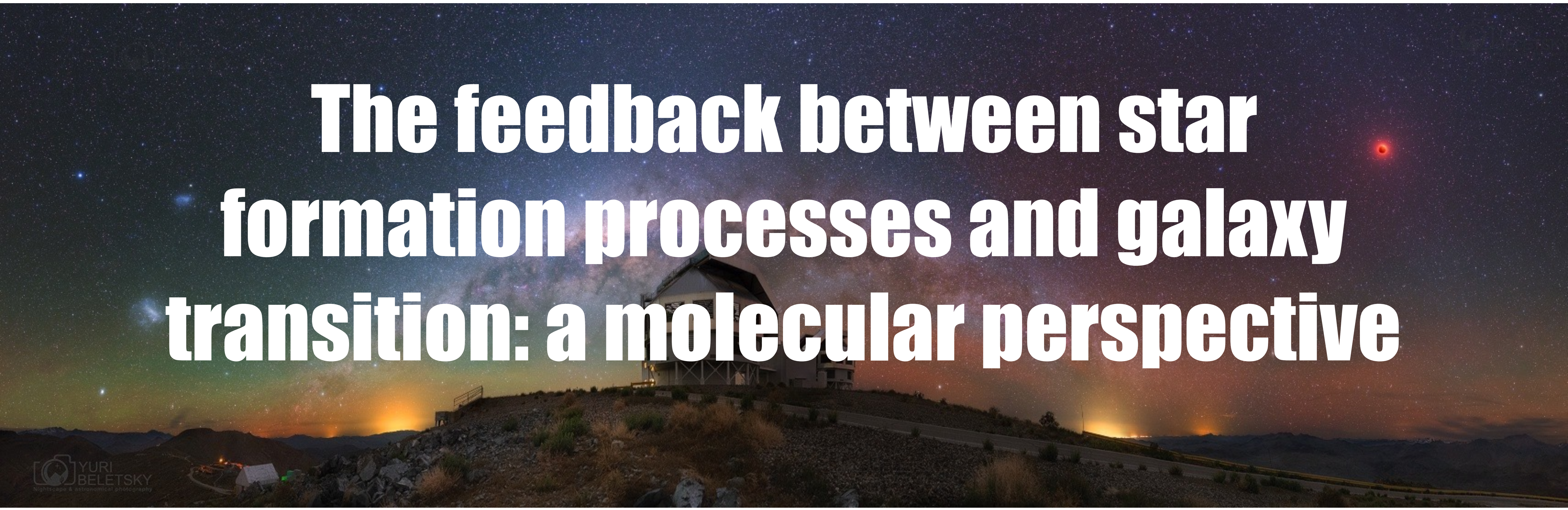
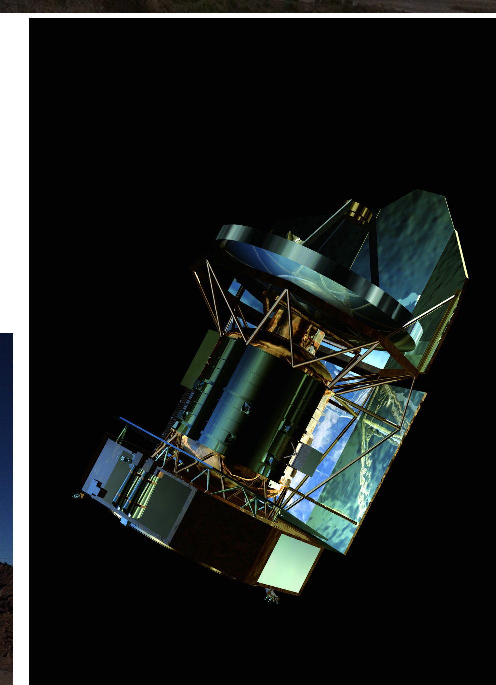
The feedback between star formation processes and galaxy transition: a molecular perspective



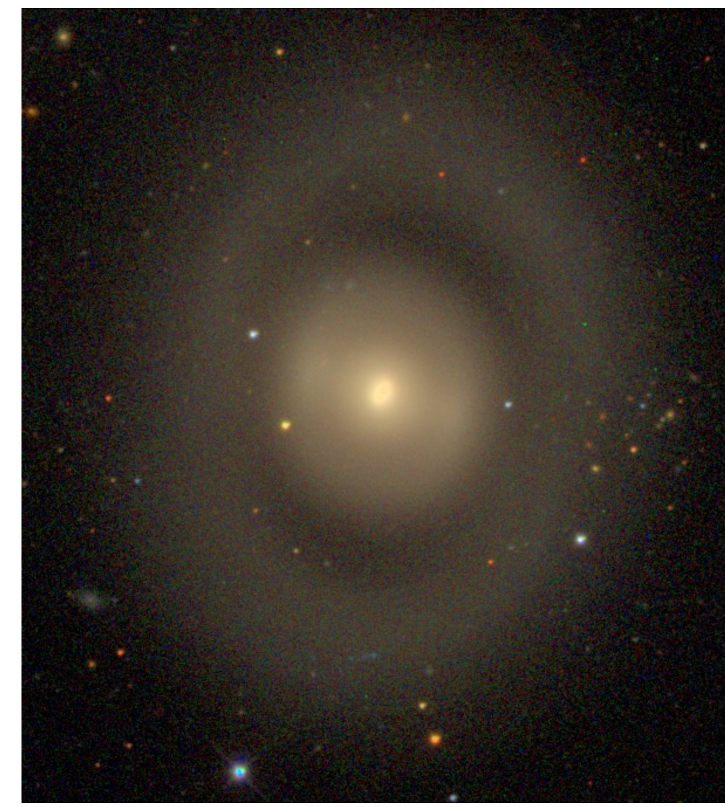
Katey Alatalo, Hubble Fellow
The Carnegie Observatories
kalatalo@carnegiescience.edu



Paths to transition

late-type

early-type



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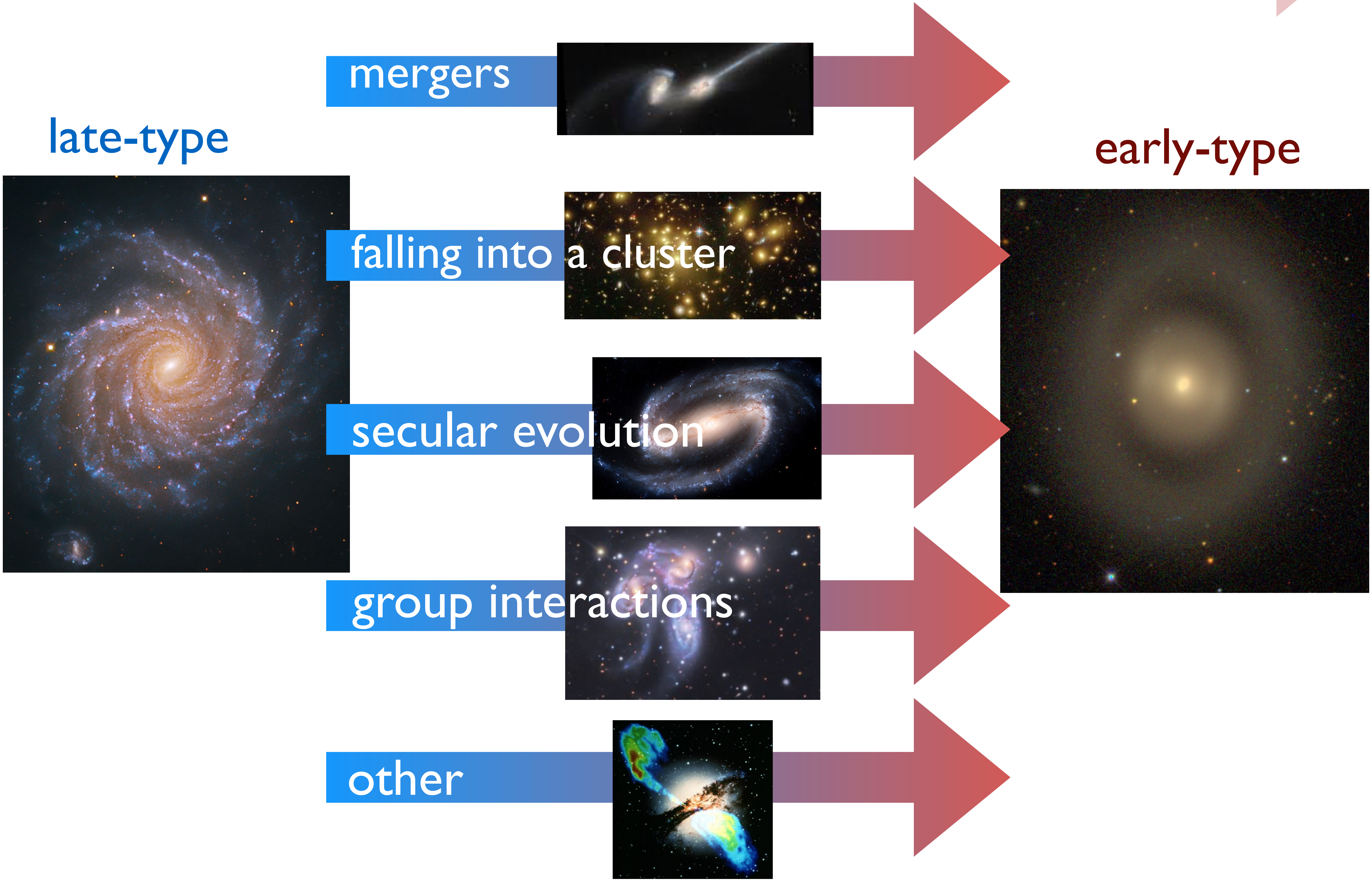
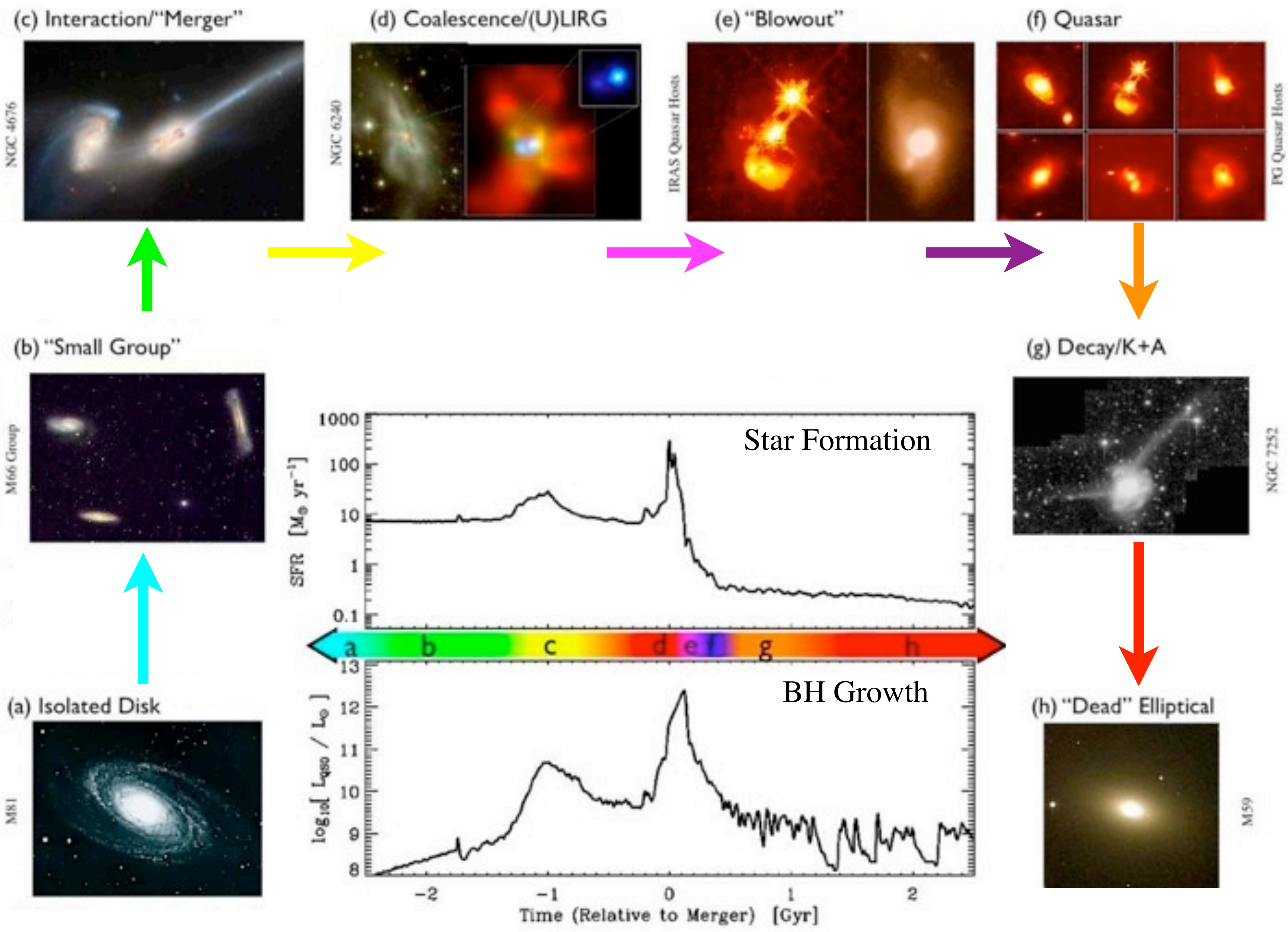


