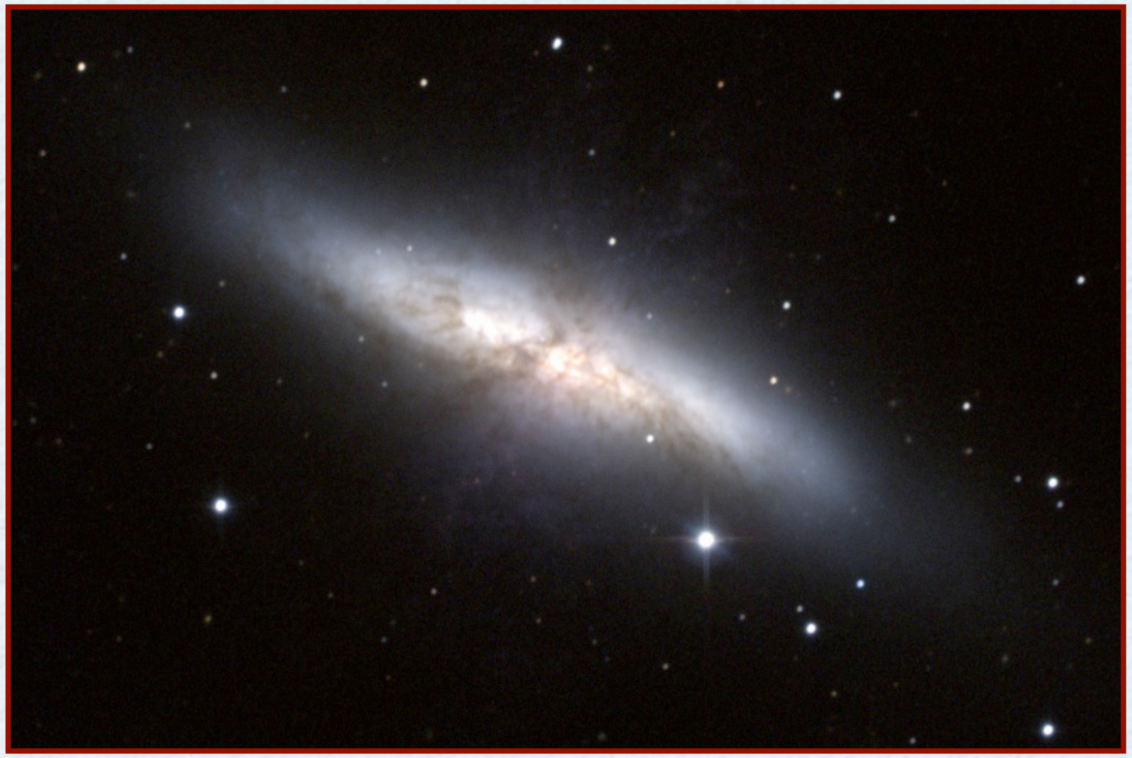
Is M82 the same as Cen A?

J. Eilek (NMT/NRAO), with

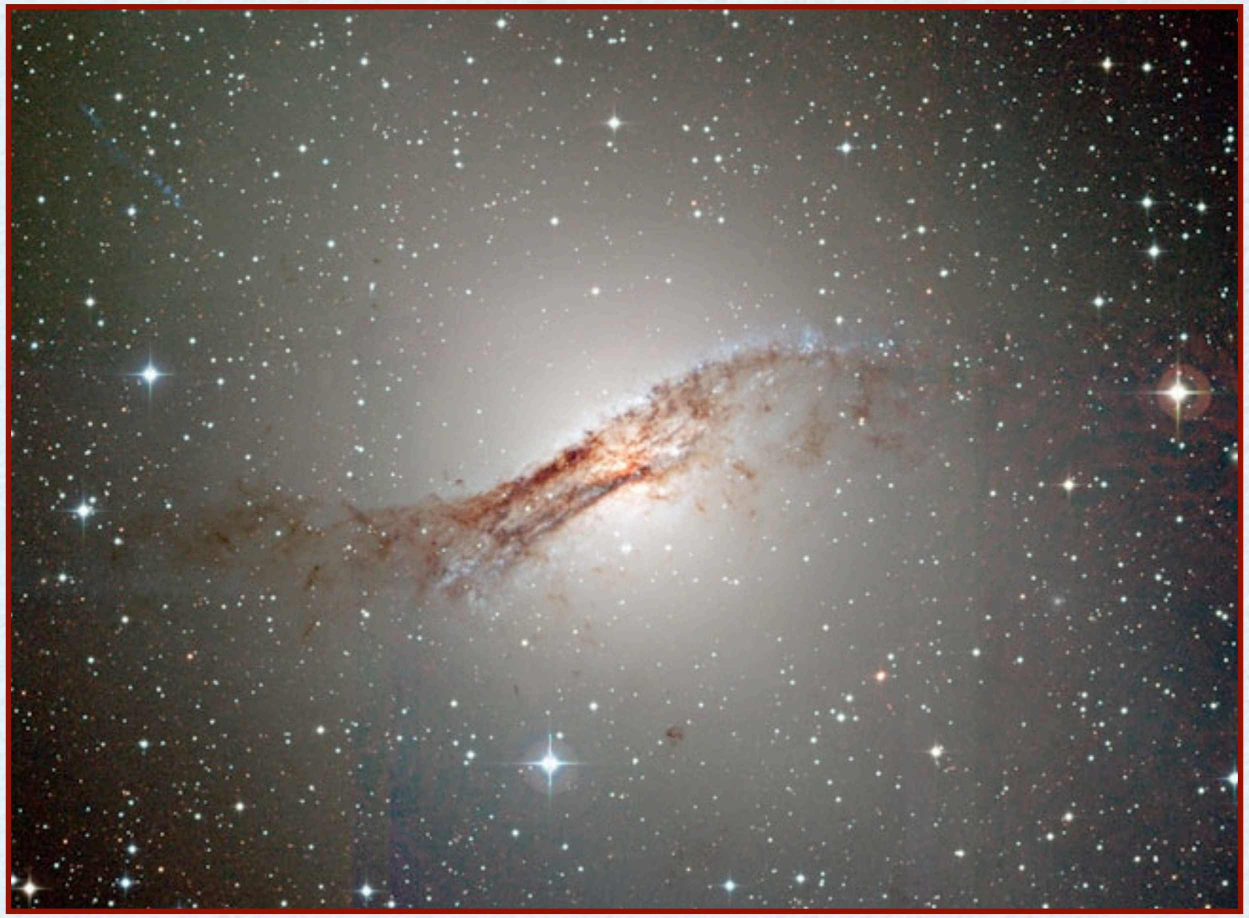
J. Marvil (NMT/NRAO); S. Neff (GSFC); F. Owen (NRAO)

(note: they did the heavy lifting)

Compare M82 to Cen A: the galaxies

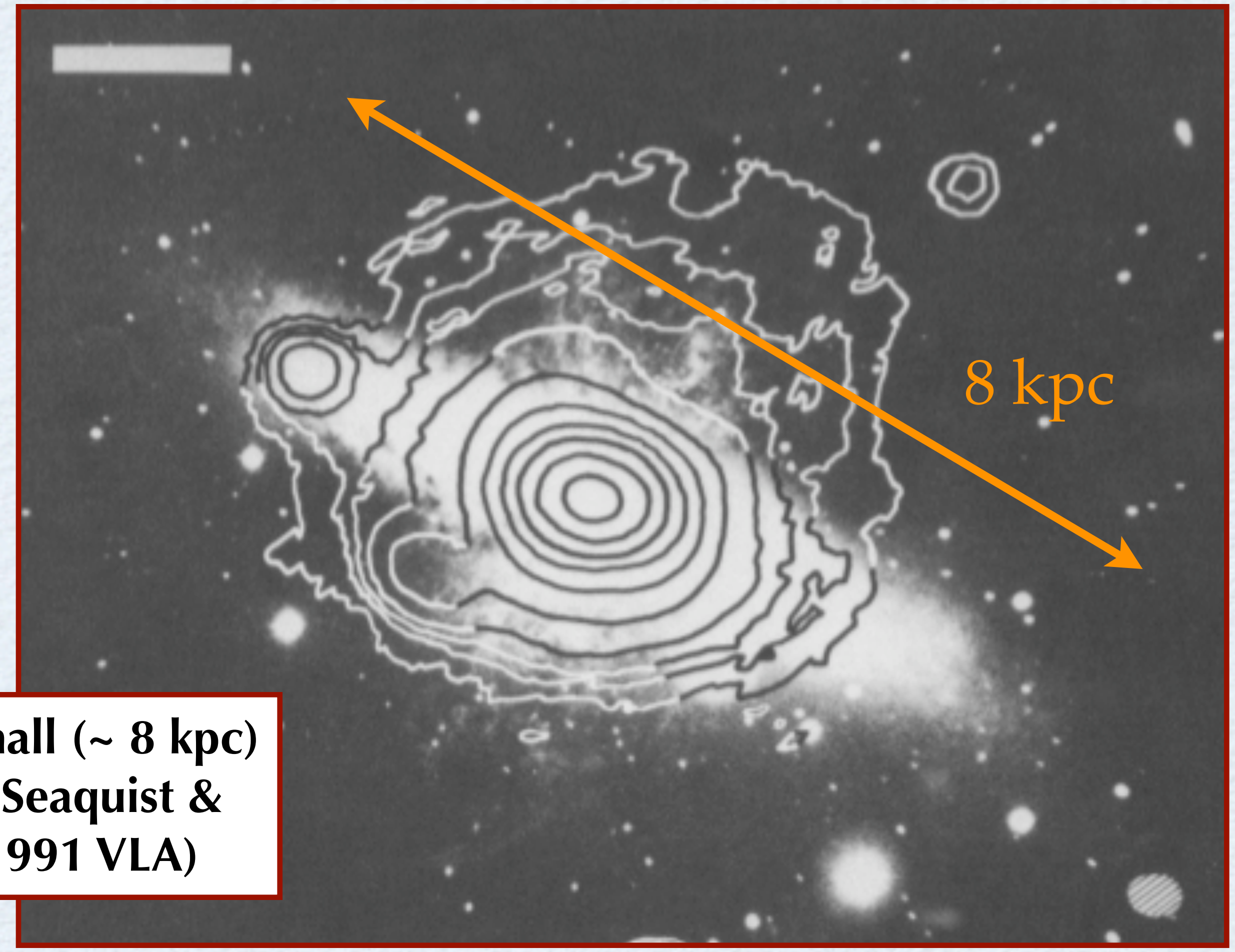


Small disk/irregular galaxy, ~4 kpc radius
Rotation supported
Dynamical mass ~ 1E10 suns
Middle-aged stars (0.5-1 Gyr old)
Dust dominates optical image



