Galaxy Morphologies with

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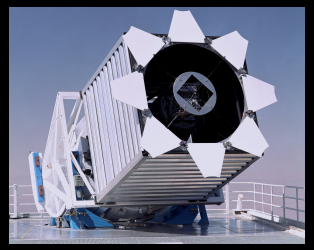
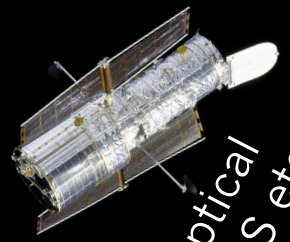
6.5 years of Galaxy Zoo

GALAXY ZOO → GALAXY ZOO





Galaxy Zoo 1: spiral vs elliptical, 900,000 SDSS MGS

Galaxy Zoo 2: detailed morphology, 240,000 SDSS r<17mag

Galaxy Zoo Bars: Bar lengths, widths for 3000 GZ2 bars

Galaxy Zoo Hubble: Public optical HST surveys COSMOS, GOODS etc.

Galaxy Zoo 4: relaunched with CANDELS, SDSS DR8

Galaxy Zoo Quench: Small project, more engagement

Galaxy Zoo UKIDSS: 70,000 UKIDSS images of MGS galaxies (+FERENGI redshifted images, SDSS DR8, CANDELS)

July 2007- Feb 2009 | Feb 2009- April 2010 | Sept 2009- Jan 2010 | Apr 2010- Aug 2012 | Aug 2012 - | Aug 2013 - | Oct 2013 -

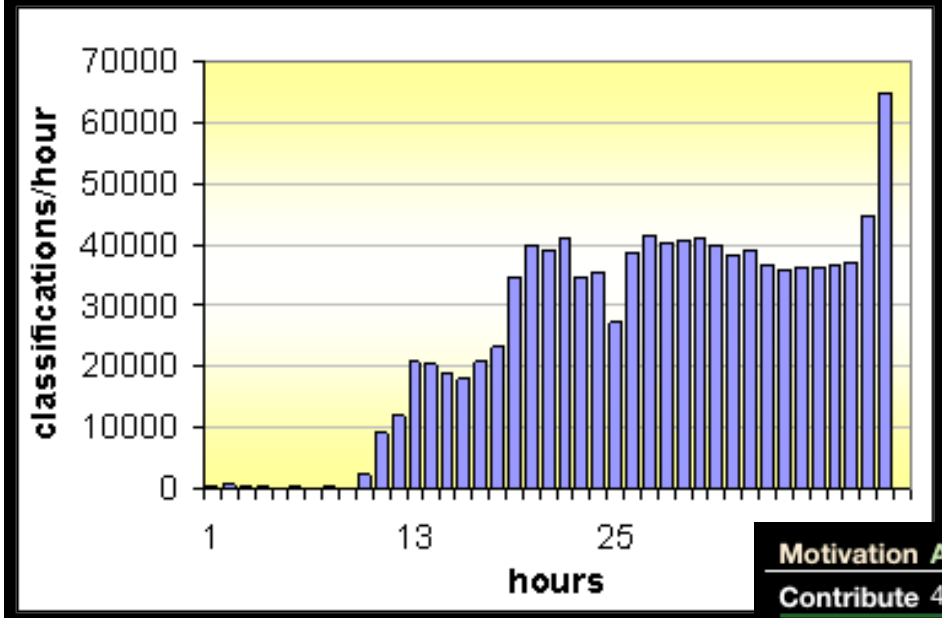
Data Access

- www.data.galaxyzoo.org
- Available in Casjobs (DR8 and DR10)

- Lintott et al. 2011 – for GZ1
- Willett et al. 2013 – for GZ2
- Ask us about other morphologies

The Zooites

(Our Telescope/Computer)



Motivation	All	Female	Male	Description (used in survey)
Contribute	40%	37%	41%	I am excited to contribute to original scientific research.
Astronomy	13%	10%	13%	I am interested in astronomy.
Discovery	11%	10%	11%	I can look at galaxies that few people have seen before.
Beauty	9%	12%	8%	I enjoy looking at the beautiful galaxy images.

This publication has been made possible by the participation of more than 160 000 volunteers in the first phase of the Galaxy Zoo project. Their contributions are individually acknowledged at http://www.galaxyzoo.org/volunteers.

(Raddick et al. 2009 astroph/0909.2925)

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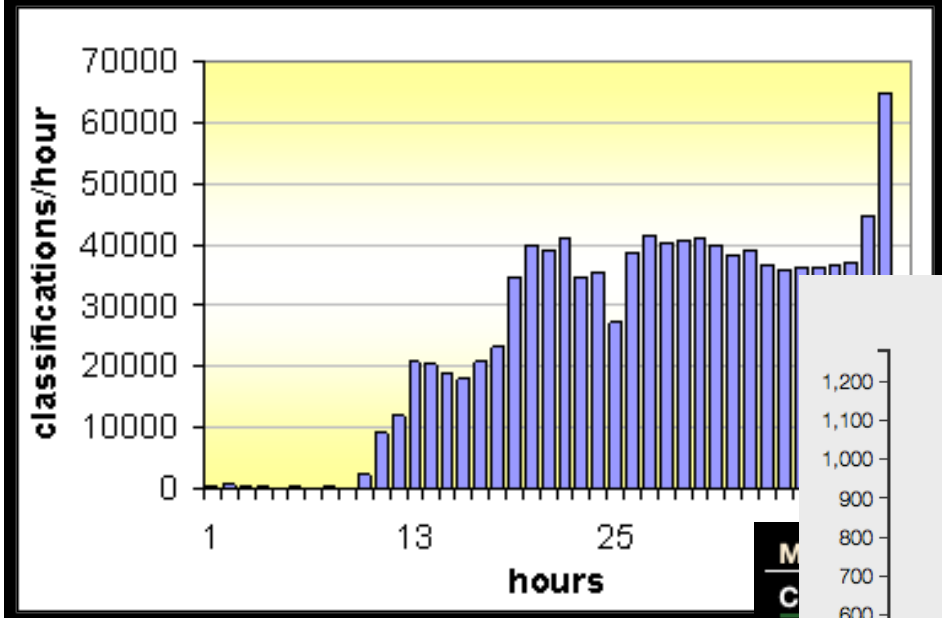
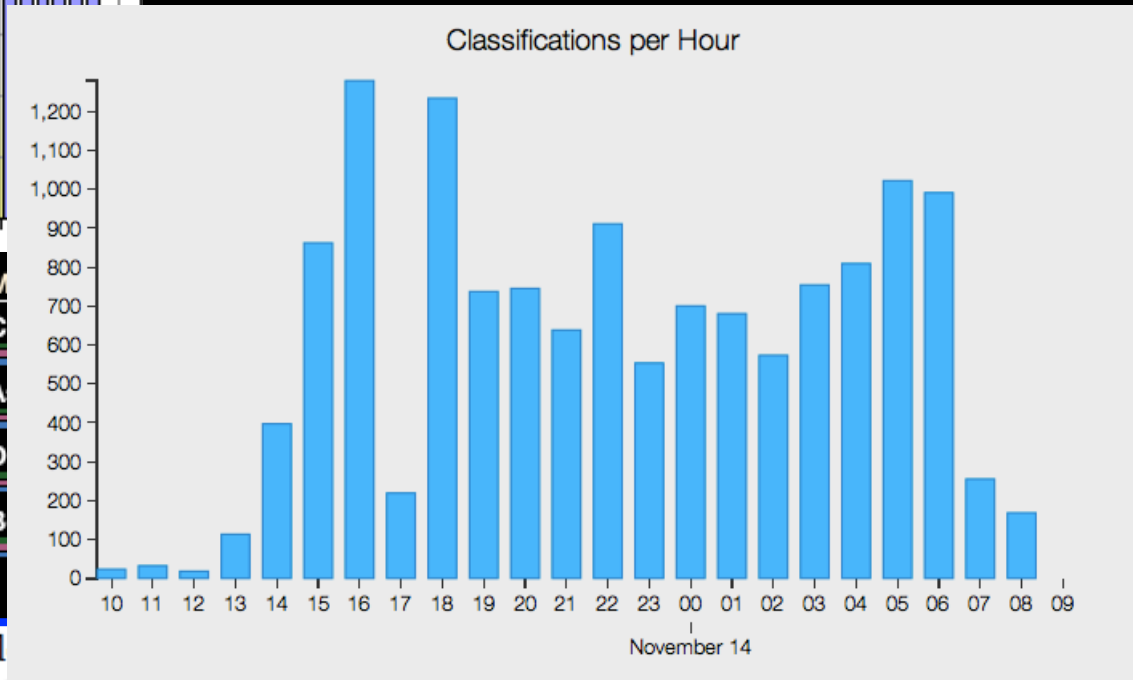
(Our Telescope/Computer)





