Evolutionary Paths in Galaxy Morphology

Conference Summary

Matthew Colless

Powerhouse Museum, Sydney

26 September 2013

Caveat emptor

- A summary of 51 talks and >3 Gb of presentations in <30 minutes…
- Caveat #1: Not all the great ideas (and speakers) are represented here – so this summary exemplifies the general rule:

  In astronomy, everything is a selection effect until proved innocent.

- Some of the highlights I couldn't fit in my talk will be included in the version of this presentation appearing on the meeting webpage.
- Caveat #2: I have borrowed speakers' slides and then taken them out of context, mashed them together, added my own spin, and generally done terrible things to them – so another rule applies:

  All the good stuff is due to the original presenters; all the errors, misrepresentations and prejudices are my own. Apologies!

Matthew Colless

First, a word from our sponsors…

CLASSIFY SCIENCE STORY GALAXY ZOO ASTRONOMERS DISCUSS

Few have witnessed what you're about to see

Experience a privileged glimpse of the distant universe, observed by the Sloan Digital Sky Survey and Hubble Space Telescope

GALAXY ZOO QUENCH

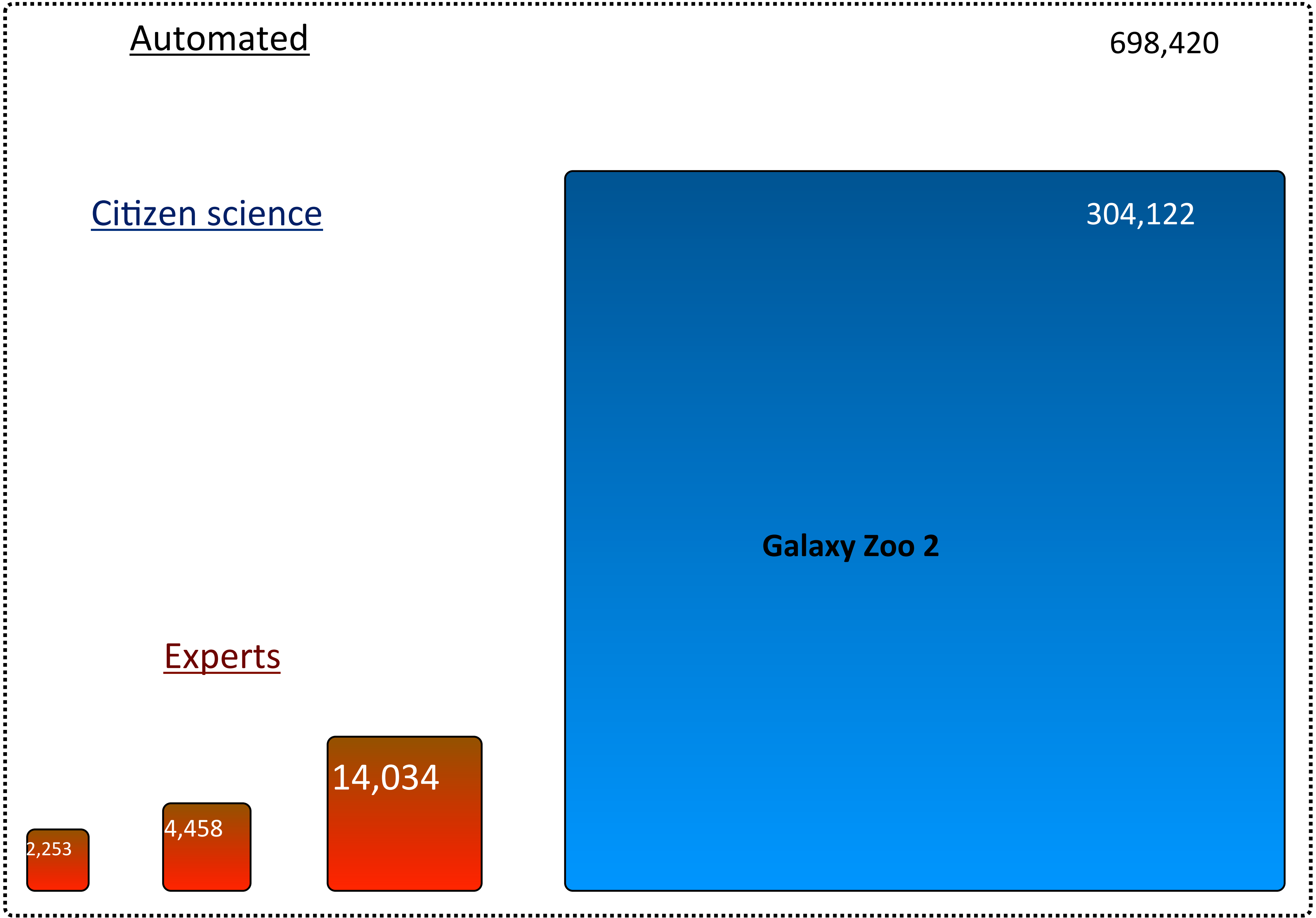
We are trying something new! Come help us understand a very specific type of galaxy and experince science from start to end. Take part

Classify Galaxies

To understand how galaxies formed we need your help to classify them according to their shapes. If you're quick, you may even be the first person to see the galaxies you're asked to classify.

Begin Classifying

Chris Lintott



Kyle Willett

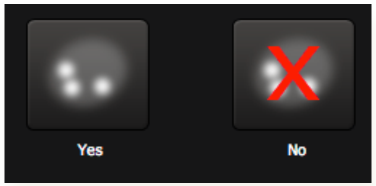
Galaxy Zoo

~900,000 galaxies from SDSS Lintott et al. (2011)
30+ publications

Galaxy Zoo 2

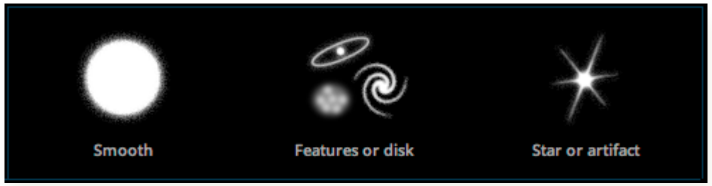
~300,000 galaxies from SDSS
Willett et al. (2013)
9+ publications

Galaxy Zoo: Hubble



~100,000 ACS images from COSMOS
~50,000 SDSS images
analyzing and reducing data

Galaxy Zoo

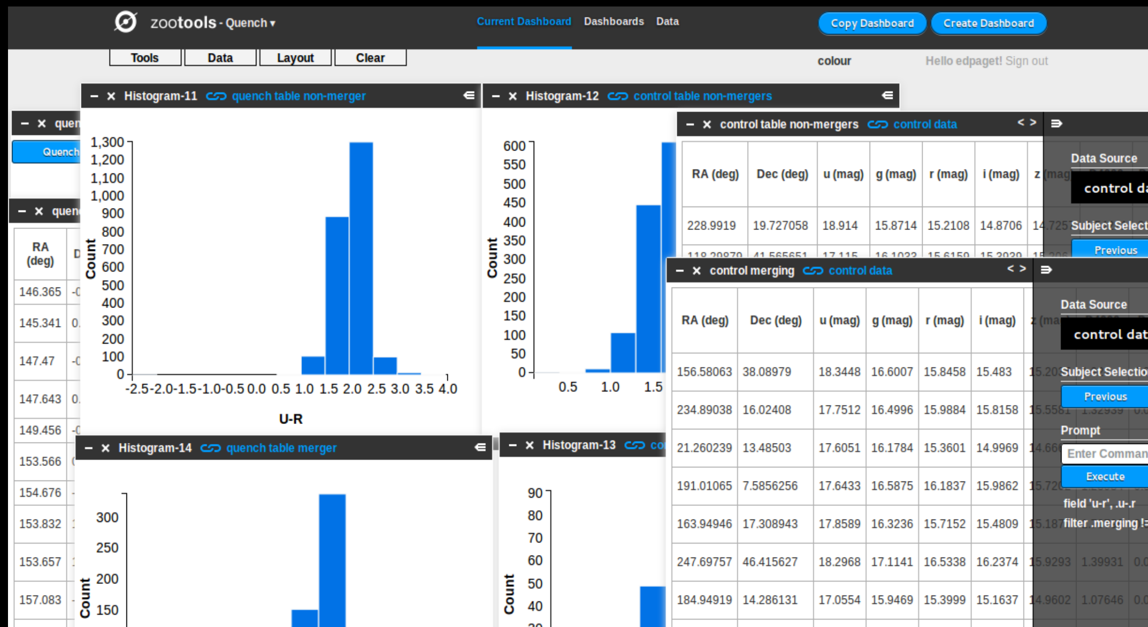


~50,000 images from CANDELS
~230,000 images from SDSS DR8
still collecting classifications

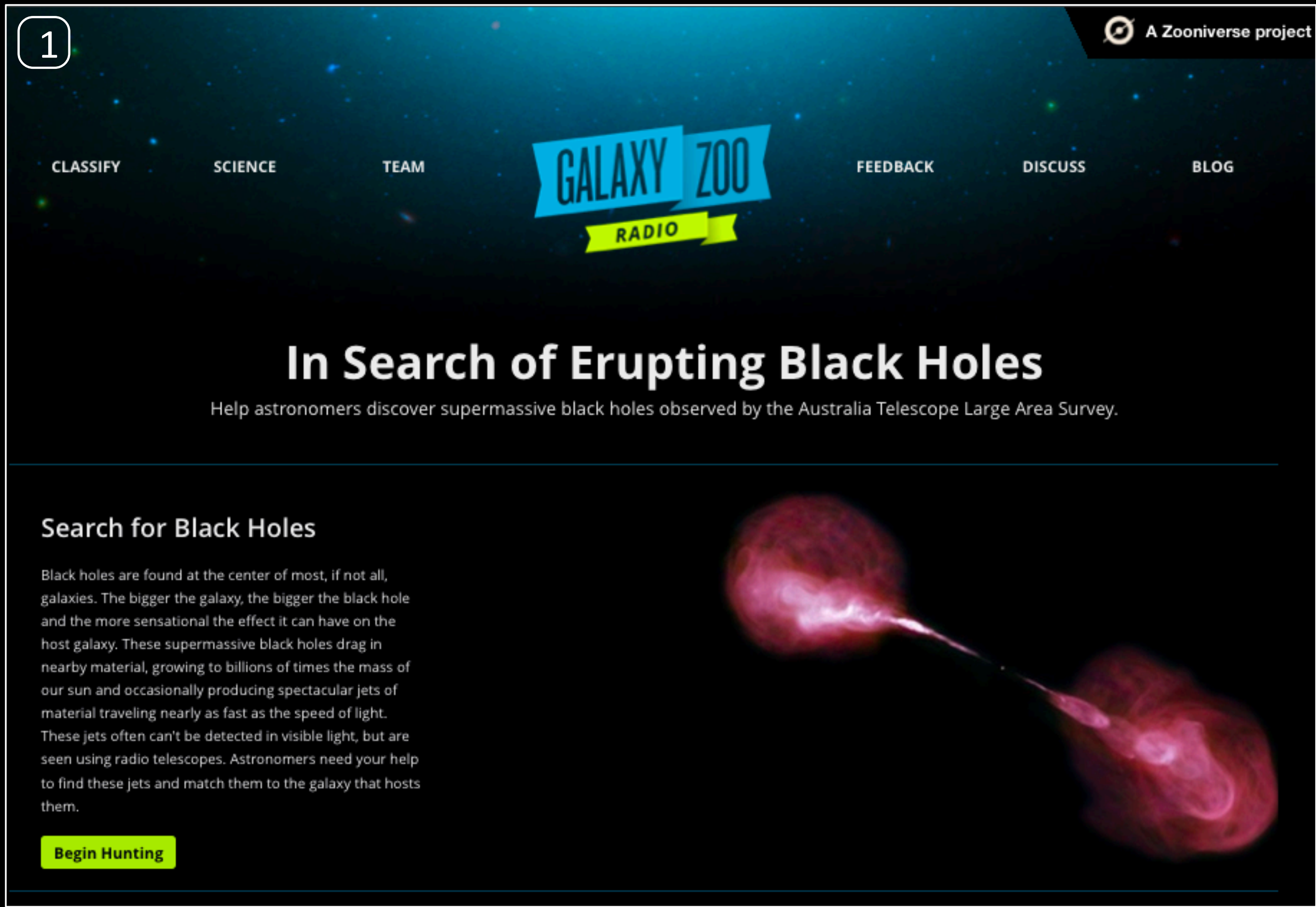
Kyle Willett

Galaxy Zoo Navigator

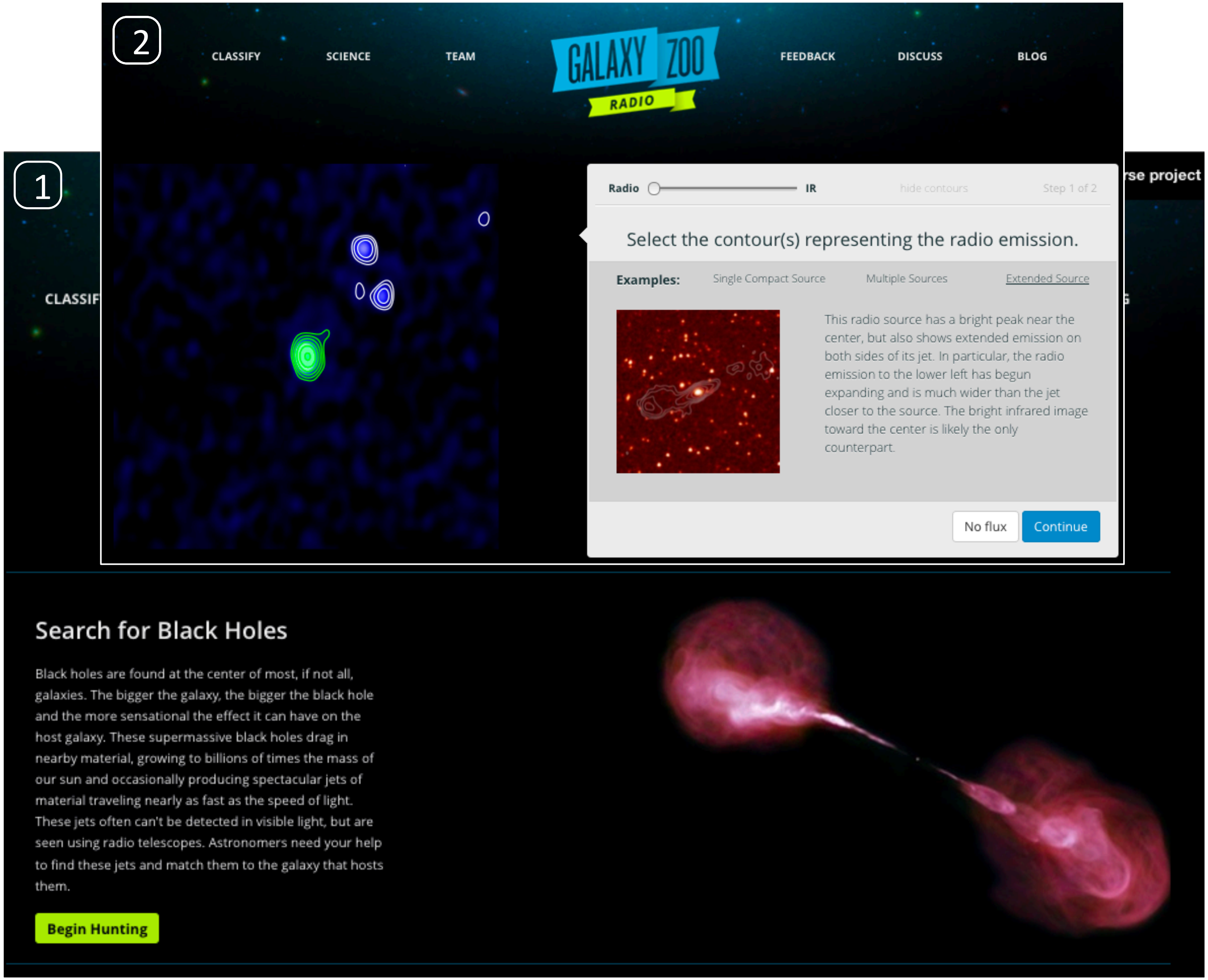
ZooTools

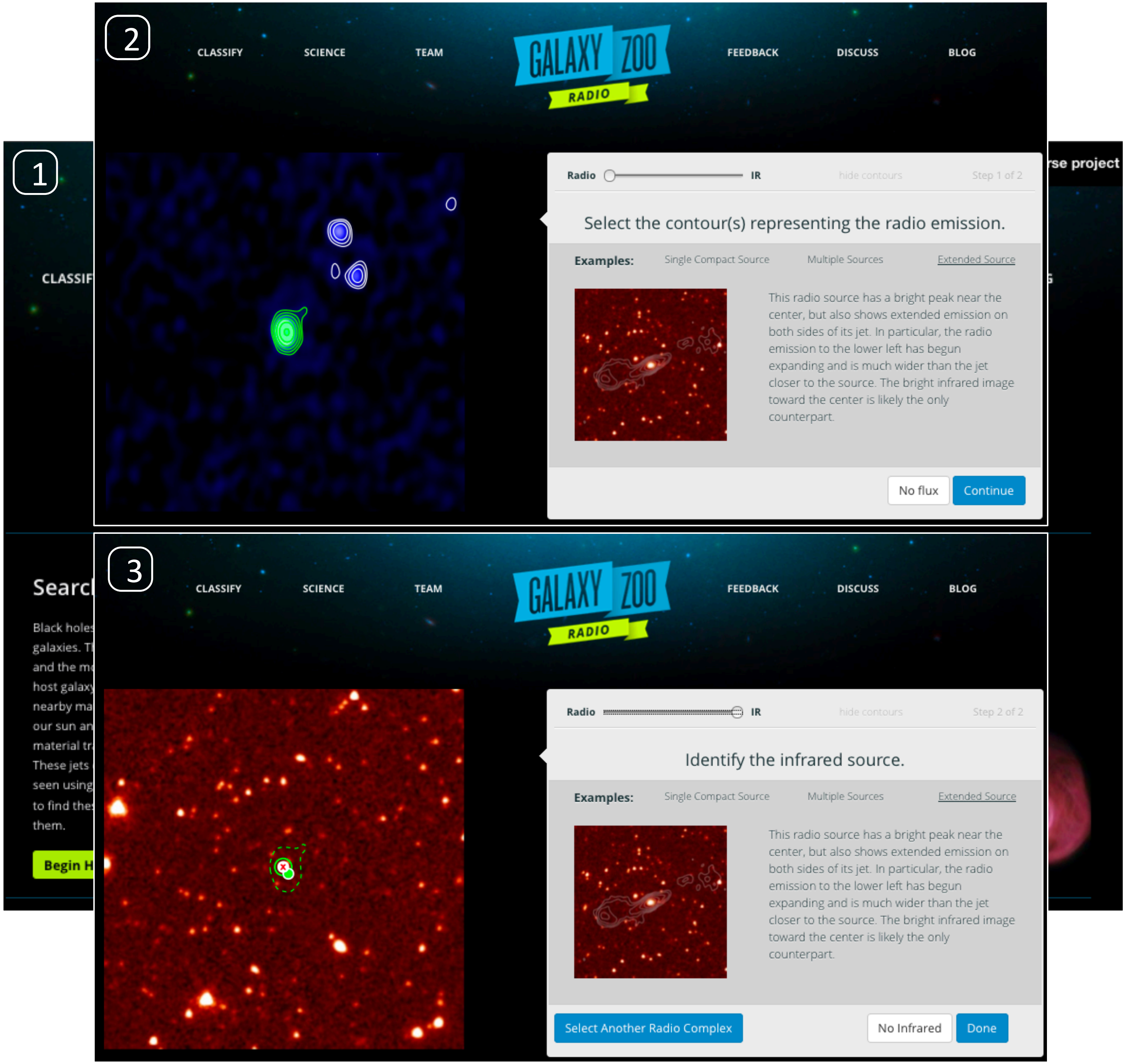


Chris Snyder


1
A Zooniverse project
CLASSIFY
SCIENCE
TEAM
GALAXY ZOO
RADIO
FEEDBACK
DISCUSS
BLOG
In Search of Erupting Black Holes
Help astronomers discover supermassive black holes observed by the Australia Telescope Large Area Survey.
Search for Black Holes
Black holes are found at the center of most, if not all, galaxies. The bigger the galaxy, the bigger the black hole and the more sensational the effect it can have on the host galaxy. These supermassive black holes drag in nearby material, growing to billions of times the mass of our sun and occasionally producing spectacular jets of material traveling nearly as fast as the speed of light. These jets often can't be detected in visible light, but are seen using radio telescopes. Astronomers need your help to find these jets and match them to the galaxy that hosts them.
Begin Hunting

Ivy Wong


2
CLASSIFY
SCIENCE
TEAM
GALAXY ZOO
RADIO
FEEDBACK
DISCUSS
BLOG
Radio
IR
hide contours
Step 1 of 2
Select the contour(s) representing the radio emission.
Examples:
Single Compact Source
Multiple Sources
Extended Source
This radio source has a bright peak near the center, but also shows extended emission on both sides of its jet. In particular, the radio emission to the lower left has begun expanding and is much wider than the jet closer to the source. The bright infrared image toward the center is likely the only counterpart.
No flux
Continue
1
Search for Black Holes
Black holes are found at the center of most, if not all, galaxies. The bigger the galaxy, the bigger the black hole and the more sensational the effect it can have on the host galaxy. These supermassive black holes drag in nearby material, growing to billions of times the mass of our sun and occasionally producing spectacular jets of material traveling nearly as fast as the speed of light. These jets often can't be detected in visible light, but are seen using radio telescopes. Astronomers need your help to find these jets and match them to the galaxy that hosts them.
Begin Hunting



1
CLASSIF
Searc
Black holes
galaxies. T
and the m
host galax
nearby ma
our sun an
material tr
These jets
seen using
to find the
them.
Begin H
se project
2
CLASSIFY
SCIENCE
TEAM
GALAXY ZOO
RADIO
FEEDBACK
DISCUSS
BLOG
Radio
IR
hide contours
Step 1 of 2
Select the contour(s) representing the radio emission.
Examples:
Single Compact Source
Multiple Sources
Extended Source
This radio source has a bright peak near the center, but also shows extended emission on both sides of its jet. In particular, the radio emission to the lower left has begun expanding and is much wider than the jet closer to the source. The bright infrared image toward the center is likely the only counterpart.
No flux
Continue
3
CLASSIFY
SCIENCE
TEAM
GALAXY ZOO
RADIO
FEEDBACK
DISCUSS
BLOG
Radio
IR
hide contours
Step 2 of 2
Identify the infrared source.
Examples:
Single Compact Source
Multiple Sources
Extended Source
This radio source has a bright peak near the center, but also shows extended emission on both sides of its jet. In particular, the radio emission to the lower left has begun expanding and is much wider than the jet closer to the source. The bright infrared image toward the center is likely the only counterpart.
Select Another Radio Complex
No Infrared
Done

Citizen Science projects with HST & MAST

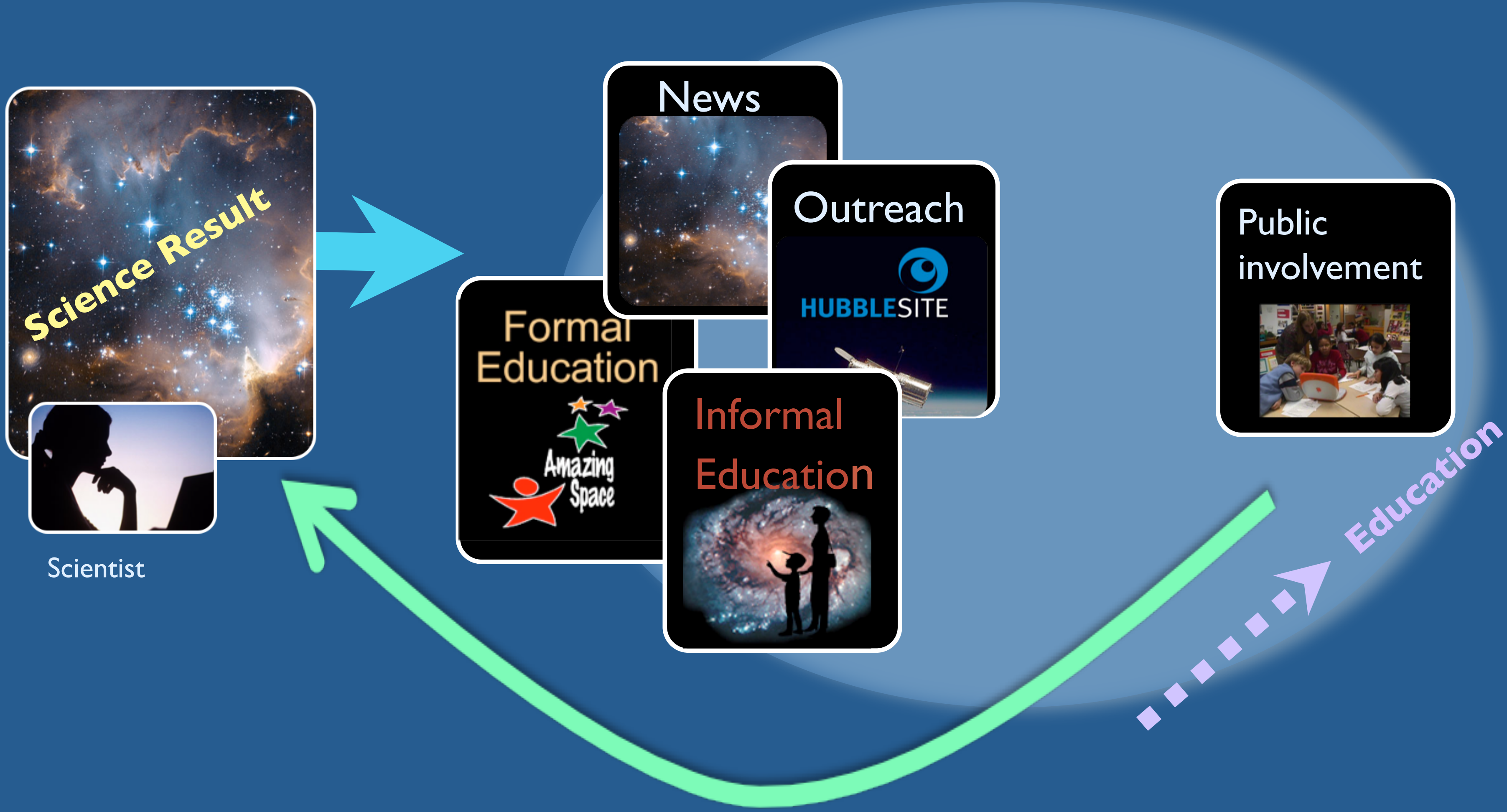
- **Galaxy Zoo Hubble :** distant galaxy morphology
- **Galaxy Zoo 3 :** HST MCT CANDELS HST data - SN search
- **Andromeda Project :** part 1, II of MCT PHAT HST data - identify clusters in M31
- **Planet Investigators :** HST archive data - moving targets in solar system
- **Space Warps :** HST data - find lensed objects
- **Pinwheel Parts :** M83 HST data - classify clusters by age (development)
- **PlanetHunters :** Kepler MAST data - identify planet candidates and other variables

Galex Transients : Galex MAST data - identify transients (in planning)

- **Frontier Fields :** HST data - identify parts of lensed objects (planning)

Carol Christian

CITIZEN SCIENCE = COLLABORATION



Carol Christian

theSkyNet – the future of citizen science?

arXiv.org > astro-ph > arXiv:1306.1618

Astrophysics > Instrumentation and Methods for Astrophysics

A BOINC based, citizen-science project for pixel Spectral Energy Distribution fitting of resolved galaxies in multi-wavelength surveys

Kevin Vinsen, David Thilker

(Submitted on 7 Jun 2013 (v1), last revised 20 Sep 2013 (this version, v2))

In this work we present our experience from the first year of theSkyNet Pan-STARRS1 Optical Galaxy Survey (POGS) project. This citizen-scientist driven research project uses the Berkeley Open Infrastructure for Network Computing (BOINC) middleware and thousands of Internet-connected computers to measure the resolved galactic structural properties of ~100,000 low redshift galaxies.