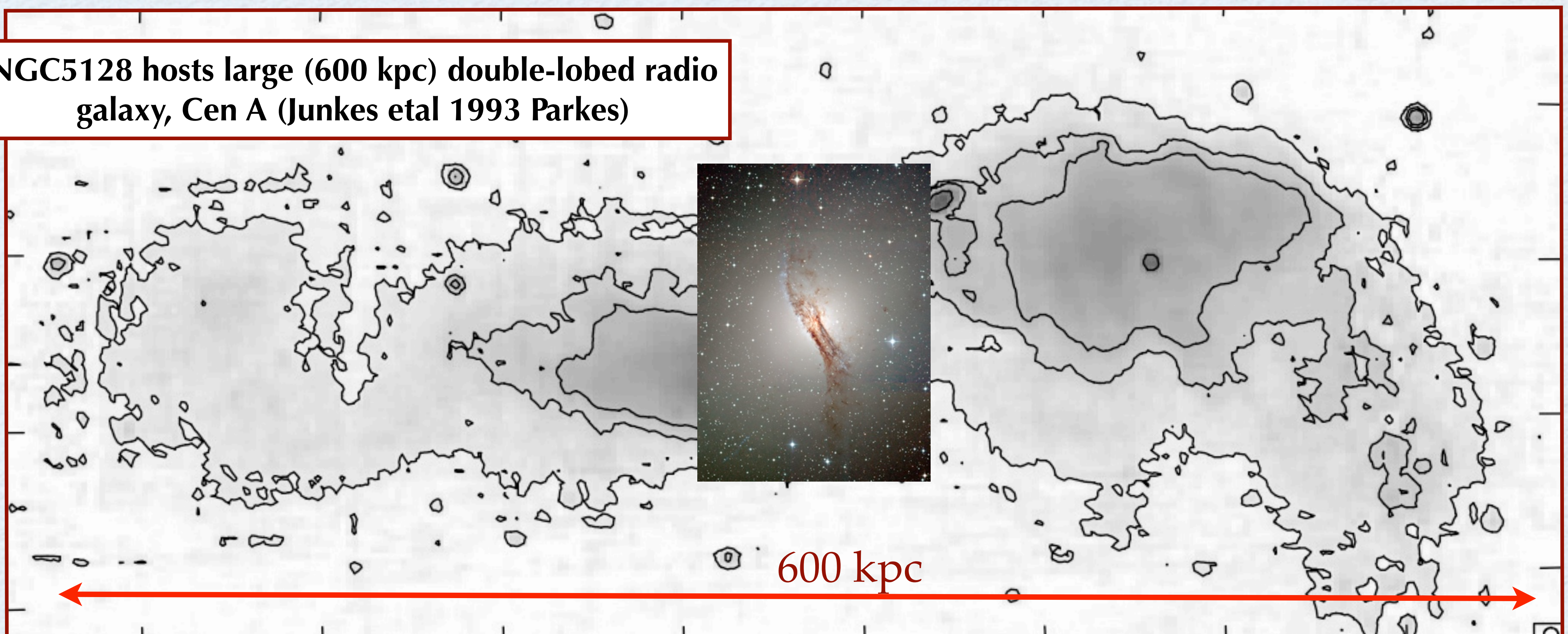
Large elliptical galaxy, ~ 30-40 kpc radius
Heat (random stellar motions) supported
Dynamical mass ~ 6-10E11 suns
Old stellar population (several Gyr)
Iconic central dust lane

Compare M82 to Cen A: the radio structures

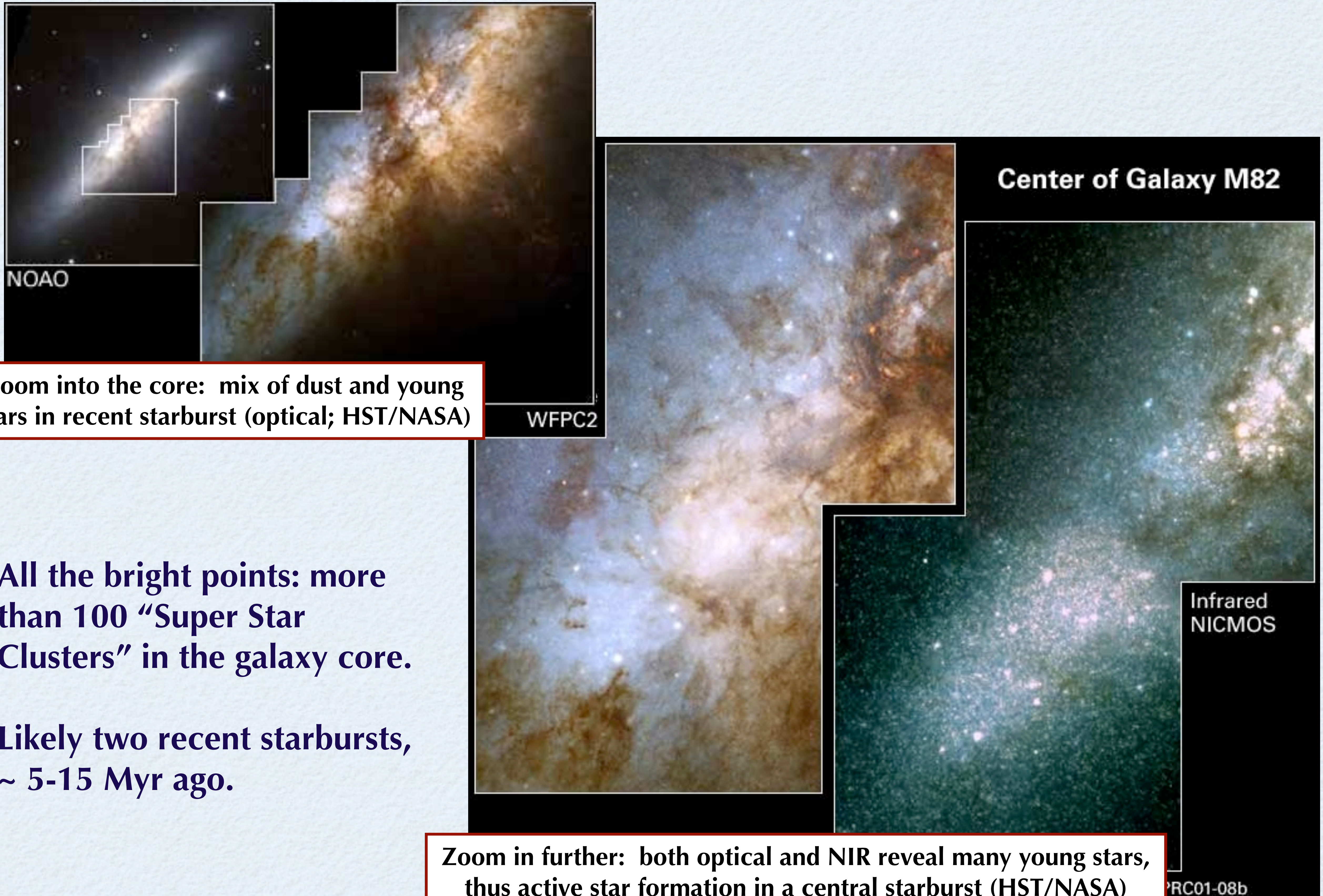


M82 hosts small (~ 8 kpc) radio halo (Seaquist & Odegard 1991 VLA)

NGC5128 hosts large (600 kpc) double-lobed radio galaxy, Cen A (Junkes etal 1993 Parkes)



M82: strong central starburst in optical/NIR



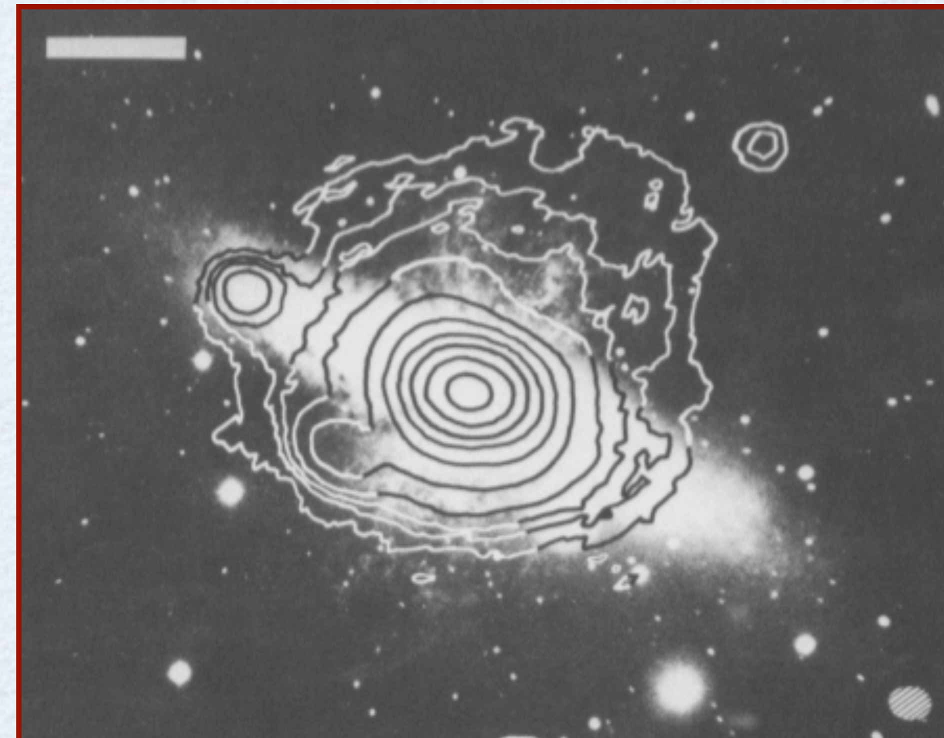
Zoom into the core: mix of dust and young stars in recent starburst (optical; HST/NASA)

Zoom in further: both optical and NIR reveal many young stars, thus active star formation in a central starburst (HST/NASA)

