RAGERS - The Radio Galaxy Environment Reference Survey

Thomas R. Greve (UCL/DAWN)  
+ the rest of the RAGERS Team
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OUTLINE

• Motivation

• RAGERS in a Nutshell

• Status & Preliminary Results

• Followup Efforts

Credit: ESO/M. Kornmesser
High-z Radio Galaxies (HzRGs) are beacons of protoclusters.

Bright SMGs become today’s massive ellipticals.

BCGs & Galaxy Clusters Today

High-z Radio Galaxies (HzRGs) beacons of protoclusters

Expectation: an increase in SMG sources around HzRGs wrt the field — especially around Cosmic Noon where the Cosmic Starformation Density peaks.

What is the SMG-HzRG Connection?

- NIR imaging
- X-ray selection
- Millimeter selection
- SZ effect
- Ly-alpha NB imaging
- Deep and large-area OIR surveys
- Large spectroscopic surveys
- Targetting environments of massive AGN and QSO

Overzier+19
High-z Radio Galaxies (HzRGs) beacons of protoclusters

Bright SMGs become today’s massive ellipticals

BCGs & Galaxy Clusters Today

High-z Radio Galaxies (HzRGs) beacons of protoclusters

What is the SMG-HzRG Connection?

Chiang+17
The Dusty Environments of HzRGs

- High central SMG overdensities (~7× the field) in the most luminous HzRGs
- Follow-up studies of these extreme systems have lead to important new insights (See works by Jin, Lee, Gullberg, Dannerbauer)

- But moderate to no overdensity on less luminous HzRGs
The Dusty Environments of HzRGs

The $z = 2.16$ Spiderweb Galaxy - a Treasure Trove
What is the AGN-Dense Environment Connection?

**CARLA Survey**
- RL-galaxies reside in IRAC-overdense environments compared to similar RQ-galaxies (1.3 < z < 3.2)
- 50% of massive galaxies undergo AGN feedback
- Launching of jet connected to dense environment

**Simulations**
- RL-galaxies sit in more massive DM halos than RQs with same stellar mass
- The impact of powerful AGN is reflected in the environment
- A higher fraction of passive galaxies around RL than RQ.

Izquierdo-Villalba+17

Hatch+14; Wylezalek+13+14
Questions That RAGERS Will Address

Radio-loud (RL) massive galaxies

- What fraction of massive radio galaxies at high redshift sit in SMG overdensities?
- How do SMG-HzRG overdensities evolve with redshift? Strength, radial extent?
- Do SMG-HzRG overdensities depend on the intrinsic properties of the central radio galaxy?

Radio-quiet (RQ) massive galaxies

- The effect of powerful AGN feedback on the growth of protoclusters
- Quenching of star formation and stellar mass buildup
- Jet-induced star formation
- The role of the IGM

- What fraction of massive radio-quiet galaxies at high redshift sit in SMG overdensities?
- How do SMG-RQ overdensities evolve with redshift? Strength, radial extent?
- Do SMG-RQ overdensities depend on the intrinsic properties of the central massive galaxy?
RAGERS in a Nutshell

A JCMT/SCUBA-2 Large Program to Map the Mpc-Scale Environments and SMG Overdensities Around 33 Radio-Loud and 33 Radio-Quiet Massive Galaxies at $1 < z < 3.5$

- Allocated 168hrs of SCUBA-2 time in Band 1 and 2
- Daisy Maps (~5’ FOV) down to r.m.s. ~0.7mJy
- Probe r~3Mpc (co-moving) regions
- Can expect >10 SMGs detected at SNR > 3.5 in each map
RAGERS in a Nutshell

A JCMT/SCUBA-2 Large Program to Map the Mpc-Scale Environments and SMG Overdensities Around 33 Radio-Loud and 33 Radio-Quiet Massive Galaxies at 1 < z < 3.5

- RL sample selected from the Herschel Radio Galaxy Evolution Project (Seymour+07+12; de Breuck+10)
- RQ sample selected from DR11 12-band matched catalogue from UKIDSS UDS Survey
- log($M_\star$) = 10.7-11.5 (RL and RQ samples matched)
- At least 4 sources in each z-bin
RAGERS in a Nutshell

