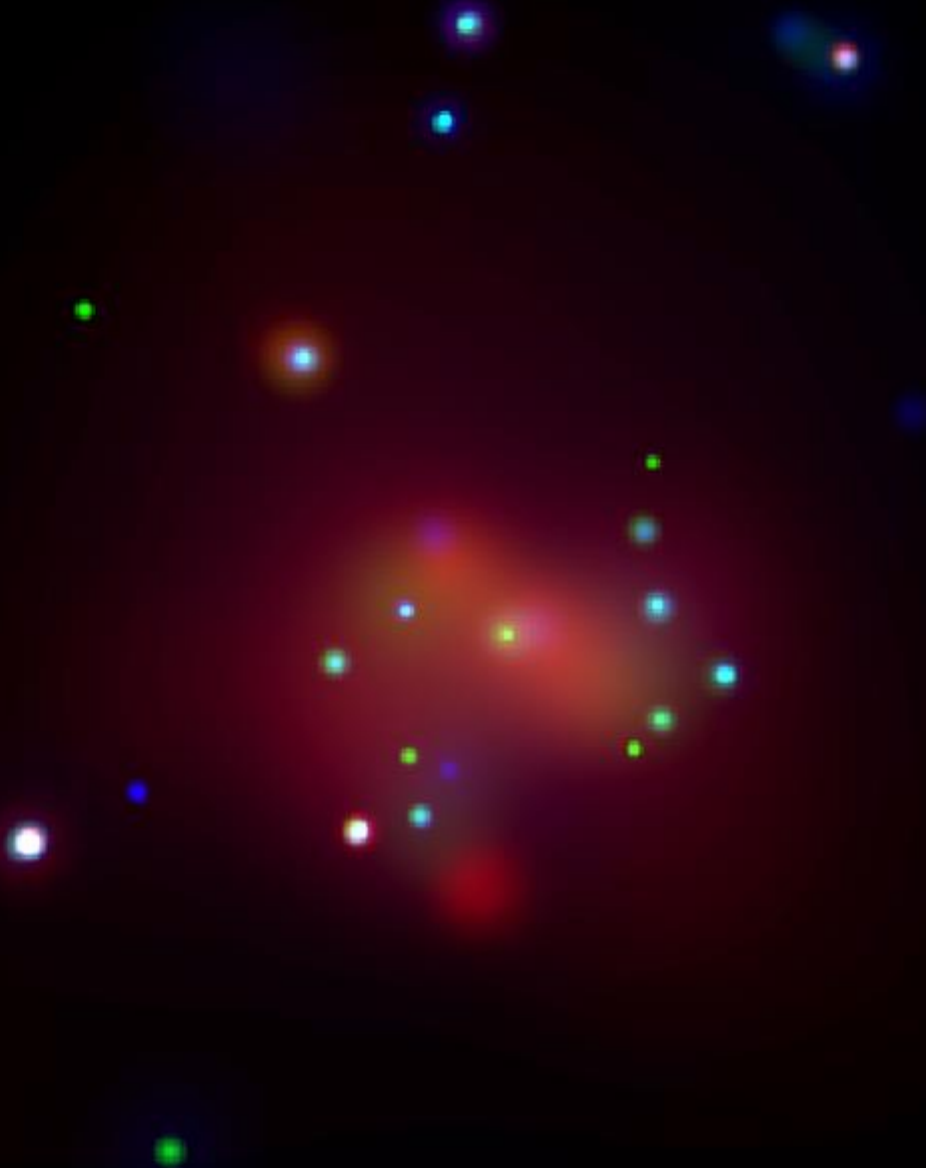
M90



M99



M90



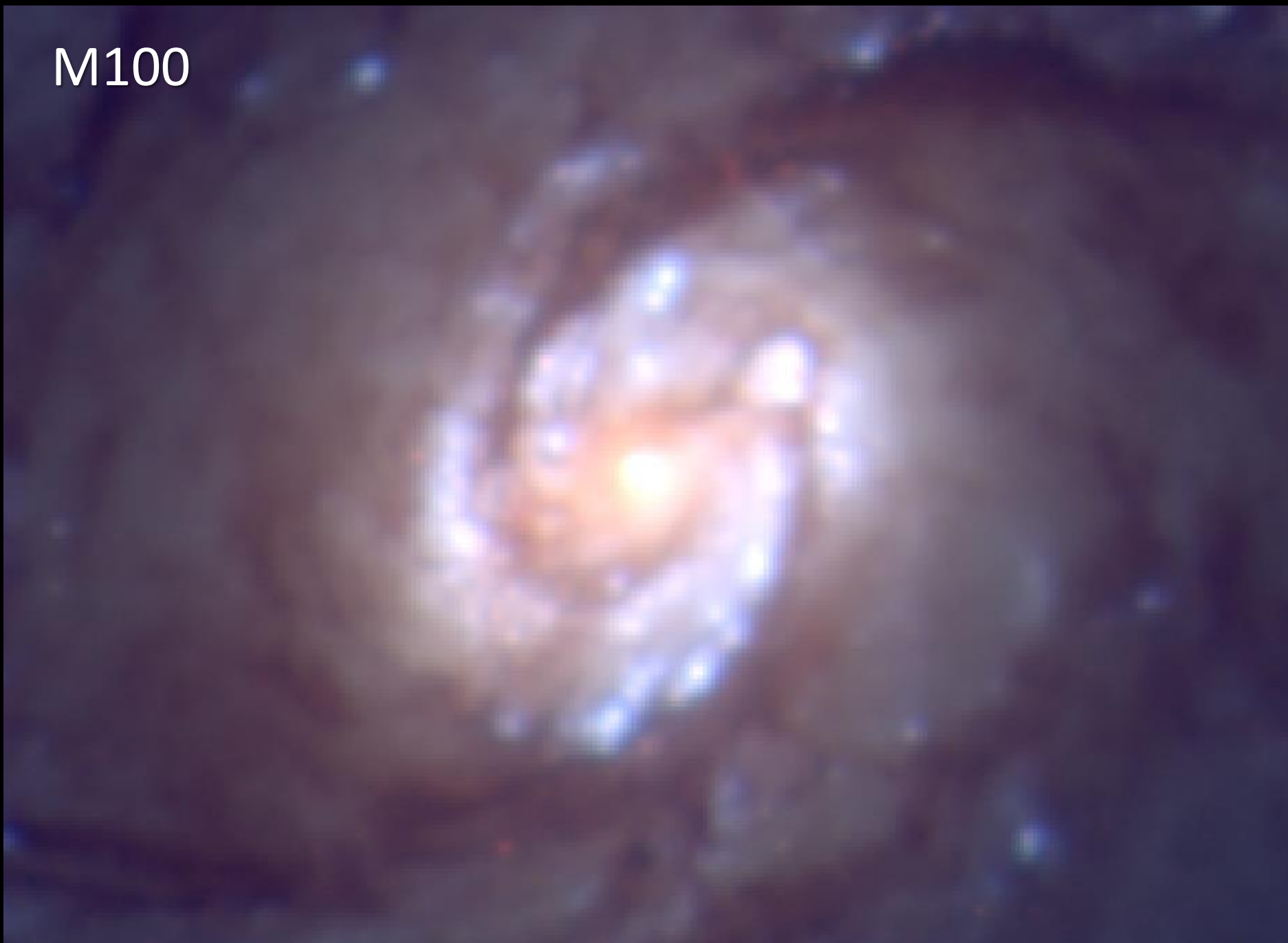
M100



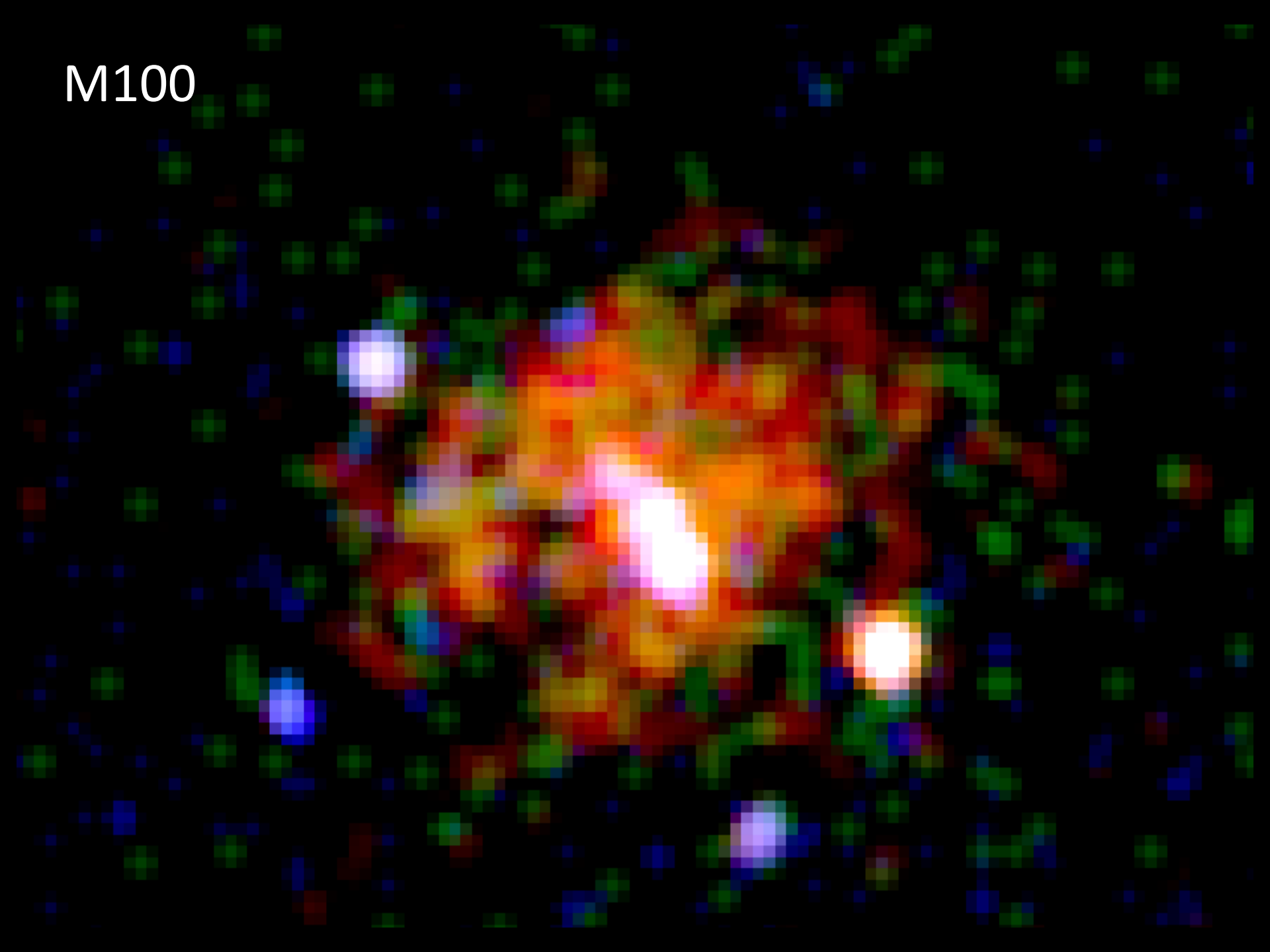
M100



M100



M100



NGC 4435

NGC 4438



