# Elusive dual AGN revealed by WISE



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#### (c) Interaction/"Merger"



- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)
- (b) "Small Group"



- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M<sub>halo</sub> still similar to before: dynamical friction merges the subhalos efficiently
- (a) Isolated Disk



- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with M<sub>B</sub>>-23)
- cannot redden to the red sequence

#### (d) Coalescence/(U)LIRG



- galaxies coalesce: violent relaxation in core - gas inflows to center:
- starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

#### (e) "Blowout"



- BH grows rapidly: briefly dominates luminosity/feedback
   remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host high Eddington ratios merger signatures still visible

#### (f) Quasar



- dust removed: now a "traditional" QSO
   host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

#### (g) Decay/K+A



NGC 7252

 QSO luminosity fades rapidly

 tidal features visible only with very deep observations
 remnant reddens rapidly (E+A/K+A)
 "hot halo" from feedback

- sets up quasi-static cooling

#### (h) "Dead" Elliptical



 large BH/spheroid - efficient feedback
 halo grows to "large group" scales: mergers become inefficient
 growth by "dry" mergers



### Hopkins et al. (2008)

# Recent challenges to the picture that mergers can trigger AGN, even at the highest luminosities.

THE BULK OF THE BLACK HOLE GROWTH SINCE  $z\sim 1$  OCCURS IN A SECULAR UNIVERSE: NO MAJOR MERGER–AGN CONNECTION\*

### Cisternas et al. (2011)

MAURICIO CISTERNAS<sup>1,20</sup>, KNUD JAHNKE<sup>1</sup>, KATHERINE J. INSKIP<sup>1</sup>, JEYHAN KARTALTEPE<sup>2</sup>, ANTON M. KOEKEMOER<sup>3</sup>, THORSTEN LISKER<sup>4</sup>, ADAY R. ROBAINA<sup>1,5</sup>, MARCO SCODEGGIO<sup>6</sup>, KARTIK SHETH<sup>7,8</sup>, JONATHAN R. TRUMP<sup>9</sup>, RENÉ ANDRAE<sup>1</sup>, TAKAMITSU MIYAJI<sup>10,11</sup>, ELISABETA LUSSO<sup>12</sup>, MARCELLA BRUSA<sup>13</sup>, PETER CAPAK<sup>7</sup>, NICO CAPPELLUTI<sup>13</sup>, FRANCESCA CIVANO<sup>14</sup>, OLIVIER ILBERT<sup>15</sup>, CHRIS D. IMPEY<sup>9</sup>, ALEXIE LEAUTHAUD<sup>16</sup>, SIMON J. LILLY<sup>17</sup>, MARA SALVATO<sup>18</sup>, NICK Z. SCOVILLE<sup>7</sup>, AND YOSHI TANIGUCHI<sup>19</sup>

### Schawinski et al. (2012)

# Heavily obscured quasar host galaxies at $z \sim 2$ are discs, not major mergers<sup>\*</sup>

Kevin Schawinski,<sup>1,2</sup>†‡ Brooke D. Simmons,<sup>2,3</sup> C. Megan Urry,<sup>1,2,3</sup> Ezequiel Treister<sup>4</sup> and Eilat Glikman<sup>2,3</sup>§

### Morphologies of $z \sim 0.7$ AGN host galaxies in CANDELS: no trend of merger incidence with AGN luminosity

C. Villforth,<sup>1,2</sup>\* F. Hamann,<sup>1</sup> D. J. Rosario,<sup>3</sup> P. Santini,<sup>4</sup> E. J. McGrath,<sup>5</sup>

A. van der Wel,<sup>6</sup> Y. Y. Chang,<sup>6</sup> Y. Guo,<sup>7</sup> T. Dahlen,<sup>8</sup> E. F. Bell,<sup>9</sup> C. J. Conselice,<sup>10</sup>

D. Croton,<sup>11</sup> A. Dekel,<sup>12</sup> S. M. Faber,<sup>7</sup> N. Grogin,<sup>8</sup> T. Hamilton,<sup>13</sup> P. F. Hopkins,<sup>14,15</sup>

