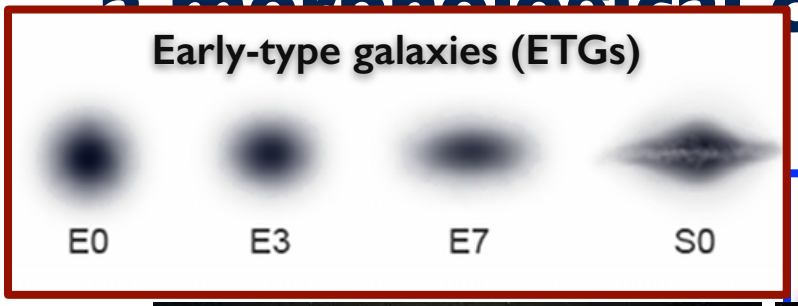
Catching quenching galaxies: how WISE follows the road less traveled from blue spirals to red ellipticals

Katey Alatalo
The Infrared Processing & Analysis Center
Caltech
kalatalo@ipac.caltech.edu

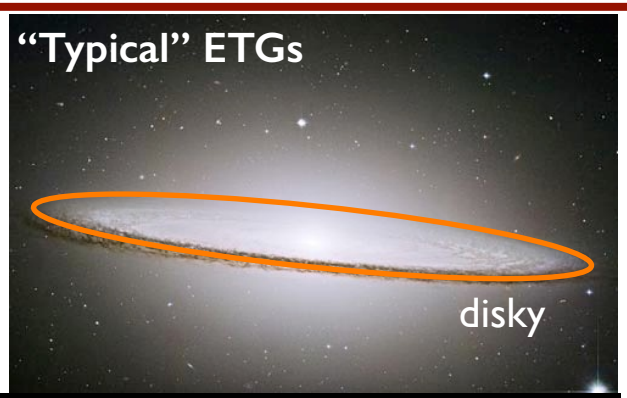
with: **Philip Appleton (IPAC),** Theodoros Bitsakis (UNAM), Sabrina Cales (Yale), Philip Chang (UW - Milwaukee), Vassilis Charmandaris (U. Crete), Michelle Cluver (UCT), Tim Davis (Hertfordshire), P.T. de Zeeuw (ESO), Mike Dopita (ANU), Emily Freeland (Stockholm), Pierre Guillard (IAS), Tom Jarrett (UCT), Lisa J. Kewley (ANU), Mark Lacy (NRAO), Lauranne Lanz (IPAC), Ute Lisenfeld (U. Granada), Carol Lonsdale (NRAO), Sergio Martín (IRAM), David Meier (NMT, NRAO), Kristina Nyland (ASTRON), Patrick Ogle (IPAC), Jesper Rasmussen (Dark Cosmology Centre), Jeff Rich (IPAC/Carnegie), Lourdes Verdes-Montenegro (U. Andalucía), C. Kevin Xu (IPAC) and Min Yun (UMass - Amherst)

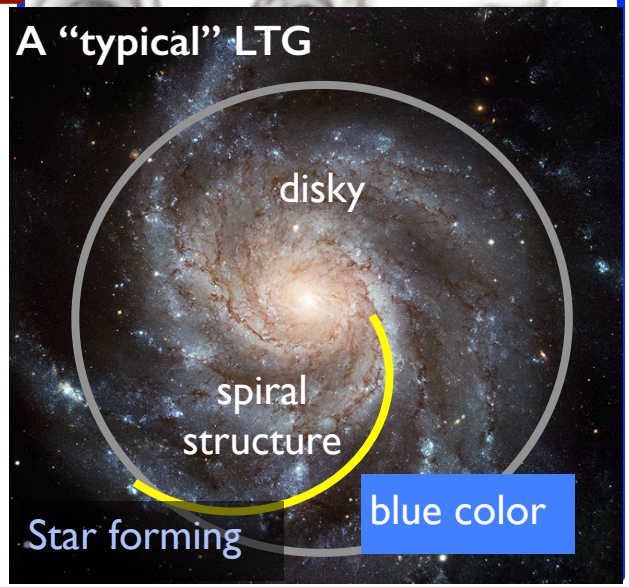
The Hubble sequence
a morphological classification



Late-type galaxies (LTGs)

Lenticular / S0

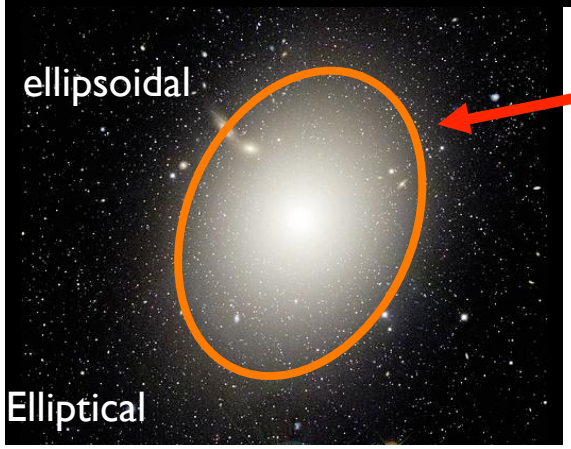




smooth light profile : lack spiral structure

red color

Quiescent



Paths to transition

late-type

mergers

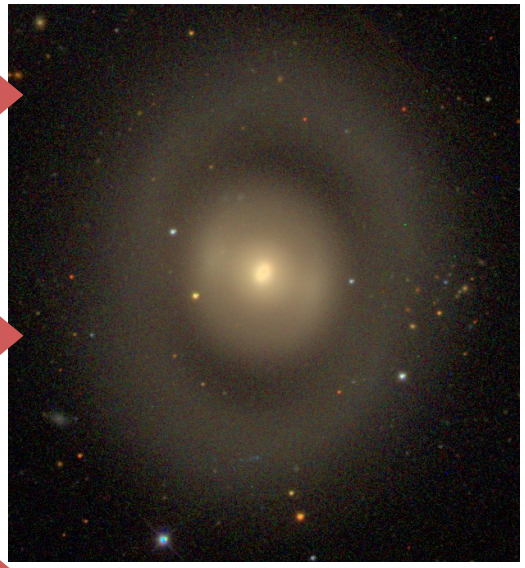
falling into a cluster

secular evolution

group interactions

other

early-type



Quenching SF

other

Poststarburst Phase
~1 Gyr in duration

Signs of young stars but no recent star formation

Likely to be found in the green valley (between blue cloud and red sequence)

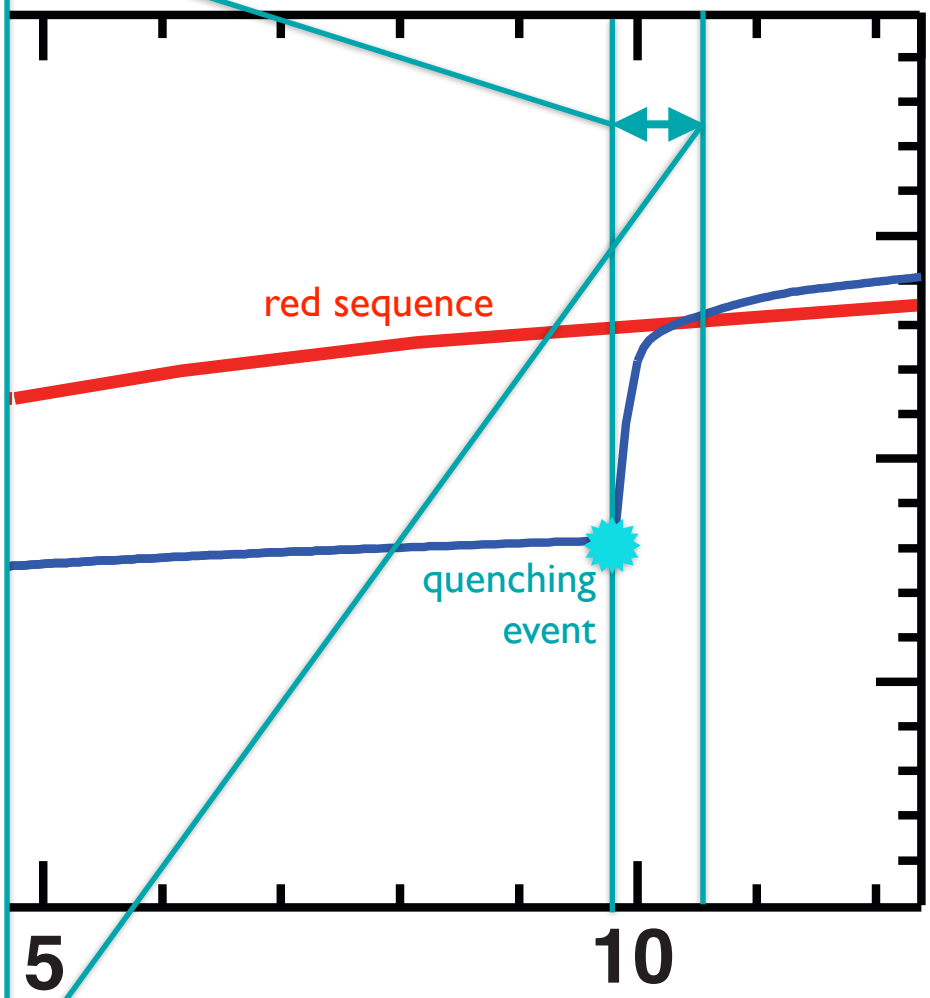
Found both to be merger remnants and non-interacting galaxies