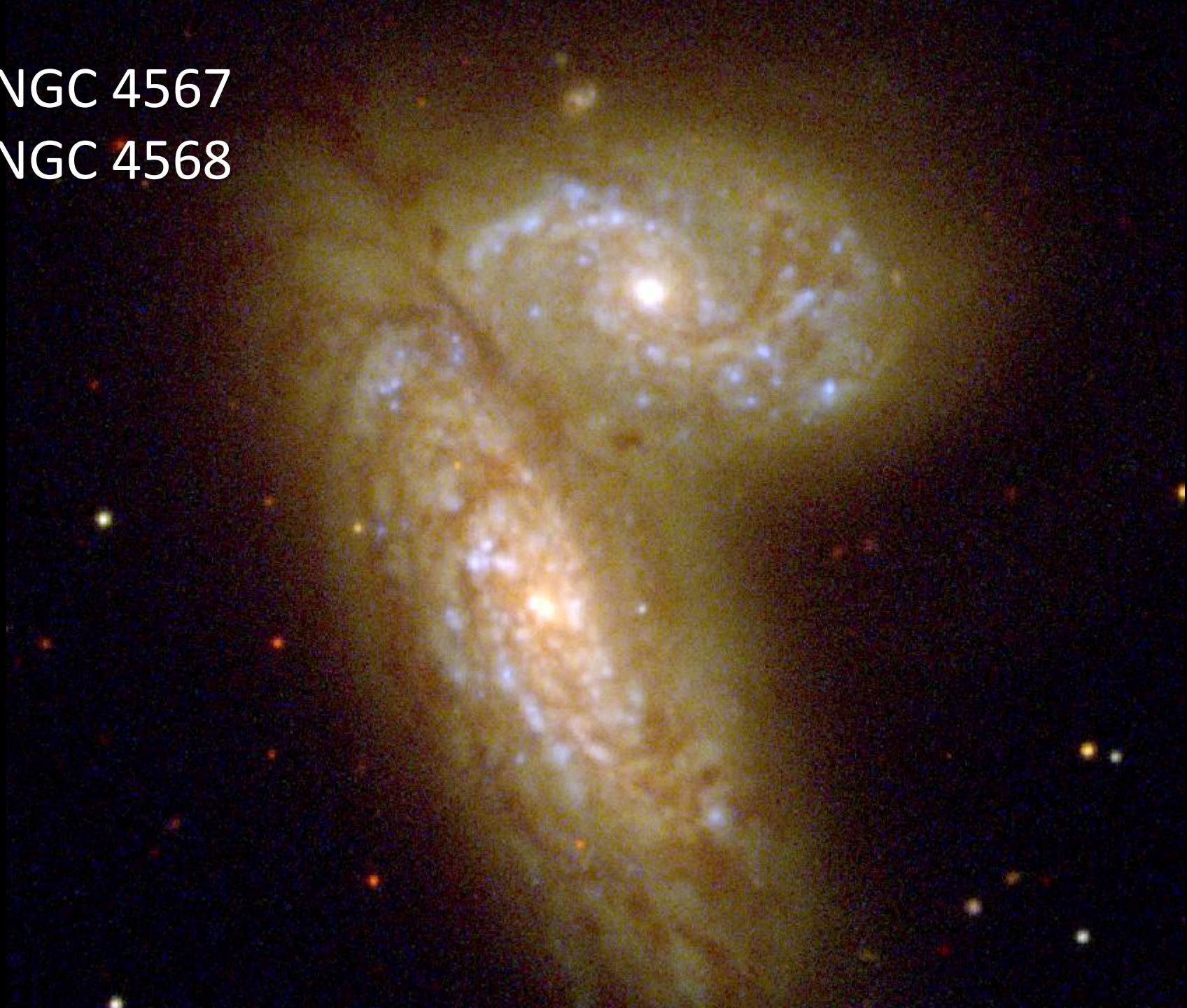
NGC 4435

NGC 4438



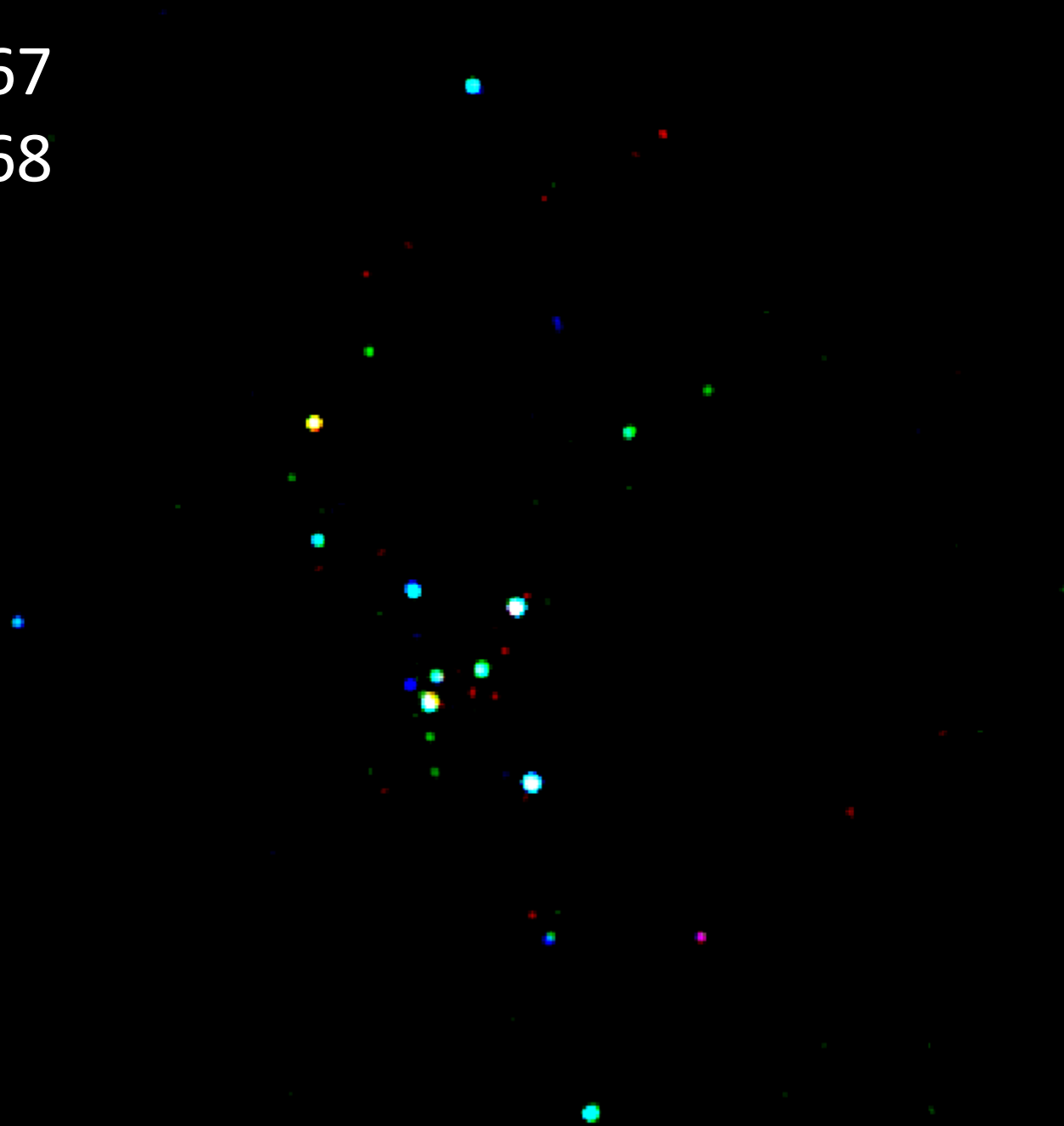
NGC 4567

NGC 4568



NGC 4567

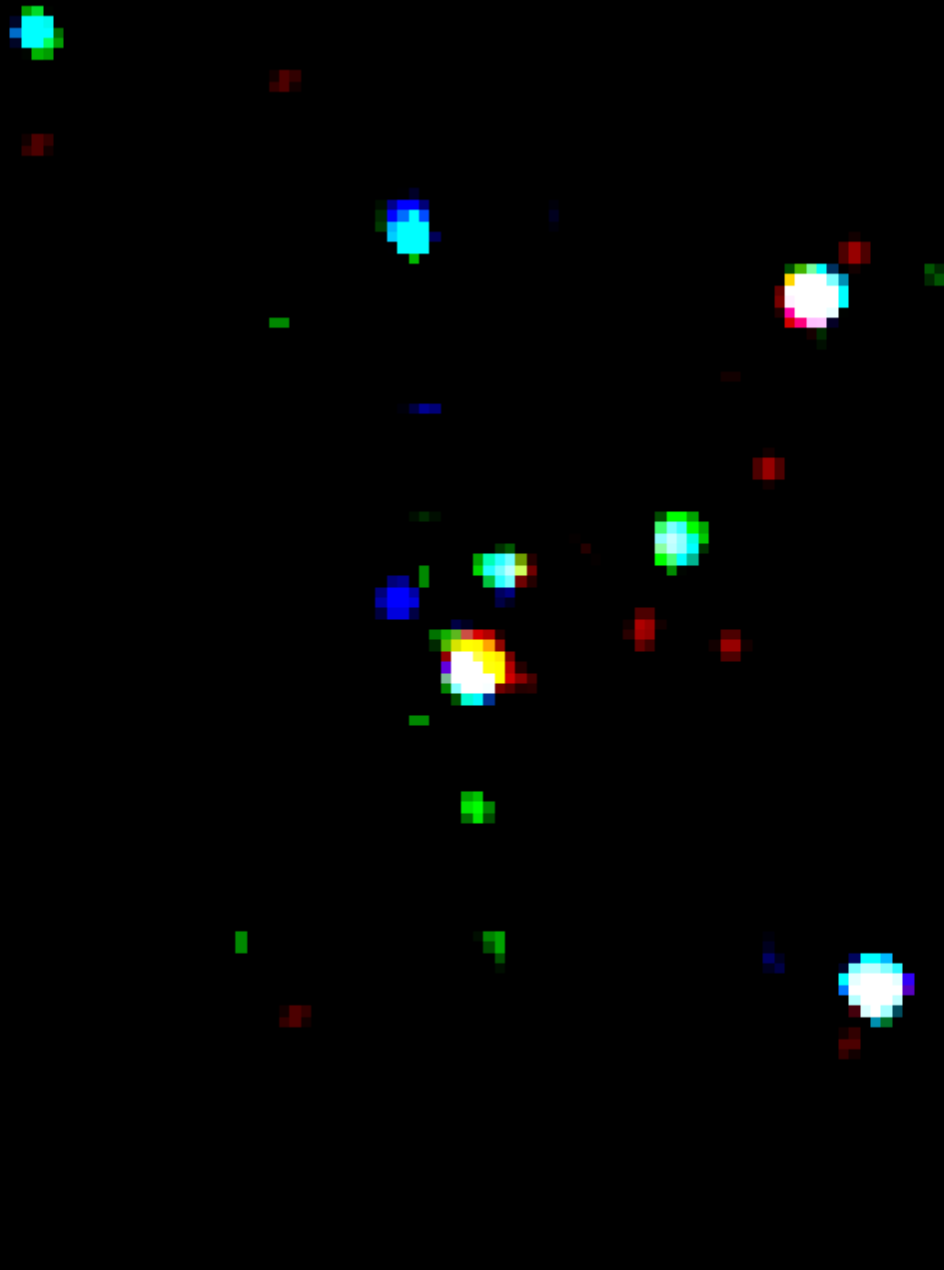
NGC 4568



