# The interplay between galaxy transition and molecular gas in the next generation of radio facilities.

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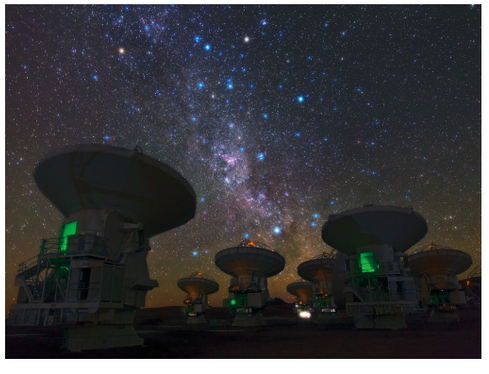
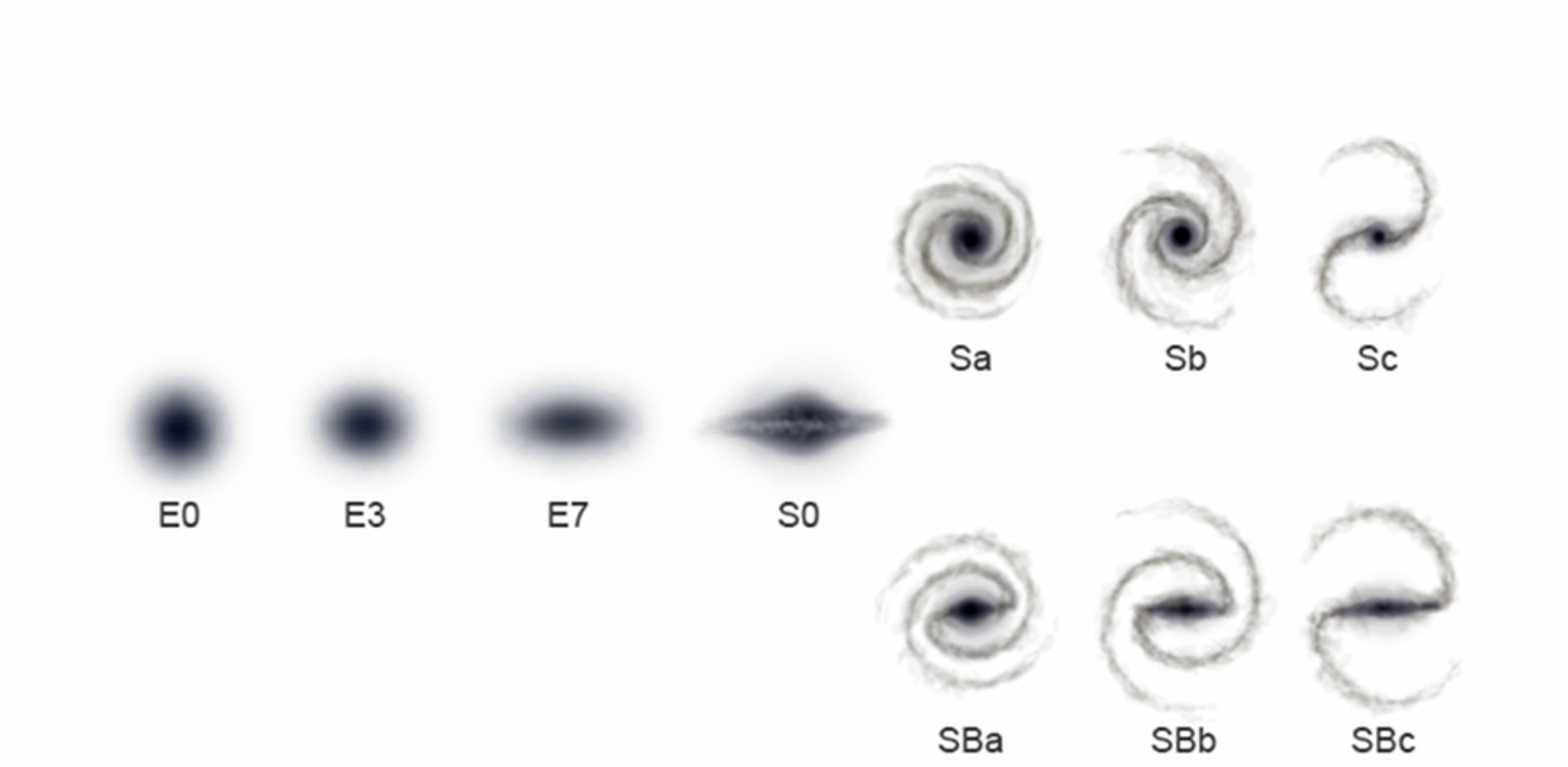


# The Hubble sequence
## a morphological classification



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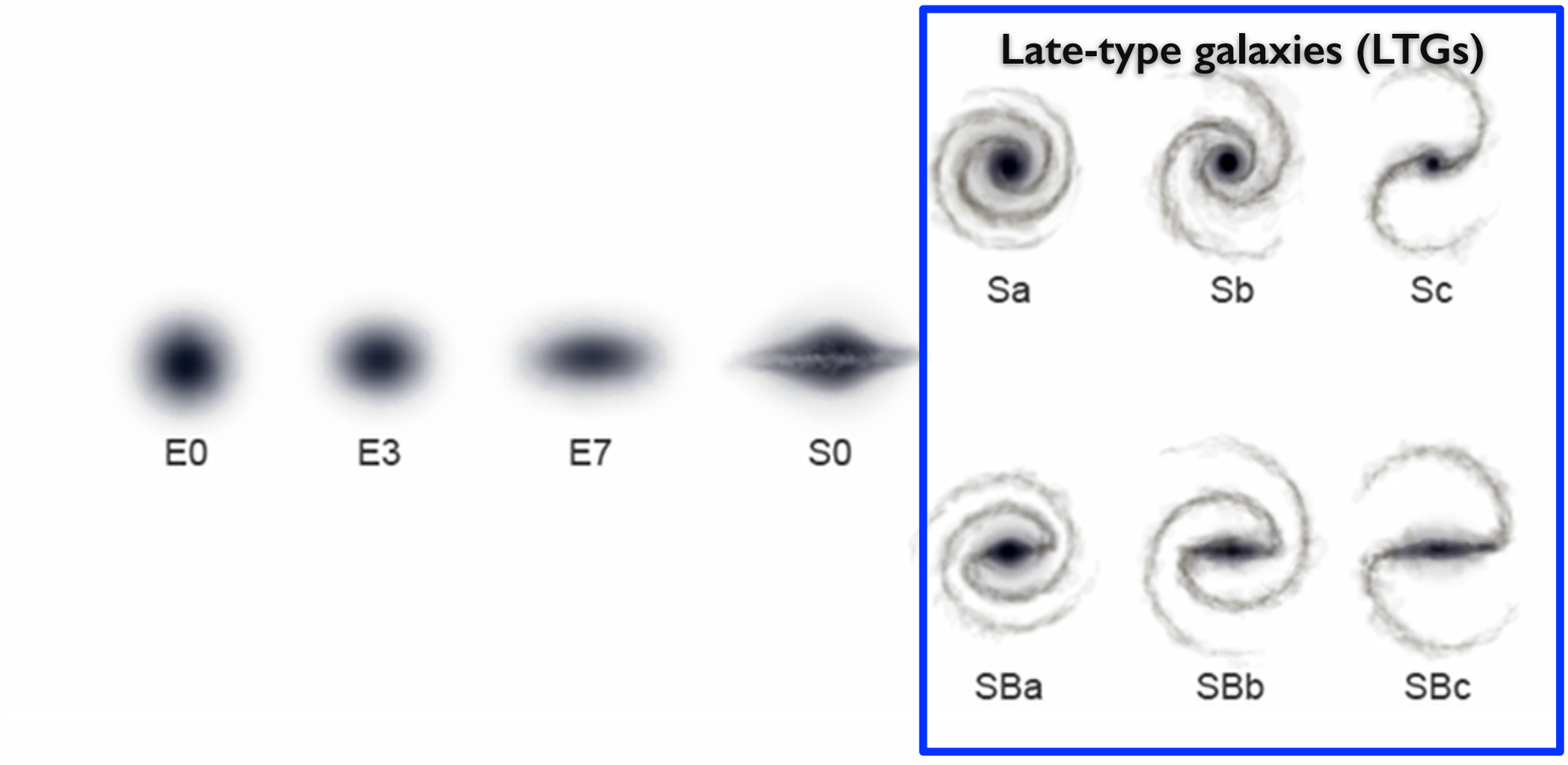