Cales et al. 2010

Quenching Event

Much shorter duration

Mechanism less well understood



Harker et al. 2006

NGC 1266

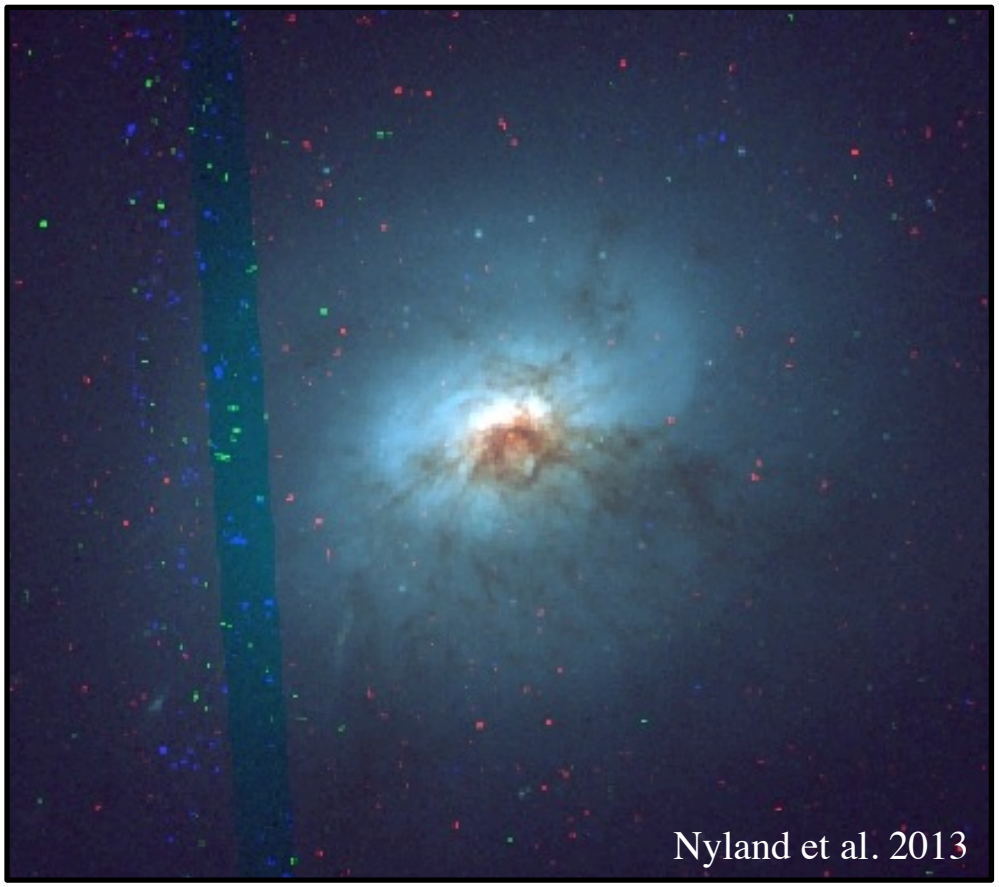
NGC 1266 appears to be a “quiescent” S0

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

NGC 1266 contains an AGN

A young (1/2 Gyr) stellar population outside the nucleus points to a gravitational interaction causing the molecular gas to move to the center

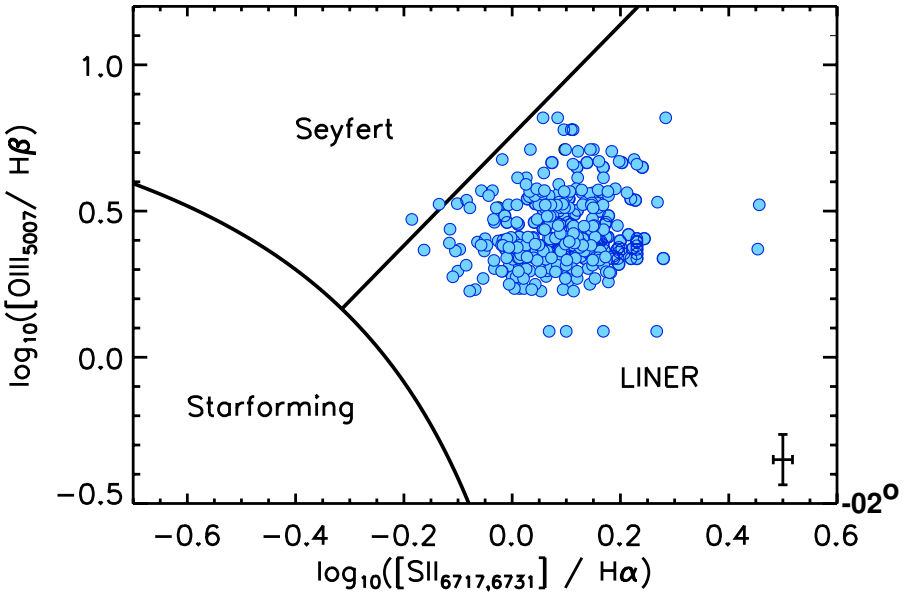
Star formation is suppressed by a factor of 50-150 seen in the nucleus



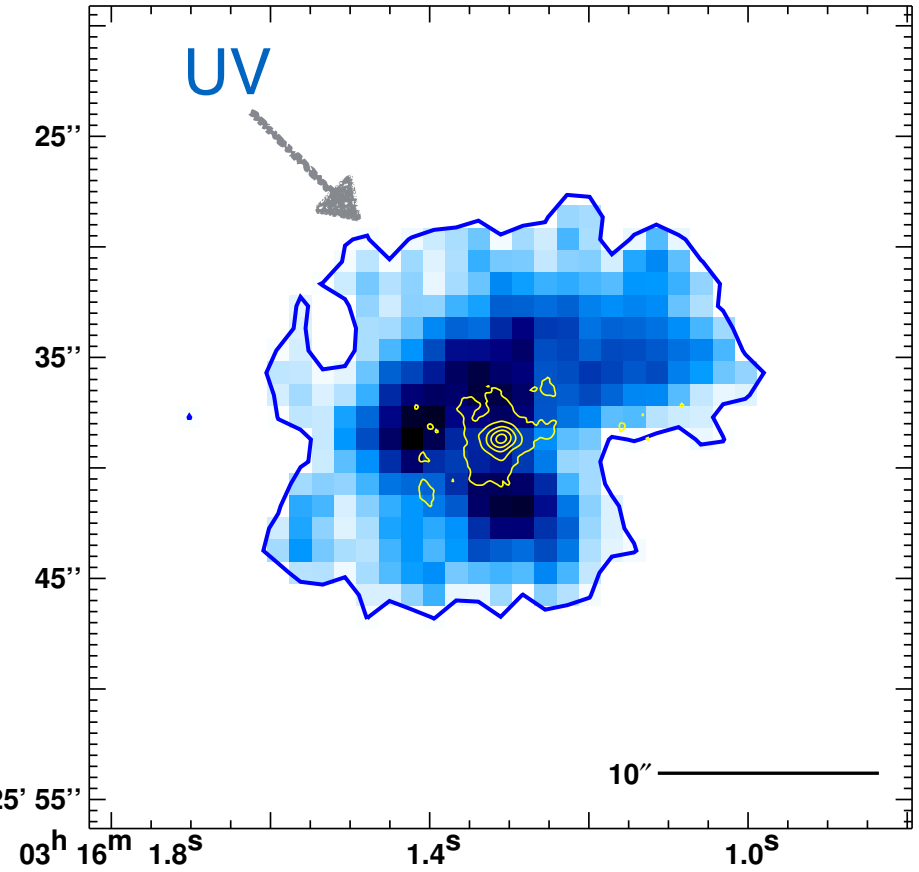
Alatalo et al. 2011, 2014a, 2015

Finding the needle in the haystack

NGC 1266 hosts an AGN-driven outflow, but also contains a unique set of optical features



shocked ionized gas (Davis et al 2012)



young(ish) stellar population (Alatalo et al. 2014a)