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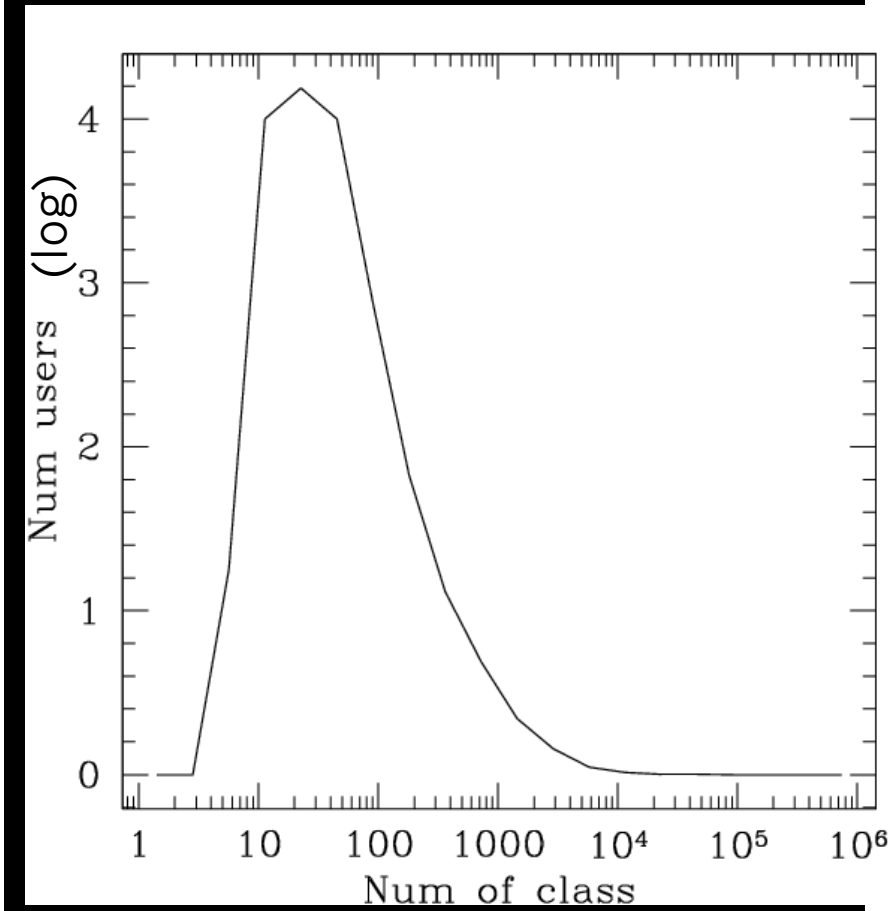
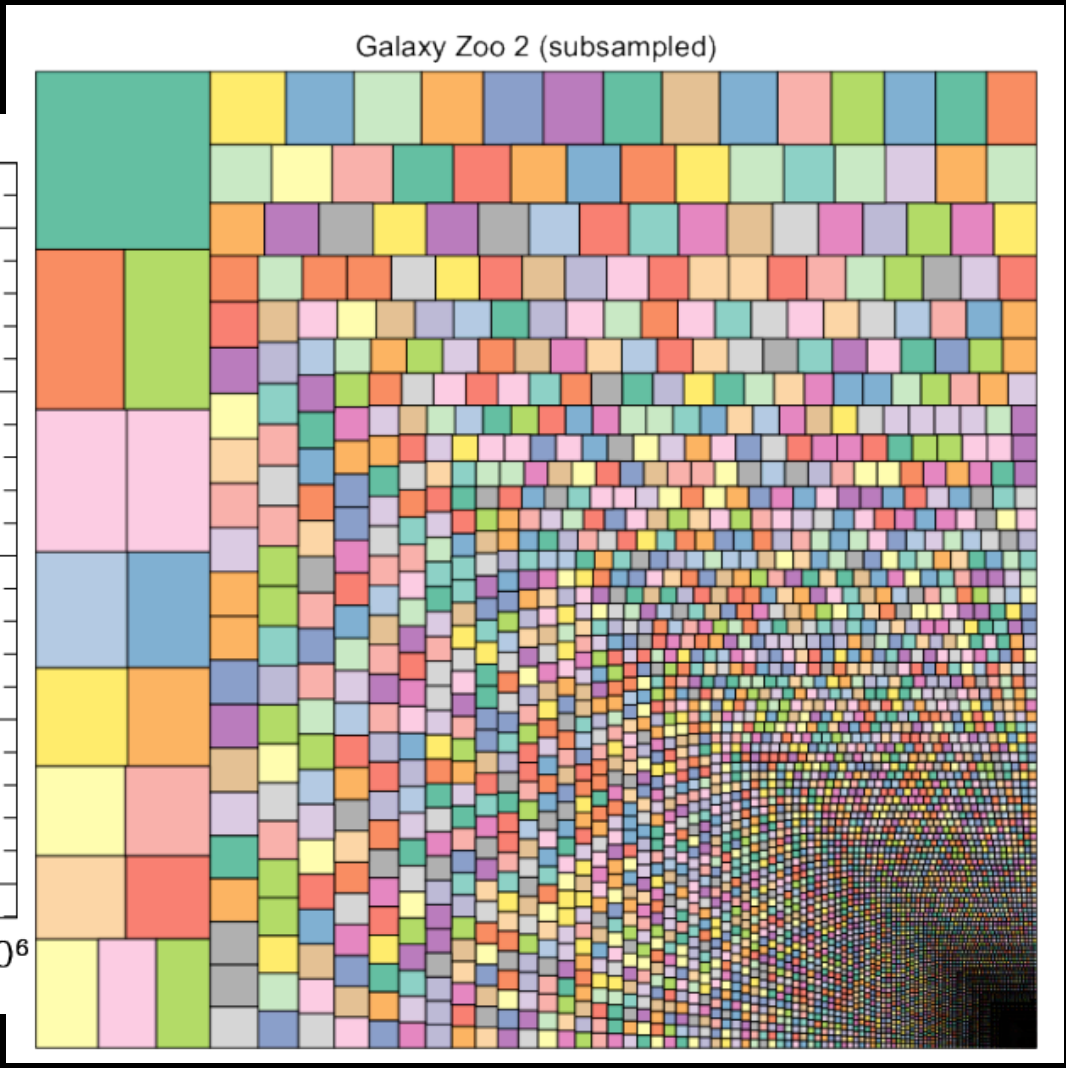
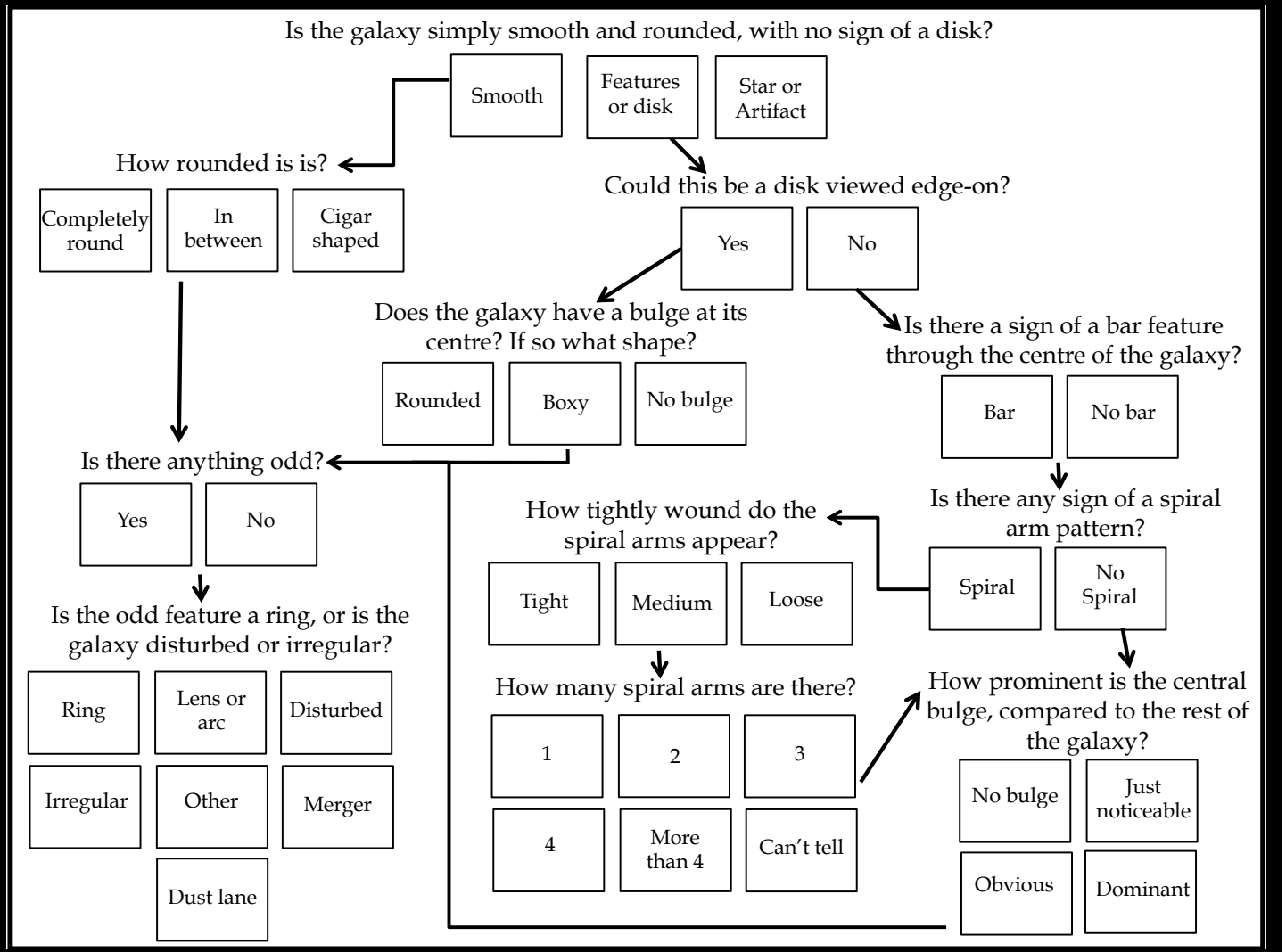




