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BRIGHT ULXs FROM RING GALAXIES

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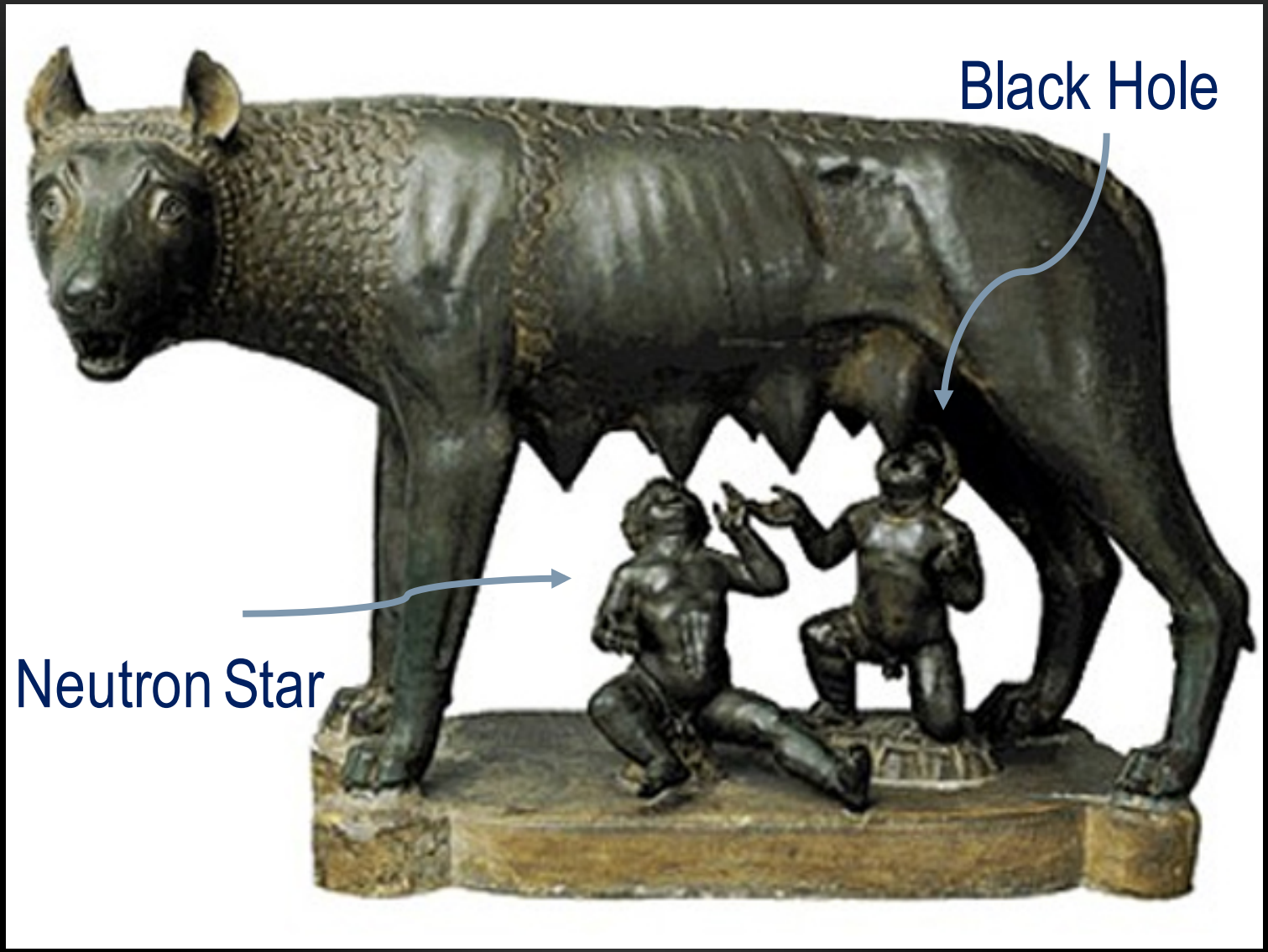
ULXs: A MIXED BAG OF SOURCES

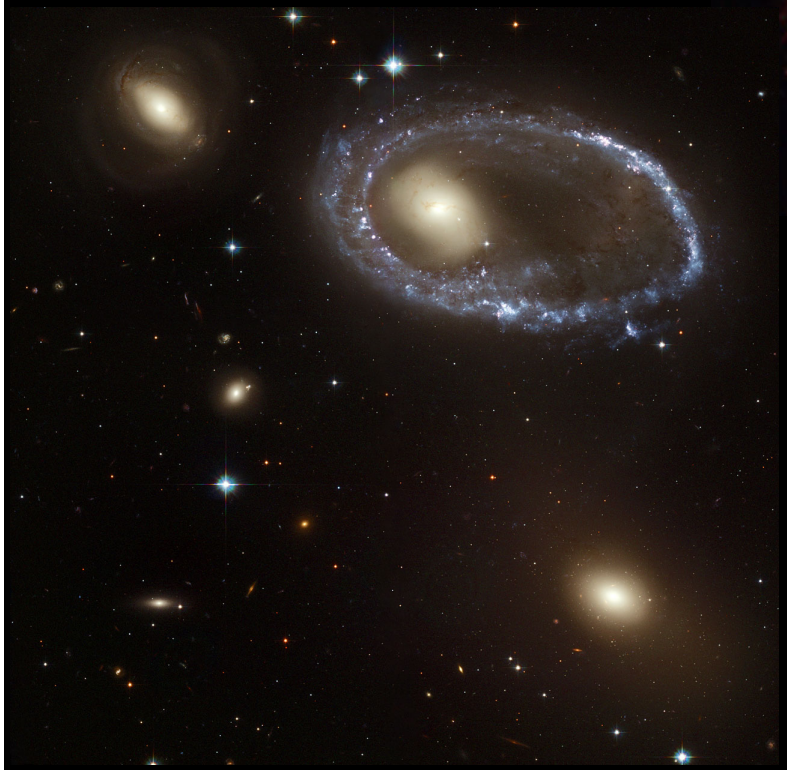
- Heavy stellar: most are probably HMXB with heavy (>50 $M_\odot$) companions; linked to new star formation episodes; possibly to low metallicity.
- NS: at least 3 (Bachetti et al, Israel et al, Fuerst et al.) show pulsation in their high energy emission; linked to older population (see *Fuerst, Israel, Mushtukov* talks)
- IMBH: no clear evidence yet for M $\sim 10^2 - 10^4 M_\odot$