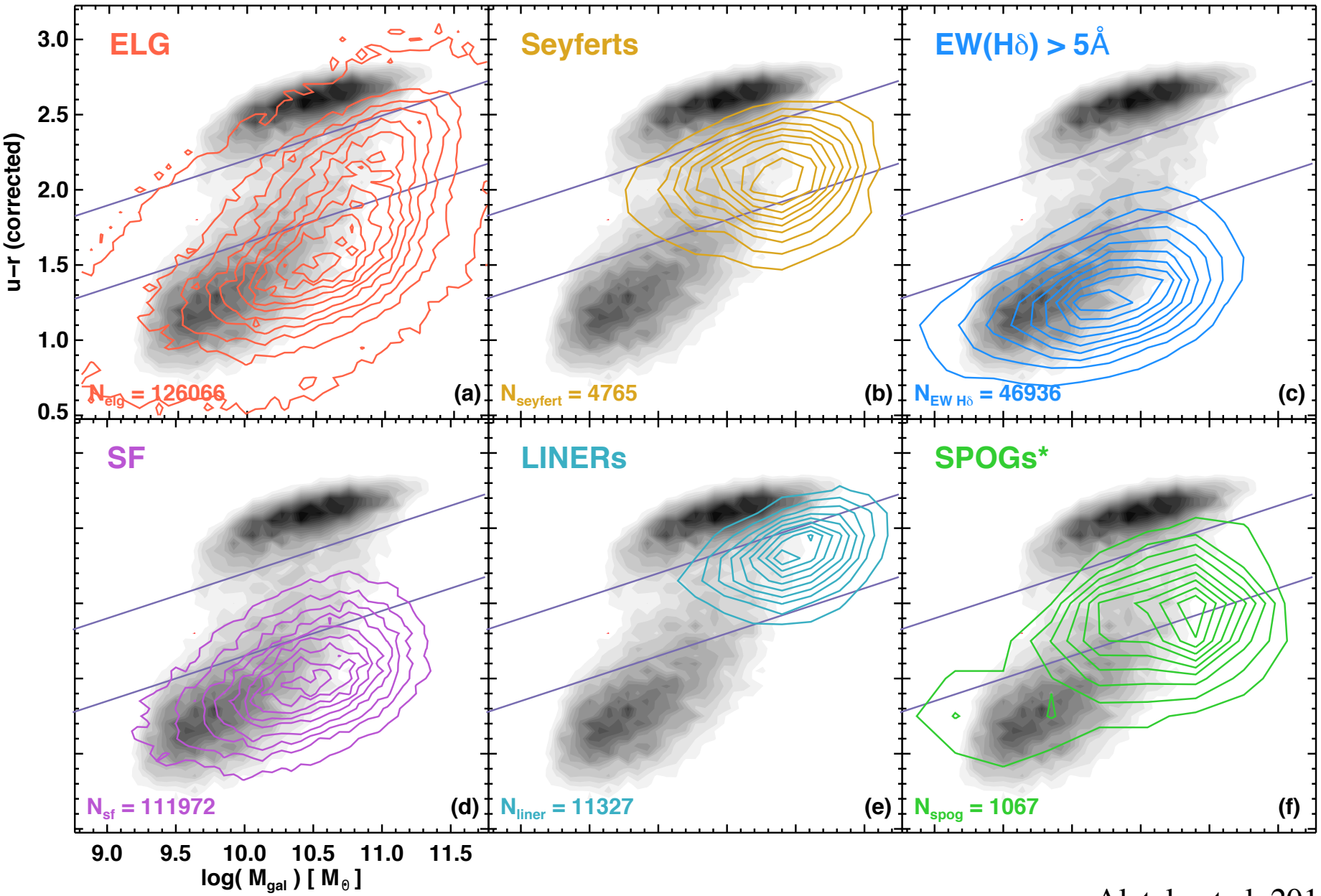
shocked ionized gas ratios + poststarburst stellar population

=

a Shocked Poststarburst Galaxy (SPOG)

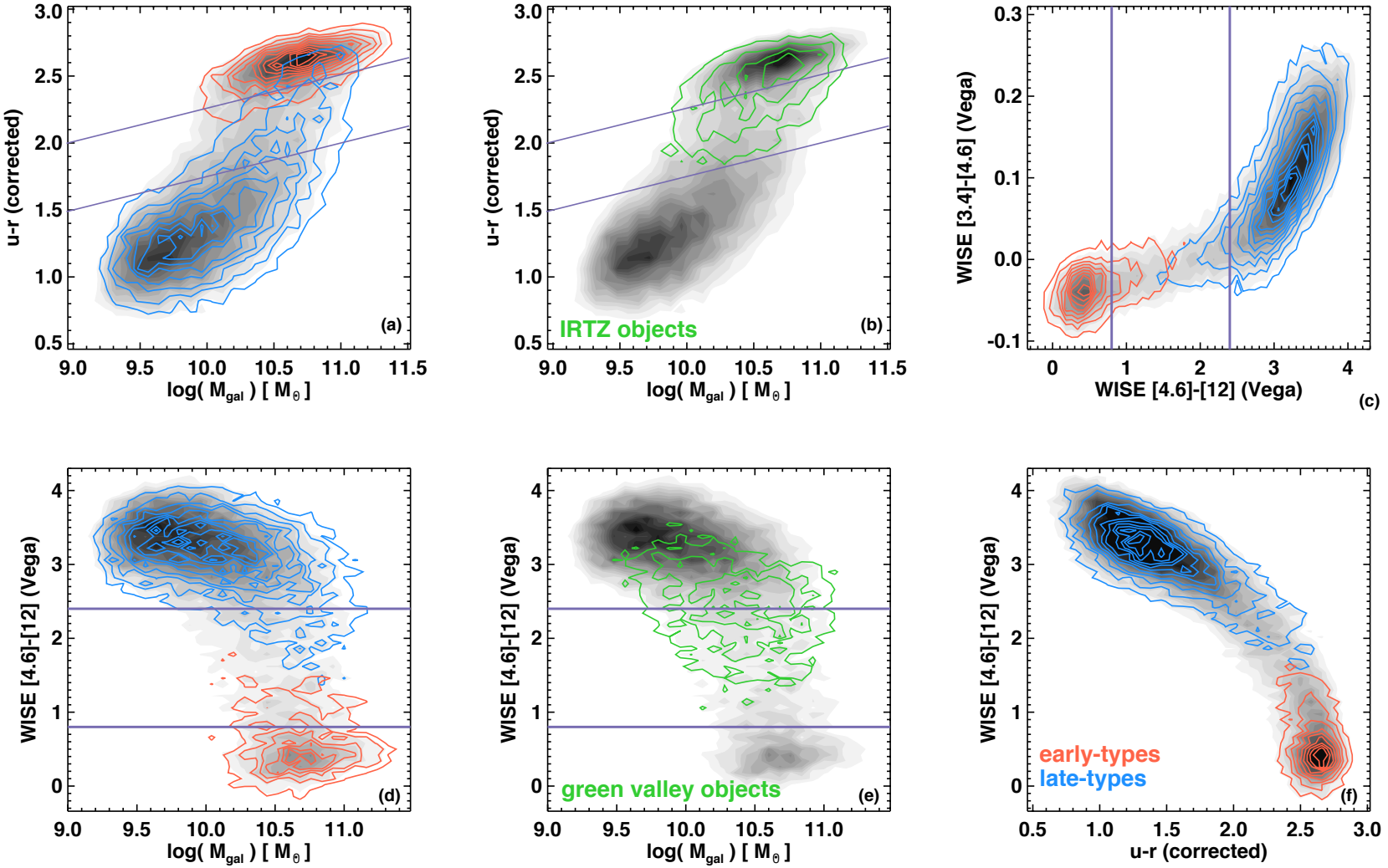
NGC 1266 is a SPOG.