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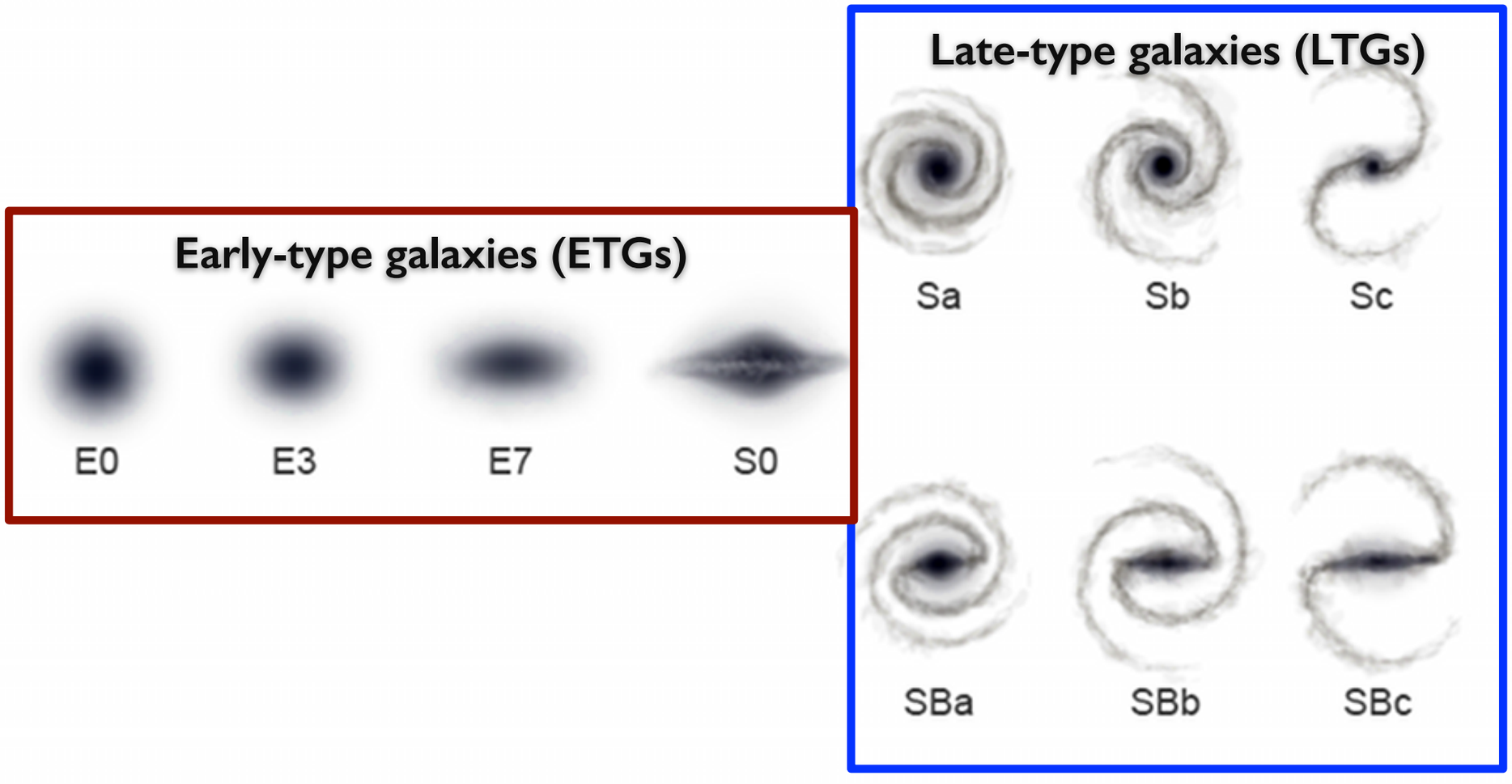

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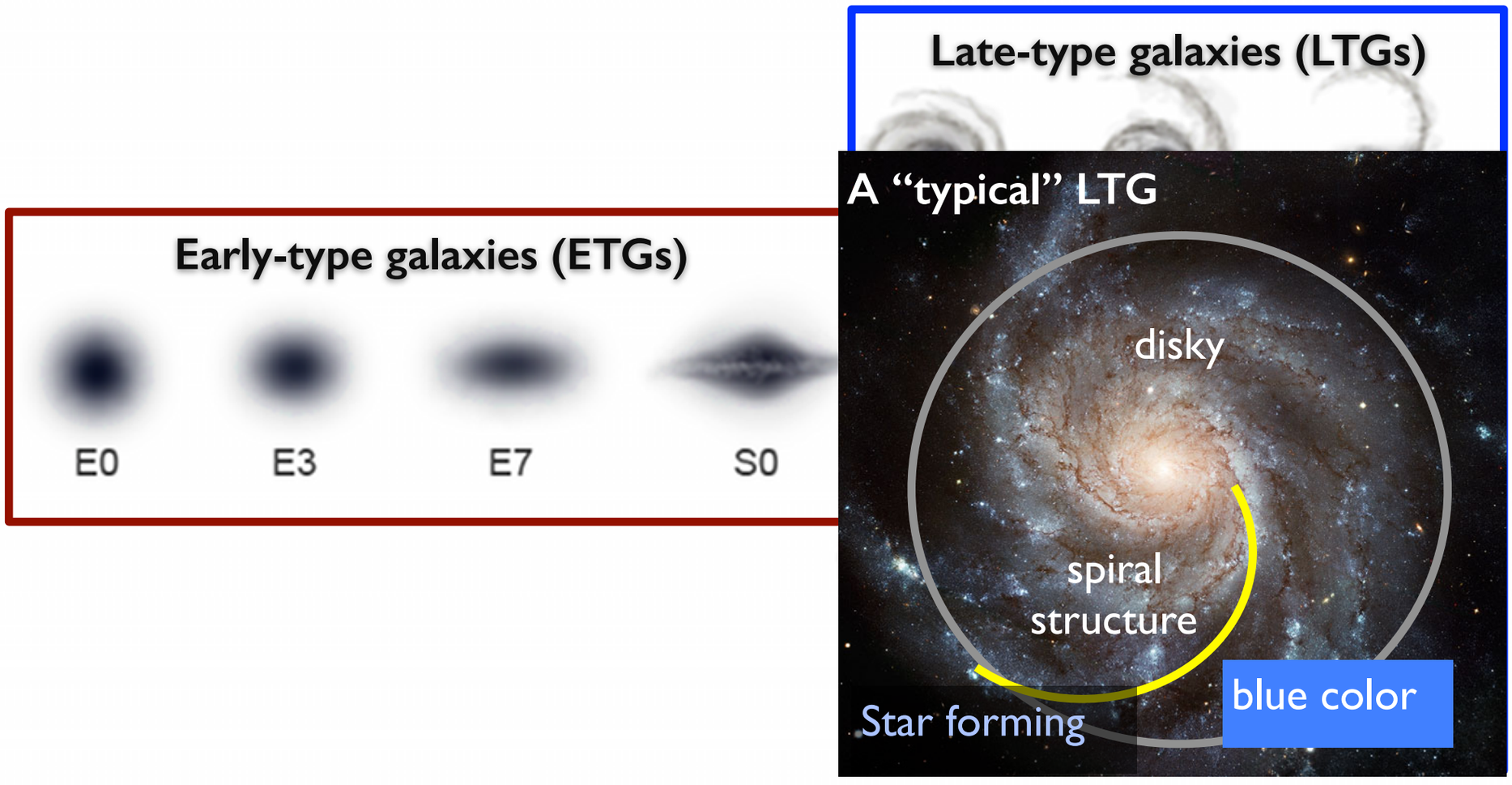

