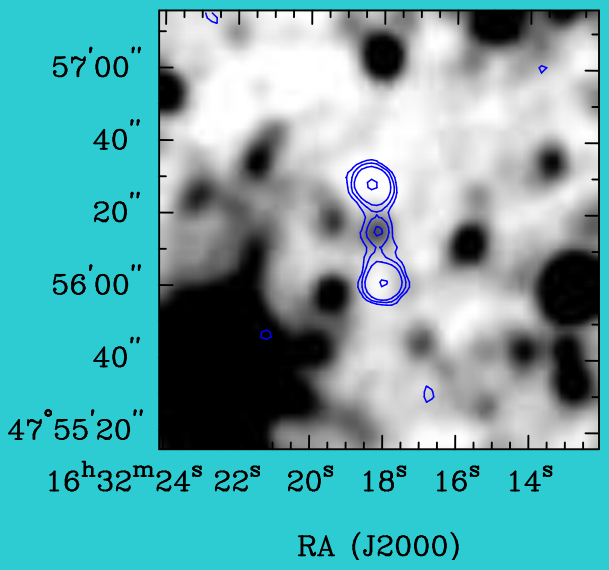

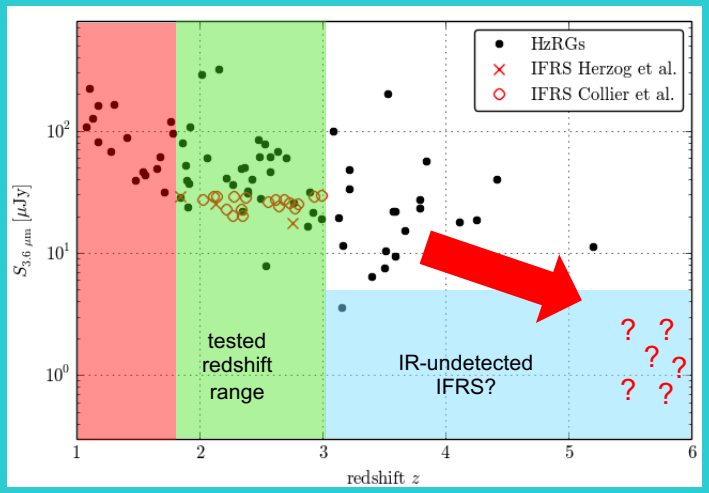

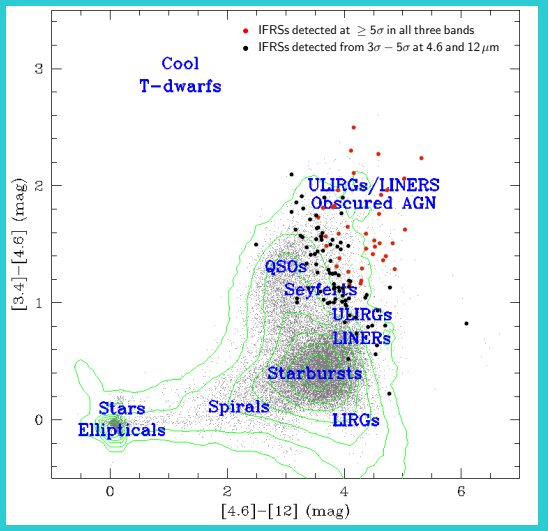

Infrared-Faint Radio Sources: a new population of high-redshift radio galaxies.

2014MNRAS.439..545C
2019MNRAS.484.1021O

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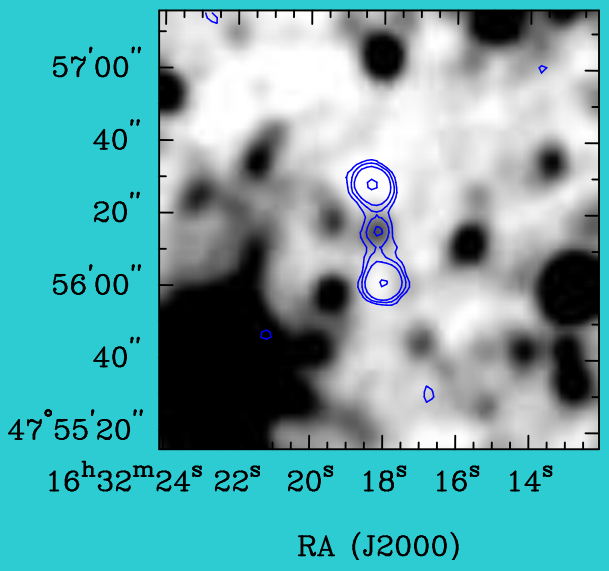
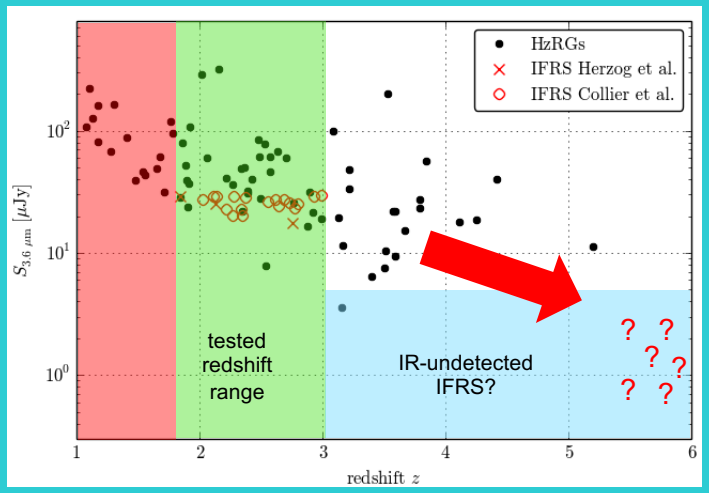
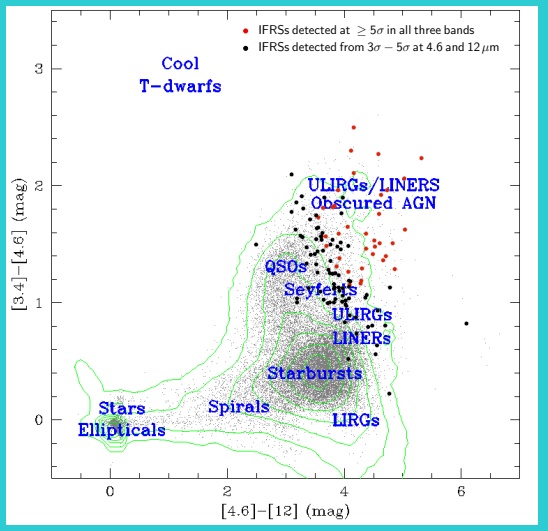
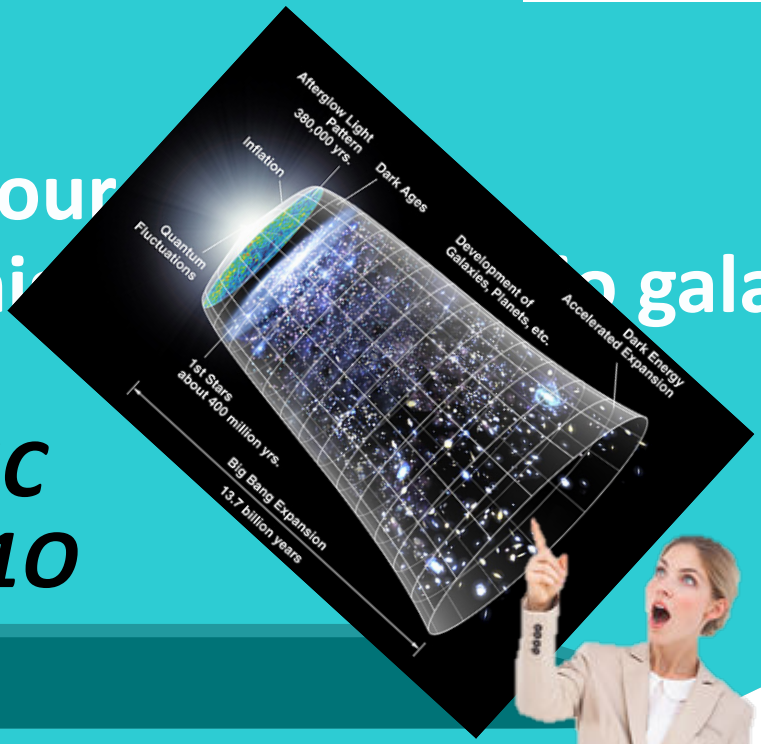