The "standard" pathway



Hopkins et al. 2008

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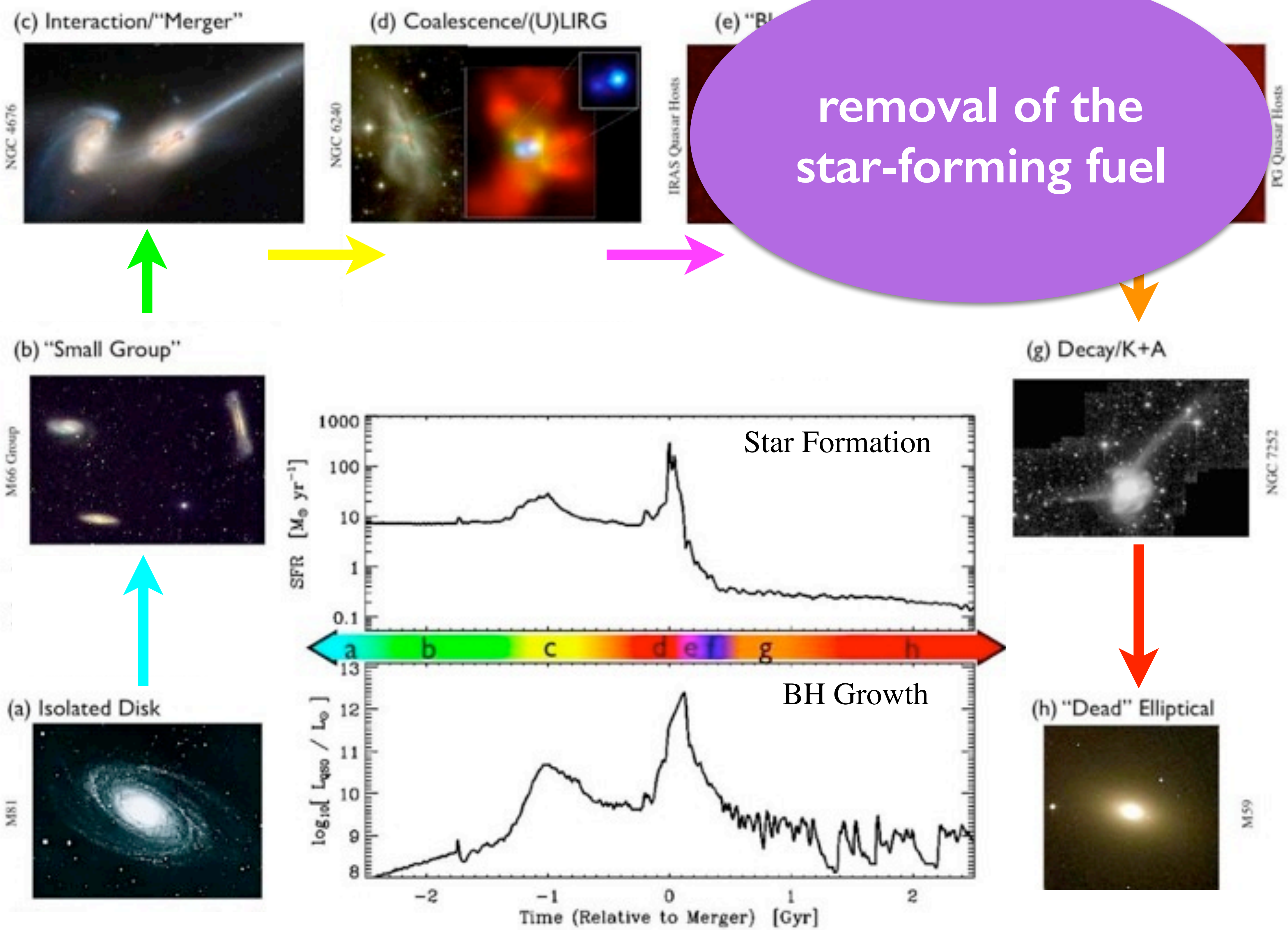