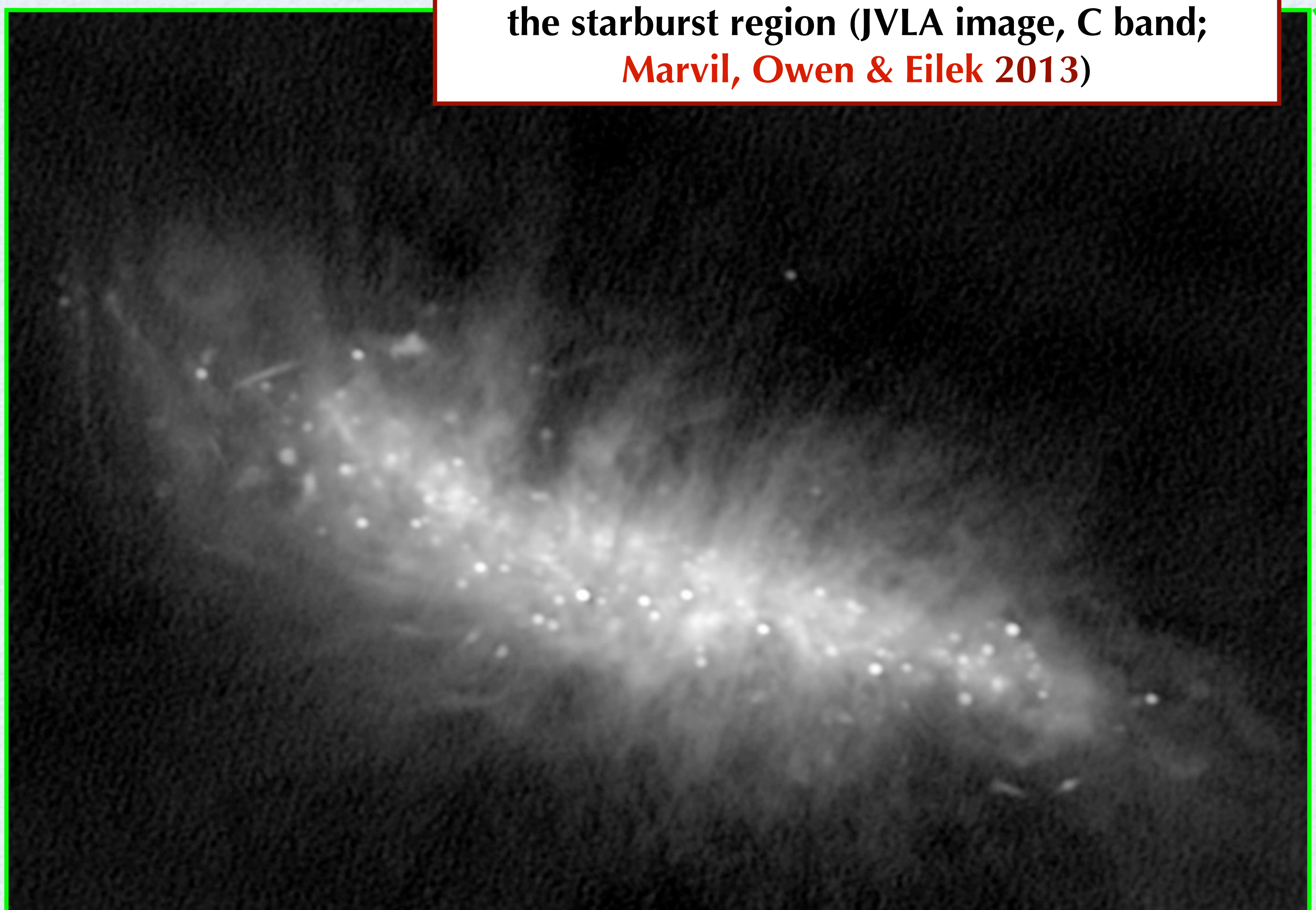
All the bright points: more than 100 “Super Star Clusters” in the galaxy core.

Likely two recent starbursts, ~ 5-15 Myr ago.

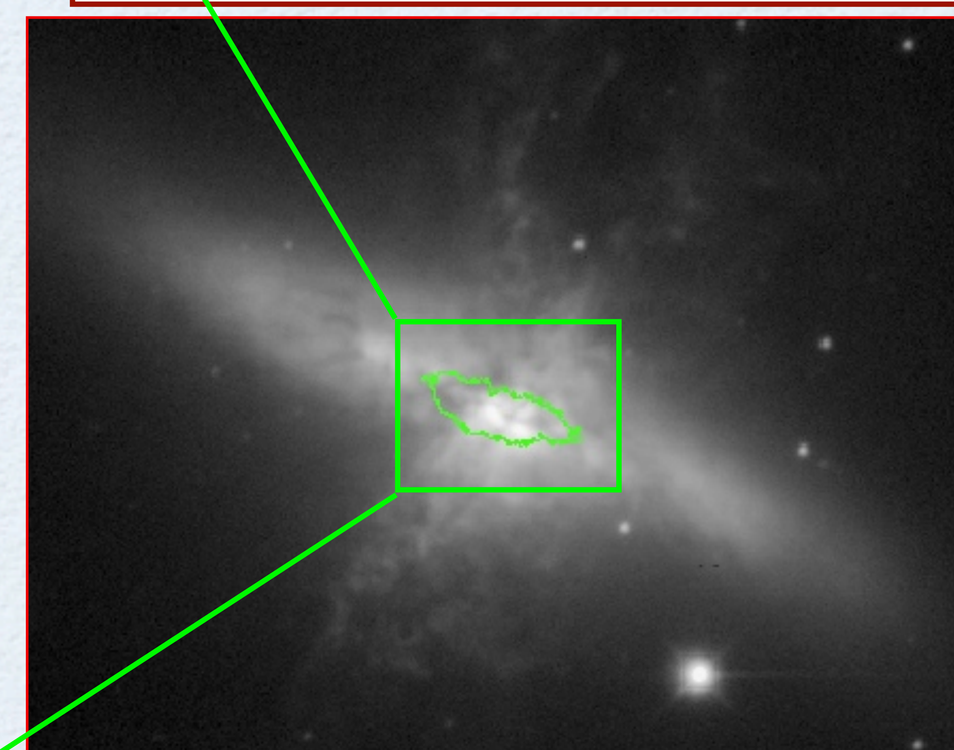
The M82 starburst in radio: SNRs, HII regions and a wind



Zoom into the starburst core: NEW radio image reveals many point sources (SNRs, HII regions) associated with young stars, and a diffuse, filamented structure hinting at an outflow from the starburst region (JVLA image, C band; Marvil, Owen & Eilek 2013)

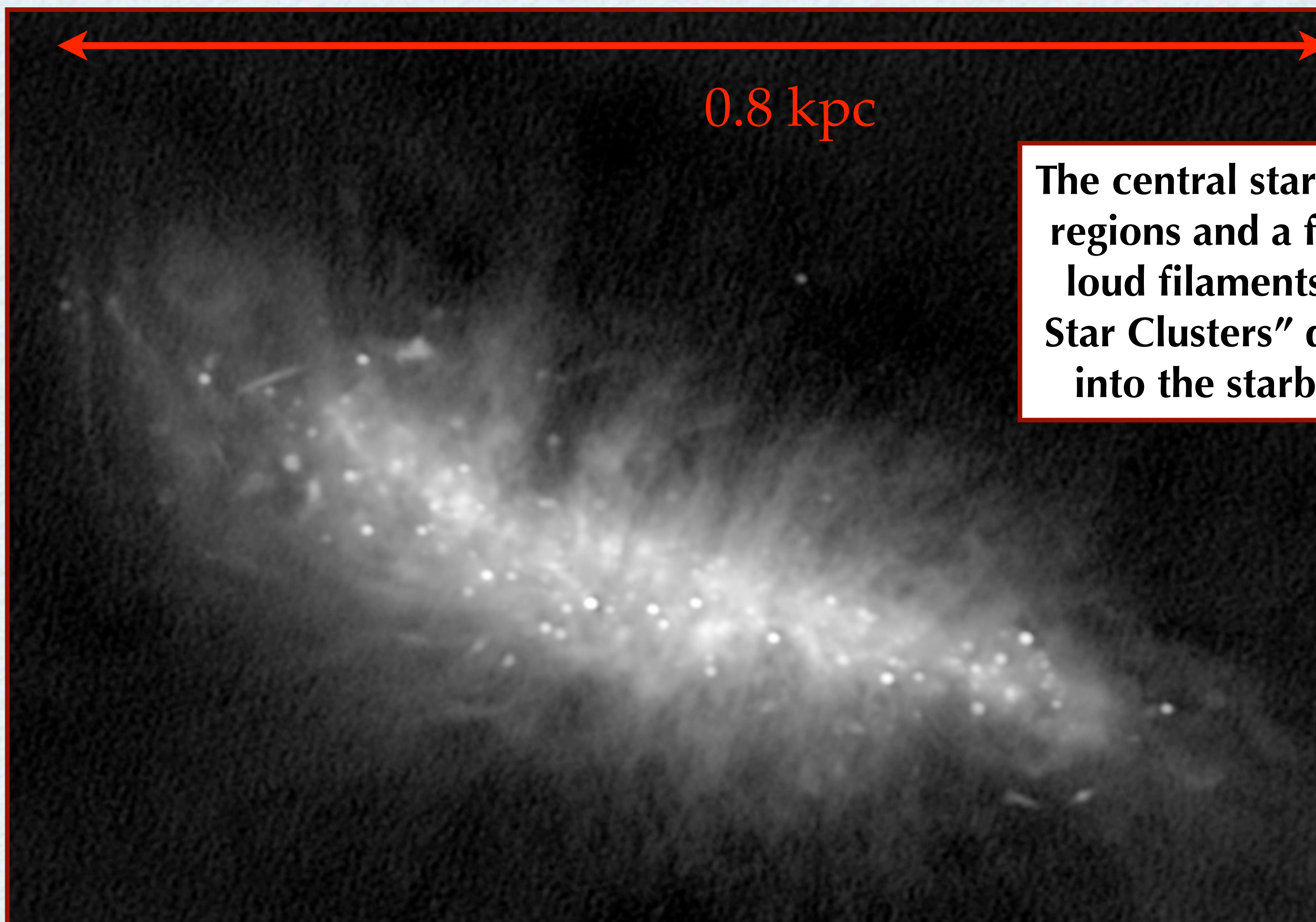


Above: large-scale radio “halo” (Seaquist & Odegard 1991).
Below: green outlines central starburst (Marvil 2012);
both on optical DSS image of galaxy



How do we measure a starburst?

- Proxy 1: FIR flux -- tracks hidden star formation (dust enshrouding SB, reradiates starlight); strong in M82
- Proxy 2: FUV flux -- tracks naked star formation (seeing young massive stars directly); weak in M82
- Collect all: star formation rate ~ 7 suns/year in M82



The central starburst core in radio: SNRs, HII regions and a filamented outflow. The radio-loud filaments show how individual “Super Star Clusters” drive out plasma which merges into the starburst wind (Marvil etal 2013)

The outflow: why do starbursts make winds?