Infrared-Faint Radio Sour
a new population of hi galaxies.



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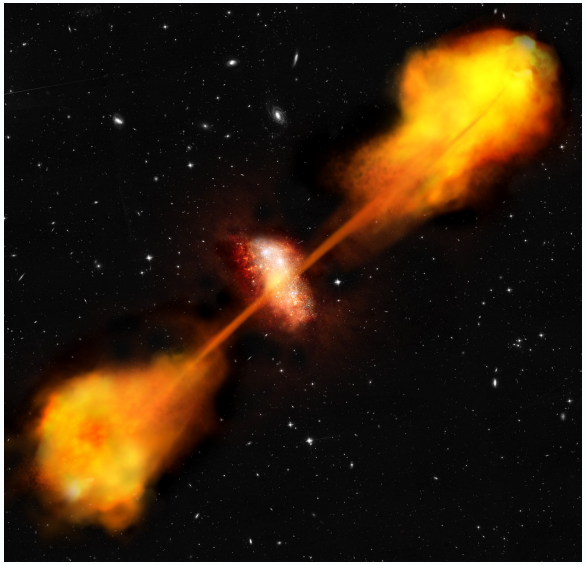
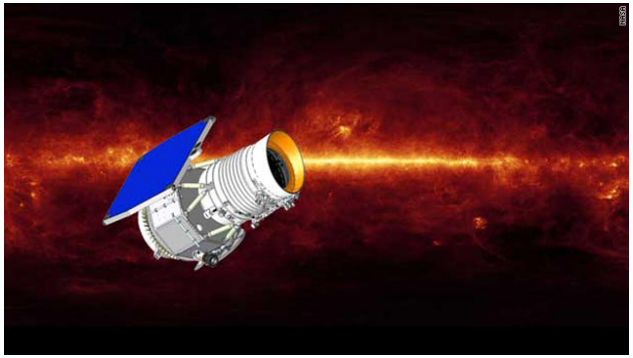
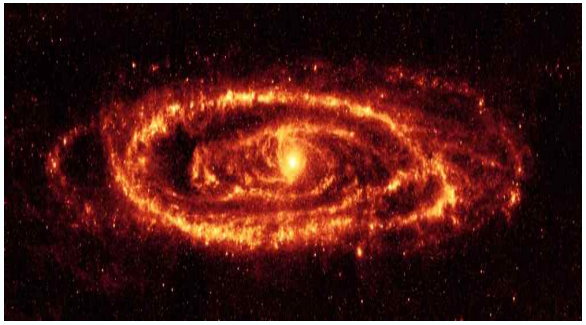
Introduction

What do we see in the radio?



What do we see in the infrared?



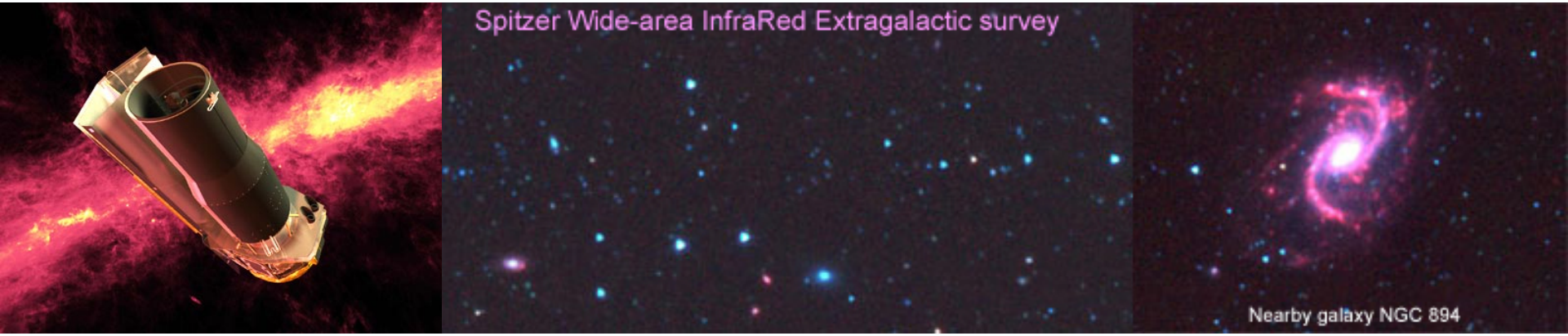


Infrared Faint Radio Sources (IFRSs)