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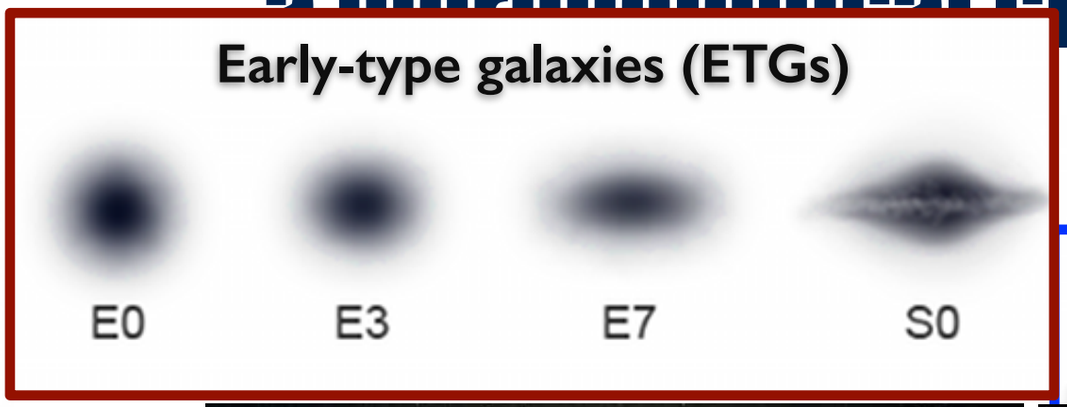
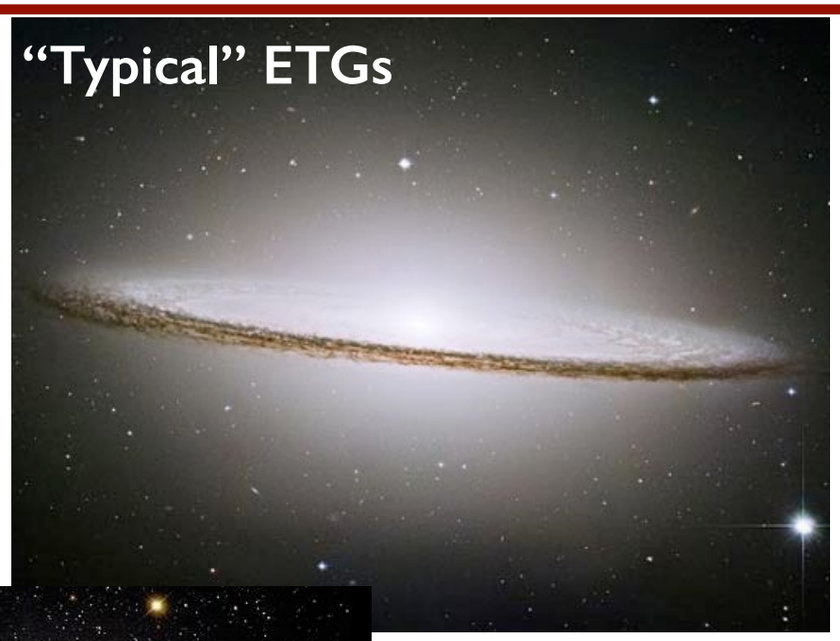
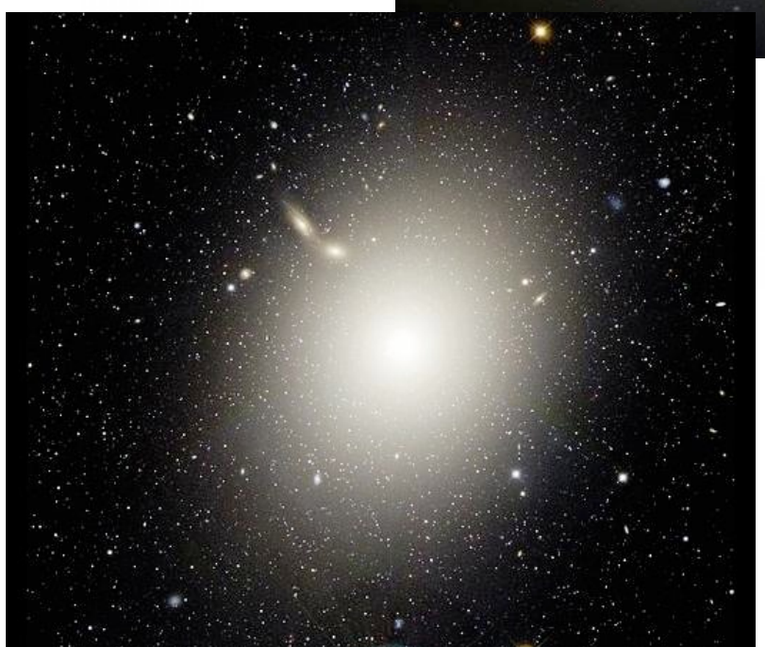
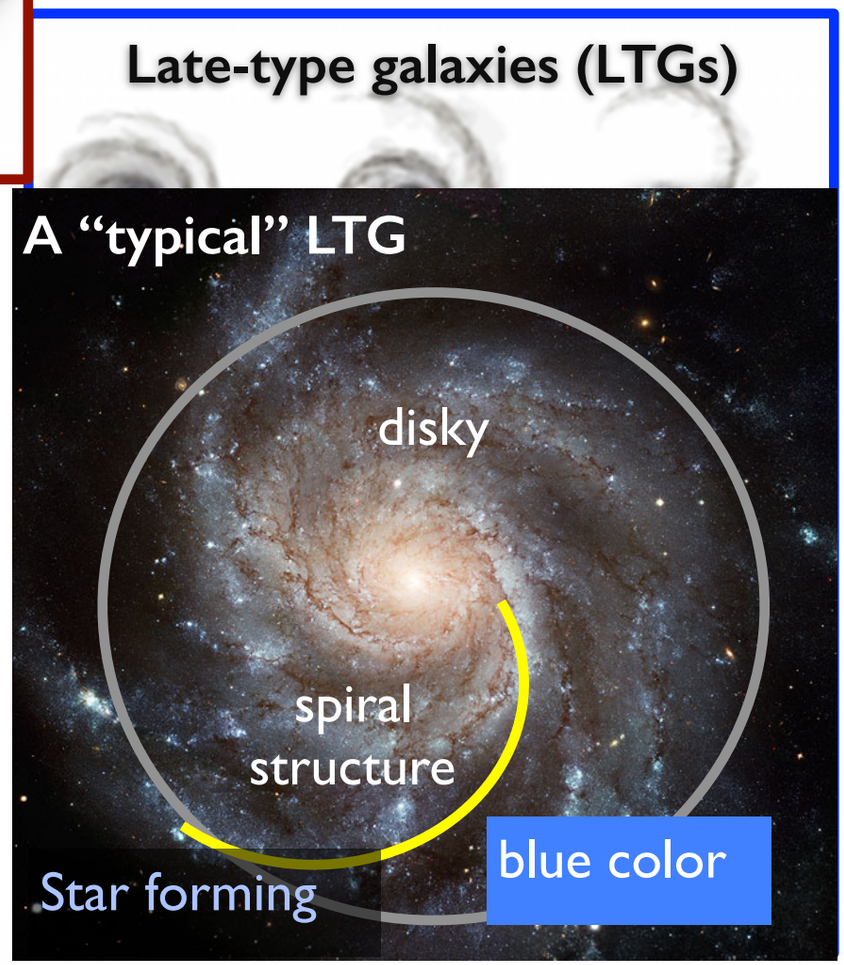




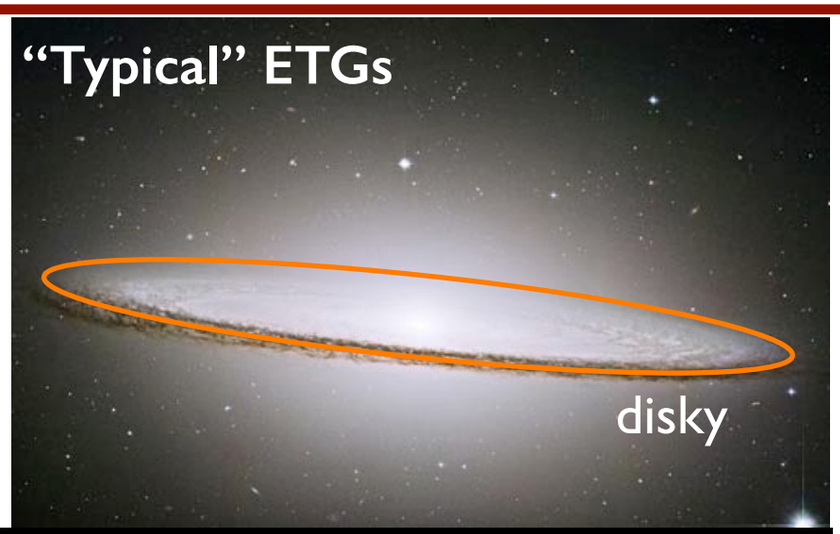
# The Hubble sequence

## a morphological classification

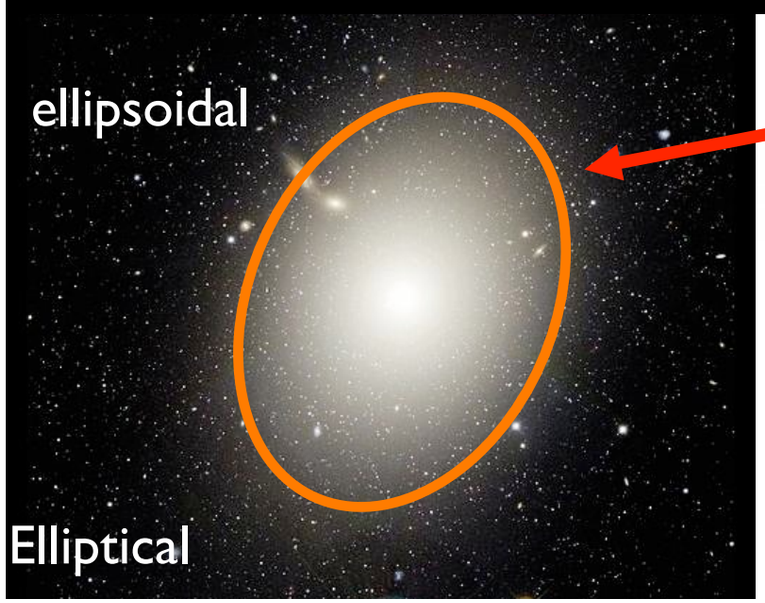
Early-type galaxies (ETGs)


Late-type galaxies (LTGs)