S. Juneau,<sup>16</sup> J. Kartaltepe,<sup>17</sup> D. Kocevski,<sup>18</sup> A. Koekemoer,<sup>8</sup> D. C. Koo,<sup>7</sup> J. Lotz,<sup>8</sup>

D. McIntosh,<sup>19</sup> M. Mozena,<sup>7</sup> R. Somerville<sup>20</sup> and V. Wild<sup>2</sup>

### Villforth et al. (2014)

### Villforth et al. (2017)

Host galaxies of luminous z~0.6 quasars: Major mergers are not prevalent at the highest AGN luminosities \*

C. Villforth<sup>1,2</sup>, T. Hamilton<sup>3</sup>, M. M. Pawlik<sup>2</sup>, T. Hewlett<sup>2</sup>, K. Rowlands<sup>2</sup>, H. Herbst<sup>4</sup>, F. Shankar<sup>5</sup>, A. Fontana<sup>6</sup>, F. Hamann<sup>4,8</sup>, A. Koekemoer<sup>7</sup>, J. Pforr<sup>9,10</sup>, J. Trump<sup>11,12</sup>, S. Wuyts<sup>1</sup>

### Observational tests of merger induced transformations: Galaxy pairs in the SDSS



DR7 pairs sample: Projected separation <80 kpc  $\Delta V$  <300 km/s Mass ratio 0.1 - 10

Yields: ~14,000 galaxies in pairs.

Construct control samples that are matched in mass, redshift and environment: typically 100s control galaxies per pair.

## Post-merger sample

587736947747053602	587732494342415393	536946900971839657	507725551741370430	587738409785557168
J101833.64+361326.6	J084344.98+354942	J094711.78+004209.6	J083551.6+612111.3	J083347.41+104842.3
		.71		
587736543096799321	587734948595236905	587732484897964080	587735666377949228	587741603112157297
J150517.88+080912.7	J104103.74+110546.2	J123040.3+510614.3	J13444216+555313.5	J132505 73+273243.3
587725550135214103	587735667454247018	587726032776265850	587736586047914003	538017720630020337
J110213.01+645924.8	J142459.77+543106.2	J103831.87+022144	J155517.83+290621.2	J110654.44+404755
567726031175221368	587735349633351726	587739720296626334	587722983883407448	587732470387703859
J120359.57+012439	.J095312.32+130603.4	J135831 05+272326.8	J112154.61+003344.8	J083818 43+333441.3
587732580077410186	588017605220171808	537739707051809602	588010880378404042	587741533323526200
J100049.35+534655.6	J120813.49+452001.3	J151151.35+230903.7	J131957.89+054828.3	J113507.51+295327.7

97 visually selected post-mergers from Galaxy Zoo.

Control matching and analysis done exactly same as for pairs.

## AGN frequency: from optical emission lines



Although AGN *may* be triggered by first pass, fraction increases most strongly after coalescence

See also Ellison et al. (2011), Khabiboulline et al. (2014)

# AGN frequency: from mid-IR colours



Significant fraction of merger triggered AGN are dust obscured and not seen as AGN in optical. Satyapal et al. (2014)

# Increase in AGN luminosity at smaller separations.





Measured in the mid-IR with WISE: Satyapal et al. (2014)

Measured in the optical with [OIII]: Ellison et al. (2013)

### AGN excess depends on selection technique



Low excitation radio galaxies – not triggered by mergers Ellison, Patton & Hickox 2015 More evidence that not all AGN exhibit same galaxy host properties: star formation rates.