- Rare type of object discovered by Norris+ (2006) in deep radio observations that didn't meet this expectation
  - From Australia Telescope Large Area Survey (ATLAS; Norris+ 2006)
  - Wavelength of λ = 20 cm (ν = 1.4 GHz)
  - Using Australia Telescope Compact Array (ATCA)

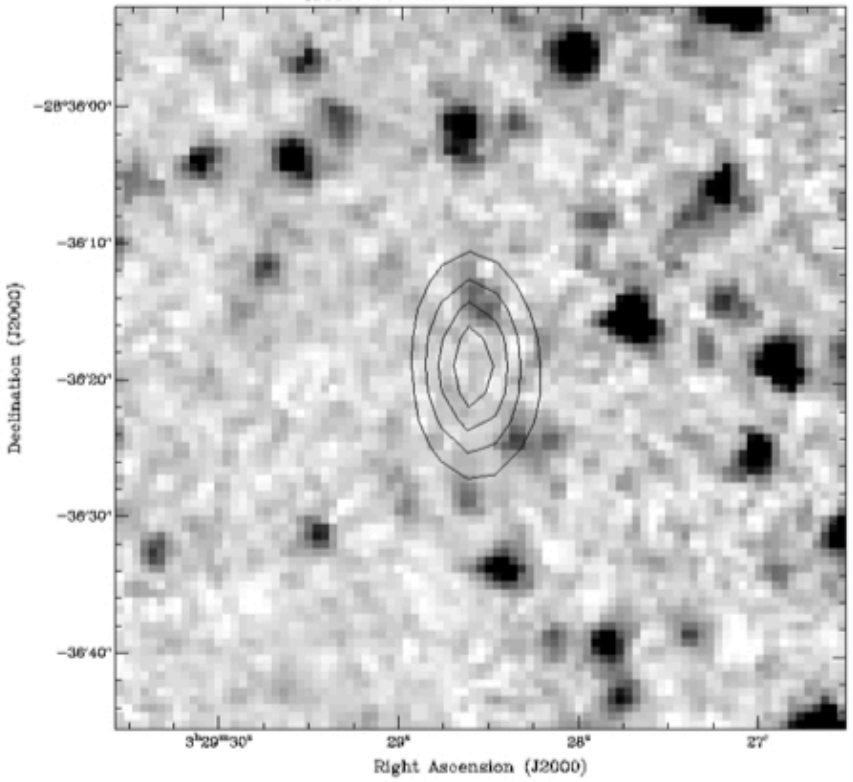
Infrared Faint Radio Sources (IFRSs)

- Radio sources with no detectable counterpart in infrared (IR) observations
  - From *Spitzer* Space Telescope's SWIRE survey (Lonsdale+ 2003)
  - Wavelength of $\lambda = 3.6\ \mu$m
  - Undetected down to 3σ level of 3 μJy or ~0.2 μJy in stacked images!
  - Also not detected at 4.5, 5.8, 8 & 24 μm, nor in optical light



Infrared Faint Radio Sources (IFRSs)

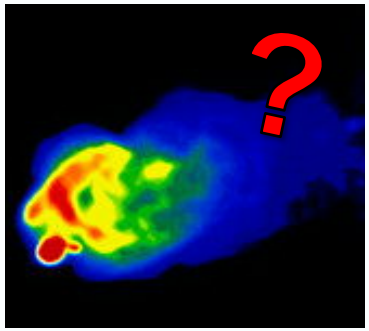
- Unexpected at time, since ATLAS radio sources thought to have detectable IR emission from host galaxy
- 53 identified by Norris+ (2006) & Middelberg+ (2008) in CDFS and ELAIS-S1 fields

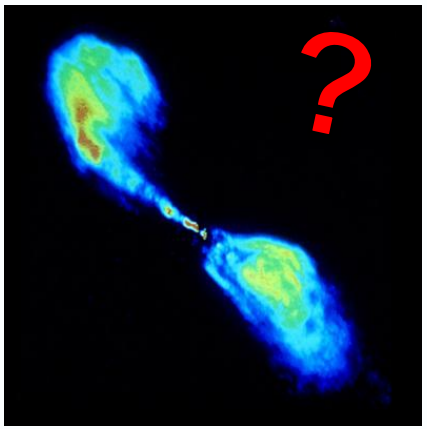


Norris et al. (2011)

The Nature of IFRSs

- Still unconfirmed exactly what IFRSs are
- Hypotheses about their nature have included:
  - Very distant, radio-loud galaxies at $z > 3$
  - Very obscured radio galaxies at moderate z ($1 < z < 2$)
  - Lobes or hot-spots of nearby unknown RGs
  - Very obscured, luminous starbursts
  - High-latitude pulsars
  - Mis-IDs





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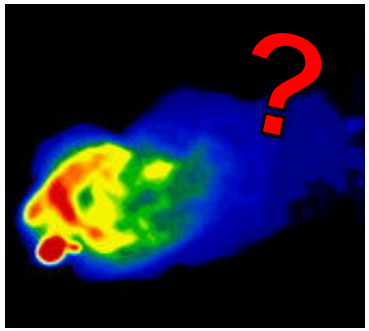

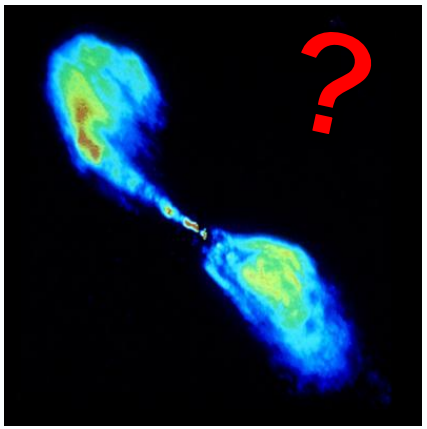

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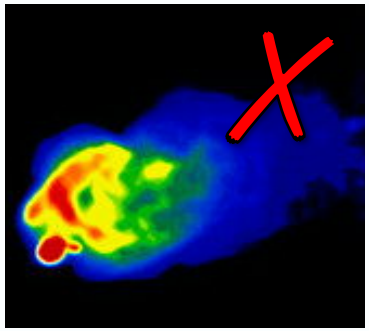