Lenticular / S0

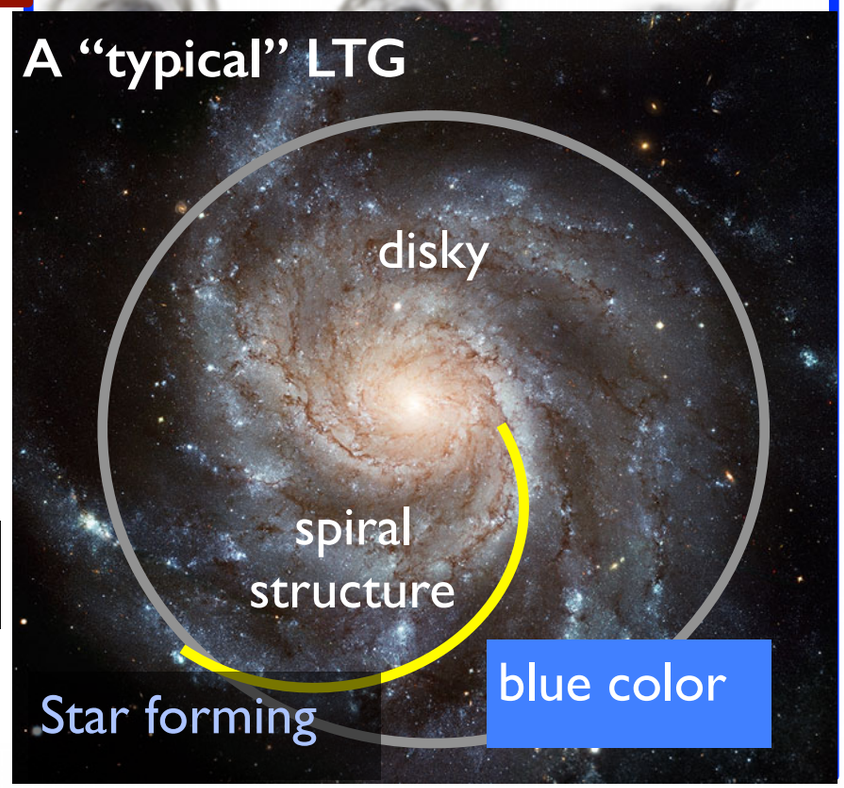



smooth light profile : lack spiral structure




red color

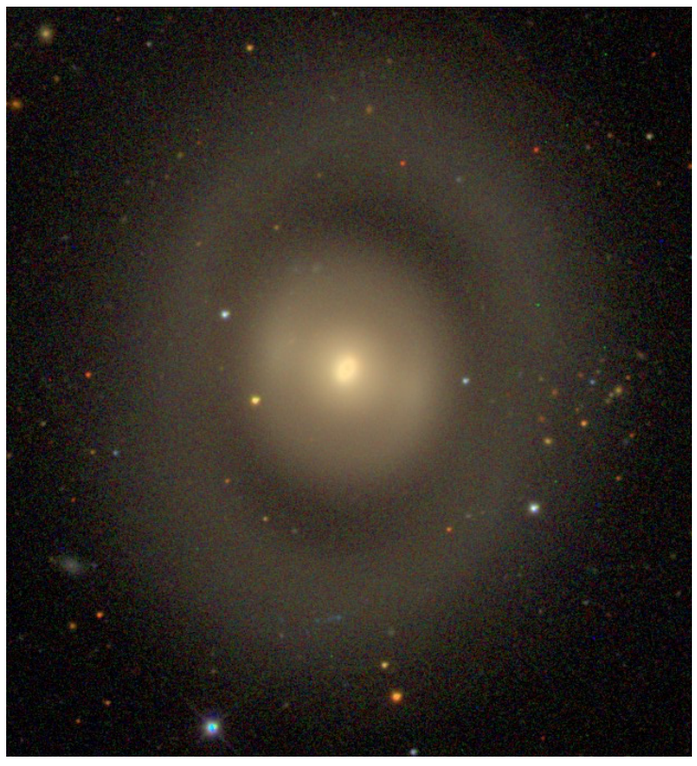
Quiescent



# Paths to transition

late-type

early-type



# Paths to transition

late-type

mergers

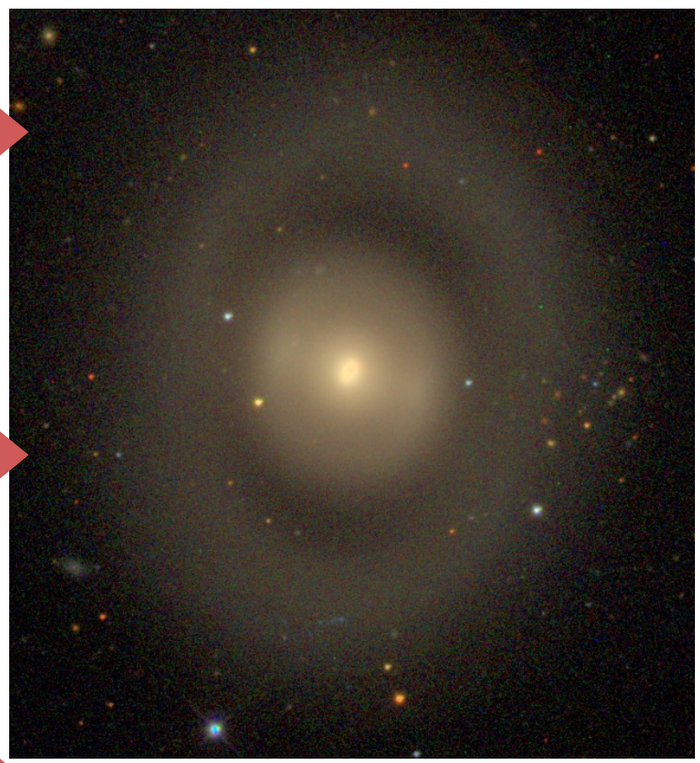
falling into a cluster

secular evolution

group interactions

other

early-type



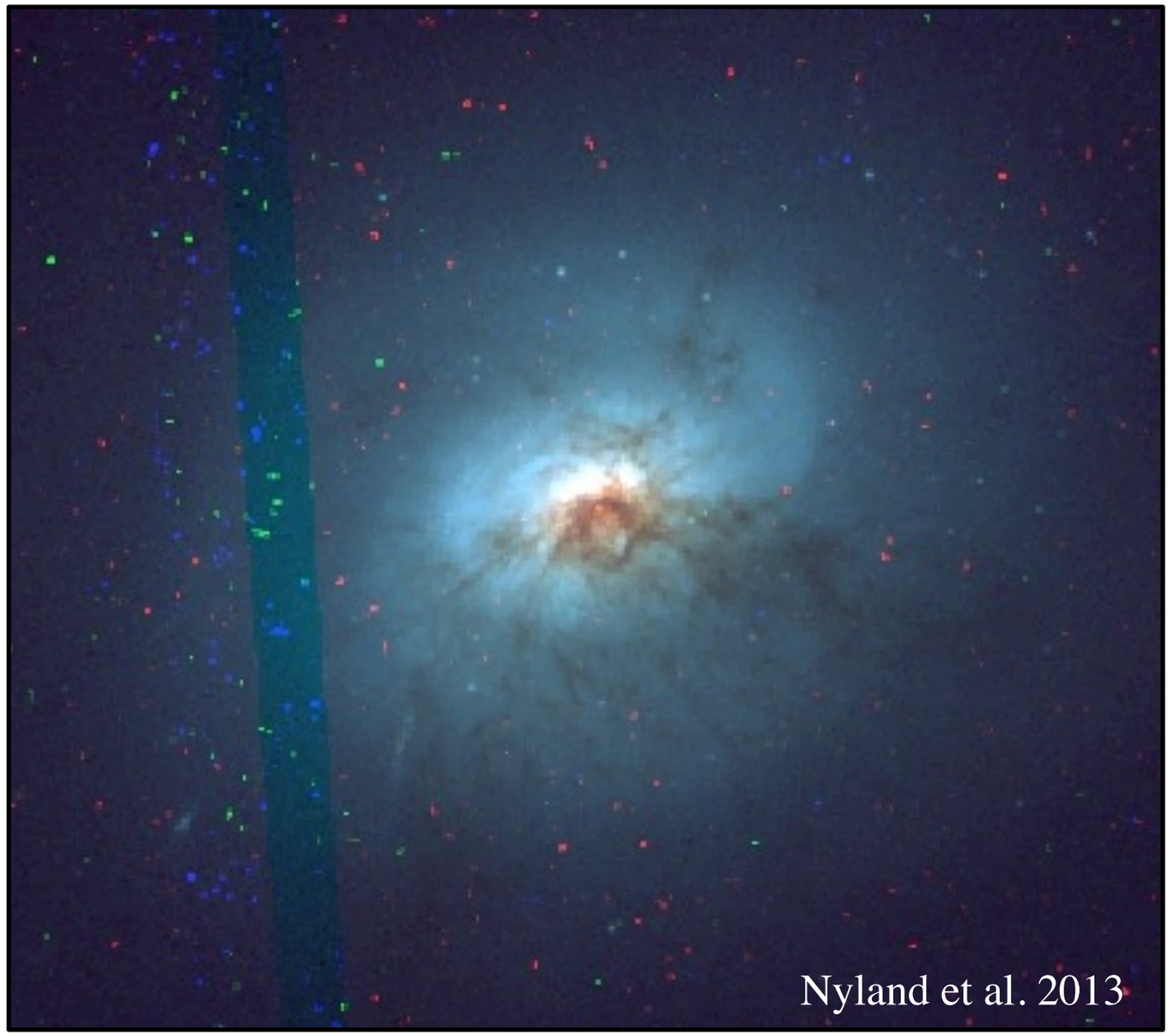
