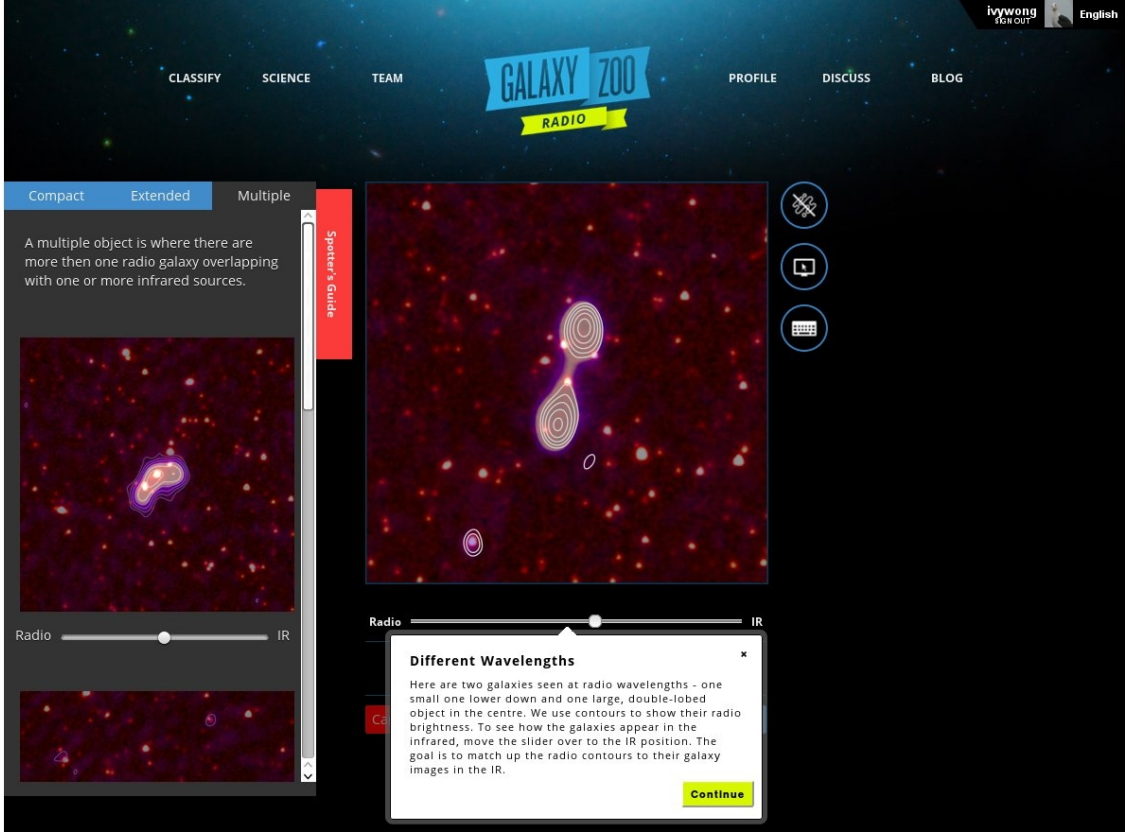


The Radio Galaxy Zoo Data Release 1: classifications for 75,589 sources

O. Ivy Wong & Radio Galaxy Zoo Team

ICRAR/University of Western Australia

SPARCS VII – the precursors awaken, 19 July 2017

International Centre for Radio Astronomy Research

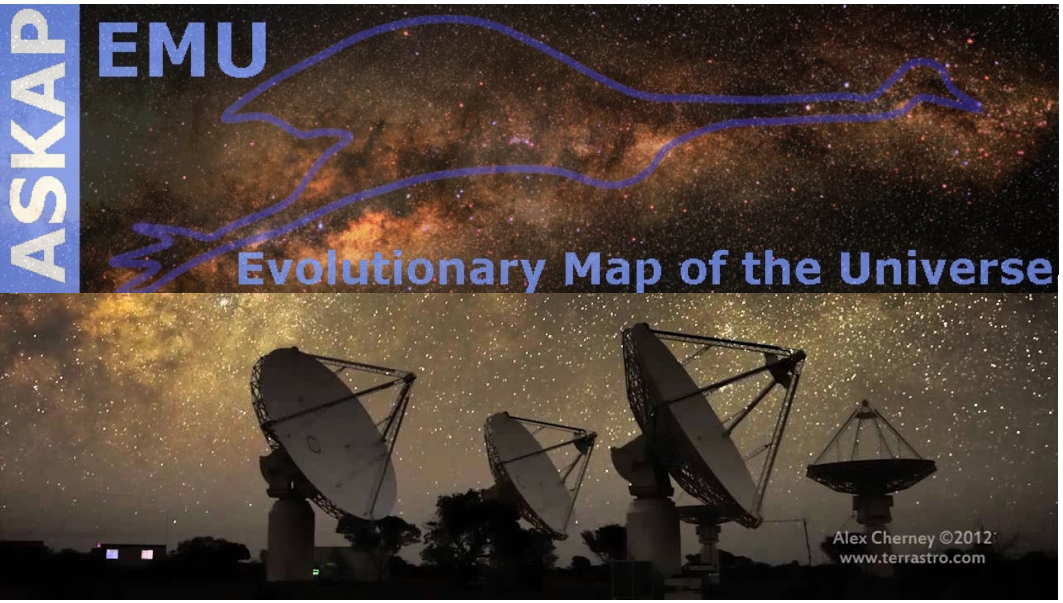
Help us hunt supermassive black holes at http://radio.galaxyzoo.org

@radiogalaxyzoo
@galaxyzoo
@the_zooniverse

Curtin University

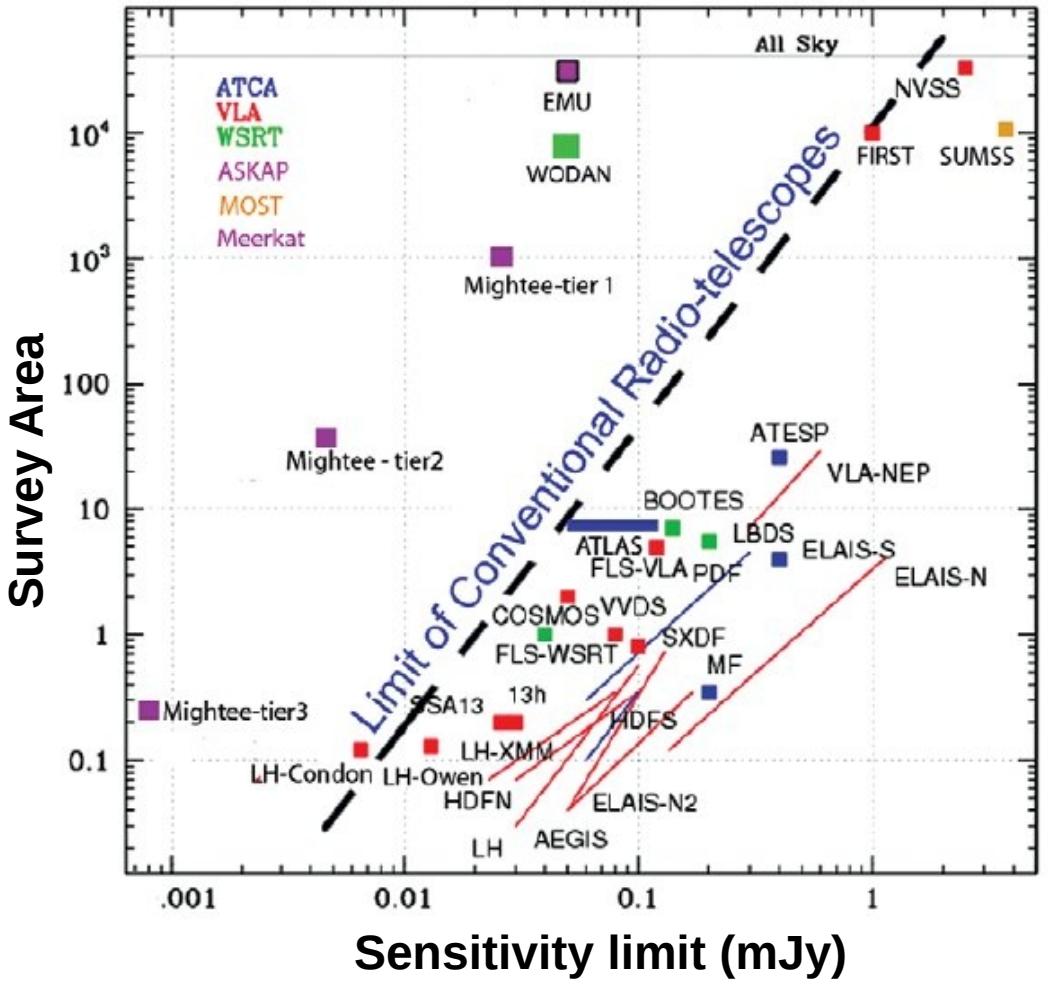
THE UNIVERSITY OF WESTERN AUSTRALIA

riding on the EMU's back...