# Radio-selected AGN (LERGs) are strongly UNDER star forming

Optically-selected AGN are slightly UNDER star forming

mid-IR-selected AGN are OVER star forming

Ellison et al. (2016)

### Mergers preferentially related to obscured AGN: simulations



Blecha et al. (in prep)

### Growing supermassive black holes in the late stages of galaxy mergers are heavily obscured

C. Ricci<sup>1,2,3\*</sup>, F. E. Bauer<sup>1,2,4,5</sup>, E. Treister<sup>1,2</sup>, K. Schawinski<sup>6</sup>, G. C. Privon<sup>1,2</sup>, L. Blecha<sup>7</sup>, P. Arevalo<sup>8</sup>, L. Armus<sup>9</sup>, F. Harrison<sup>10</sup>, L. C. Ho<sup>3,11</sup>, K. Iwasawa<sup>12,13</sup>, D. B. Sanders<sup>14</sup>, D. Stern<sup>15</sup>

### ARE COMPTON-THICK AGN THE MISSING LINK BETWEEN MERGERS AND BLACK HOLE GROWTH?

DALE D. KOCEVSKI<sup>1</sup>, MURRAY BRIGHTMAN<sup>2</sup>, KIRPAL NANDRA<sup>3</sup>, ANTON M. KOEKEMOER<sup>4</sup>, MARA SALVATO<sup>3</sup>, JAMES AIRD<sup>5</sup>, ERIC F. BELL<sup>6</sup>, LI-TING HSU<sup>3</sup>, JEYHAN S. KARTALTEPE<sup>7</sup>, DAVID C. KOO<sup>8</sup>, JENNIFER M. LOTZ<sup>4</sup>, DANIEL H. MCINTOSH<sup>9</sup>, MARK MOZENA<sup>8</sup>, DAVID ROSARIO<sup>3</sup>, JONATHAN R. TRUMP<sup>10</sup> Department of Physics and Astronomy, Colby College, Waterville, ME 04961 Draft version September 15, 2015

### A NEW POPULATION OF COMPTON-THICK AGN IDENTIFIED USING THE SPECTRAL CURVATURE ABOVE 10 KEV

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### The final stages of the merger sequence: the hunt for dual AGN



Small number of dual (r<10 kpc) AGN known. Most discovered serendipitously in X-rays or radio. Targeted searches (e.g. dual peak emission lines) largely unsuccessful.

## The search for binary AGN: a pilot study with Chandra



6 mergers from SDSS selected to have red WISE colour: W1-W2>0.5. All are classified as SF or composite on BPT diagram.

# The search for binary AGN: a pilot study with Chandra Satyapal, Secrest, Ricci, Ellison et al. (2017, submitted)



4/6 mergers ( $r_p$  <10 kpc) with WISE AGN colours identified as dual AGN candidates with Chandra, increase number of close dual AGN confirmed in X-rays by 50%.

### WISE mid-IR selected duals tend to be highly absorbed



Satyapal, Secrest, Ricci, Ellison et al. (2017, submitted)

## Finding dual AGN with IFU spectroscopy.



### Combining MaNGA (SDSS-IV) with WISE



First public release of MaNGA data in July 2016, as part of SDSS IV DR13 ~ 1400 galaxies.

## Combining MaNGA (SDSS-IV) with WISE



Ellison et al. (2017)

Dual AGN with 8 kpc separation confirmed with 30 ks of Chandra DDT time.



X1: Log  $L_X = 4x10^{43}$  erg/s X2: Log  $L_X = 4x10^{41}$  erg/s

X1 fit: Gamma = 1.6,Log  $N_{H}$  = 2x10<sup>22</sup> cm<sup>-2</sup>



### Ellison et al. (2017)

# Summary

- Mergers can trigger AGN, and enhance their accretion rate. Ellison et al. (2011, 2013).
- IR selected AGN more prevalent in mergers than optically selected AGN – mergers more frequently to lead to obscured AGN. Satyapal et al. (2014)
- Mergers are *not* responsible for most low excitation (low luminosity) RL-AGN Ellison, Patton & Hickox (2015).
- AGN host galaxies have different star formation rates depending on their selection technique. Ellison et al. (2016)
- IR selection very effective for finding dual AGN (which are often highly obscured). We have increased the number of X-ray confirmed dual AGN by over 50%: Satyapal et al. (2017), Ellison et al. (2017).