SPOGS: the first results



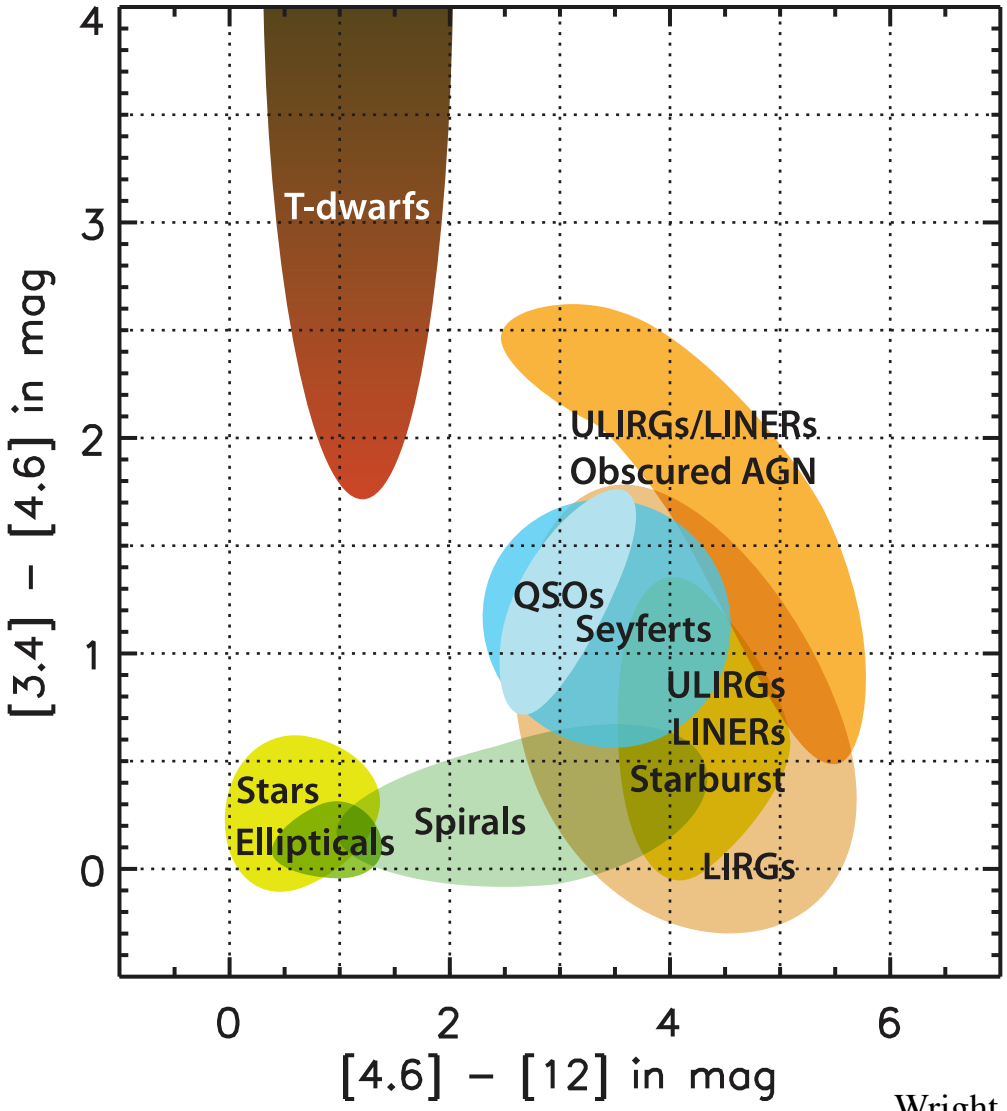
Alatalo et al. 2014b

The unexpected



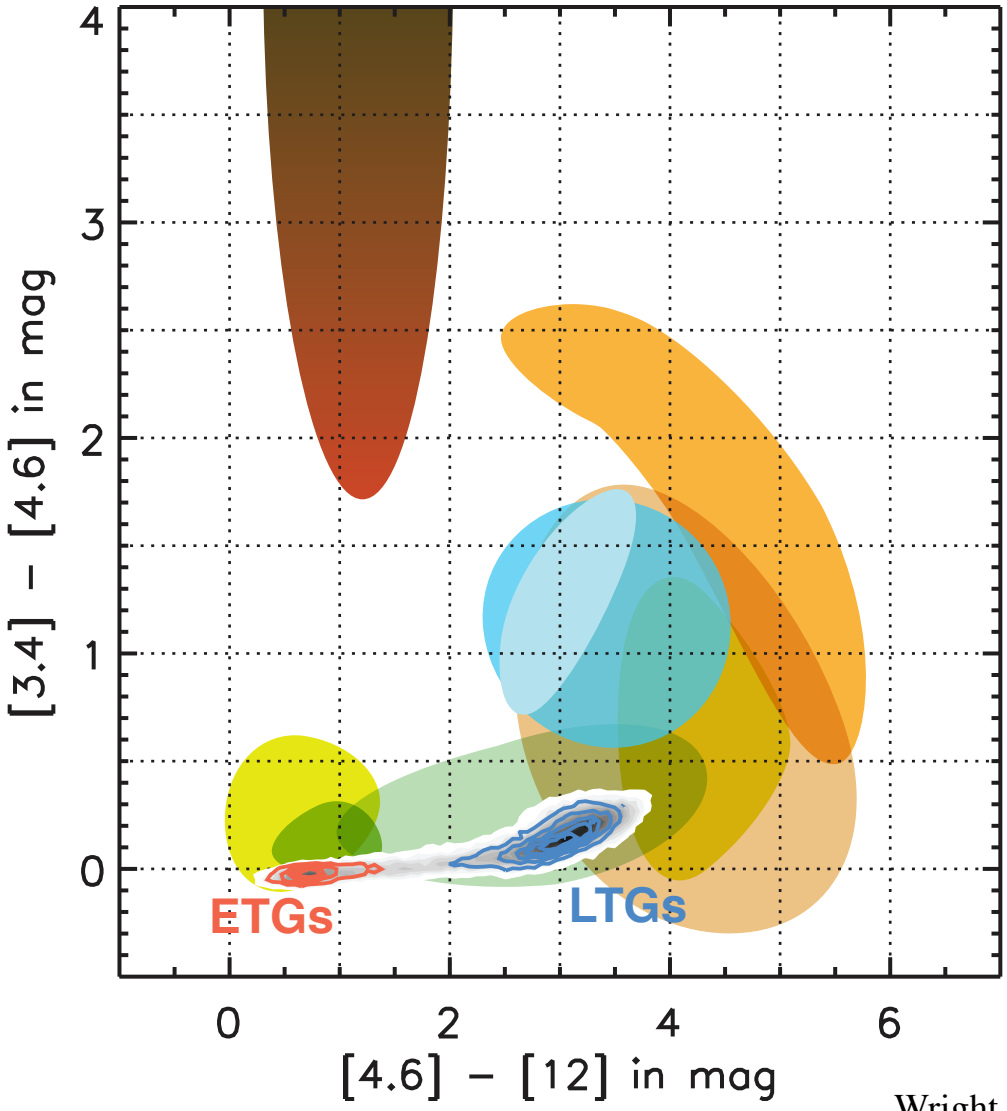
The WISE Infrared Transition Zone (IRTZ); Alatalo et al. 2014b, Schawinski et al. 2014

What do these WISE colors mean?



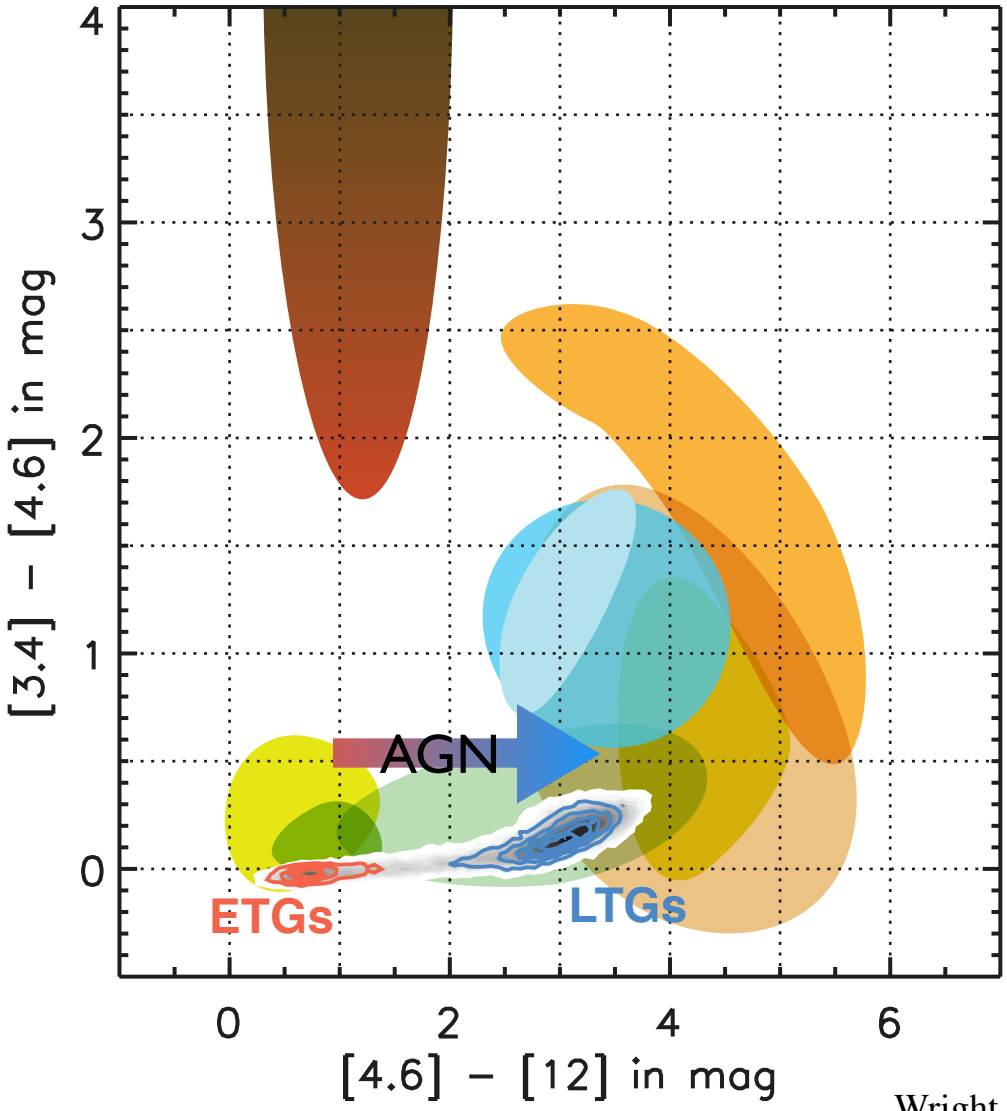
Wright et al. 2010, Alatalo et al. 2014b