removal of the star-forming fuel

Hopkins et al. 2008

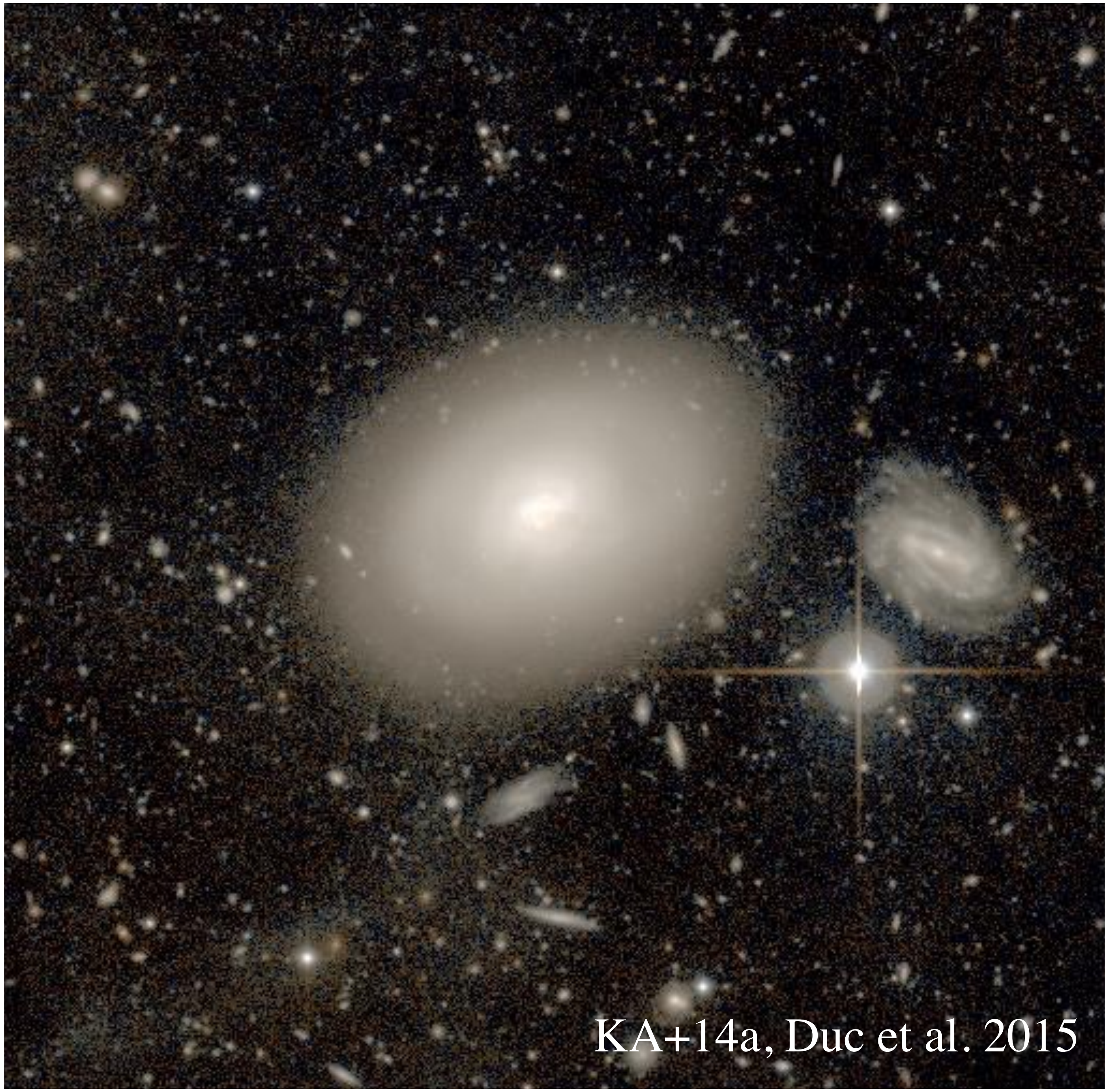
NGC 1266

NGC 1266 has optical colors on the **red sequence**

NGC 1266 hosts a massive molecular disk (>10^9 $M_\odot$) and an AGN-driven massive (>10^8 $M_\odot$) molecular outflow that is multiphase

NGC 1266 contains a 1/2 Gyr stellar population, so it is **poststarburst**

Star formation is suppressed in the molecular gas by a factor of 50-150



Alatalo et al. 2011, 2014a, 2015a

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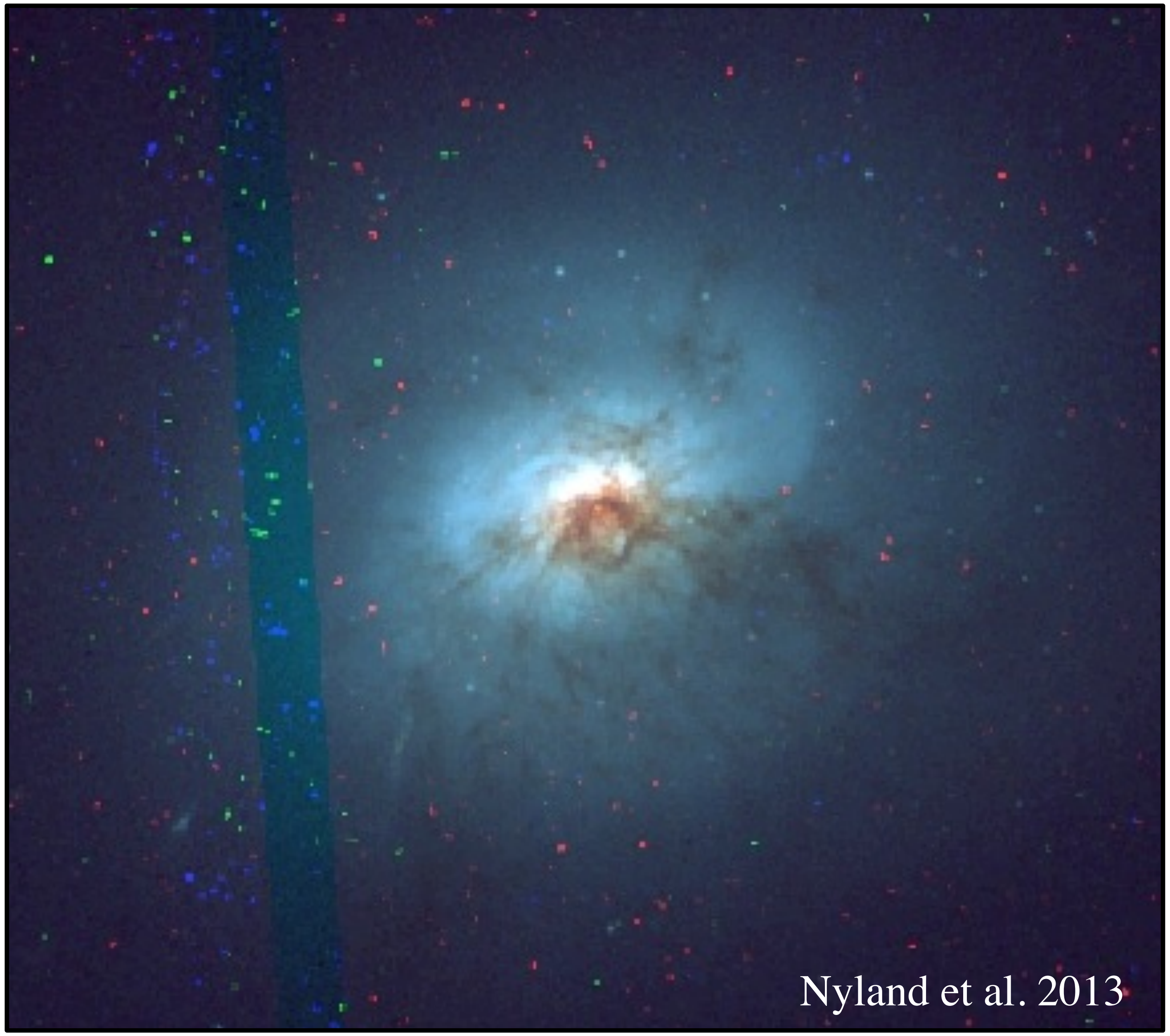

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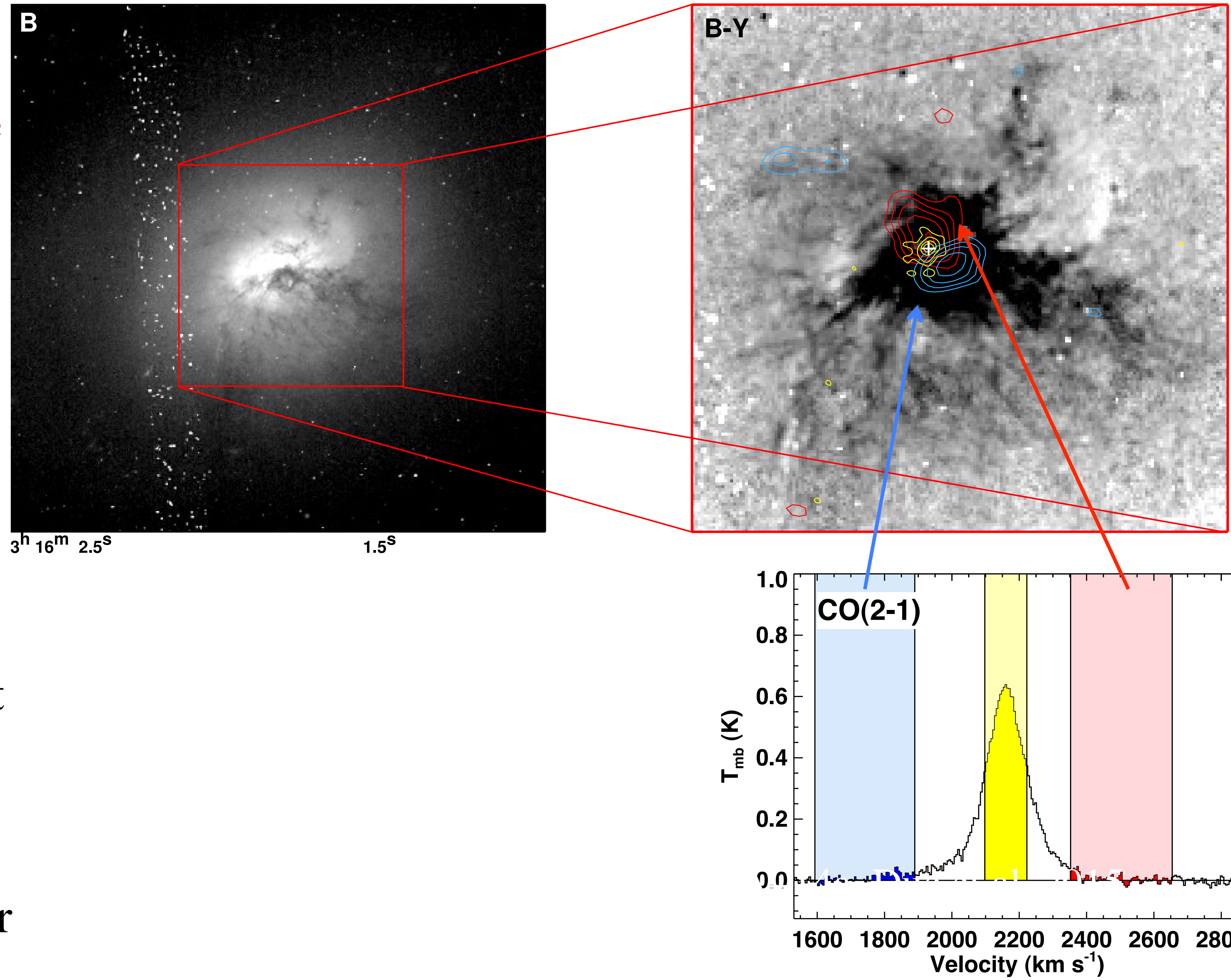