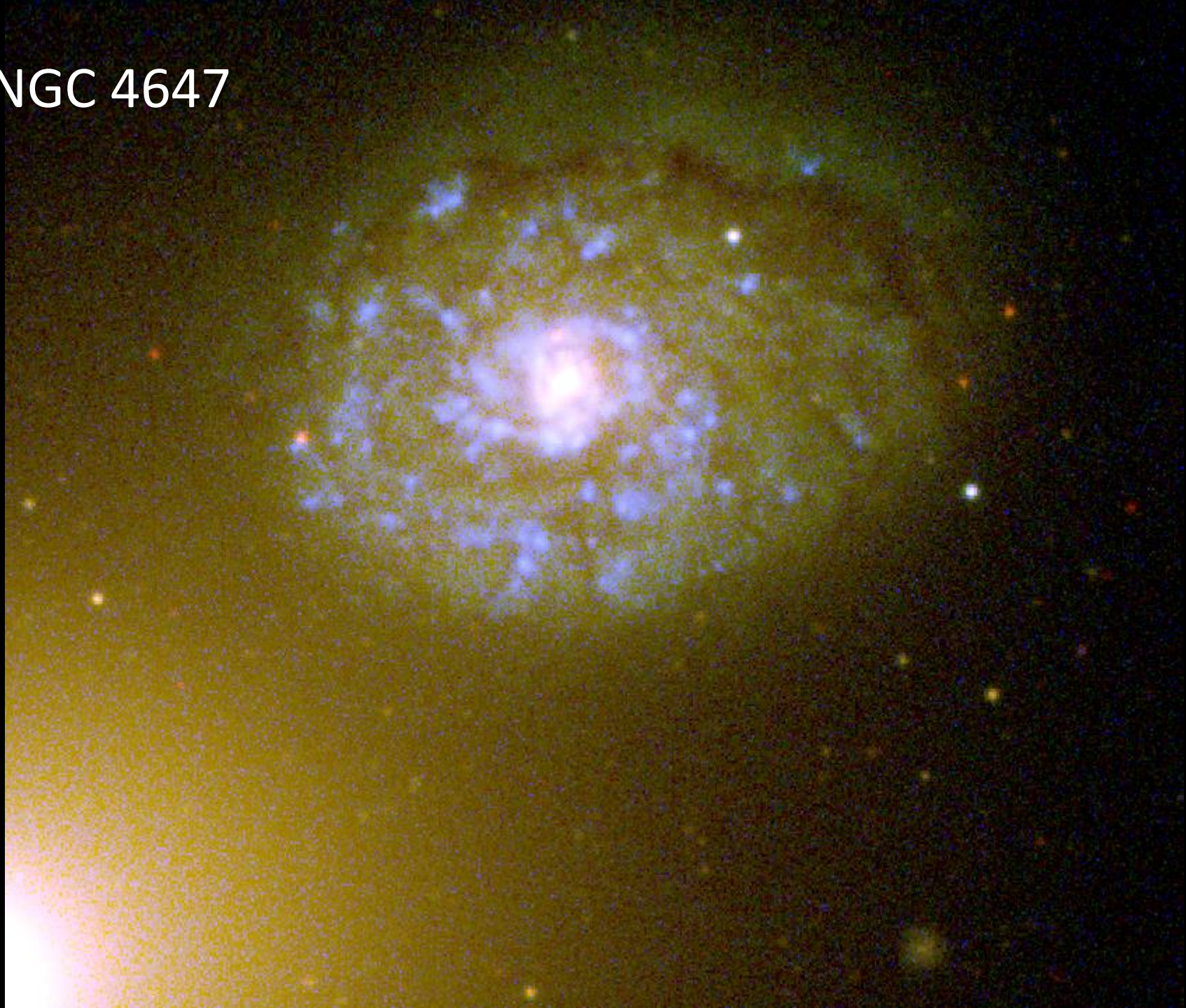
NGC 4568



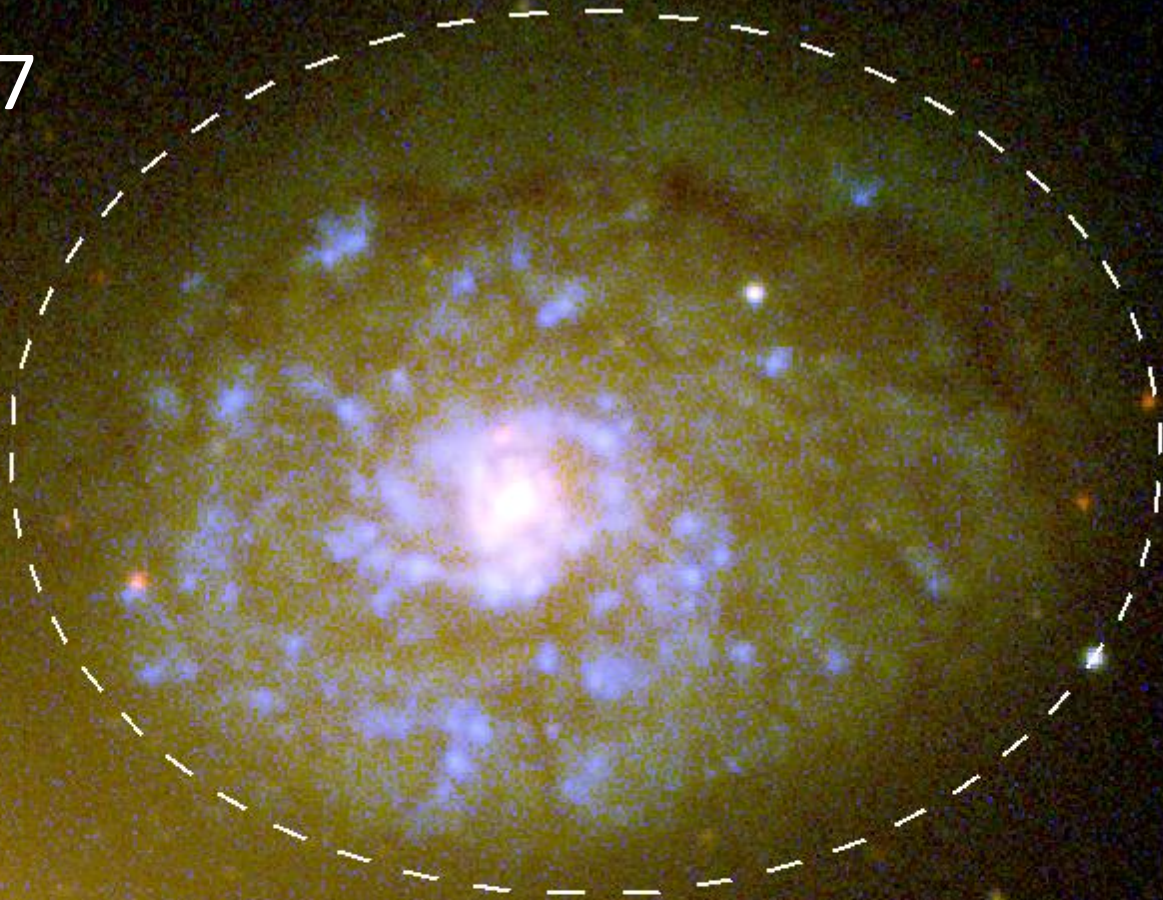
NGC 4568



NGC 4647



NGC 4647



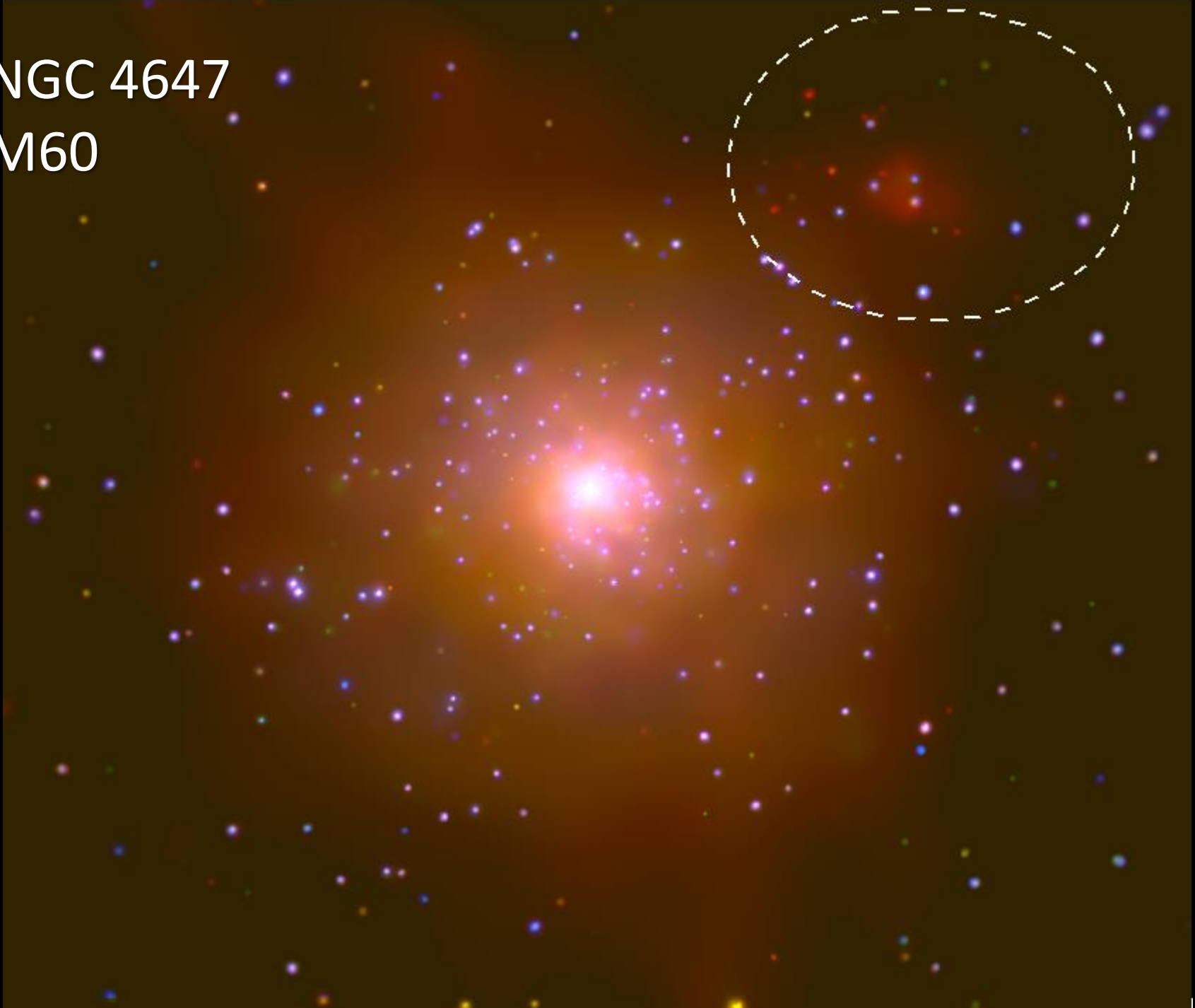
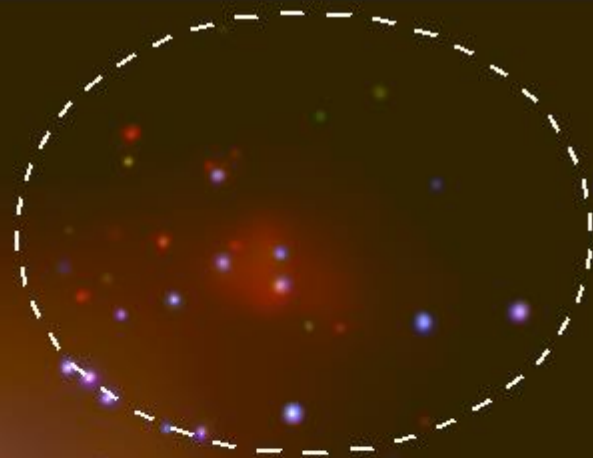
NGC 4647