- theSkyNet now…
  - 4,400+ Users
    (cf. SETI@Home 1.4 million)
  - 11,200+ Computers
    (cf. Einstein@Home 5.6 million)
  - 8,015+ galaxies
  - 50 Million+ pixels

Kevin Vinsen

theSkyNet – the future of CYBORG science?

arXiv.org > astro-ph > arXiv:1306.1618

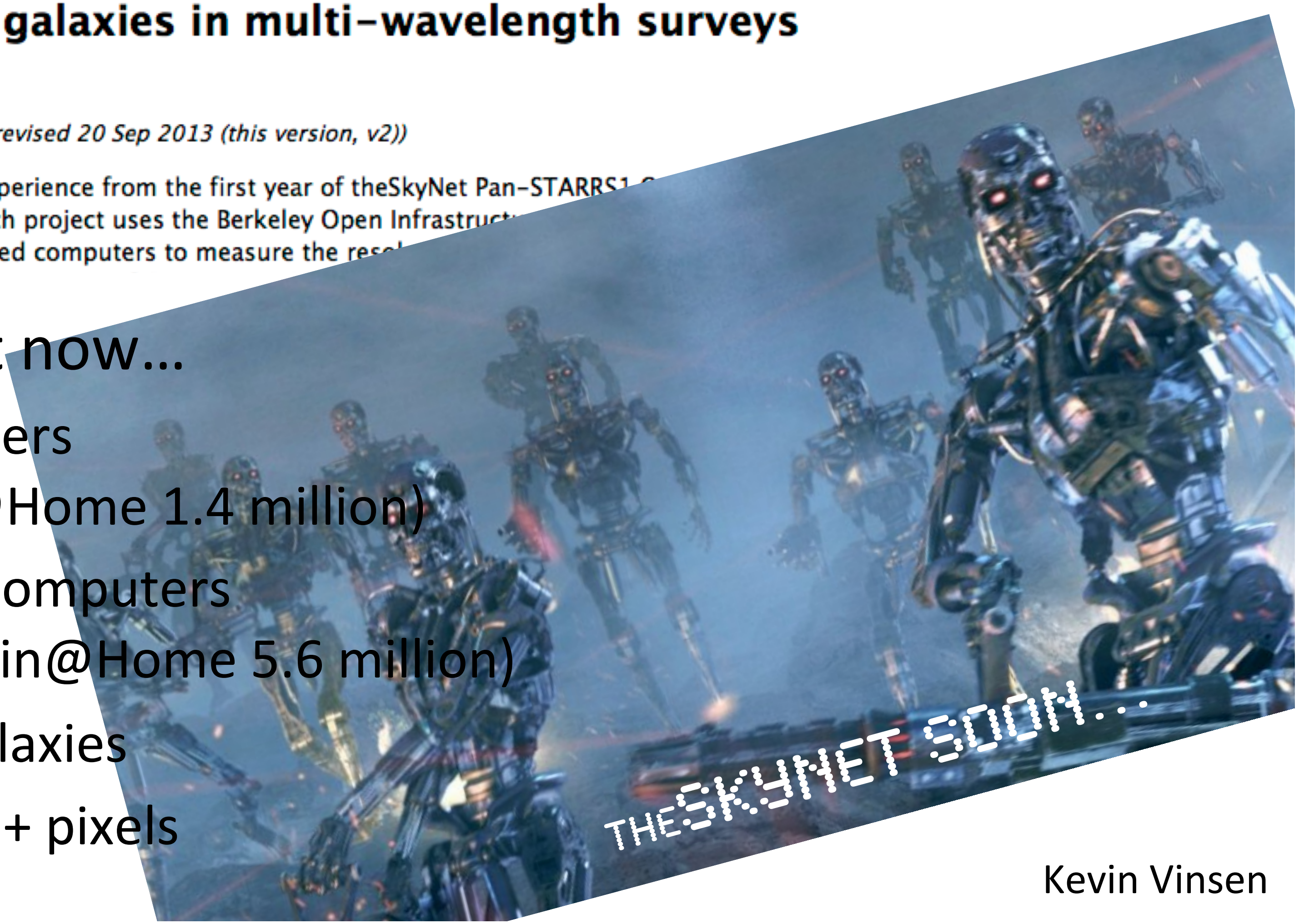
Astrophysics > Instrumentation and Methods for Astrophysics

A BOINC based, citizen-science project for pixel Spectral Energy Distribution fitting of resolved galaxies in multi-wavelength surveys

Kevin Vinsen, David Thilker

(Submitted on 7 Jun 2013 (v1), last revised 20 Sep 2013 (this version, v2))

In this work we present our experience from the first year of theSkyNet Pan-STARRS1 …
citizen-scientist driven research project uses the Berkeley Open Infrastruct…
thousands of Internet-connected computers to measure the res…

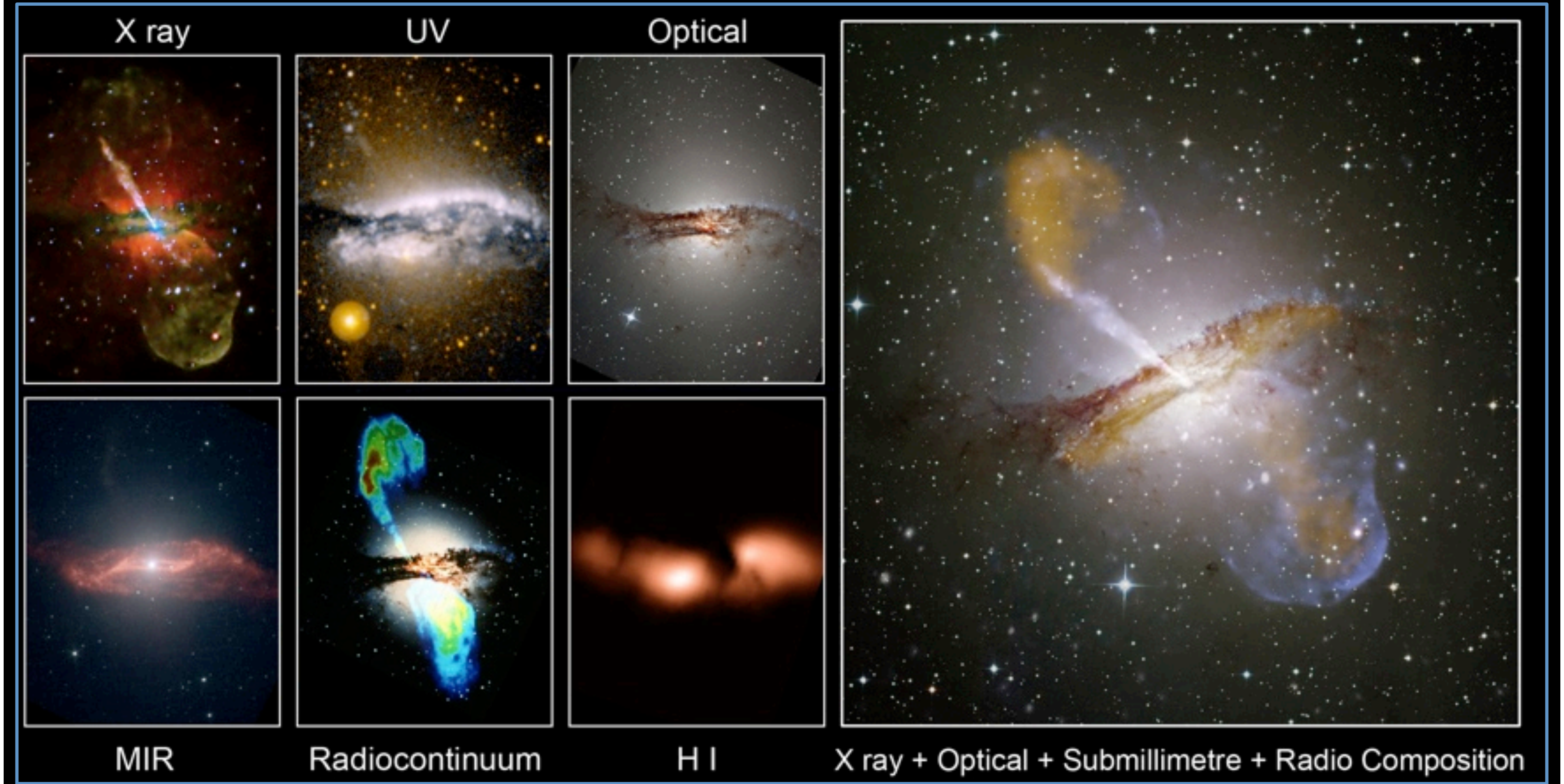


- theSkyNet now…
  - 4,400+ Users
    (cf. SETI@Home 1.4 million)
  - 11,200+ Computers
    (cf. Einstein@Home 5.6 million)
  - 8,015+ galaxies
  - 50 Million+ pixels

Kevin Vinsen

Now, the science…

Is there information in morphology?



Julie Banfield & Ángel López-Sánchez

Galaxy evolution: what can morphology tell us?

- Morphology is determined by orbital structure [excl. jets etc.!]
- Galaxy potentials determine the orbital families present
- *Stars* moving on the allowed orbits occupy specific parts of phase space and generate observed morphological features (bars, rings, peanut bulges, pseudo-bulges etc.)
- *Gas* piles up close to orbital resonances producing regions of star formation (e.g. rings at the end of bars)
- Morphology as a joint function of mass and angular momentum gives the star formation history & secular evolution of galaxies
- The stability or otherwise of such features reveals the distribution of mass (both luminous and dark)

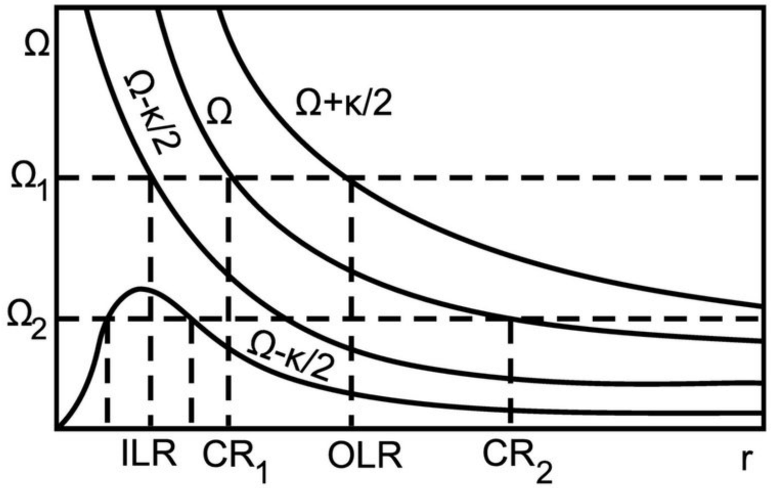
Roger Davies

Disk galaxy morphology

- Optical morphology is determined by orbits
- In disk potentials orbital resonances occur where:

$$\Omega_p = \Omega \pm \kappa/m$$

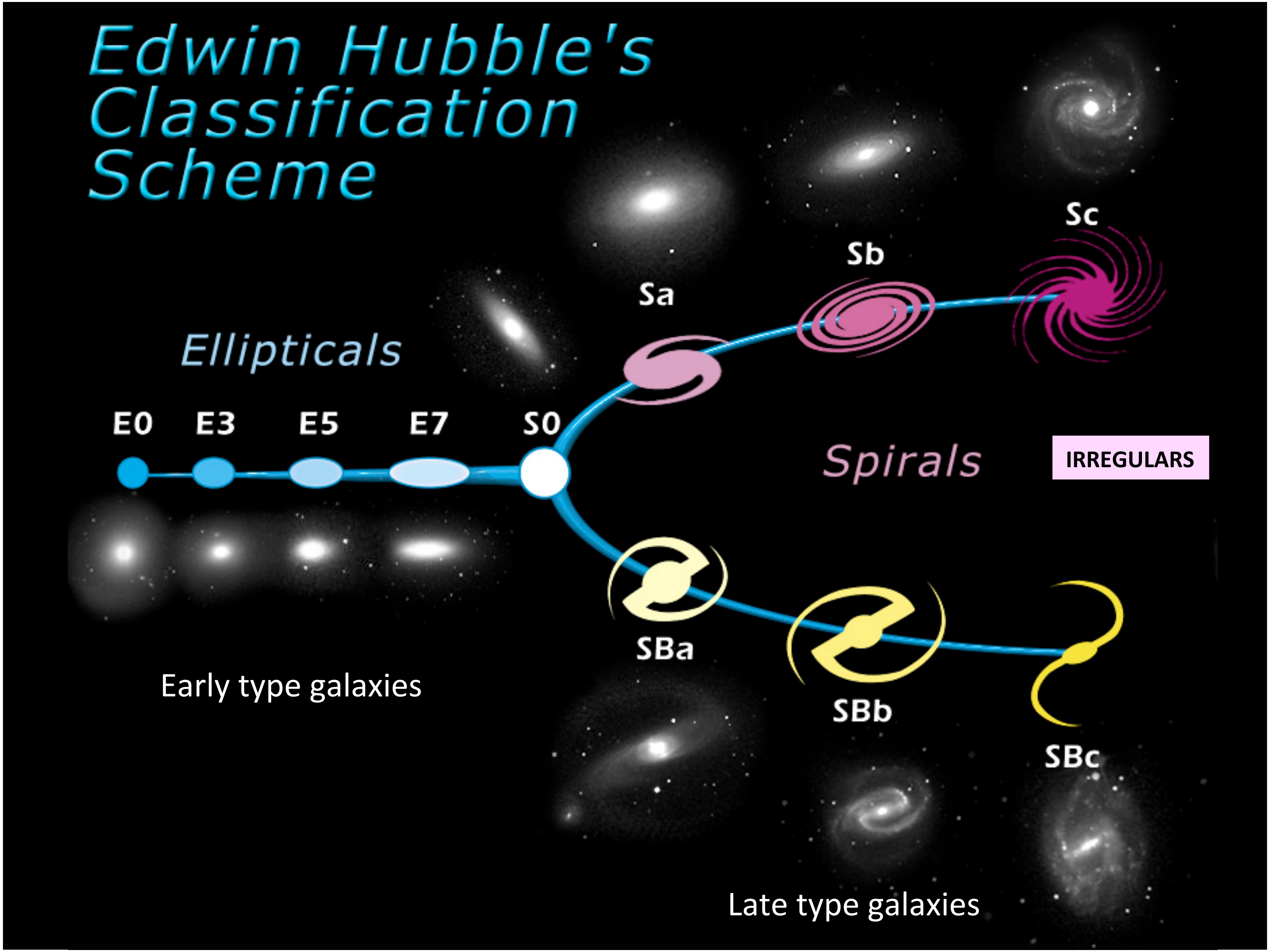
where Ω_p is pattern speed, κ the radial epicyclic frequency and m an integer



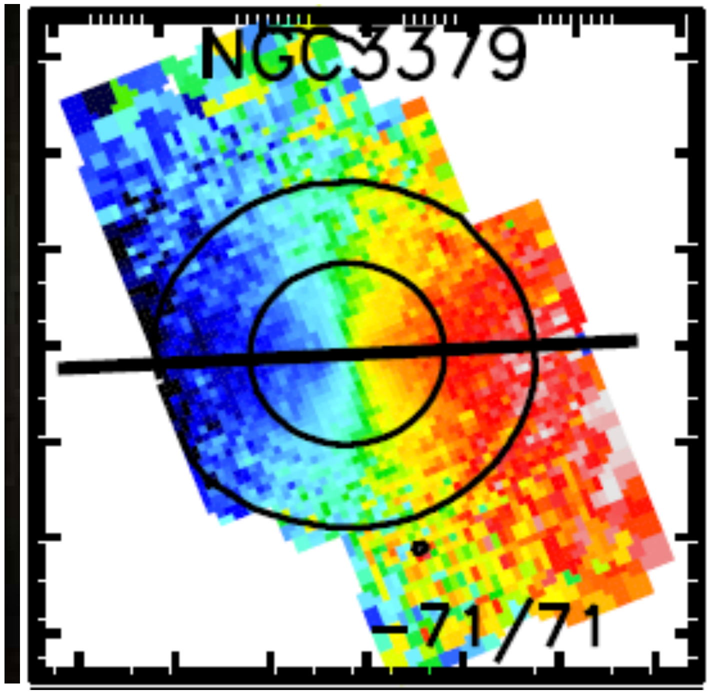
- Bars and rings trace the orbital resonances
- Gas settles in rings and results in star formation
- For cold disks:
  - morphology → orbits → star formation history
  - morphology → secular evolution

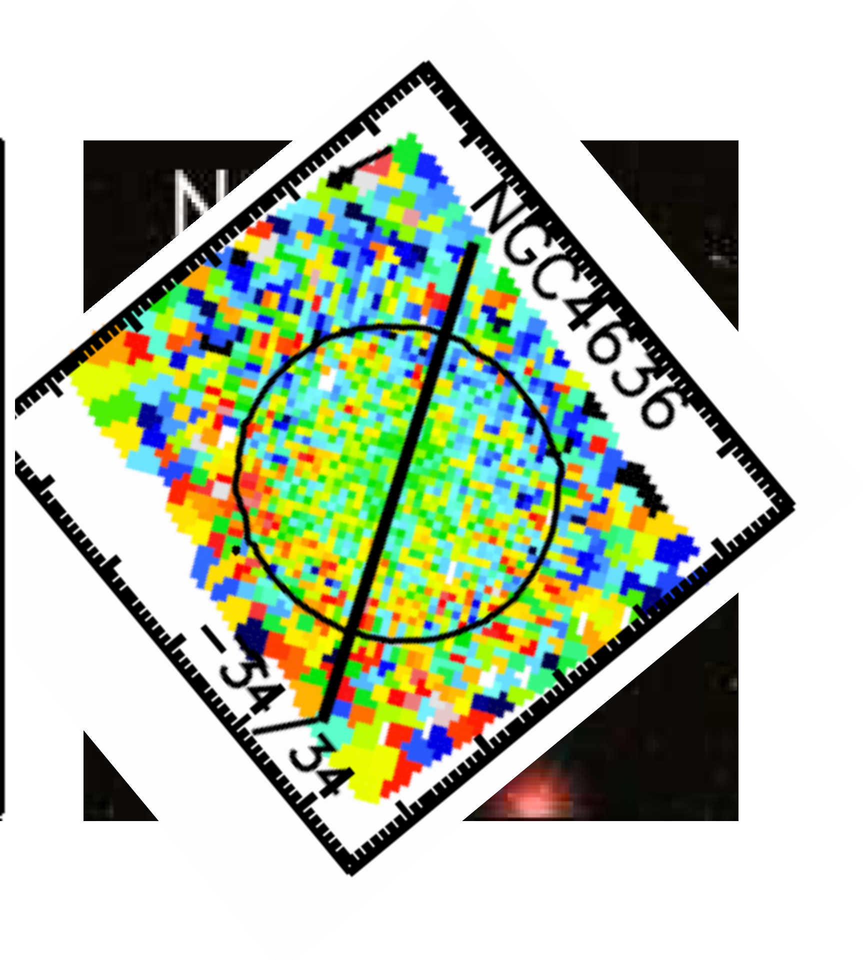
Roger Davies

Quantifying morphology…


Edwin Hubble's Classification Scheme
Ellipticals
E0
E3
E5
E7
S0
Sa
Sb
Sc
Spirals
IRREGULARS
SBa
SBb
SBc
Early type galaxies
Late type galaxies