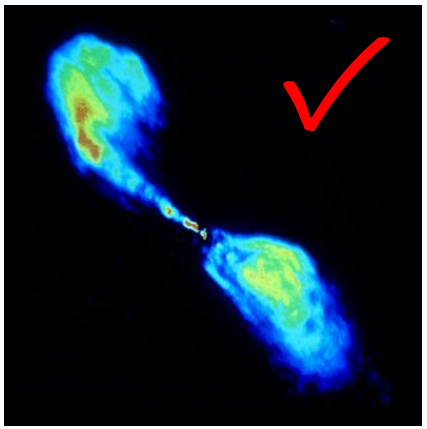

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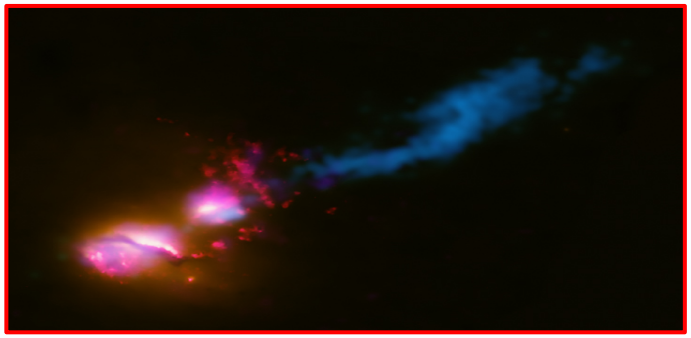
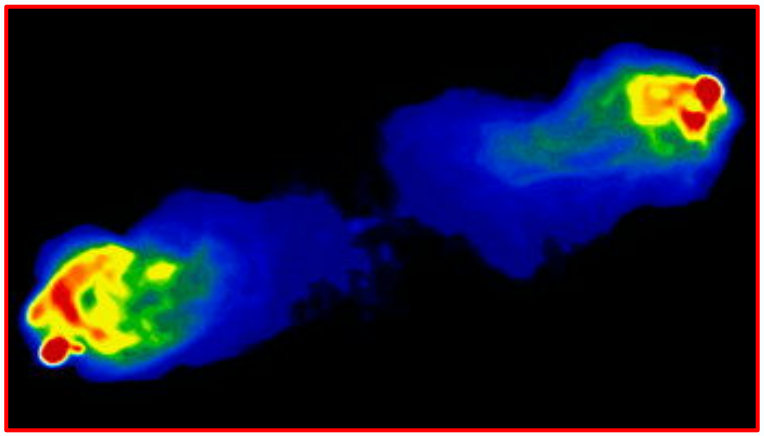
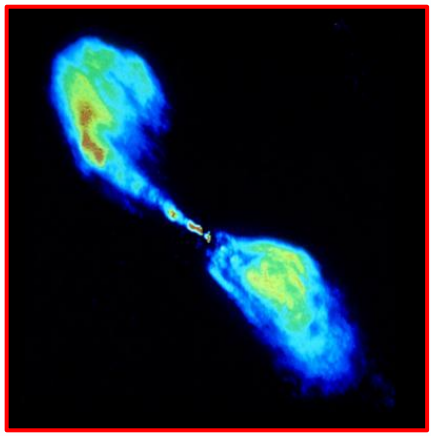
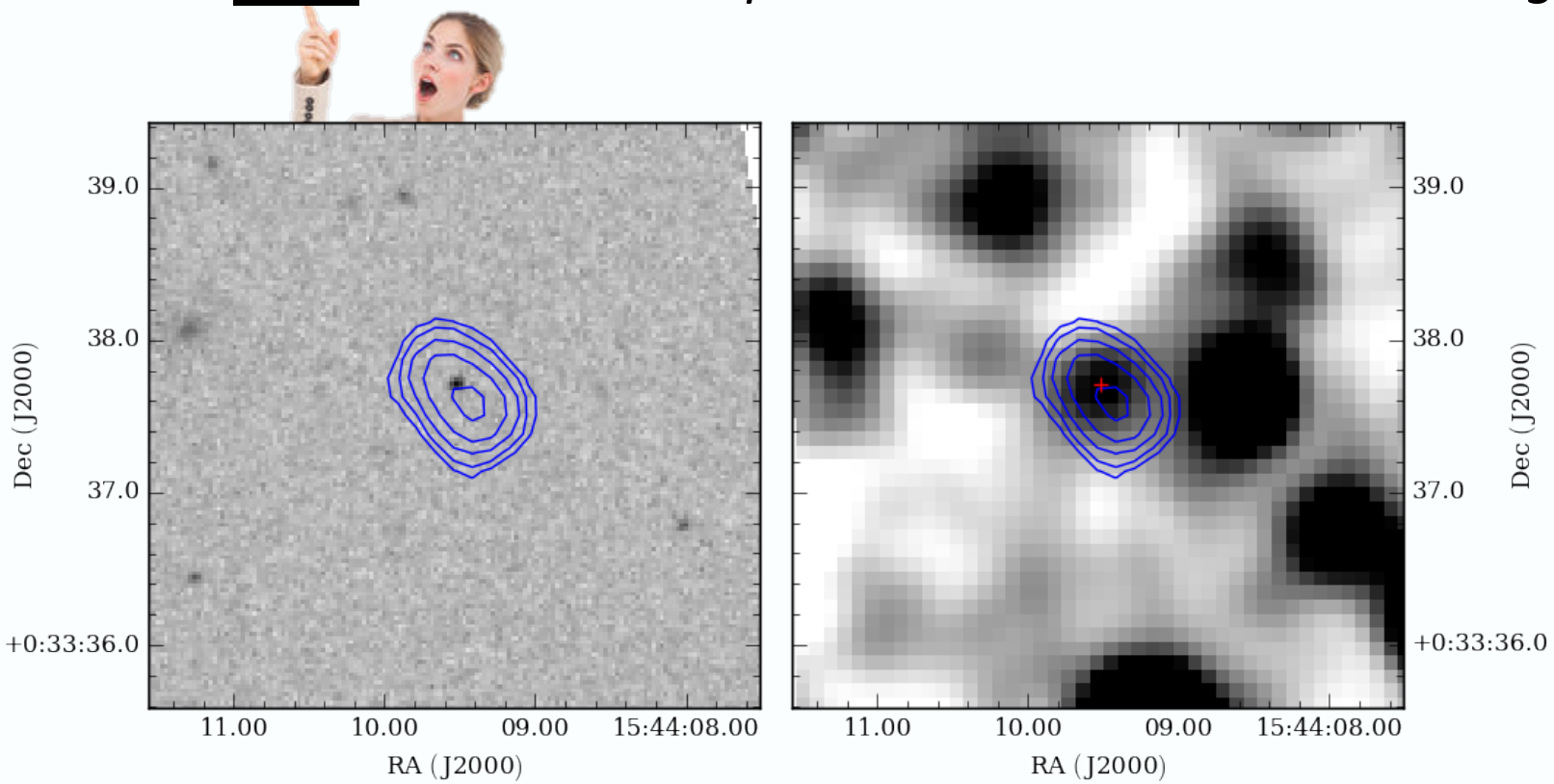