All-sky below declinations +20 deg

Expect 70 million radio sources



Norris+ 2012

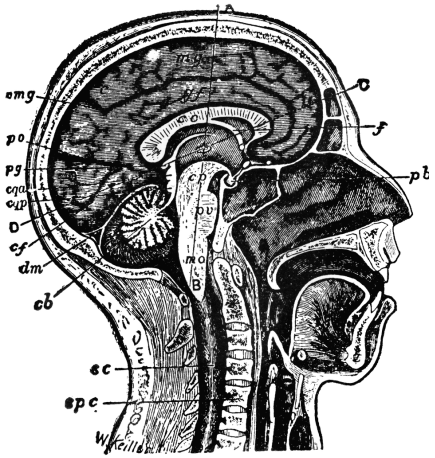
Motivation

There is nothing quite as useless as a radio source.
– Condon, 2013

Translation:

to understand how galaxies grow supermassive black holes & evolve, one needs context from multiwavelength observations

How to match 70 million radio sources to their hosts?



- ✔ humans (astronomers/their students)
- ✔ software matching algorithms

- current matching algorithms work for 90% of sources (Norris'12)

… so what about the other 7 million sources ?

- ➔ advance machine learning algorithms
- ➔ more humans?

Path ahead ...

Clear need for new automated methods to make accurate cross-ids

But, there exists many exotic radio morphologies that are not well catalogued/documented

Step 1: create a large dataset with different radio source morphologies

radio.galaxyzoo.org

ivywong SIGN OUT

English

English
繁體中文
Español
русский
Deutsch
Français
Polski
Magyar

CLASSIFY SCIENCE TEAM GALAXY ZOO RADIO PROFILE DISCUSS BLOG

In Search of Erupting Black Holes

Help astronomers discover supermassive black holes observed by the KG Jansky Very Large Array (NRAO) and the Australia Telescope Compact Array (CSIRO)

Search for Black Holes

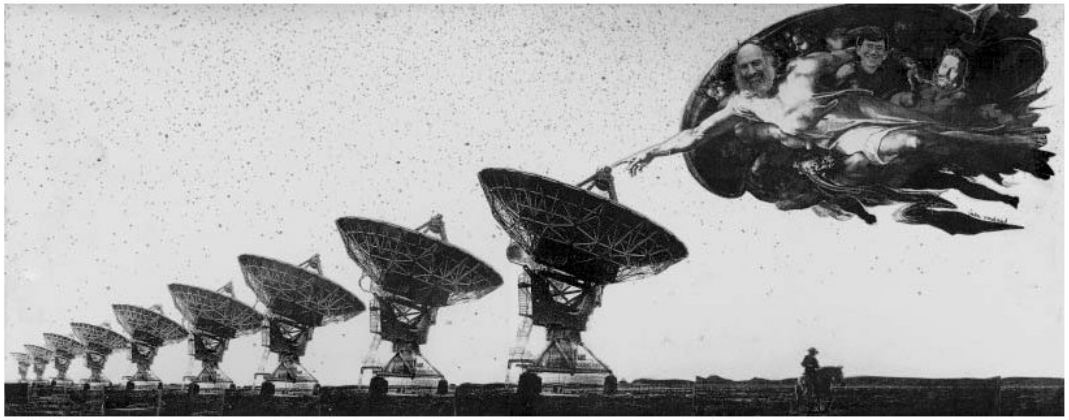
Black holes are found at the center of most, if not all, galaxies. The bigger the galaxy, the bigger the black hole and the more sensational the effect it can have on the host galaxy. These supermassive black holes drag in nearby material, growing to billions of times the mass of our sun and occasionally 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.

NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team (STScI/AURA)

Begin Hunting

Combining archival datasets

The VLA FIRST Survey



Faint Images of the Radio Sky at Twenty-Centimeters

Becker, White & Helfand 1995

+

WISE

Cutri+ 2013

ATLAS

Australia Telescope Large Area Survey

Franzen+ 2015, Norris+2006

+

Lonsdale+ 2003

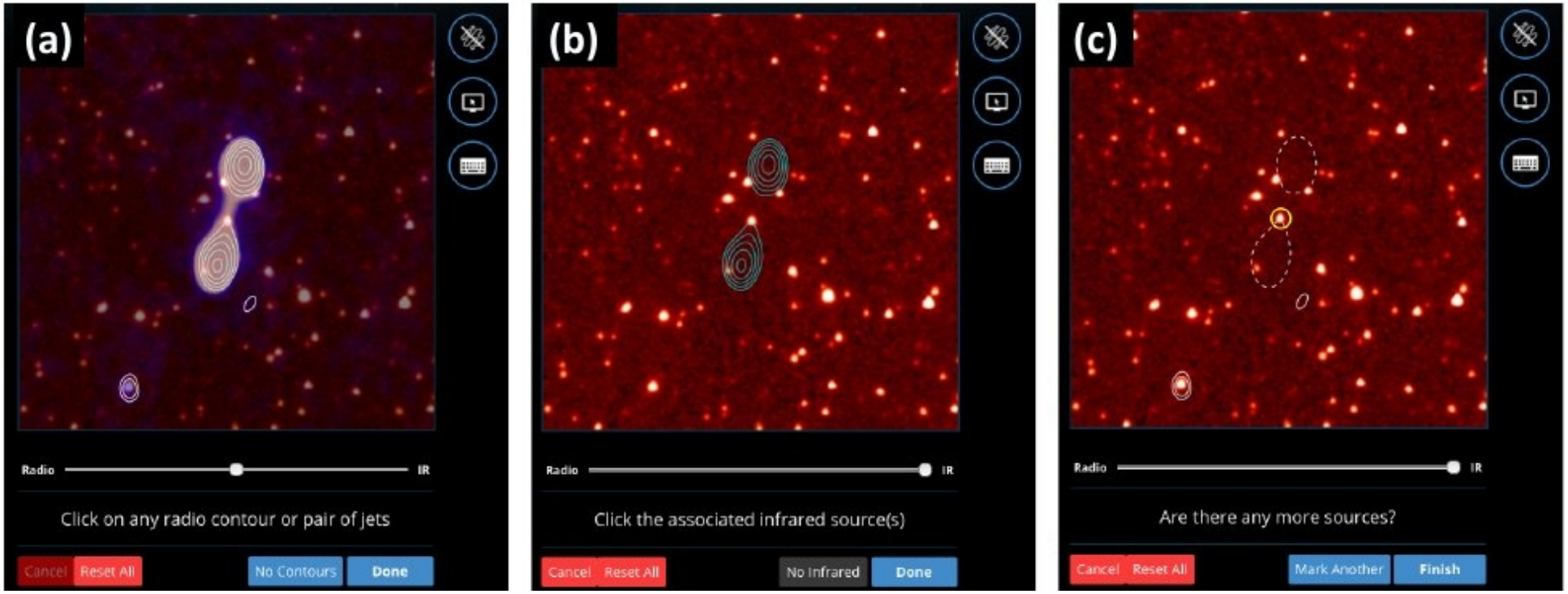
Citizen scientists (radio.galaxyzoo.org)