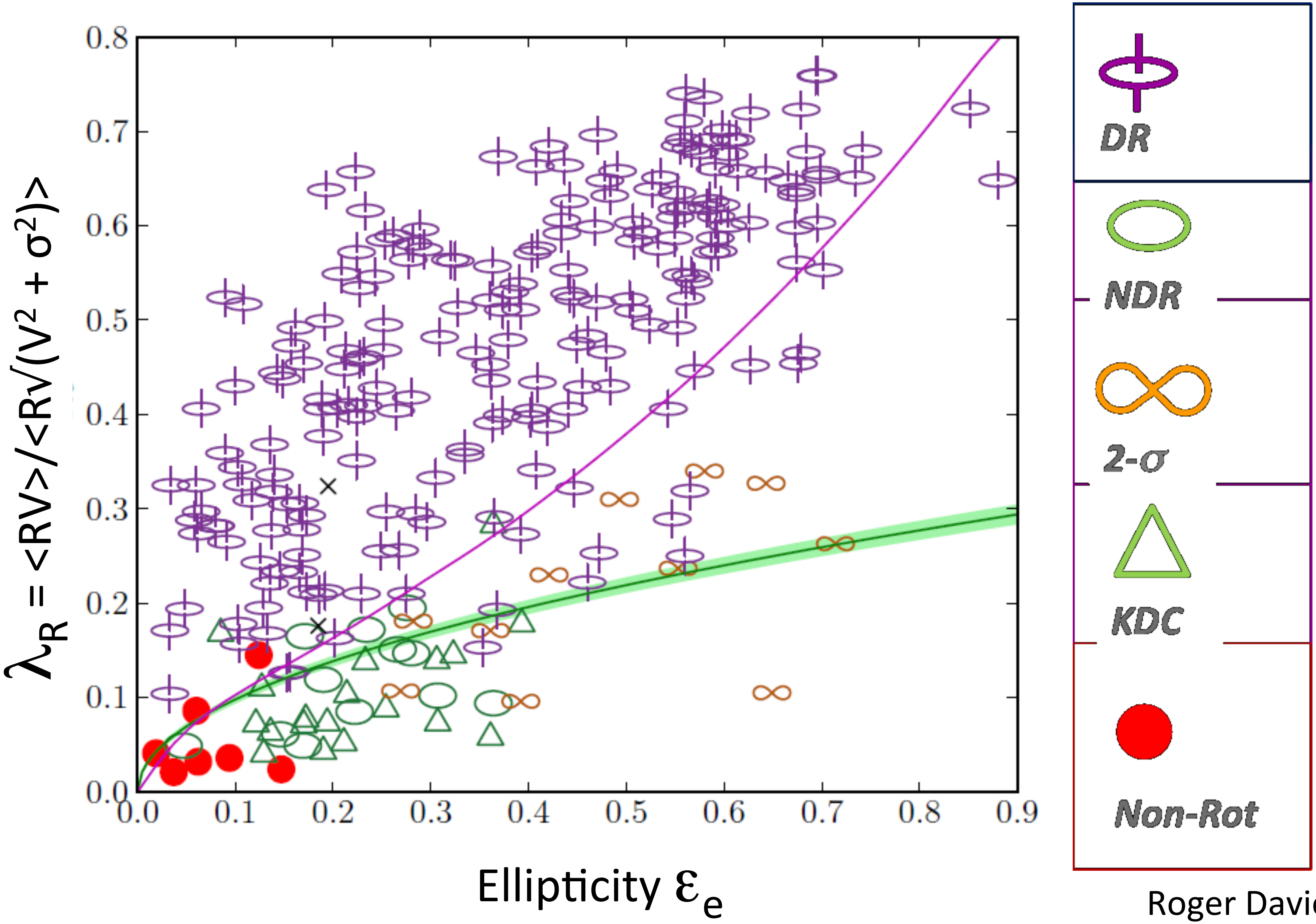
Kinematic morphology



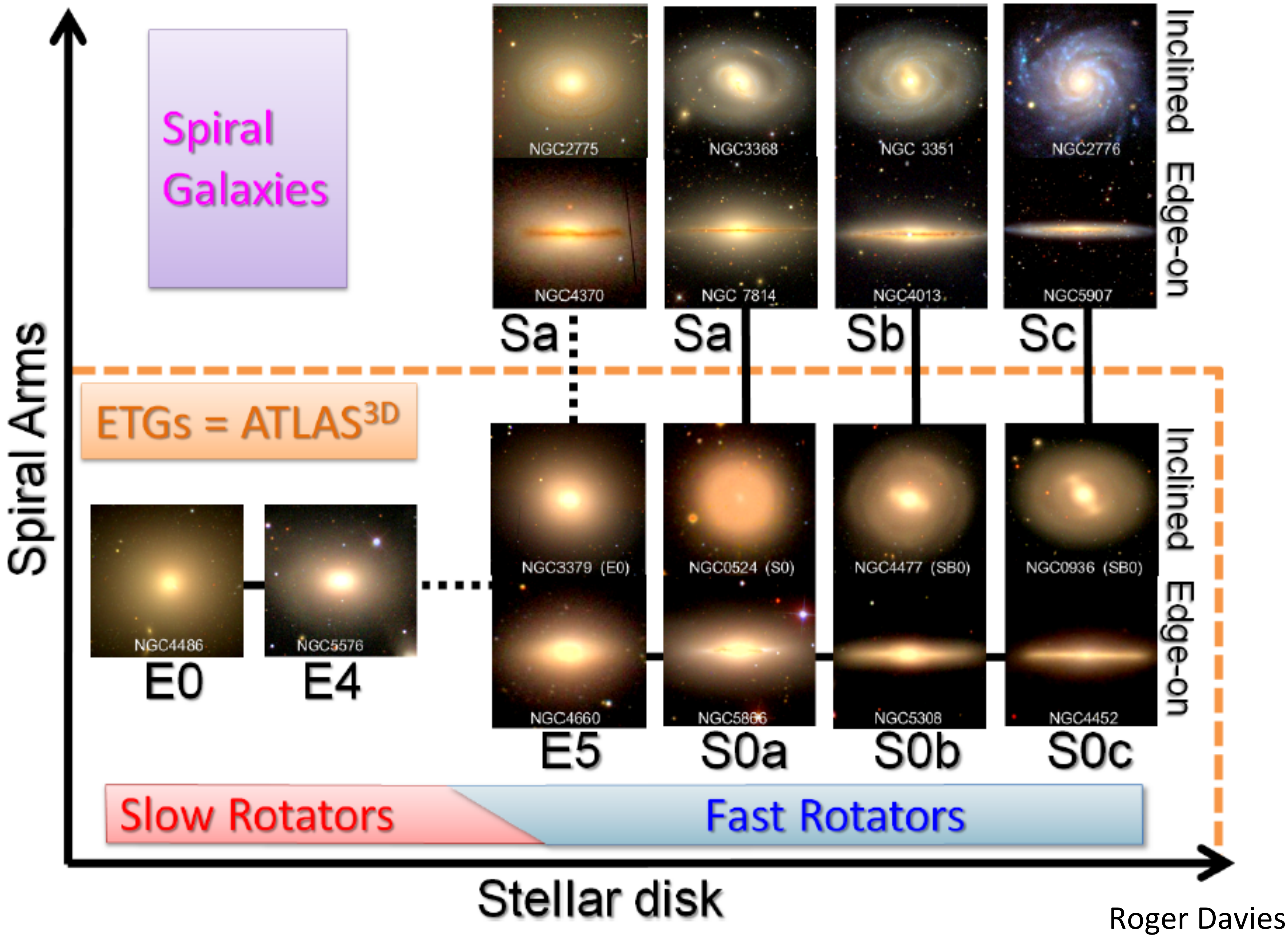


Roger Davies

Kinematic morphology

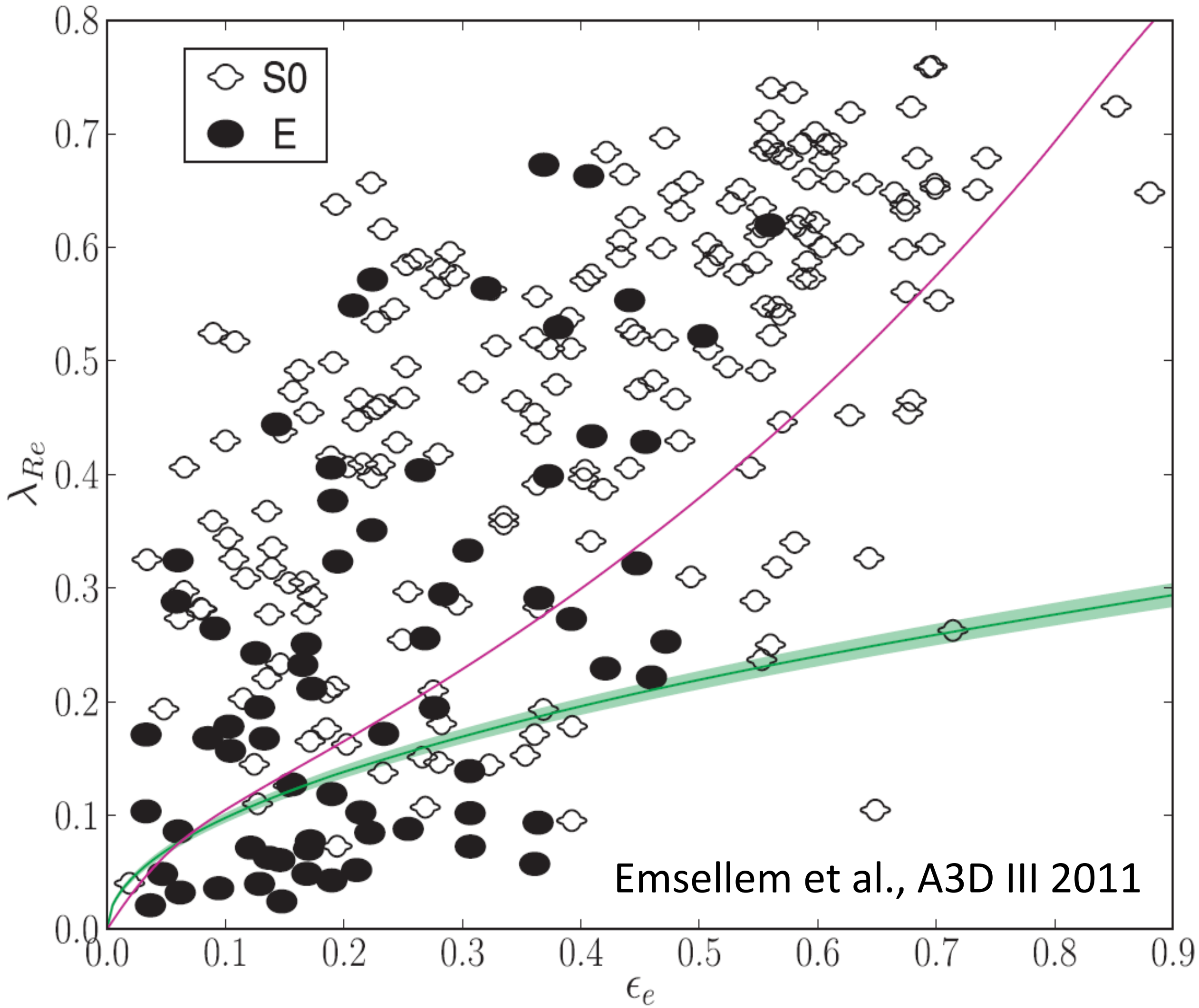


Roger Davies



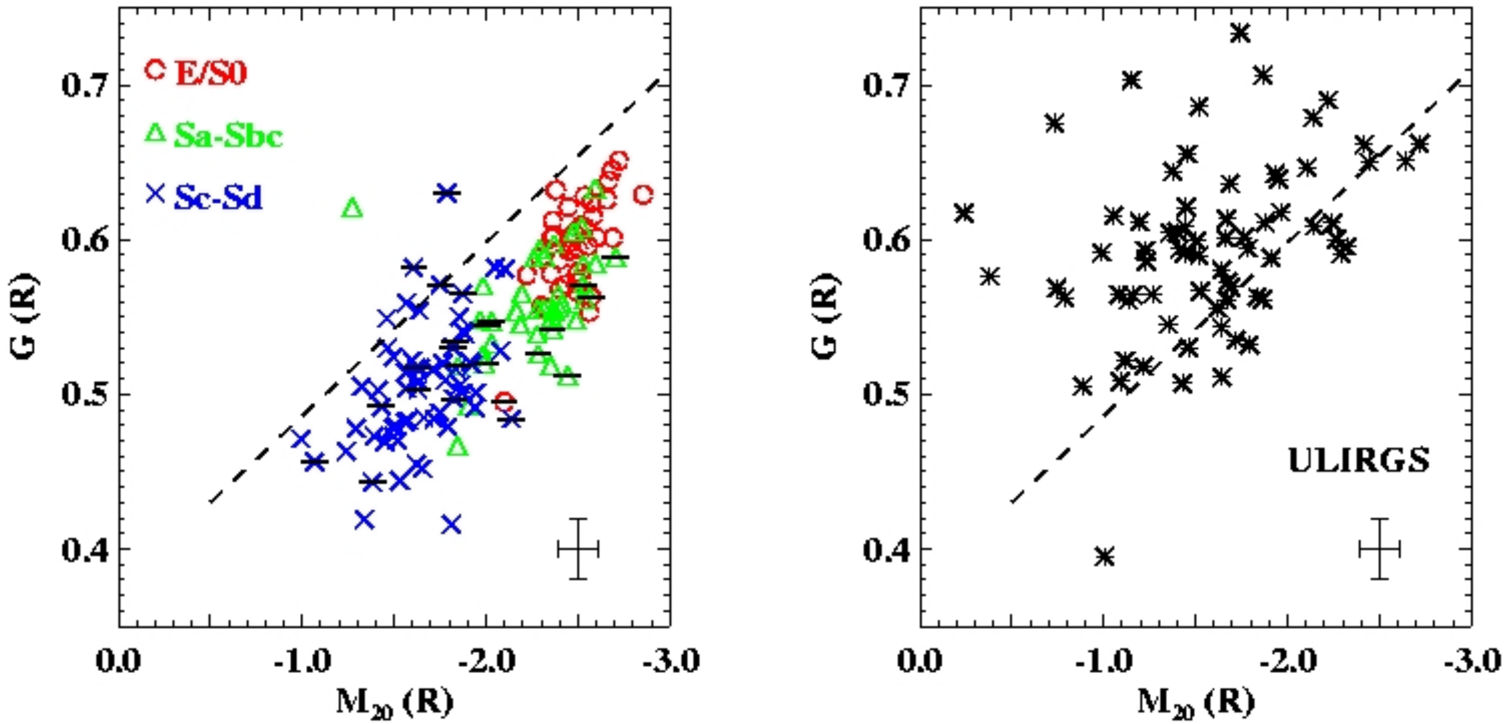
Spiral Galaxies
ETGs = ATLAS3D
Spiral Arms
Stellar disk
Inclined
Edge-on
NGC2775
NGC3368
NGC 3351
NGC2776
NGC4370
NGC 7814
NGC4013
NGC5907
Sa
Sa
Sb
Sc
NGC4486
NGC5576
E0
E4
NGC3379 (E0)
NGC0524 (S0)
NGC4477 (SB0)
NGC0936 (SB0)
NGC4660
NGC5866
NGC5308
NGC4452
E5
S0a
S0b
S0c
Slow Rotators
Fast Rotators
Roger Davies

Kinematic and visual morphologies are not well correlated…



Roger Davies

Many other quantitative classification schemes…



For example, G-M_{20} is very effective at selecting multiply-nucleated galaxies (Lotz, Primack & Madau 2004)

Jennifer Lotz

Caveats on morphological classification

CAN YOU SEE
THE HIDDEN TIGER
IN THIS PICTURE?

ARE YOU SURE YOU
KNOW WHAT YOU
ARE LOOKING FOR?

- Move past the Hubble Tuning Fork to more quantitative measures of stellar/gas distribution/kinematics and how these are related.
- Define quantitative metrics that encompass the all available information (IFS data, multiwavelength imaging, redshifts) to get more physical insight.
- Bimodality is clearly a real phenomenon, but artificially classifying galaxies into two populations is limiting & at worst erroneous (false dichotomies).
  - Early-type and late-type. Stop it. Really, just stop it.

Andrew Hopkins

Some fundamental problems in galaxy evolution - 10 years ago

1. True abundance of red/elliptical galaxies at z>1? ✓
2. Morphological dist^{n} at z>1 in *mass-selected* samples ✓
3. Dependence of M vs SFR vs Z vs redshift? ✓
4. Can we measure circular velocities of z>1 galaxies? ✓
5. Can we detect the BAO feature in the galaxies? ✓

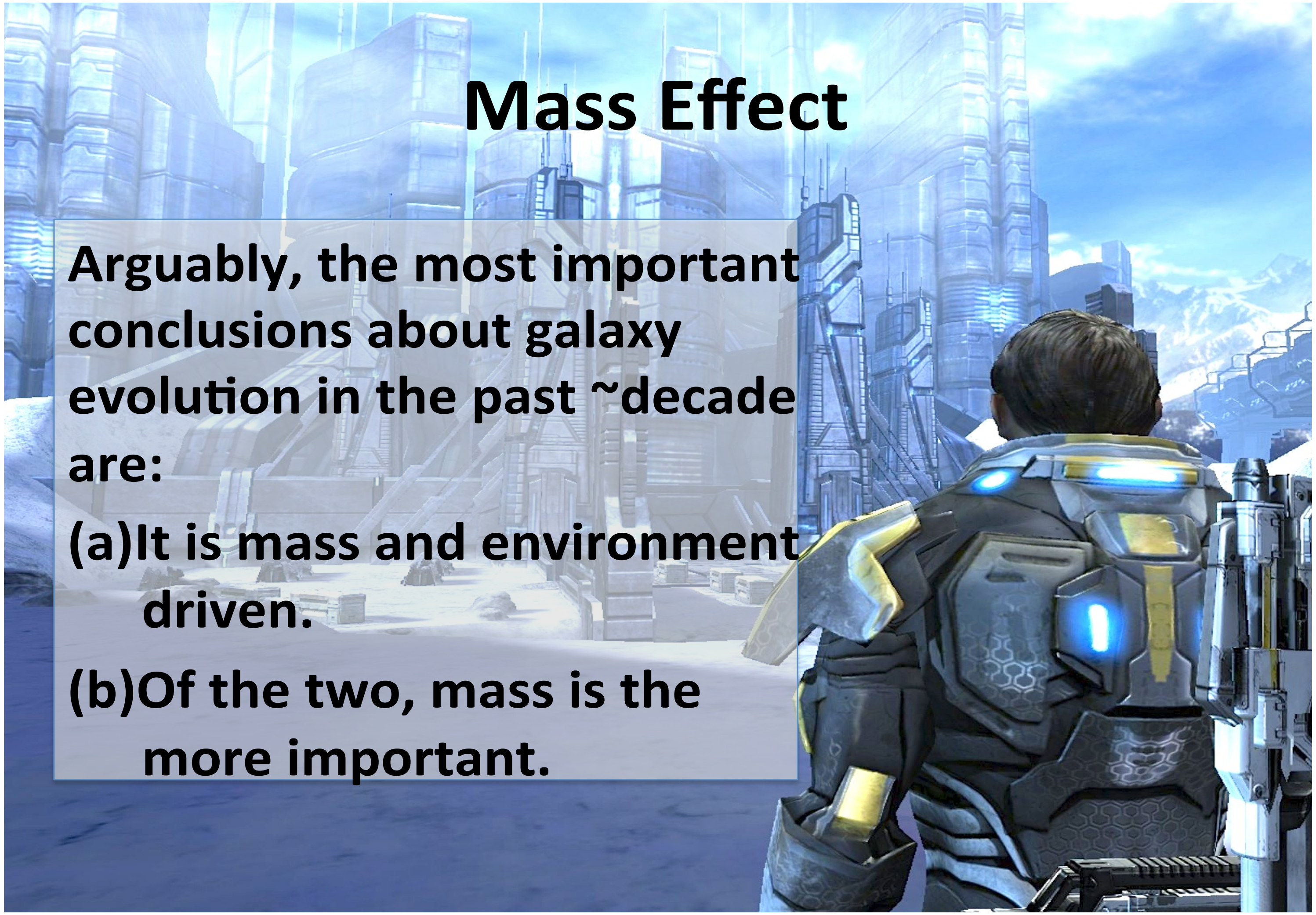
Karl Glazebrook

Fundamental problems - today

1. What are *kinematic* morphology fractions at z>0.5?
2. What is the galaxy merger rate?
3. What drives turbulence in high-z disks?
4. How do 'clumps' drive galaxy evolution?
5. How does the Tully-Fisher relation evolve?
6. Are the IMF and SF law universal in space and time?
7. *Not to mention star formation quenching!*

Karl Glazebrook

Nature *vs* nurture
= mass *vs* environment



Mass Effect

Arguably, the most important conclusions about galaxy evolution in the past ~decade are:

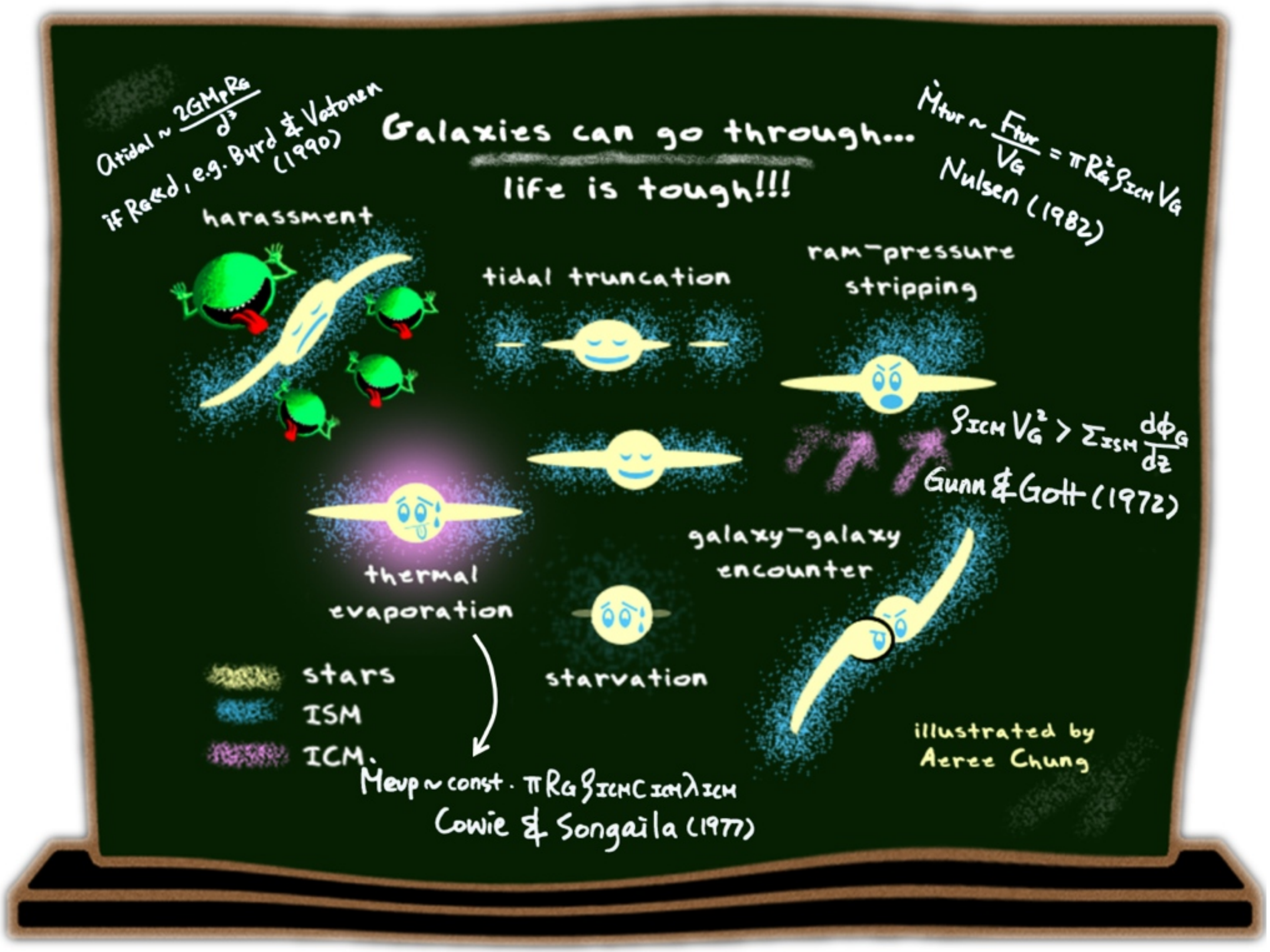
(a) It is mass and environment driven.

(b) Of the two, mass is the more important.

Mass matters…

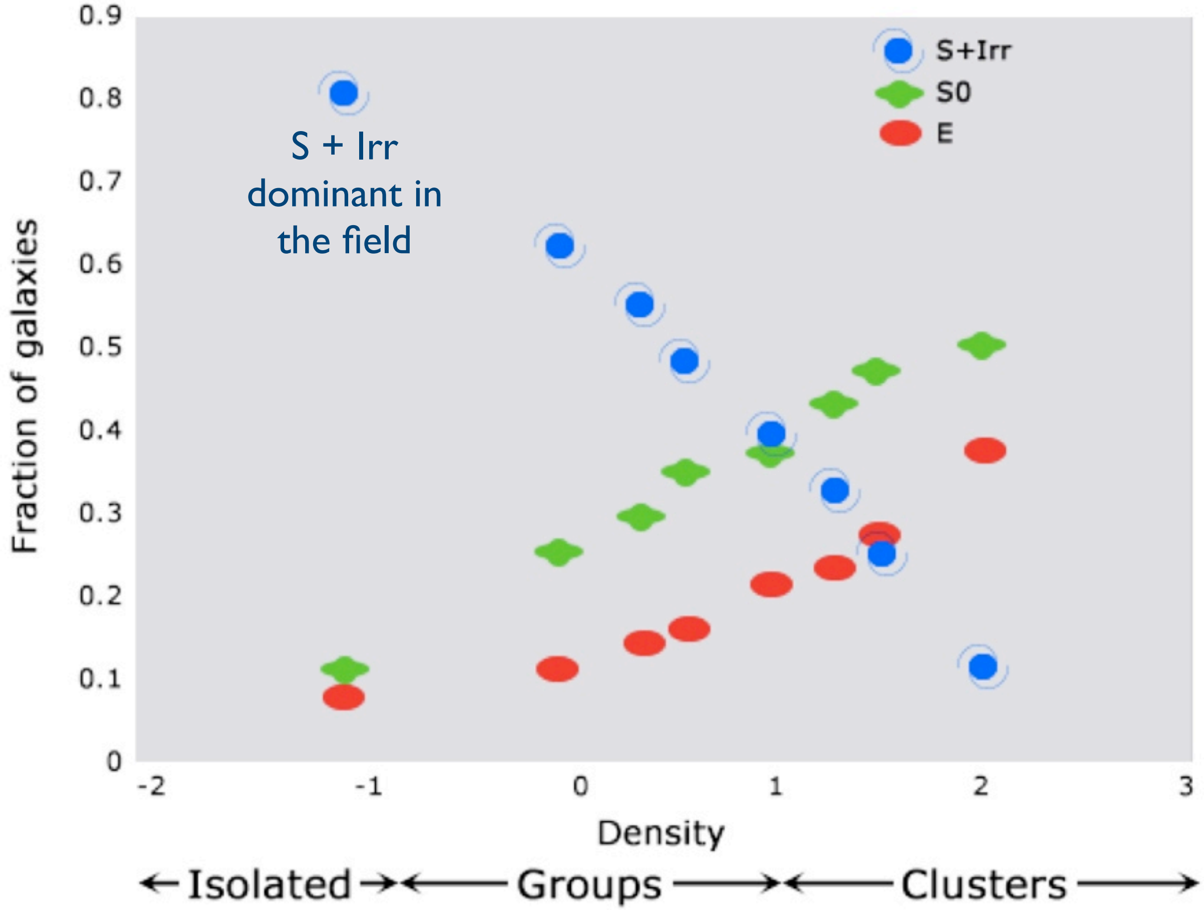
…but environment matters too…

Environmental effects



Aeree Chung

Environmental effects - 1



Morphology-density relation (Dressler 1980)
A study of ~50 nearby clusters

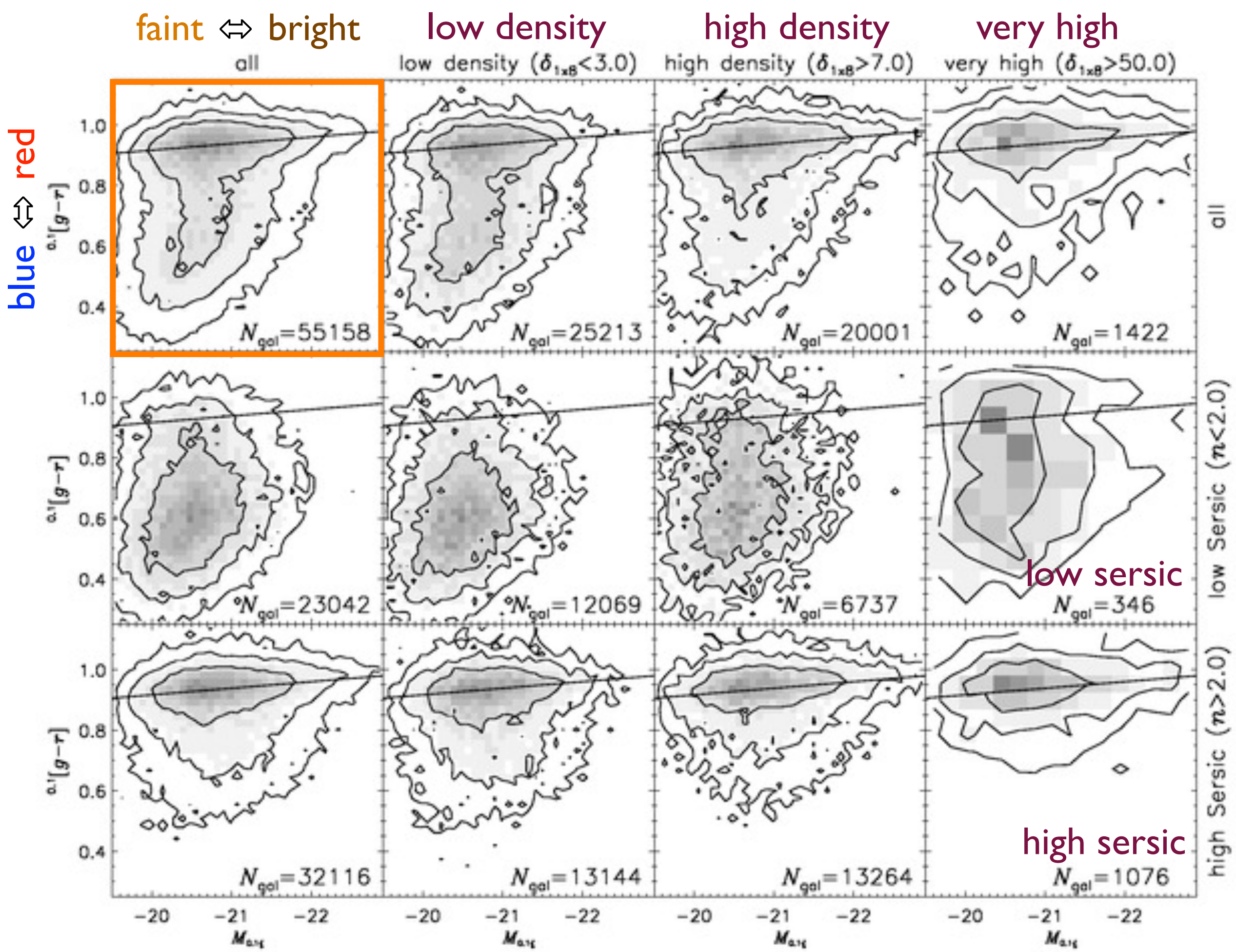
~90% E + S0
in cluster cores

But beware!