M60

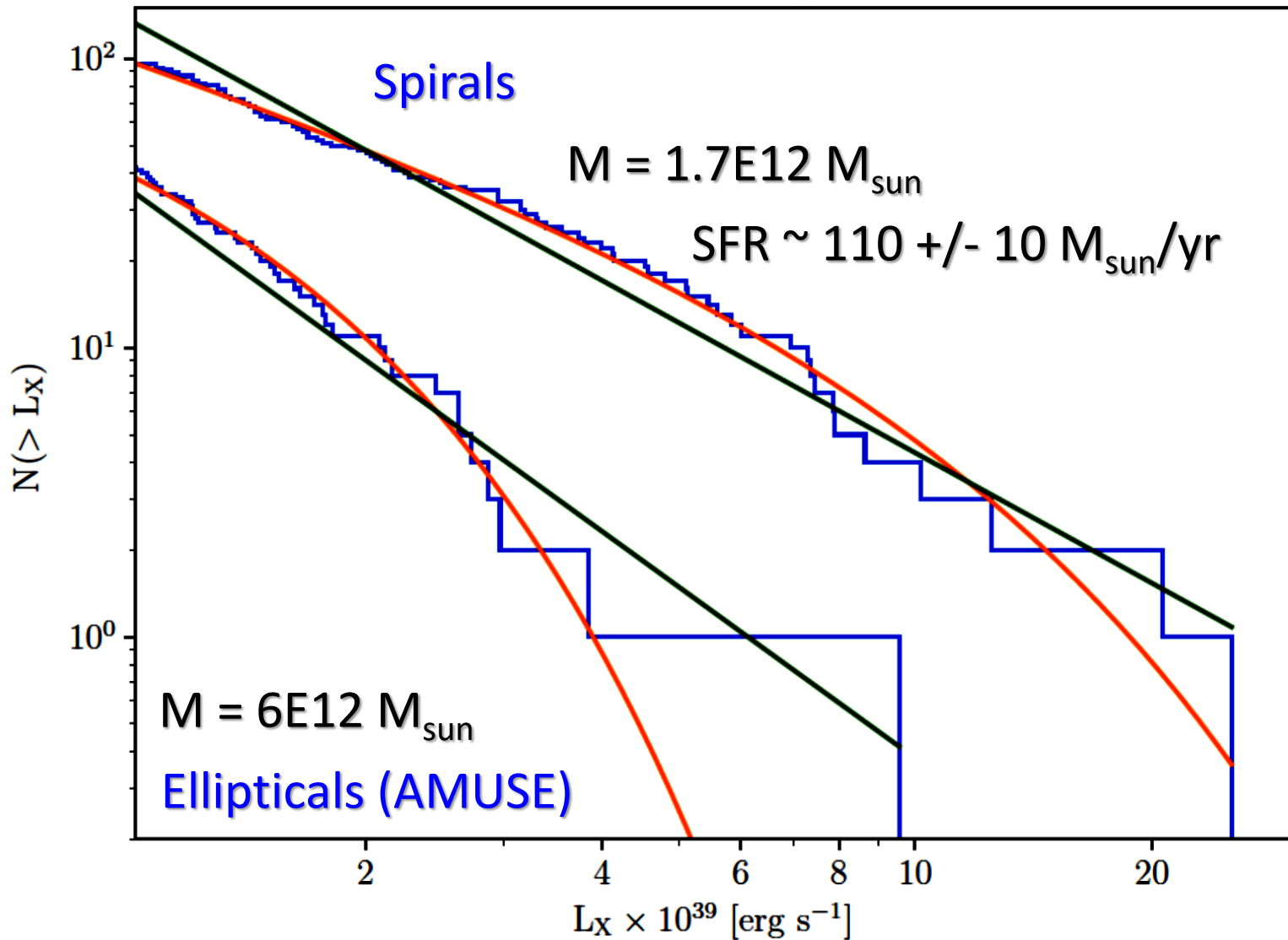


NGC 4647

M60

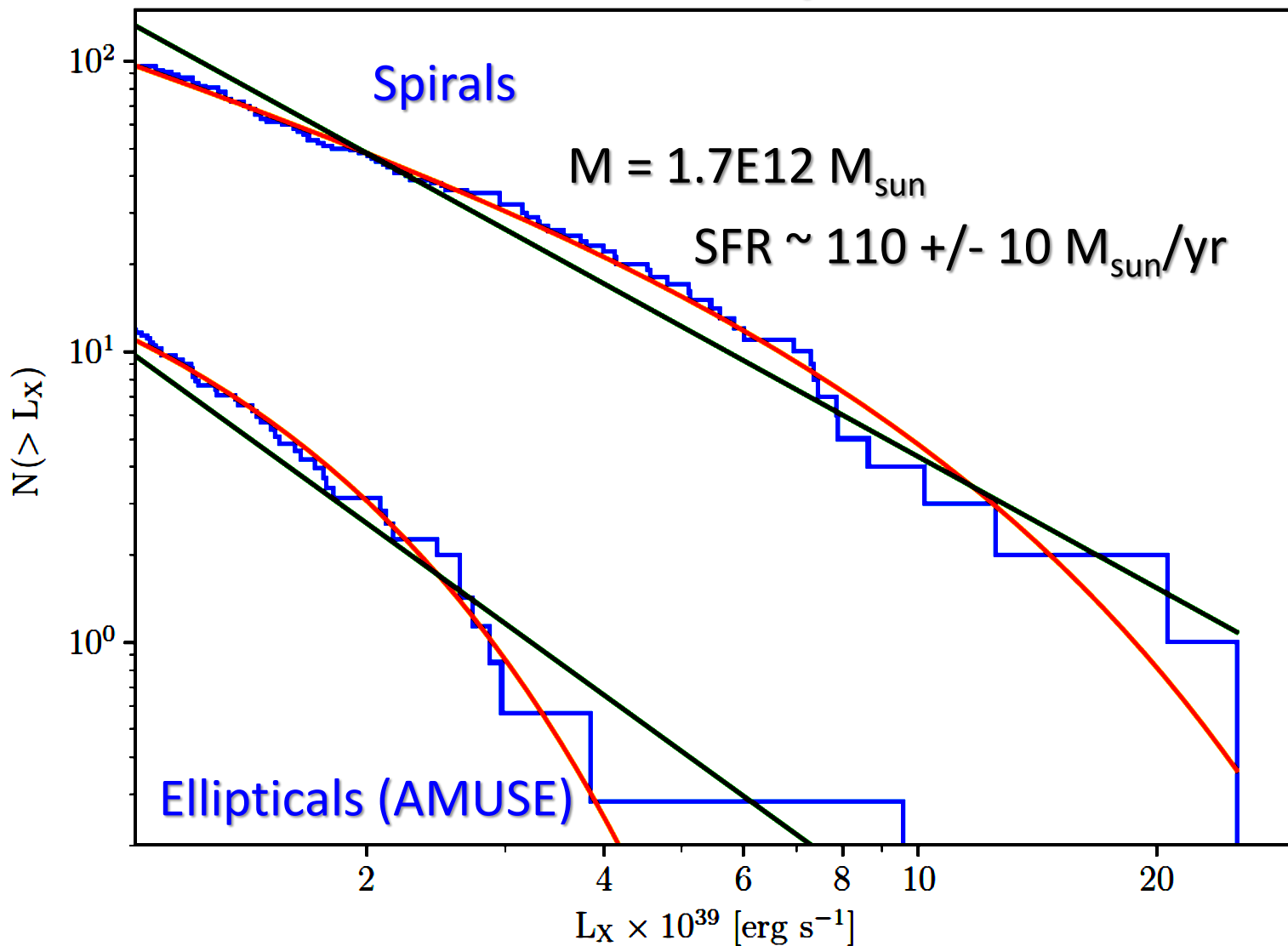


ULX luminosity functions



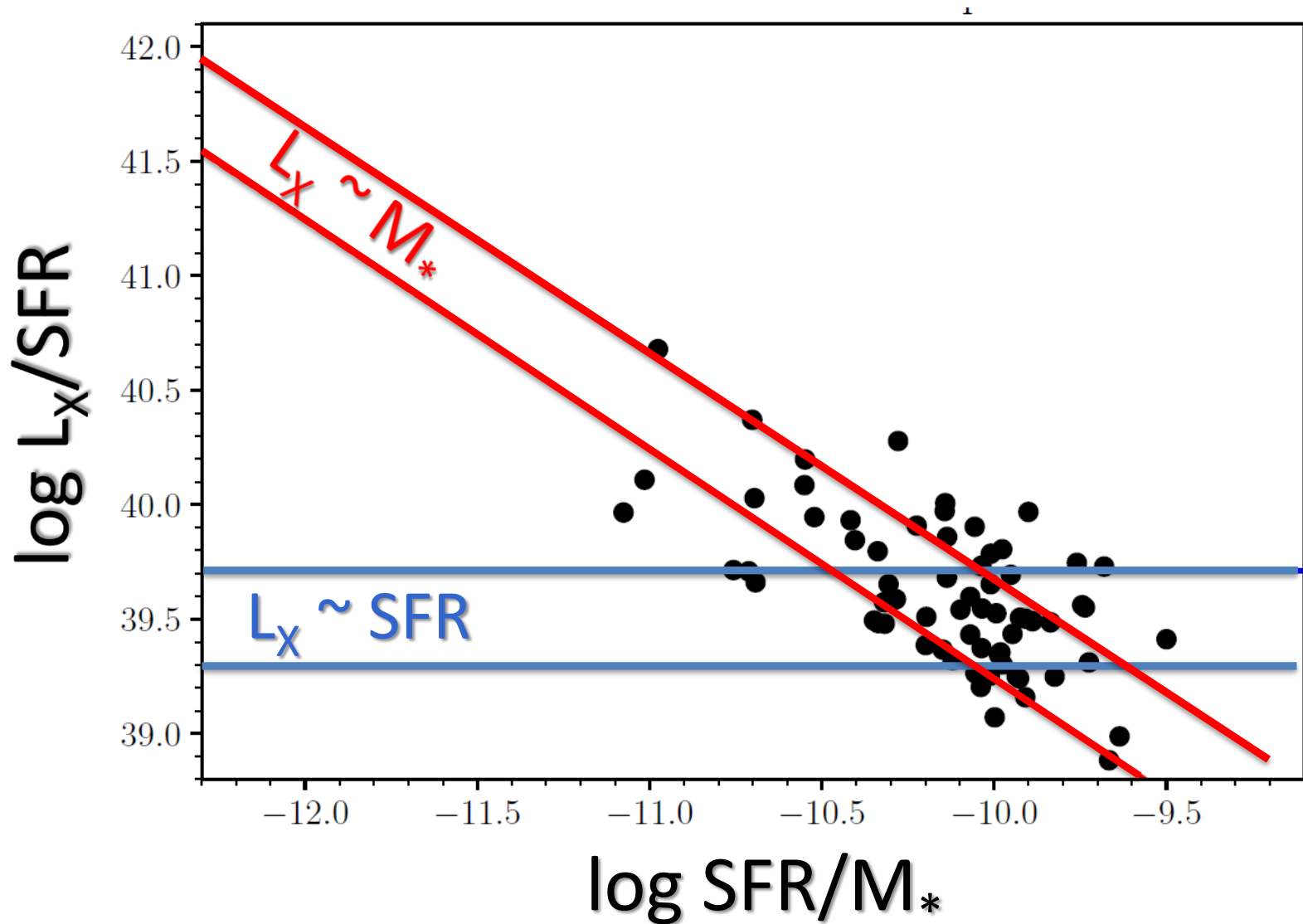
(Kolehmainen et al 2020, Plotkin et al 2014)

ULX luminosity functions



(Kolehmainen et al 2020, Plotkin et al 2014)

Galaxies dominated by LMXBs or HMXBs?



(Kolehmainen et al 2020)