The Questions



GZ Hubble:
+ questions about clumpy galaxies

Clicks to Classifications

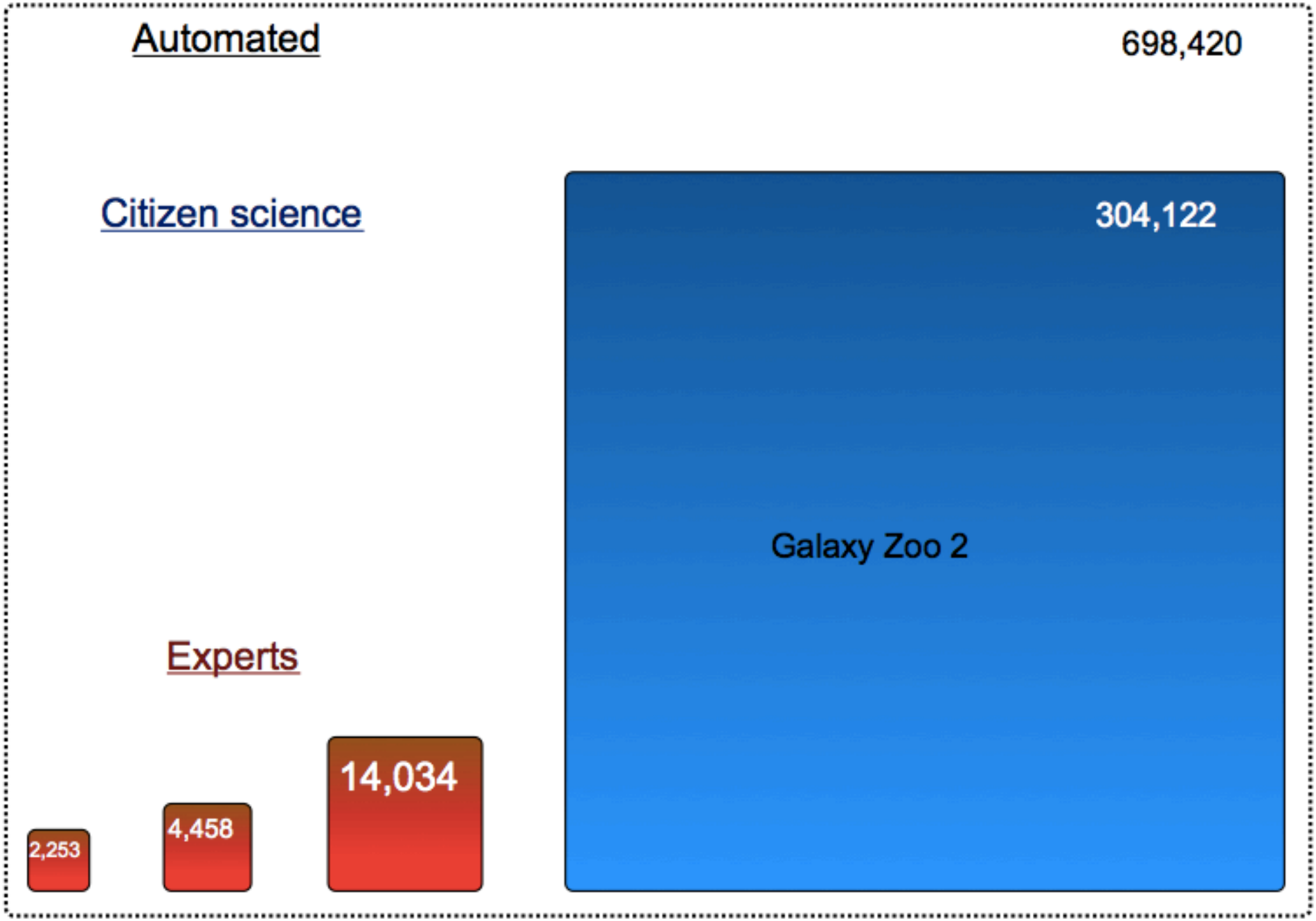
(our data reduction)

Collect 20-40 answers for each question
(raw vote fraction)

Weight users by consistency

Correct for observational biases
(Bamford et al. 2009, Willett et al. 2013)

"Debiased" classification likelihoods
p_{spiral}, p_{bar} etc.



Credit: Kyle Willett

Is it Reliable?

p>0.8

	?	E	E/S0	S0	S0/a	Sa	Sab	Sb	Sbc	Sc	Scd	Sd	Sdm	Im
Elliptical	1	267	190	170	41	11	2	0	0	0	0	0	0	0
Spiral	3	0	0	0	5	21	71	136	151	160	38	13	5	2
Star/don't know	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Merger	5	0	1	0	0	1	1	2	0	1	1	0	0	0
Total	9	268	191	170	46	33	74	138	151	161	39	13	5	2