✗

✓

radio.galaxyzoo.org

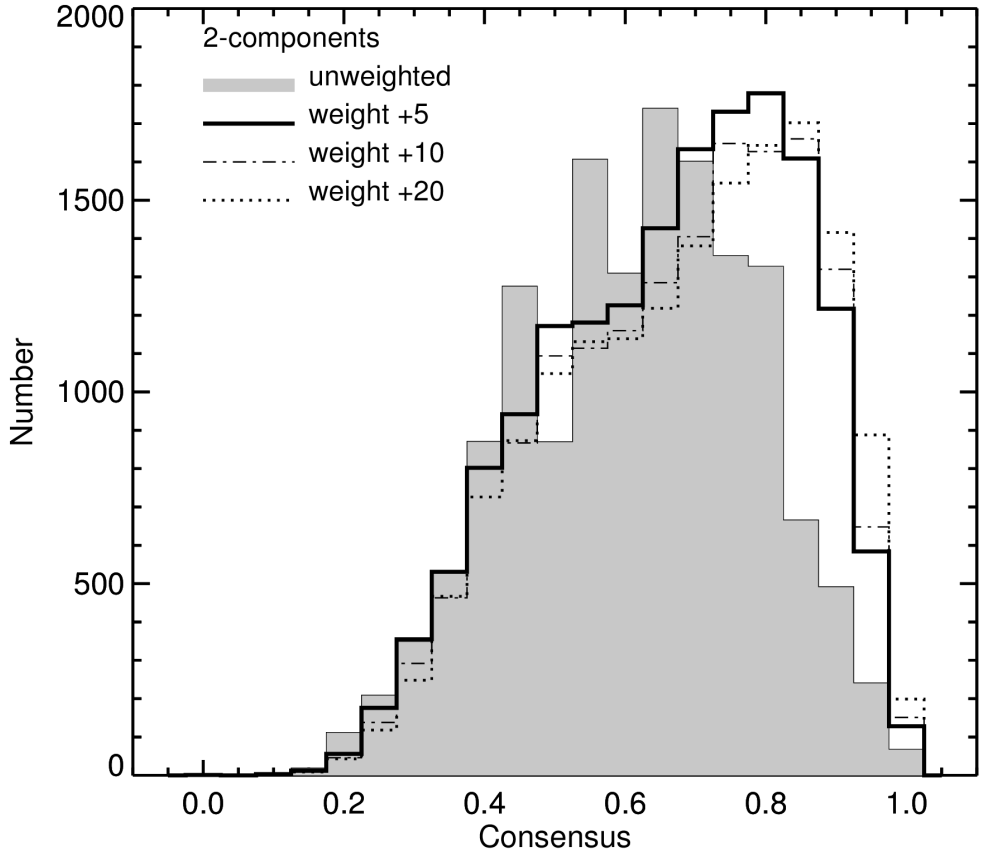
1) Examine radio & IR images
2) Identify radio source components
3) Mark location of host galaxy



... stay tuned for Julie's talk

Radio Galaxy Zoo Data Release 1

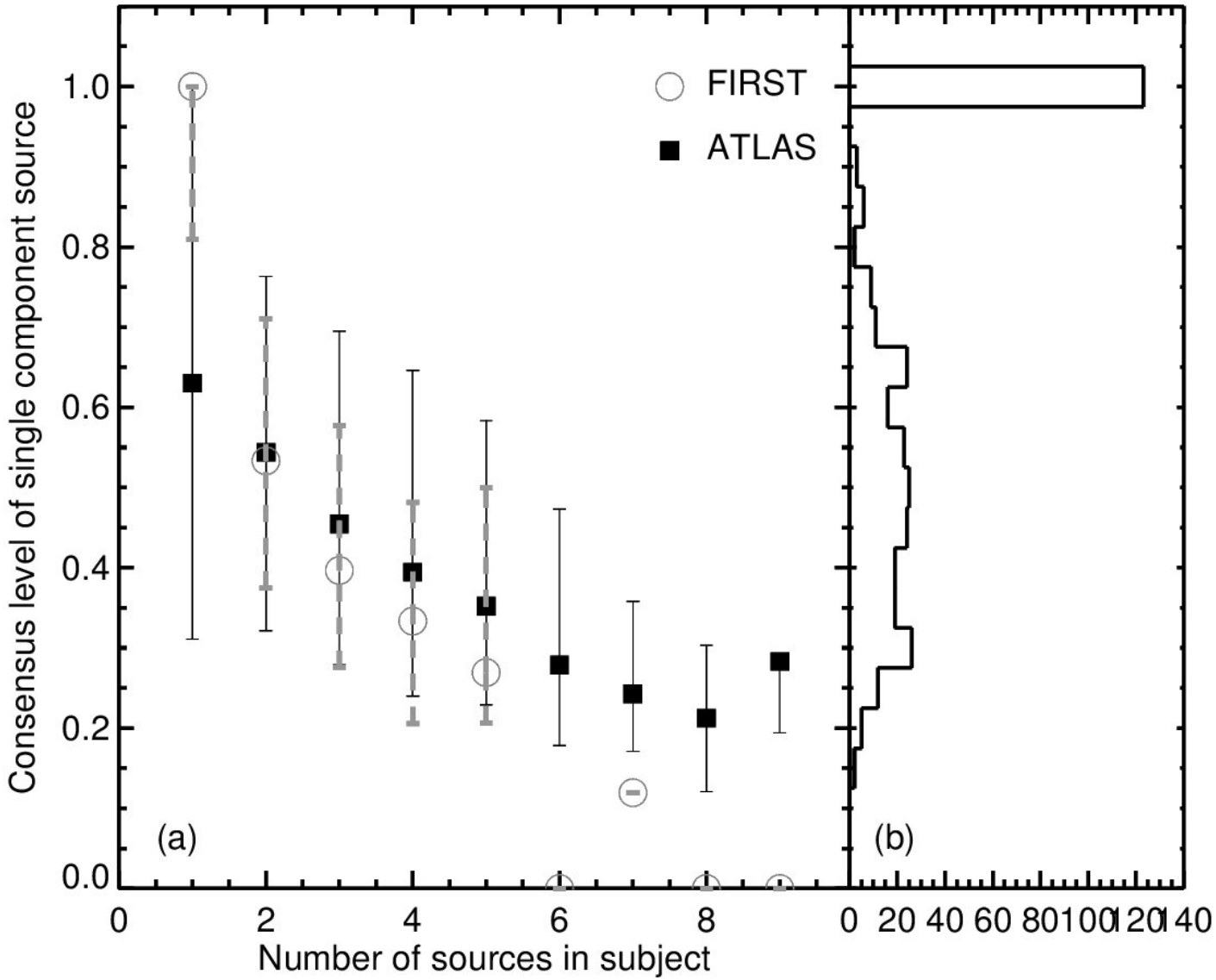
- ✔ Classifications between Dec 2013 & March 2016
- ✔ 11,214 registered citizen scientists
- ✔ >1.69 million classifications → 75, 589 source classifications
  - 74,627 from FIRST
  - 962 from ATLAS
- ✔ Catalogue of radio source components + WISE host for all sources with consensus ≥ 0.65



Wong+ 2017 in prep

Comparing FIRST & ATLAS

- ✔ Median consensus of FIRST much higher than those of ATLAS
- ✔ Why?
  - ➔ Match resolution and confusion matters!