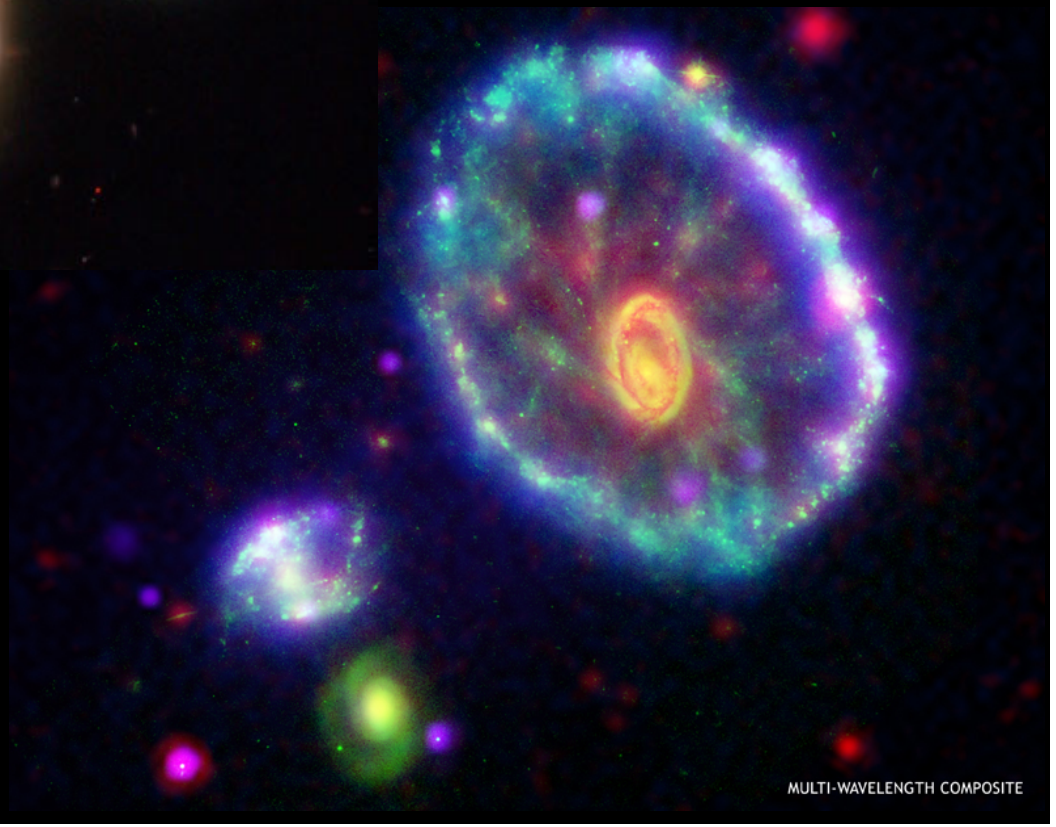


Who will win in the end?

ULXs: A MIXED BAG OF SOURCES

Where to look for them?





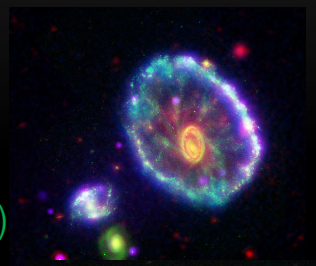
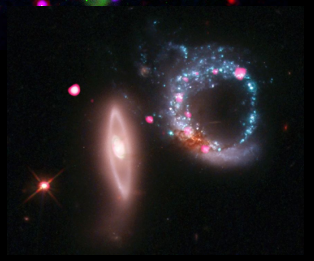
RING GALAXIES – WHY?

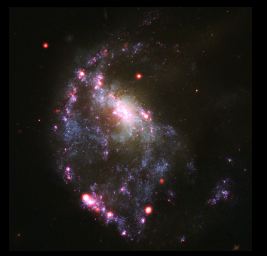
- Fresh burst of Star Formation:
  - low metallicity (higher mass of BH);
  - young age (higher mass for both donor and accretor)
- Precise location of source
  - Smaller chance of interlopers