WISE IFRSs

- From WISE, NVSS & FIRST (radio from Kimball & Ivezić 2008/14 URC)
  - NVSS for measure of total flux and polarised flux density
  - FIRST for accurate (< 1”) positional information
  - WISE for “deep” IR detections (in strips towards poles)
- Meet Zinn+ (2011) selection criteria plus:
  - NVSS flux density > 7.5 mJy (max. completeness and min. polarisation bias)
  - 1+ FIRST counterpart within NVSS beam
  - WISE counterpart within 5” of FIRST position
  - SNR at 3.4 μm ≥ 5
  - Visually don’t appear as radio lobe match to IR source

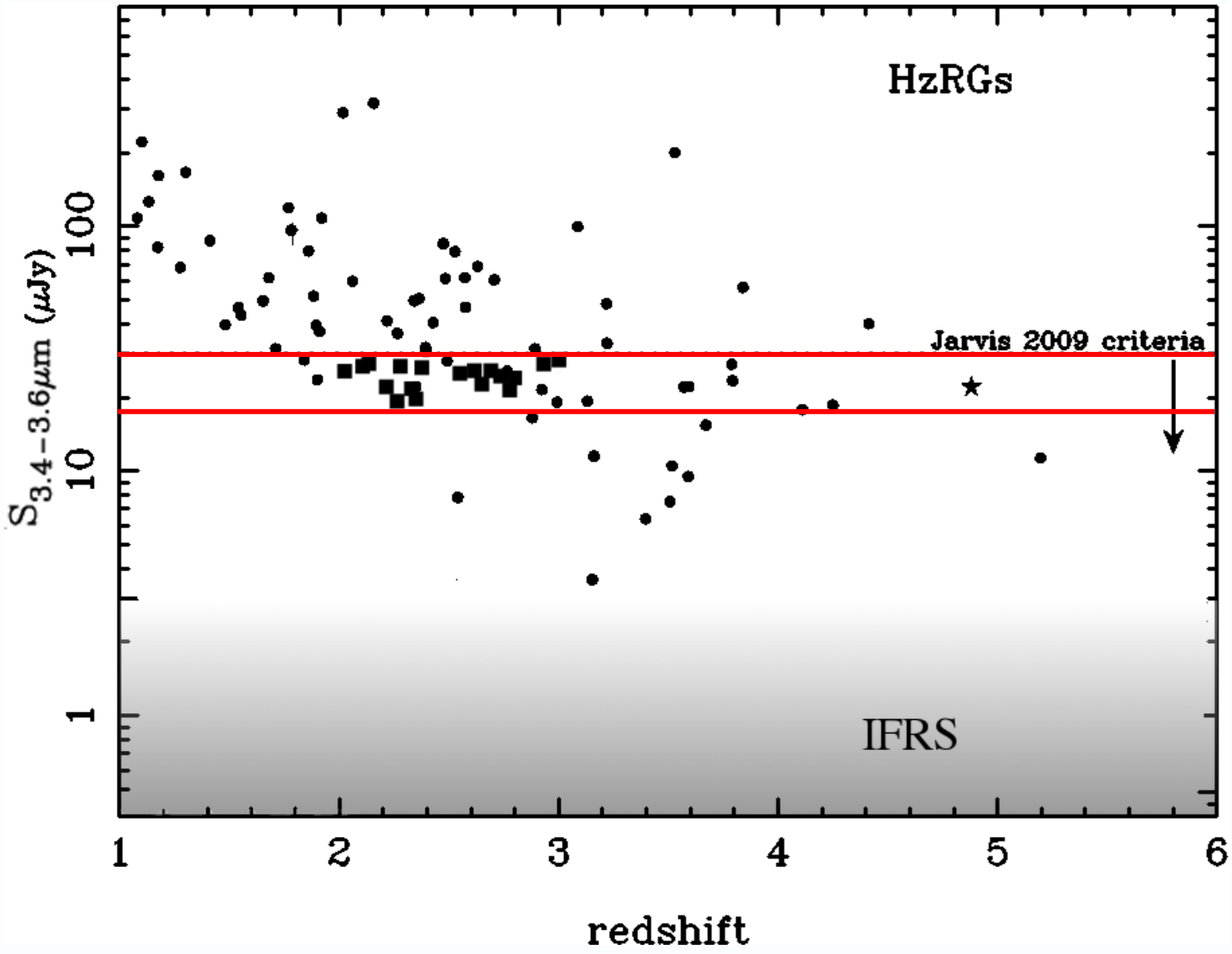
Results

- We find **1317** IFRSs!!!! – *compiled into cross-matched catalogue*



- We find **41** (3%) polarised IFRSs from Taylor+ 2009 RM catalogue
- First population of IFRSs reliably detected in the IR