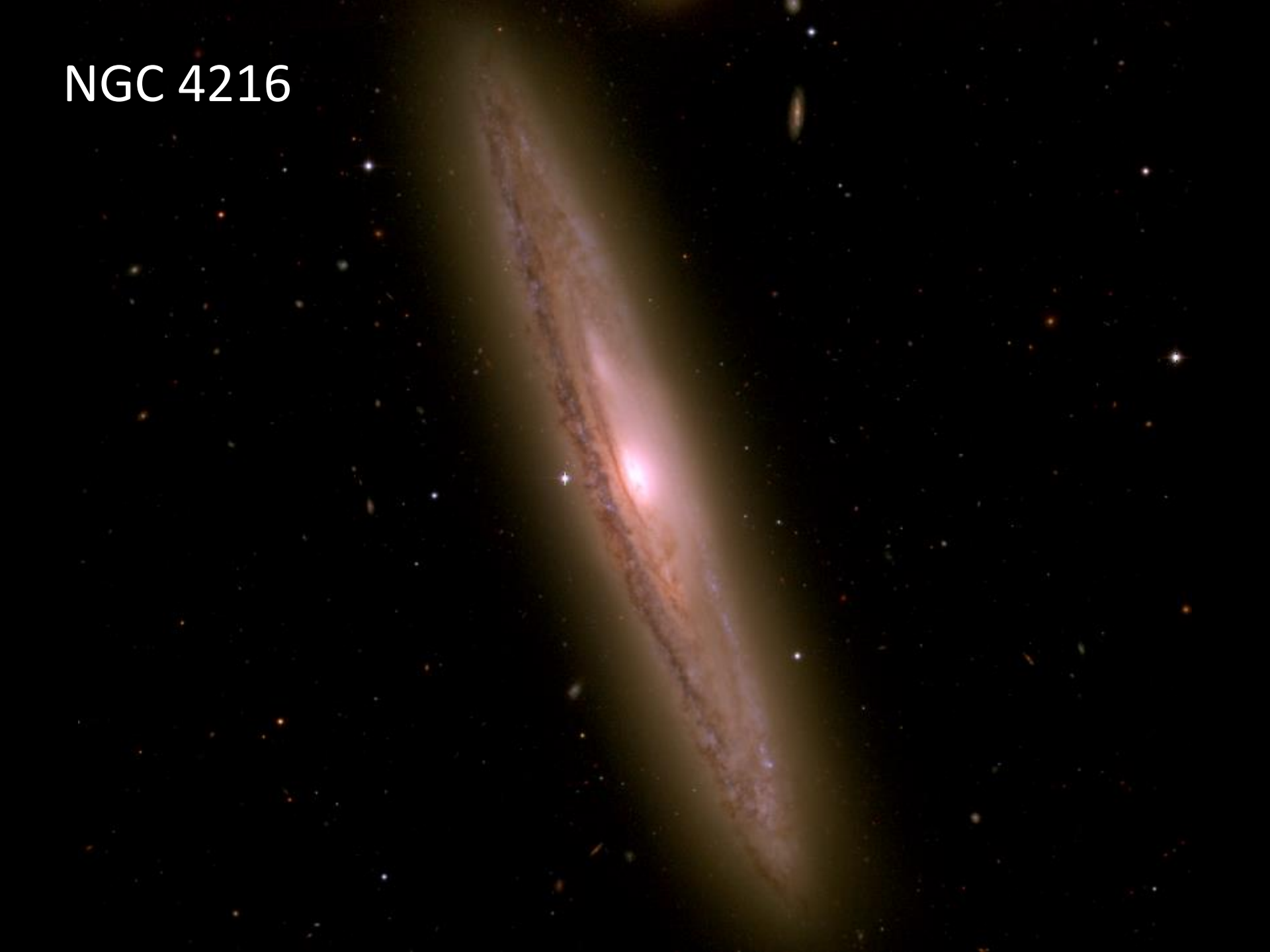
Nuclear BH activity

Resolve nuclear BH from nuclear starburst

Eddington ratio as a function of Hubble type

Evidence of nuclear BHs in bulgeless galaxies

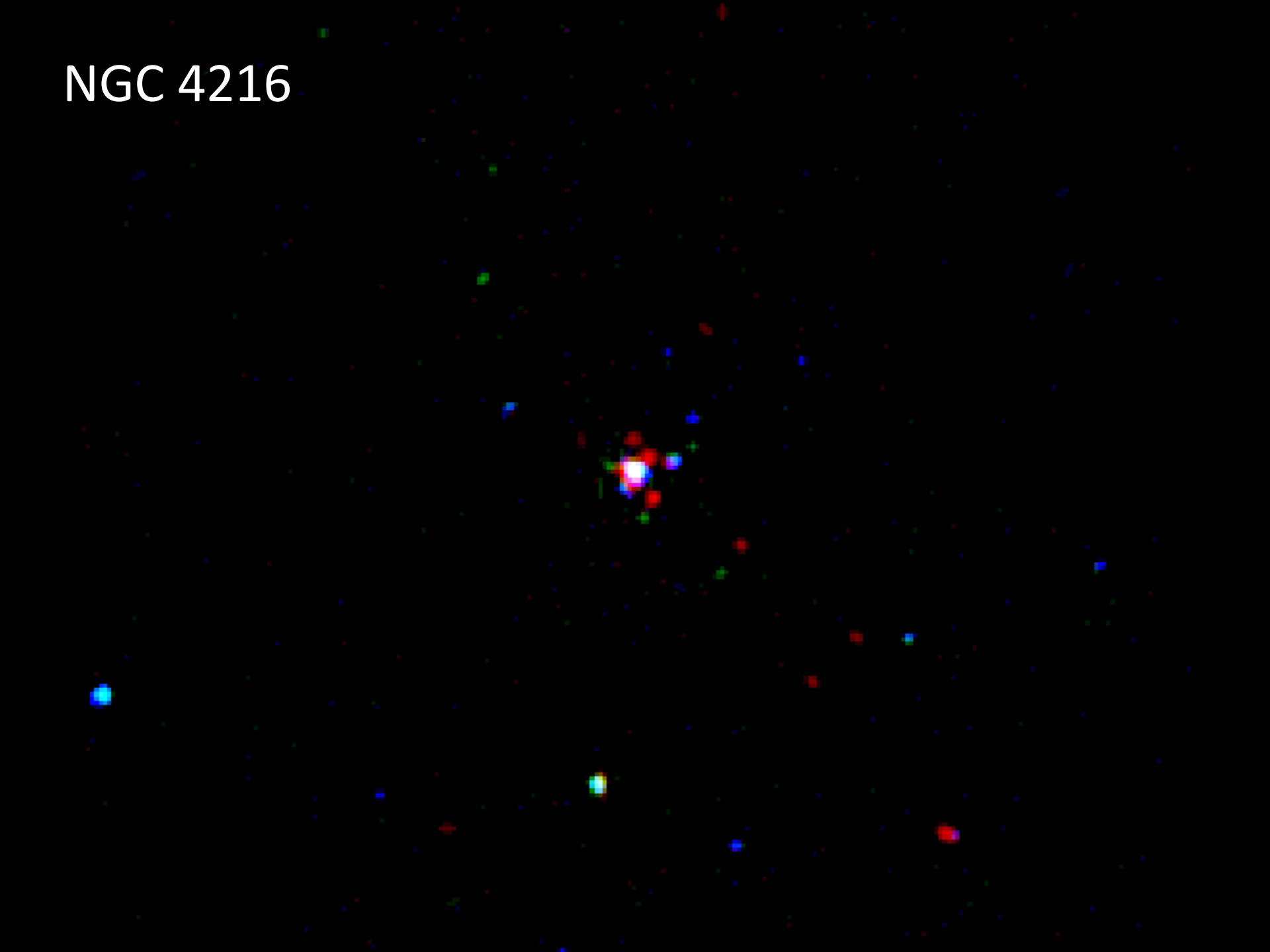
NGC 4216



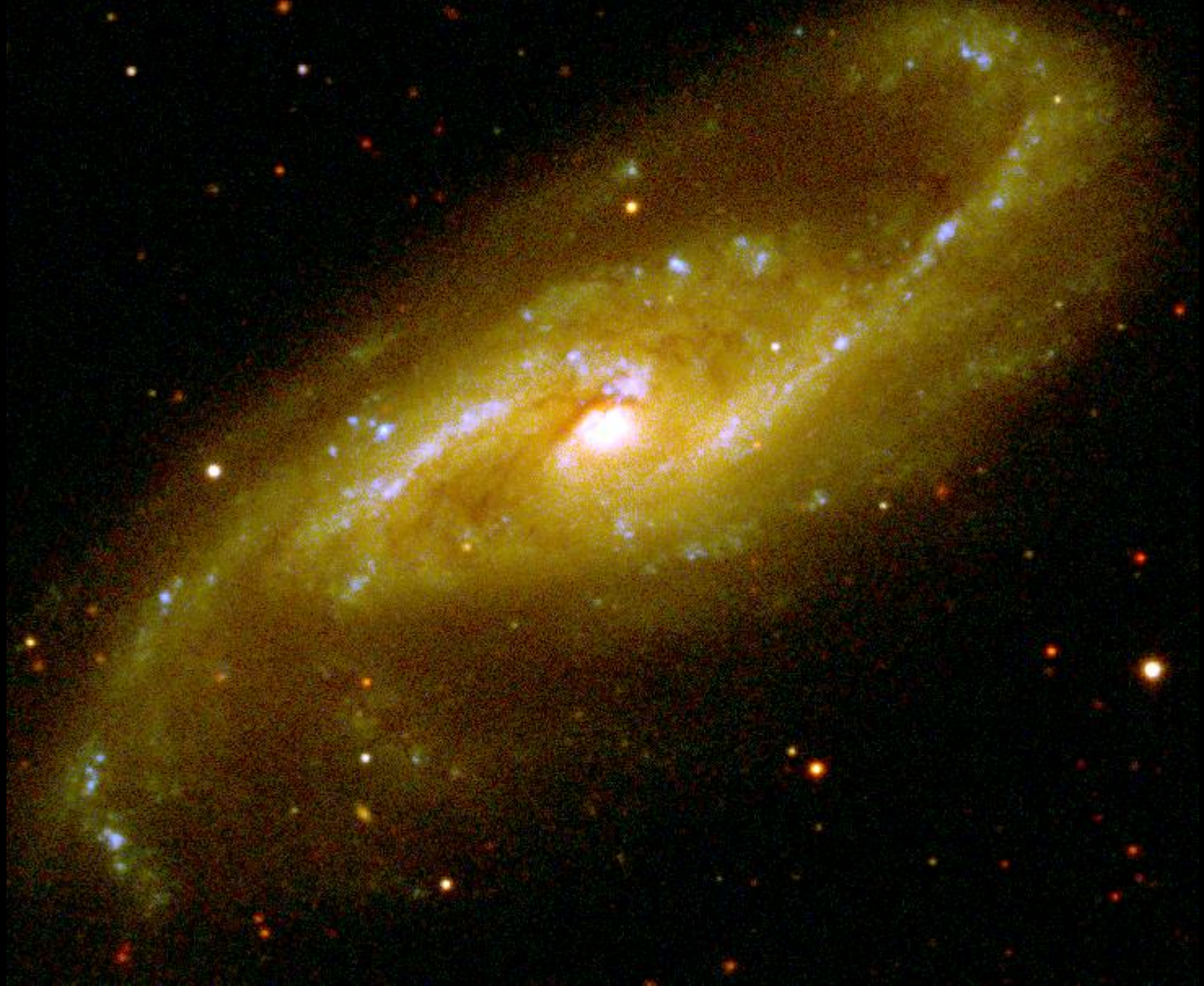
NGC 4216



NGC 4216



NGC 4536



NGC 4536



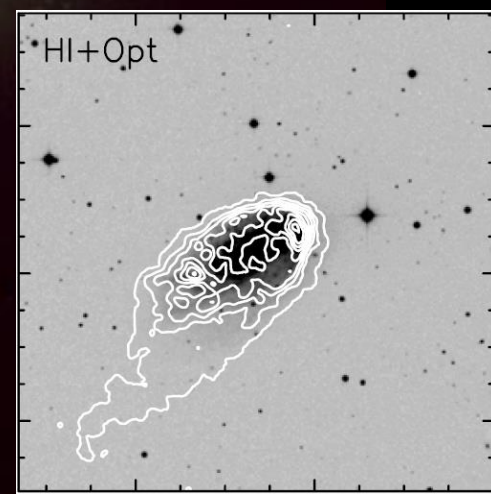
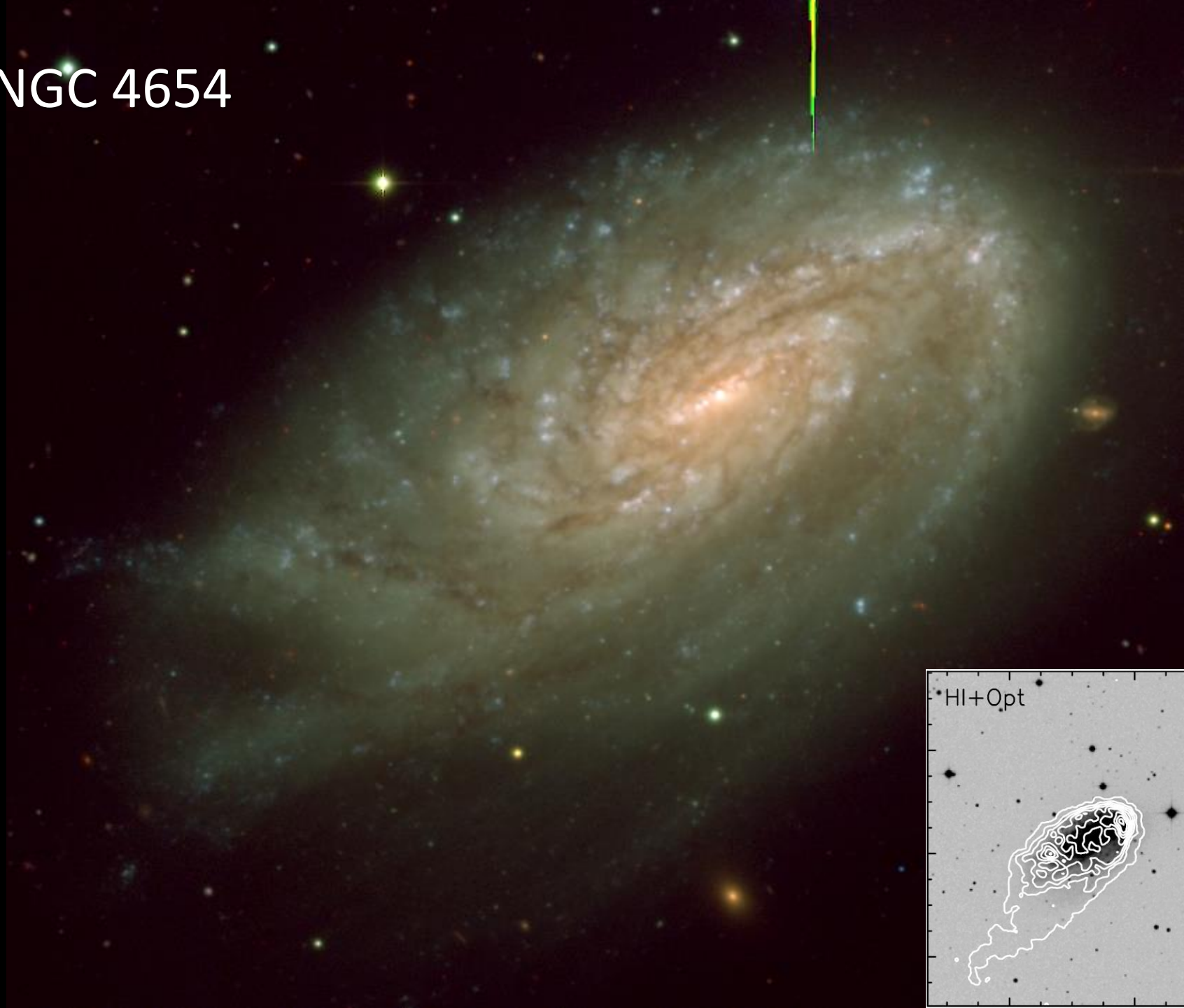
NGC 4527