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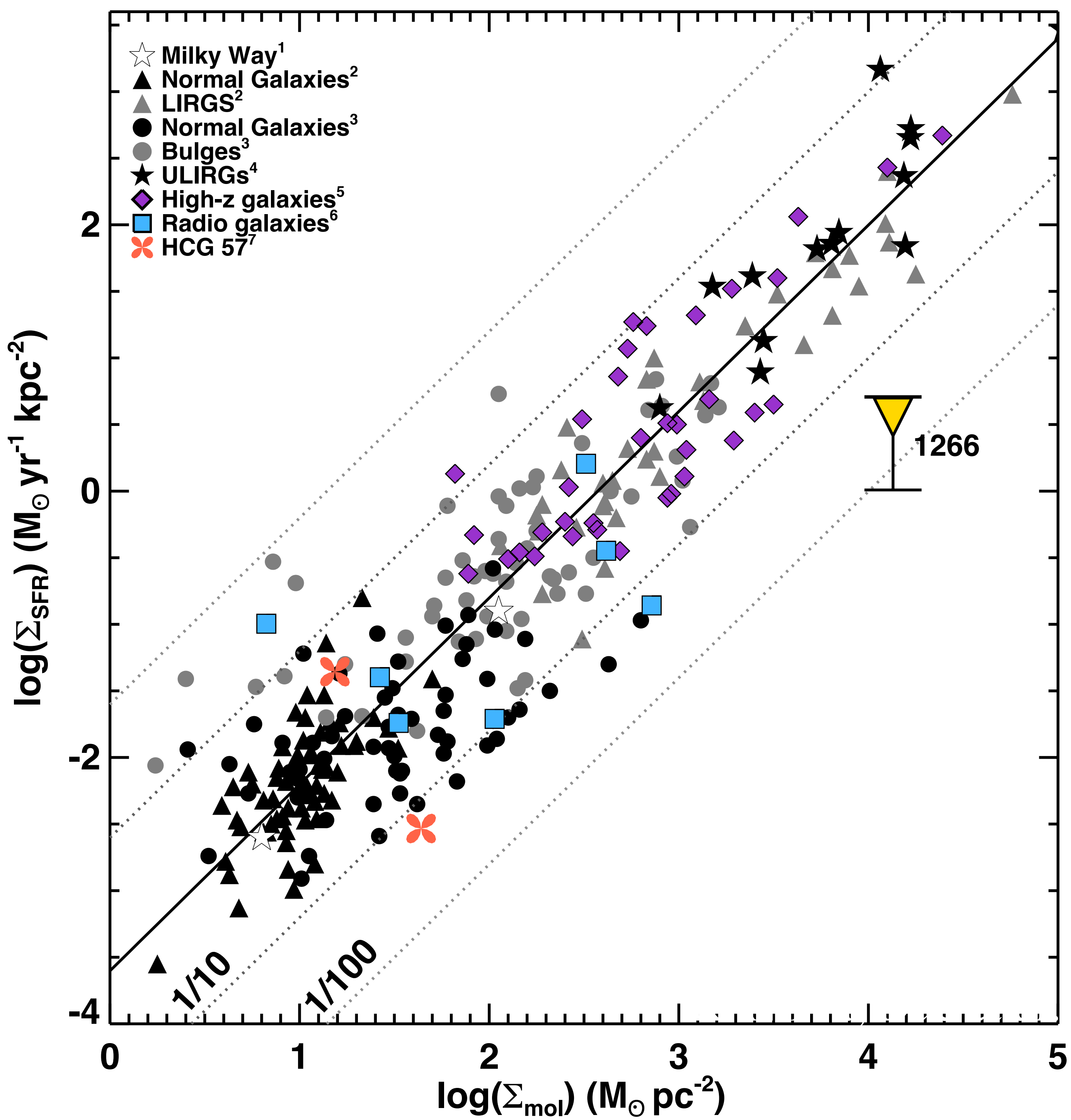


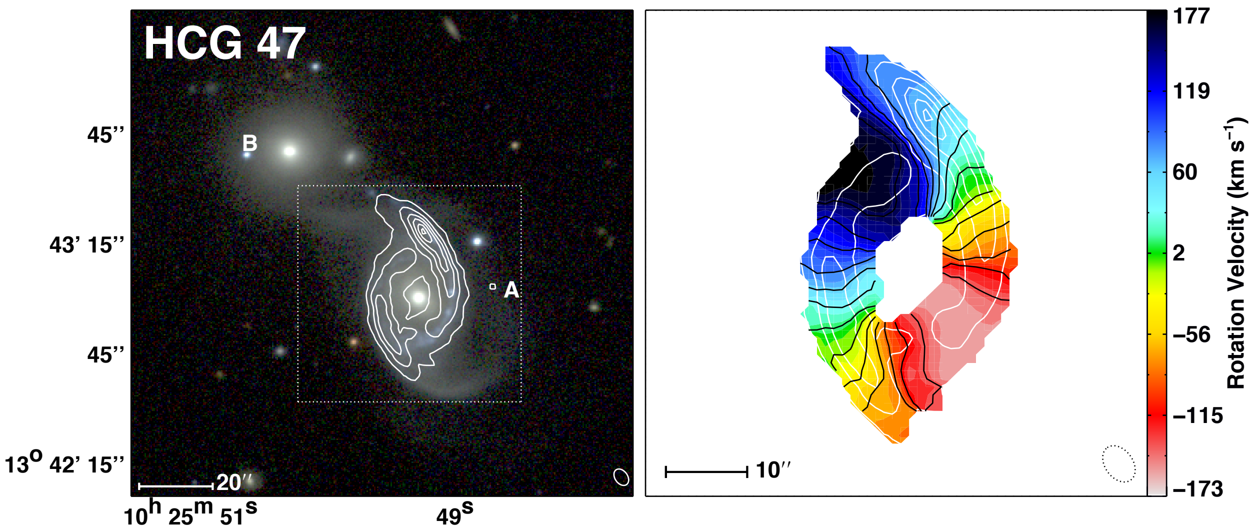
Alatalo et al. 2011, 2014a, 2015a

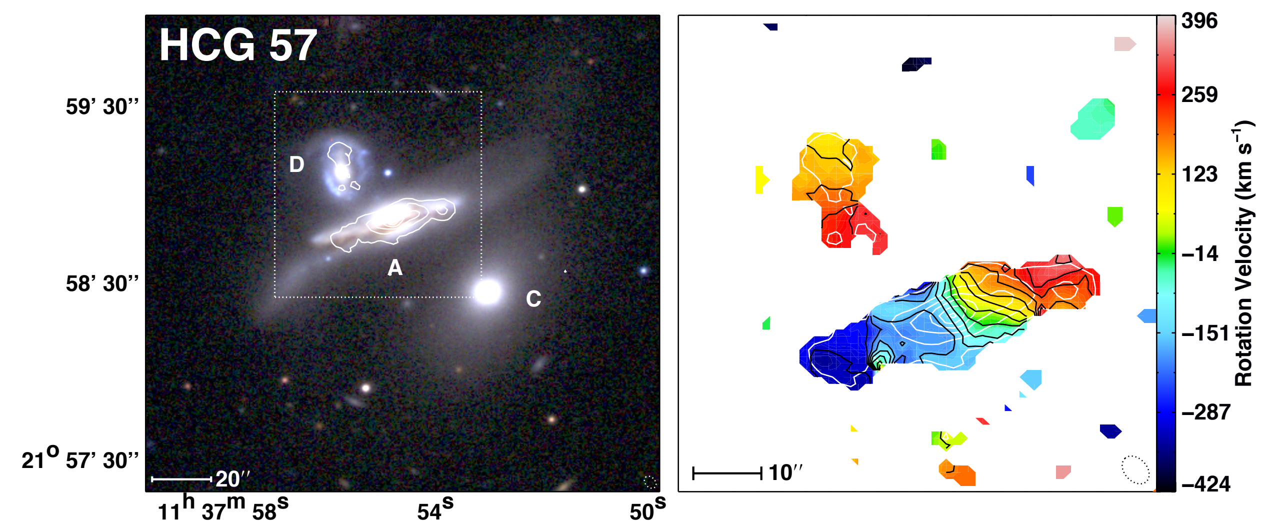
Hickson Compact Groups:

Galaxy evolution on steroids

group interactions

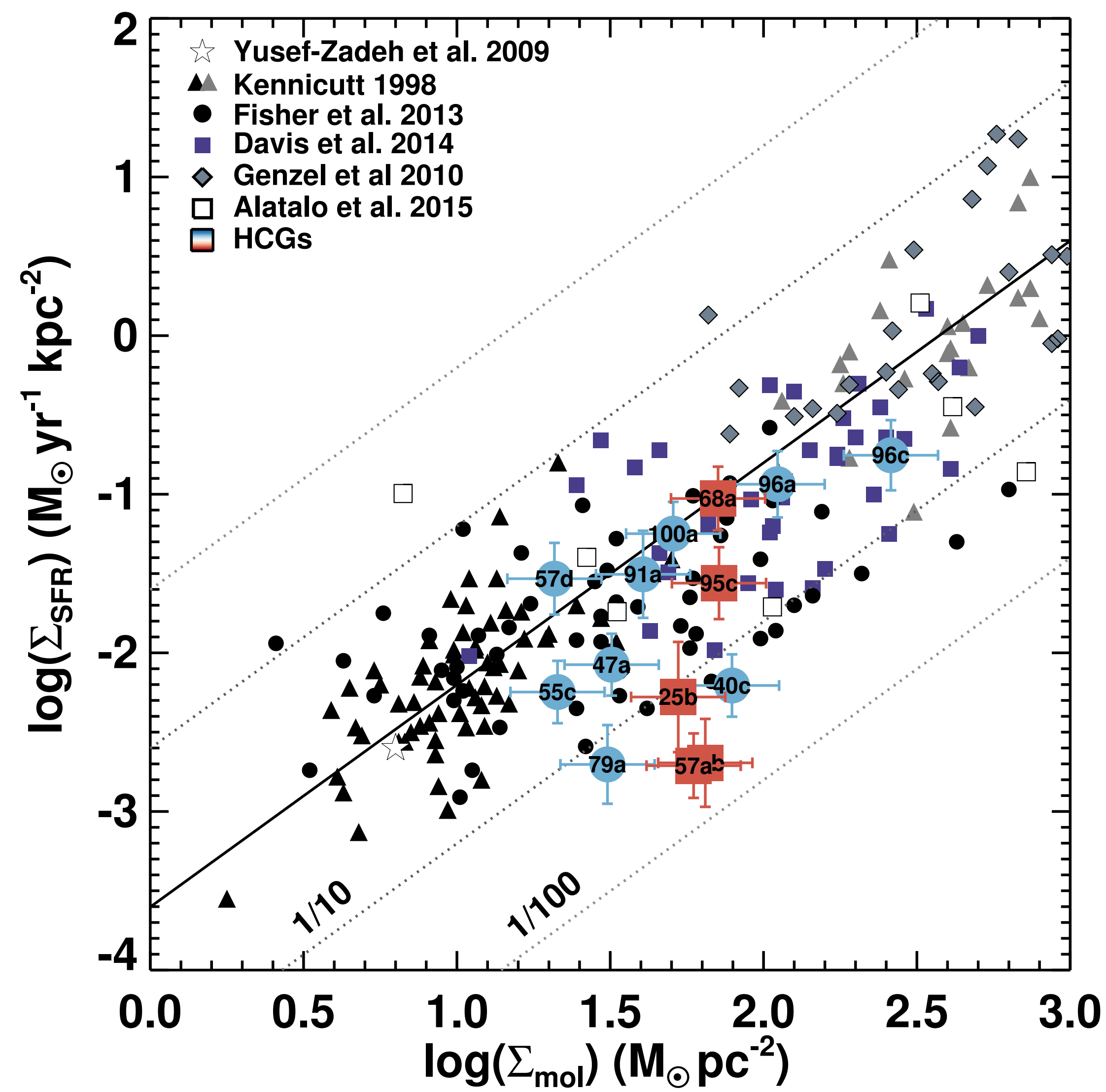
CO(1-0) imaging in HCGs





CARMA imaging of the 12 warm H_2-bright HCGs (14 galaxies) were detected to high significance.

In 5/14 galaxies, there is significant evidence that star formation is **inefficient within the molecular gas**



Alatalo et al. 2015b

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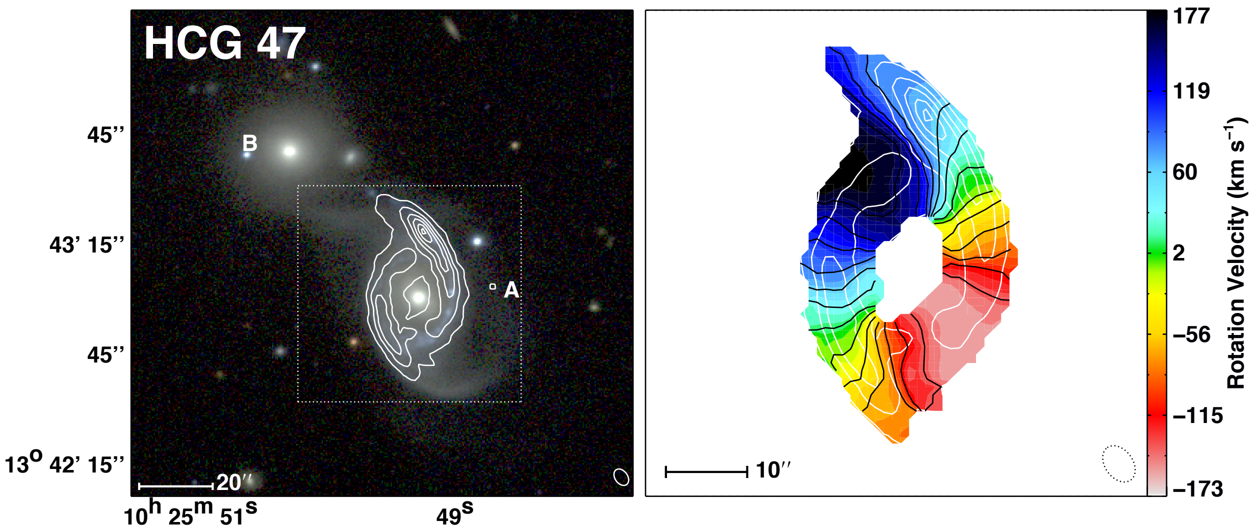