The Nature of WISE IFRSs



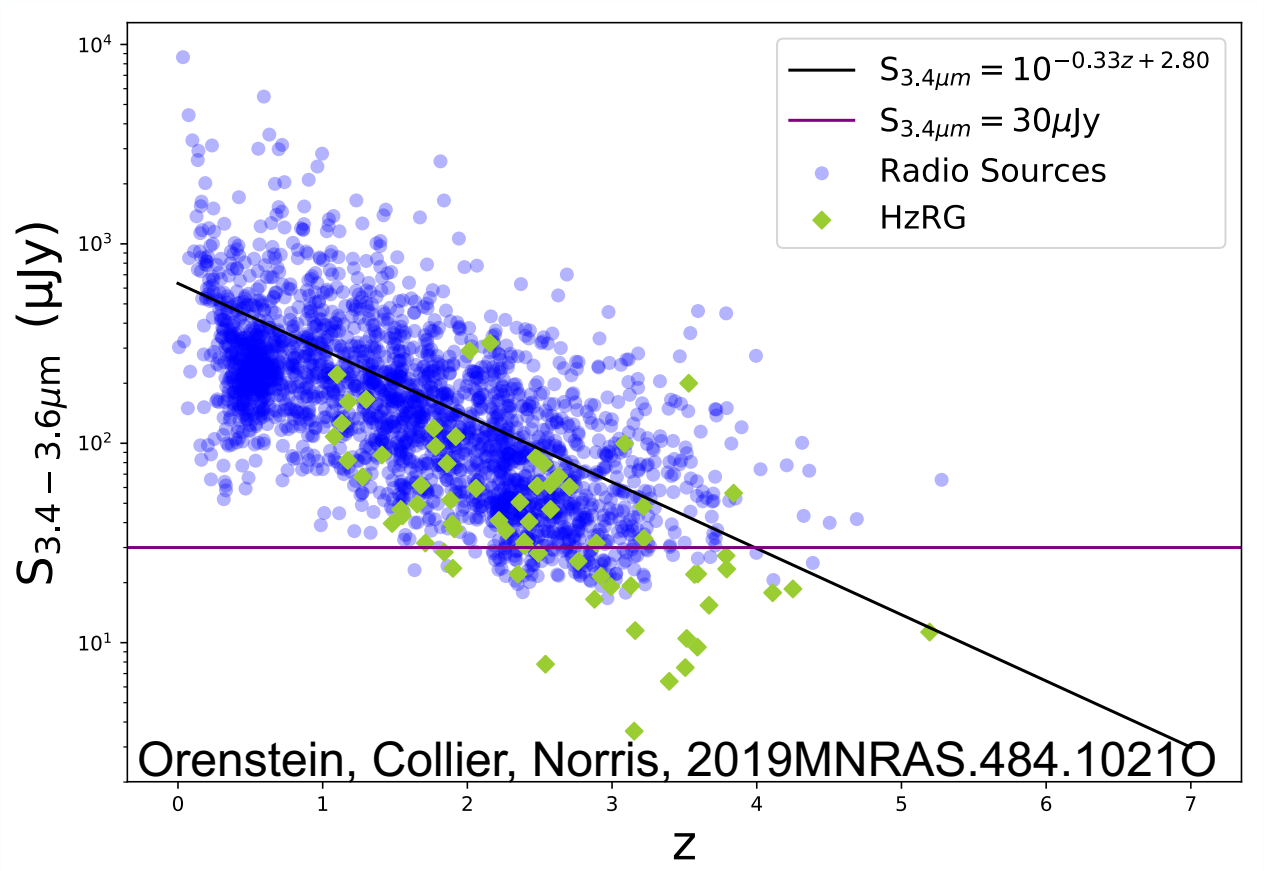
The Nature of WISE IFRSs

- Orenstein, Collier, Norris, 2019MNRAS.484.1021O
  - Apply IR-faintness criterion last, giving large parent sample of sources similar to IFRSs, giving many more redshifts

No.	Selection Criterion	Sources
0	Total Unified Radio Catalog	2,866,856
1	NVSS flux density $S_{20\,\mathrm{cm}} > 7.5$ mJy	1,139,132
2	At least one FIRST counterpart	621,316
3	AllWISE match within 5″ of FIRST	303,043
4	$S_{20\,\mathrm{cm}}/S_{3.4\,\mu\mathrm{m}} > 500$	64826
5	$S_{3.4\,\mu\mathrm{m}}$ SNR >= 5	63998
6	SDSS match within 1″ of AllWISE	46490
7	SDSS source with Spectroscopic Redshift	5761
8	Remove SDSS duplicates	2798
9	Not a star	2747
10	No zWarning flag	2566
11	Positive z Error	2551
12	Good quality observation	2521
13	$S_{3.4\,\mu\mathrm{m}} < 30\,\mu$Jy	108
14	Visual Inspection of images and spectra	108

The Nature of WISE IFRSs

- Unlikely that dust obscuration is main mechanism for IR-faintness
  - i.e. unlikely that WISE IFRSs are low-z RGs!