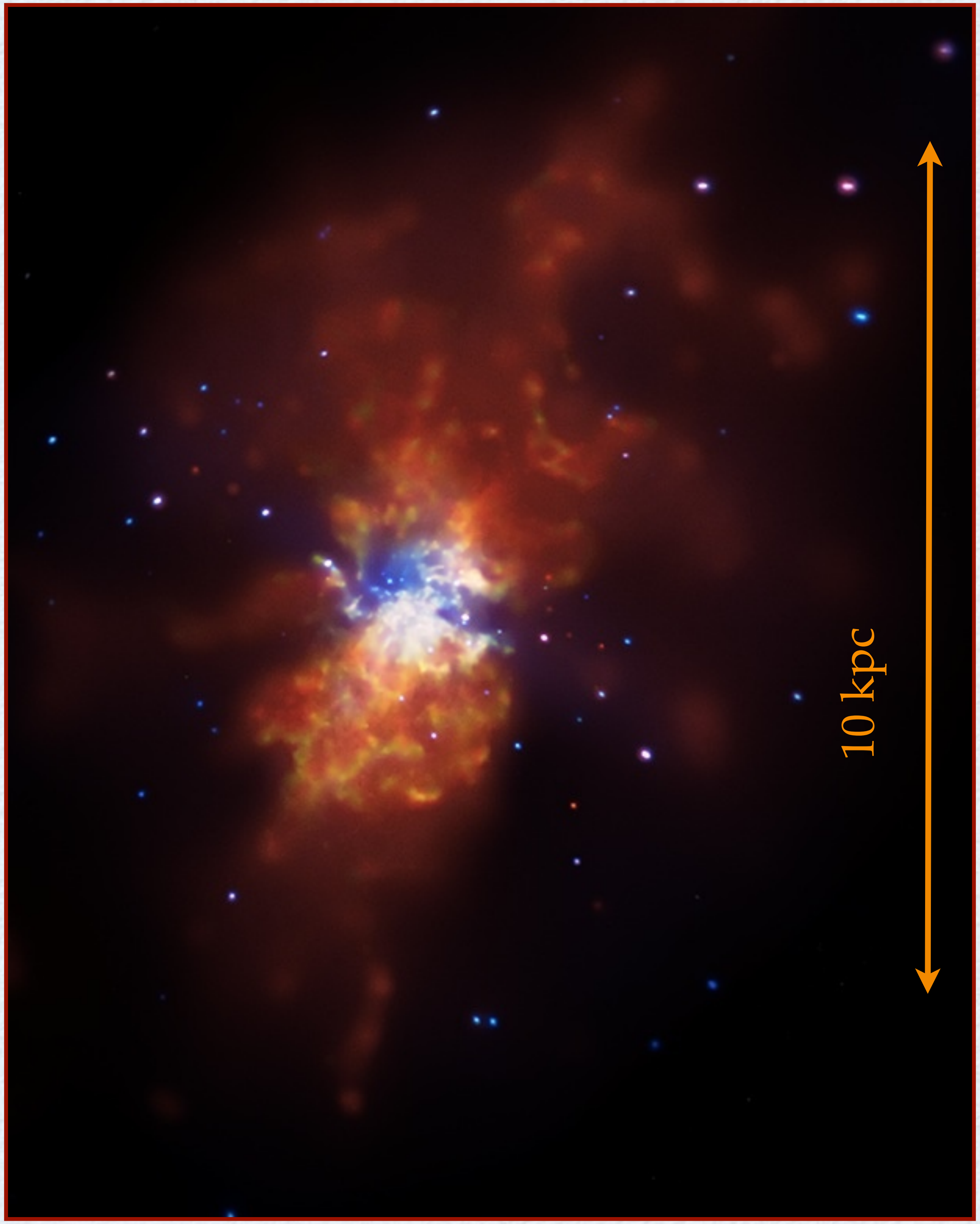
- SNe and stellar winds : heat ISM to kT ~ keV
- Hot enough to beat galactic escape velocity ==> starburst
- Energetics: models give wind power ~ few E 42 erg/s for M82

Seeing the M82 wind: plumes of H alpha emission, probably from shock-heated clouds. (NASA/HST; Gallagher etal).

Note: wind itself is faster. H alpha clouds are slower-moving tracers, cold gas dragged out by the hot wind flow.

The wind in M82: X-rays

Must go to X-rays to see the wind itself: hot (~keV), fast (> 1000 km/s) plasma, driven out from the starburst core.



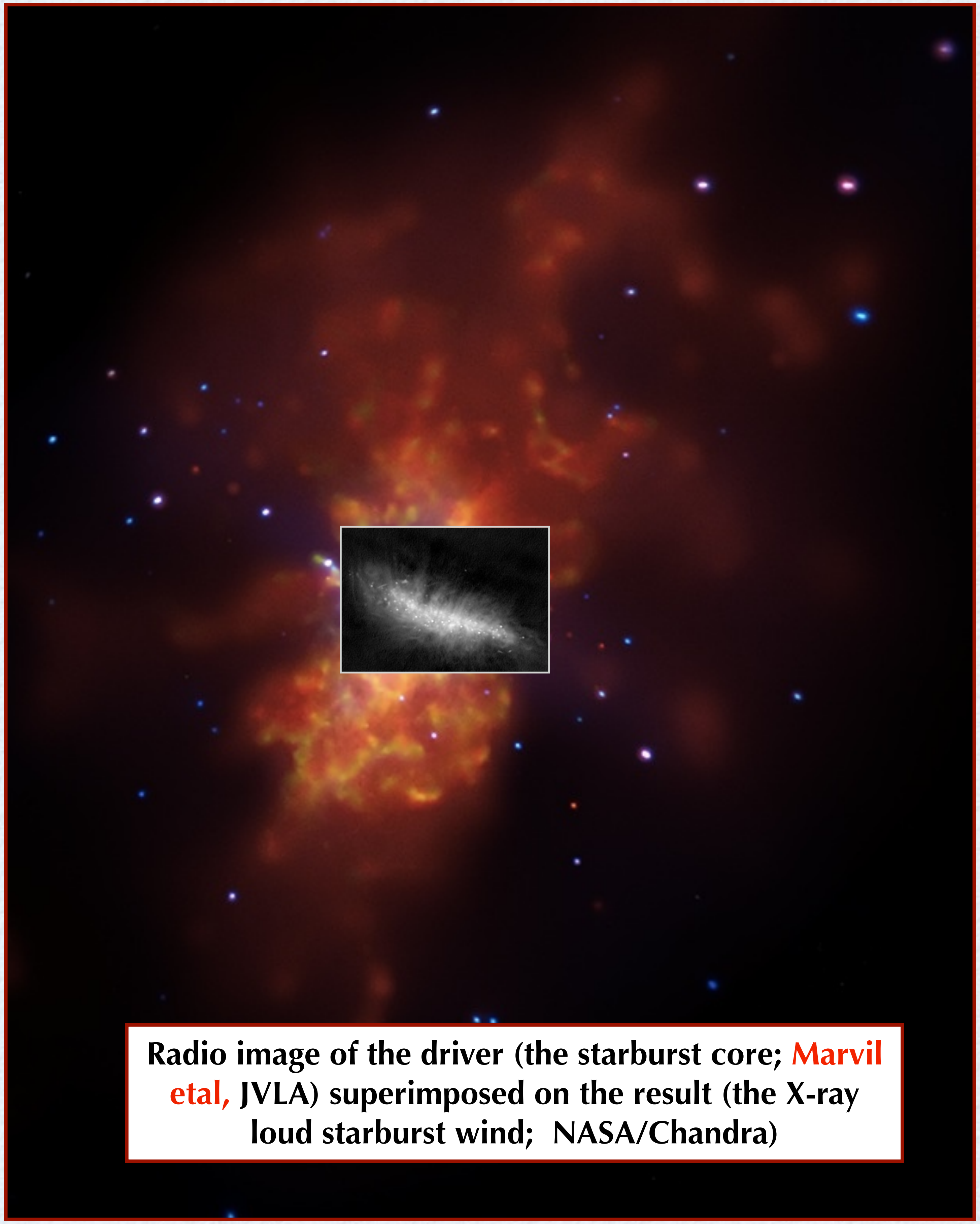
Chandra X-ray image. Hard X-rays (blue) show very hot plasma and compact objects (X-ray binaries? black holes?) in the starburst. Softer X-rays (red) show the starburst wind (NASA; Feng etal, Strickland etal)

Summary of M82:

Strong starburst in the core (~7 suns/year) is the poster child of starbursts;

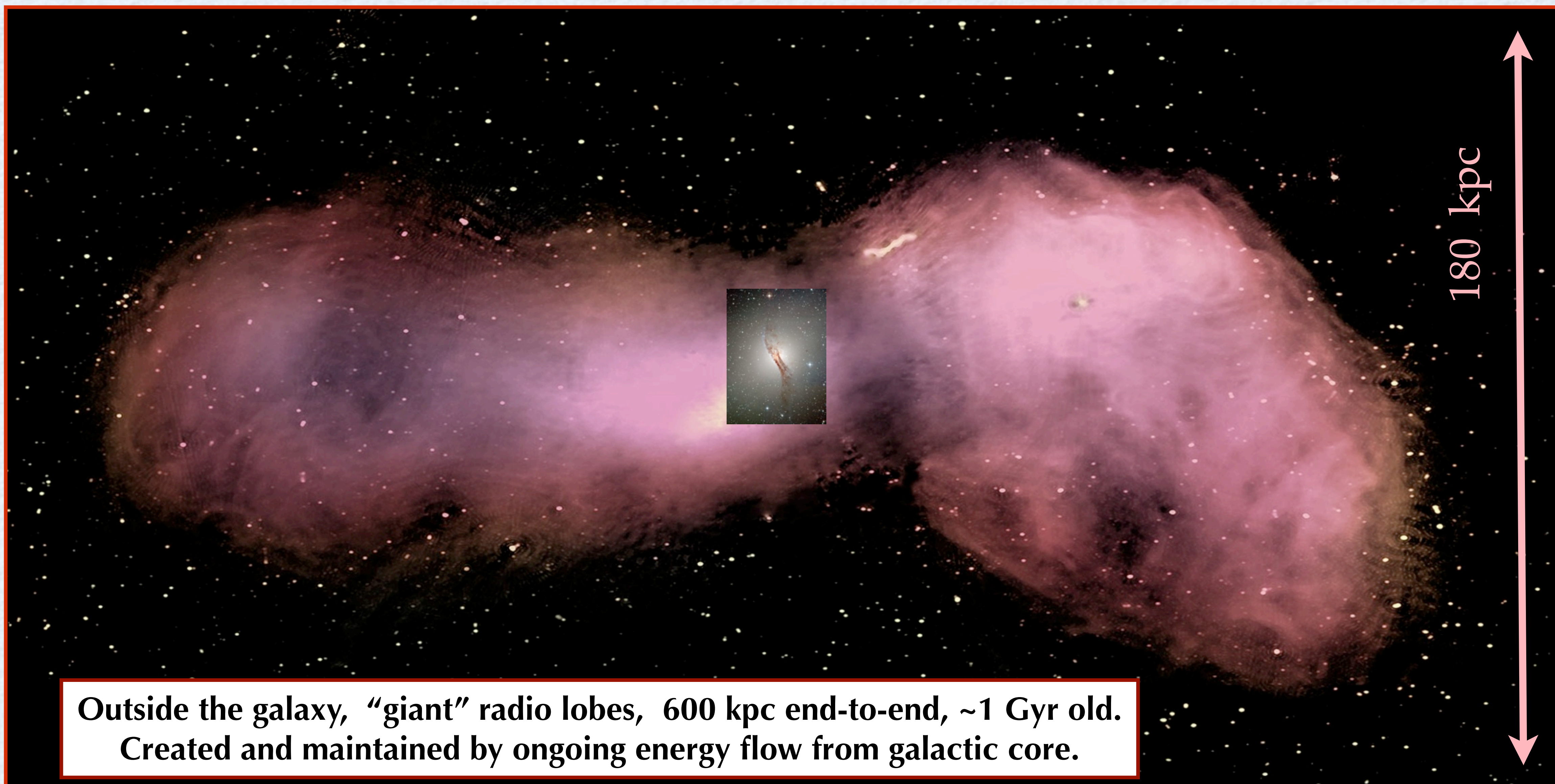
it drives out powerful, photogenic wind.