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Checking DR1

* Big thanks to Larry Rudnick, HeinzAndernach, Stas Shabala, Ray Norris & Jesse Swan for doing this with me

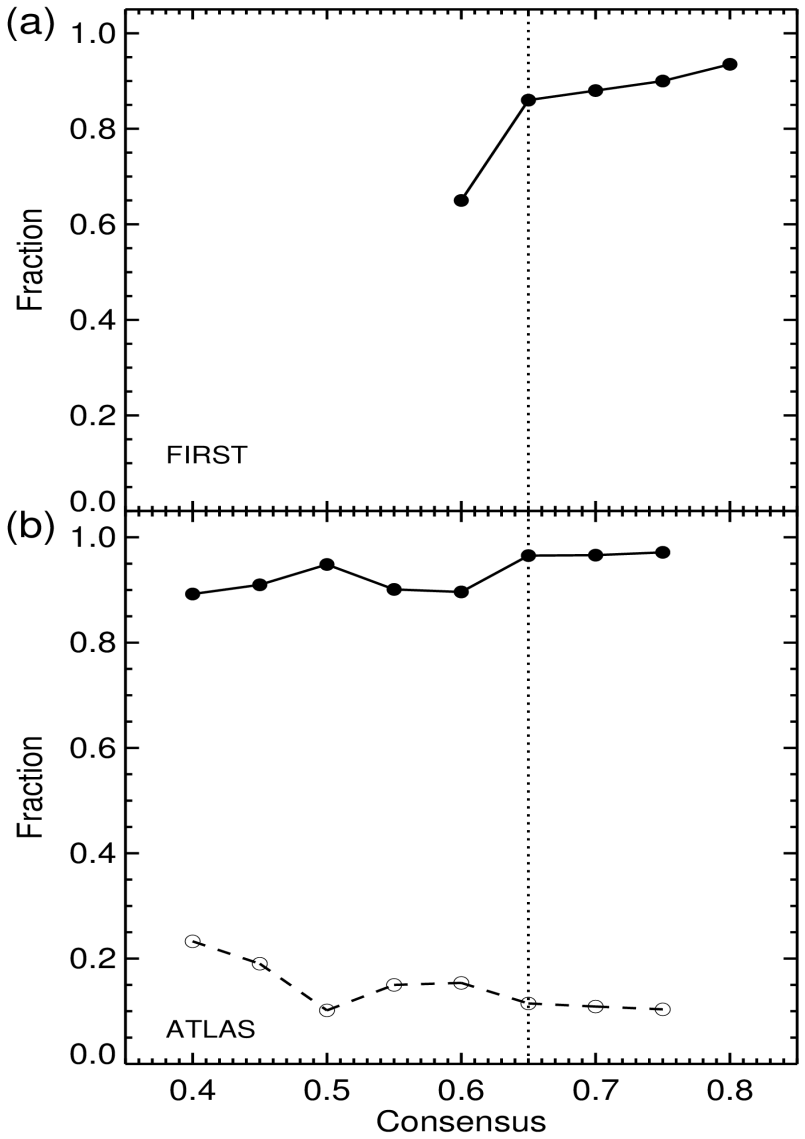
Visual verification of 1001 sources from FIRST and ~2123 sources from ATLAS*

✔ DR1-FIRST consensus levels correlate with the average fraction of classifications verified (within limits of obs)

- The 6 of us can disagree at a 5 – 10% level

✔ However,

➔ ATLAS data shows that this verified fraction is misleading because confusion → cross-id degeneracies



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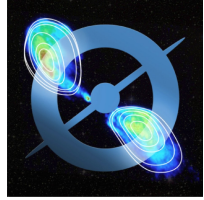
Quantified reliability of DR1-FIRST

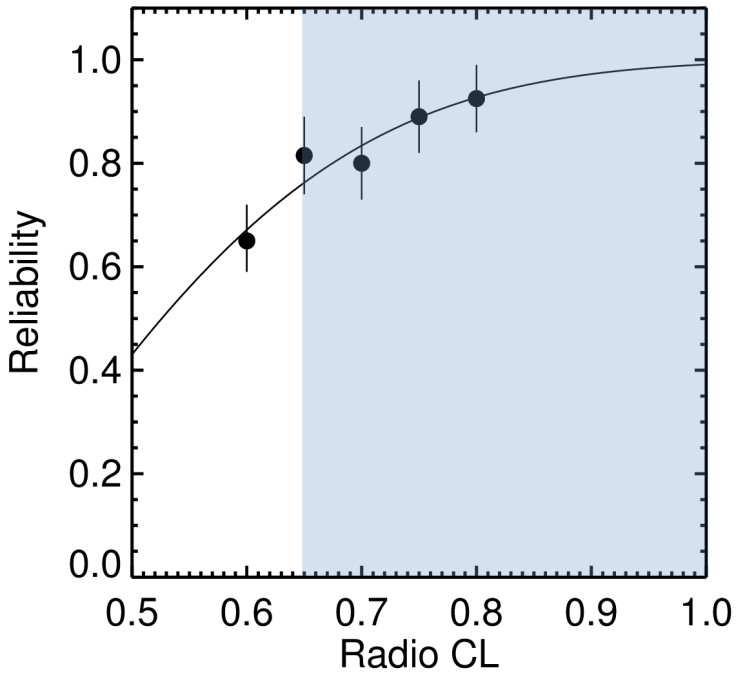


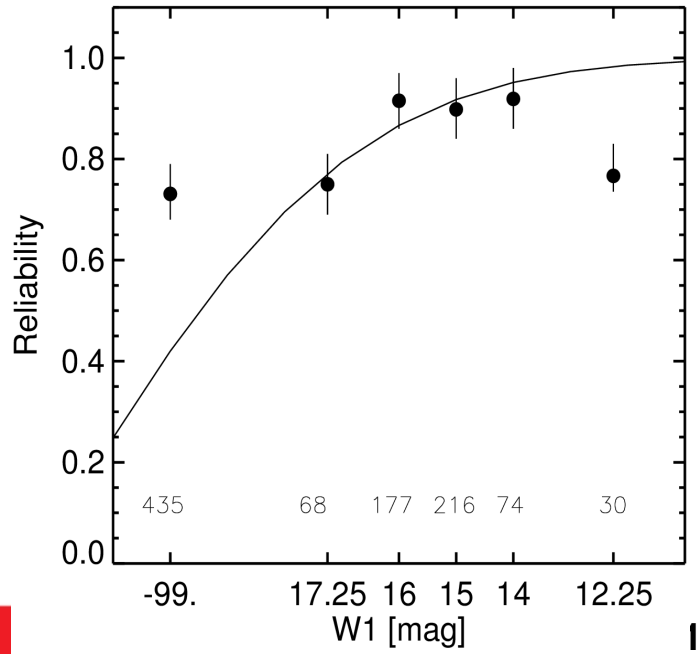
The verified fraction (f) cannot quantify Re(single parameter)

Re(single parameter) = mean f, weighted by n_sources per bin

$$Re(cl) = \frac{[\sum_{w=0}^{\infty}(N(cl,w) \times F(cl,w)]}{[\sum_{w=0}^{\infty}(N(cl,w))]} \quad (1)$$

$$Re(w) = \frac{\sum_{cl=0}^{1}(N(cl,w) \times F(cl,w)]}{[\sum_{cl=0}^{1}(N(cl,w))]} \quad (2)$$