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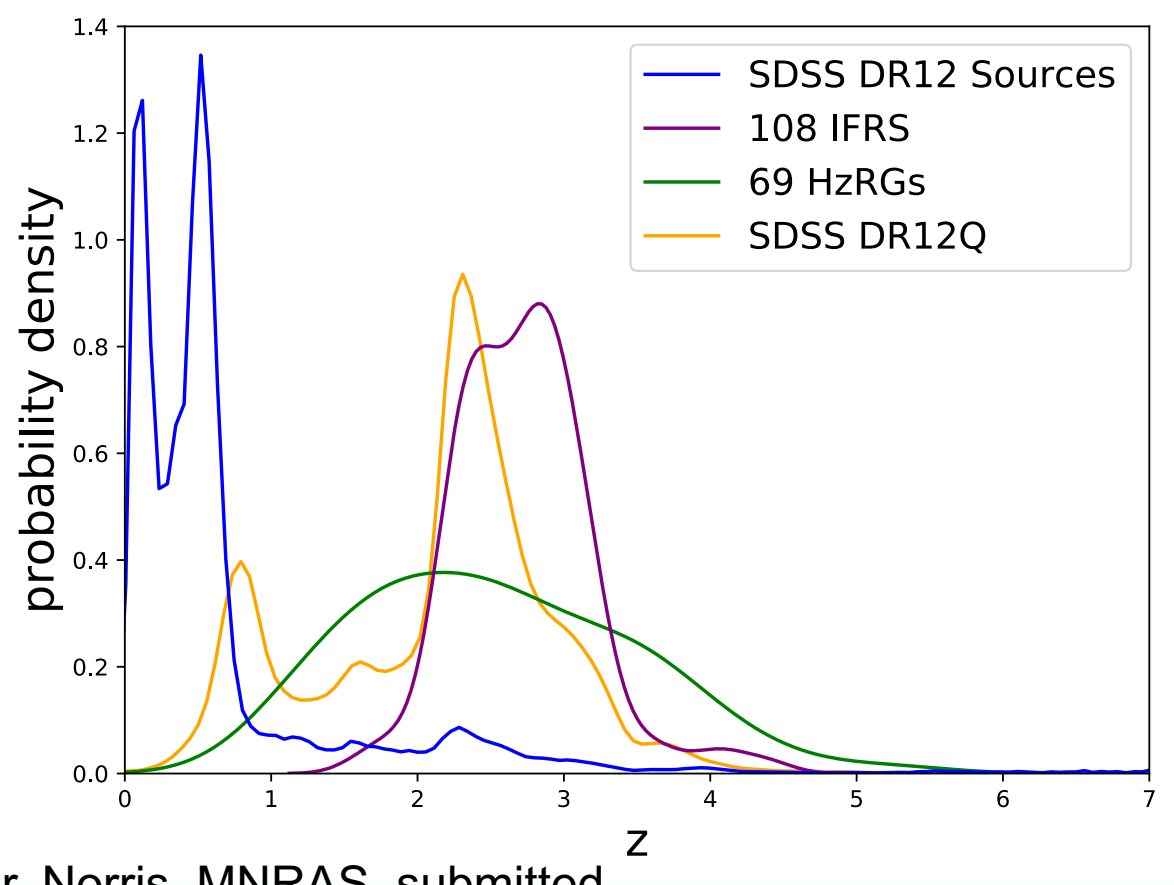
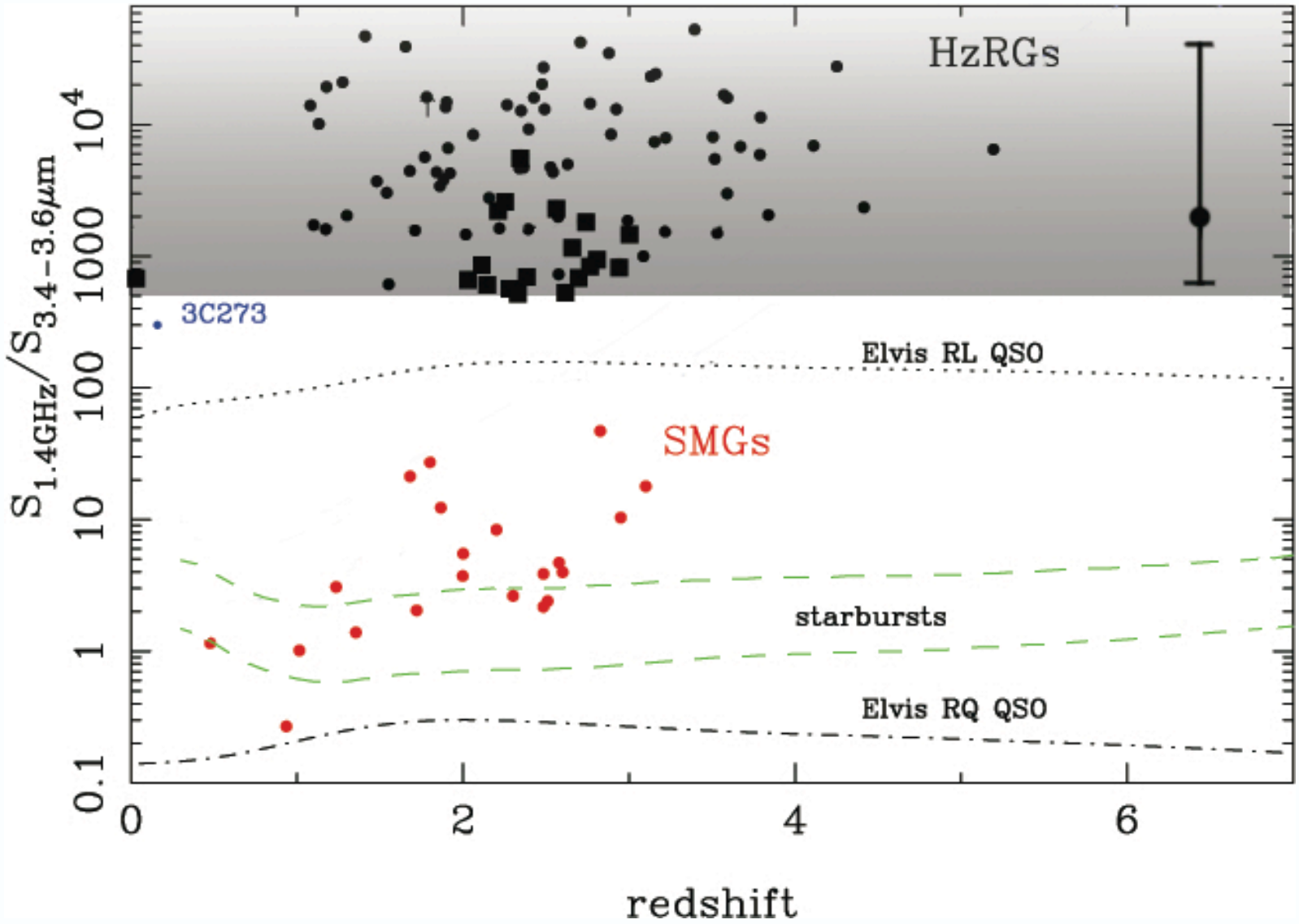


Orenstein, Collier, Norris, MNRAS, submitted

The Nature of WISE IFRSs



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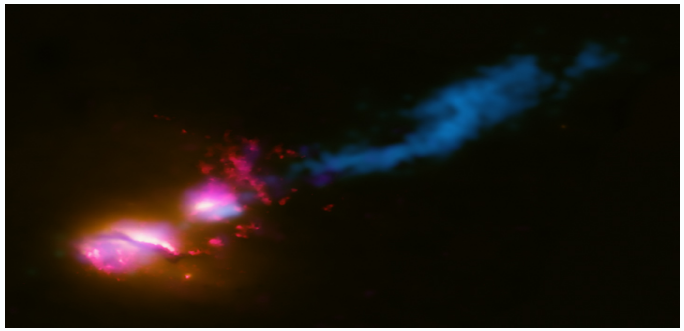
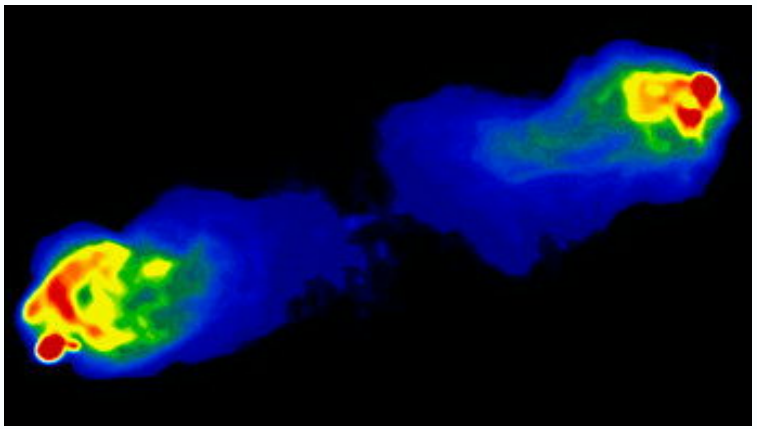
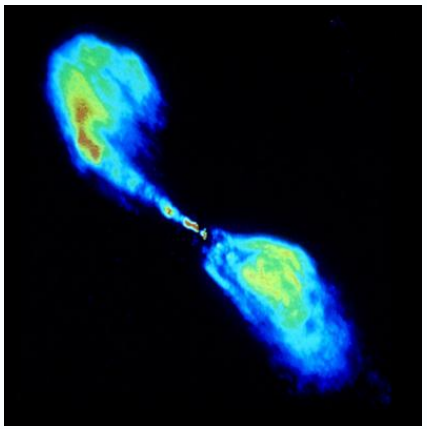