Now: what does this have to do with Cen A?



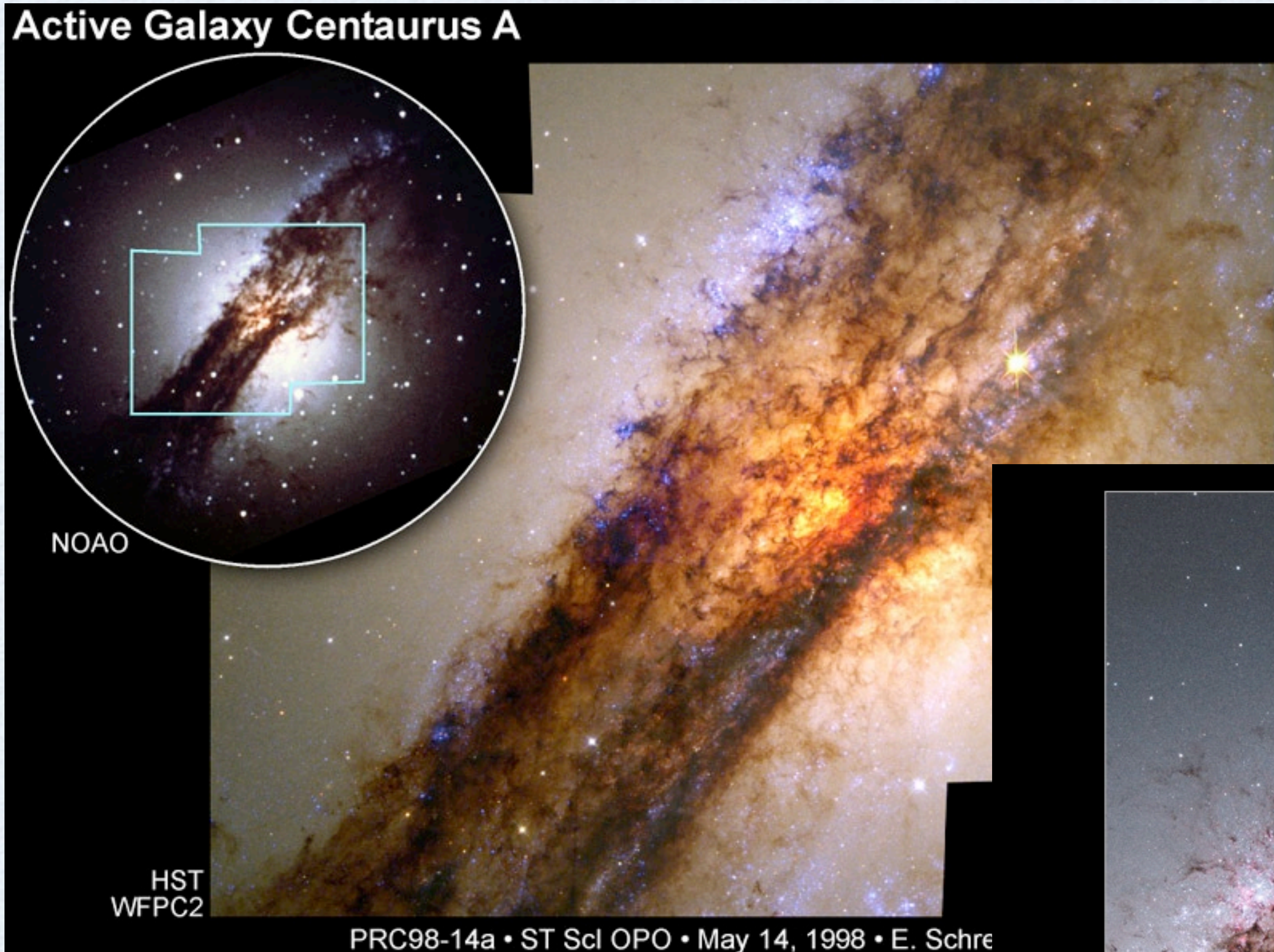
NGC5128 & CenA: dust lane + double radio lobes

Within the galaxy, a complex system: Optical image of dust disk; APEX image (340 GHz) of young radio jets (~2 Myr old); Chandra X-ray image of disturbed galactic ISM (NASA/ESO; Weiss etal 2008)



Outside the galaxy, "giant" radio lobes, 600 kpc end-to-end, ~1 Gyr old. Created and maintained by ongoing energy flow from galactic core.

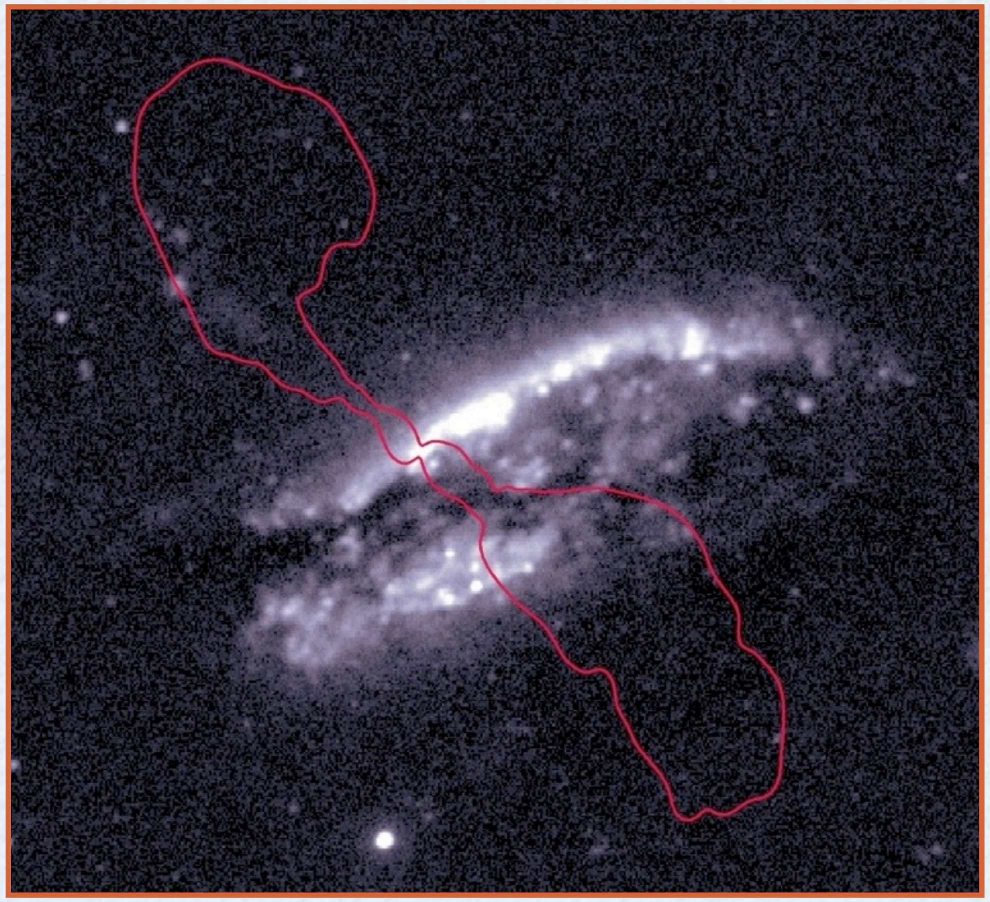
NGC5128 : young stars in the dust lane



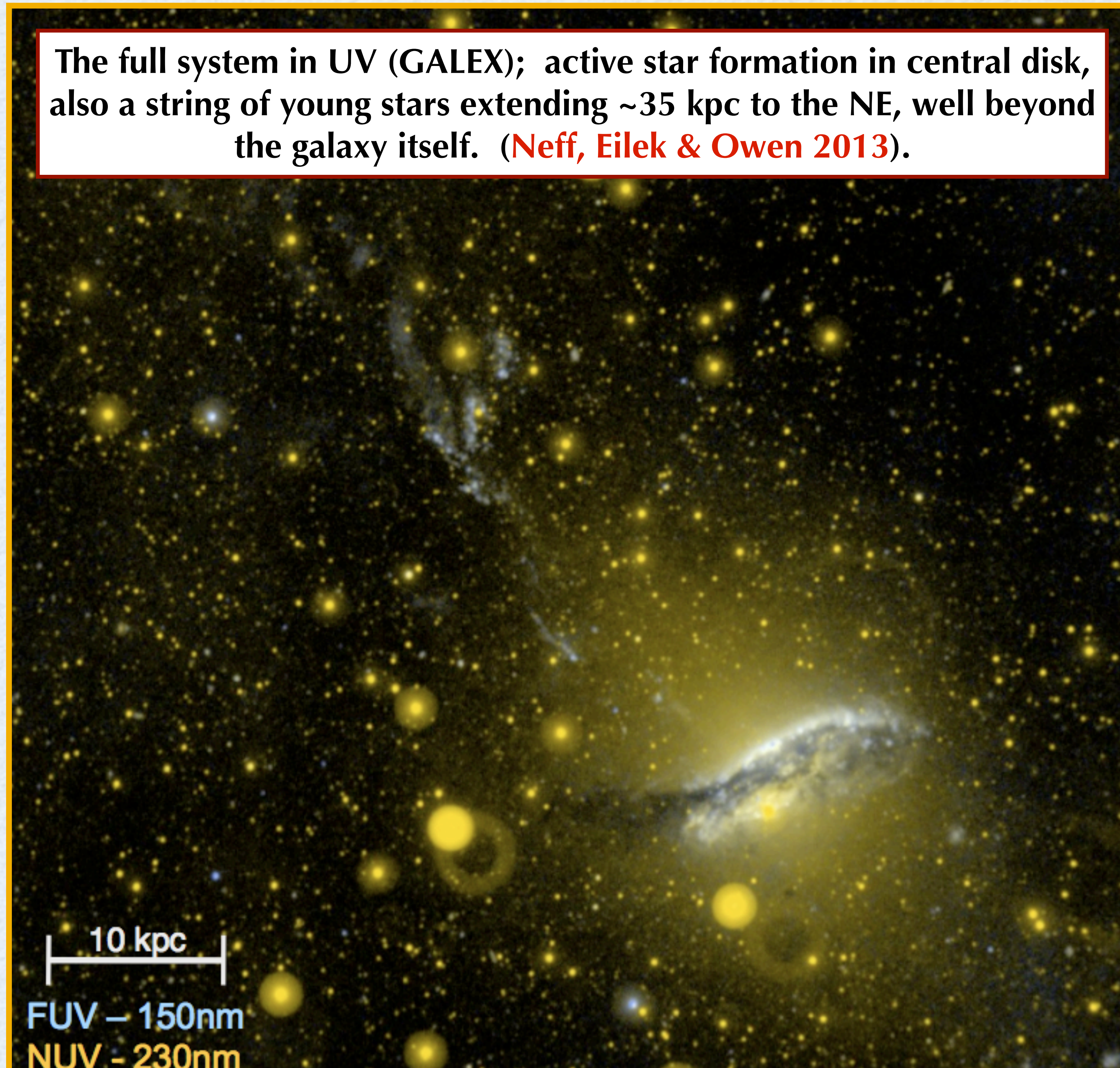
Optical work suggests a "firestorm" of recent star formation: young stars(age only 10-30 Myr) exist in the central dust lane.