# NGC 1266

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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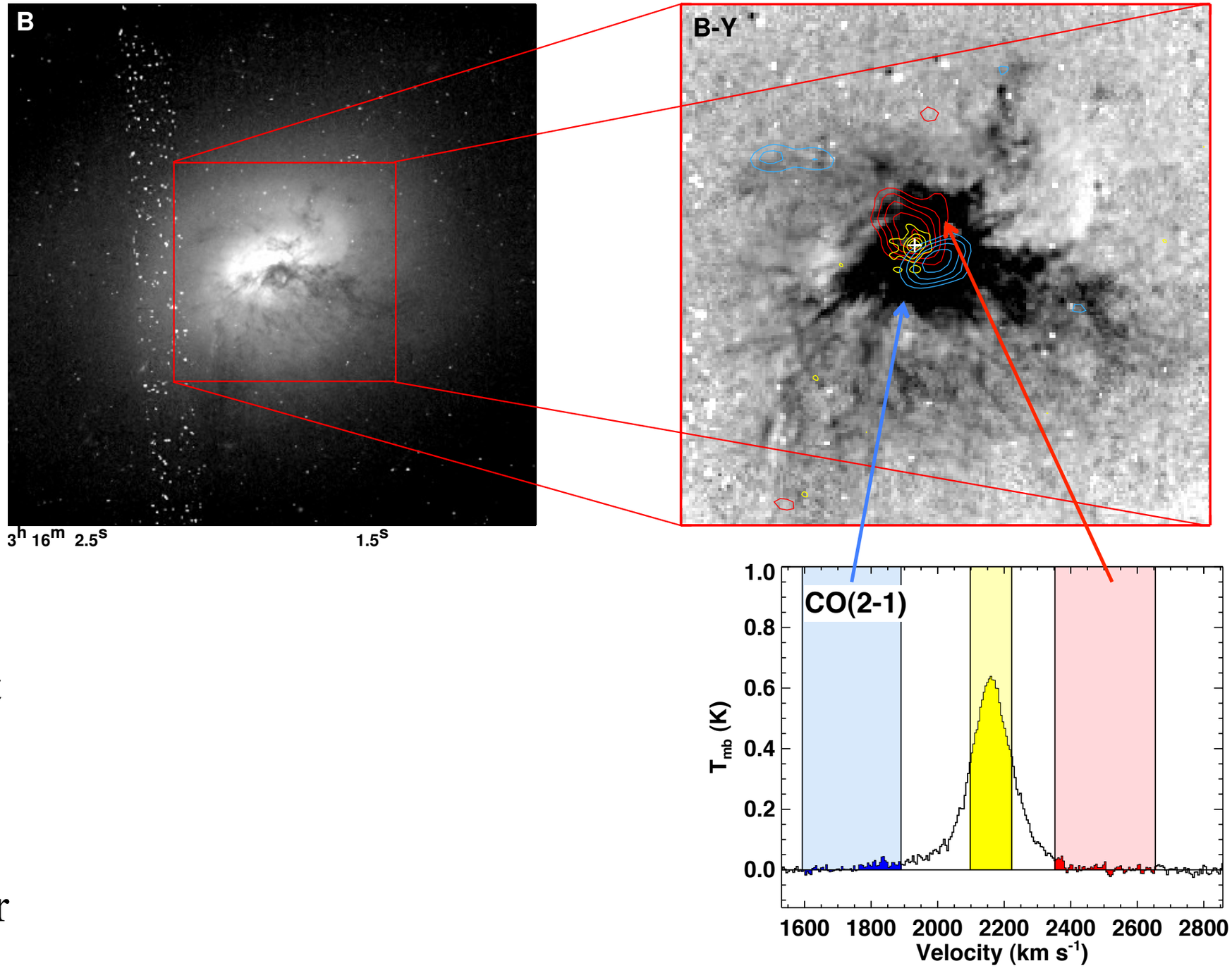


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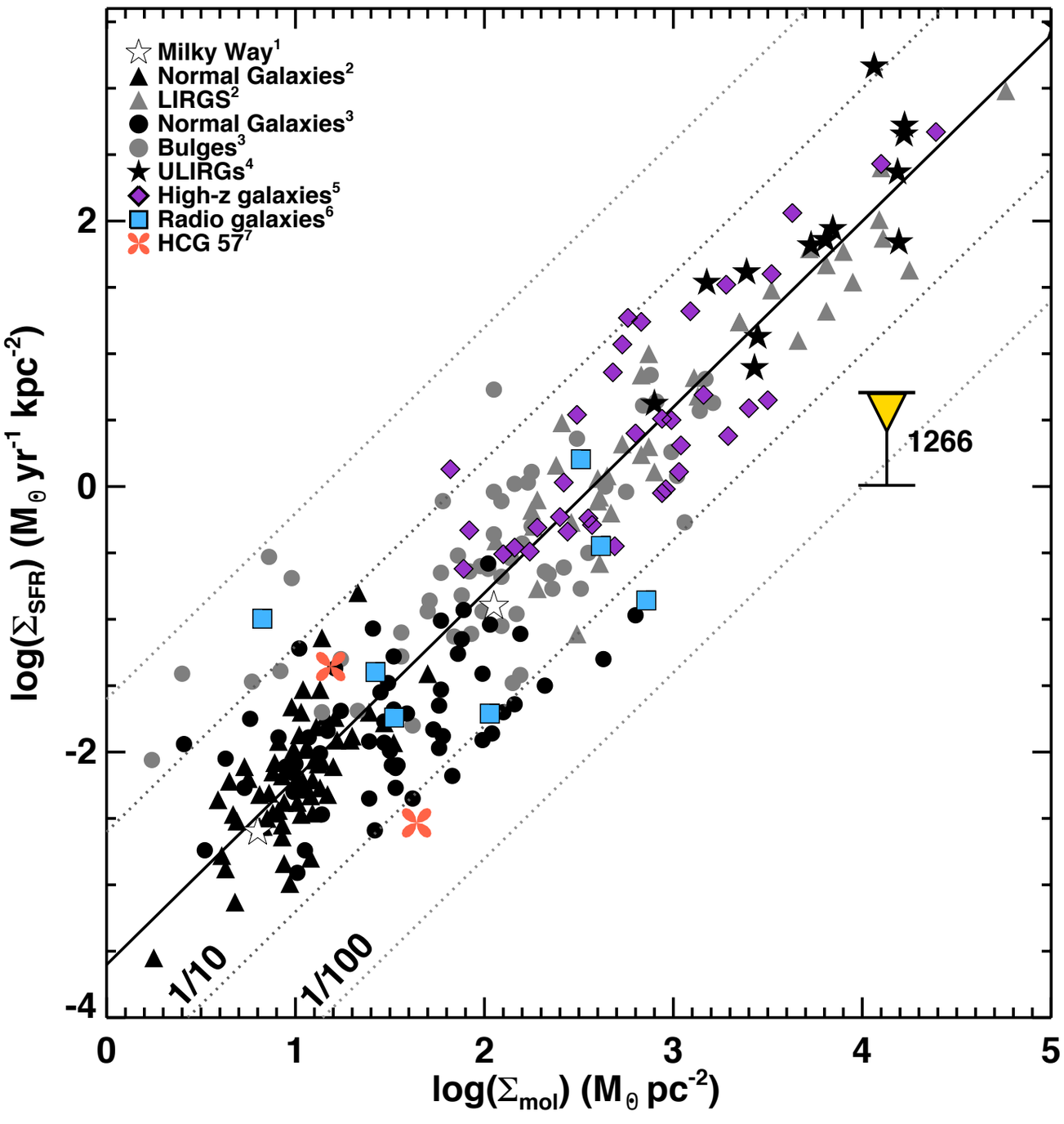



Alatalo et al. 2011, 2014a, 2015a

# Hickson Compact Groups

"By *compact group*, we mean a small, relatively isolated system of typically four or five galaxies in close proximity to one another."