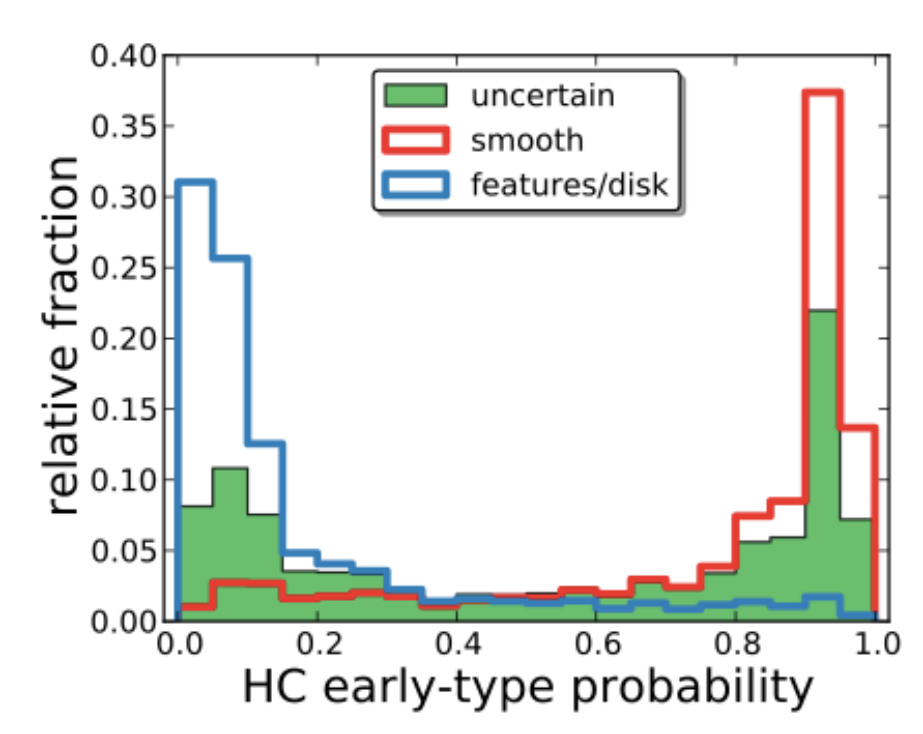
Comparison with Fukugita et al. 2007 (cross over is 1300 galaxies)

Lintott et al. 2008
- agree with experts more than 90% of the time
- increase sample size by at least factor of 10

Lintott et al. 2011

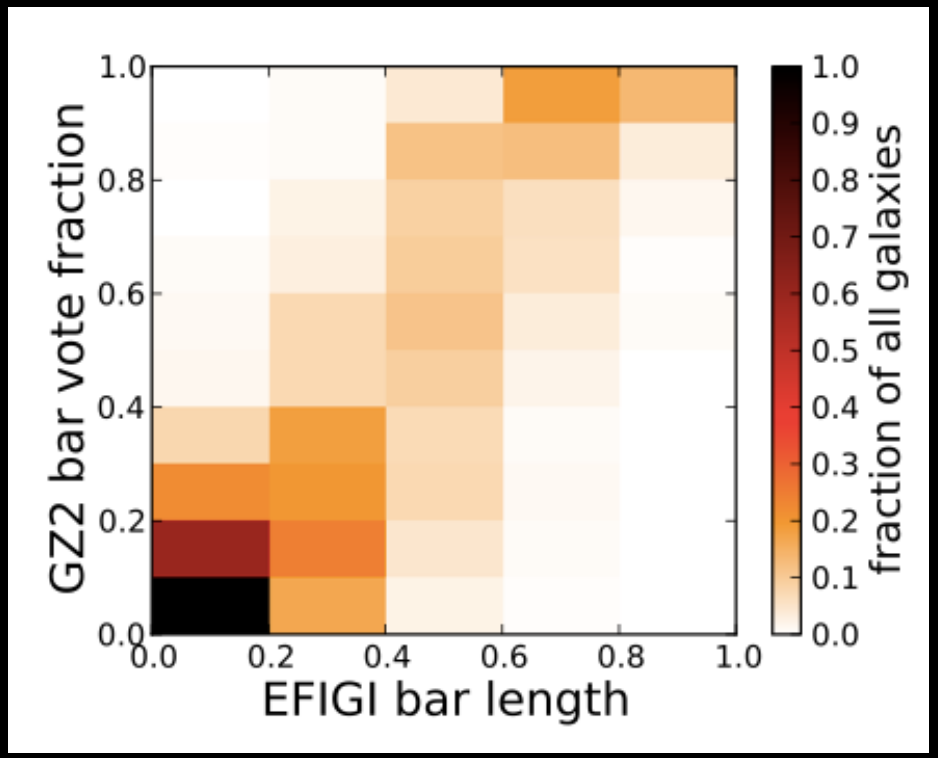
www.data.galaxyzoo.org

Is it Reliable (cont)



Huertas-Company et al. 2011
(automated based on shape, colour, luminosity and redshift)

EFIGI (Baillard et al. 2011) – expert visual classification



Willett et al. 2013
www.data.galaxyzoo.org

Galaxy Zoo Papers

30+ peer reviewed papers (incomplete list below)
(over 550 citations – 100+ on description paper; h-index=18)

Lintott et al. 2008, *Morphologies derived from visual inspection of galaxies from the SDSS*
Banerji et al, 2010, *Reproducing galaxy morphologies via machine learning*
Lintott et al. 2011, *Data Release of Morphological Classifications for nearly 900,000 galaxies*
Willett et al. 2013, *Detailed morphological classifications for 304,122 galaxies from the Sloan Digital Sky Survey*

Bamford et al. 2009, *The dependence of morphology and colour on environment*
Skibba et al. 2009, *Disentangling the environmental dependence of morphology and colour*
Schawinski et al. 2009, *A sample of blue early-type galaxies at low redshift*
Masters et al. 2010, *Passive red spirals*
Wong et al. 2011, *Building the Low Mass end of the Red Sequence with Poststarburst Galaxies*
Tojeiro et al. 2013, *The differenct star-formation histories of red and blue spiral and elliptical galaxies*
Schawinski et al. submitted, *The Green Valley is a Red Herring*

Schawinski et al. 2010, *The Fundamentally Different Co-Evolution of Supermassive Black Holes and Their Early- and Late-Type Host Galaxies*
Simmons et al. 2013, *Bulgeless galaxies with growing black holes*

Darg et al. 2010, *The properties of merging galaxies in the nearby Universe*
Darg et al. 2010, *The fraction of merging galaxies in the SDSS and their morphologies*
Darg et al. 2011, *Multi-Mergers and the Millennium Simulation*
Casteels et al. 2013, *Quantifying morphological indicators of galaxy interaction*

Cardamone et al. 2009, *Green Peas: discovery of a class of compact extremely SF galaxies*

Land et al. 2008, *The large-scale spin statistics of spiral galaxies in the Sloan Digital Sky Survey*
Slosar et al. 2009, *Chiral correlation function of galaxy spins*
Jimenez et al. 2010, *A correlation between the coherence of galaxy spin chirality and SF efficiency*

Lintott et al. 2009, *`Hanny's Voorwerp', a quasar light echo?*
Keel et al. 2012, *The Galaxy Zoo survey for giant AGN-ionized clouds: past and present black hole accretion events (Voorwerpjies)*

Masters et al. 2011, *Bars in Disk Galaxies*
Hoyle et al. 2011, *Bar Lengths in Local Disk Galaxies*
Skibba et al. 2012, *The environmental dependence of bars and bulges in disc galaxies*
Masters et al. 2012, *Atomic gas and the regulation of starformation in barred disc galaxies*
Cheung et al. 2013, *Observing secular evolution through bars*
Melvin et al. submitted, *An independent look at the bar fraction over the last eight billion years from HST-COSMOS*

Masters et al. 2010, *Dust in spiral galaxies*
Kaviraj et al. 2012, *Dust and Molecular gas in early-type galaxies with prominent dust lanes*
Shabala et al. 2012, *Dust lane early-type galaxies are tracers of recent, gas-rich minor mergers*
Keel et al. 2013, *A Catalogue of Overlapping Galaxy Pairs for Dust Studies*

www.zooniverse.org/publications
blog.galaxyzoo.org/papers

Galaxy Zoo Data Papers

Lintott et al. 2008
Morphologies derived from visual inspection of galaxies from the SDSS

Banerji et al, 2010
Reproducing galaxy morphologies via machine learning

Lintott et al. 2011
Data Release of Morphological Classifications for nearly 900,000 galaxies

Willett et al. 2013
Detailed morphological classifications for 304,122 galaxies from the Sloan Digital Sky Survey

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Morphology ≠ Colour

Bamford et al. 2009
The dependence of morphology and colour on environment

Skibba et al. 2009
Disentangling the environmental dependence of morphology and colour

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A sample of blue early-type galaxies at low redshift