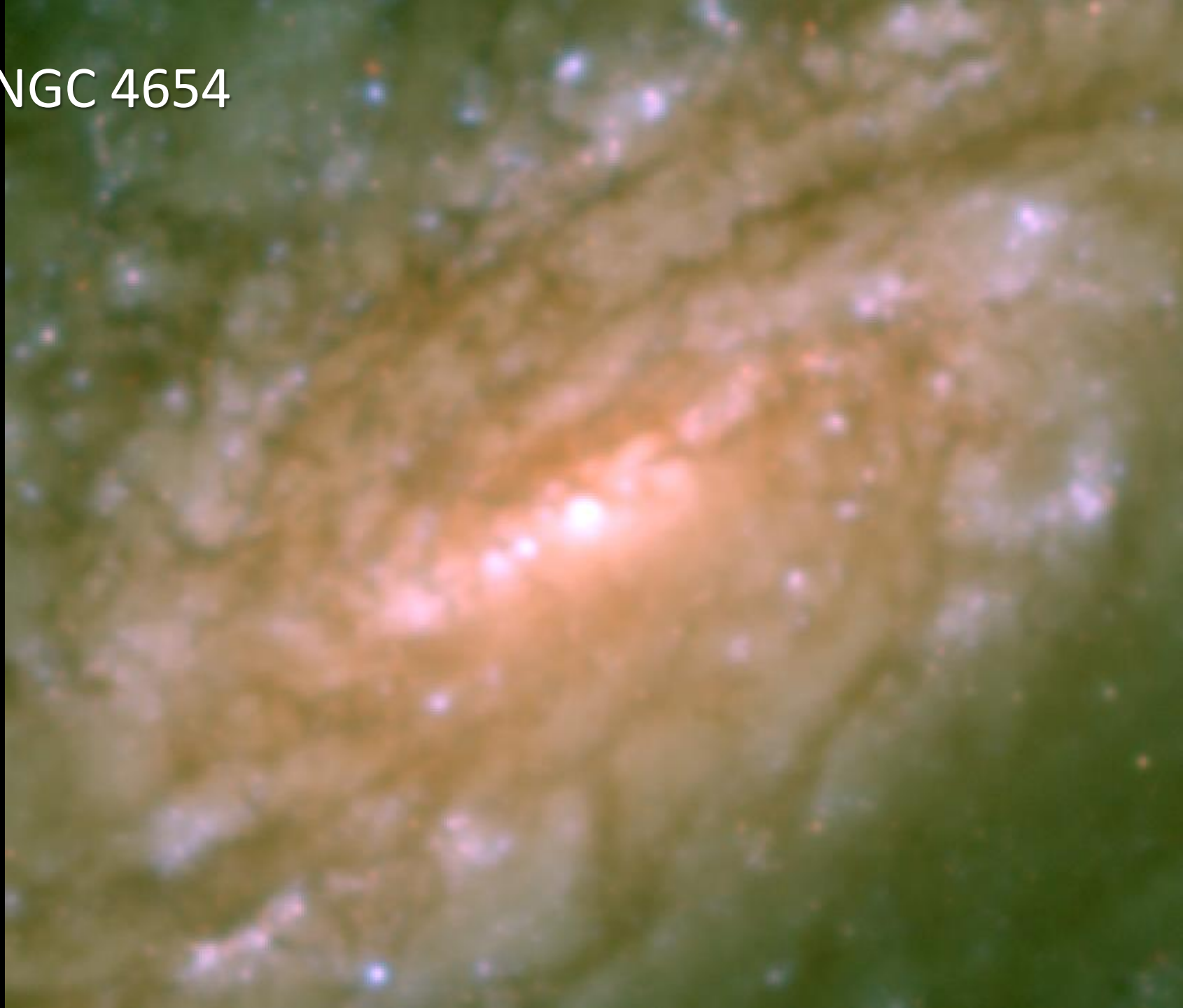
NGC 4527



NGC 4654



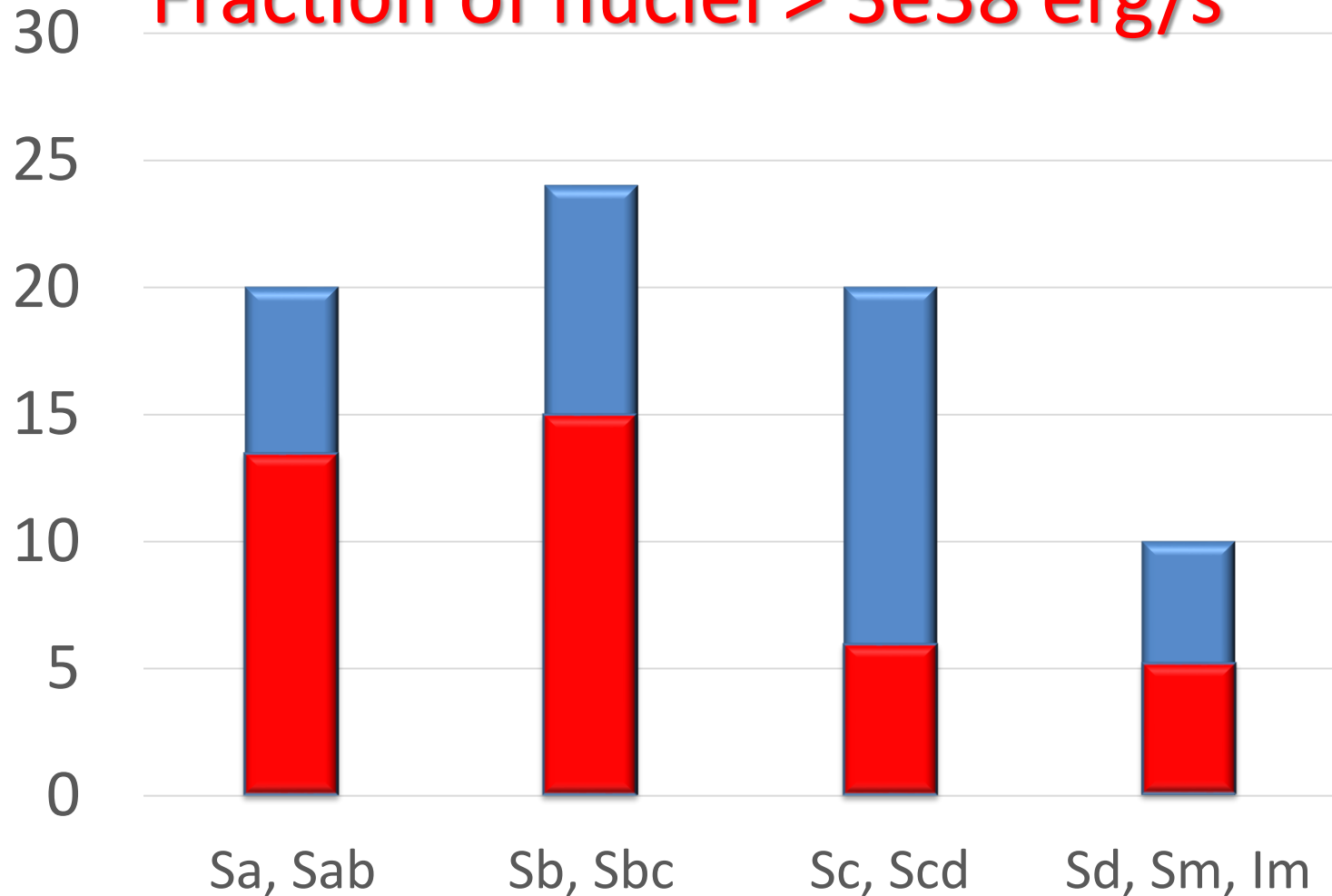
NGC 4654



NGC 4654



Fraction of nuclei $> 3e38$ erg/s



Active fraction $\sim 30\%$ for the AMUSE sample
(Gallo et al 2010, Plotkin et al 2014)

Search for IMBHs in the nuclei of bulgeless spirals

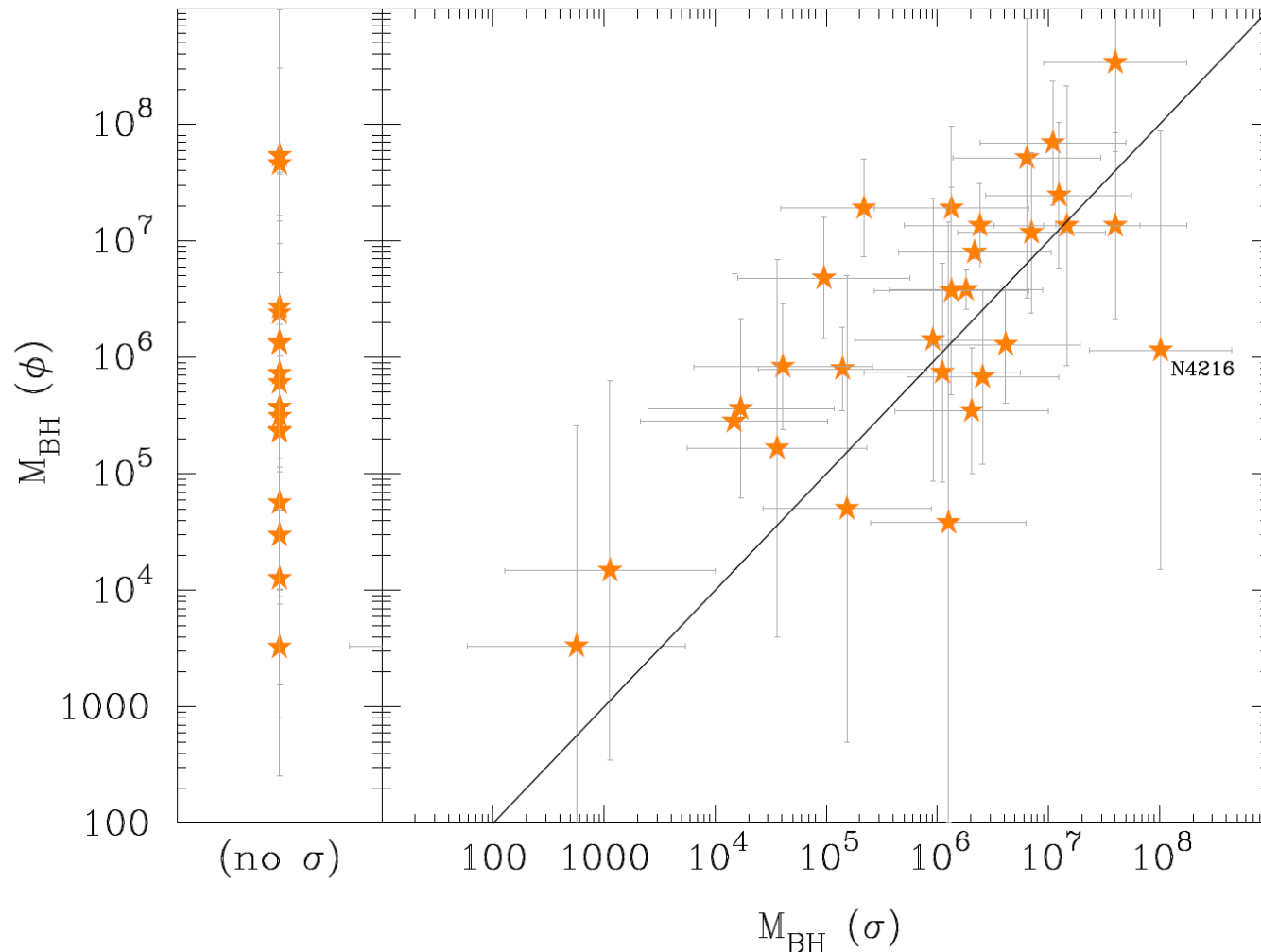
Three proxies for nuclear BH masses

$M_{\text{BH}} - \sigma$ relation

$M_{\text{BH}} - M_*$ relation

$M_{\text{BH}} - \phi$ relation (pitch angle relation)

Search for IMBHs in the nuclei of bulgeless spirals

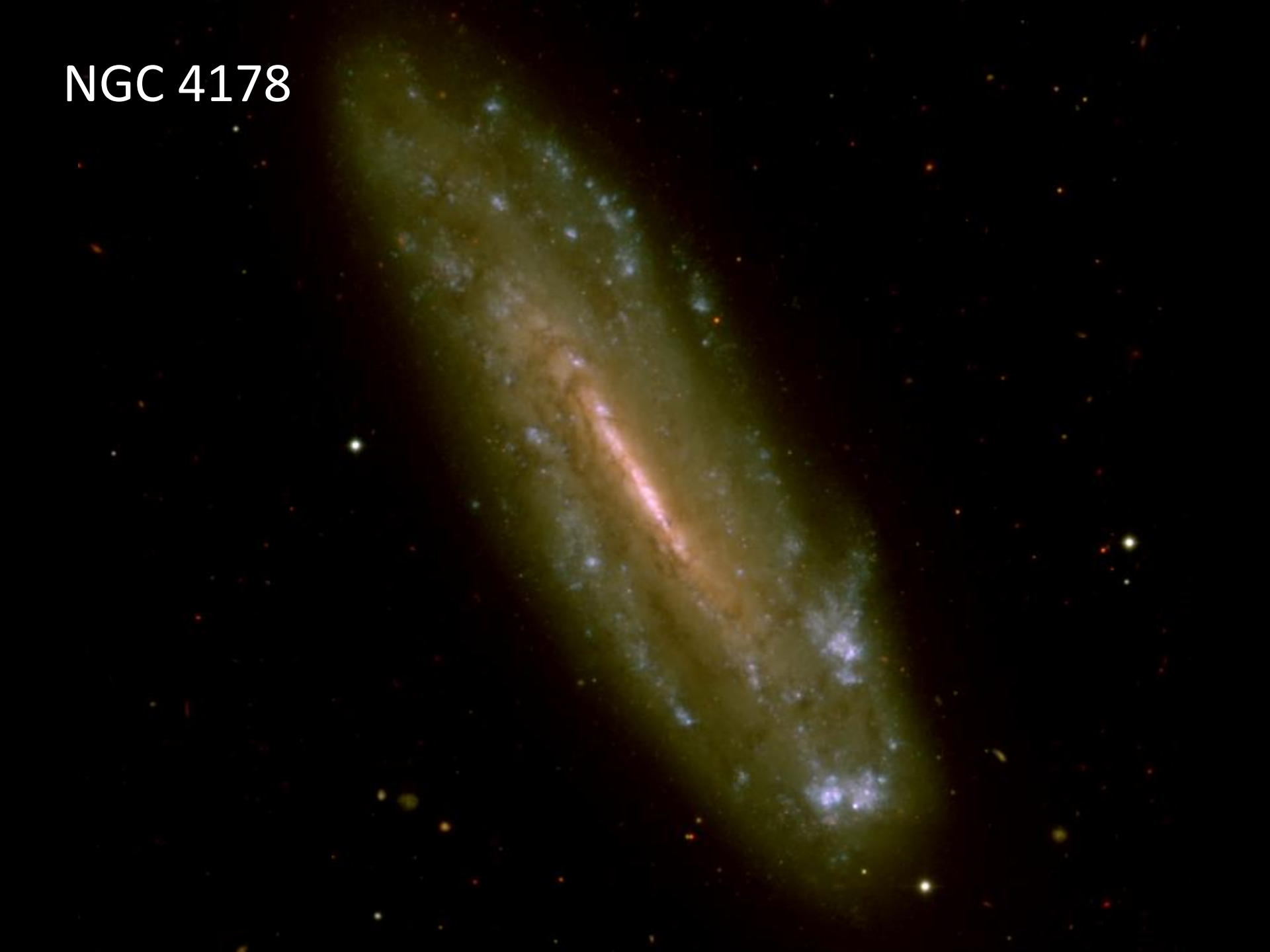


Small pitch angle = tightly wound arms = high BH mass
(Graham et al 2018, Davis et al 2017)