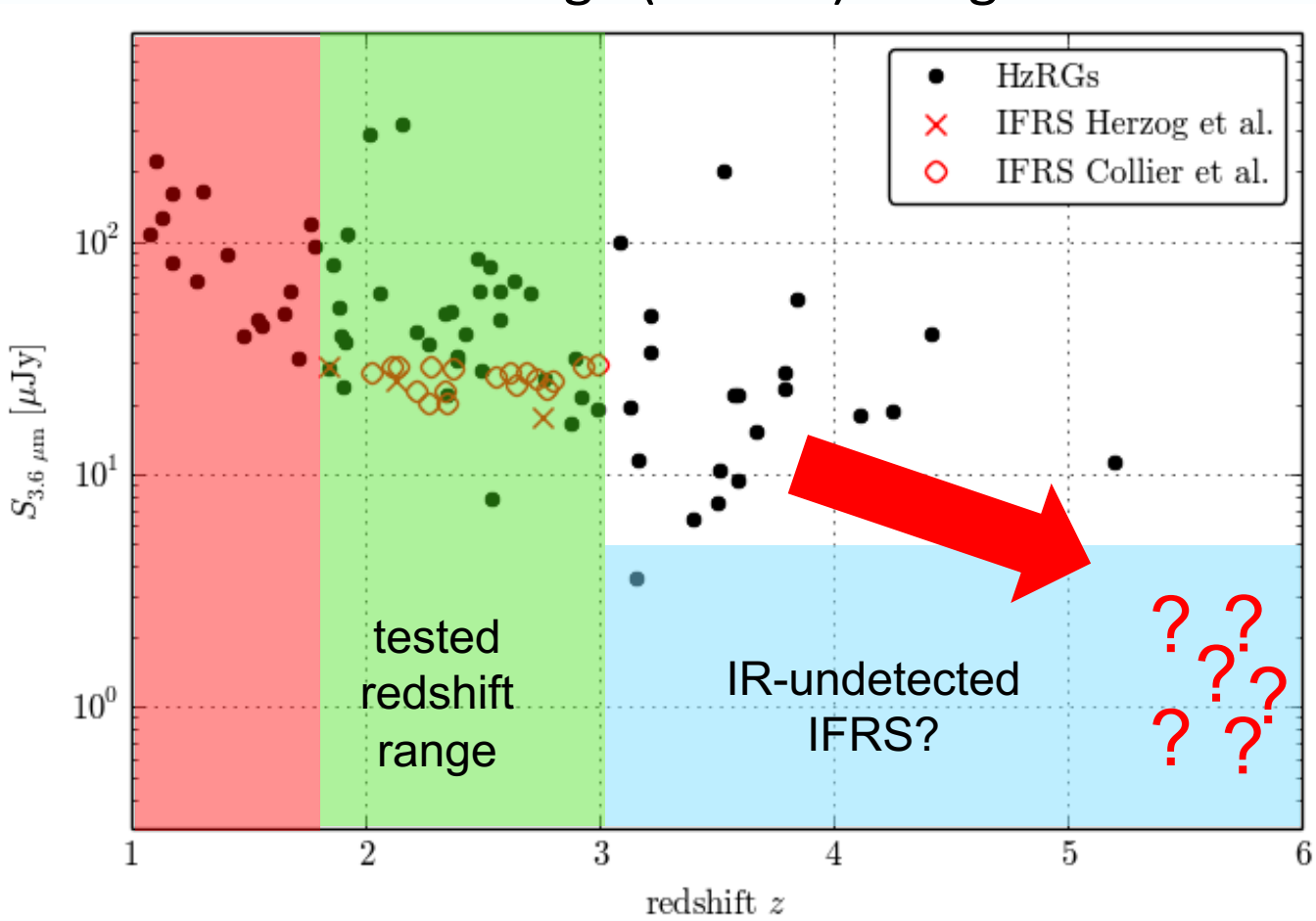


The Nature of IFRSs

- Link between IFRSs and HzRGs
  - HzRGs amongst most luminous and massive galaxies in early universe
  - High SFRs and host powerful AGN – key probes of SFG / AGN relationship
  - Significant similarity, but only about ~200 HzRGs currently known
  - IFRSs have sky density of ~7 / deg^2
  - A few hundred thousand across sub-mJy 1.4 GHz sky!
  - If expected redshift range correct, IFRSs are cosmologically significant
    - Overlooked population of high-z AGN influencing evolution of universe!
    - Number of AGN in early universe much higher!
    - Much worse problems with cosmological model for structure formation and growth of SMBHs after Big Bang!

Future Work

- #1 = measure redshift range (z ~ 7??) using CO with ALMA



EMU IFRSs

- EMU pilot data: ~270 deg^2 / ~30 uJy
- IR data
  - DECam ~1 um data: ~270 deg^2 / ~10 uJy (pilot)
  - NEOWISE 3.4 um data: ~270 deg / ~20 uJy (at best – all sky)
  - ~1,900 “no-IR” IFRSs at ~7 per deg^2 (Norris+) & hundred+ IR-detected
- IFRSs seem to span continuous population of RGs extending to high z
- EMU + NEOWISE should find a few 100 000 IFRSs across the sky
- We have an effective technique of finding HzRGs
  - Valuable in studying cosmic AGN evolution (radio properties of distant AGN)

THANK YOU

Dr Jordan Collier

ilifu Support Astronomer, IDIA
Department of Astronomy,
University of Cape Town

Adjunct Fellow, Western Sydney University
School of Computing, Engineering and Mathematics

Jordan@idia.ac.za
+27 664 343 953 (RSA Mobile)
+61 414 443 622 (AU Mobile / WhatsApp)

IDIA Inter-University Institute for Data Intensive Astronomy

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

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