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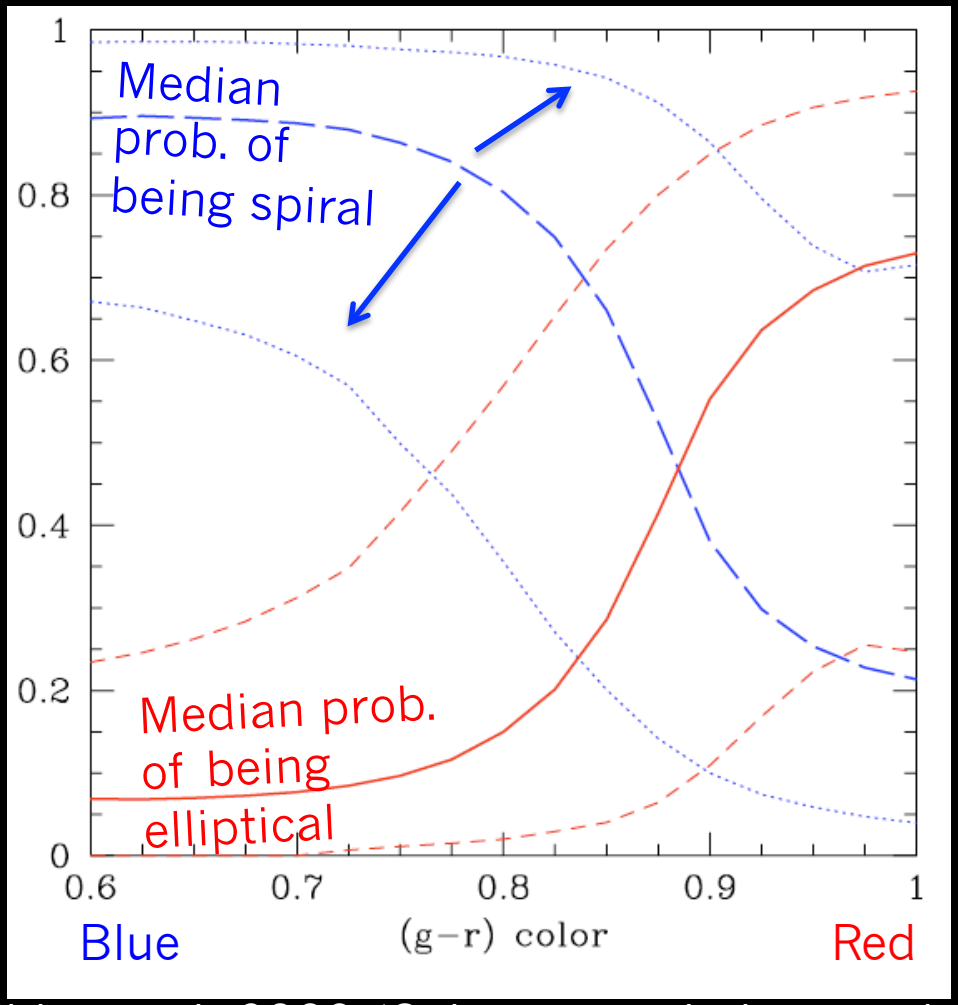
Wong et al. 2011
Building the Low Mass end of the Red Sequence with Poststarburst Galaxies

Tojeiro et al. 2013
The different star-formation histories of red and blue spiral and elliptical galaxies

Schawinski et al. submitted
The Green Valley is a Red Herring: Galaxy Zoo reveals two evolutionary pathways towards quenching of star formation in early- and late-type galaxies

Morphology ≠ Colour



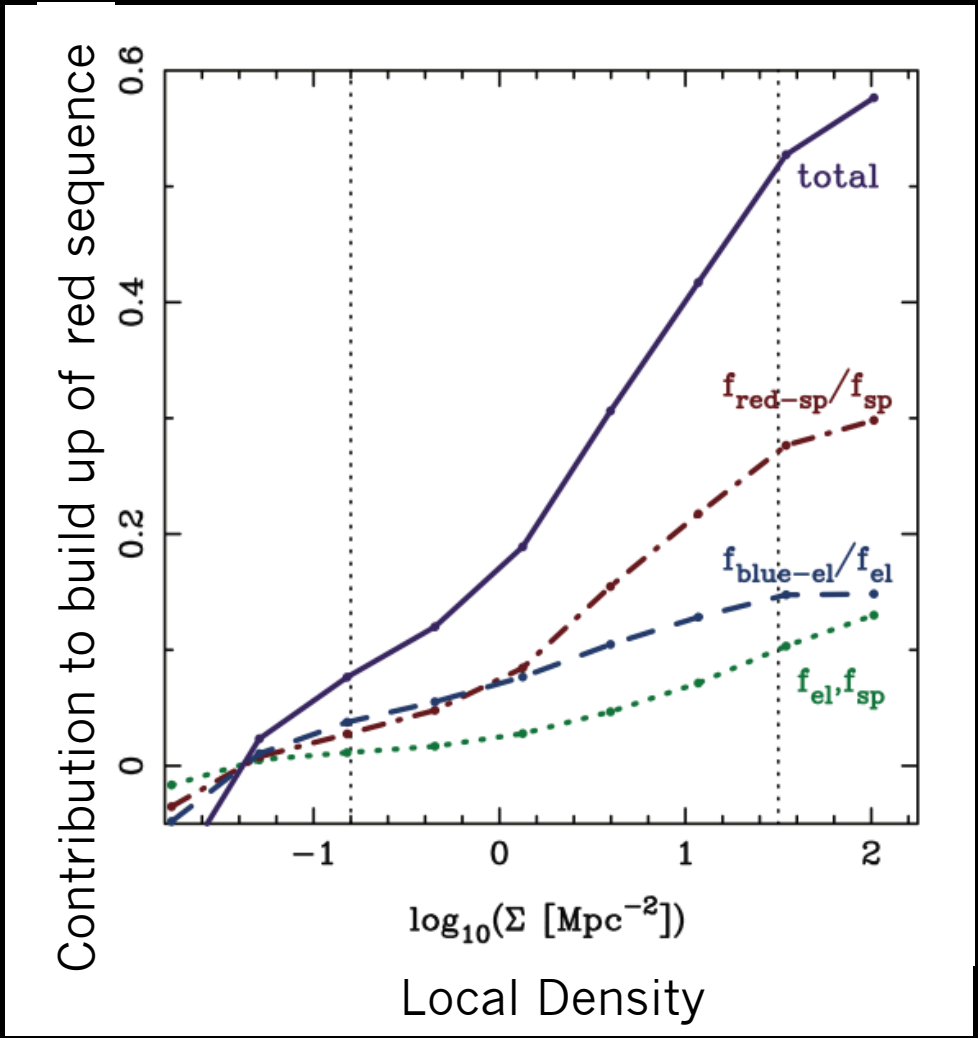
Colour and morphology are correlated, but not equivalent

Colour = star formation history

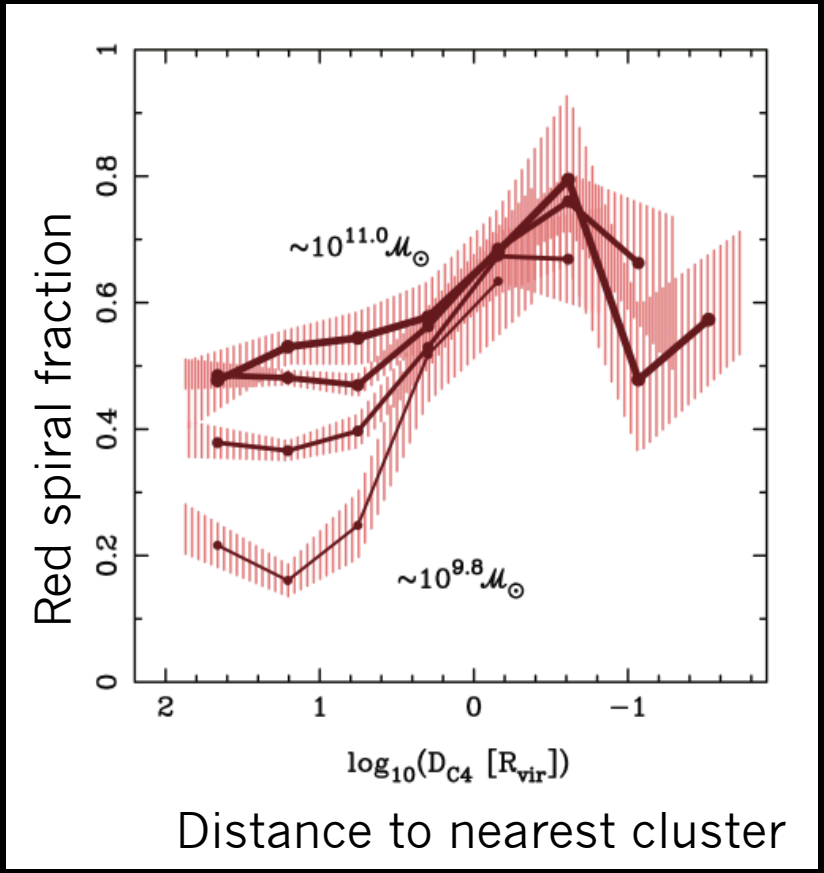
Morphology = dynamical history

Skibba et al. 2009 (Colour, morphology and environment), or Bamford et al. 2009

Build up of red sequence is mostly due to spirals turning red...