Mass correlates with environment too (hierarchical peaks-on-peaks)

Aeree Chung

Environmental effects - 2



Color-Magnitude diagram (SDSS galaxies; Hogg et al. 2004)

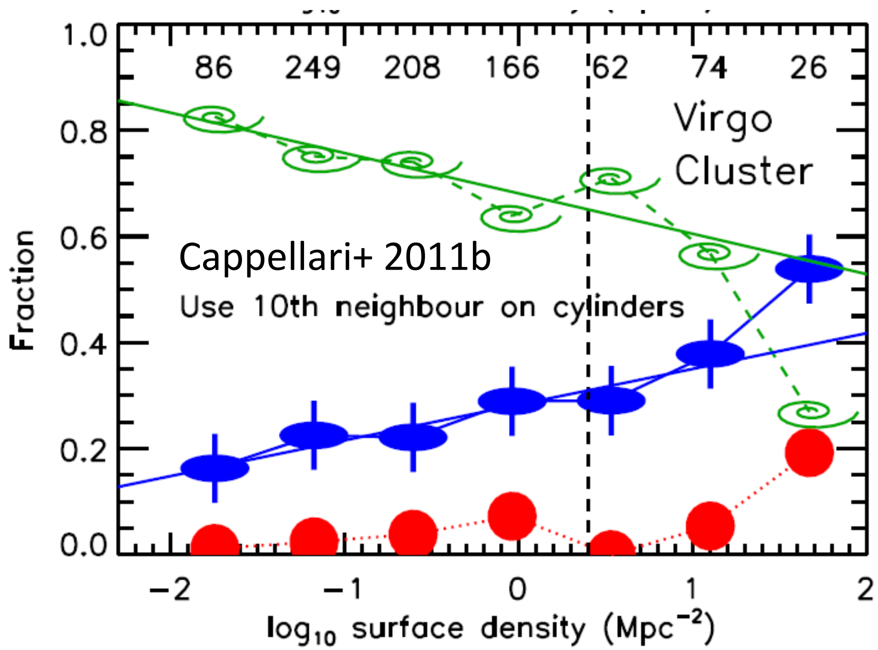
In higher density environments, the fraction of disky, blue galaxies dramatically decreases

Environment matters in galaxy evolution!

Aeree Chung

Kinematic morphology–density relation

- Steady increase of FRs w.r.t. spirals across all environments
- Significant increase in the SR fraction **only** at centre of Virgo
- But limited range of density (essentially Virgo & non-Virgo)

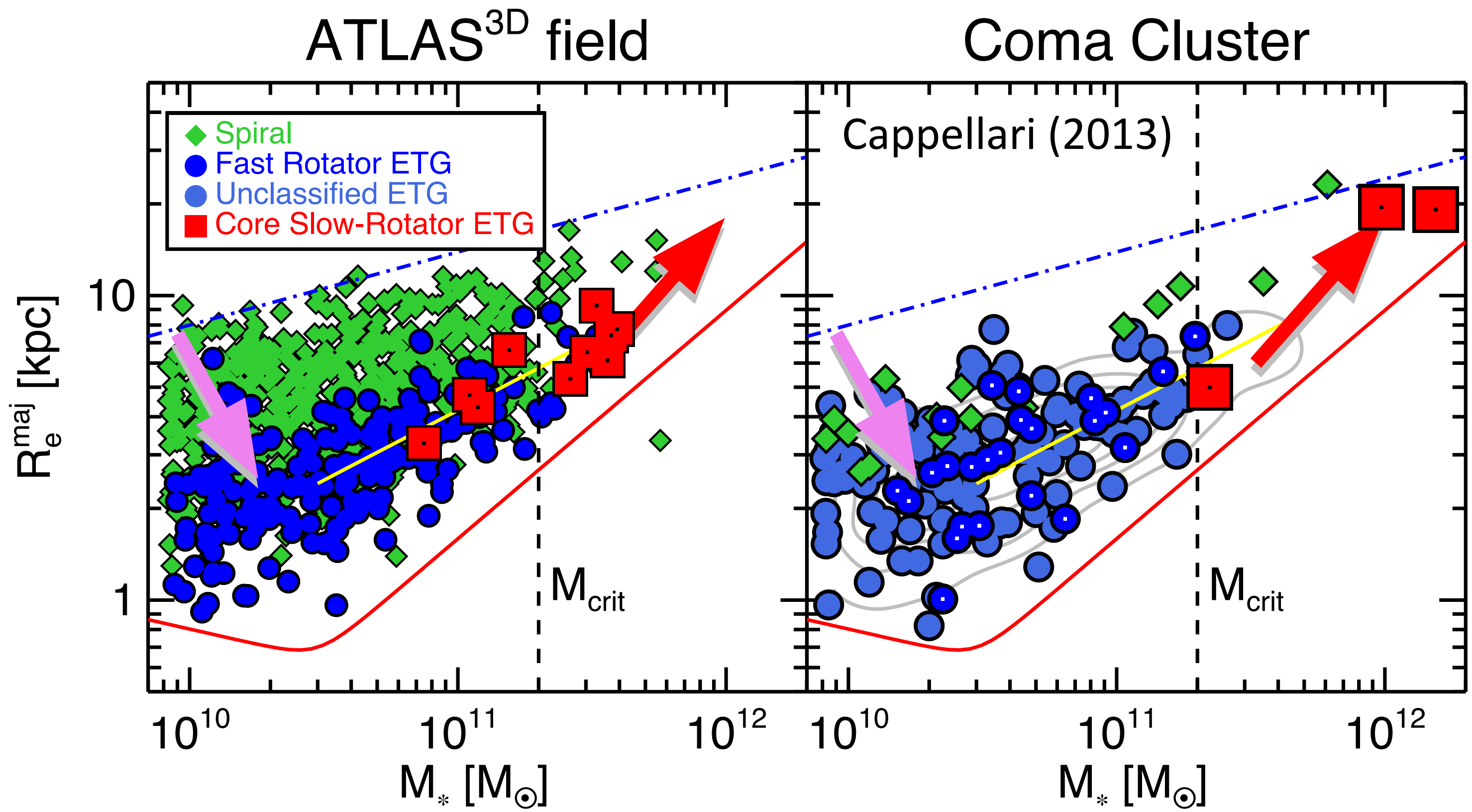


More generally…

- Early-type fraction increases smoothly with environmental density from the field to cluster outskirts, then shows a sharp increase
- Slow rotators make up a constant ~15% of early-type galaxies across all global (halo) environments
- Slow rotators are strongly segregated in clusters, with very few found in cluster outskirts and a significant over-abundance in cluster cores
- This behaviour is seen from small (low-M) to large (high-M) clusters

Nic Scott

Producing the morphology–density relation



1. Late-types transformed to early-types more efficiently in high-density environments via quenching + bulge growth without significant mass growth
2. SRs produced as a constant fraction of all early-types, indep. of environment, then concentrated in high local density environments due to mass segregation

Nic Scott

What about mergers?

- Do major mergers contribute significantly to SF at z~2?

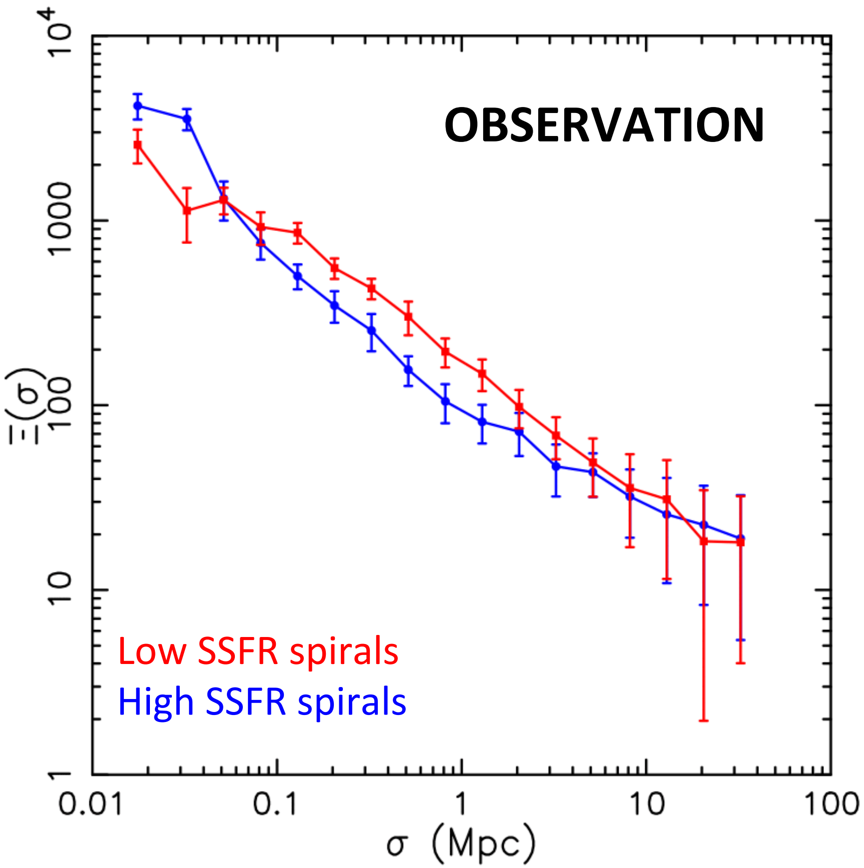
  Major merger contribution <15%

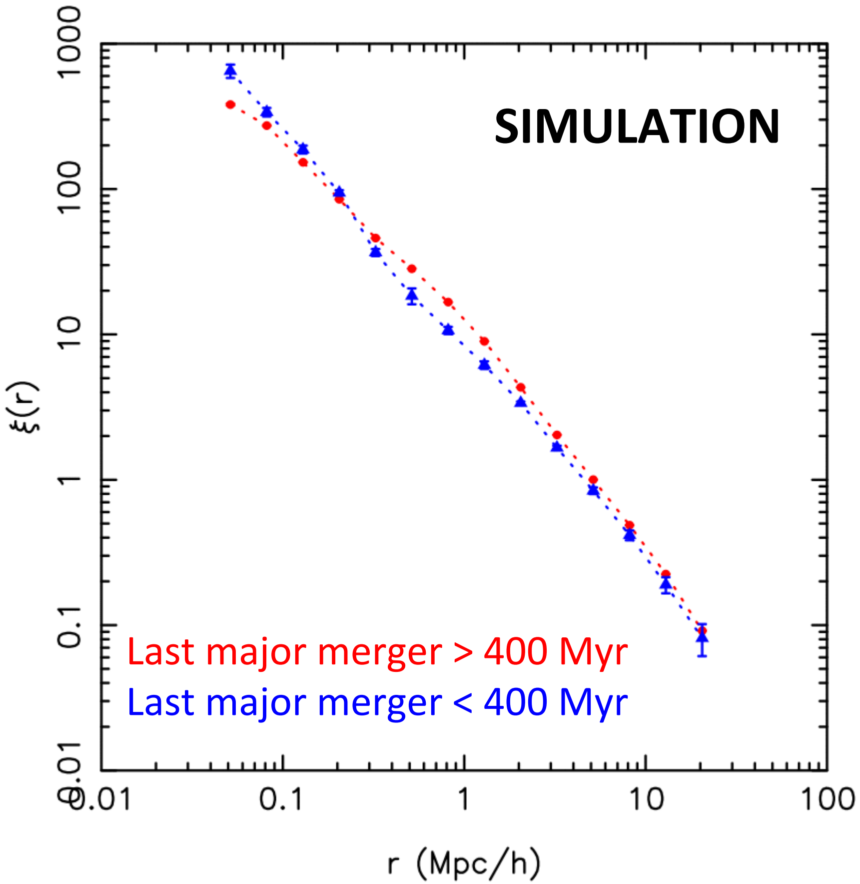
- Do major mergers create early spheroids?

  No recent major merger for >50 of blue spheroids at z~1.5

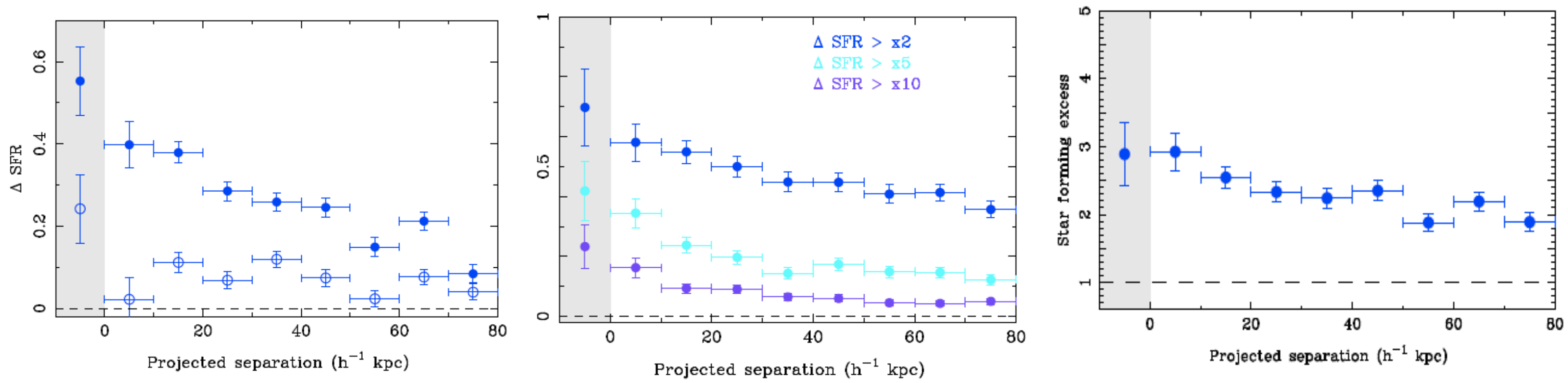
The role of merging in driving strong star formation diminishes rapidly after z~1

Clustering and star formation



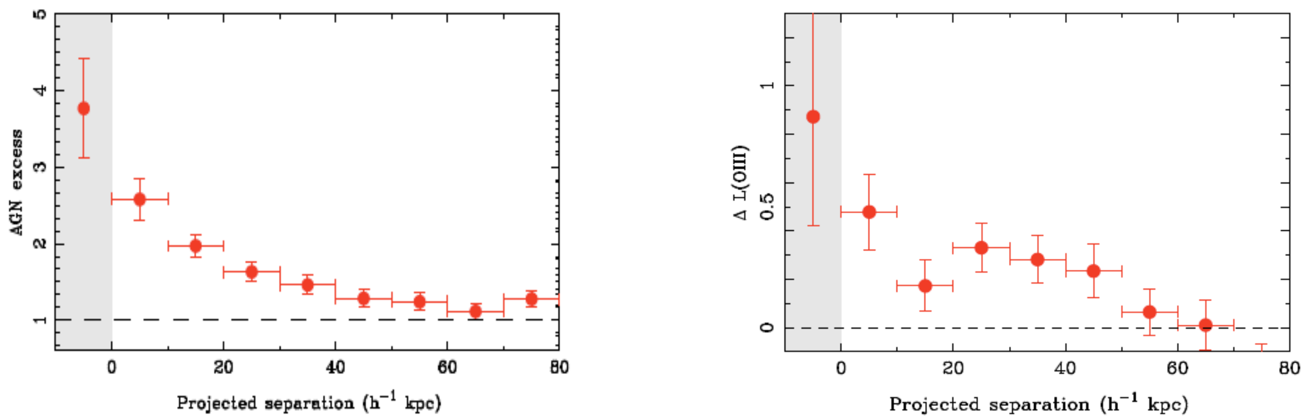


Tim Dolley



Star formation: happens centrally and globally, triggered early; starbursts are rare.

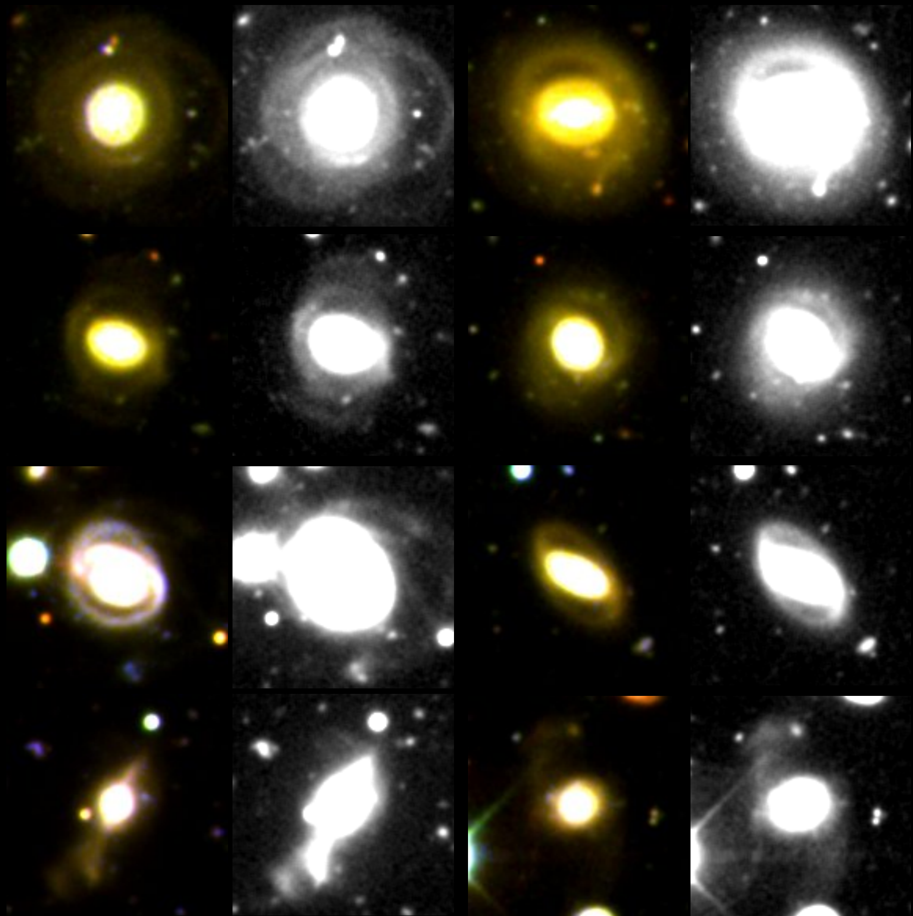
AGN: predominantly associated with coalescence; not all mergers trigger luminous AGN.

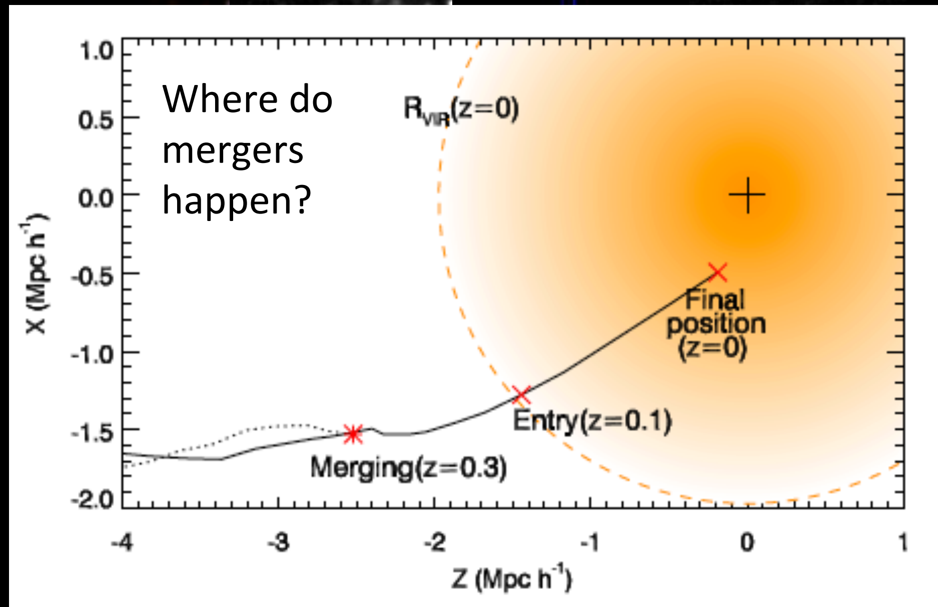


Sarah Ellison

Merger signatures in red-sequence galaxies

composite r

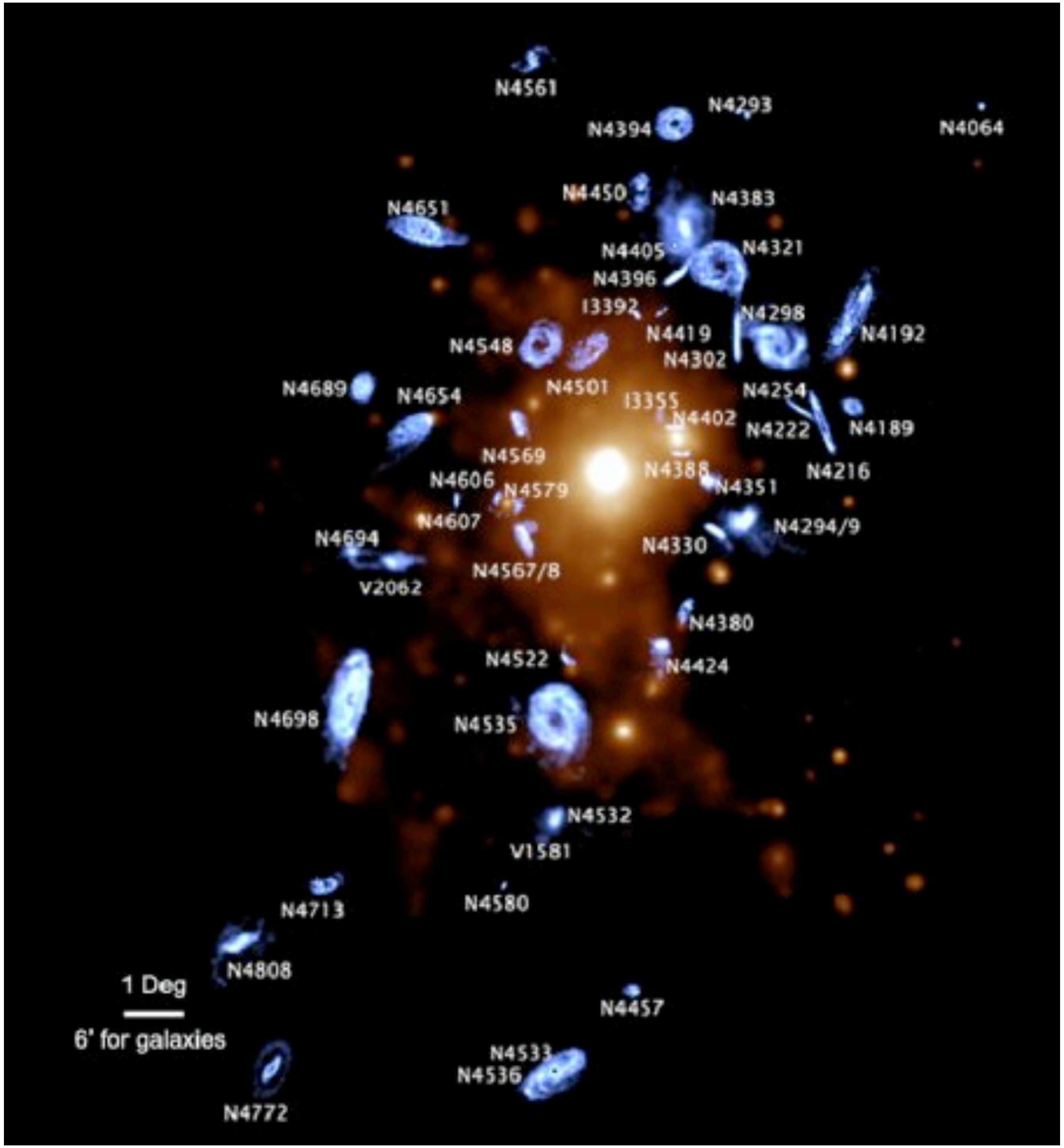




Sukyoung Yi

VIVA HI Atlas

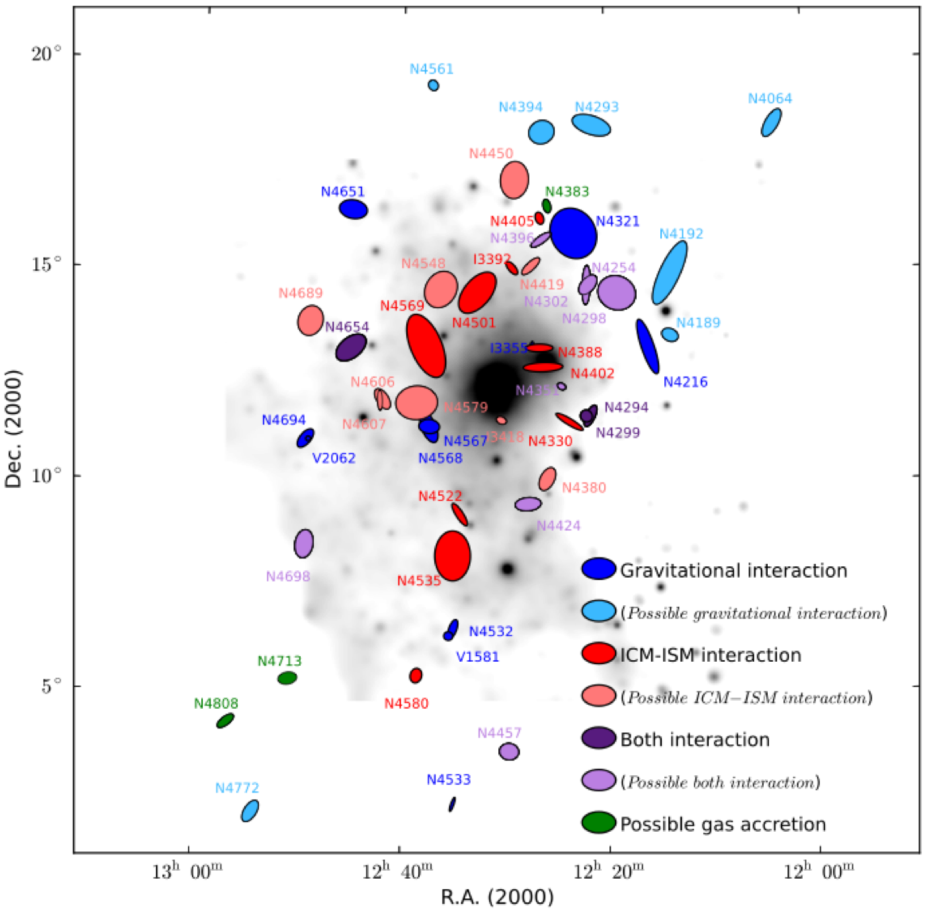
HI in blue, magnified by a factor of 10+X-ray in orange (Chung et al. 2009)