Hickson 1997 ARA&A 35, 357

High fraction of E/S0

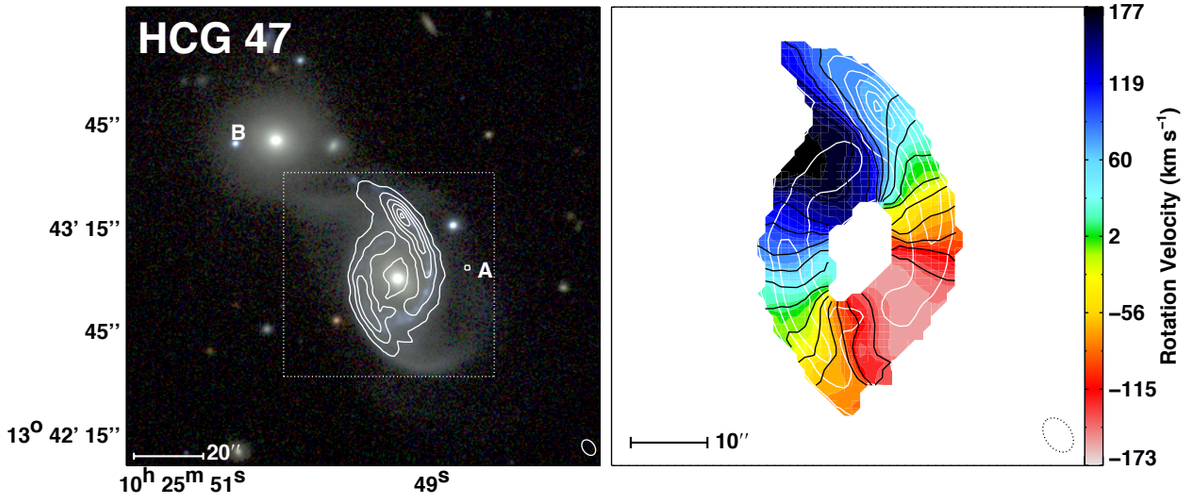
Evidence of tidal interactions

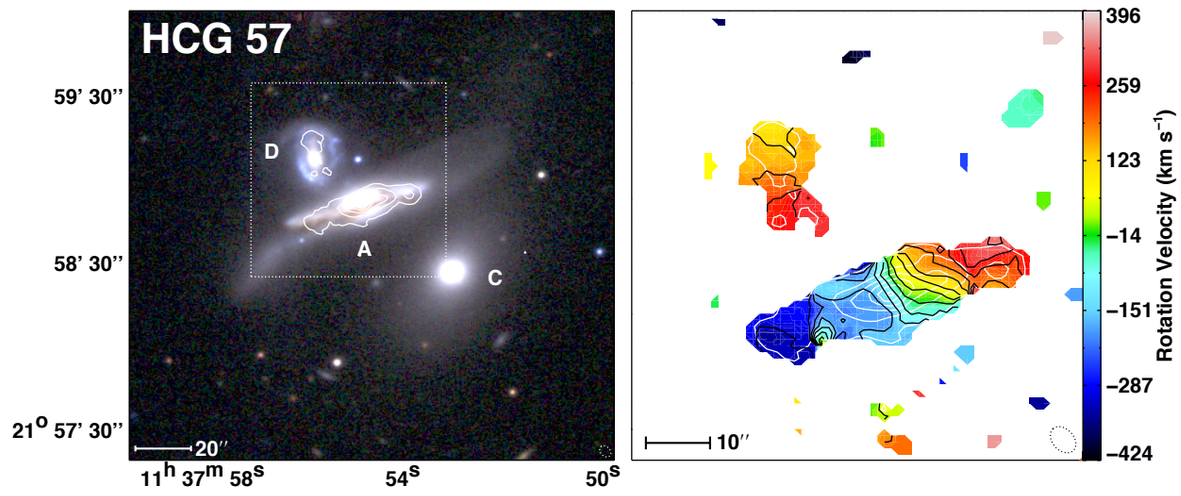
High density, low $\sigma_v$

Generally deficient in H I

Galaxies rapidly evolve within them

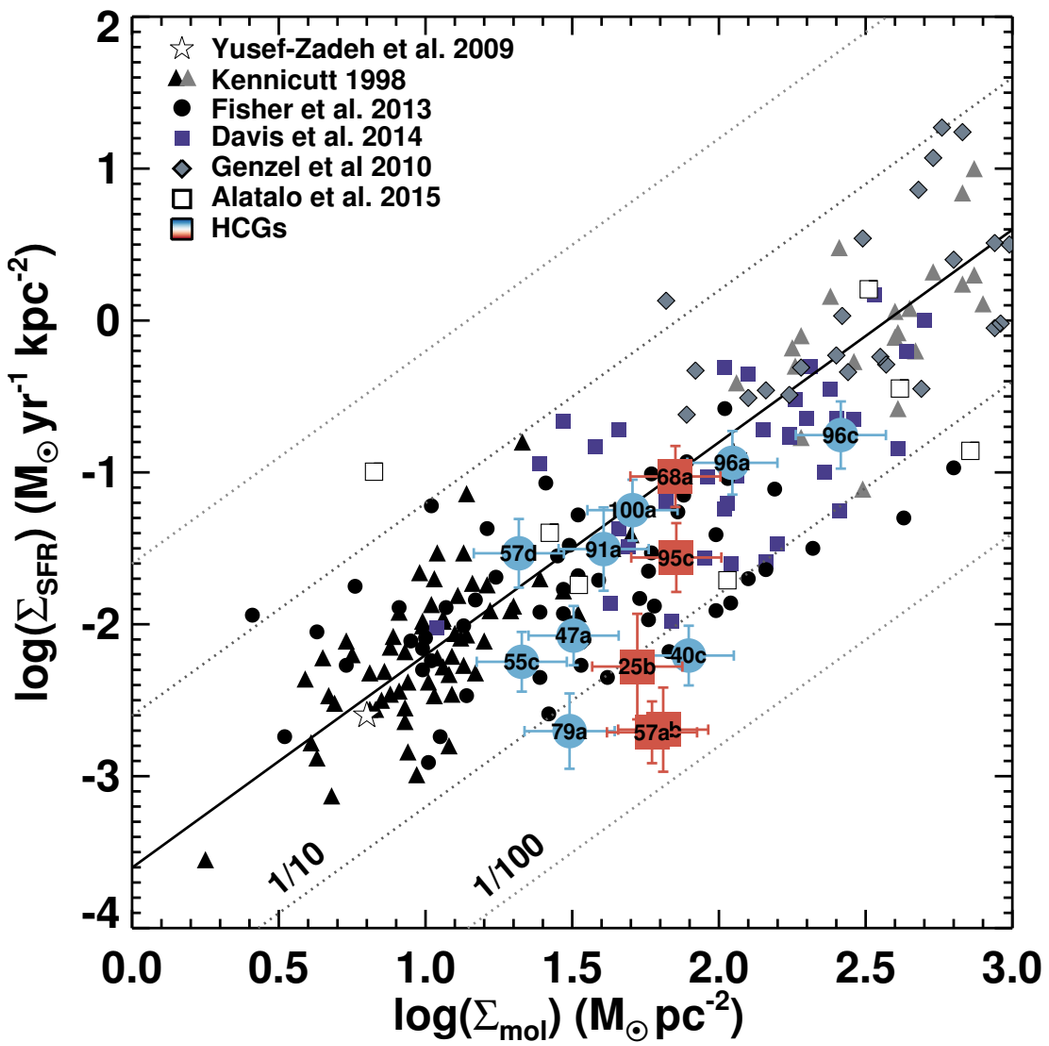
# CO(1-0) imaging in HCGs



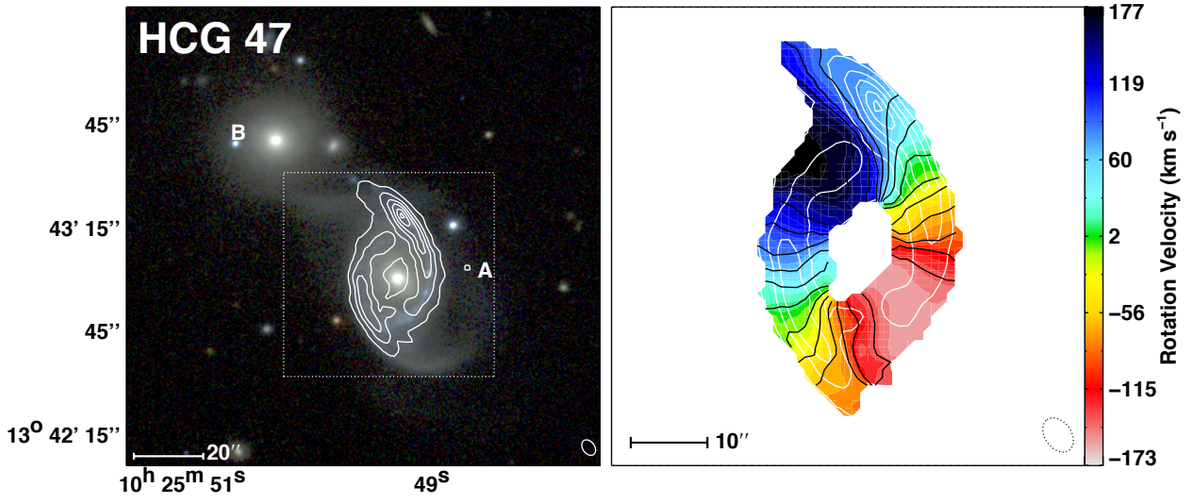

CARMA imaging of the 12 warm $H_2$-bright HCGs (14 galaxies) were detected to high significance.