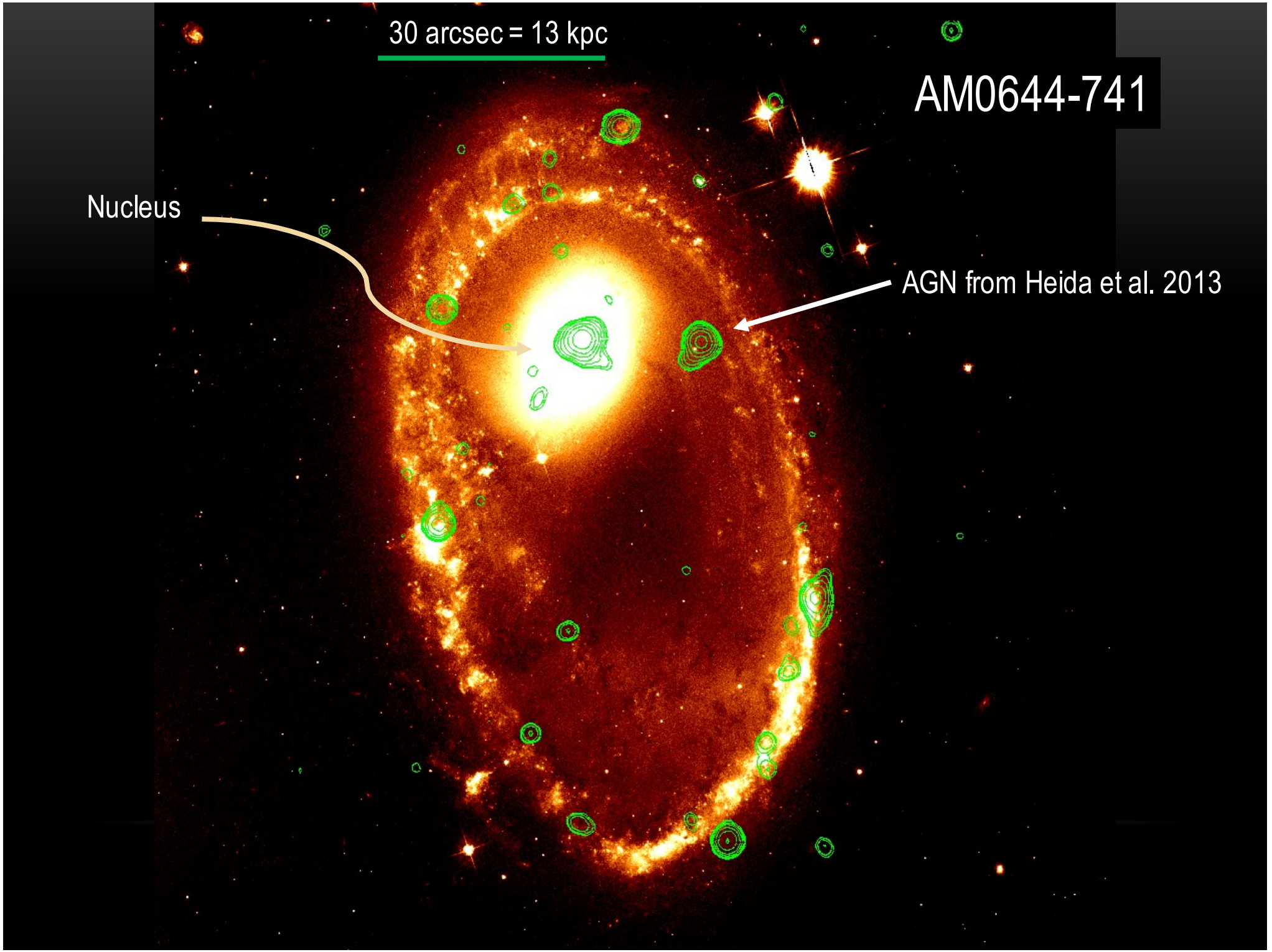
There are 7 “bright and famous” Ring Galaxies observed by Chandra (3 of which have also XMM-Newton data)