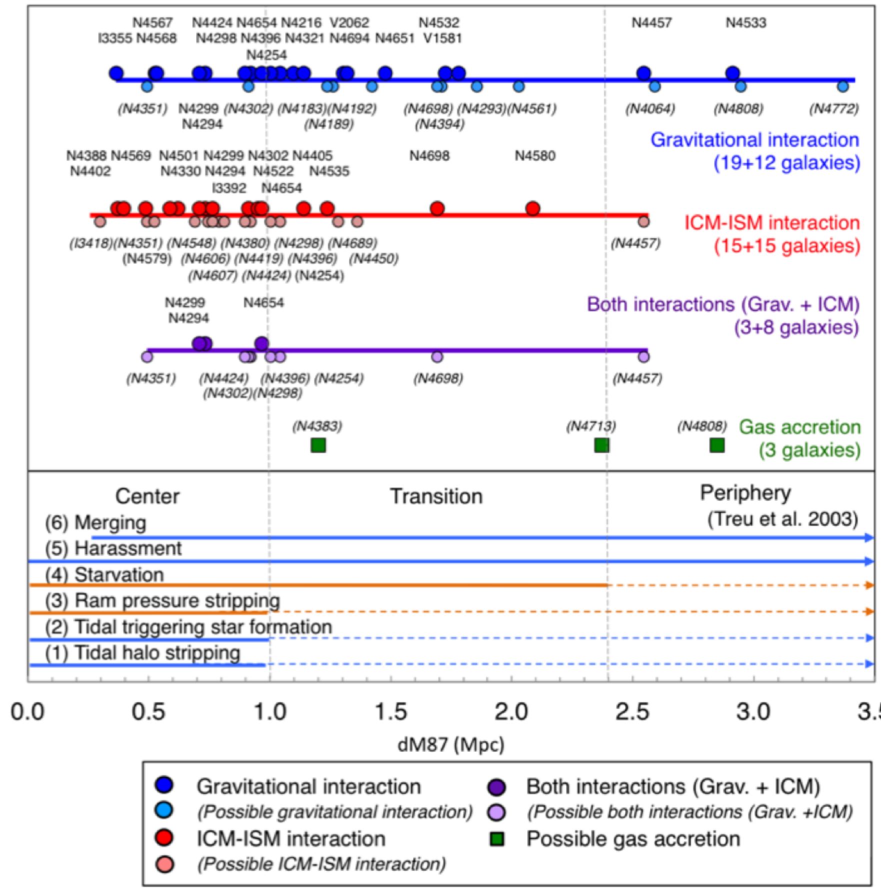


Aeree Chung

Environmental effects

- Diagnosed by multi-wavelength data including HI (Hyein Yoon et al., in prep)



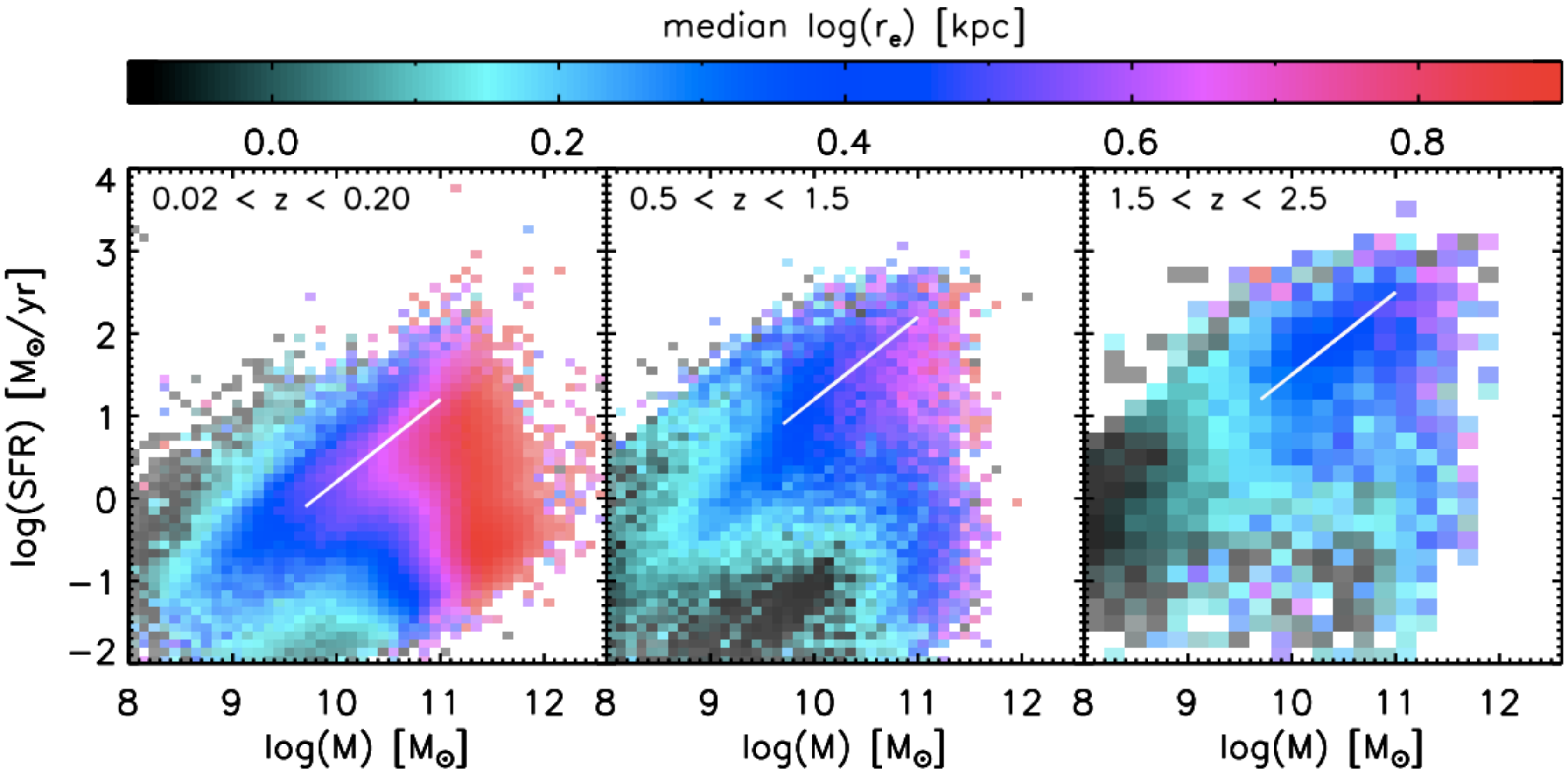


- Optical image + spectra (WIYN +), UV (GALEX), IR (Spitzer), etc. (J. H. van Gorkom, J. Kenney, H. Crowl, E. Murphy, D. Schiminovich, A. Abramson, S. Tonnesen, B. Vollmer, I. Wong +)

Aeree Chung

But back to mass…

SFR increases with mass…



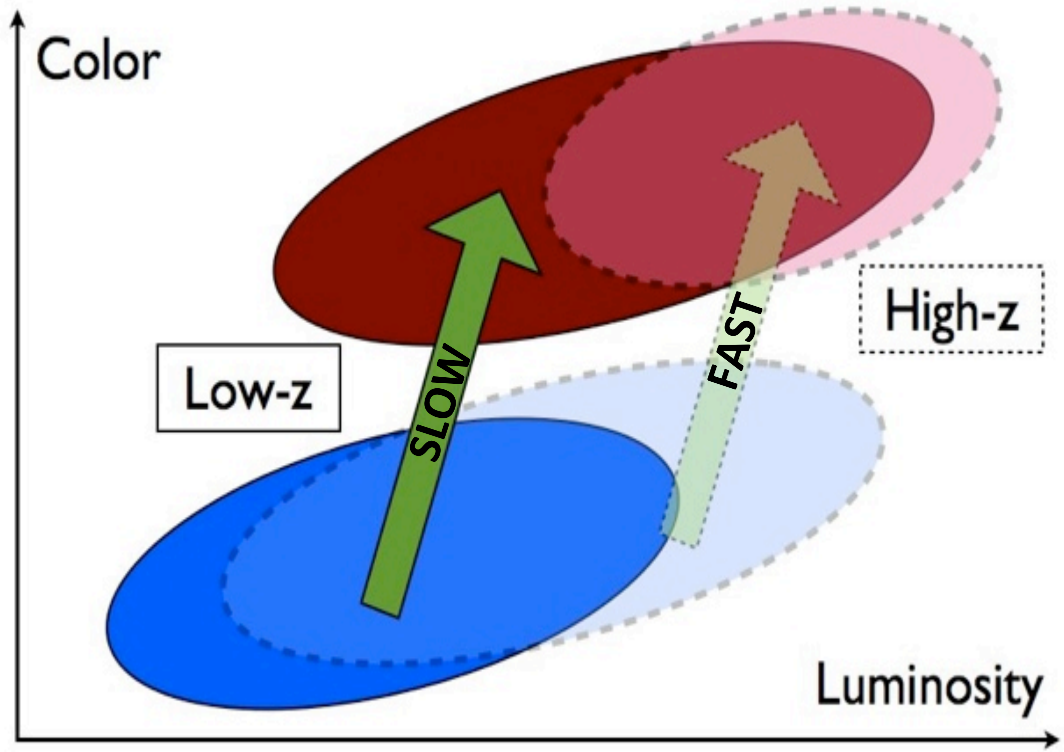
…but sSFR broadly decreases with mass

…and the scatter is enormous!

Wuyts et al. 2011

Evolution in the CM diagram

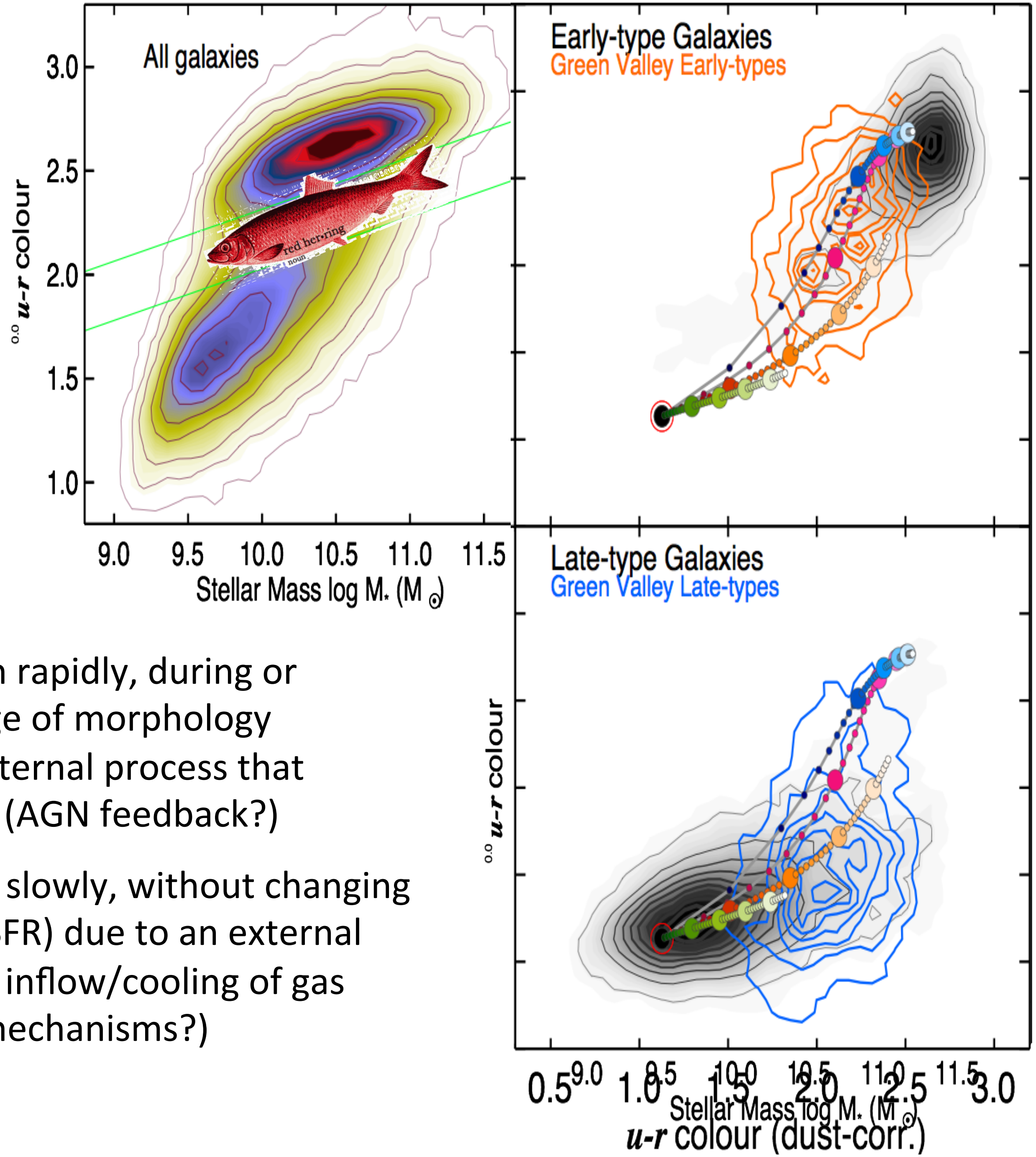
- Evolution of the mass flux density across green valley: at earlier times a faster transition in more massive galaxies
- 'Top-down' scenario: more massive galaxies in the red sequence were formed earlier, and less massive objects fill in at later times
- What is the role of bars in quenching star formation? Is it stronger at a given epoch?



Thiago Gonçalves

The green valley is a red herring™

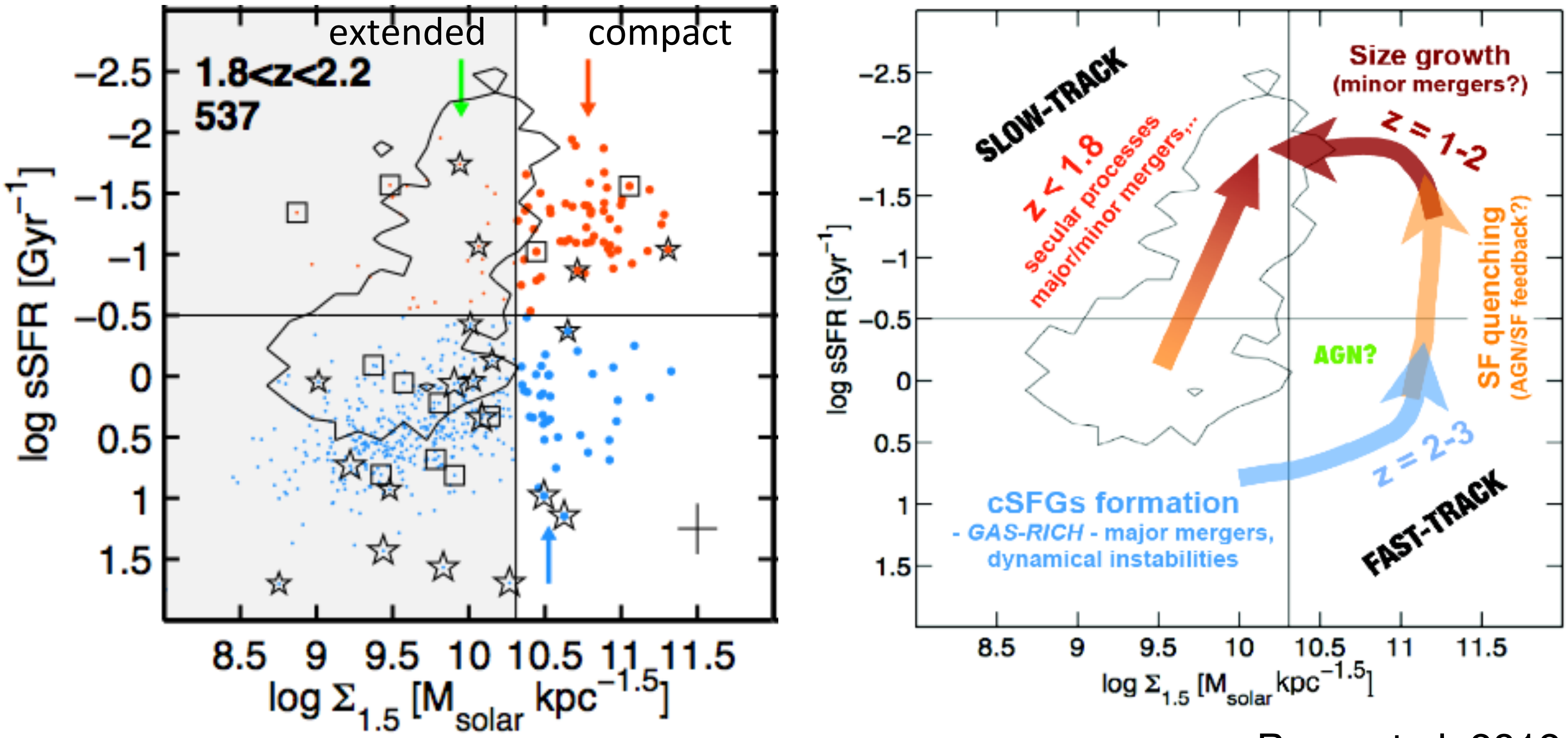
- sSFR + UV/optical colours show two different quenching pathways though green valley associated with early/late-type galaxies



- Early-type galaxies quench rapidly, during or after merger-driven change of morphology (large d/dt sSFR) due to internal process that destroys the gas reservoir (AGN feedback?)
- Late-type galaxies quench slowly, without changing morphology (small d/dt sSFR) due to an external process that stops further inflow/cooling of gas (classical environmental mechanisms?)

™Kevin Schawinski

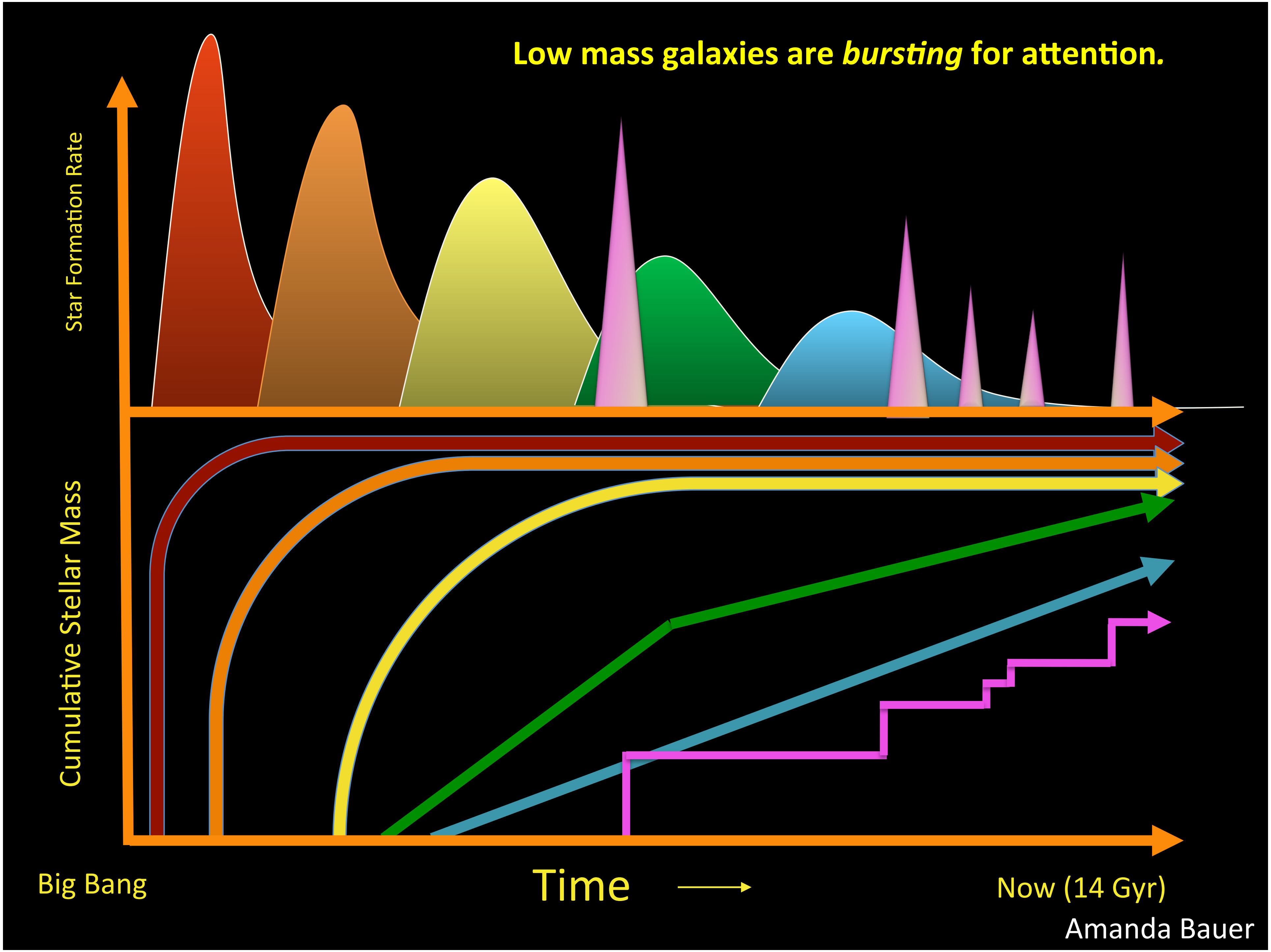
Two pathways to quiescent galaxies?