What do these WISE colors mean?



Wright et al. 2010, Alatalo et al. 2014b

What do these WISE colors mean?



Wright et al. 2010, Alatalo et al. 2014b

Hickson Compact Groups:

Galaxy evolution on steroids

group interactions

Introducing: Hickson Compact groups

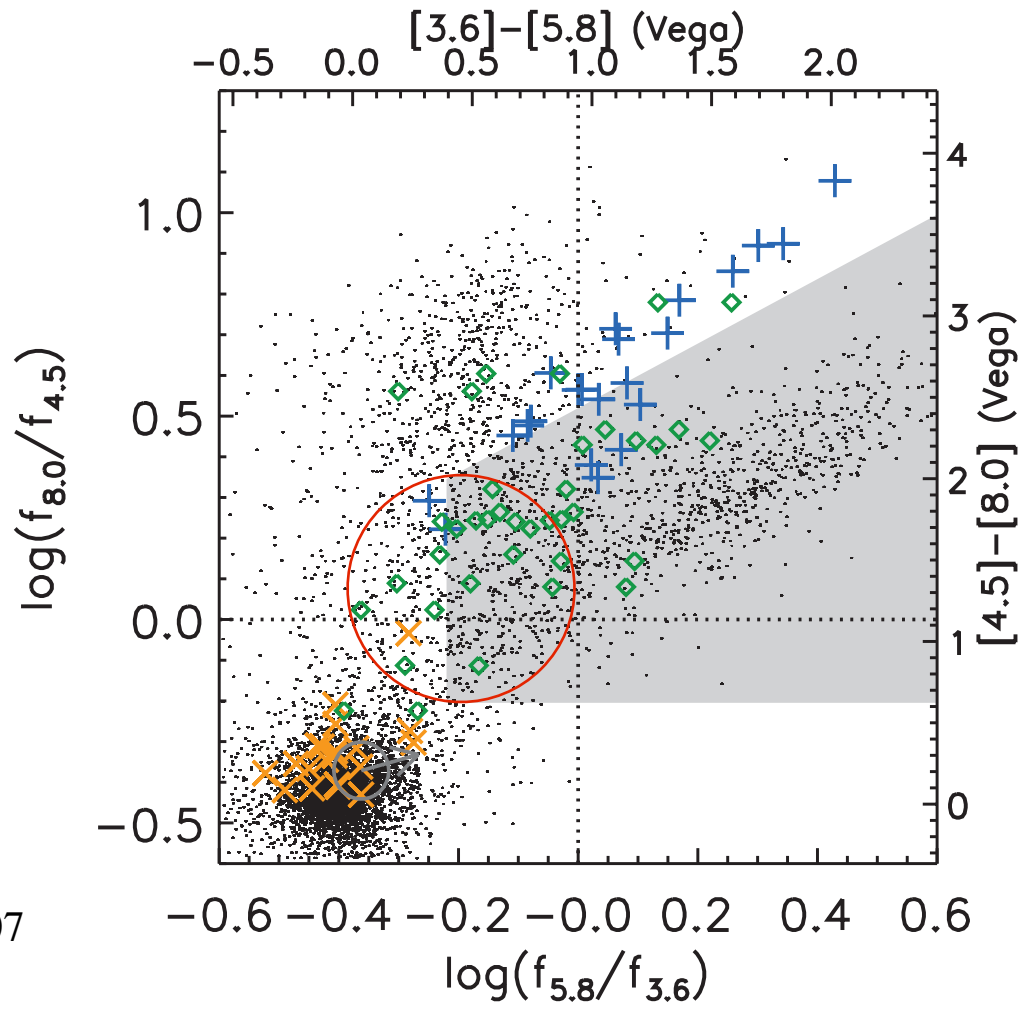
HCGs have bimodal IR colors

Color-color plot from Lacy et al. (2004)
Lower left: red ETG HCGs
Upper right: blue spiral HCGs
Green: star-forming (non-HCG) galaxies

HCGs show bimodality between red colors (X) and blue colors (+) with very few in the gap