A JCMT/SCUBA-2 Large Program to Map the Mpc-Scale Environments and SMG Overdensities Around 33 Radio-Loud and 33 Radio-Quiet Massive Galaxies at $1 < z < 3.5$

- 56 astronomers from primarily EAO countries, UK, and CA

- Regional coordinators:
  - Thomas Greve, UCL, UK
  - Chian-Chou Chen, ASIAA, Taiwan
  - Zhiyu Zhang, Nanjing University, China
  - Tadayuki Kodama, Tohoku University, Japan
  - Hyunjin Shim, Kyungpook National University, Korea
  - Scott Chapman, Dalhousie University, Canada
  - Wiphu Rujopakarn, Chulalongkorn University, Thailand

https://www.eaobservatory.org/jcmt/science/large-programs/ragers/
• Survey is 56% complete
• 14 fields completed.
• DR Pipeline
• Deboosting and completeness correction
Example Fields
Current Status

- Most of our fields are mildly overense (2-4x) at the bright end
ARCHIVE-RAGERS
Sample Selection

- Mining the SCUBA-2 archive
- 14 HzRGs at $1.5 < z < 4.5$ targeted with SCUBA-2
- Pong900 maps of 14 HzRGs (FOV 12'). Rms noise 2mJy/beam
- Selected from the Herschel Radio Galaxy Evolution Project (PI: Seymour). Spitzer coverage (De Breuck) + LABOCA or AzTEC (in some cases)

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• Weak trend of decreasing total SMG overdensities with redshift - but consistent with no evolution

• Tentative trend of evolution with redshift of the SMG overdensity profile

• Qualitatively consistent with Rigby+14 results

• Is such a trend expected?
• No correlation between SMG overdensity and RG radio power

• Weak trend with radio power
  (Rigby+14; Galametz+12)

• No correlation between SMG overdensity and RG stellar mass

cf. Miley & De Breuck+08; Falder+10
Radio Followup: VLA-RAGERS

- Completed 94hr VLA program for S-band followup of RAGERS targets (VLA/20B-375)
- Lead by PhD student **Yuanqi Liu, PKU**
- All RAGERS Fields observed and imaged at 3GHz
Radio Followup: VLA-RAGERS

- Completed 94hr VLA program for S-band followup of RAGERS targets (VLA/20B-375)

- Lead by PhD student Yuanqi Liu, PKU

- All RAGERS Fields observed and imaged at 3GHz

- Targeted rms 2.9uJy, actual rms ~10uJy due to dynamical range issues from central RG

- Source extraction using Pybdsf
Radio Followup: WNJ1123+3141 (z=3.22)

- Jet-induced star-formation?
- Radio galaxy - ICM connection?
- Mapping of spectral index of radio lobes

Liu in prep.
Radio Followup: 4C23.56 (z=2.48)

- Completed 10hr GBT MUSTANG-2 3mm program mapping 4C23.56 (GBT-21A-299)
- Lead by PhD student Dazhi Zhou, DAWN
- Targeted rms ~16uJy
Radio Followup: 4C23.56 (z=2.48)

- Completed 30hr VLA Ka-band program for blind CO survey of 4C23.56 (VLA-21A-294)
- Lead by PhD student Dazhi Zhou, DAWN
- No CO lines detected
• We still do not have an adequate census of the submm environments of HzRGs

• Upon completion RAGERS will be the largest submm survey to date of the dusty Mpc-Scale environments around HzRGs

• RAGERS will provided a much needed comparison with radio-quiet galaxies

• Address evolutionary trends in SMG overdensities with redshift, stellar mass, and radio power. Trends that are only weakly constrained with current data.

• Coupled with simulations this will lead to a better understanding of proto-cluster growth in the presence/absence of powerful AGN and the interplay between AGN feedback, stellar mass and the IGM

https://www.eaobservatory.org/jcmt/science/large-programs/ragers/