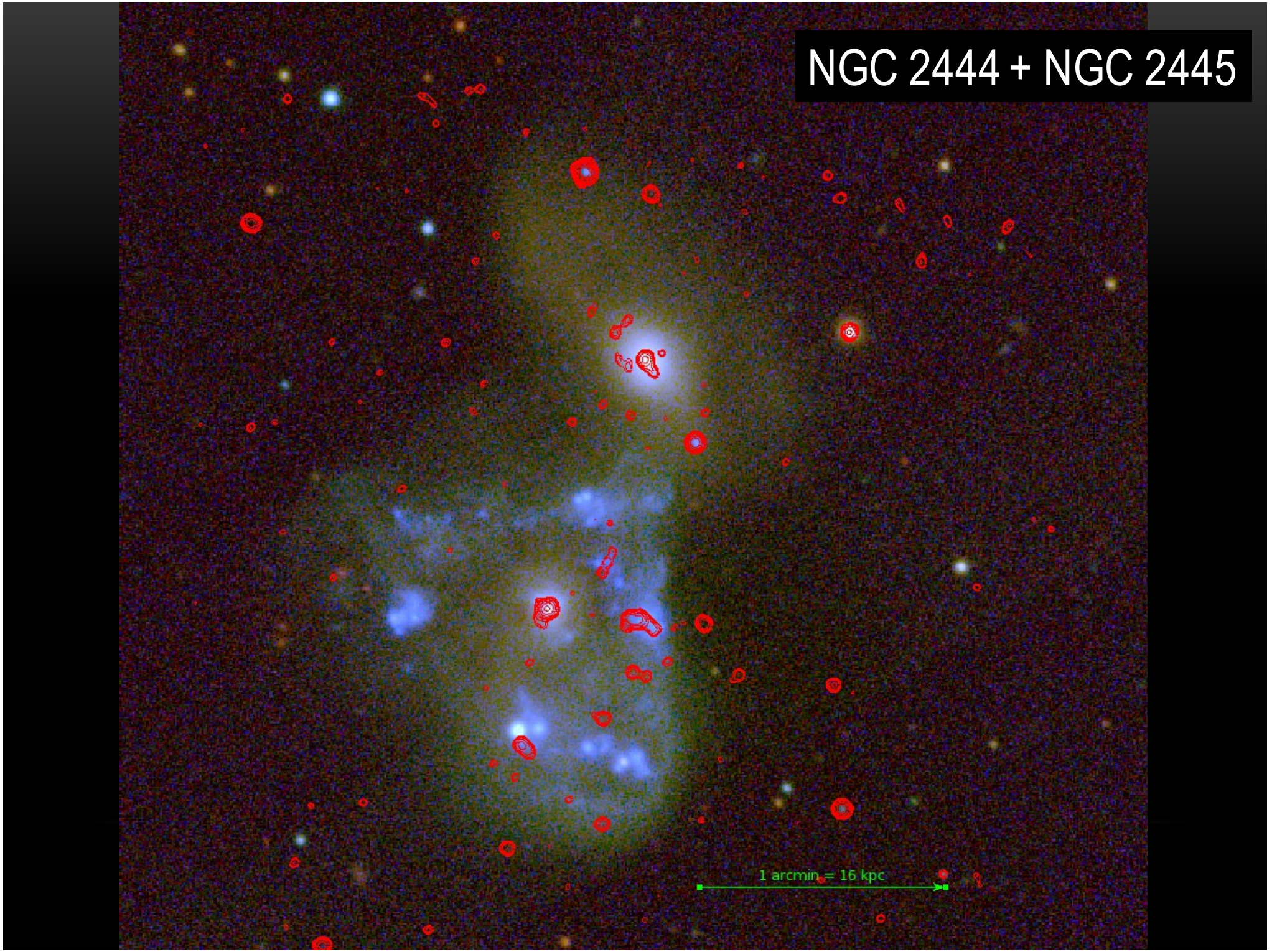
OBS. RING GALAXIES & # OF ULXs IN RING

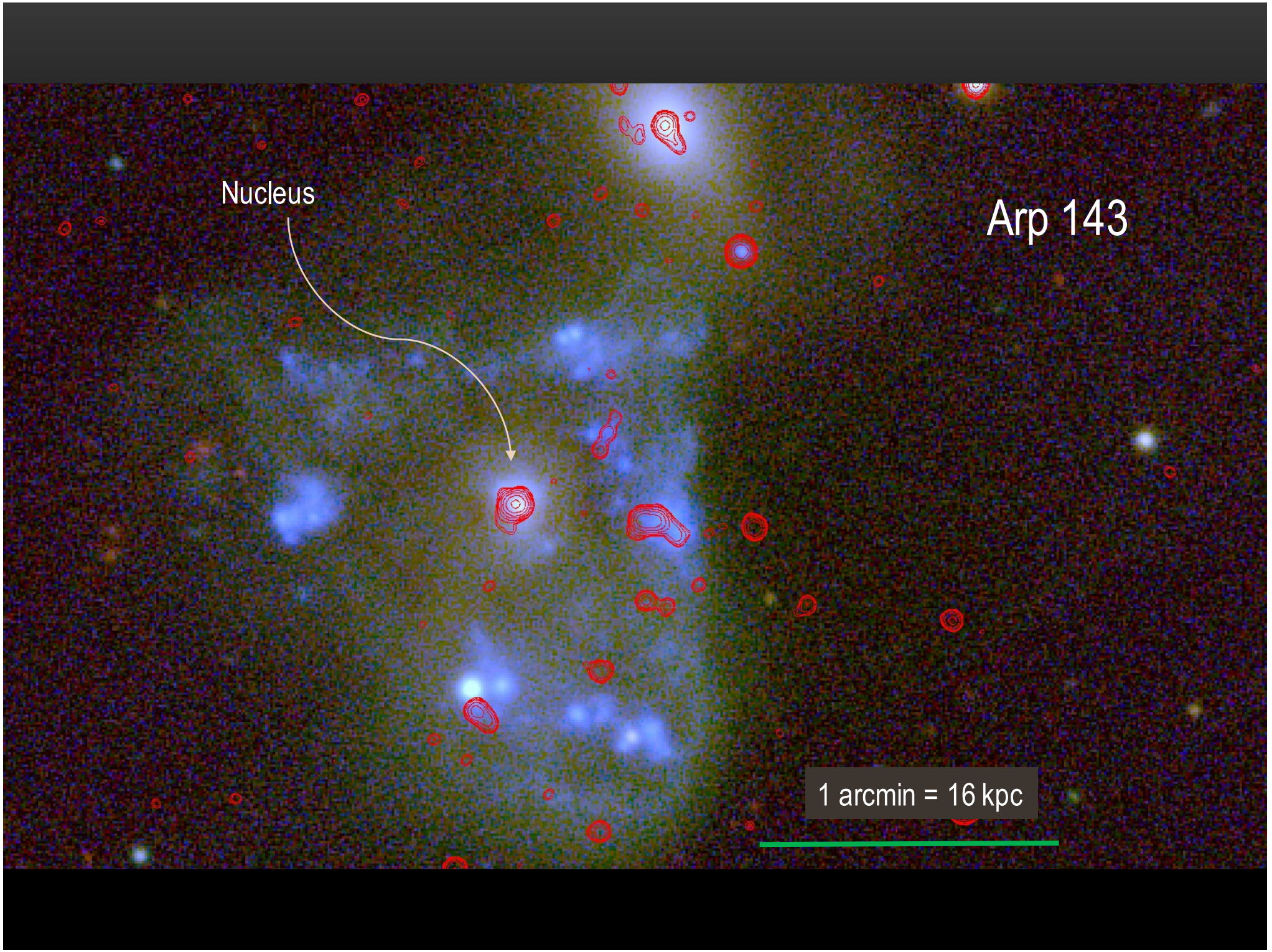
- Cartwheel (14+1) Wolter et al. 2006
- Arp 284 (2+7) Smith, Struck, & Nowak (2005)
- Arp 147 (9+0) Rappaport et al. (2010)
- NGC 922 (7+5) Prestwich et al (2012)
- AM 0644-741 (7) AW+ in prep
- Arp 148 (2) AW+ in prep
- Arp 143 (9) AW+ in prep