Barro et al. 2012

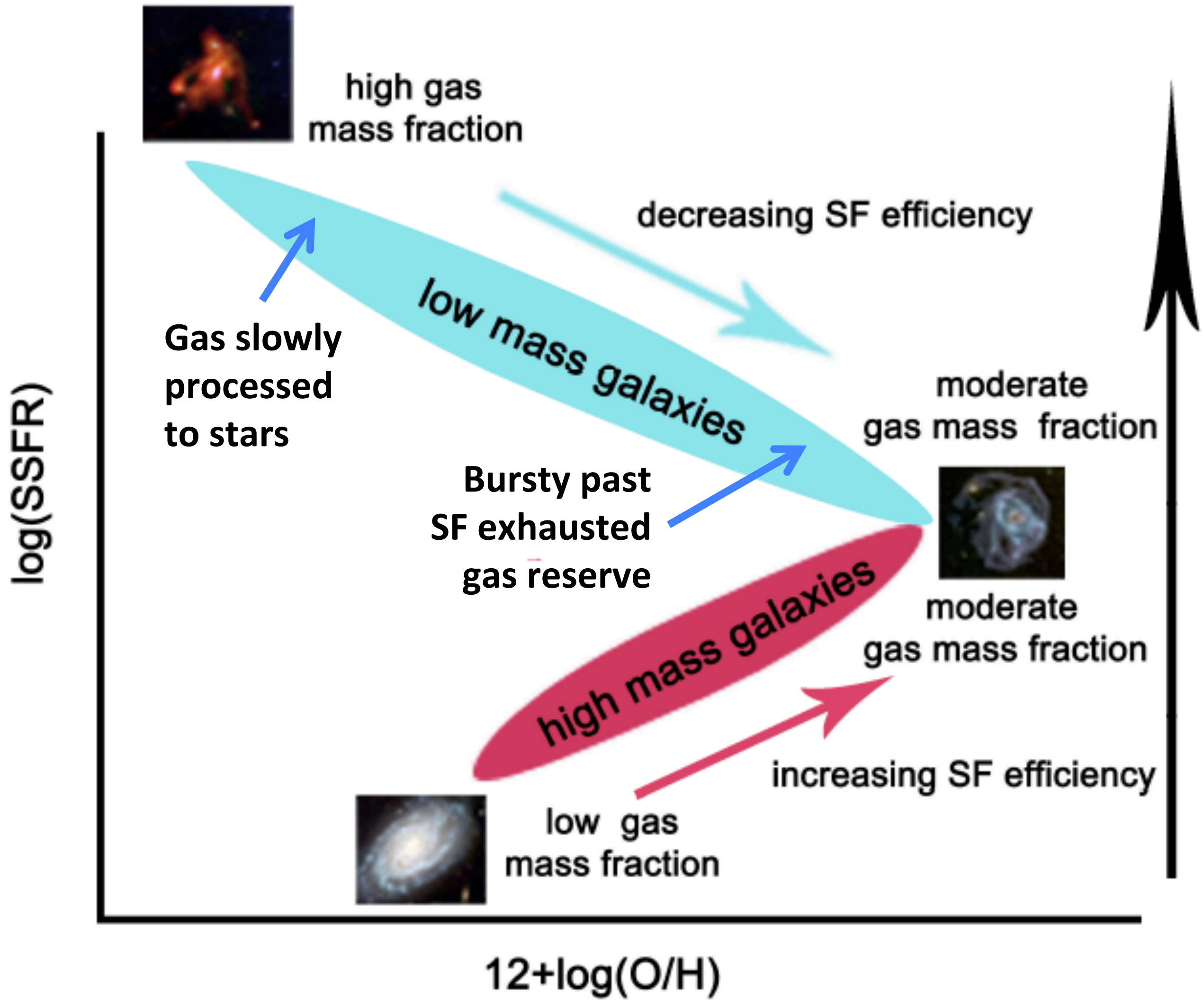
- compact star-forming galaxies more common at z>2
- 30x more likely to host luminous X-ray AGN

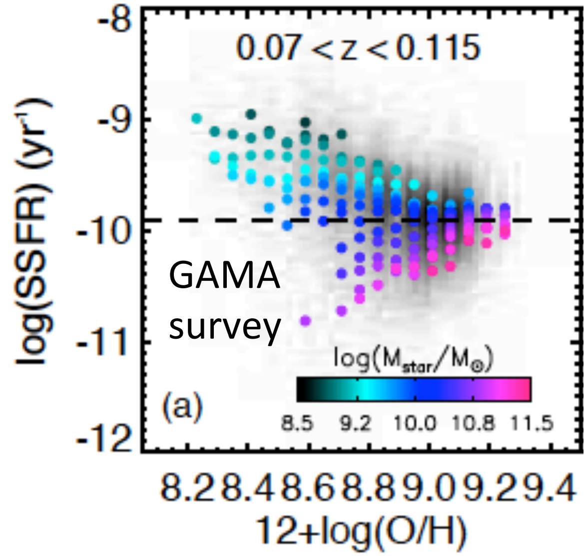
Jennifer Lotz



Low mass galaxies are *bursting* for attention.
Star Formation Rate
Cumulative Stellar Mass
Big Bang
Time
Now (14 Gyr)
Amanda Bauer

Z-SSFR relation

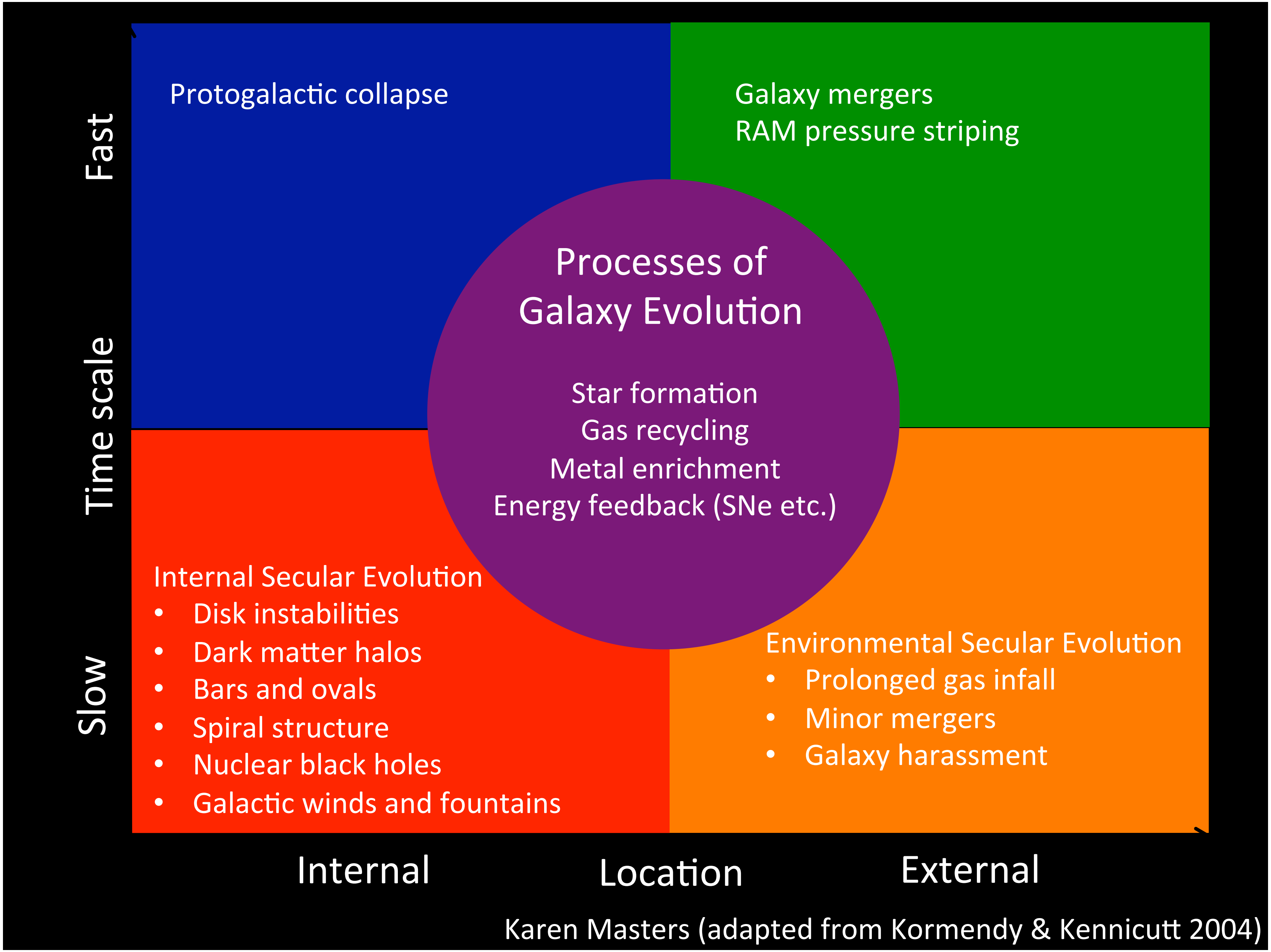




Closed-box models suggest inflows/outflows responsible for the scatter in the relationships

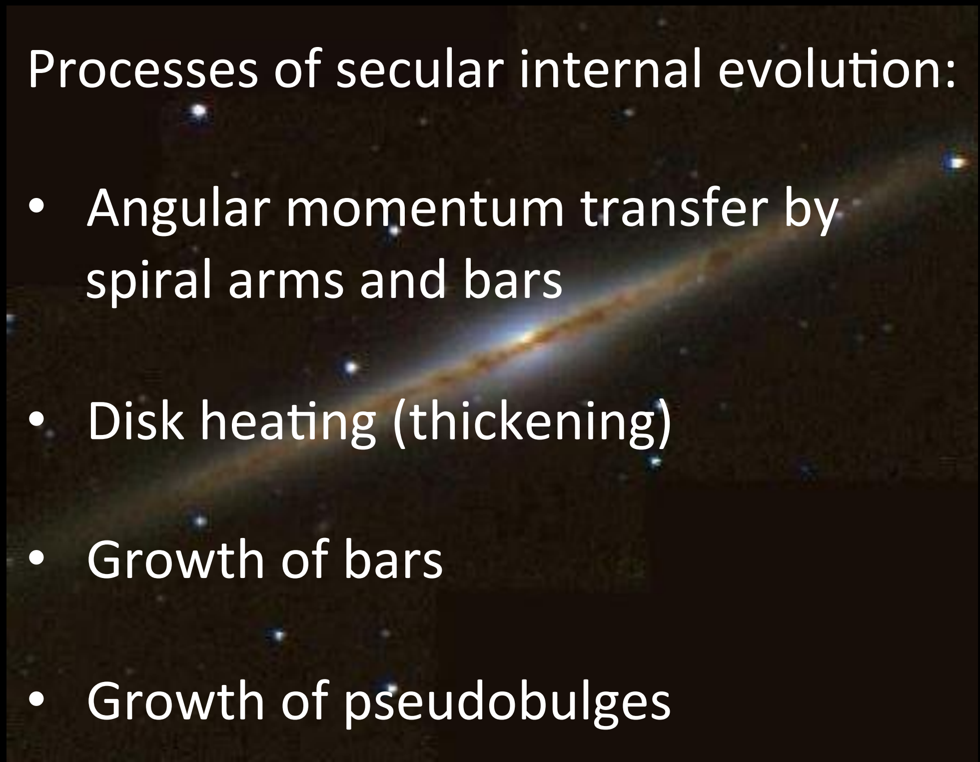
Maritza Lara-López

…but don't forget about secular evolution…


Protogalactic collapse
Galaxy mergers
RAM pressure striping
Processes of Galaxy Evolution
Star formation
Gas recycling
Metal enrichment
Energy feedback (SNe etc.)
Internal Secular Evolution
Disk instabilities
Dark matter halos
Bars and ovals
Spiral structure
Nuclear black holes
Galactic winds and fountains
Environmental Secular Evolution
Prolonged gas infall
Minor mergers
Galaxy harassment
Fast
Time scale
Slow
Internal
Location
External
Karen Masters (adapted from Kormendy & Kennicutt 2004)

Hierarchical merging can't explain everything

Merging occurs, but is it the dominant process in galaxy evolution?

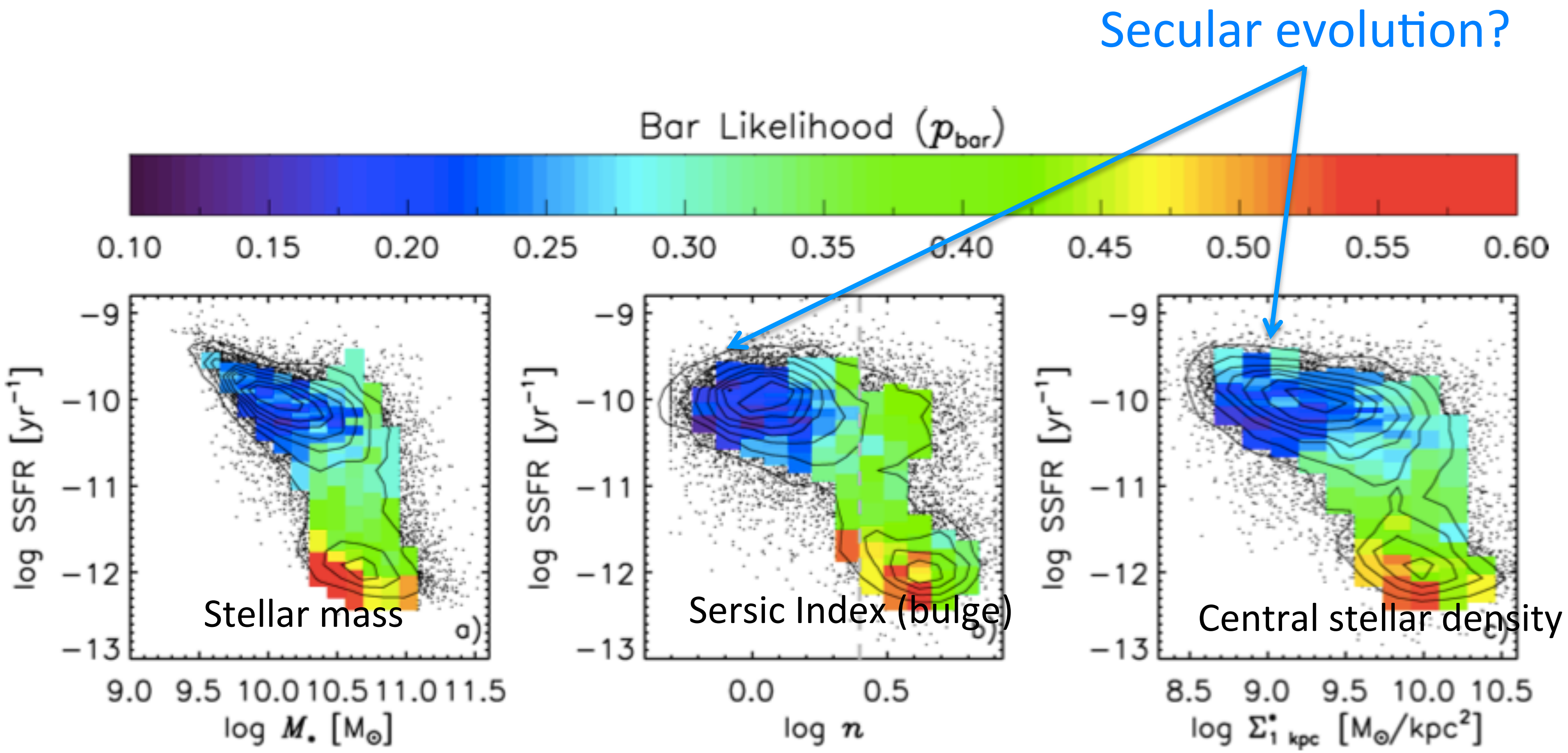


Processes of secular internal evolution:

- Angular momentum transfer by spiral arms and bars
- Disk heating (thickening)
- Growth of bars
- Growth of pseudobulges

- Really thin disks and very late-type spirals (>15% bulgeless)
- Major mergers are rare: local merger fraction 1-3% (Darg et al. 2010)
- Massive galaxies ($M>10^{10}$ $M_{\odot}$) have few mergers after z~1 (Conselice et al. 2008)
- Last major merger of Milky Way was ~10 Gyr ago

Evidence for Secular Processes

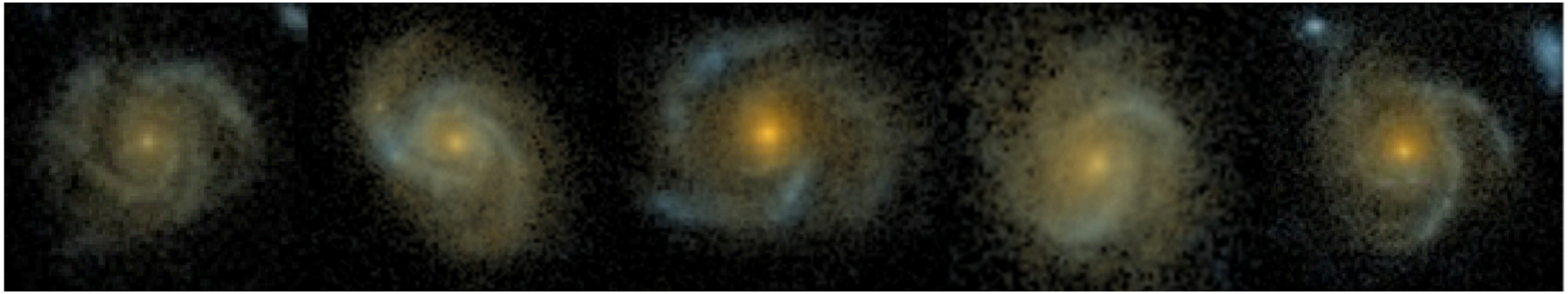


Karen Masters (Cheung et al., submitted)

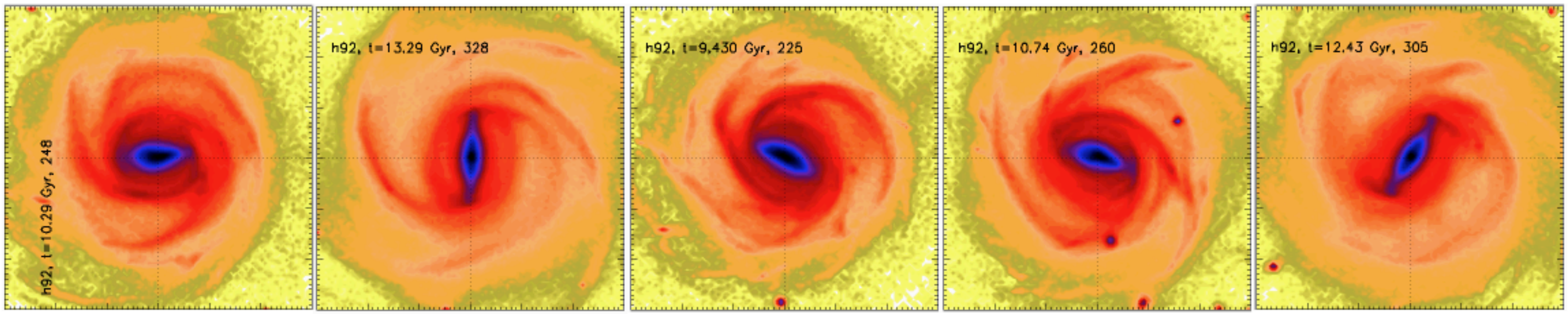
Disk structure and evolution

- Simulations suggest that galactic disks are non-equilibrium systems
- Multiple spiral modes give changing morphology on a dynamical timescale
- Different morphologies of disks don't necessarily imply different dynamics

A variety of Galaxy Zoo objects



One simulation seen at different times



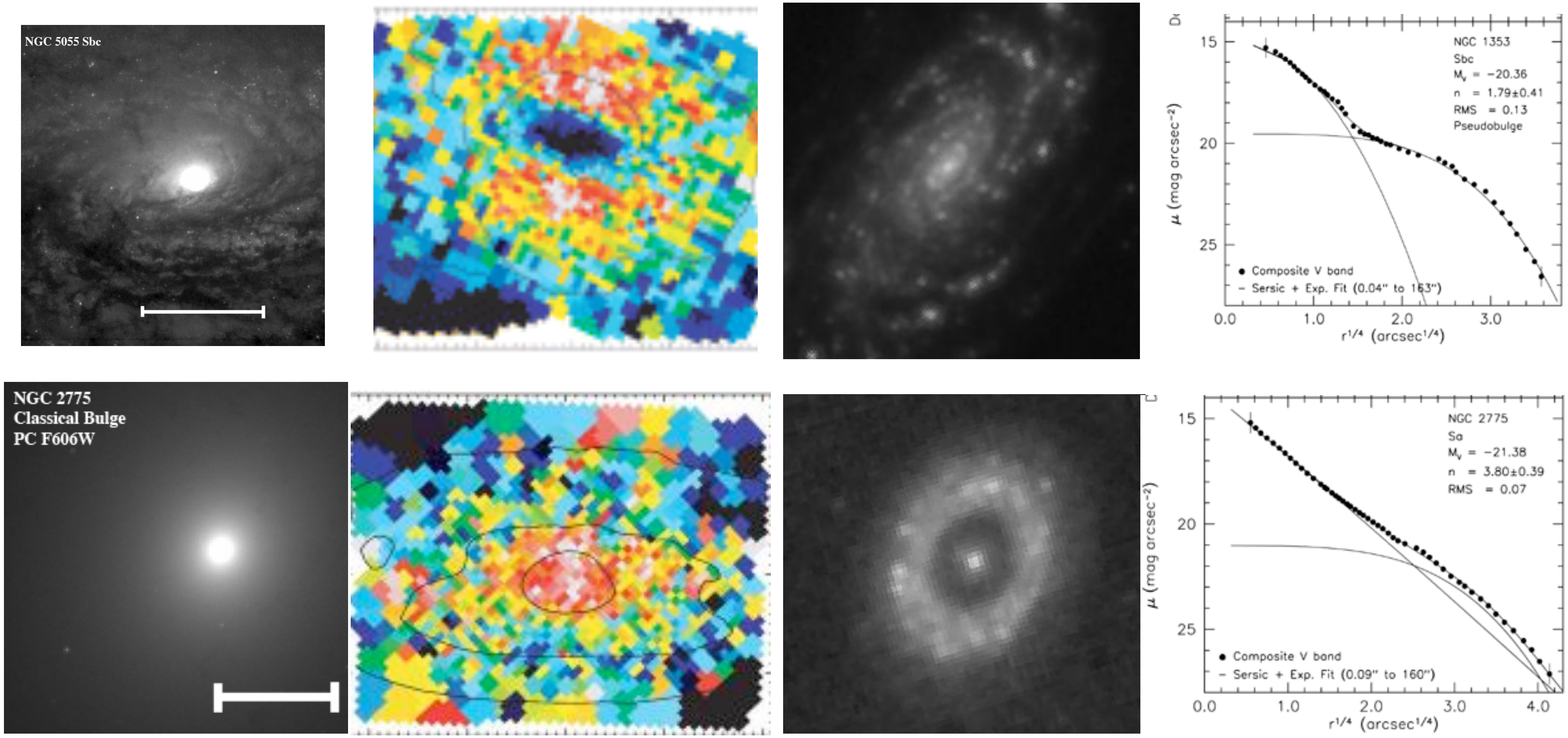
Ivan Minchev

What are pseudobulges and why do I care?

Morphology | Kinematics | SF and ISM | Structure

Pseudobulge

Classical



Many bulges look nothing like elliptical galaxies. These pseudobulges…

…are very common, especially in barred galaxies and in mid-spiral classes (Sa-Sc);

…have kinematics more like disks, smaller Sersic indices & are actively forming stars;

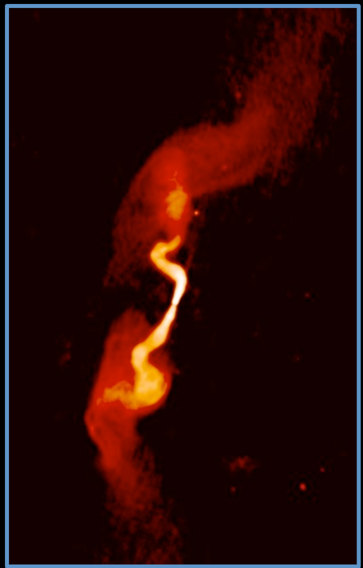
…are not on the Fundamental Plane & their sizes are correlated with disk sizes;

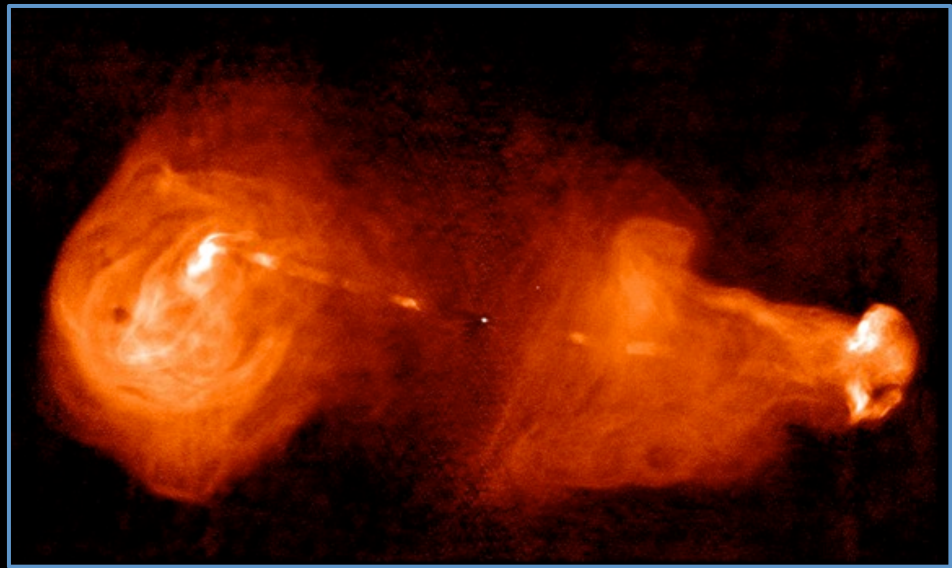
…pseudobulges = pseudodisks? ("is it just disks all the way down?")