Search for IMBHs in the nuclei of bulgeless spirals

Galaxy	$M_{\text{bh}} (M_{*,\text{total}})$ M_{\odot}	$M_{\text{bh}} (\phi)$ M_{\odot}	$M_{\text{bh}} (\sigma)$ M_{\odot}
	3 estimates $< 10^5 M_{\odot}$		
N4178	3×10^4	2×10^4	1×10^3
N4713	9×10^3	3×10^3	6×10^2
	2 estimates $< 10^5 M_{\odot}$, no estimate $> 10^5 M_{\odot}$		
IC3392	2×10^4	6×10^4	...
N4294	2×10^4	3×10^3	...
N4413	1×10^4	3×10^4	...
	2 estimates $< 10^5 M_{\odot}$, 1 estimate $\geq 10^6 M_{\odot}$		
N4424	4×10^4	5×10^6	1×10^5
N4470	1×10^4	4×10^4	1×10^6

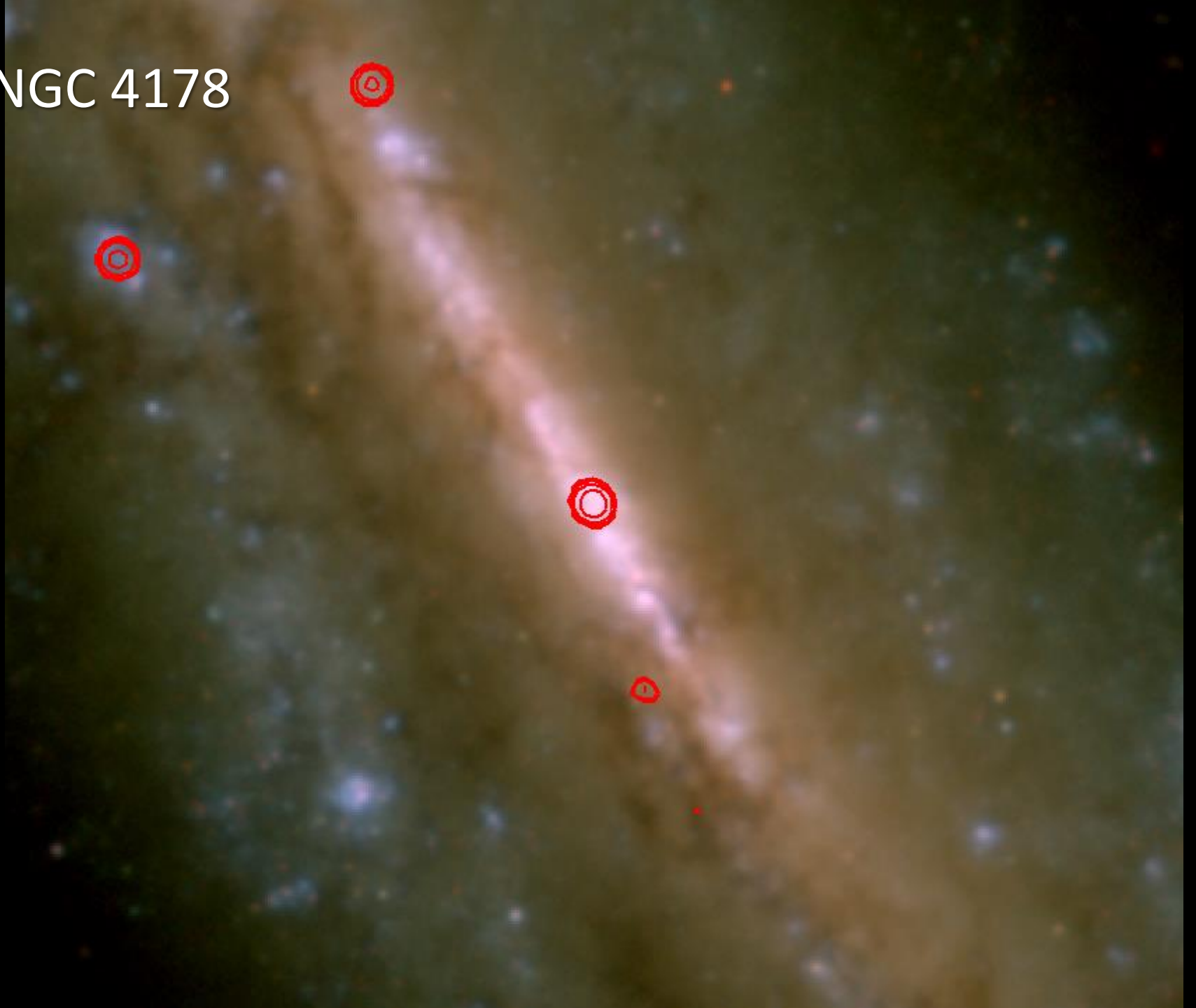
NGC 4178



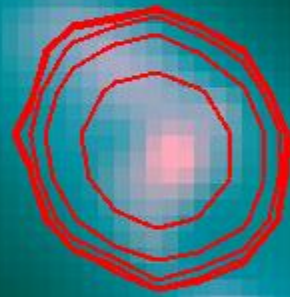
NGC 4178



NGC 4178



NGC 4178



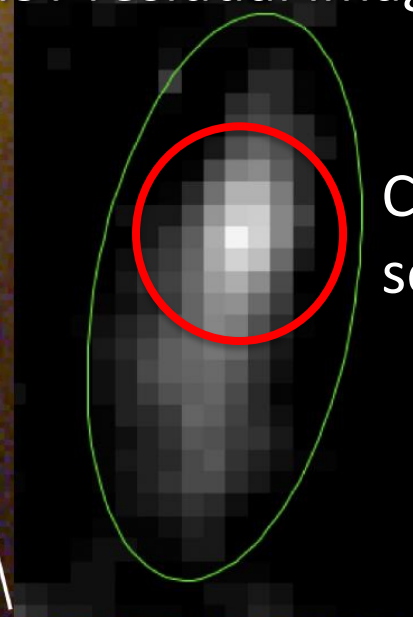
Nuclear IMBH
 $M \sim 1E4 M_{\text{sun}}?$

Search for IMBHs in the nuclei of accreted dwarfs

Best candidate: satellite dwarf near the nucleus of NGC 4424?



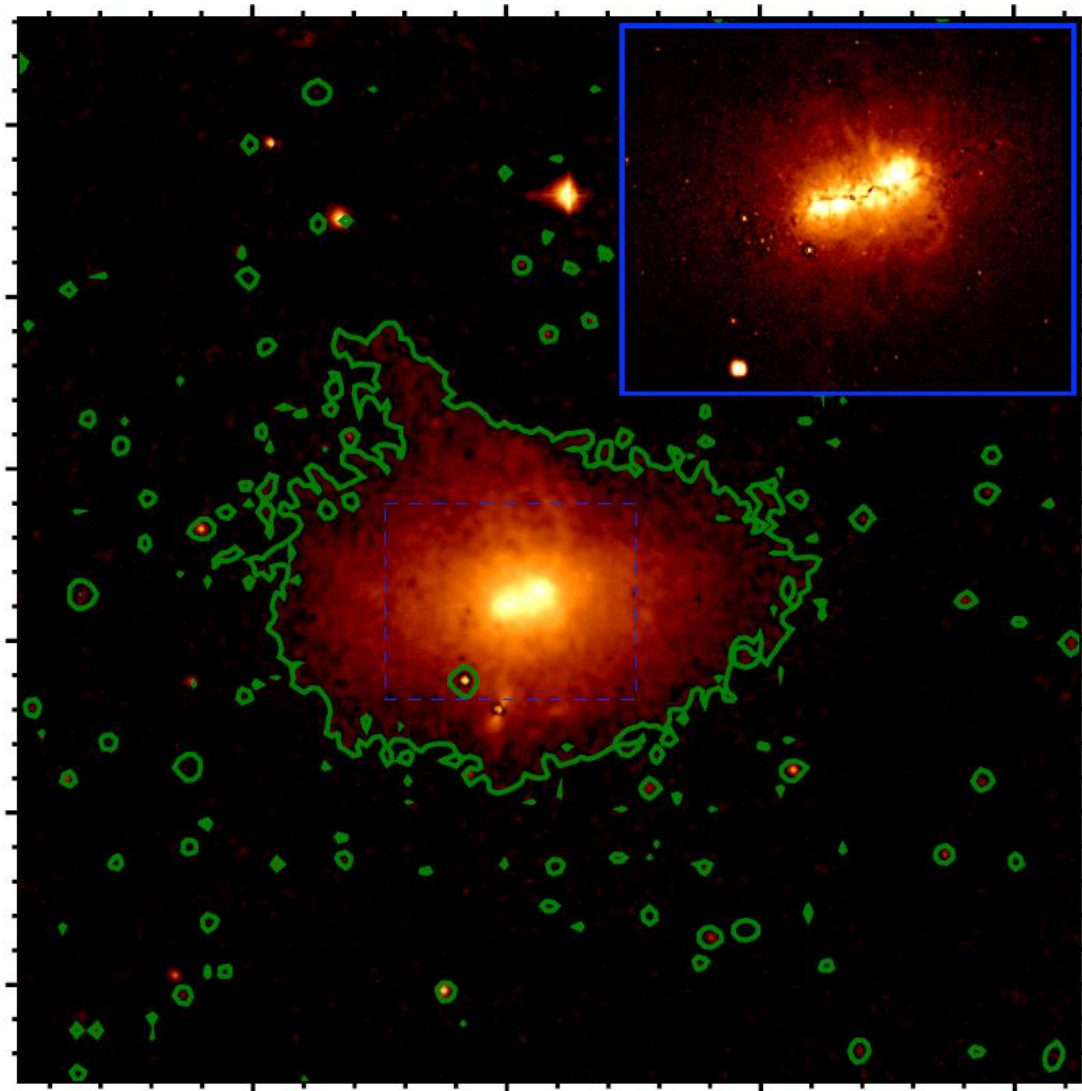
HST residual image



Chandra source

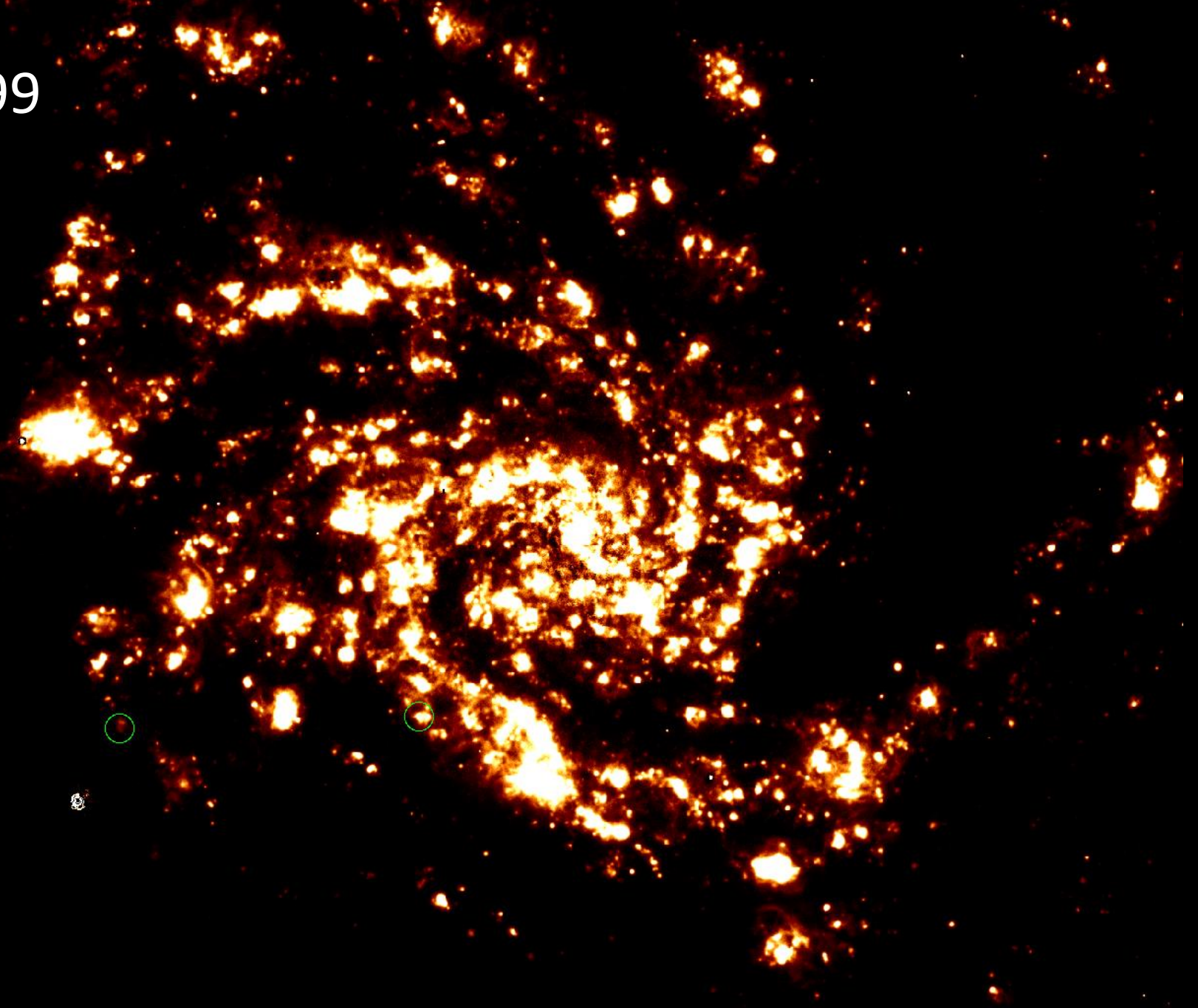
Search for IMBHs in the nuclei of accreted dwarfs