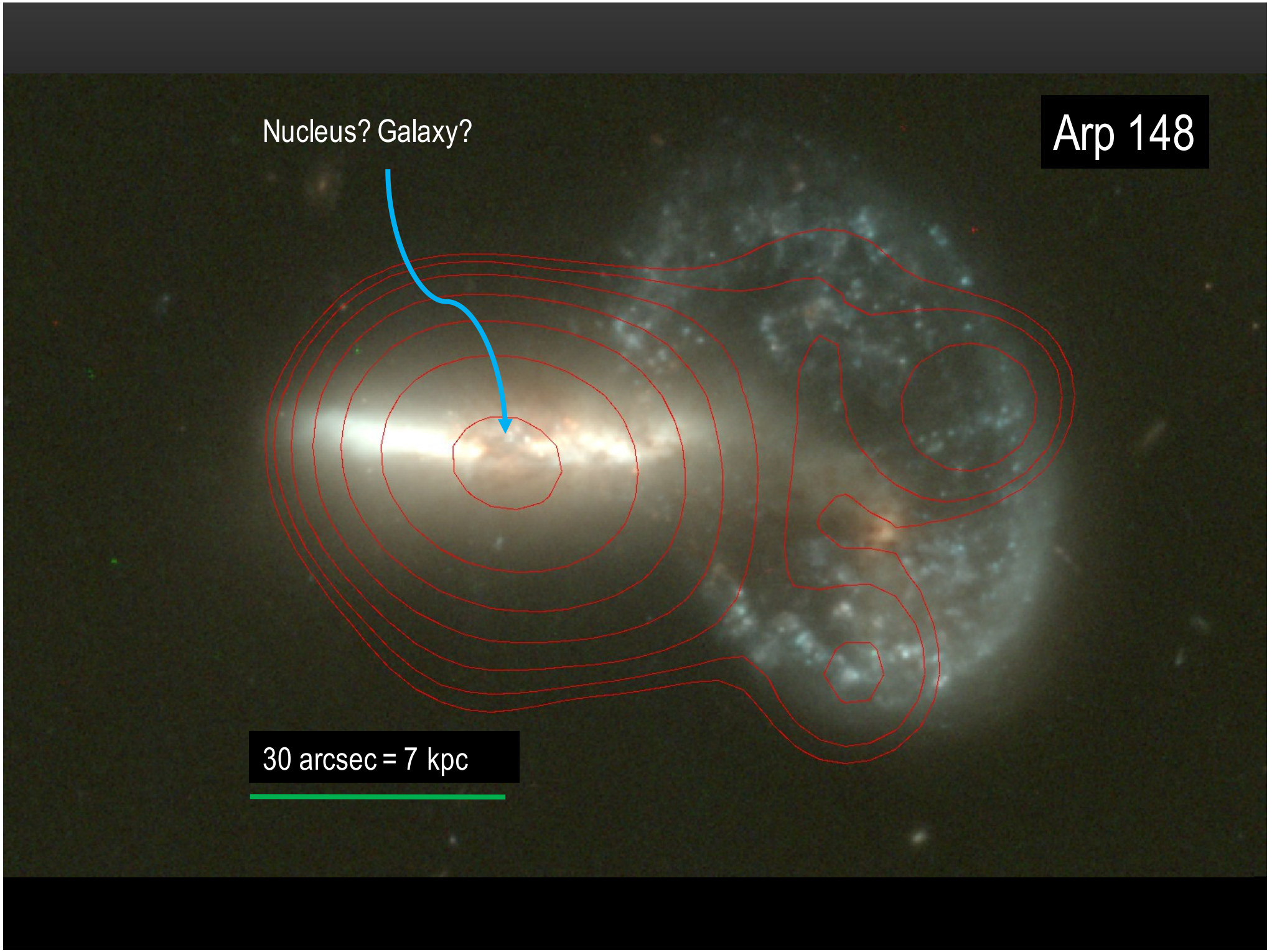






30 arcsec = 13 kpc
AM0644-741
Nucleus
AGN from Heida et al. 2013

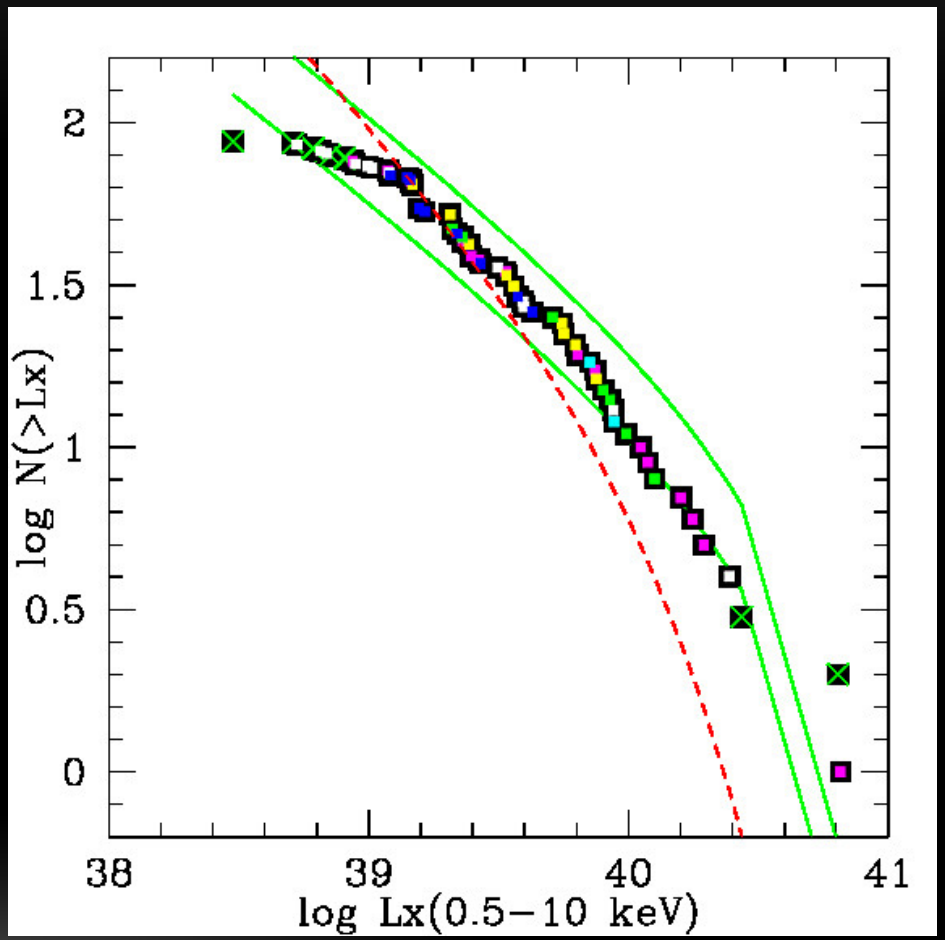

NGC 2444 + NGC 2445
1 arcmin = 16 kpc

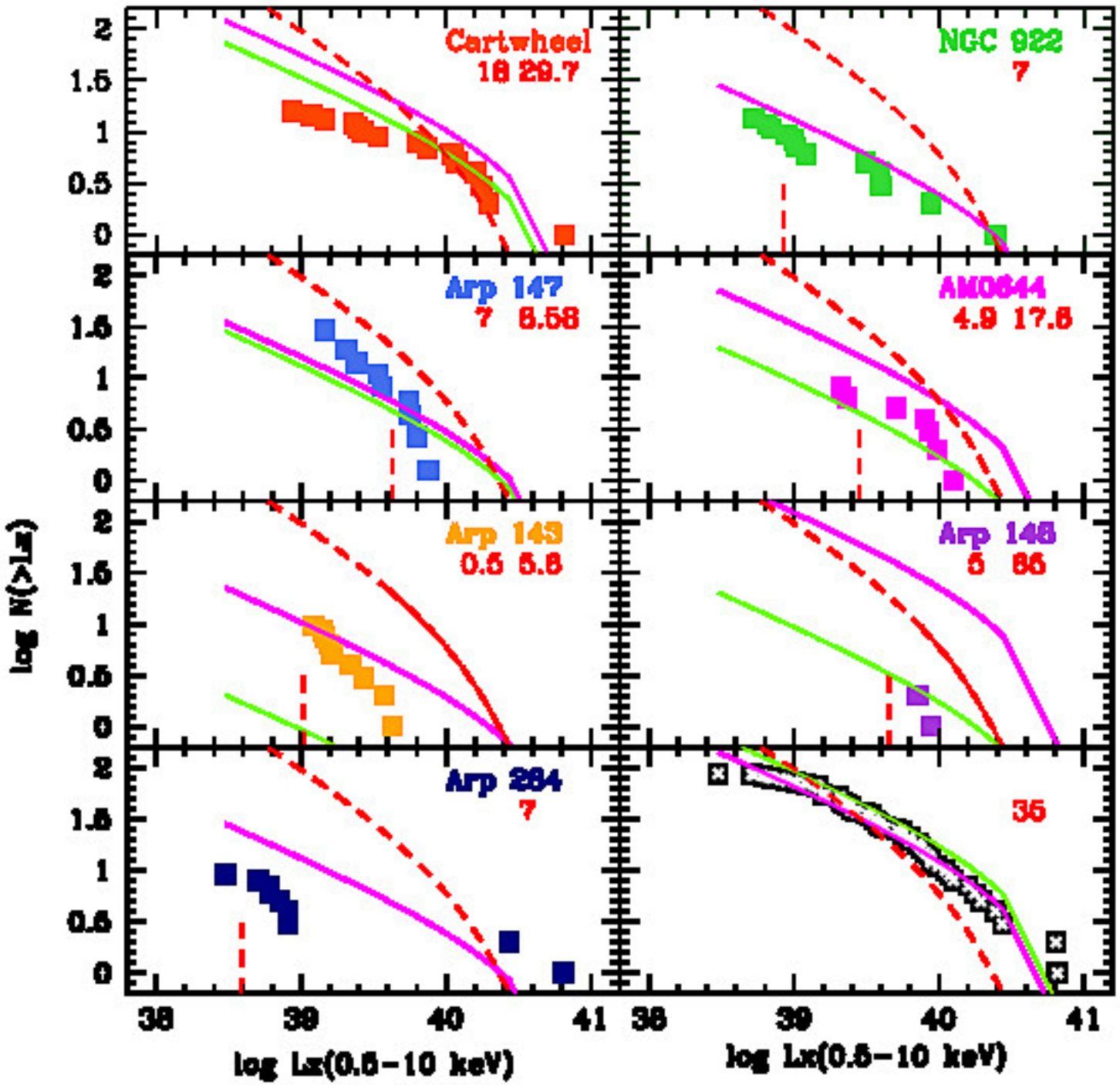

Nucleus
Arp 143
1 arcmin = 16 kpc


Nucleus? Galaxy?
Arp 148
30 arcsec = 7 kpc

X-RAY LUMINOSITY FUNCTION – RING ONLY

- We consider the population homogenous – we sum all the sources
- Colors correspond to different galaxies
- 50 are ULXs; SFR_{Tot} = 33 Msun
- COMPARISON with previous work
- Grimm et al. 2003:
  30 Msun – 50 Msun (green lines)
- Swartz et al 2011:
  ~ consistent total SFR = 51 Msun
- Consistent within errorbars BUT:
  higher Lx and two outlier sources




Cartwheel
18 29.7
NGC 922
7
Arp 147
7 5.58
AM0644
4.9 17.6
Arp 143
0.5 5.8
Arp 148
5 86
Arp 284
7
35
log N(>Lx)
log Lx(0.5-10 keV)
log Lx(0.5-10 keV)

SFR AND ULX NUMBER

Correlation between the number of ULX and the SFR of host galaxy

(Swartz+2009, Mapelli+2009,Mapelli+2010,Mineo+2010 ..)