➔ DR1 cat = min reliability of 0.75 – 0.80

➔ ~44% DR1 w/o WISE W1 but bright W1 also an issue

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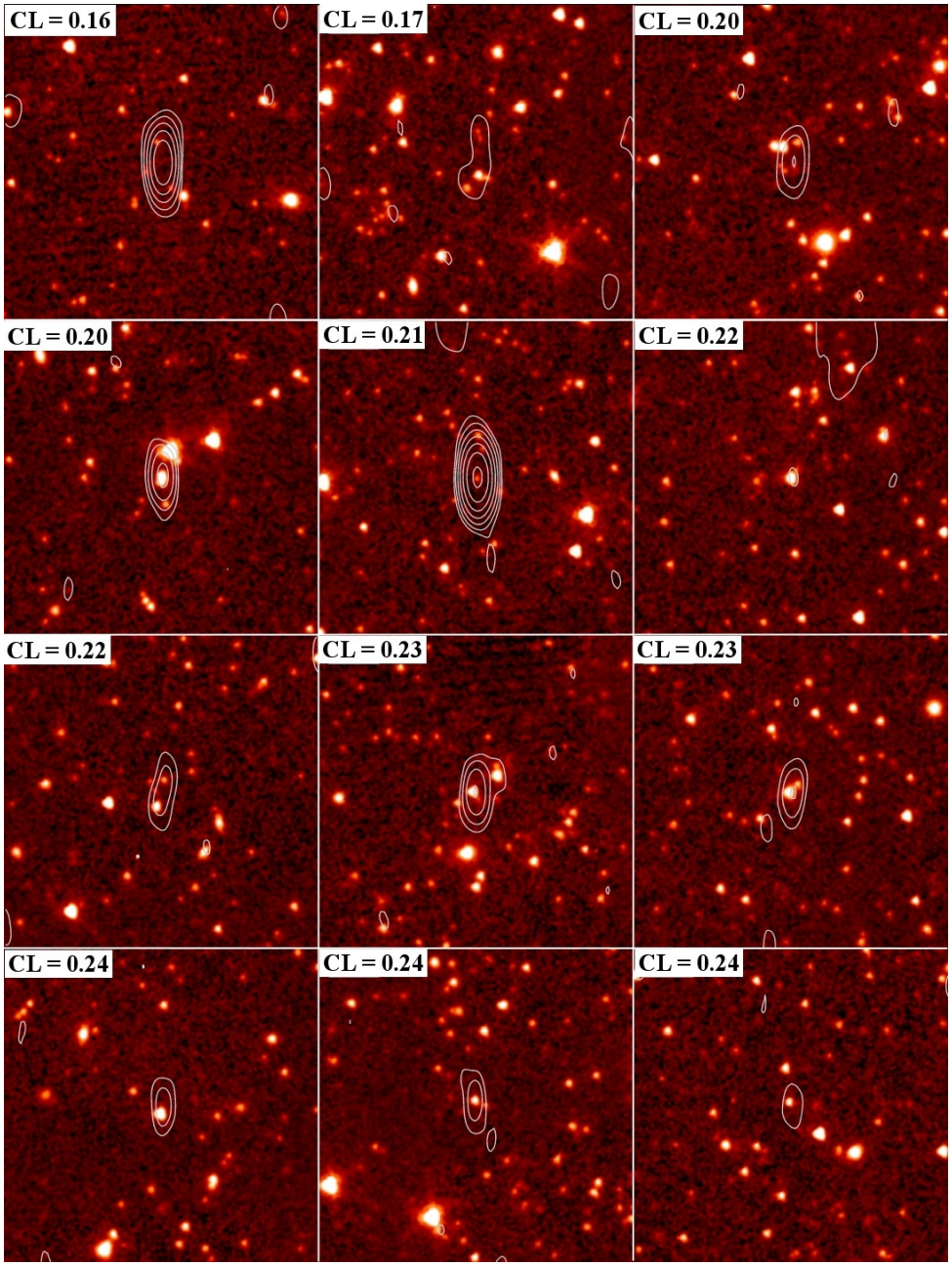
Technical lessons

What increases confusion/degeneracies in citizen scientists' classifications?

- ➔ Radio – IR resolution difference
  - ATLAS, FIRST: 12.2'' x 7.6'', 5''
  - SWIRE, WISE(W1) : 1.2'', 6''
- ➔ Deep observations (radio & IR)
  - ATLAS, FIRST: 1σ = 13, 150 μJy/beam
  - SWIRE, WISE(W1): 5σ = 7.3, 80 μJy



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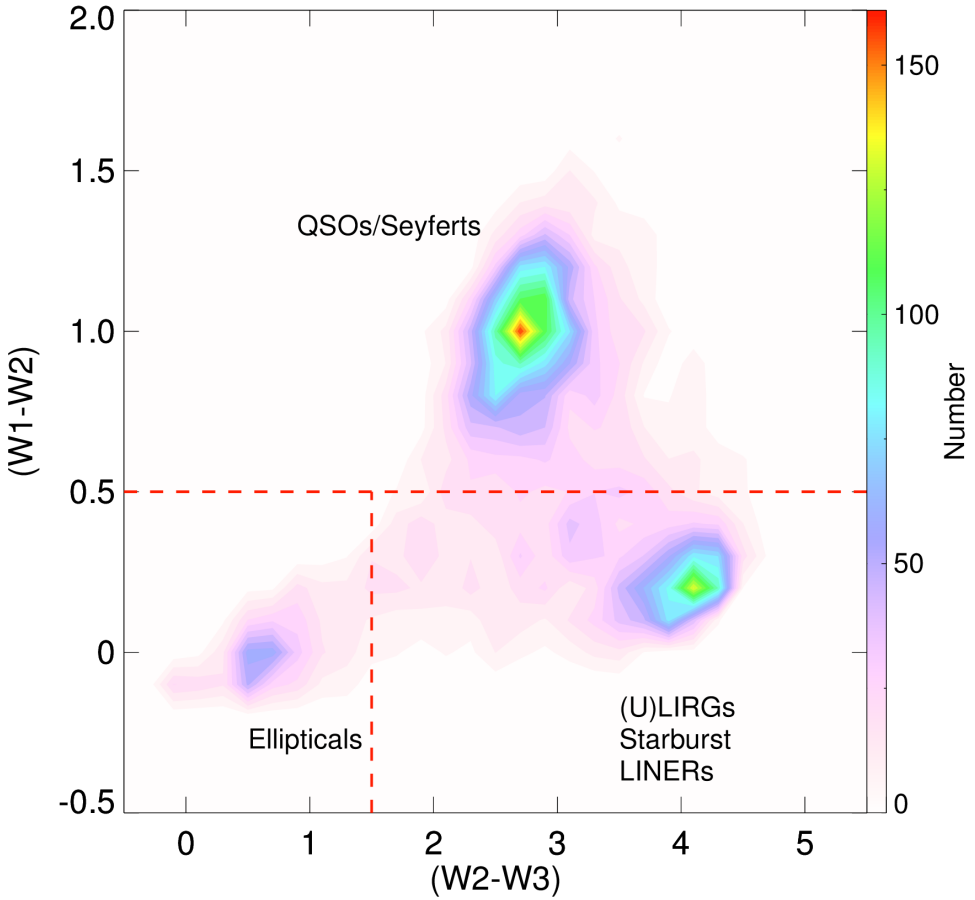
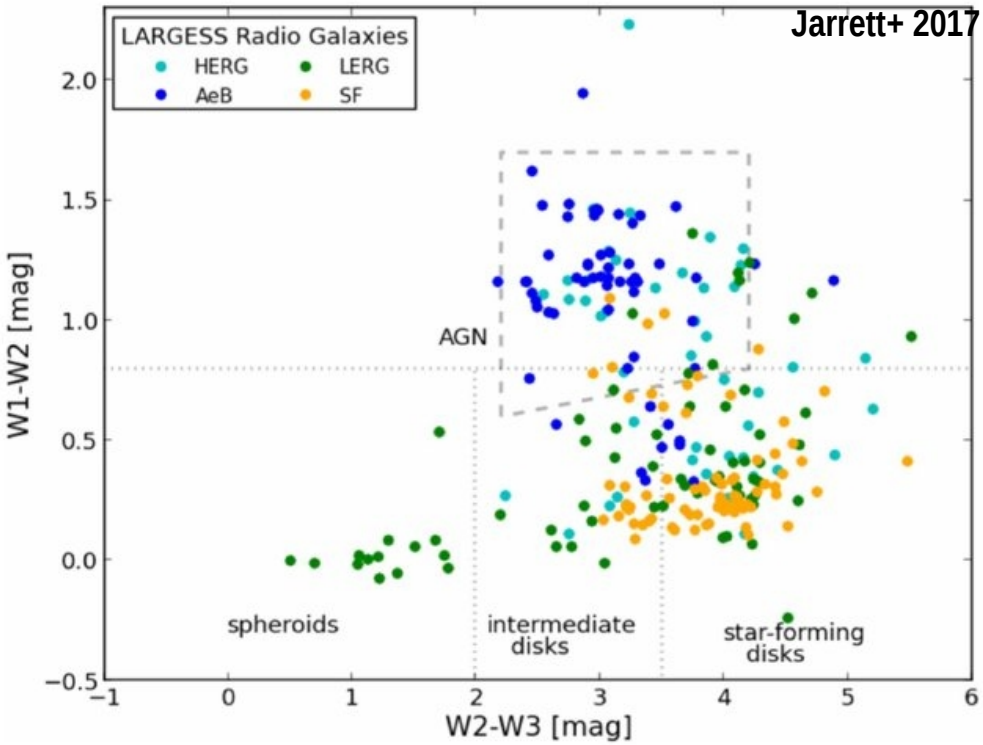
Science with Radio Galaxy Zoo Data Release 1