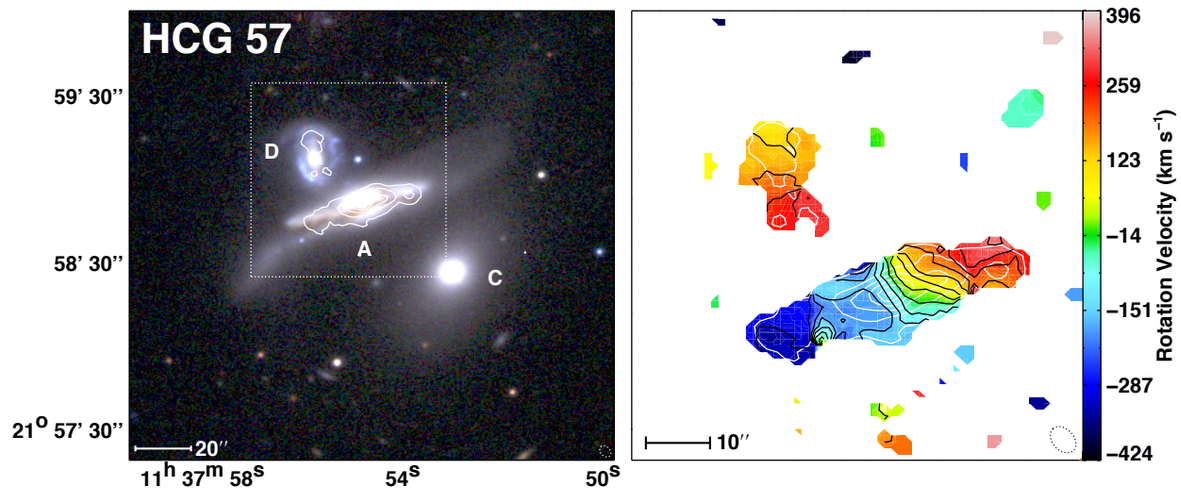
In 5/14 galaxies, there is significant evidence that star formation is inefficient within the molecular gas




Alatalo et al. 2015b

# CO(1-0) imaging in HCGs

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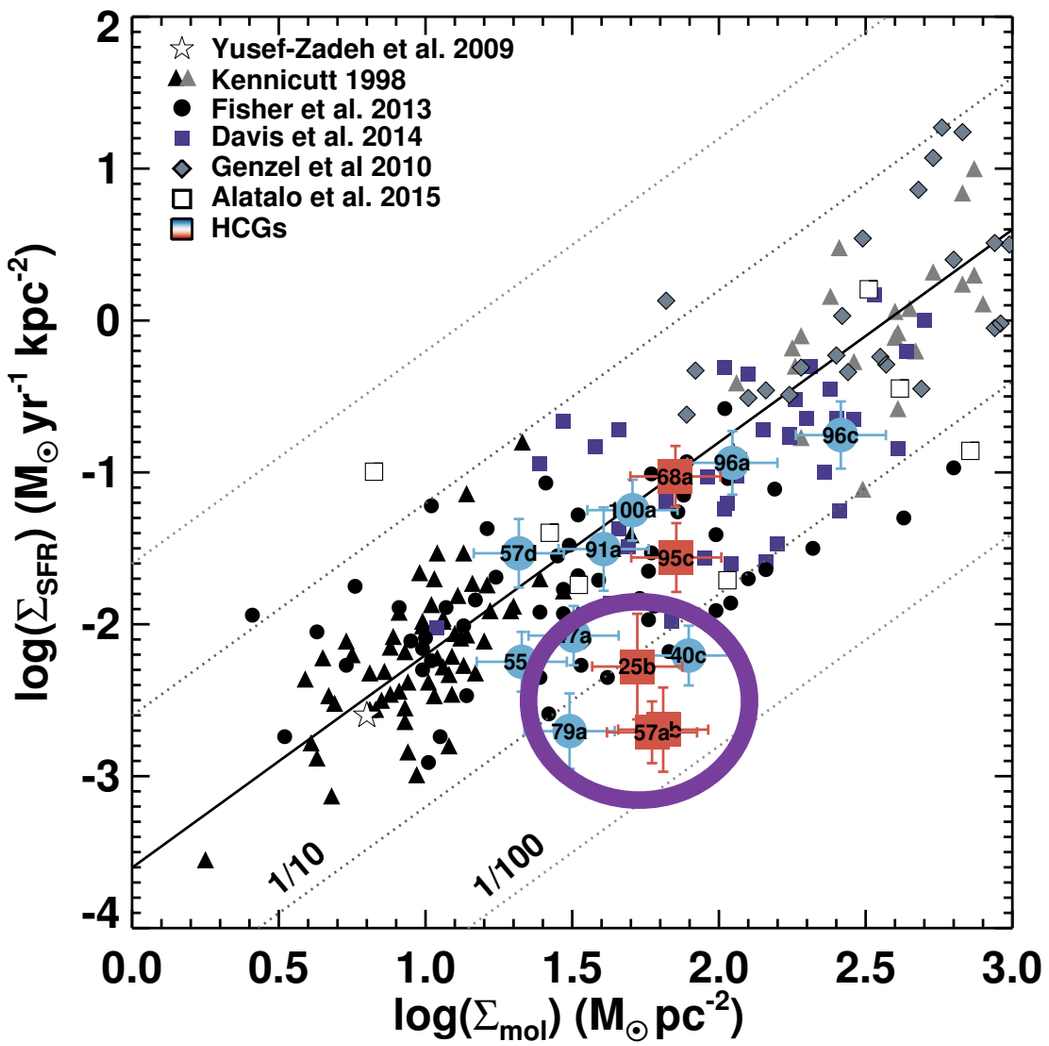
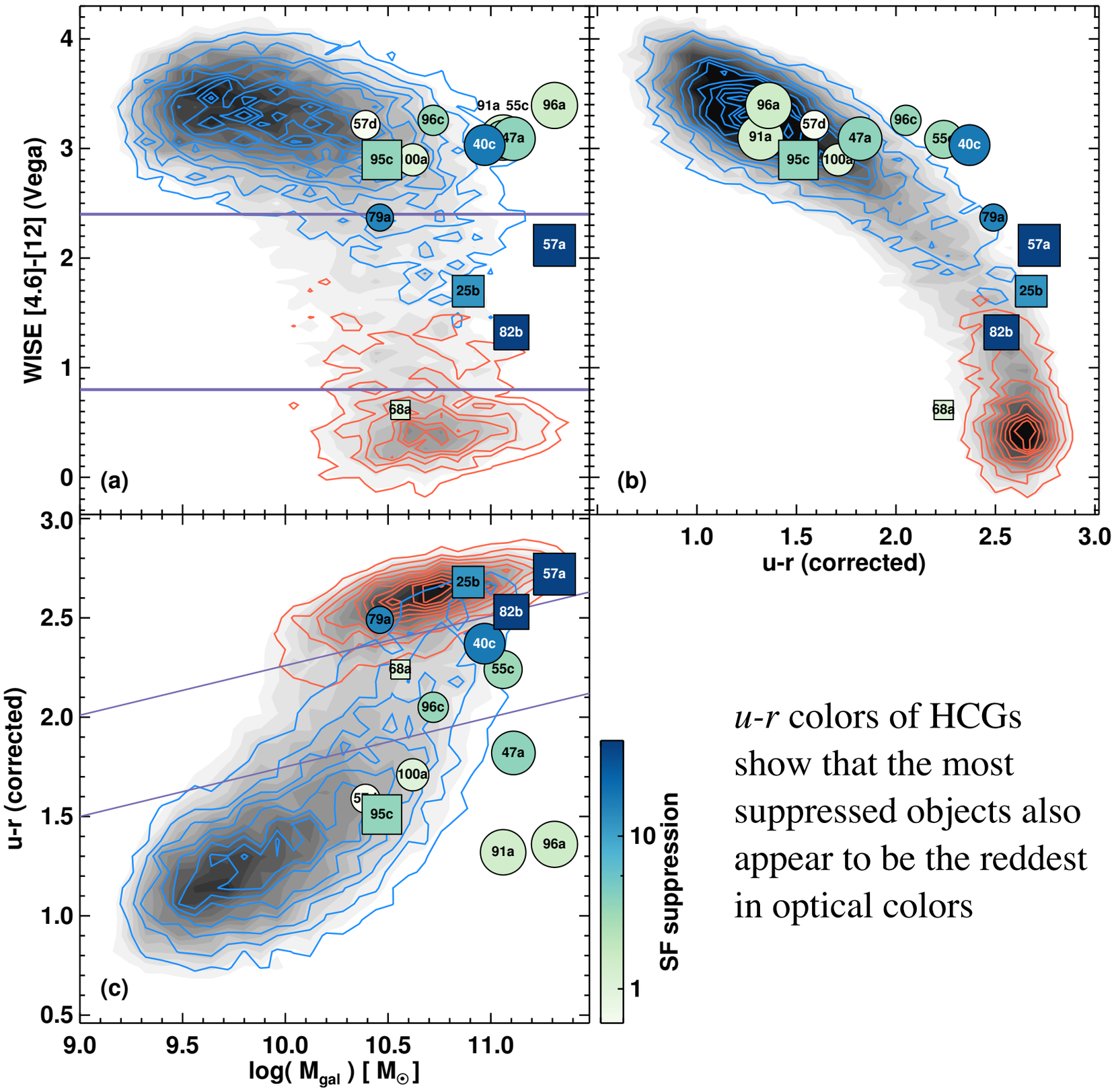



Alatalo et al. 2015b

# CO-rich HCGs in color space




[4.6]-[12]μm colors of HCGs shows that many sit at the edge of the star-forming cloud, with the suppressed galaxies sitting in the IR transition zone.