Zoom into central few kpc: complex mix of dust and young stars (NASA/HST; Schreier etal, O'Connell et al)

NGC5128: FUV reveals the extent of the central starburst



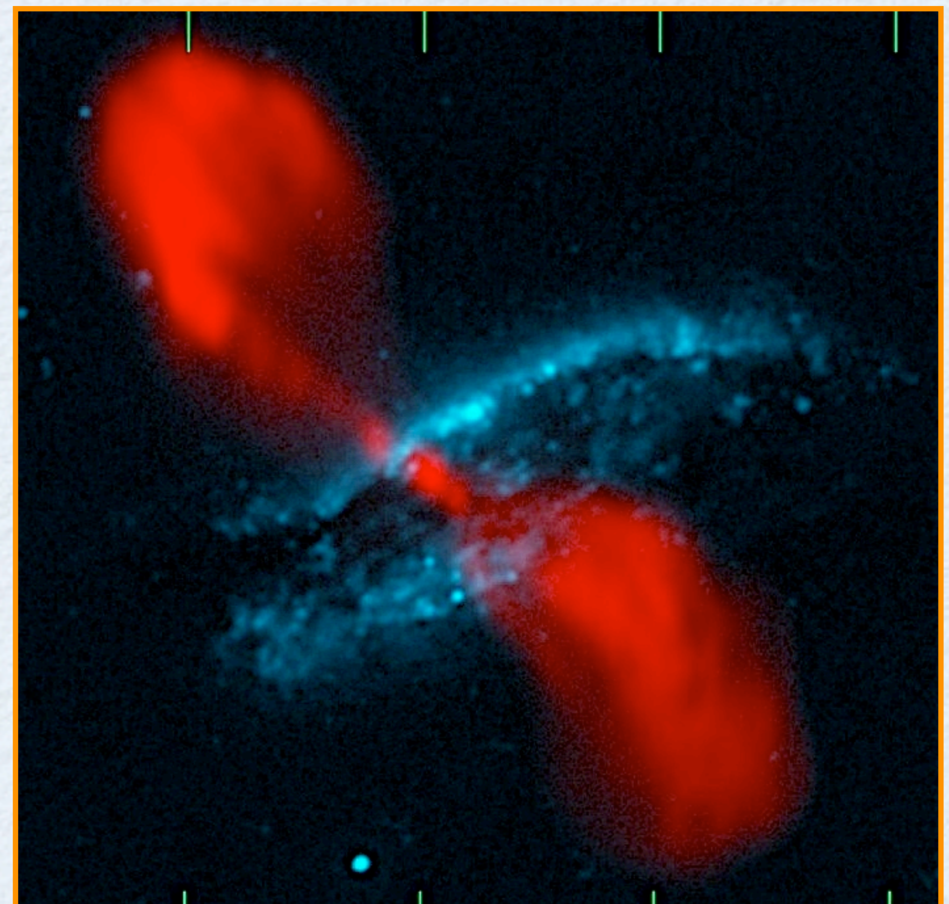
The complex inner galaxy. FUV (white; GALEX) shows extended disk of young, hot stars; radio (VLA, red) outlines inner radio lobes (Neff, Eilek & Owen 2013)



The full system in UV (GALEX); active star formation in central disk, also a string of young stars extending ~35 kpc to the NE, well beyond the galaxy itself. (Neff, Eilek & Owen 2013).

Measuring the starburst in Cen A

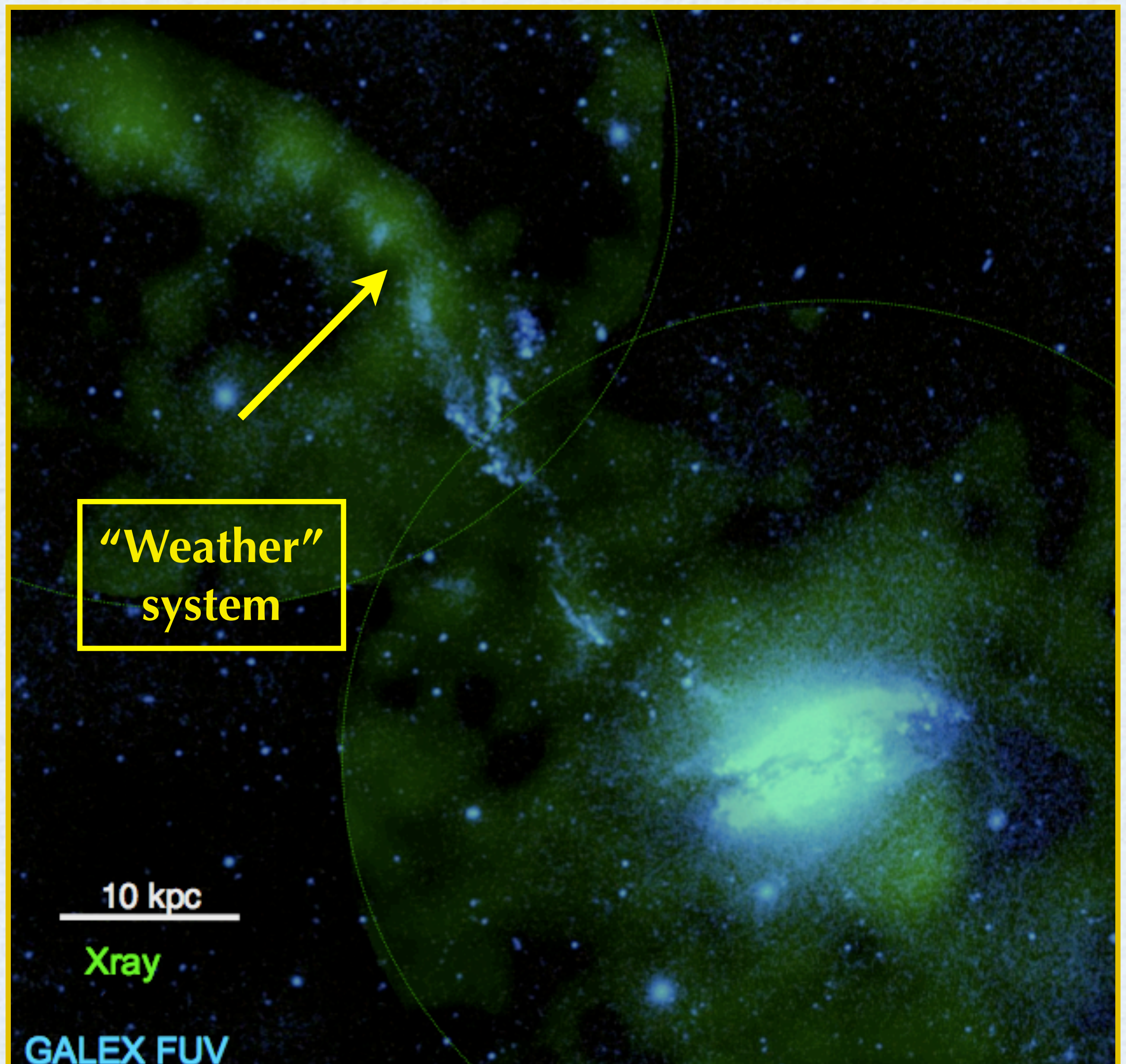
- Use same proxys: FIR and FUV luminosity;
  FIR weaker but FUV strong in NGC5128.
- Collect all: star formation rate ~ 7 suns/year;
  Comparable in size and age to starburst in M82.



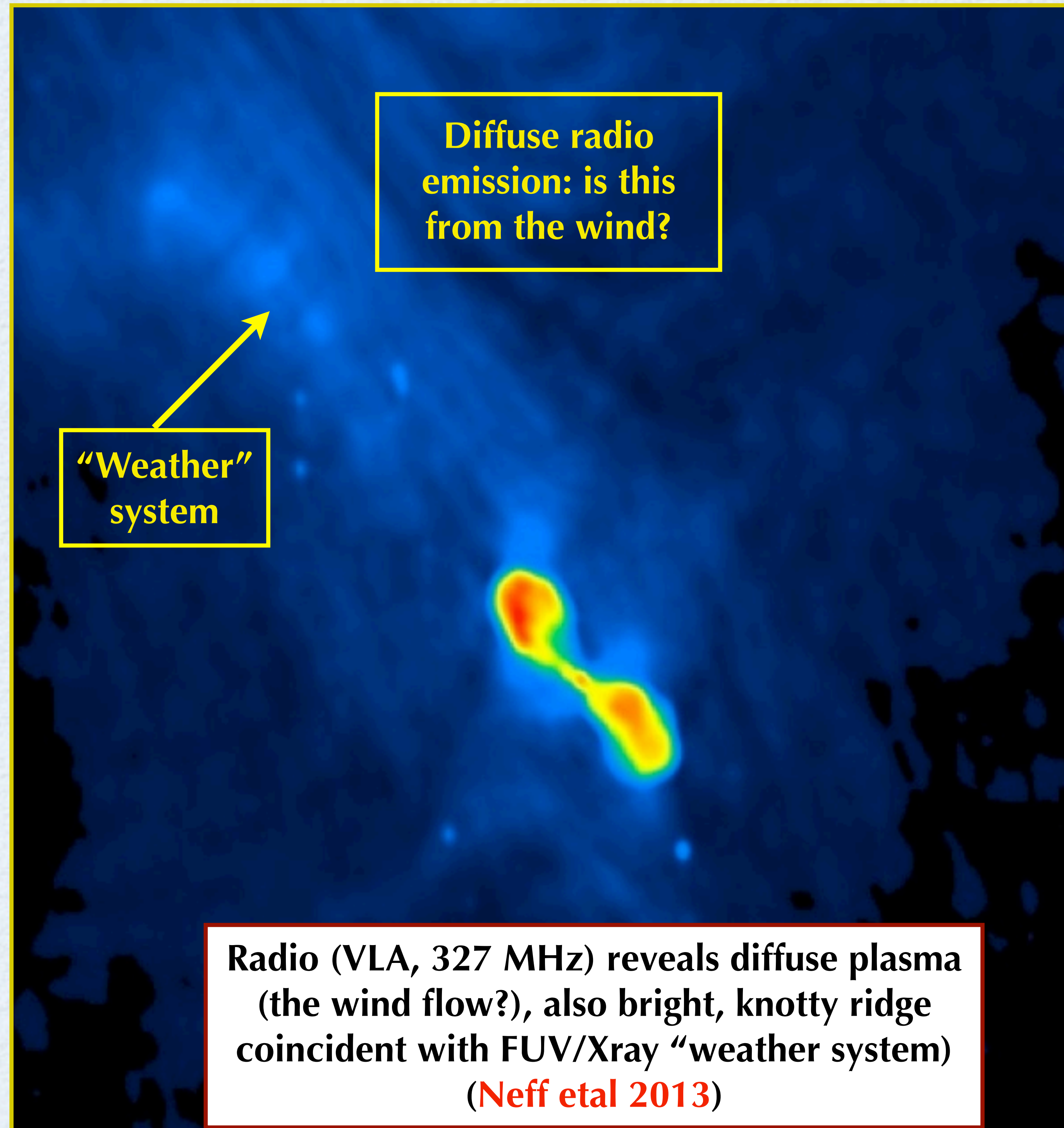
Left, GALEX NUV/FUV image of NGC5128, showing diffuse light from galaxy and bright FUV from very young stars in starburst disk. Right, two powerhouses in this galaxy: disk starburst (GALEX/FUV) and radio jets from the AGN (VLA/327 MHz). Neff etal 2013.