Disentangling the effects of mass and environment.....



(Bamford et al. 2009)

Red Spirals

- route for most evolution from blue -> red (Bundy et al. 2010 with redshift; Bamford et al. 2009 with environment)
- red because more passive than similar blue spirals (Masters et al. 2010, Tojeiro et al. 2013)
    - but not totally passive (Masters et al. 2010, Cortese 2011)

- more common at high masses, intermediate environments, with large bulges and/or strong bars

A red spiral galaxy (c), flanked by blue spiral (l) and red elliptical galaxies (r)

Masters et al. 2010

Galaxy Zoo Bars

Masters et al. 2011
Bars in (Local) Disc Galaxies

Hoyle et al. 2011
Bar Lengths in Local Disc Galaxies

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The environmental dependence of bars and bulges in disc galaxies

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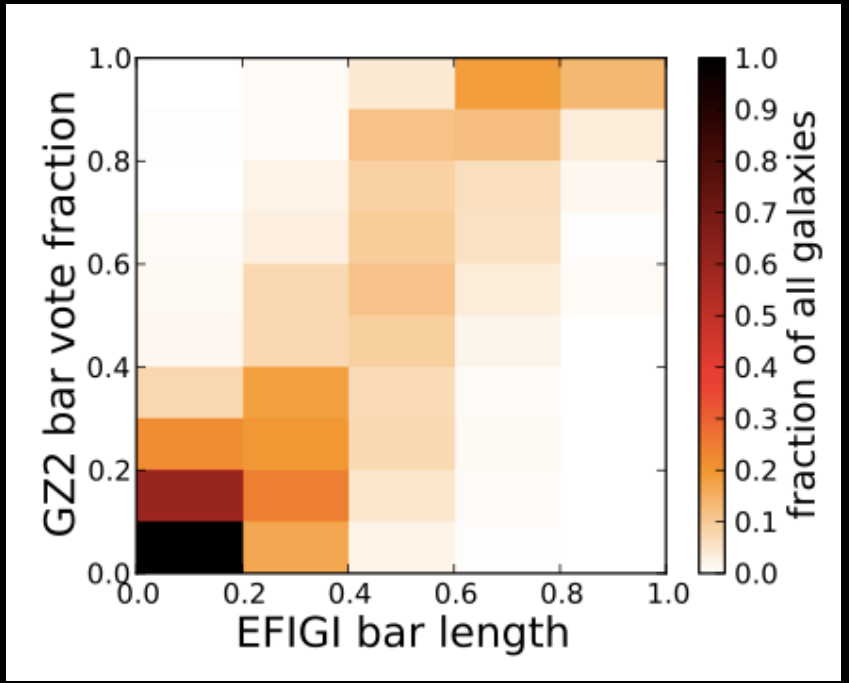
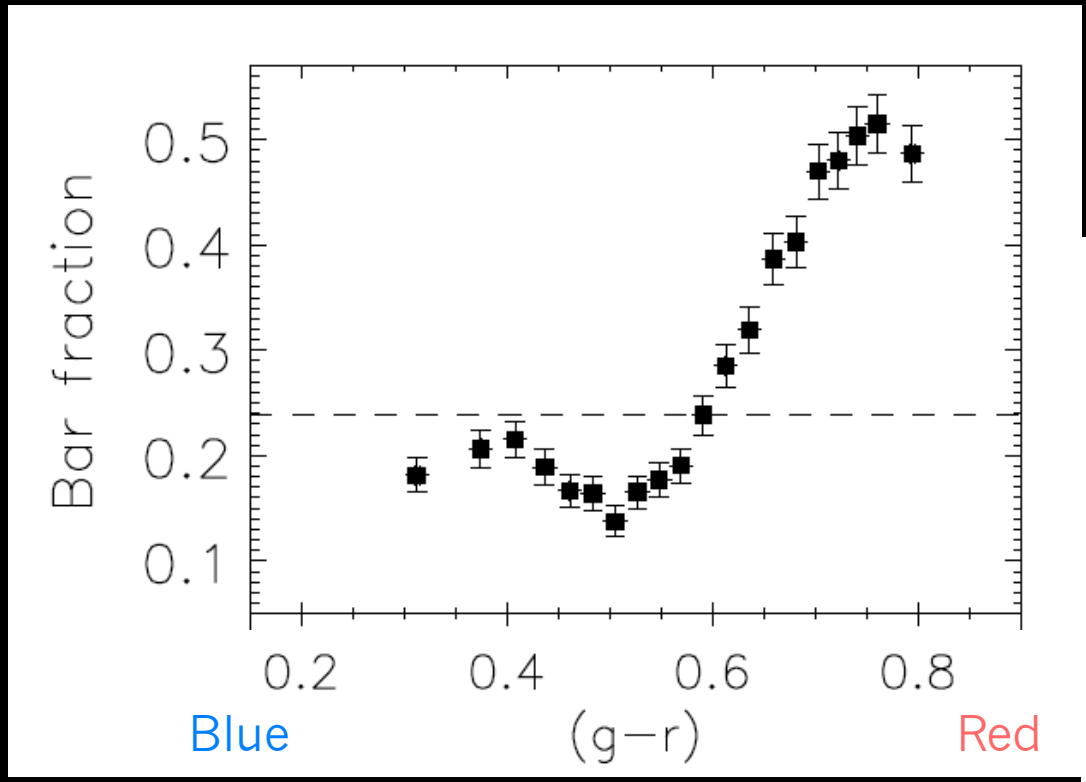


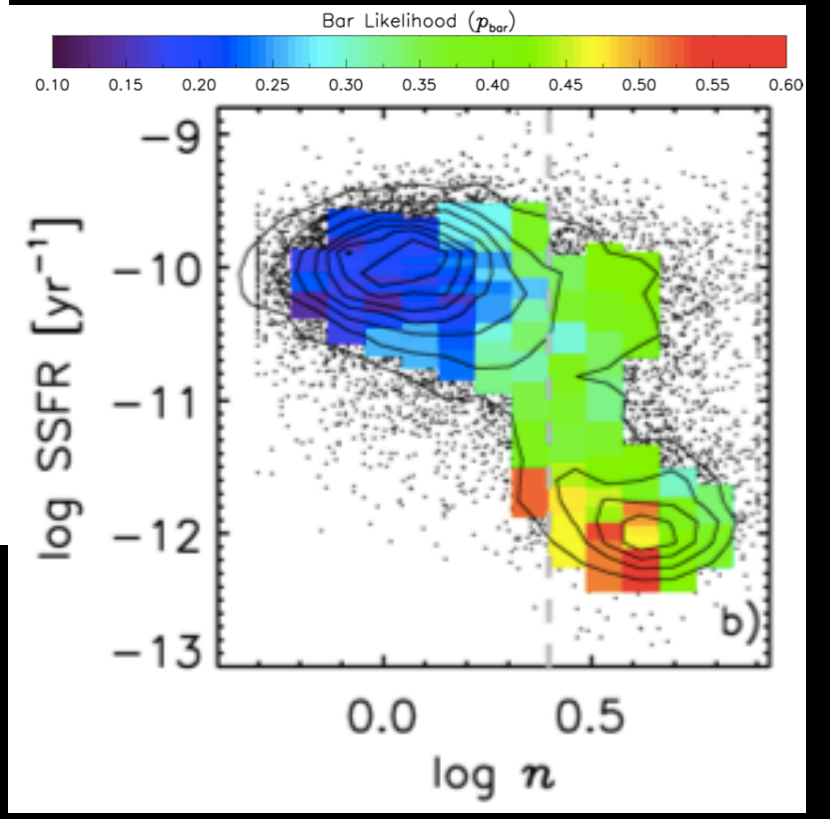
Willett et al. 2013
(EFIGI: Baillard et al. 2011 – expert visual classification)