This gap is not as obvious in underlying population

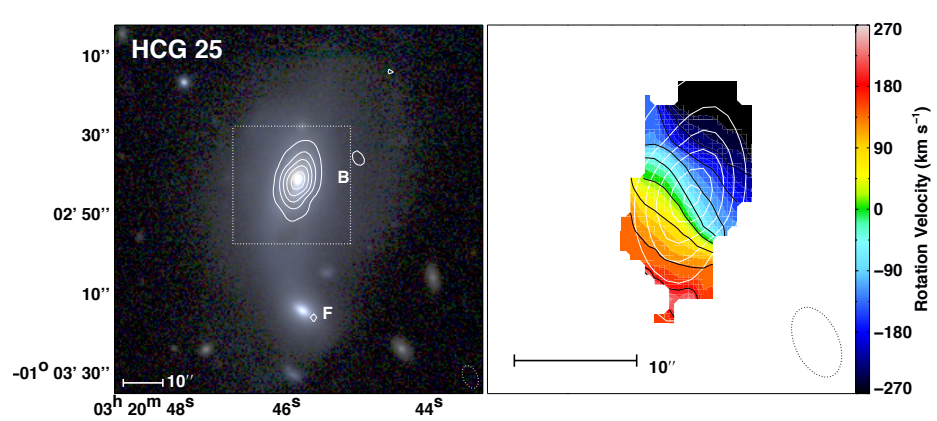
=> rapid evolution in HCGs

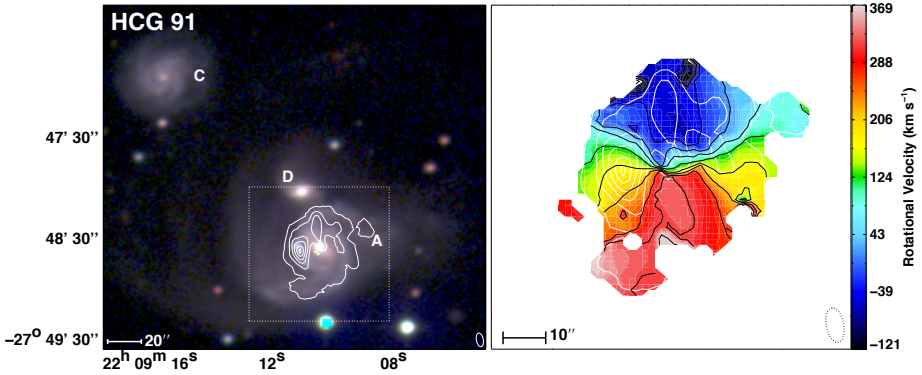


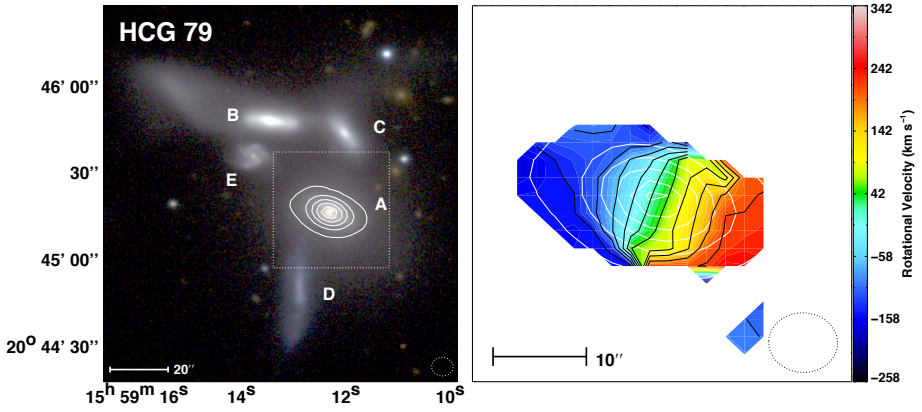
Johnson et al. 2007

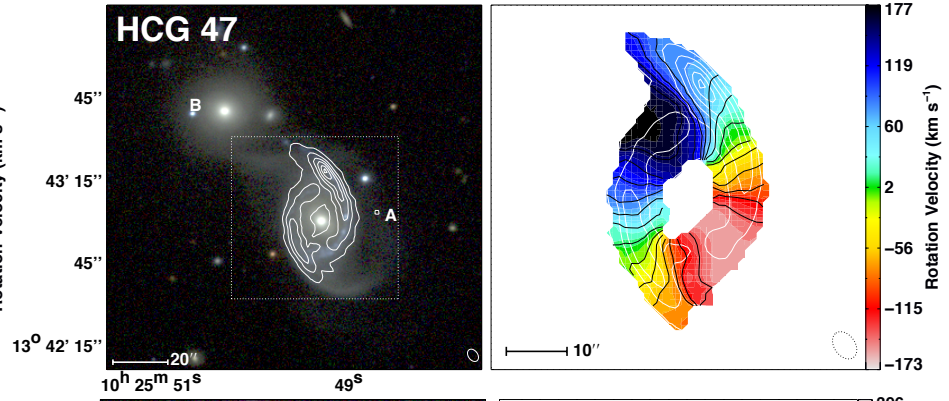
Lacy et al. 2004, 2007; Johnson et al. 2007