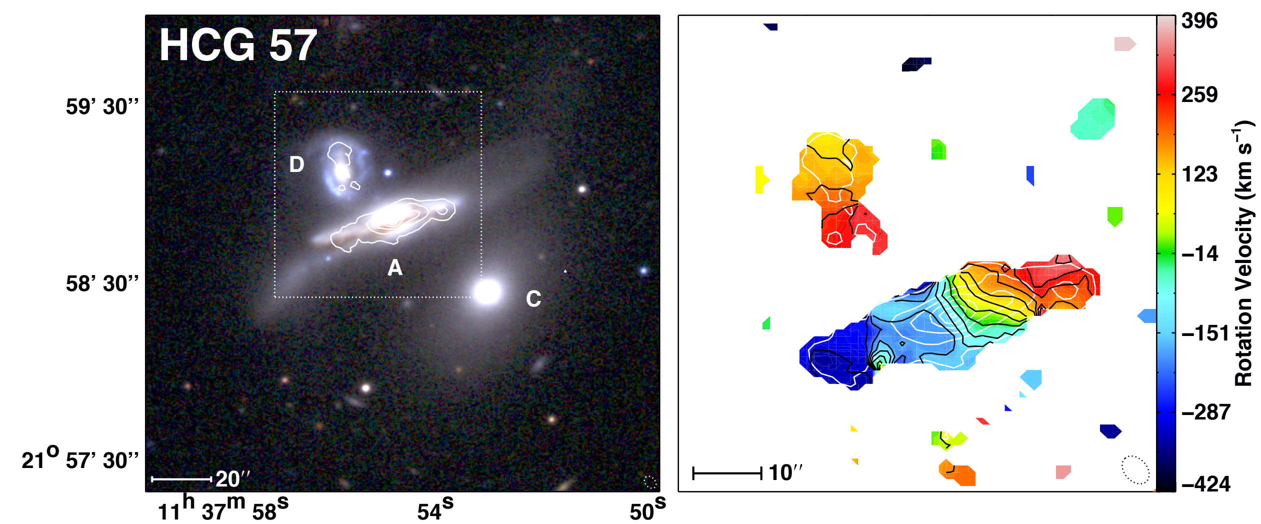

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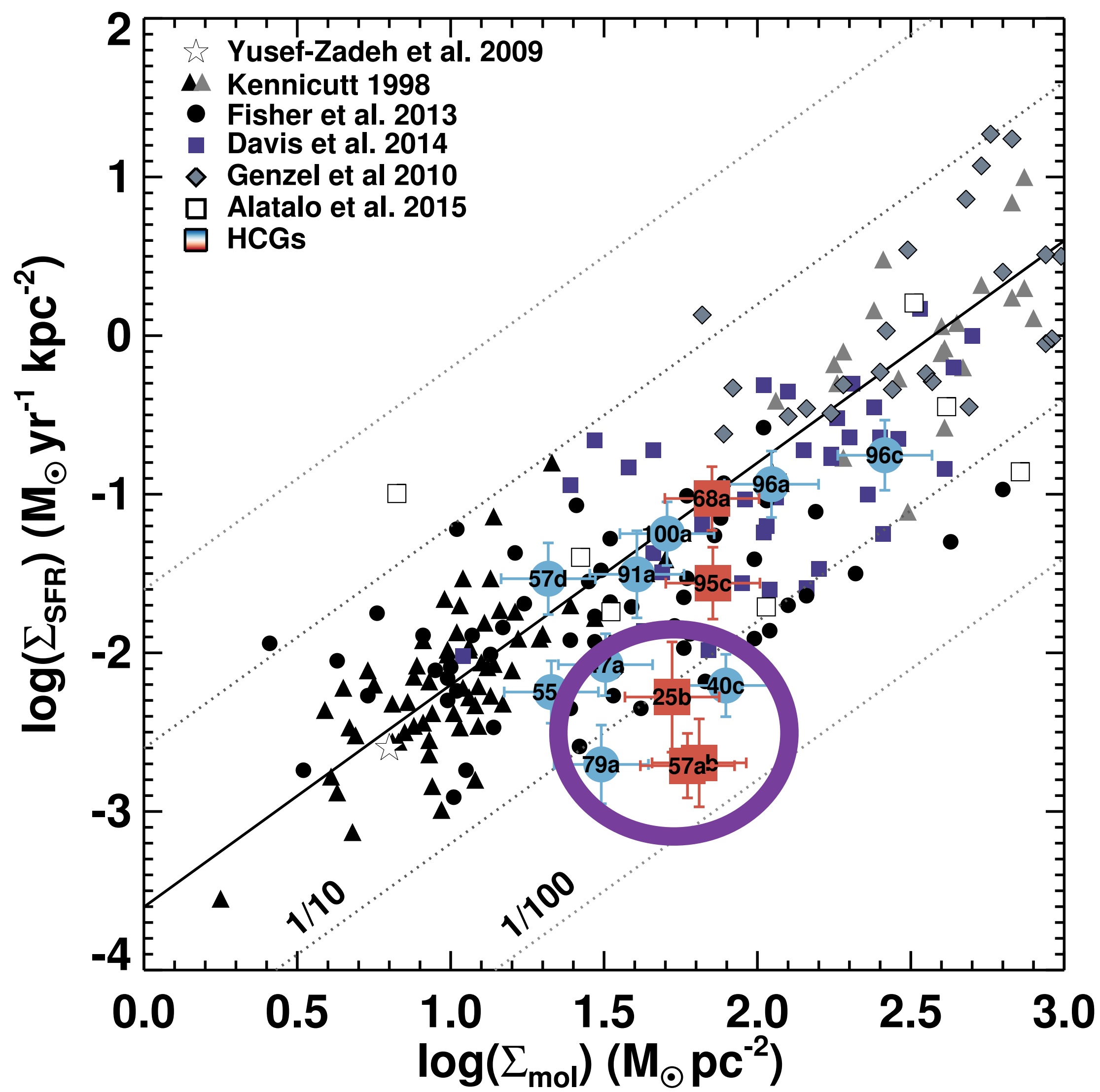
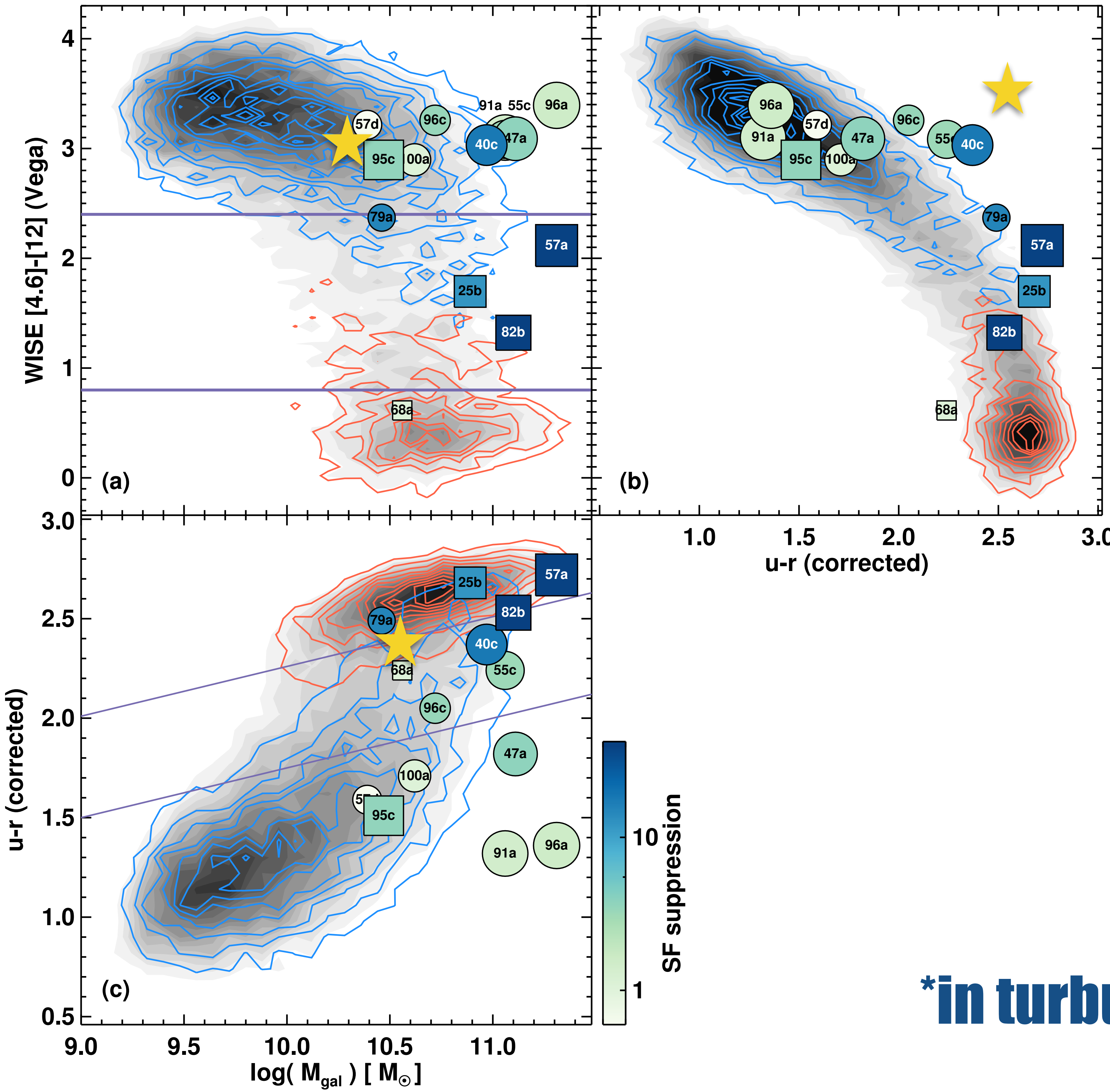


Alatalo et al. 2015b

SF suppression ⇄ Color*



***in turbulent, imaged galaxies**

Alatalo et al. 2014b, Alatalo et al. 2015b

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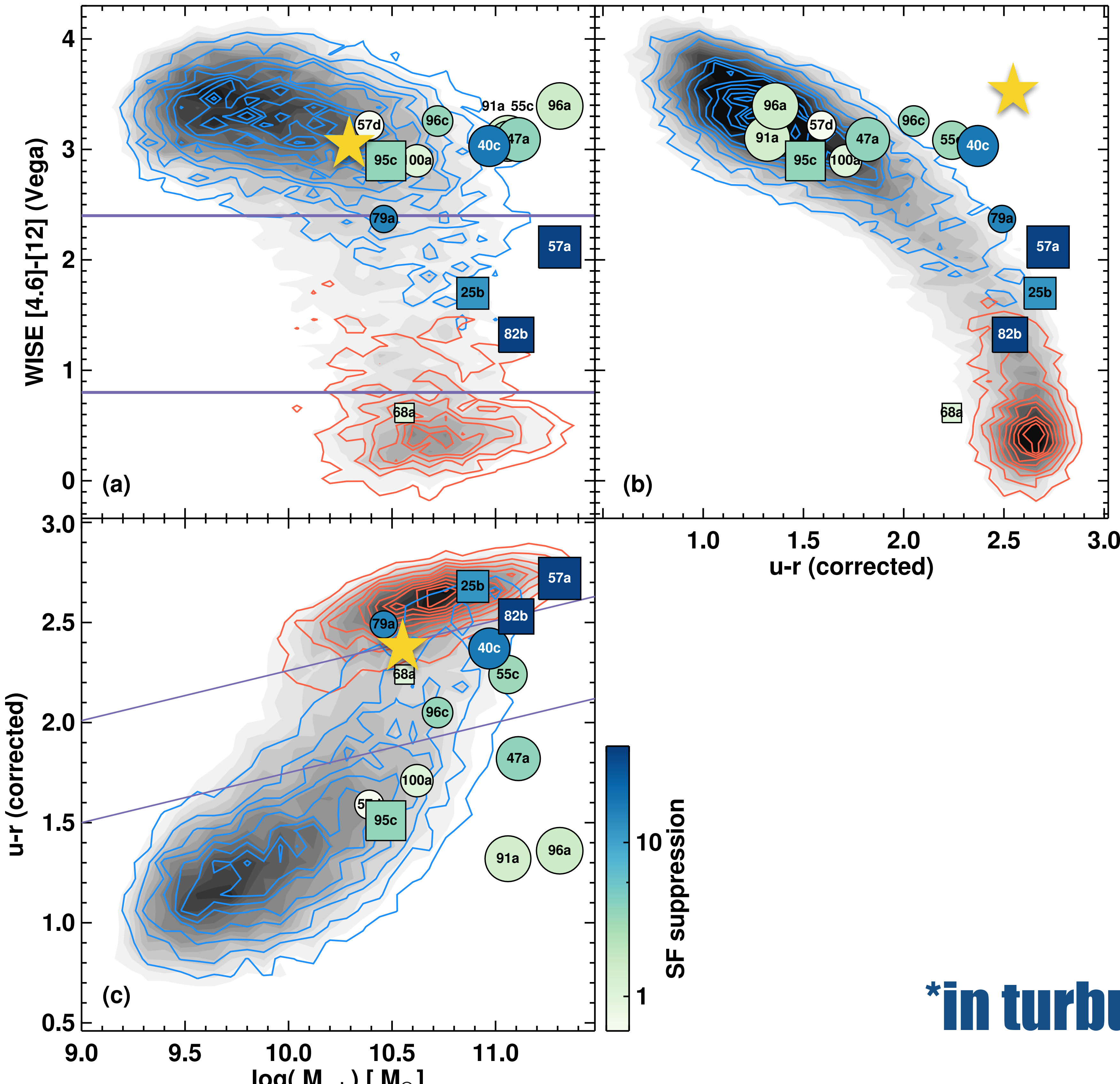
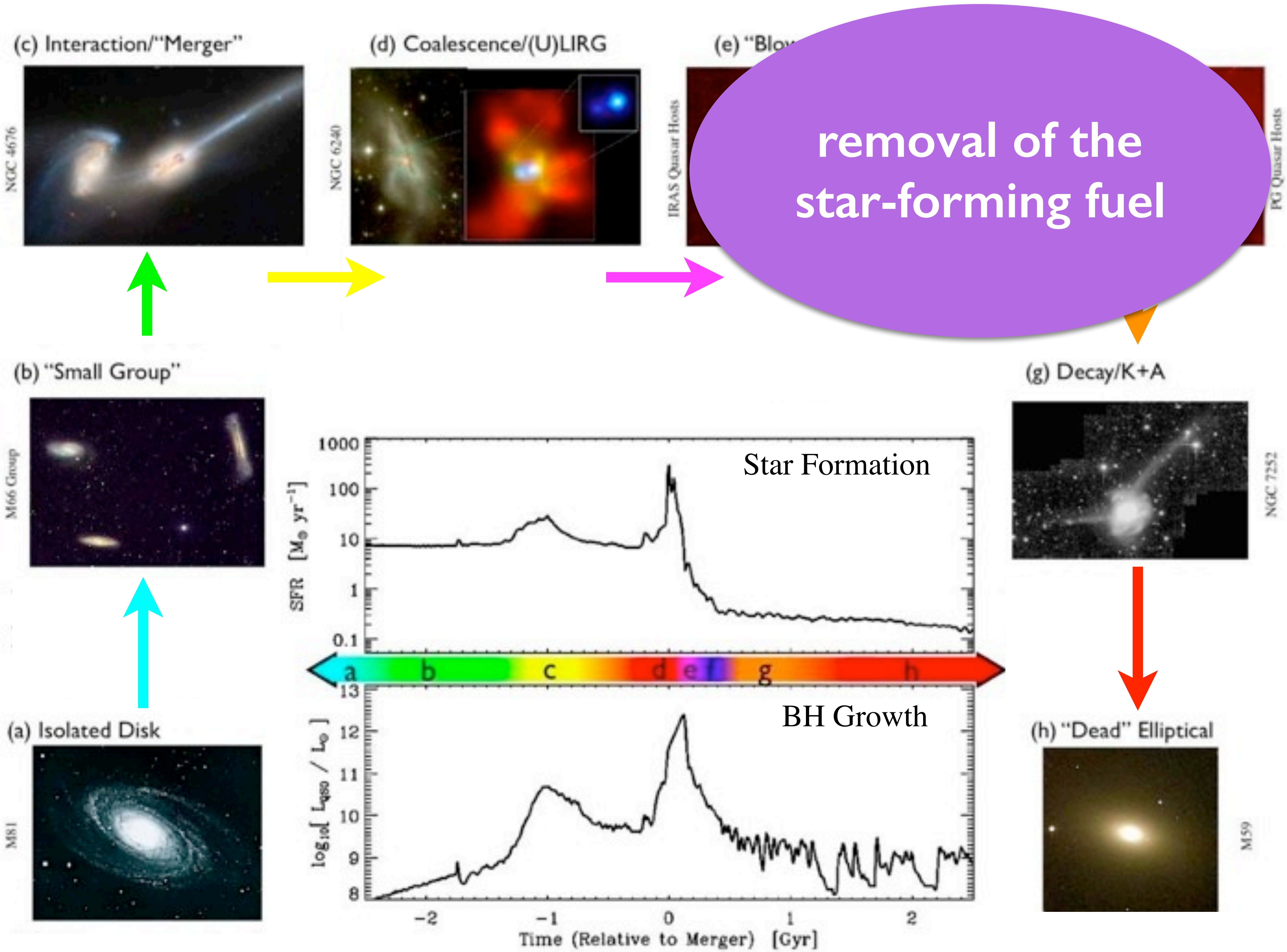