Melvin et al. submitted
An independent look at the bar fraction over the last eight billion years from HST-COSMOS

Bars and Red Spirals

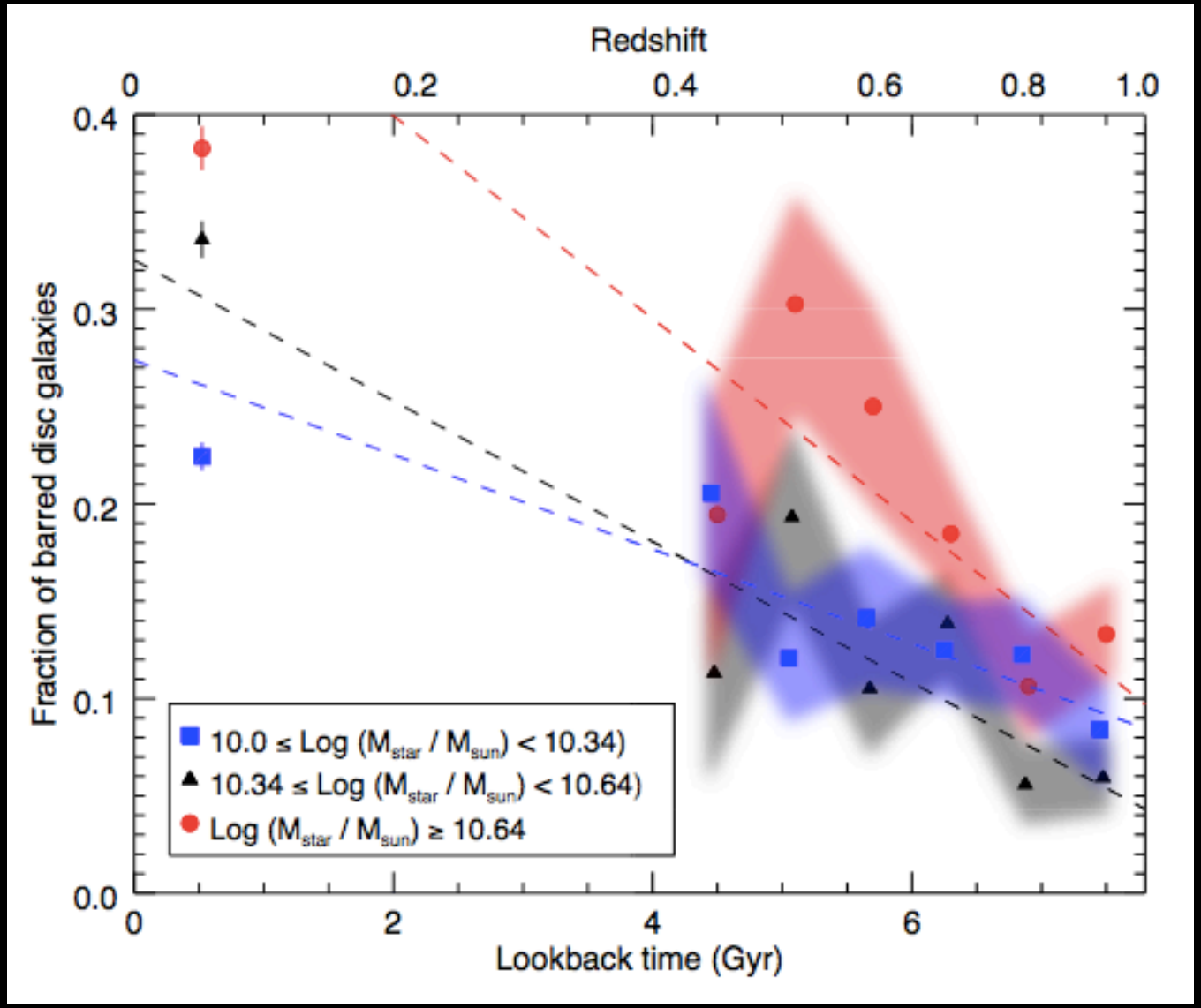


Masters et al. 2010



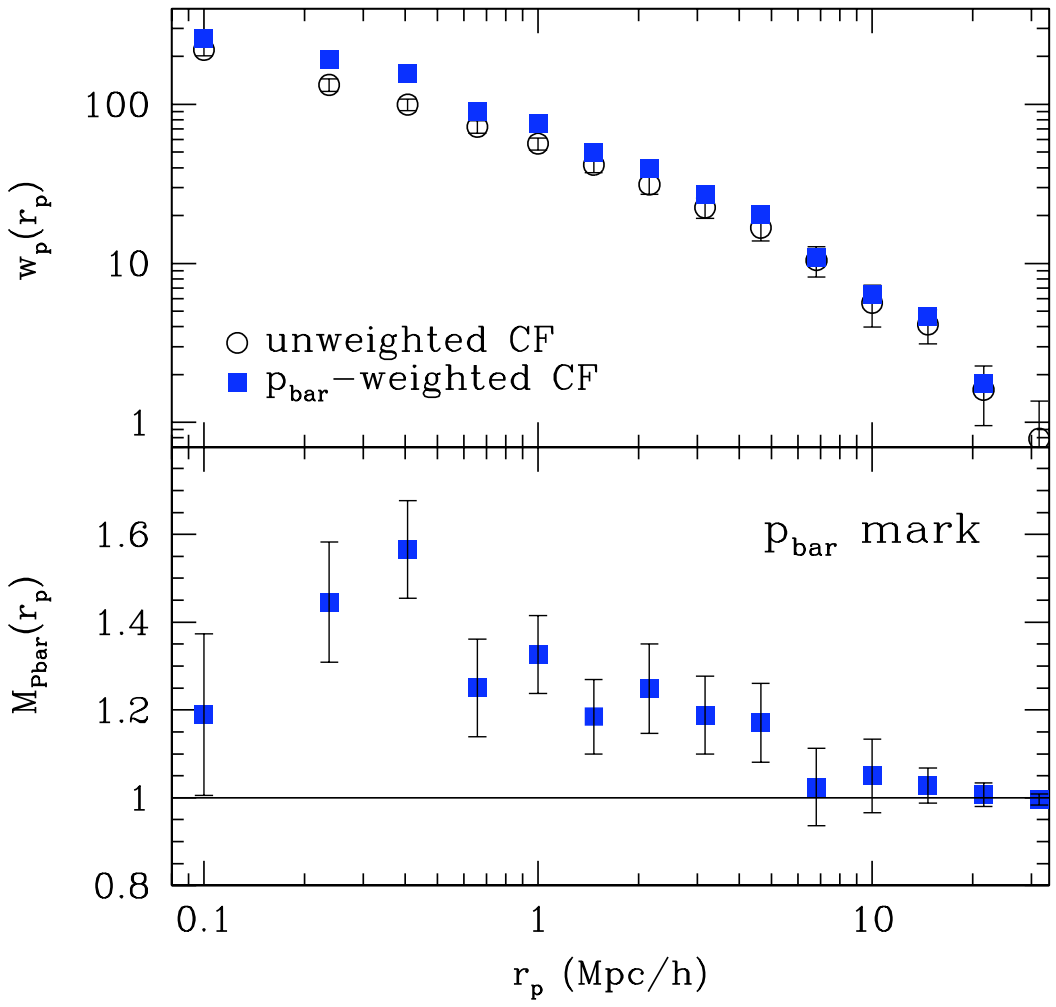
Cheung et al. 2013

Tracing the Evolution of Stable Discs with Bars



Melvin, Masters et al. submitted

Bars and Environment



Are barred spirals more clustered than unbarred spirals?