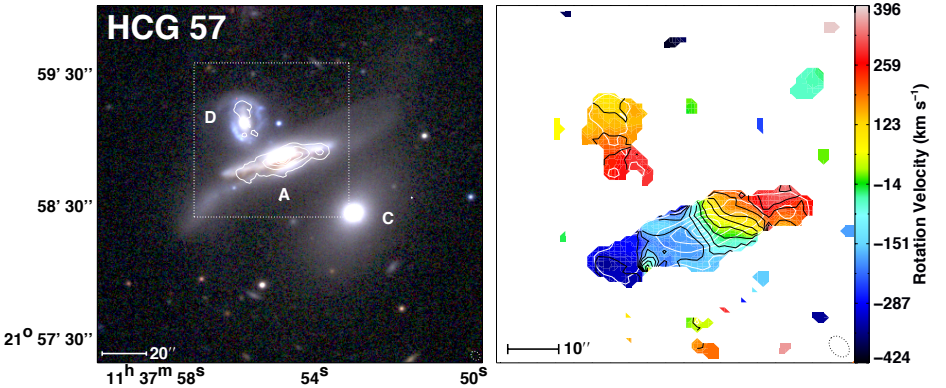
CO(1-0) imaging in HCGs

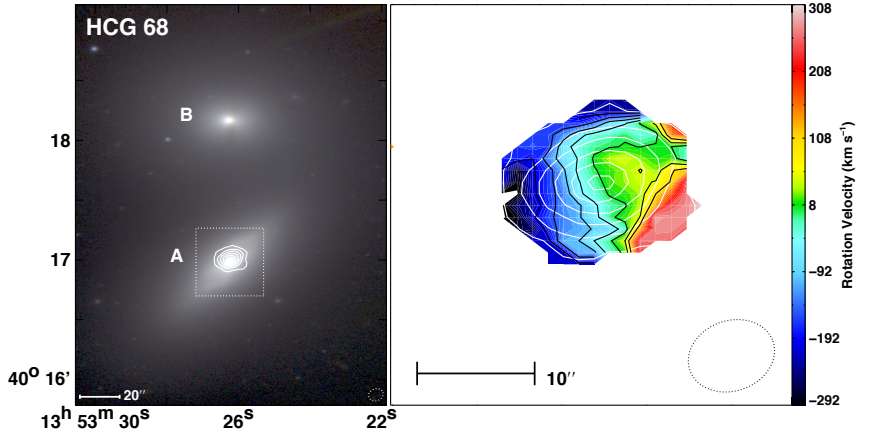






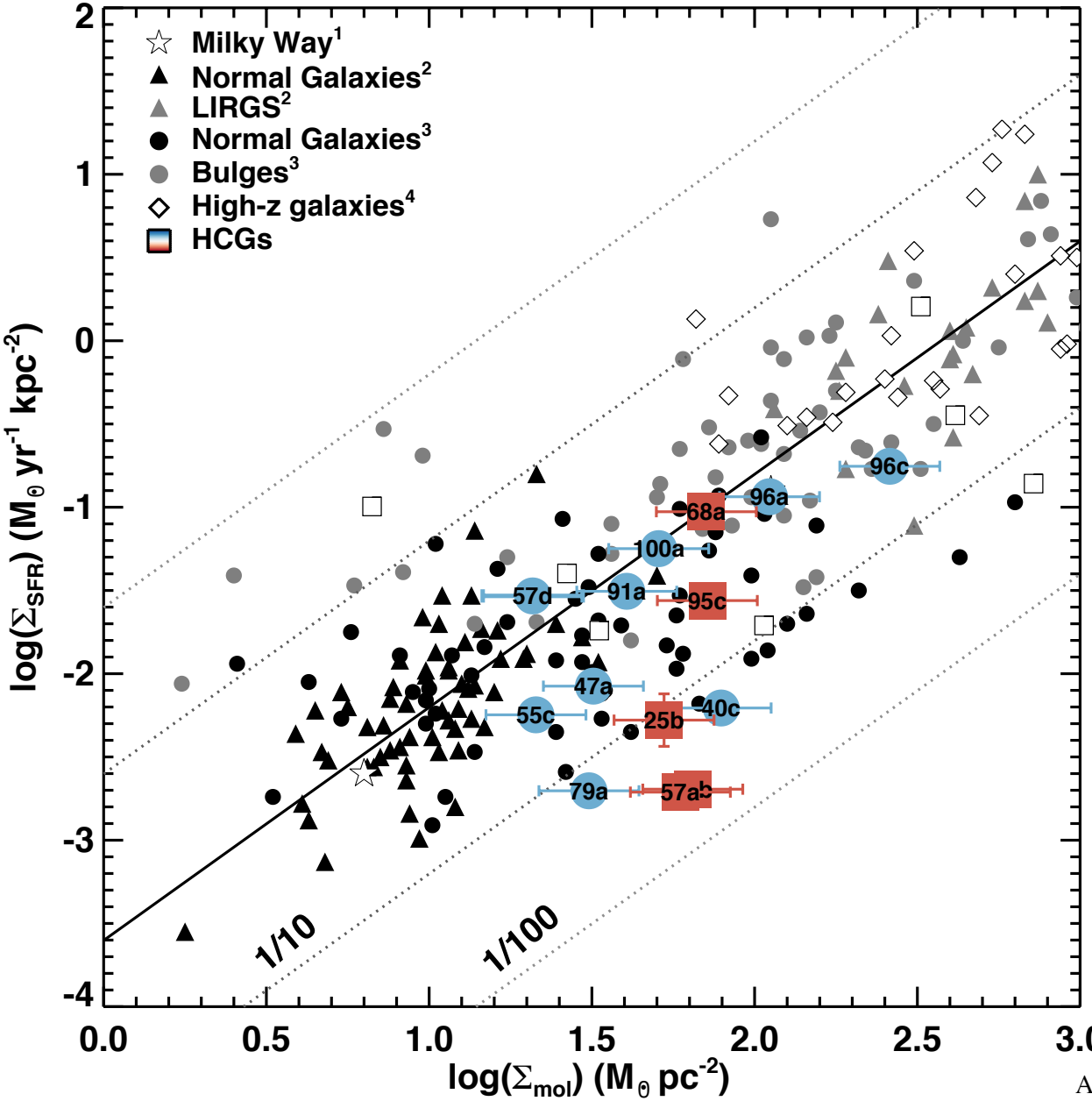






Alatalo et al. 2015, in preparation

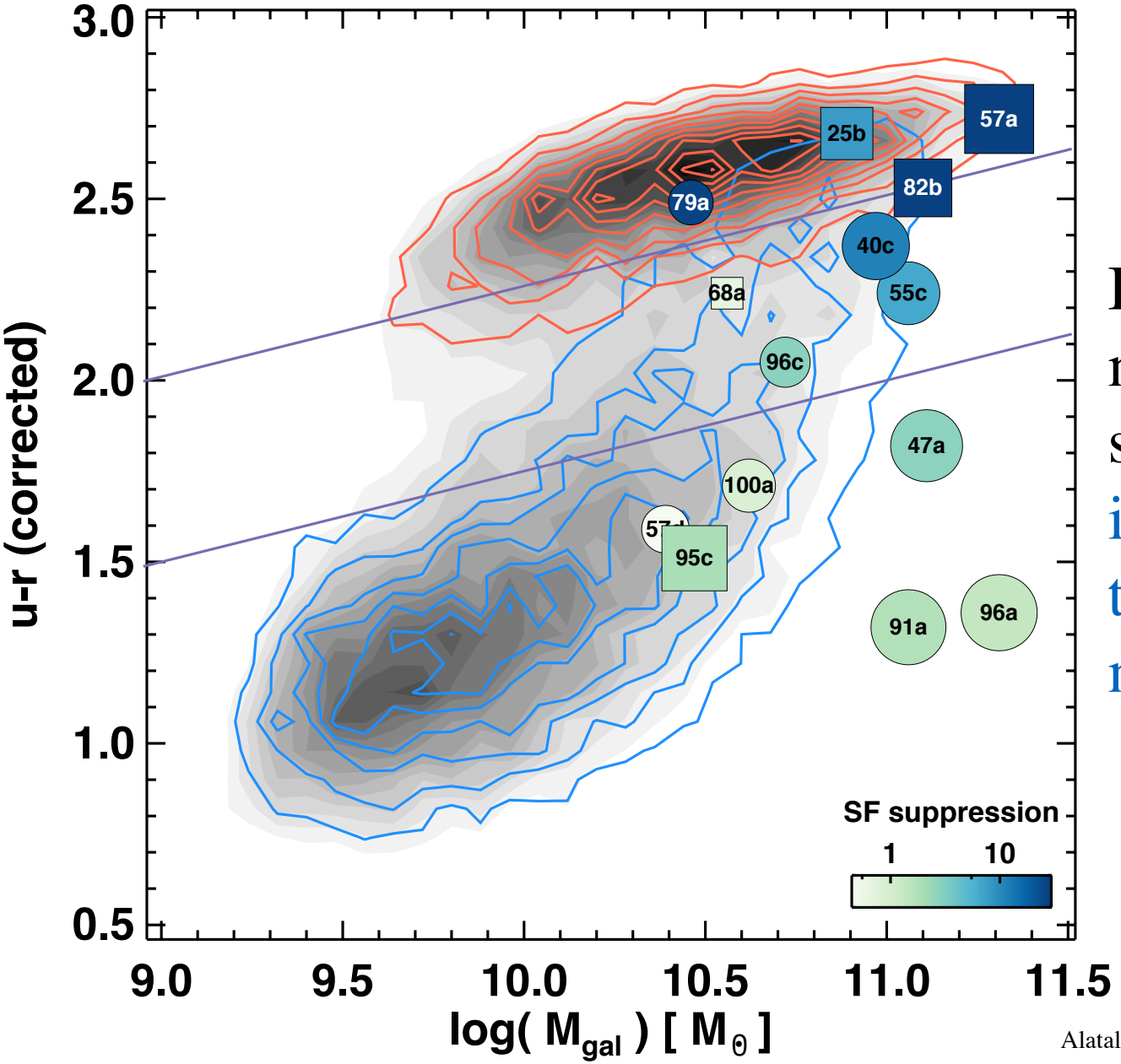
Inhibited star formation?



HCG galaxies in our sample seem to be under-producing stars for the amount of existing molecular gas.

Alatalo et al. 2014c, Alatalo et al. 2015, in preparation

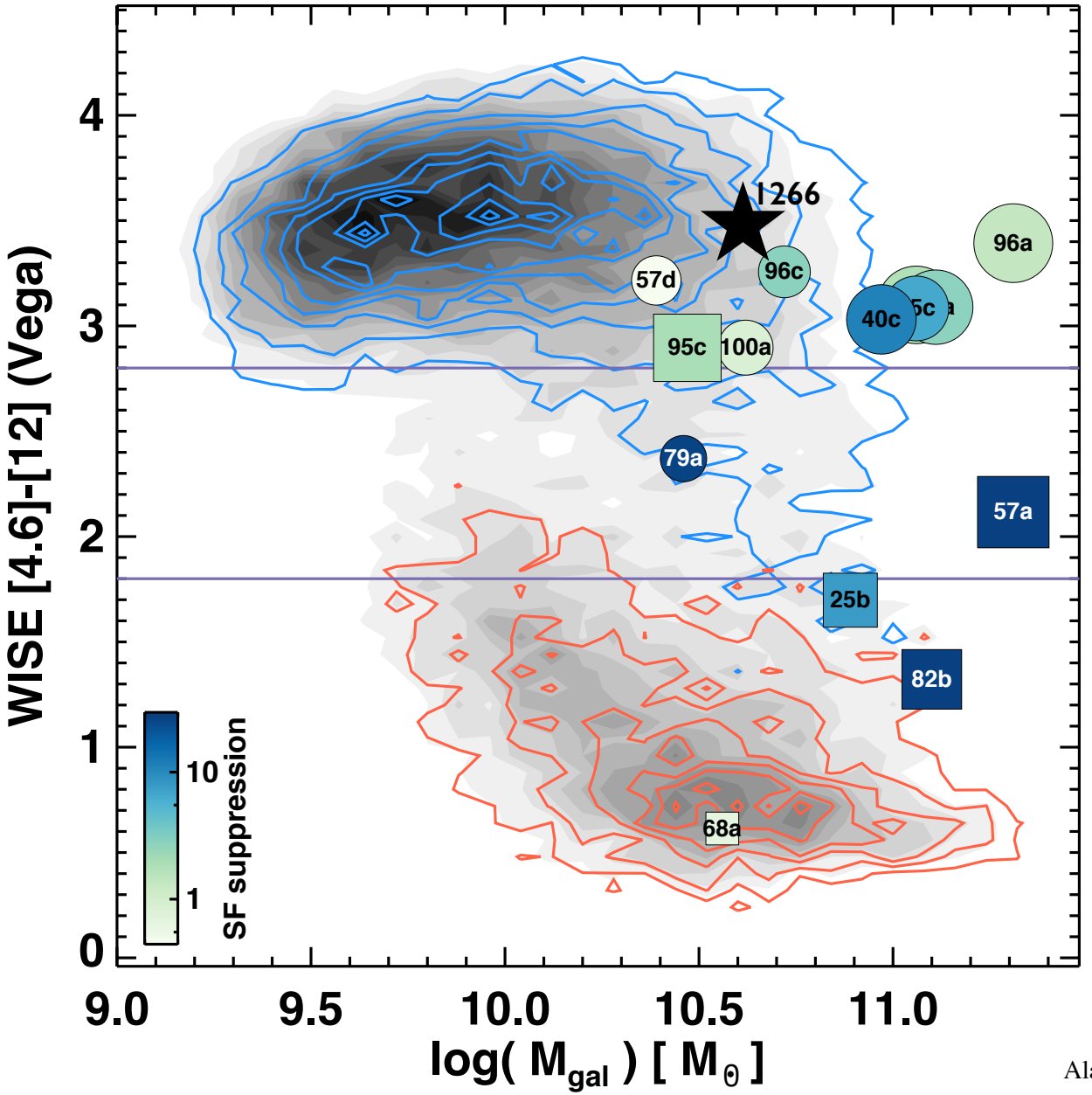
SF suppression & a connection to the IRTZ



IRTZ galaxies most likely to be suppressed, independent of the total amount of molecular gas