The color of these galaxies depends on whether the gas is forming stars efficiently, not whether there exists a reservoir

***in turbulent, imaged galaxies**

Alatalo et al. 2014b, Alatalo et al. 2015b

Does SF suppression change the galaxy evolution paradigm?



Hopkins et al. 2008

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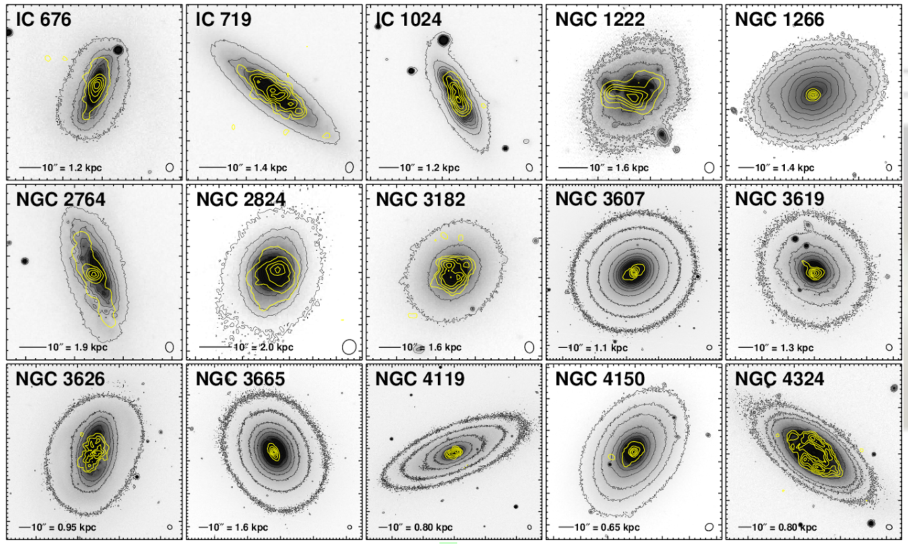