Where’s the wind from the Cen A starburst?

Two possible signs: diffuse radio emission north of the AGN, and the complex, star-forming ridge (“weather system”) which sits to the NE of the galaxy



Hot, diffuse ISM (CHANDRA, Kraft et al 2009) is enhanced around the bright FUV ridge (Neff etal 2013)



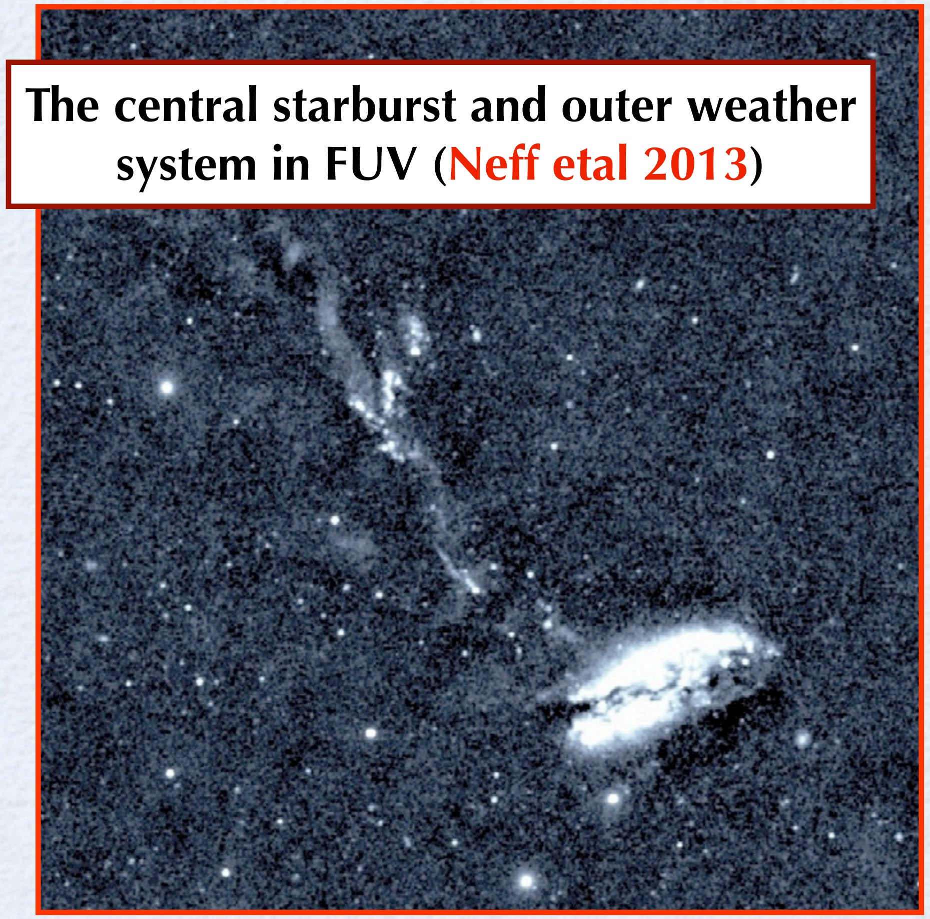
Radio (VLA, 327 MHz) reveals diffuse plasma (the wind flow?), also bright, knotty ridge coincident with FUV/Xray “weather system) (Neff etal 2013)

Summary of CenA:

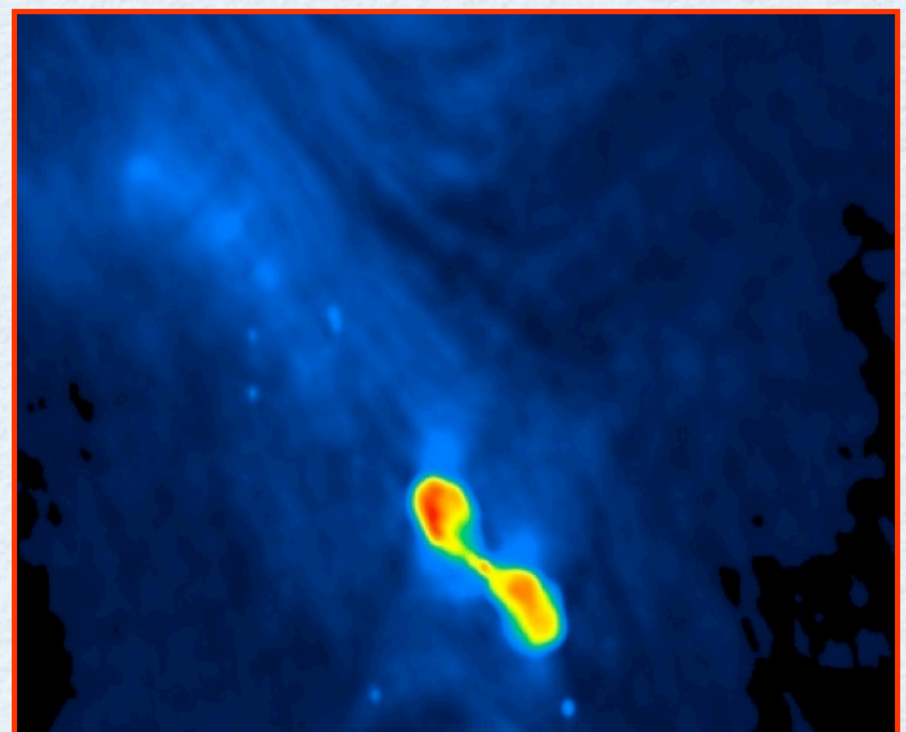
It also has a strong starburst in the central dust disk -- comparable to that in M82.

But: we see this wind only indirectly through its interaction with cold gas to the NE of the galaxy (left from previous merger?)

Thus: less of a poster child than M82.



The central starburst and outer weather system in FUV (Neff etal 2013)



The central radio double and diffuse radio emission which may be from the starburst wind (Neff etal 2013)

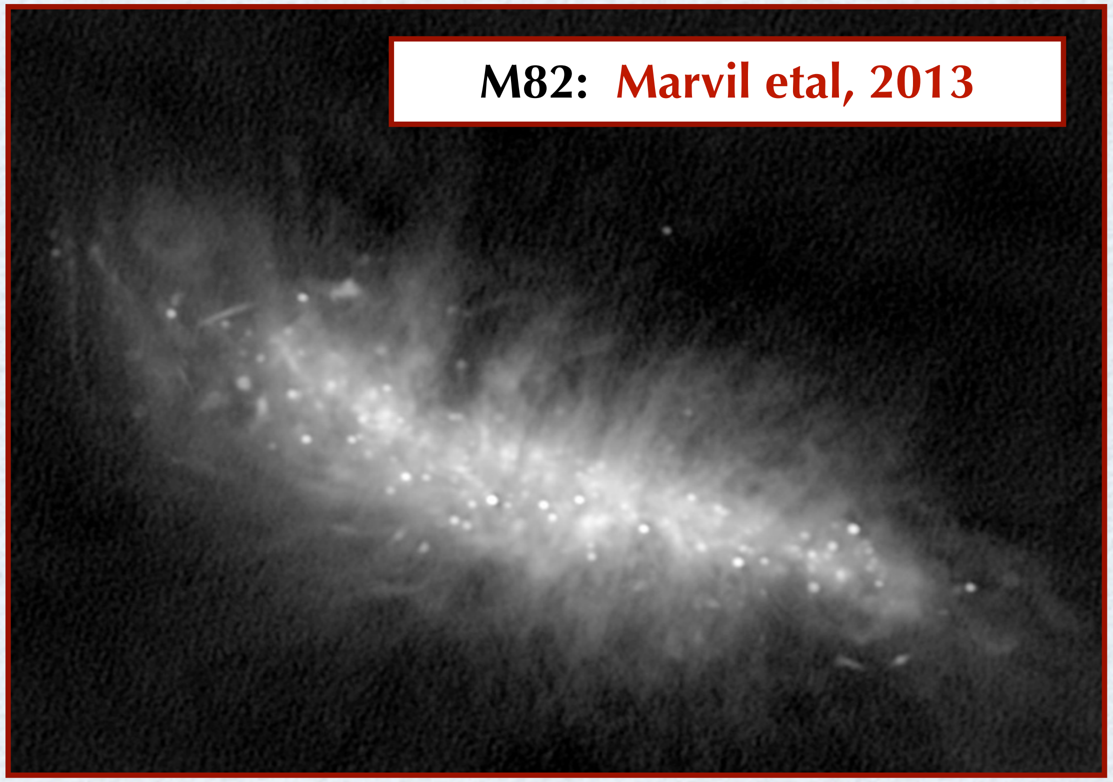
Bottom line:

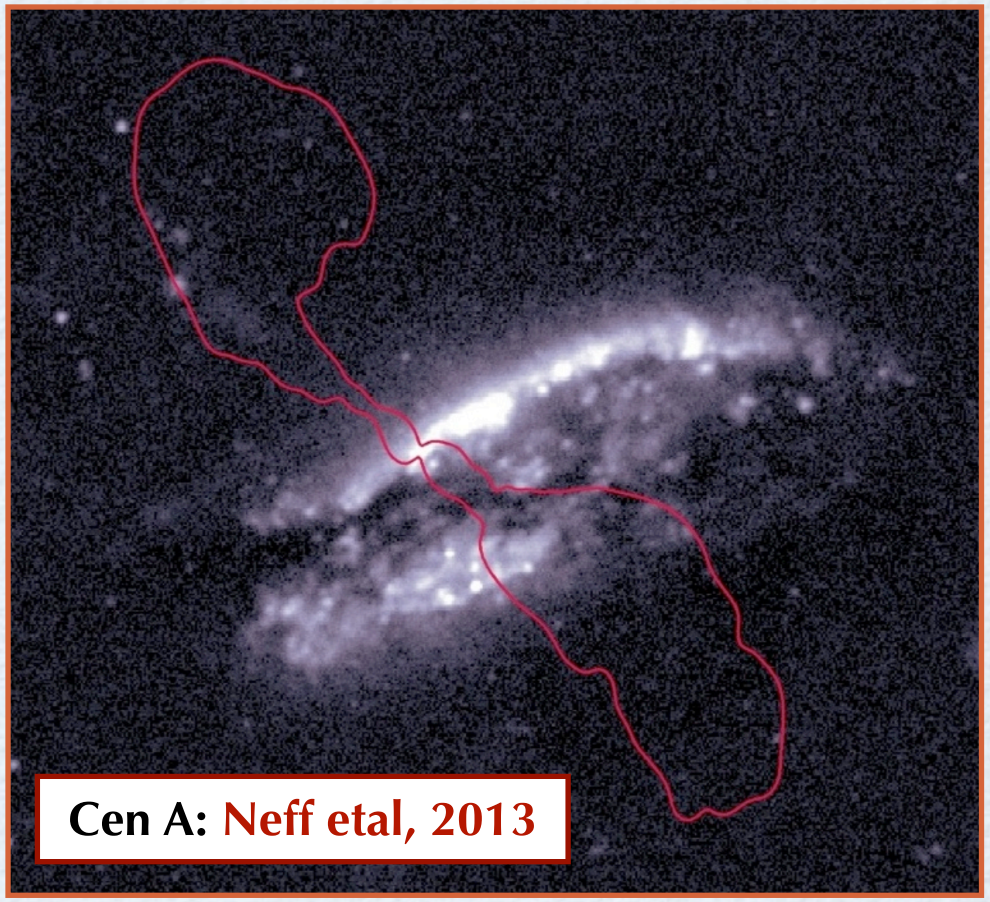
✦ M82 and Cen A have very similar central starbursts: young (10-30 Myr), strong (7 suns/yr).

✦Both should be driving out strong winds; but the wind is harder to see in Cen A.

✦Because of the different environments within the two galaxies?

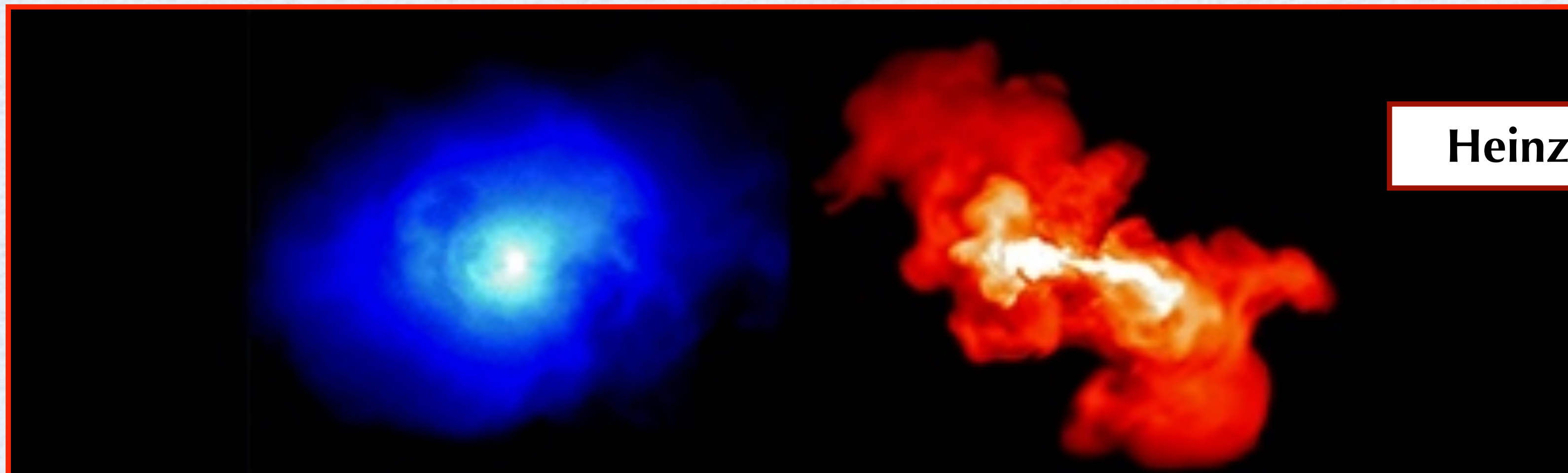
✦Because of the strong AGN in Cen A?



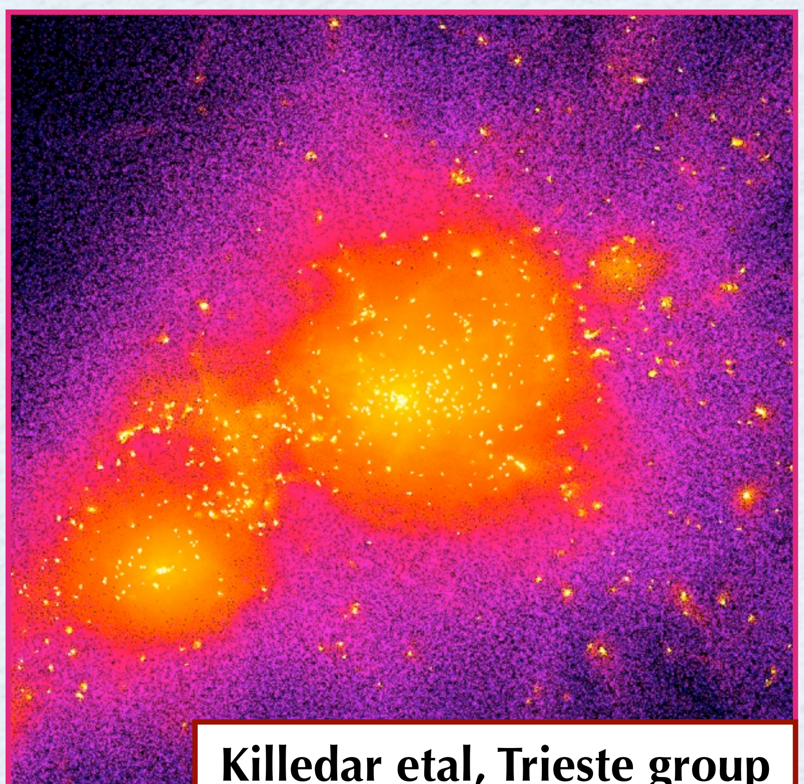


Post-bottom line:

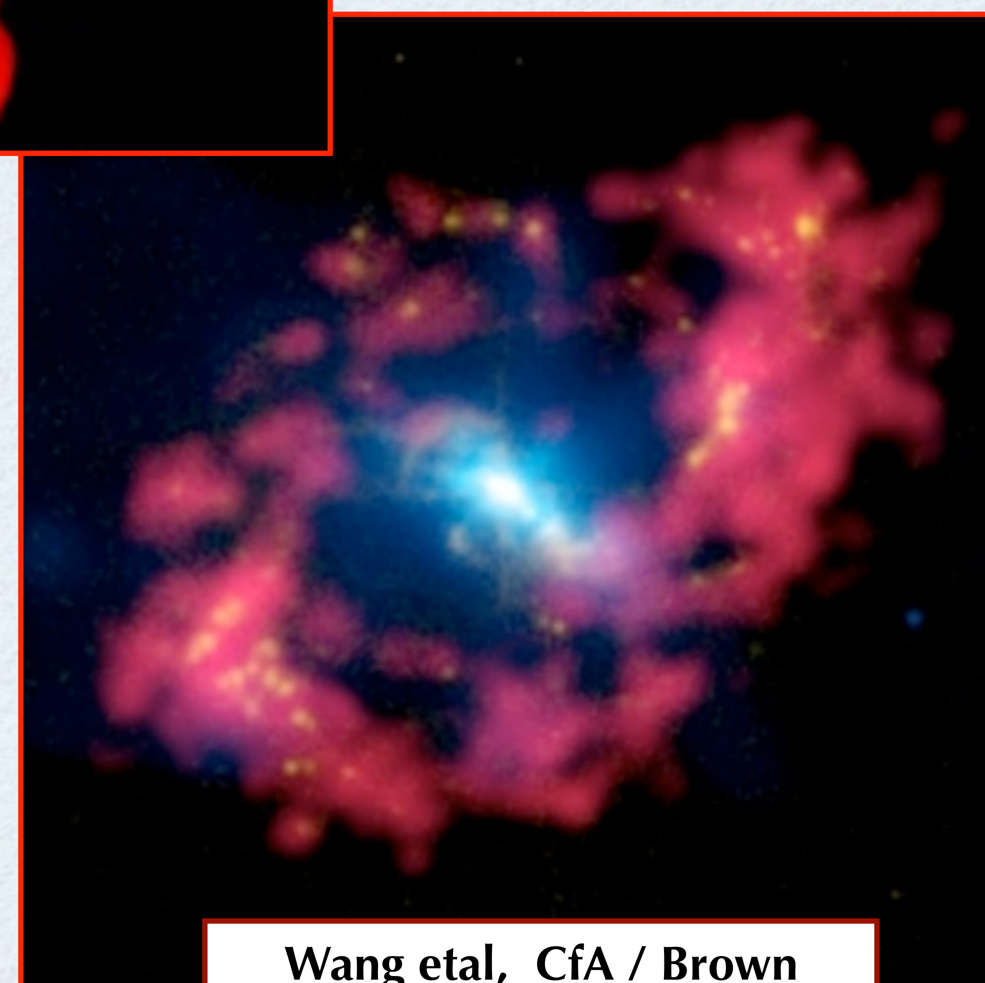
What does this say about "AGN regulating star formation?" Do AGN "always" shut off star formation? Is the current picture too simple? How does the AGN/galaxy ecosystem actually work?



Heinz etal, Madison group



Killedar etal, Trieste group



Wang etal, CfA / Brown