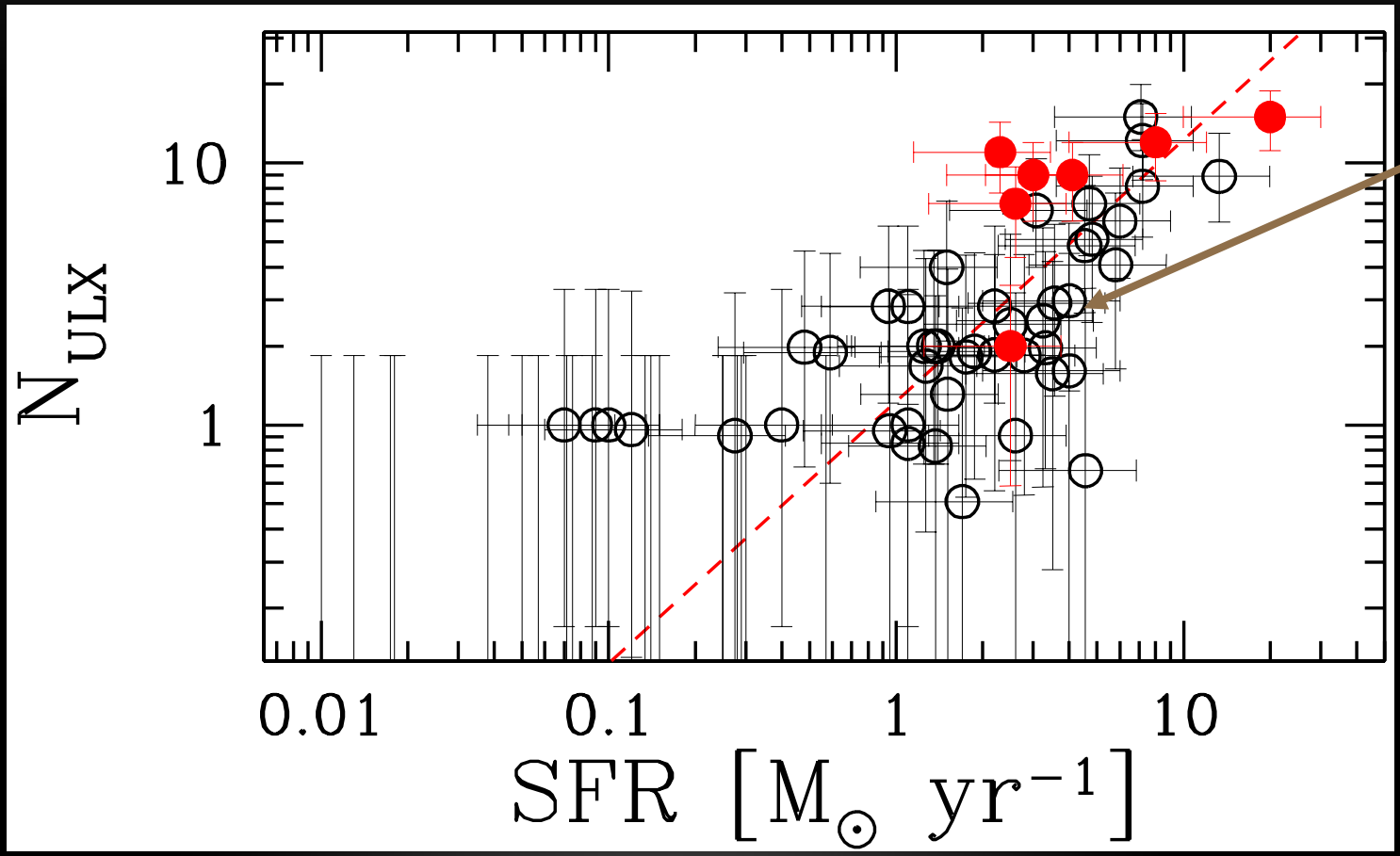
In Ring Galaxies the age of the impact is small (when estimated):

440 Myr Cartwheel (Higdon+1995)
330 Myr NGC 922 (Wong+2006)
80 Myr Arp 147 (Romano+2000)
30 Myr Arp 143 (Higdon+1995)

The large number of ULXs is linked to the **current** episode of SF.

Comparison sample of 66 late type gals (Mapelli+2011)