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

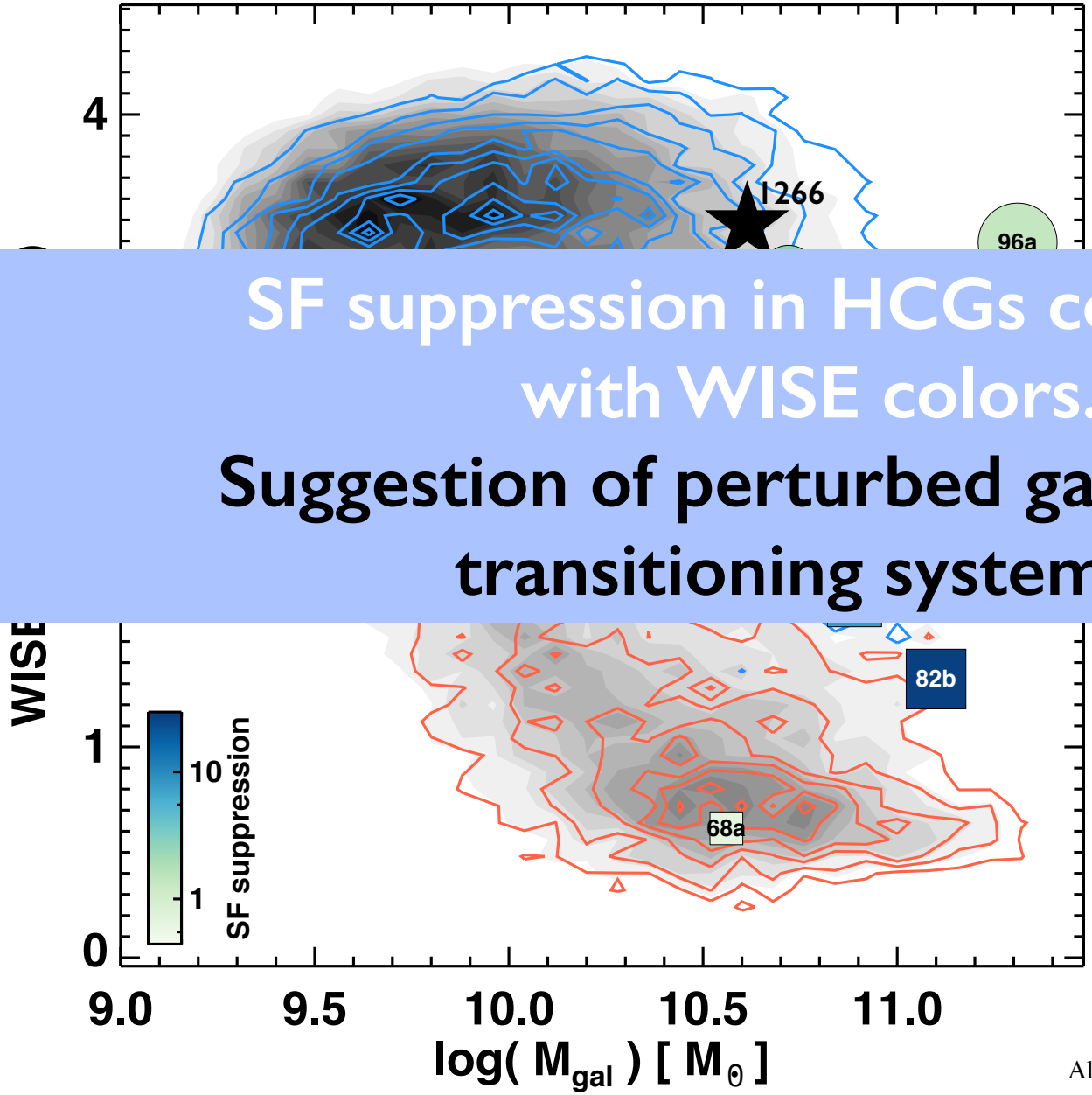
SF suppression & a connection to the IRTZ



IRTZ galaxies most likely to be suppressed, independent of the total amount of molecular gas

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

SF suppression & a connection to the IRTZ



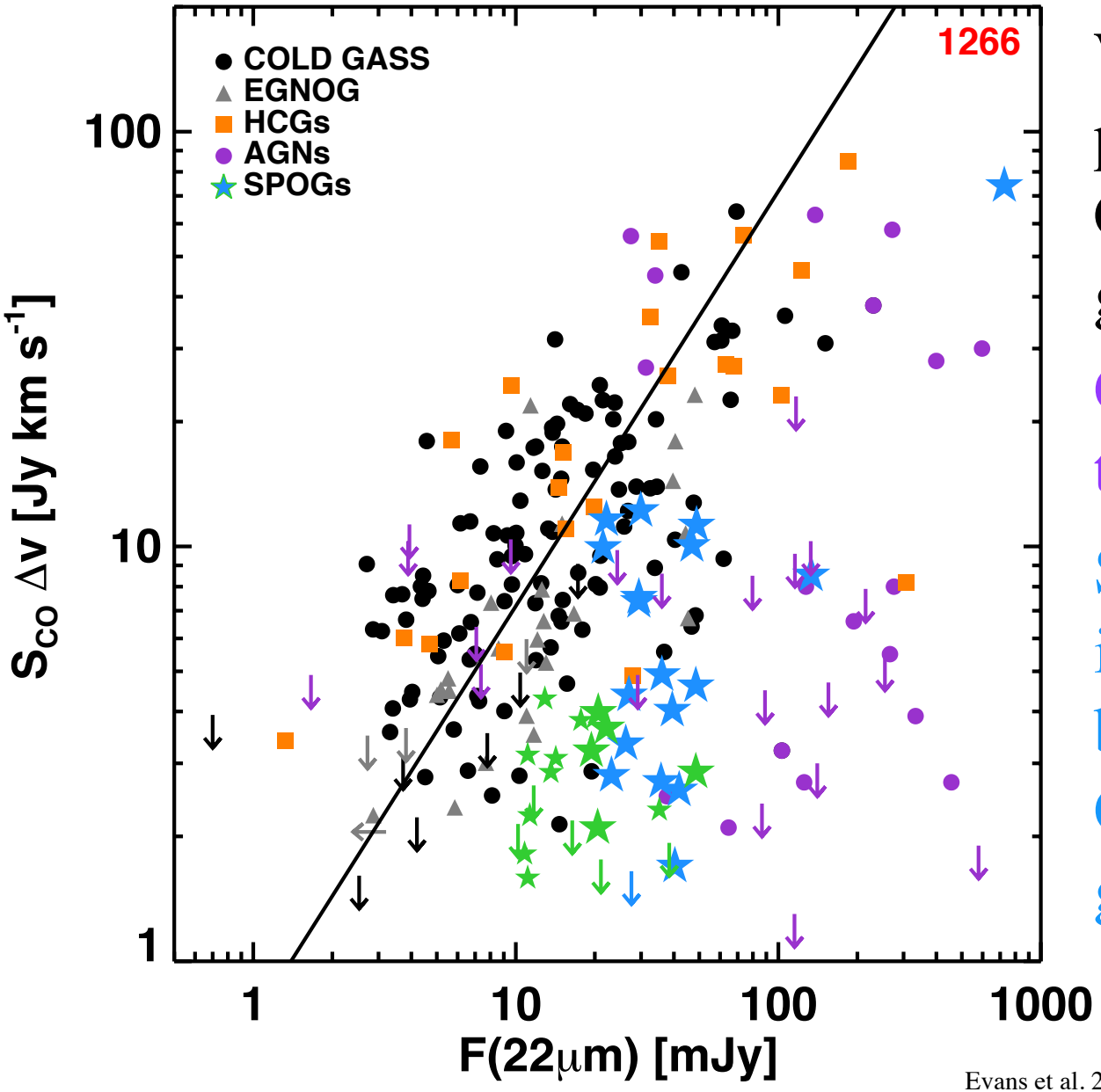
SF suppression in HCGs correlates with WISE colors.

Suggestion of perturbed gas in these transitioning systems?

molecular gas

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

WISE in the ALMA era



WISE 22μm can predict the total CO flux for SF galaxies

QSOs fall off of this relationship

SPOGs seem to lie in the region between pure QSOs and SF galaxies

Saintonge et al. 2011, Bauermeister et al. 2012, Evans et al. 2010, Lisenfeld et al. 2014, Alatalo et al. 2015, in prep

WISE and transitioning galaxies

group interactions

WISE is able to identify objects with SF suppression in HCGs through the W2-W3 color, and is best correlated with that suppression

other

W4 (22μm) can predict the molecular gas quite well in star forming galaxies except in AGNs, but can also identify the intermediate objects between SF and QSOs in a 22μm - S_{CO} plane

conclusions

When searching for new types of paths from spiral to ETG, serendipity helps (NGC 1266)

We are able to use the presence of a poststarburst stellar population plus shocked molecular gas to identify other galaxies like NGC 1266: spogs.

The selection from SPOGS identified transitioning objects, but also showed us a new lens through which to view transitions (the WISE IRTZ)

The IRTZ seems to identify galaxies in HCGs with suppressed SF, independent of the molecular gas mass

The WISE 22μm emission is able to predict the total CO flux in SF galaxies and identify those that are undergoing a transition (as SPOGs are predicted to be undergoing), or have intermediate luminosity AGNs.

WISE data has only just begun to be mined in search of new discoveries, and this is just a small window into them through a transitioning galaxy lens.