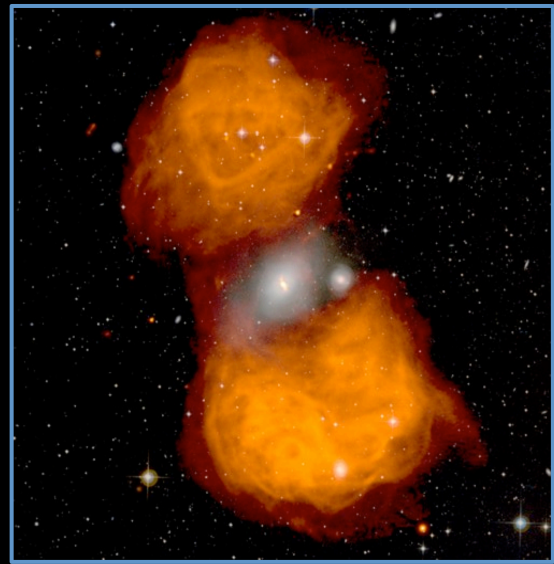
David Fisher

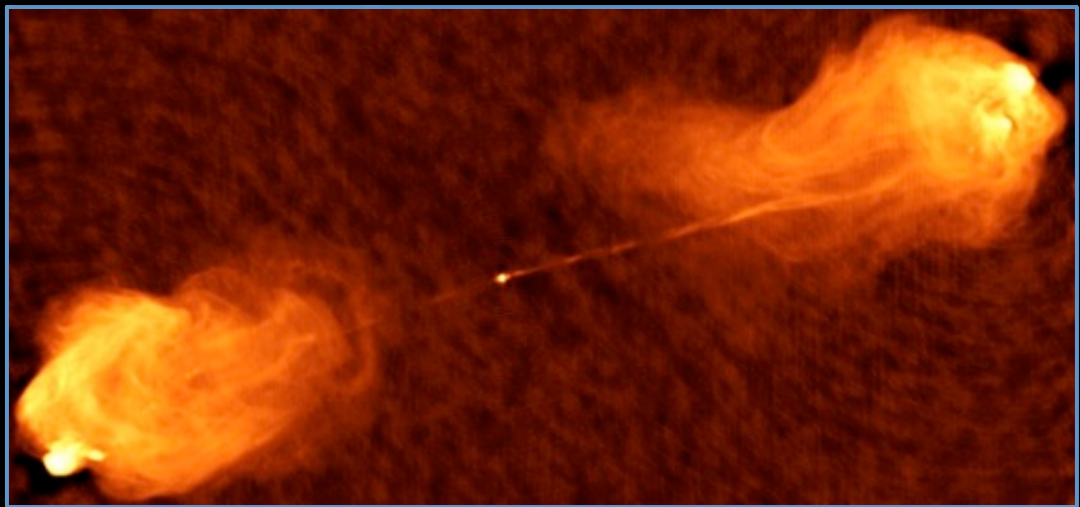
…and then there is radio morphology, and rings, and…

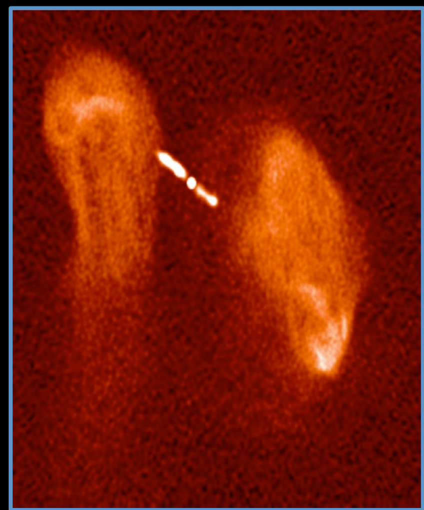
Radio source morphology - visual











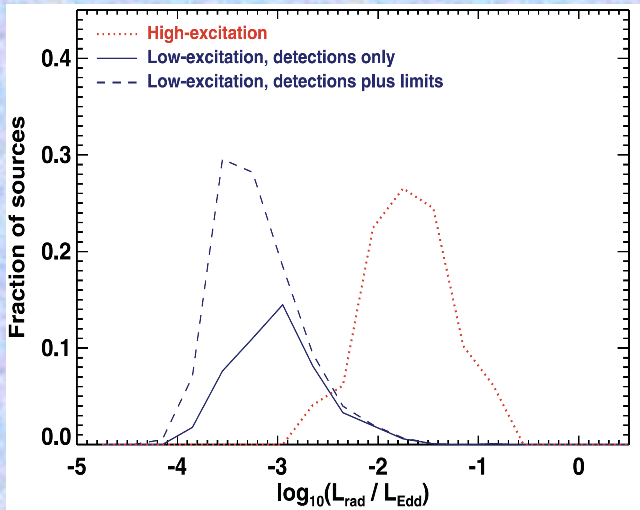
Images courtesy
of NRAO/AUI

Radio source morphology - physical

Low Excitation Radio Galaxies

- Accretion rate < 0.01 Eddington
- **Radio**-only AGN
- Hosted by massive galaxies in rich environments
- Dominant at $z \sim 0$
- No evolution to $z = 0.3$

Fuelled by cooling of **hot halo** gas (Pope+ 2012, MNRAS, 419, 50)



Best & Heckman 2012, MNRAS, 421, 1569

High Excitation Radio Galaxies

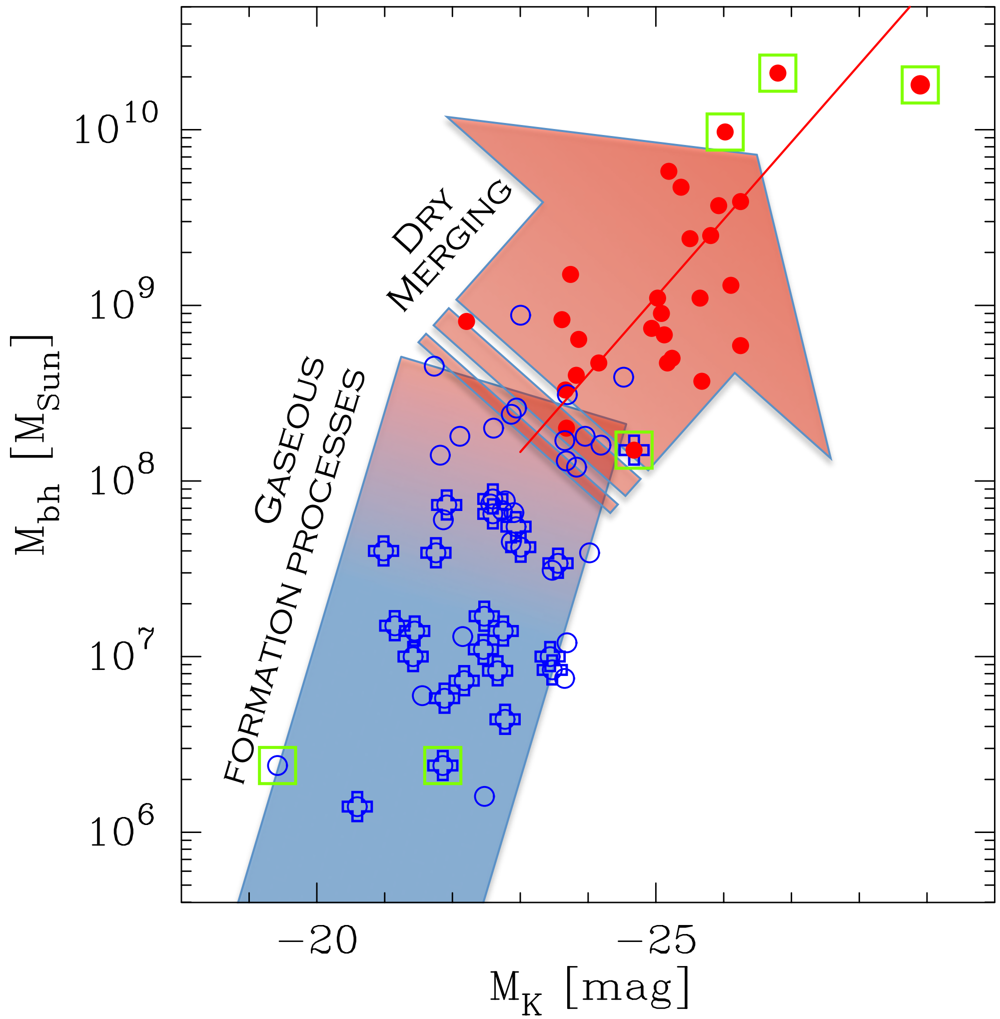
- Accretion rate > 0.01 Eddington
- **Optical** (+ radio) AGN
- Low-mass hosts in poor environments
- Scarce at $z \sim 0$
- Number density increases with z

Fuelled by **interactions**

What are the **radio + optical** AGN properties of dust lane early types ?

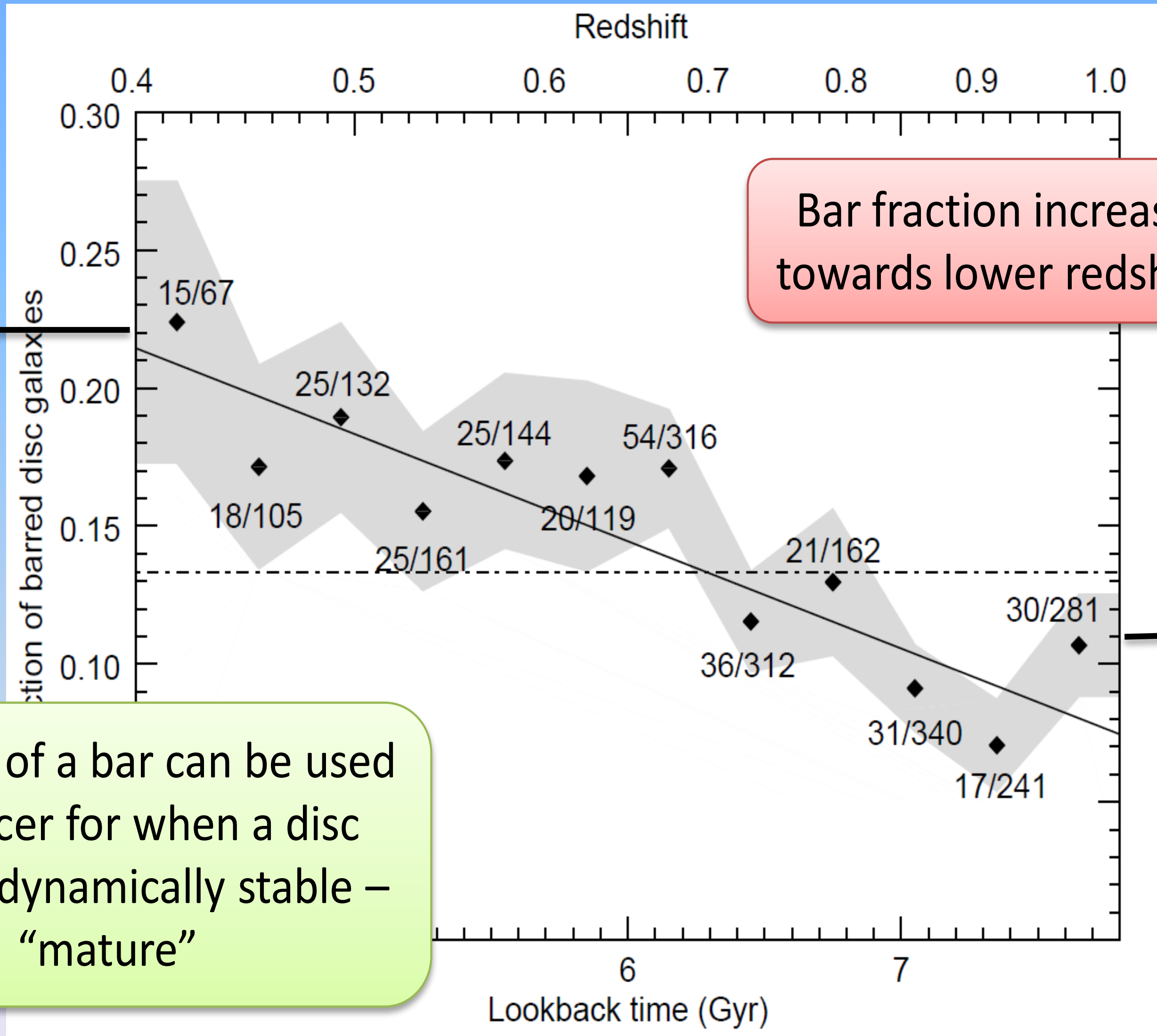
Stas Shabala

AGN feedback and M_{bh}-M_* relation



Alister Graham

Time evolution of the bar fraction



fb = 22%

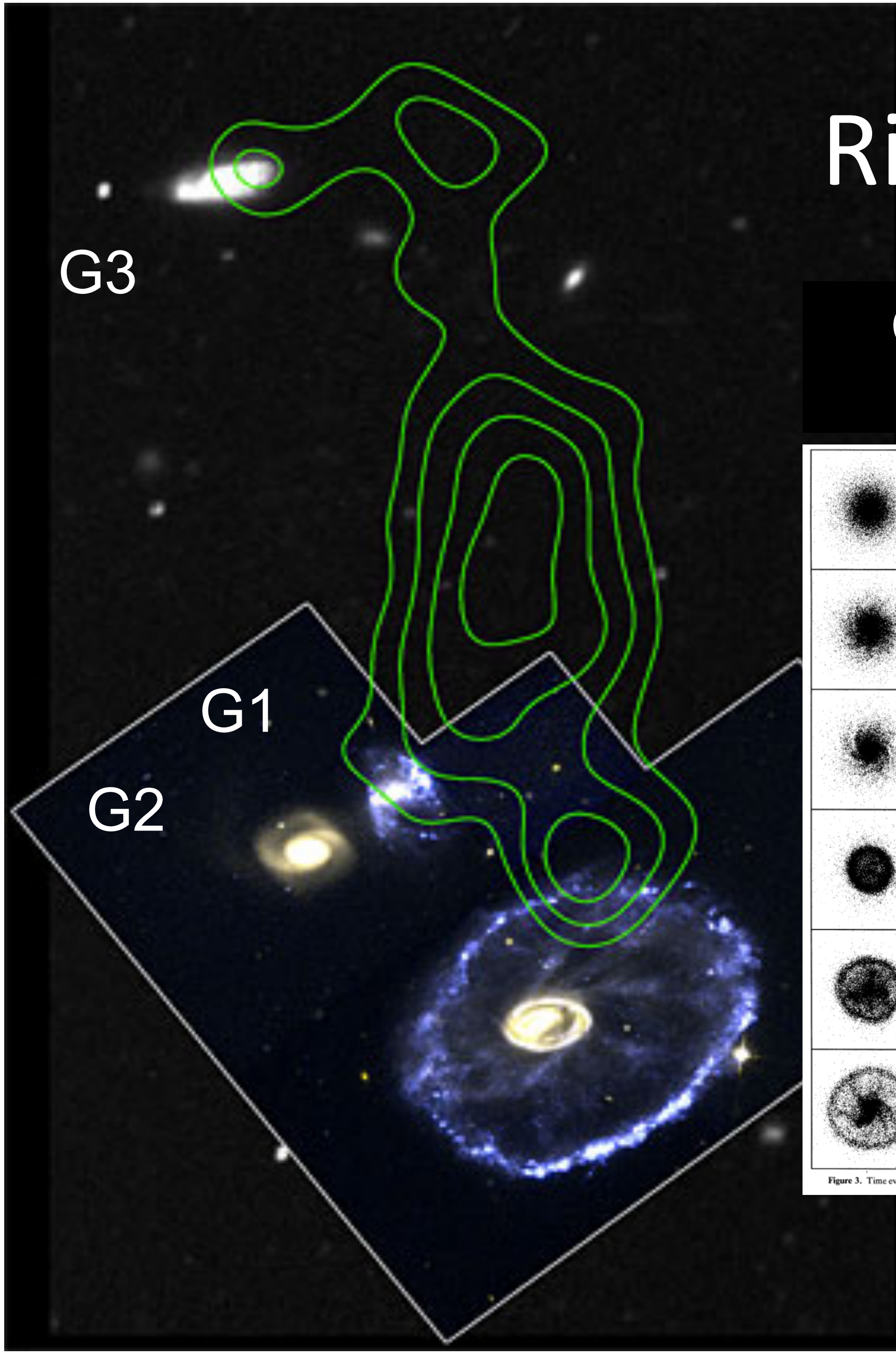
Bar fraction increases towards lower redshifts

fb = 11%

Presence of a bar can be used as a tracer for when a disc galaxy is dynamically stable – “mature”

Seulhee Oh

Ring Galaxies



Cartwheel: Hernquist & Weil 1993
(mass ratio 4:1 to 1:1)

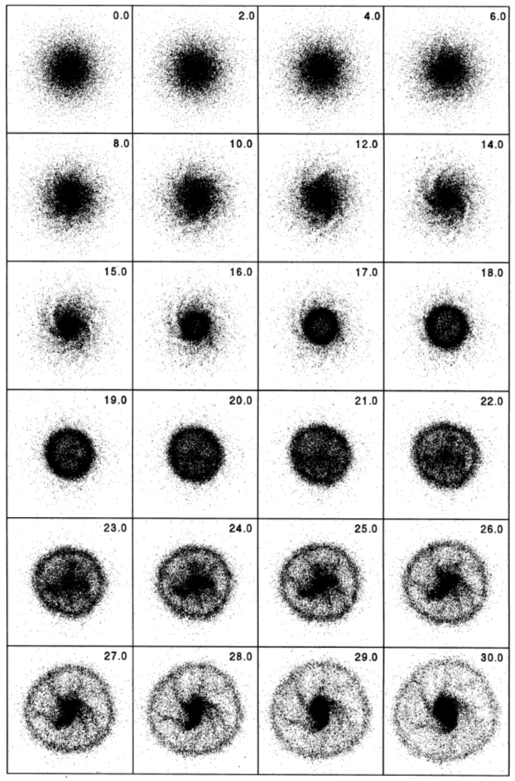


Figure 3. Time evolution of the stellar component of the primary in the fiducial model, seen face-on to the disc plane.

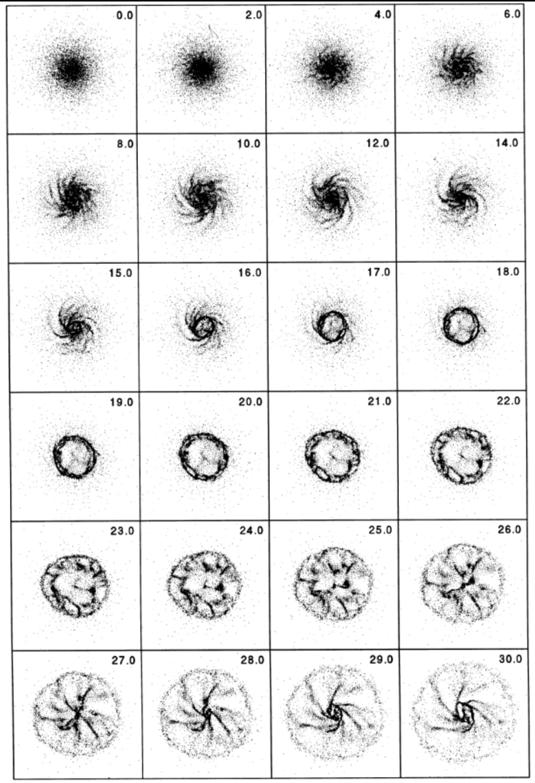


Figure 4. Time evolution of the gas component of the primary in the fiducial model, seen face-on to the disc plane.

Stars

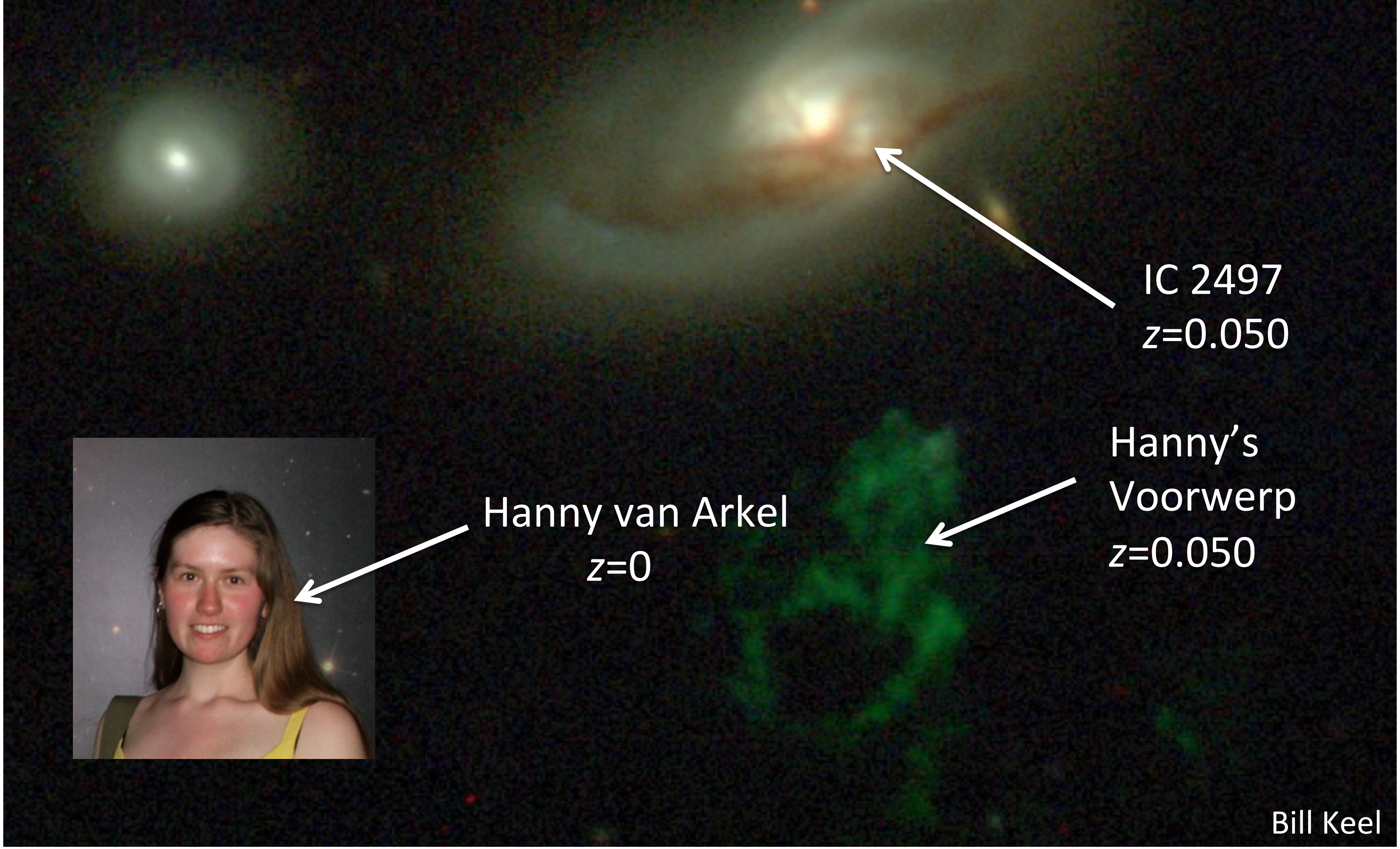
Gas

Roger Davies

Cluver+ 2010
SPHEROIDS ON
STEROIDS

Serendipitous oddities

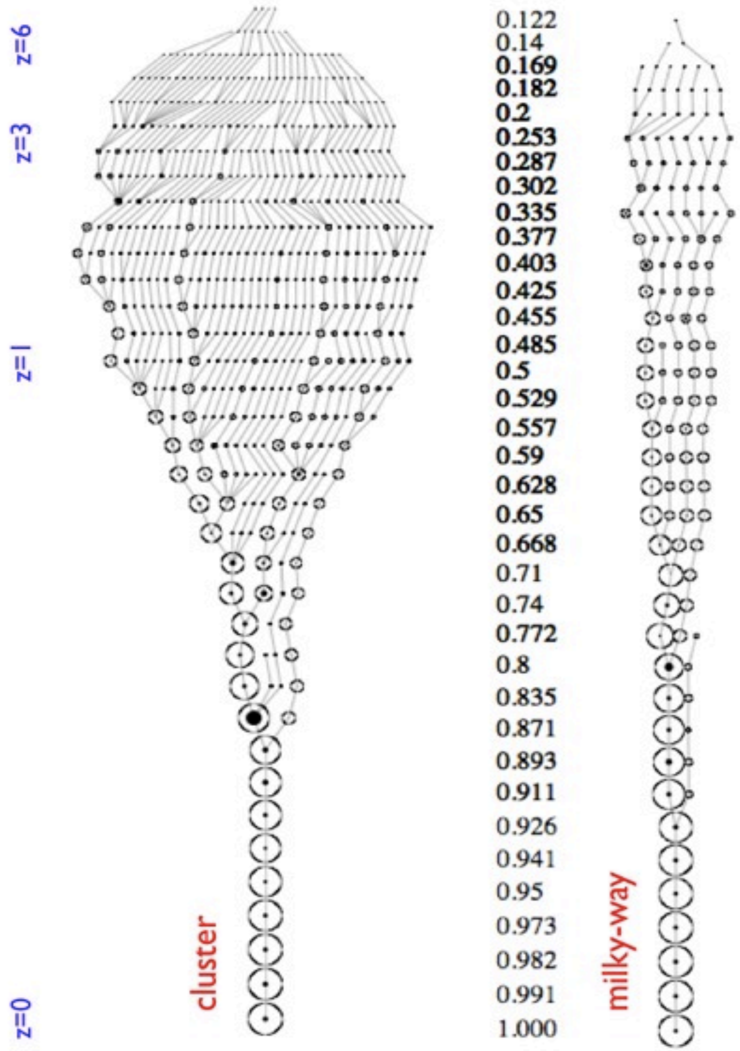
(I mean the Voorwerp!)