Wong+ 2017 in prep

6,202 DR1 sources with good W1,W2,W3



Comparable to LARGESS



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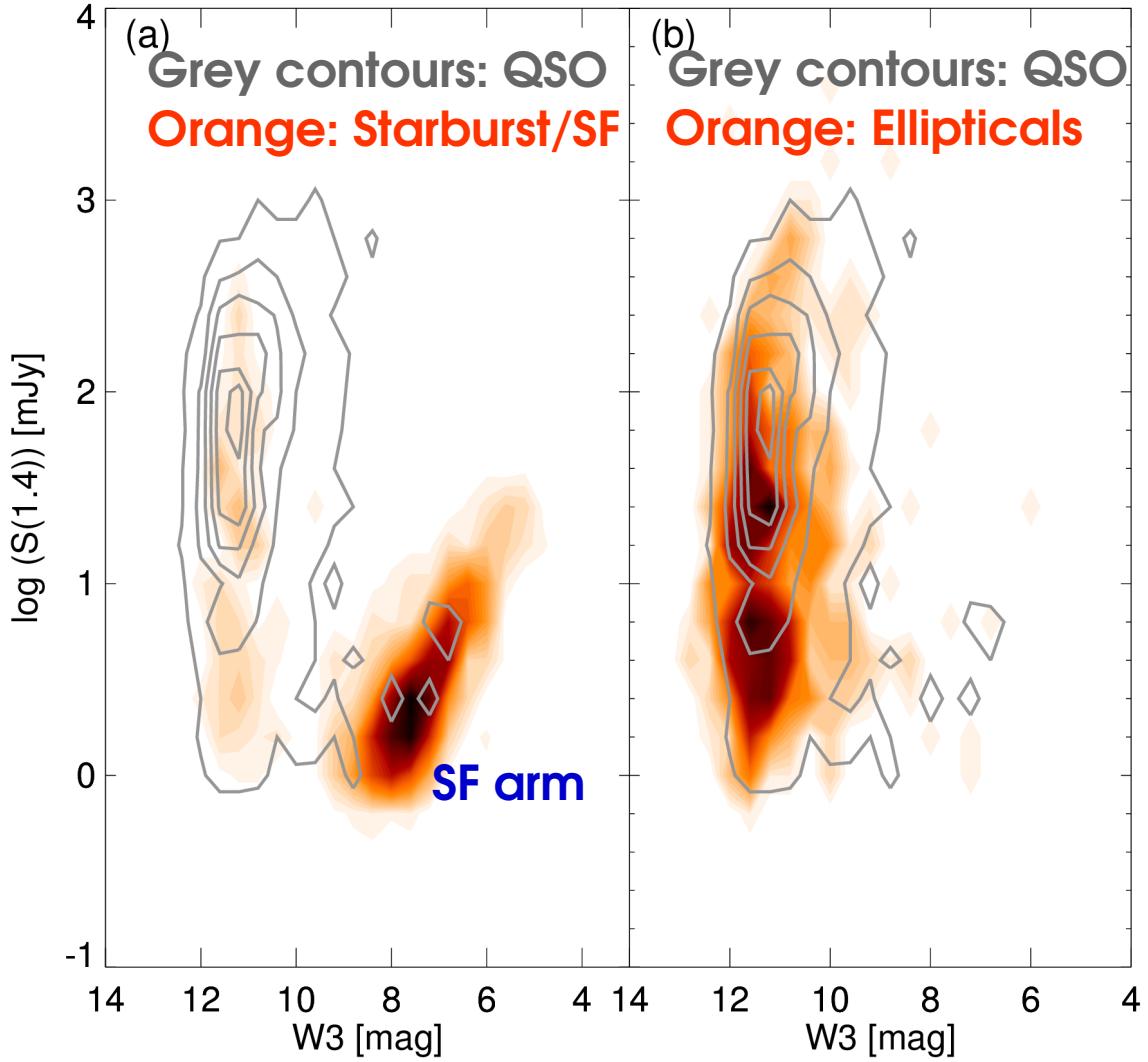
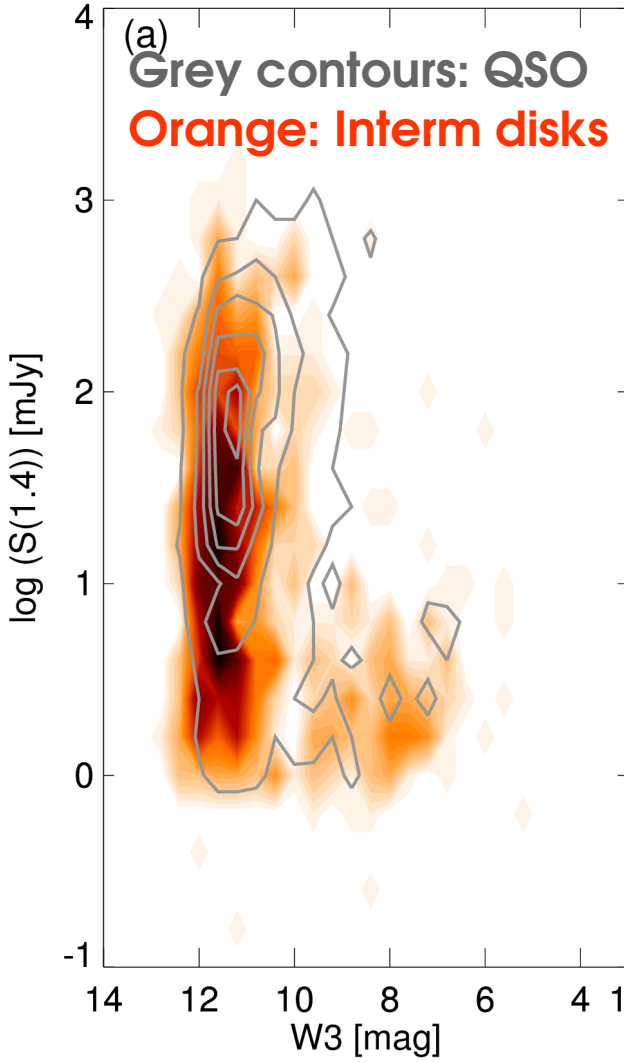
Note. DR1 ~6.3 times larger than LARGESS