*u-r* colors of HCGs show that the most suppressed objects also appear to be the reddest in optical colors

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

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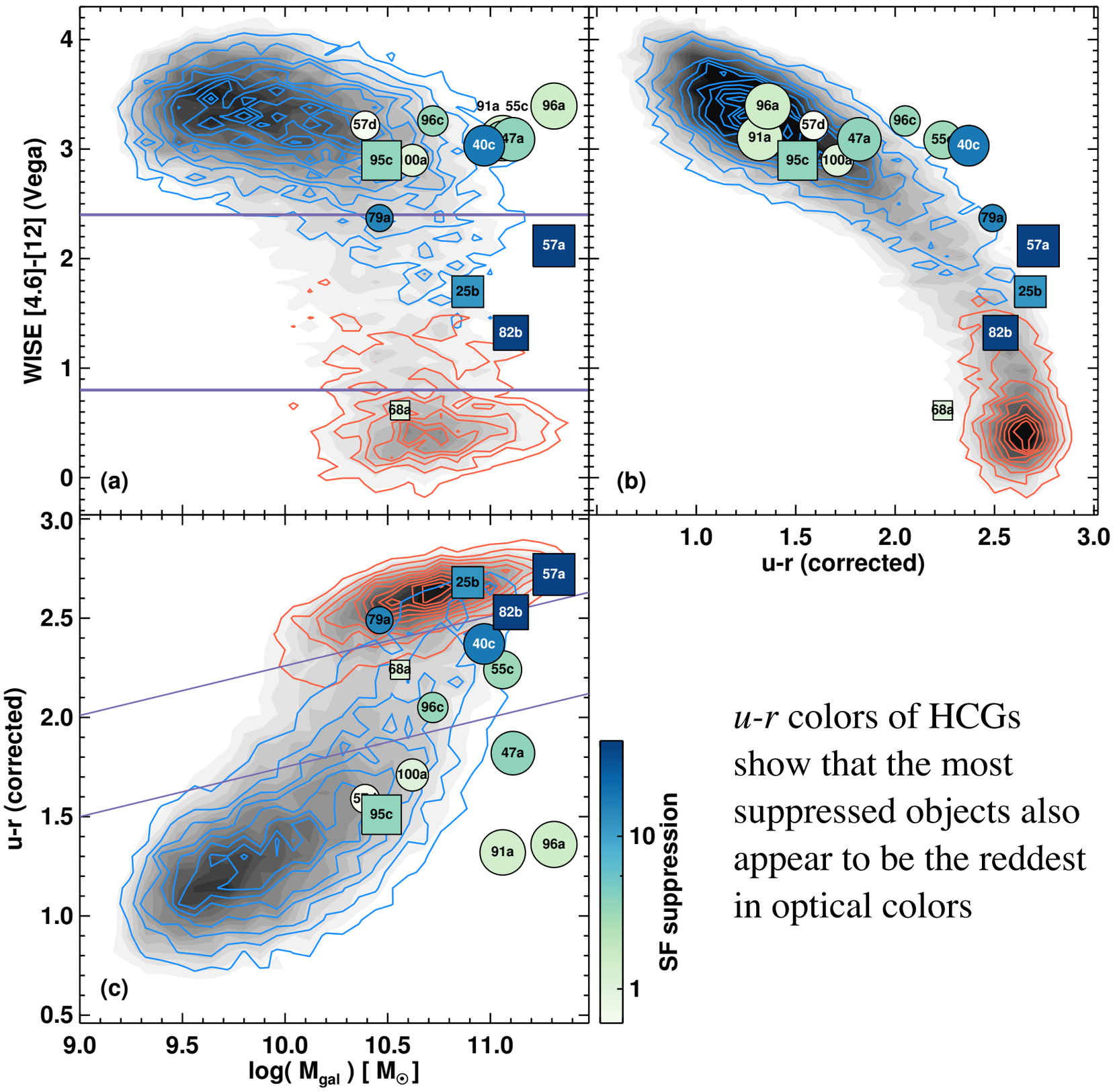


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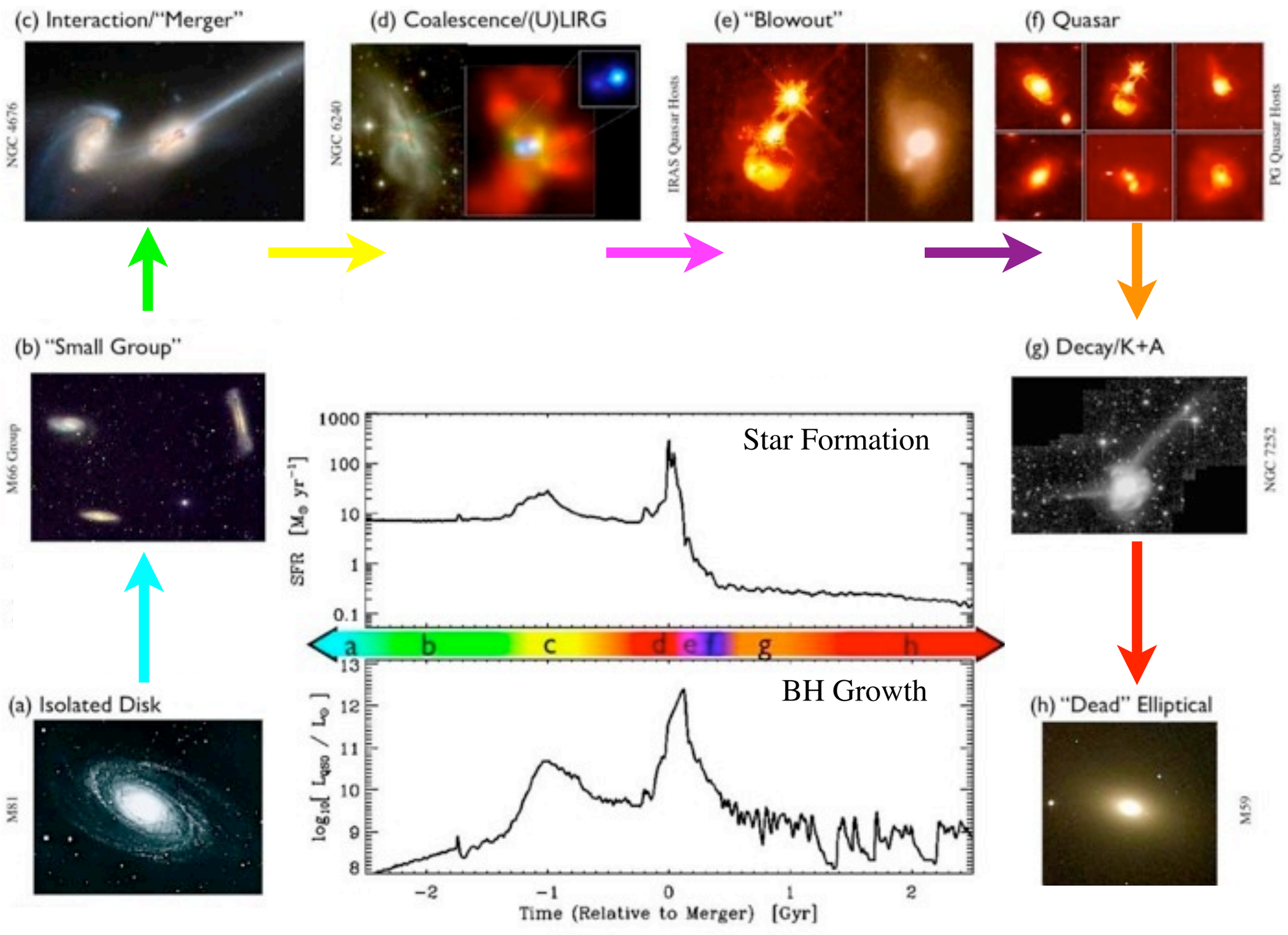
*u-r* colors of HCGs show that the most suppressed objects also appear to be the reddest in optical colors

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

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

# Transitioning galaxies and the ISM




Hopkins et al. 2008

# Transitioning galaxies and the ISM

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

New evidence is mounting that many transitioning radio galaxies (particularly those exhibiting shocks; Ogle et al. 2010) also show signs that turbulence is inhibiting star formation (Guillard et al. 2015; Lanz et al. 2016/arXiv:1511.05968)

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.

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

Hopkins et al. 2008

# The future: finding transitioning galaxies

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

What is the duty cycle of the SF quenching?

Are there many 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 of these "other" paths?

Alatalo et al. 2016, submitted

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**solution: finding other 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. 2016, submitted

# The future: radio observations change the game


maps the molecular gas in transitioning galaxies at $z$ = 0-2

detects radio free-free emission from **nearby** transitioning galaxies to accurately determine SF rates

detects dust continuum (another "SF gold standard") to high $z$ (definitely $z$ = 2)

resolved SF law at $z \approx 1$ and ability to separate AGNs from disks (including in $z$ = 1 NGC1266 analogs and SPOGs)


maps the molecular gas in transitioning galaxies at $z = 1.5^{++}$

detects radio free-free emission from transitioning galaxies to ***much higher z***, ($z$ = 2, peak of SF)

detects dust continuum to $z \gg 2$

resolved SF law past $z \approx 2$ and ability to separate AGNs from disks (including in $z$ = 2 NGC1266 analogs and SPOGs)