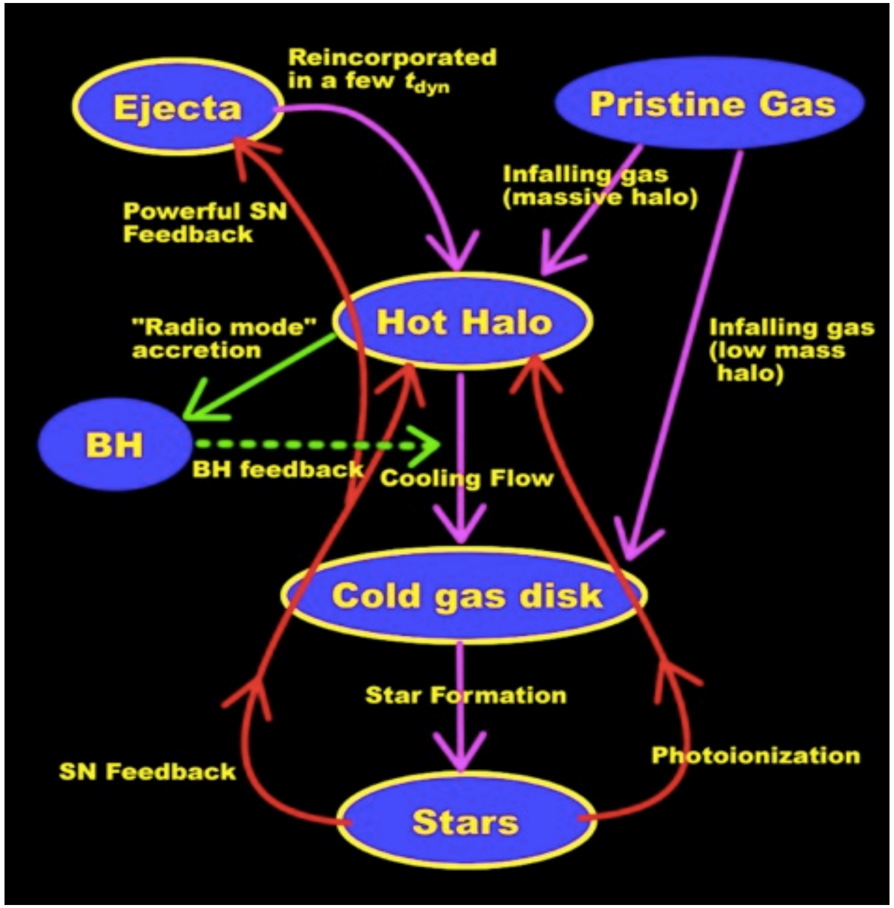


…and, crucially, there are models…

Semi-analytic models

Numerical Simulation + Analytic Simulation

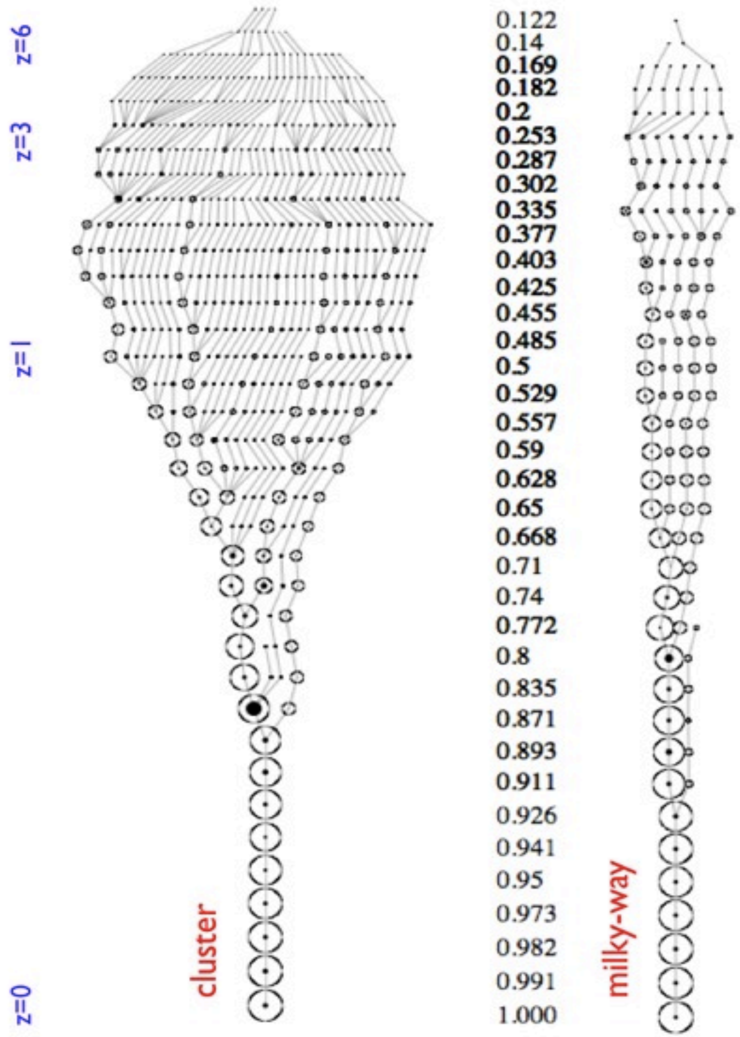




Darren Croton

Simplest model of galaxy formation

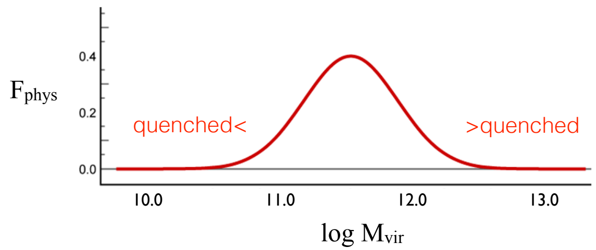
Numerical Simulation + Analytic Simulation

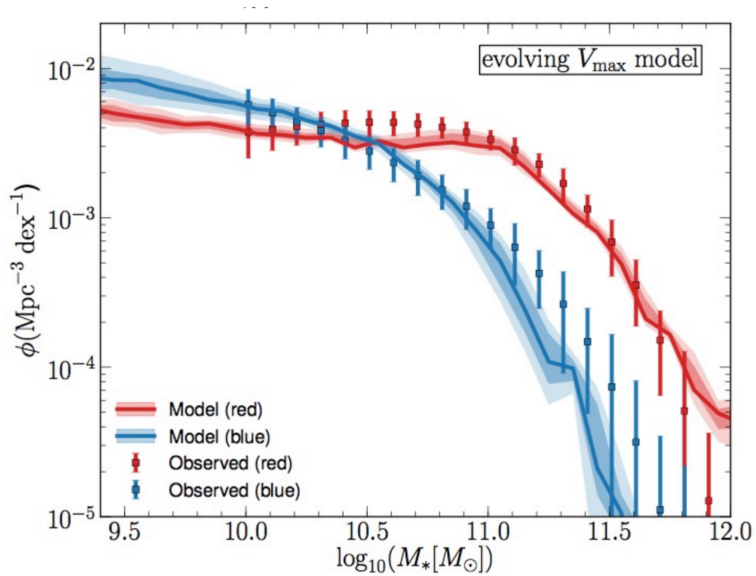


Mutch, Croton & Poole 2013

$$\dot{M}_* = f_b \frac{dM_{vir}}{dt} F_{phys}$$

"Physics function" – can be arbitrarily complex



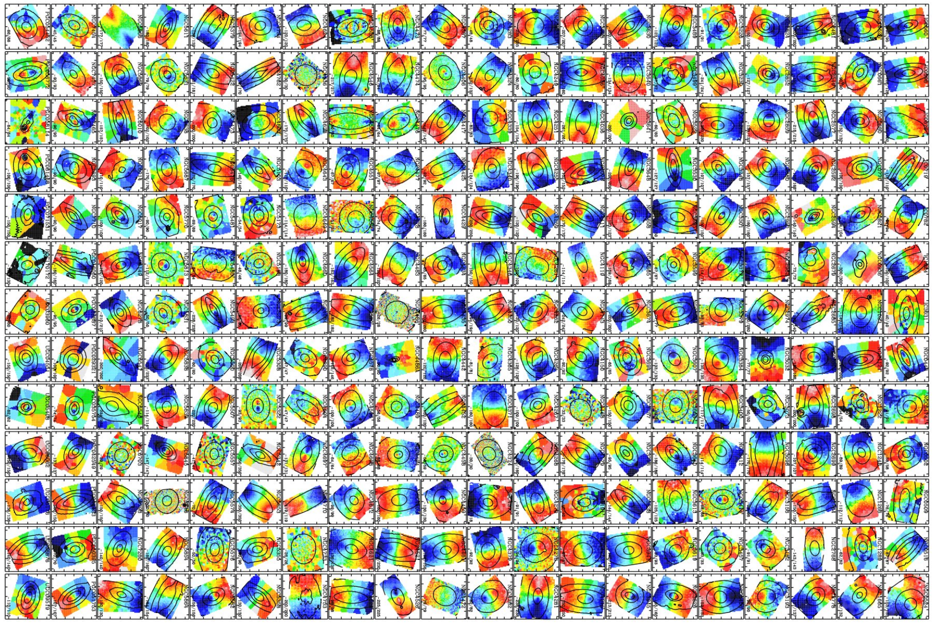


What about the future?

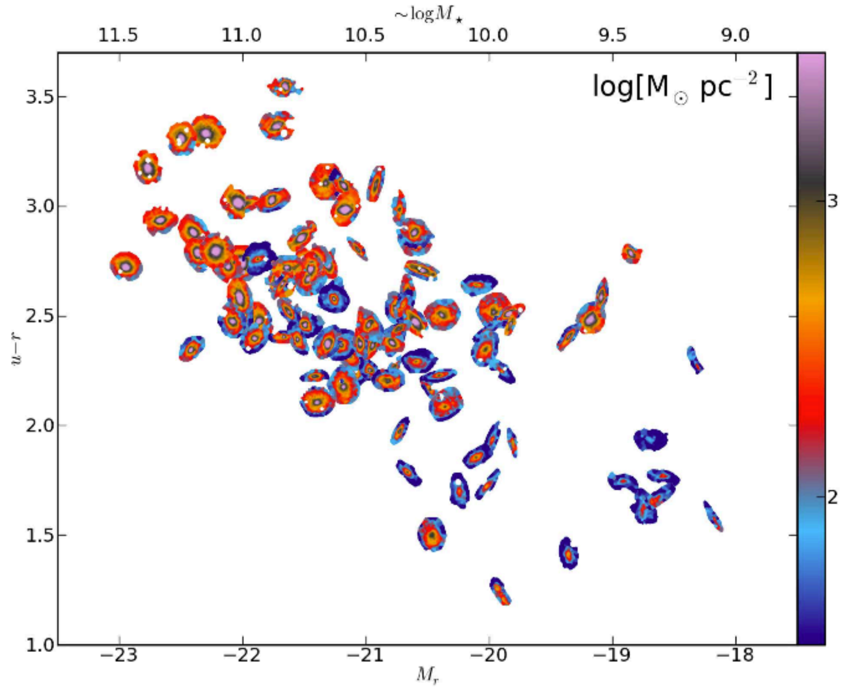
The future is IFU surveys!

(and it's already happening)

ATLAS[3D] (e.g. Krajnovic et al 2011)
260 local early types using SAURON



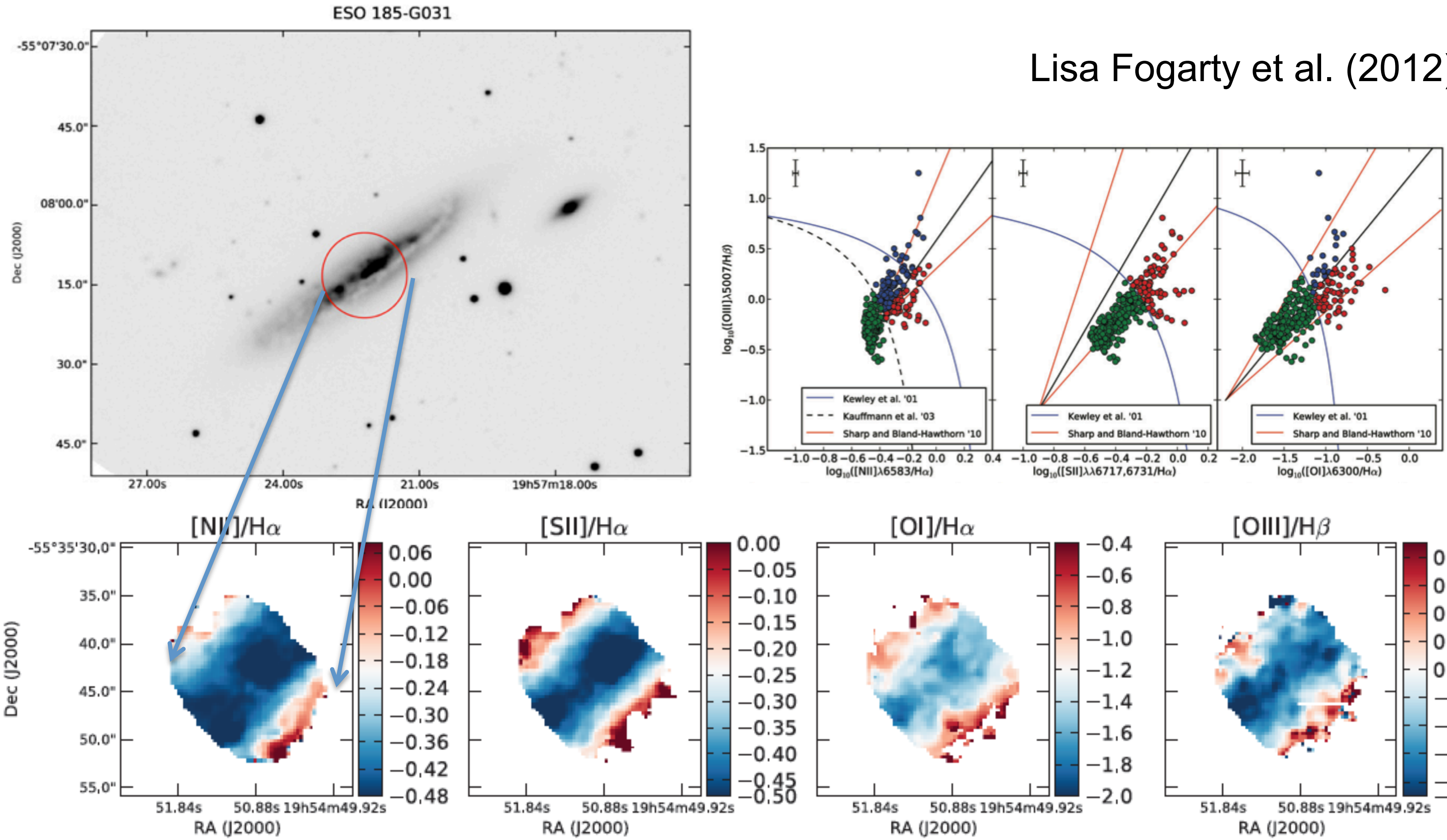
CALIFA (Sanchez et al 2012)
600 galaxies using PMAS



Scott Croom

SAMI: serendipitous wind discovery

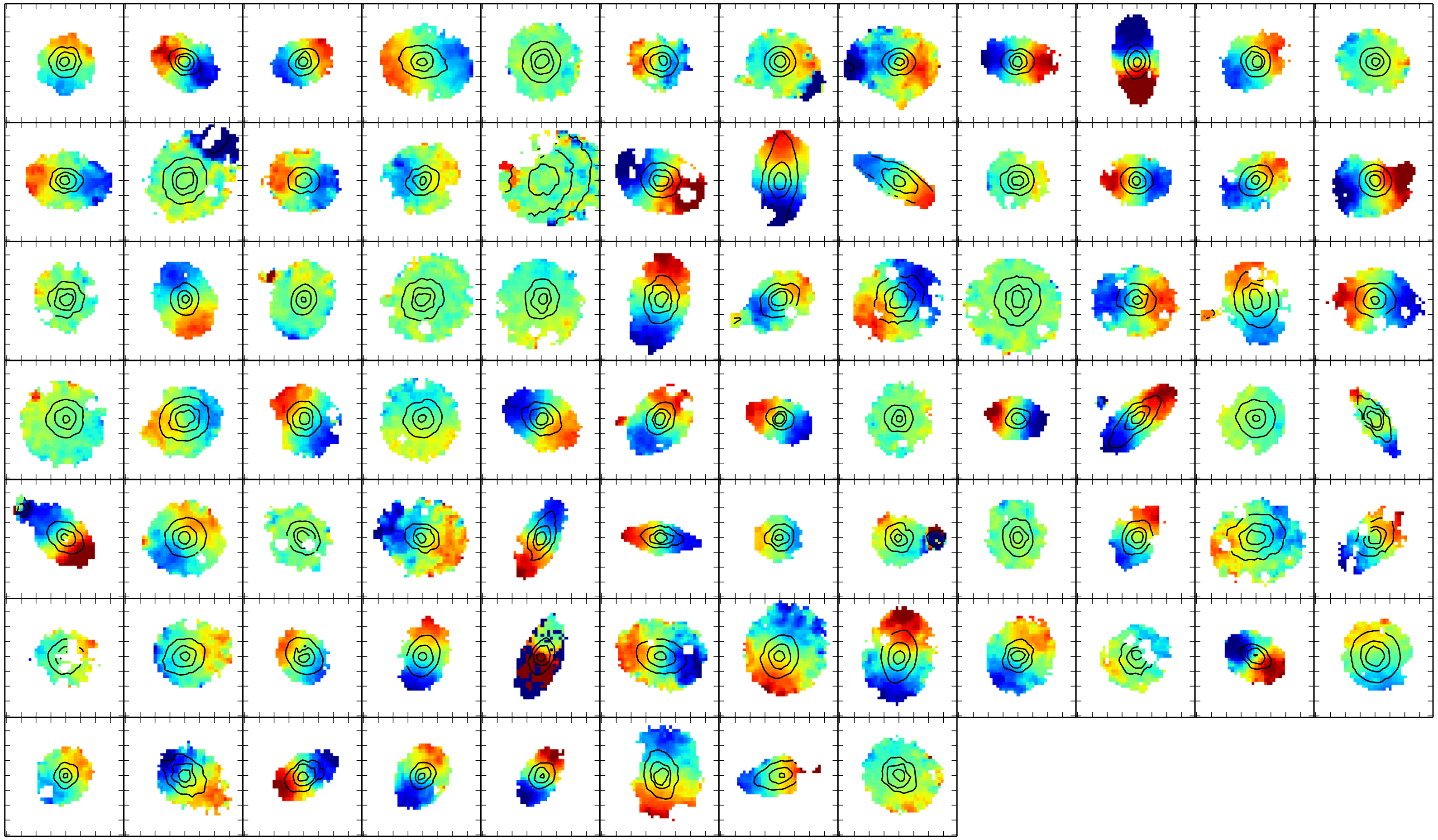
Lisa Fogarty et al. (2012)



Scott Croom

SAMI: fast/slow rotators in clusters

134 galaxies in A85, A168, A2399 with 80 early types (=non-spirals)



Scott Croom

OK, so much for *serious*…

Conference Equation

- Critical variables:
  - Number of participants, N_p
  - Pairwise interaction probability, R_2
  - Quality factor of talks and other interactions, Q
  - Finally, in the spirit of Darren Croton's "physics function" F (physics), wrapping up the vital but inexplicable factors you don't understand, there is the "fun function" F(fun)
- This gives the formula for conference success…

$$\text{Success} = N_p^2 . \langle R_2 \rangle . Q . F(\text{fun})$$

(I look forward to extensive citations in all future theoretical and observation development of this seminal contribution to conferology)

Twitter stor(if)y of the meeting

- *@MatthewColless* #MostBoringTwitterHandlesEver
  I'm doing the conference summary for "Evolutionary Paths in Galaxy Morphology" (a.k.a. #GZconf) - best tweets highlighted and prizes given! #ItSeemedLikeAGoodIdeaAtTheTime
- *@KevinSchawinski* #ditto
  There's a prize for the wittiest tweet at #GZconf! A 1st for a conference?
- *@KevinSchawinski*
  Mmmm pie chart... full of nutritious galaxies [re Kaviraj talk]
- *@jabberjabber0* [Kevin Pimbblet]
  Chris Lintott on the Galaxy Zoo legacy. Notes you can ID who is whose PhD student from how they classify galaxies. #TheAppleDoesntFallFarFromTheTree
- *@galaxyzoo*
  C. Lintott, on how to read a very long paper: "at least read the figure captions". Attn students: your figure captions matter.

Twitter stor(if)y - 2

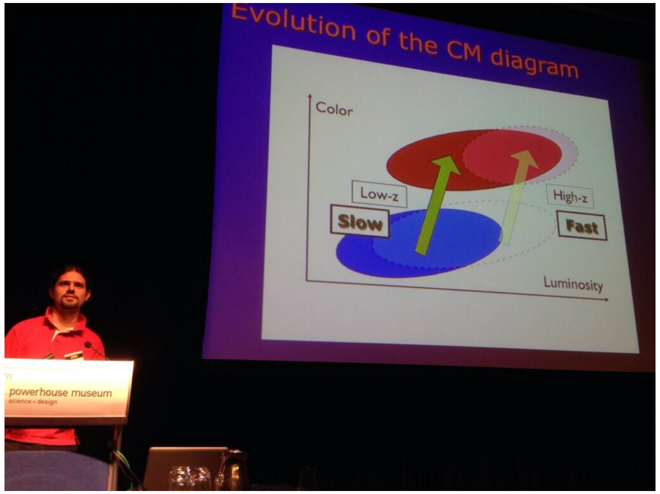
- *@vrooje* [Brooke Simmons]
  Amid the science chat at lunch, we also discussed what the street names & address nos. would be in a galaxy evolution-themed town. #NoNerdsHere

- *@vrooje* [Brooke Simmons]
  I'm no video game expert, but is that a screenshot of Mass Effect on @jabberjabber0's intro slide? #NoGamersHereEither

- *@astro_bec* [Rebecca Davies]
  The Milky Way & M31 are green valley objects – are we ourselves inside a galaxy which is quenching its star formation? D. Croton #LivingInARedHerring

- *@ChrisLintott*
  @kevinschawinski you realize you're the first person at #GZconf to mention "main sequence"? Don't be on the wrong side! #PoliticallyCorrectAstrophysics

Twitter stor(if)y - 3



- *@KevinSchawinski*
  @KarenLMasters: we are entering a secular era.
  #AstrophysicallySpeaking
- *@DarrenCroton*
  Real science must be describable in a cartoon!
  Fast vs slow quenching and the CMD.
  [re Thiago Gonçalves' talk]
- *@KevinSchawinski*
  Pro tip: ask people to take a picture and tweet your main plot!
  #ShamelessSelfpromotion [as Thiago Gonçalves self-referentially noted!]
- *@millielilly* [Millie Maier]
  My first tweet! Wait, where are all the birds? I think it's broken > *flpr flpr flpr*. Well I'm all out of ideas. I blame @MatthewColless. #Sigh,Newbies
- *@chiara_tonini*
  The next Galaxy Zoo project should be called ZooLander. #Ummmm…

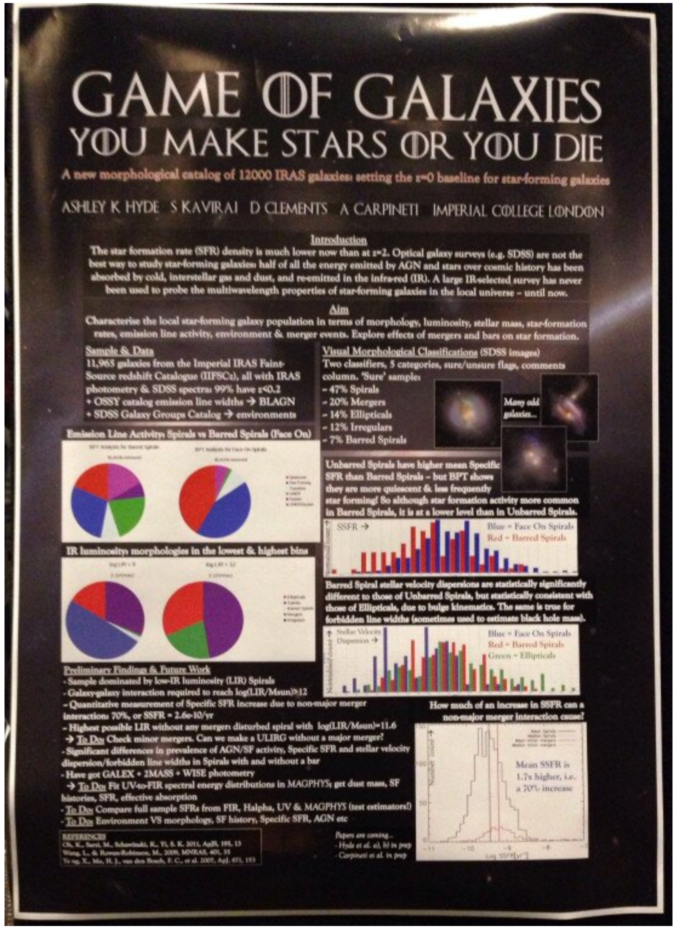
Twitter stor(if)y - 4

- *@darrencroton*
  The best poster in all of Westeros?
  #GameOfThrones

- *@chrislintott*
  It amazes me that often @galaxyzoo classifies ~250,000 galaxies so we can select 100 - rare galaxies sometimes are the answer!
  #ScarcityIsValue

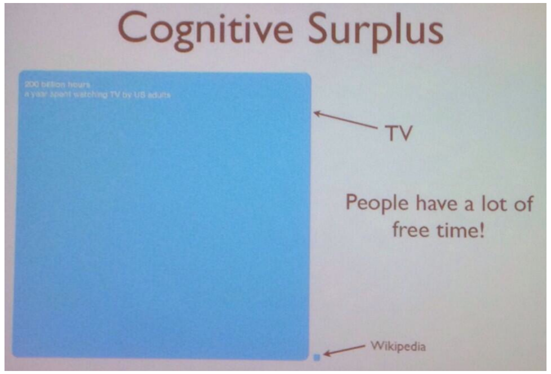
- *@darrencroton*
  Mosquito bite? “@kevinschawinski: What do you call a 1:1000 merger? Secular merger?”

- *@ional10* [John Lopez]
  "Network or swim" - Jessica Bloom's slogan for the Galaxy Zoo cruise!
  #WorkTheRoom #DontFallOffTheBoat



Twitter stor(if)y - 5

- *@darrencroton*
  Pseudo is the new normal when it comes to galaxy bulges — David Fisher
- *@vrooje* [Brooke Simmons]
  R. Davies' comment: “These are not pseudobulges at all; they're pseudodisks."
- *@astropixie* [Amanda Bauer]
  "pseudobulges are more common in barred galaxies." just saying.
  #dirtyspacenews #nuffsaid
- *@vrooje* [Brooke Simmons]
  Citizen science is open to all with a cognitive surplus. Even cats on the internet.
  #SpeciousReferenceToCuteCatPicture
  #CognitiveSurplusIsTimeSpentWatchingTV

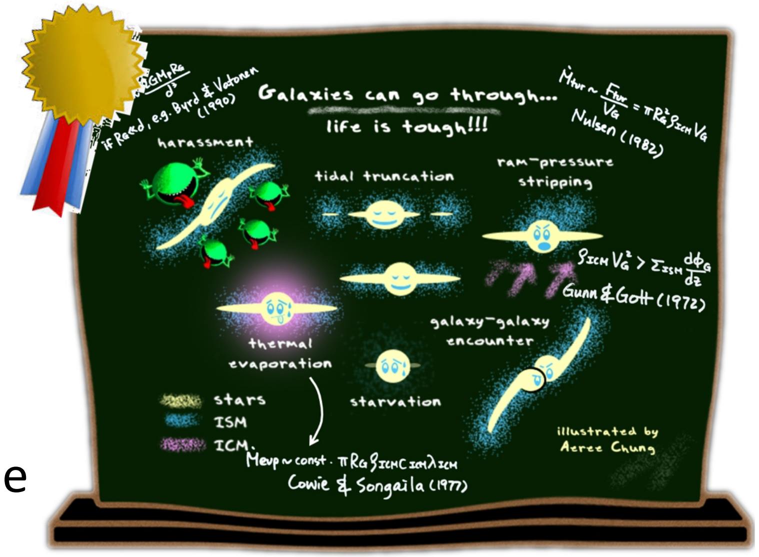


And finally, PRIZES!

- *@KevinSchawinski*
  Lots of people using cartoons to illustrate ideas at #GZconf - powerful, visual way of conveying information!

- *@chiara_tonini*
  Hope that there's a #GZconf award for best cartoon - there have been some great ones. (Early vote from me for Aeree Chung)

- *@kwwillett* [Kyle Willett]
  Love that Aeree Chung used #hitchhikersguide logos to illustrate galaxy harassment.



- *@nseymouruk* [Nick Seymour]
  @kevinschawinski: early types die quickly, late types become zombies. #zombies

WINNER!

Pithy, witty, true!

- *@El_Lobo_Rayado* [Ángel López-Sánchez]
  Conference Dinner Speeches: a toast for ~800,000 people all around the globe who helped classifying galaxies in Galaxy Zoo project. #HearHear!