1.4 GHz vs 12 microns

Dividing 1-component DR1 sample using WISE colours





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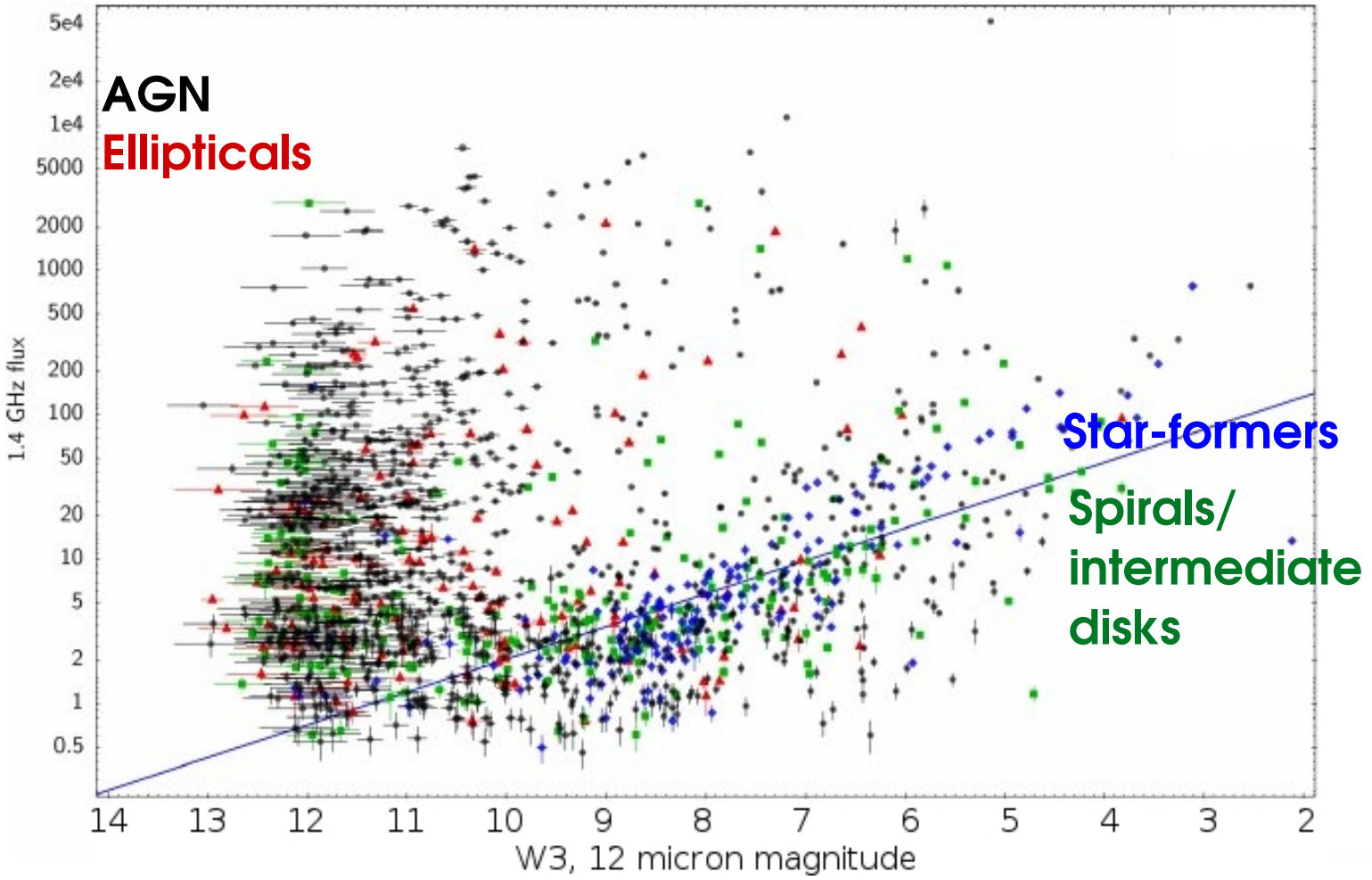
Radio-quiet ≠ radio silent

Consistent 1.4 GHz vs 12 micron results from the MIXR sample



Mingo+ 2016; see also Wong+ 2016

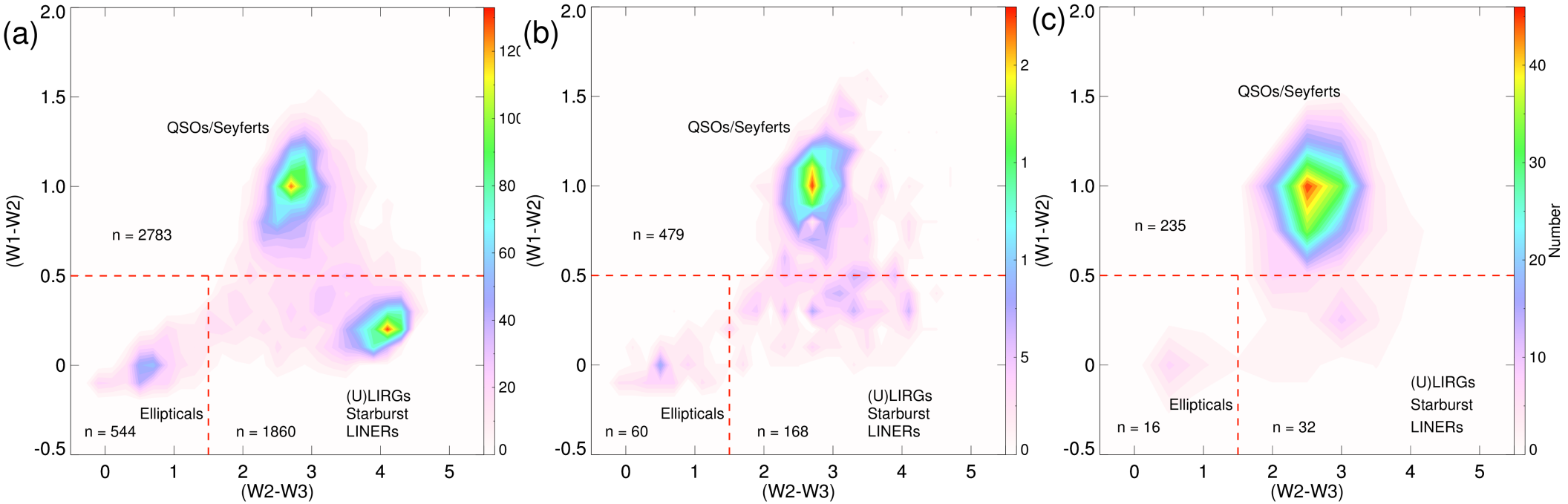
Note. DR1 ~3.9 times larger than MIXR

IR properties in terms of radio components

1-component

2-components

3-components



➔ QSO WISE colours dominate

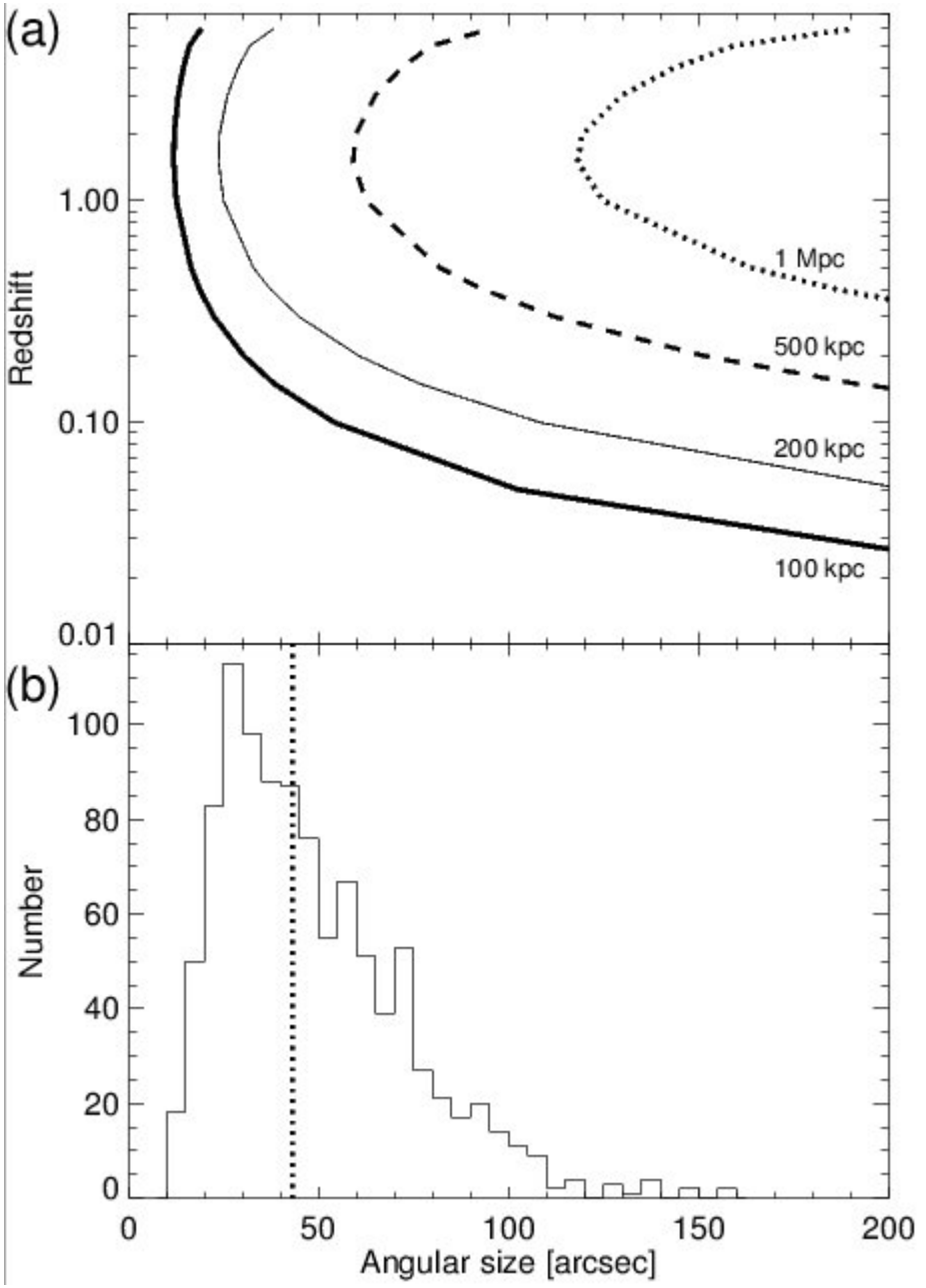
- n_comp = 1 → 3, relative QSO fraction = 53% → 83%