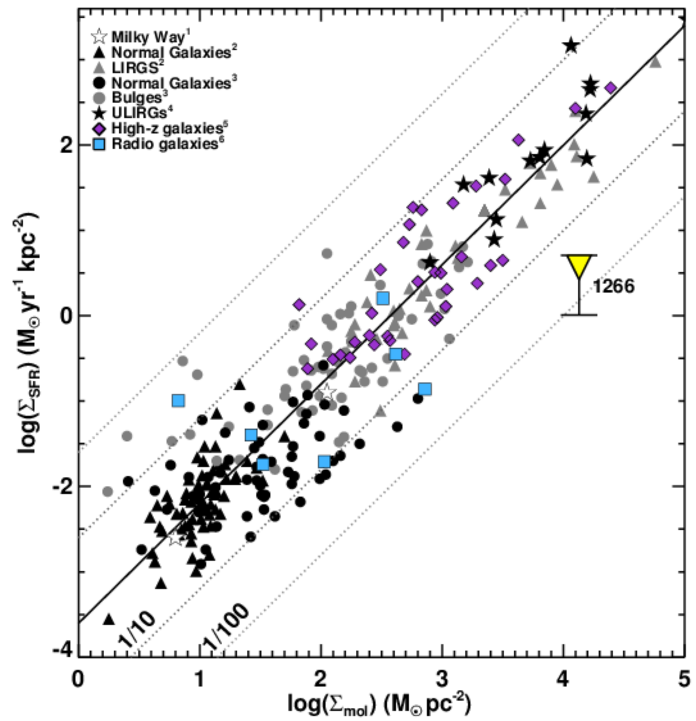

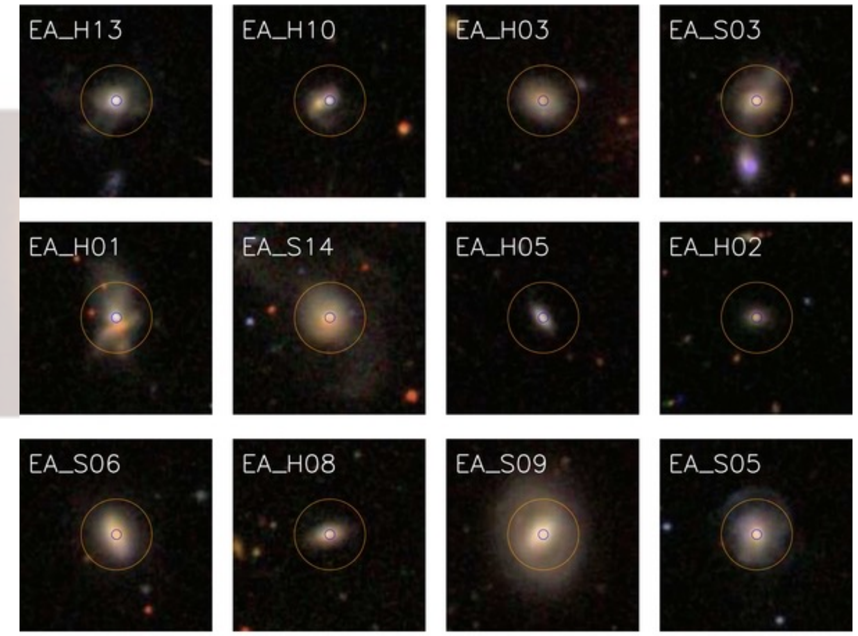

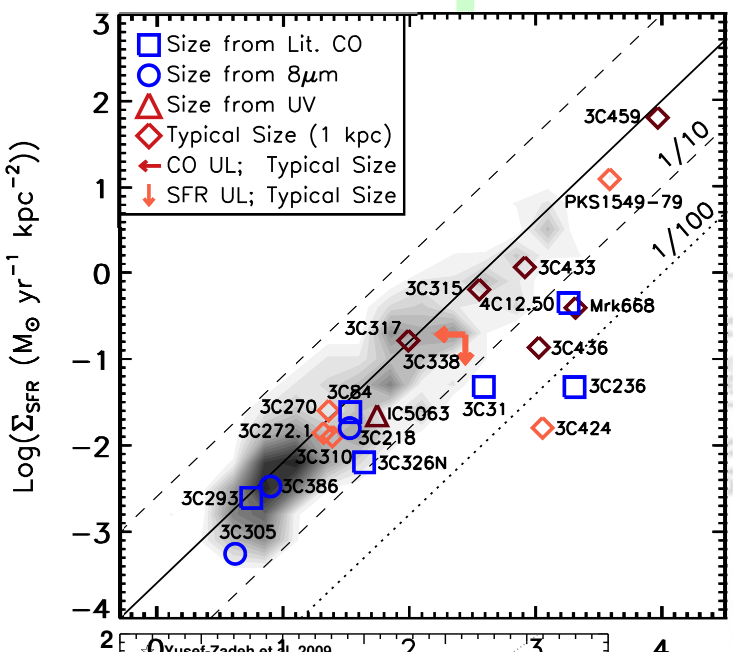

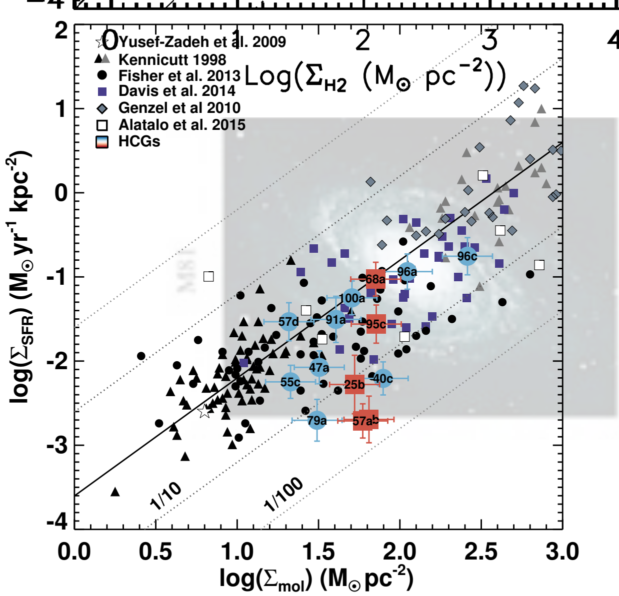

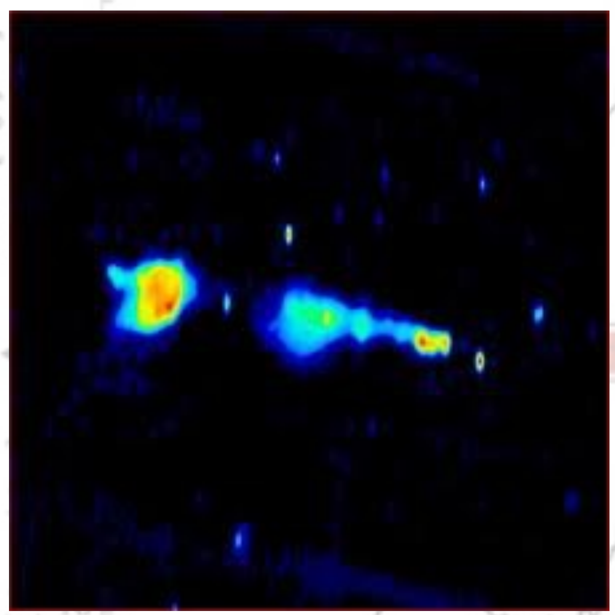

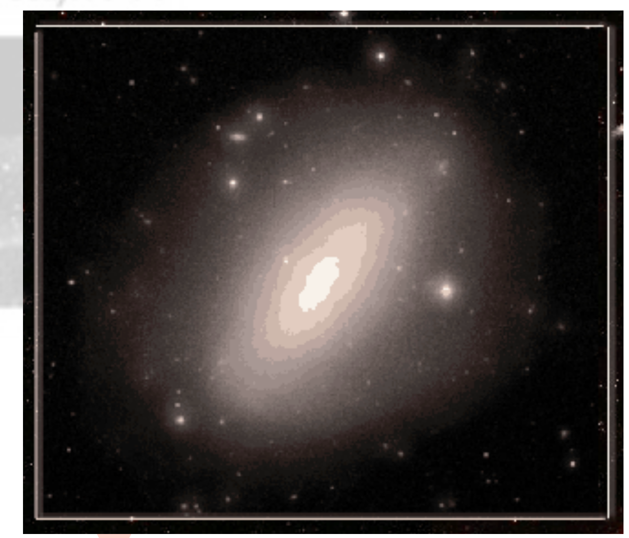

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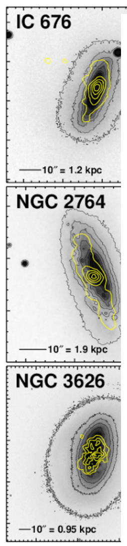
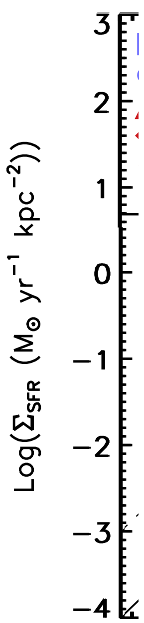


ATLAS^{3D} ETG galaxies are shown to have non-negligible reservoirs of molecular gas, forming stars sub-efficiently (Combes et al. 2007, Crocker et al. 2011, Young et al. 2011, Alatalo et al. 2013, Martig et al. 2013, Davis et al. 2014)

NGC 1266 has a massive reservoir of molecular gas that is not forming stars efficiently (Alatalo et al. 2015a)



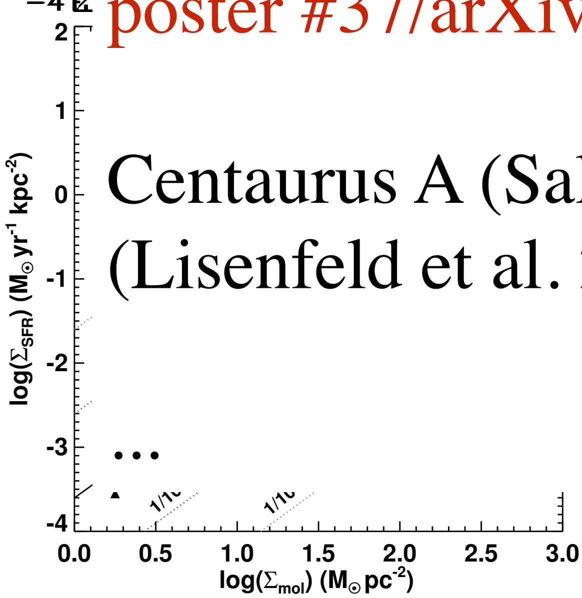
3C326N also is suppressed in star formation (Guillard et al. 2015)

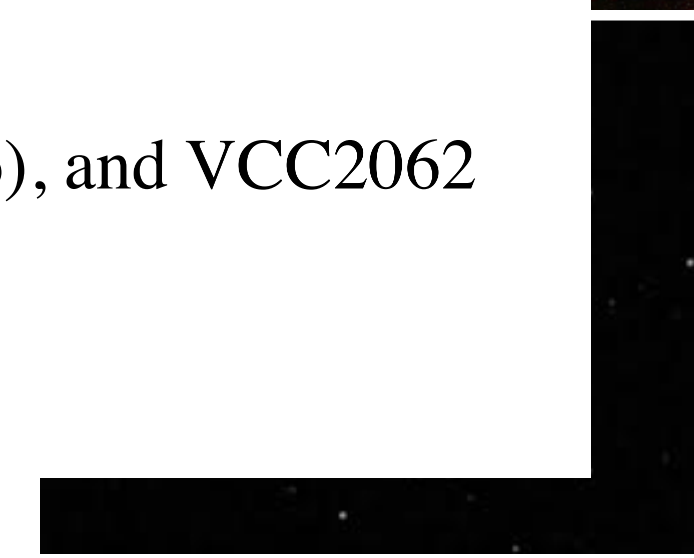
Poststarburst galaxies are found to have substantial reservoirs of molecular gas (French et al. 2015, Rowlands et al. 2015)

5 shocked HCGs (Alatalo et al. 2015b) and 6 radio galaxies (Lanz et al. 2016, poster #37/arXiv:1511.05968) are shown to be suppressed

Centaurus A (Salomé et al. 2016), NGC 1377 (Aalto et al. 2016), and VCC2062 (Lisenfeld et al. 2016) are also shown to be suppressed

...





The future: testing other transitioning galaxies

Case studies are great, but can't tell us about a population.

What is the duty cycle of the SF quenching/suppression?

Have we discovered all available paths for a galaxy to transition?

Does the ISM feed back upon the quenching galaxy in all paths?

How common is SF suppression in galaxy transition?

What is the redshift evolution?

Alatalo et al. 2016a+b, (arXiv:1601.05085, arXiv:1604.01122)

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solution: finding new selections for quenching galaxies

shocked ionized gas ratios + poststarburst stellar population

=

a Shocked Poststarburst Galaxy (spog)

NGC 1266 is a spog, as are several of the HCG galaxies.

Alatalo et al. 2016a+b, (arXiv:1601.05085, arXiv:1604.01122)

Conclusions

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NGC1266 has transitioned, despite 10^9 $M_\odot$ of H_2 being available due to turbulence stirring it up, and inhibiting star formation

The HCG galaxies studied are transitioning despite having reservoirs of molecular gas available, also likely due to turbulence

Large reservoirs of molecular gas have been found in poststarburst galaxies (French et al. 2015), confirming that the expulsion of a molecular reservoir is unnecessary for a galaxy to transform.

New evidence is mounting that many transitioning radio galaxies (particularly those exhibiting shocks) also show signs that turbulence is inhibiting star formation

Perhaps expelling the star-forming ISM is not the necessary condition for a galaxy to transform from blue to red
- or - perhaps some of the systems we are studying are not transforming for the first time at all, and are replenishing.