- barred spirals are more clustered than spirals in general

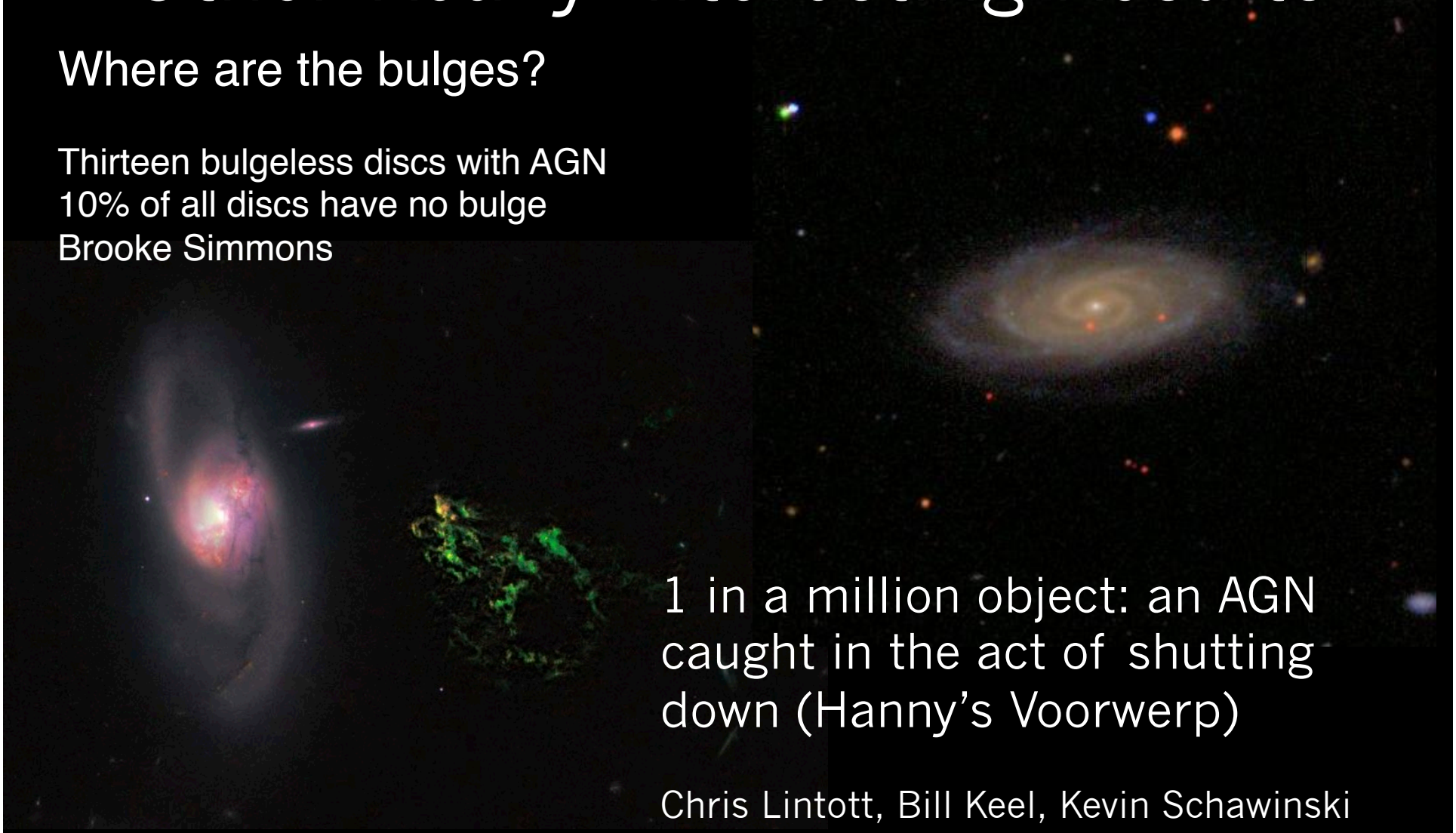
- red spirals with bars are (on some scales) more clustered than red spirals in general

Skibba, Masters et al. 2012 (MNRAS)

Other Really Interesting Results

Where are the bulges?

Thirteen bulgeless discs with AGN
10% of all discs have no bulge
Brooke Simmons



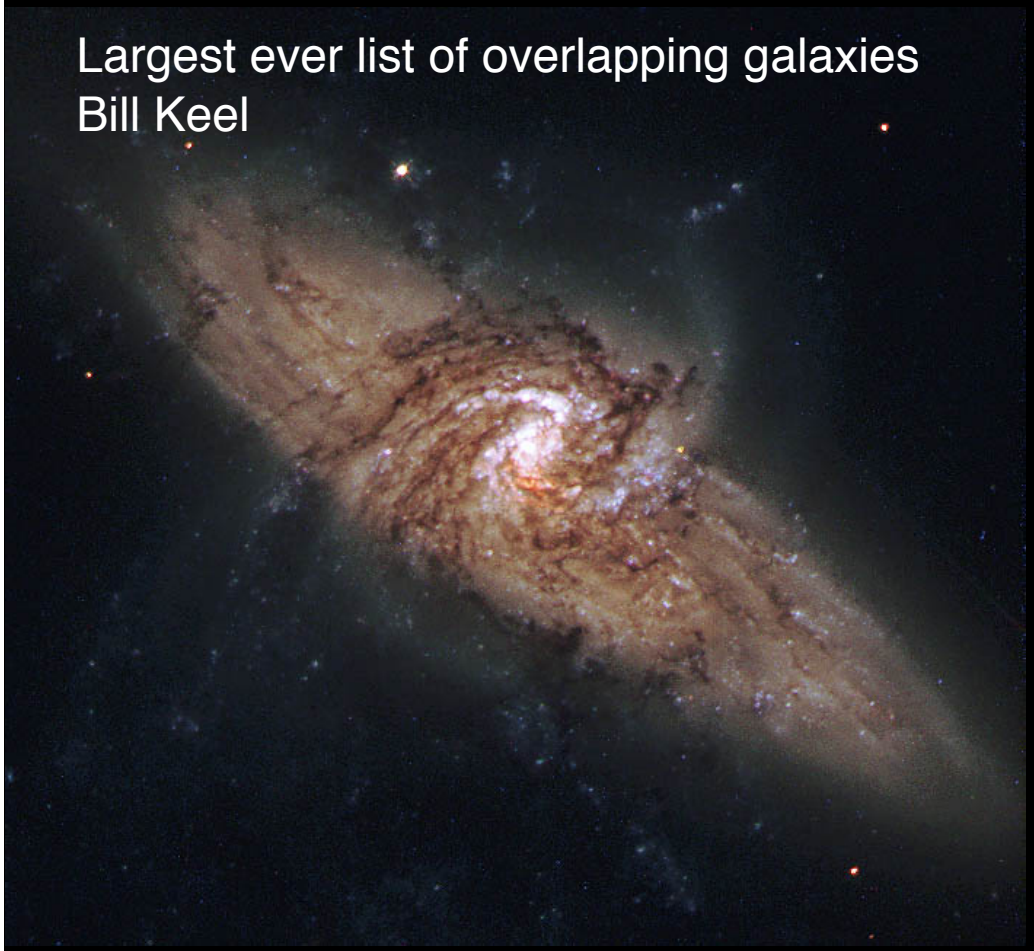
1 in a million object: an AGN caught in the act of shutting down (Hanny's Voorwerp)

Chris Lintott, Bill Keel, Kevin Schawinski

Other Really Interesting Results

Measuring Dust Properties

Largest ever list of overlapping galaxies
Bill Keel



Merger statistics

Danny Darg

GALAXY ZOO Science Team

Oxford – Chris Lintott (PI, PI Zooniverse)
Brooke Simmons (postdoc)
Becky Smethurst (STFC PhD)

Portsmouth – Karen Masters (Project Scientist)
Bob Nichol, Edd Edmondson, Daniel Thomas
Tom Melvin (STFC PhD)

Nottingham – Steven Bamford

ETH, Zurich – Kevin Schawinski (Founding Member)

Minnesota – Lucy Fortson
Kyle Willett (postdoc)

Alabama – Bill Keel

Ramin Skibba
Nic Ross
Sugata Kaviraj
Ivy Wong
Kevin Casteels
Laura Trouille
Boris Haussler
Edmund Cheung

Zooniverse developers and educators in Oxford and Adler Planetarium, Chicago

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ICG Portsmouth

ZOONIVERSE
REAL SCIENCE ONLINE

GALAXY ZOO

- Inspired by the success of Galaxy Zoo
- Runs 26+ similar projects
  - Open calls for proposals
  - "Grown up" name: The Citizen Science Alliance (NSF Funded)
- N~20 developers/designers and educators in Oxford and Chicago (Adler Planetarium)
- 650,000 volunteer members and growing