➔ Relative fraction of Spiral/starburst host decrease from 36% → 11%

Wong+ 2017 in prep

Radio source projected angular size

- ✔ 1,015 DR1 sources with more than 1 radio component
- ✔ Median projected angular size = 43.1"



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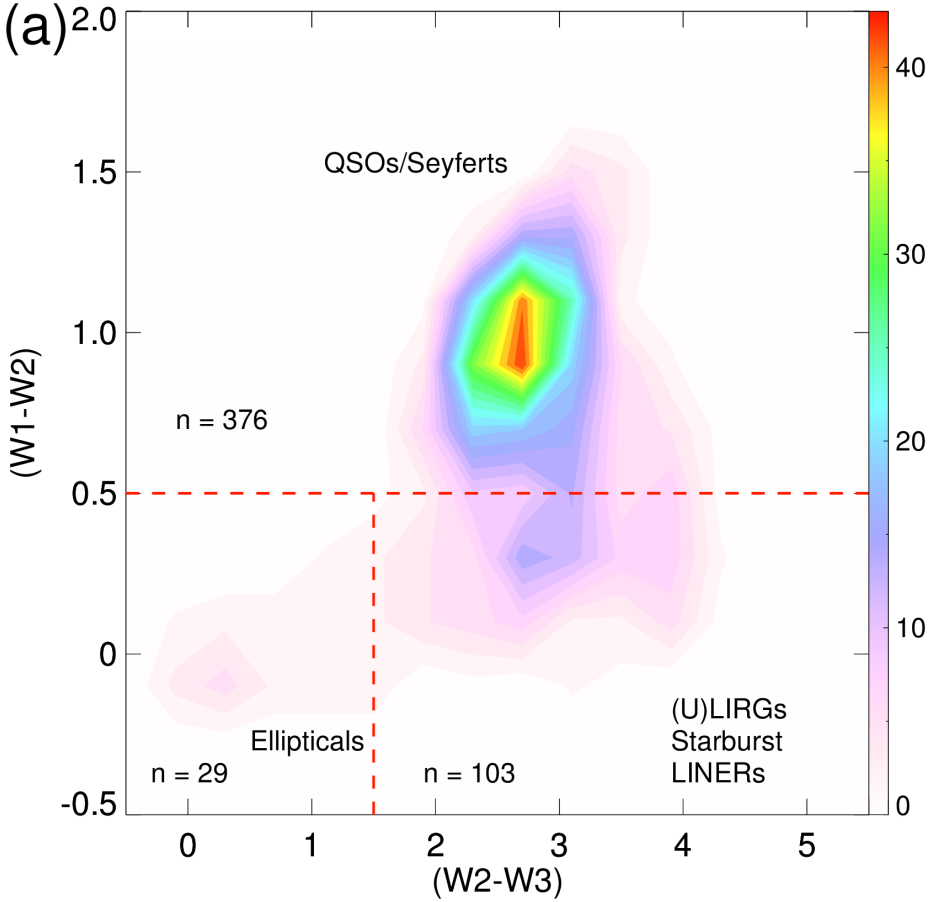
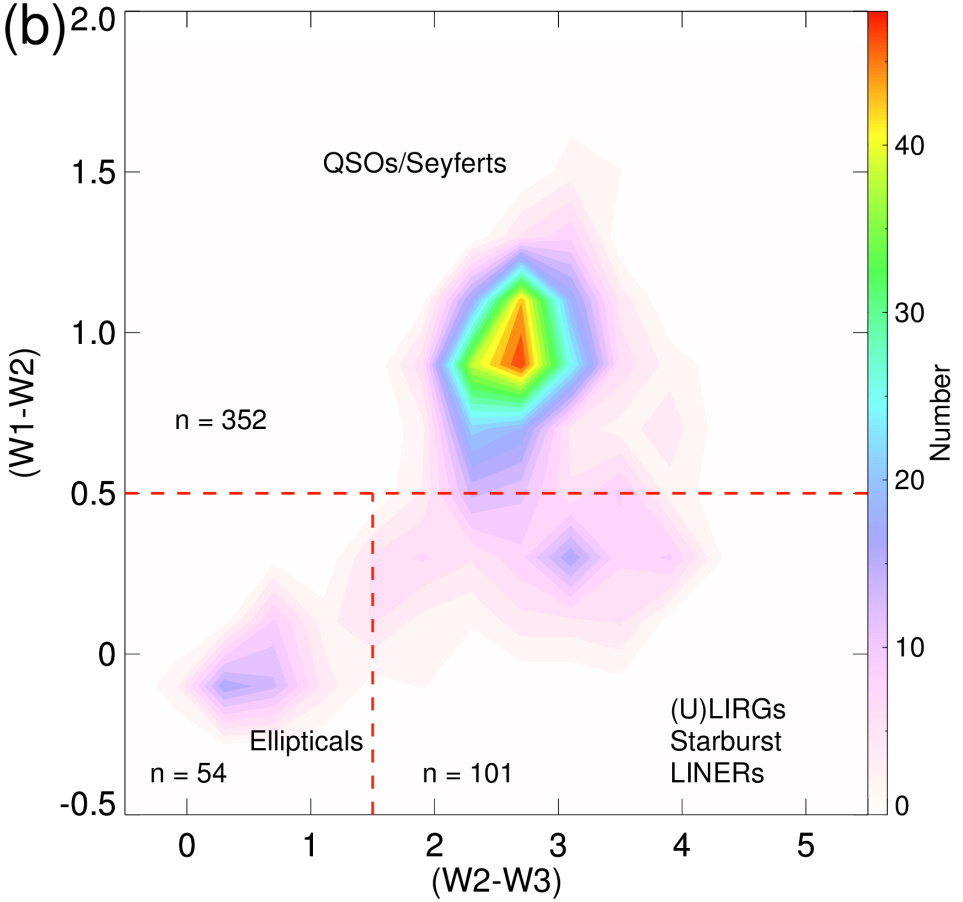
IR properties of small & large sources

Small (< 43.1")



Large (> 43.1")



➔ Small radio sources associated mostly with QSO WISE colours

➔ More elliptical hosts for radio sources with large angular sizes

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Summary

- ✔ Radio Galaxy Zoo Data Release 1 → >75,000 source classifications with a minimum reliability of 0.75 – 0.8
  - ~44% w/o IR host, 6202 (low-z) sources have good W1, W2, W3

- ✔ Many sources w spiral/starburst IR colours can have significant radio emission from a radio quiet AGN

- ✔ Multi-component sources: more likely to have QSO IR colours.

- ✔ BUT, elliptical fraction ⇑ for sources w larger angular sizes

Help us hunt supermassive black holes at http://radio.galaxyzoo.org

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