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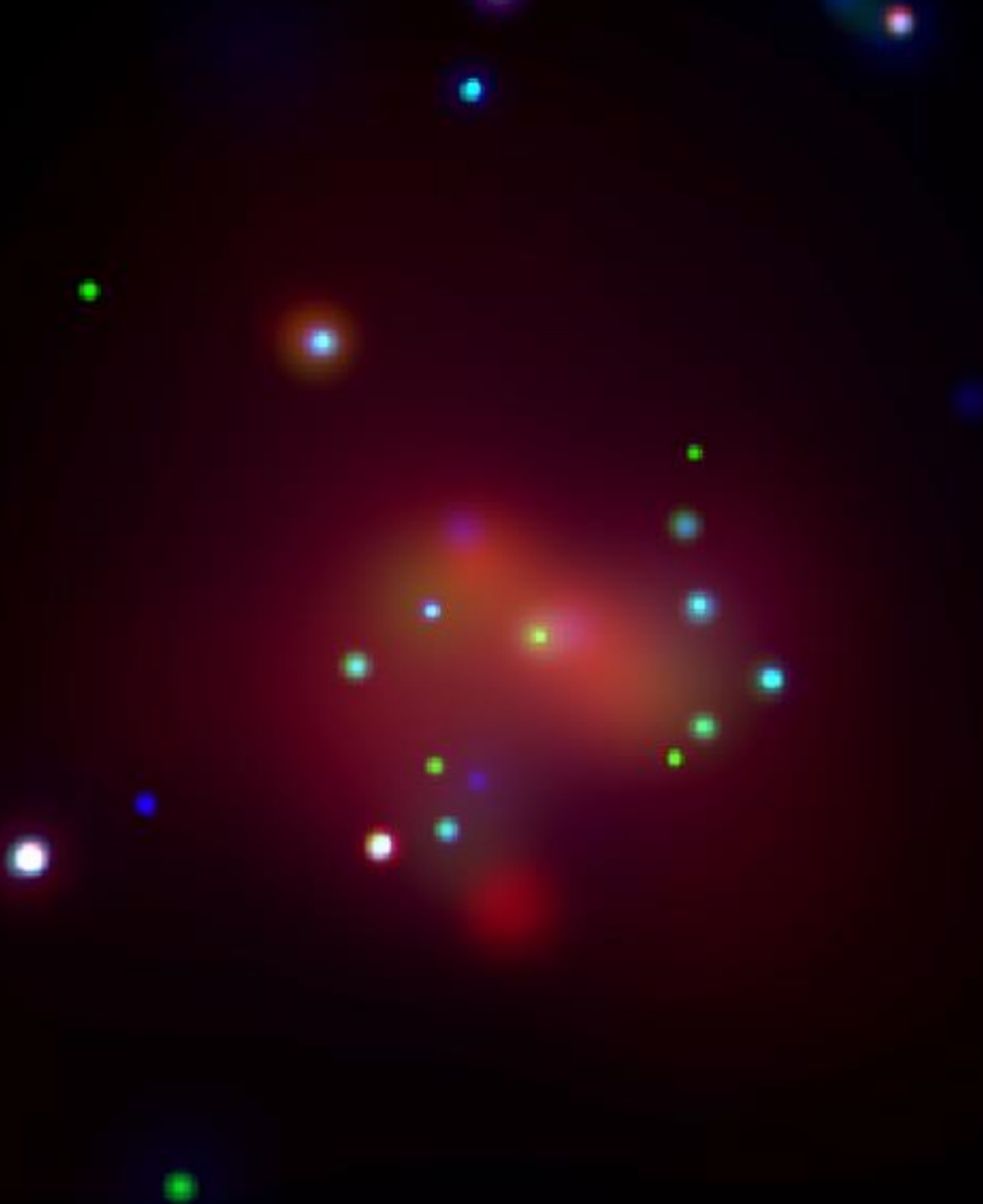


VESTIGE H α survey
(Boselli et al.)

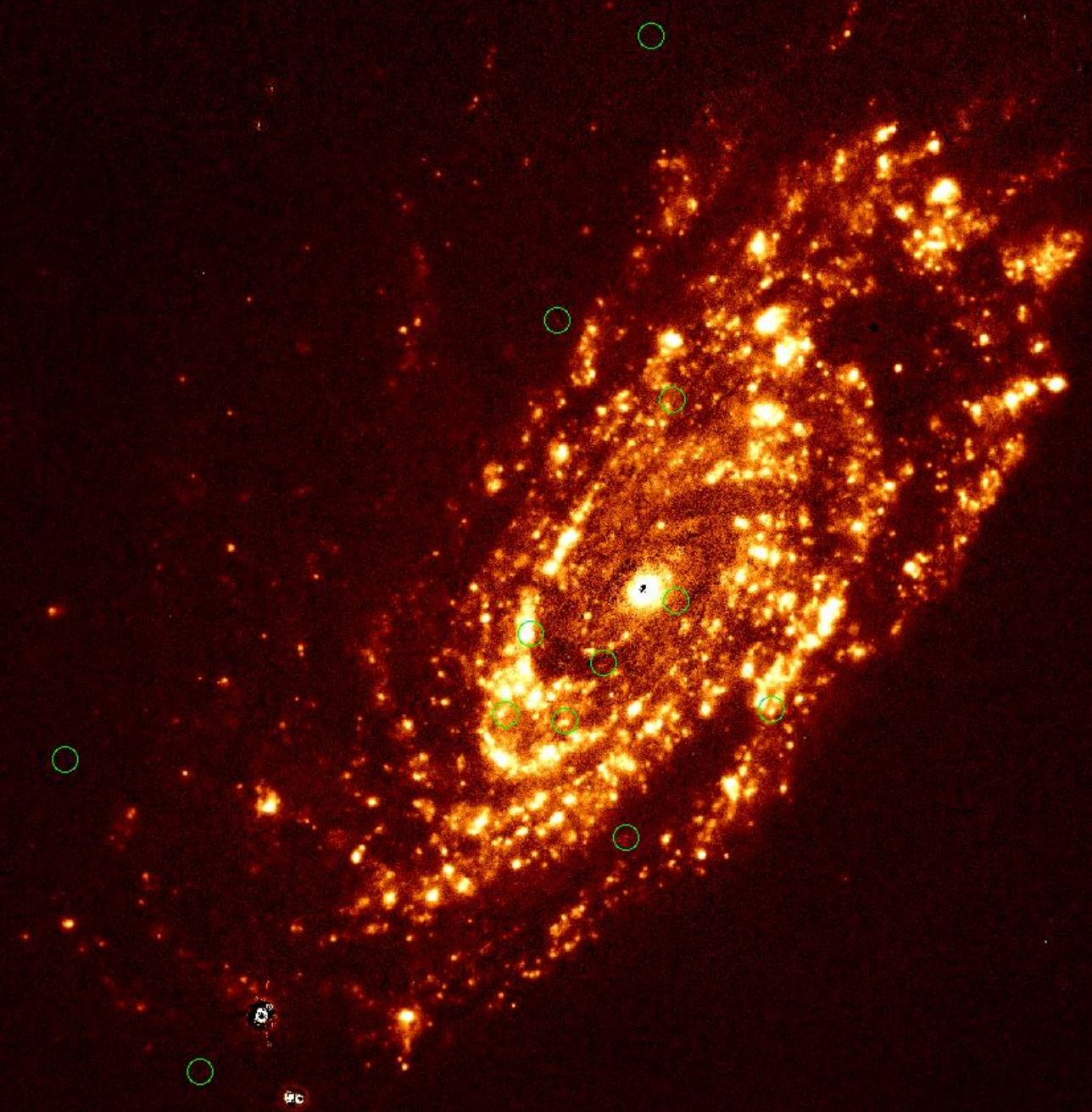
M99



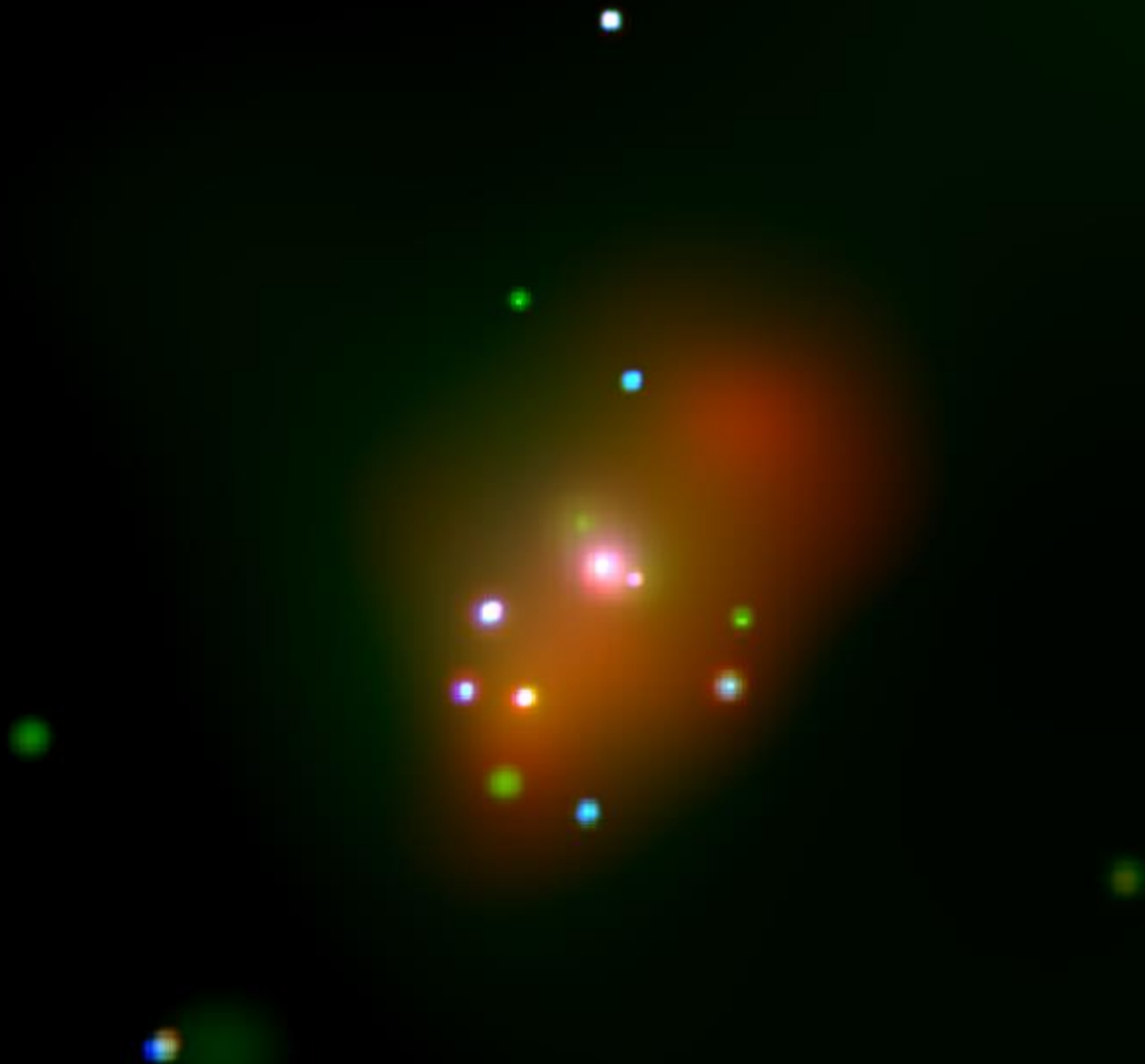
M99



M88



M88



Summary

- ULXs and nuclear BHs in Virgo spirals
- Comparison with results for ellipticals
- Search for IMBHs
- Coming soon:
 - *association with globular clusters, UCDs*
 - *H α counterparts (VESTIGE survey)*
 - *search for ULX radio bubbles*