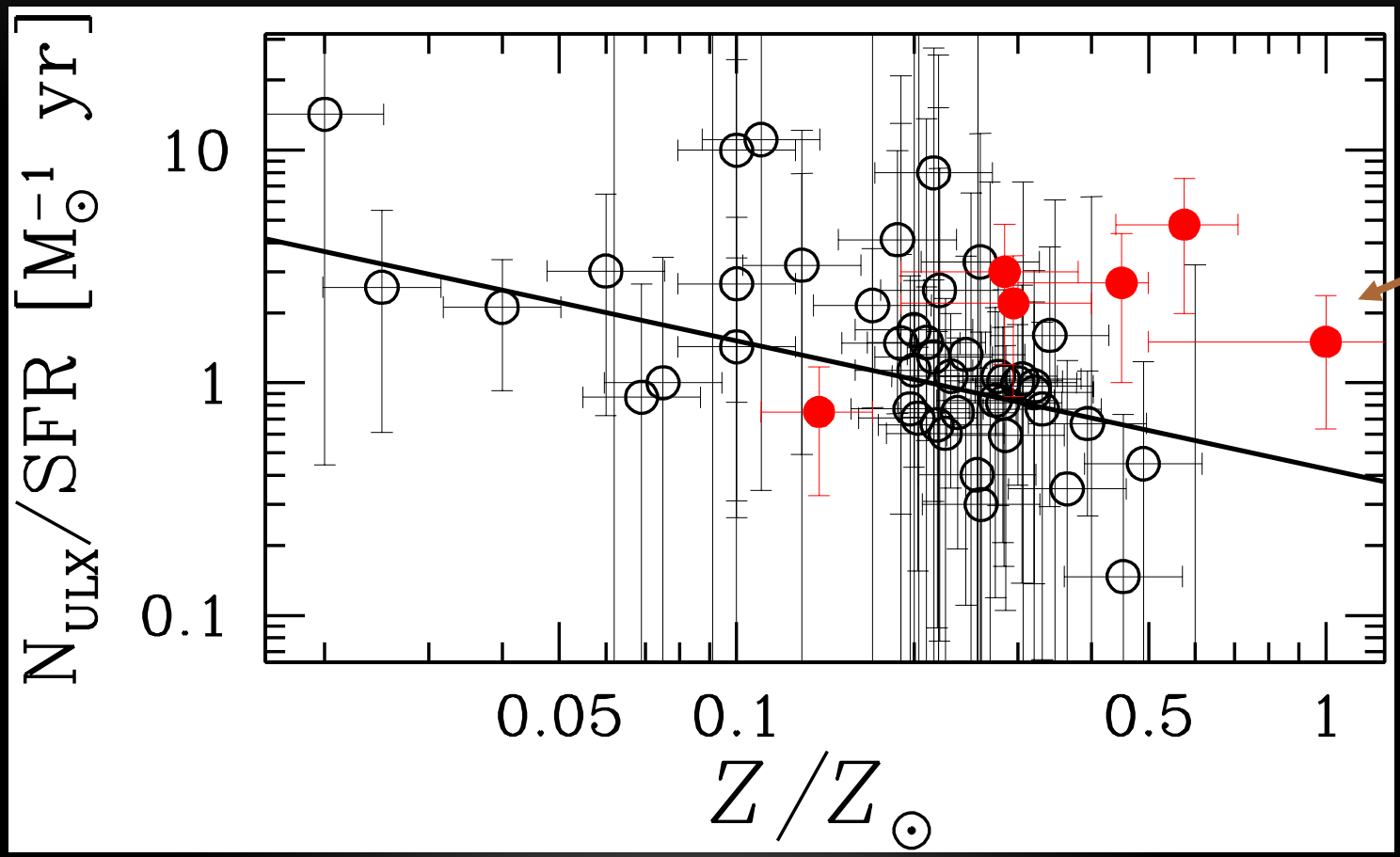
SFR AND ULX NUMBER



DEPENDENCE ON METALLICITY

- Anti-correlation between Number of ULX normalized by SFR and Z (metallicity) of host galaxy (Mapelli+2009, Kareet+2011, Prestwich+2013,Brorby+2016..)
- Large fraction of ULXs associated to massive stellar BH (M > 20 Msun) (see Mapelli+2009, Zampieri+2009,Mapelli+2014)
- Metal poor X-ray binaries are more luminous than metal rich peers (Linden+2010)
- The issue is not settled yet
- Metallicity for the Ring Galaxies – except the Cartwheel – is very uncertain

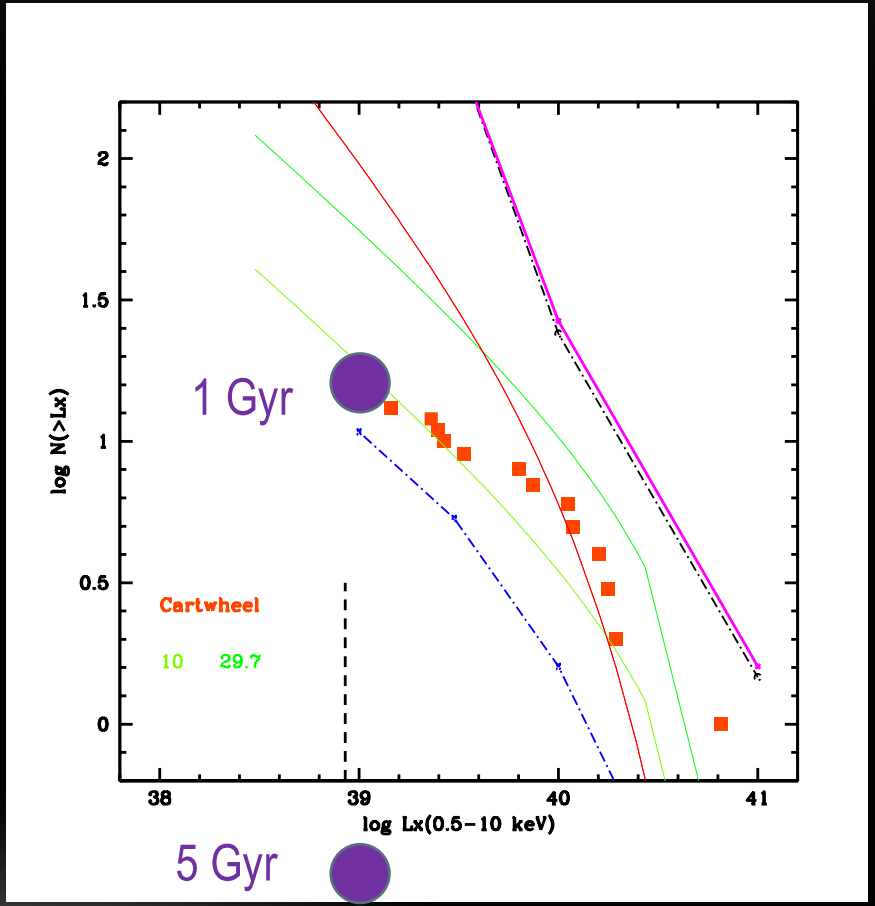
DEPENDENCE ON METALLICITY



ARE THESE OBJECTS BHs OR NSs?

Recent paper from Wiktorowicz+2017
(see also *Wiktorowicz* talk)

- Prediction of # of ULX based on StarTrack pop. synthesis (Belczynski+2002,+2003)
- Compare with Cartwheel XLF:
  Z=0.14 Zsun
  M = 8 x 10^9 Msun
- Blue: total ULX
- Dashed: BH , NS number
- @1Gyr: NS if burst; BH if constant SFR



CONCLUSION

- We have collected point sources in the ring of 7 Ring Galaxies
- For a total of > 60 sources, of which 50 are ULXs
- The combined XLF is consistent with previous results indicating a relation with the SFR of the galaxies summed up.
- There is a tendency of having brighter sources – even if not confirmed on a statistical basis
- Based on Wictorowicz et al prediction, most of these sources are most probabily BHs, especially at high Lx.
- Are the two brightest sources (1 from Cartwheel, the other from Arp284) IMBH? A new deep look in X-rays (if granted) will allow us to discriminate.