Environments of High-Redshift AGN

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Some Motivation

⇒ Galaxy overdensities (protoclusters) provide a valuable method of linking galaxies from one epoch to another

⇒ Empirical relations such as that between color and magnitude (red sequence) and morphology and density provide excellent baselines for quantifying galaxy evolution

⇒ Environmental effects on galaxy evolution/formation can be studied in rare high density regions which may not appear in general blank field surveys

Talk Summary

- ⇒ Finding (z > 2) Protoclusters
  - ⇒ **Miley et al. VLT Large Program (Kurk, Pentericci, Venemans, Overzier)**
    - ⇒ **Spectroscopically confirmed (Lyα and Hα emitters)**
  - ⇒ ACS imaging of z~6 SDSS Quasar fields (Zheng, Stiavelli)
    - ⇒ Lyman-break selection
  - ⇒ Large Spectroscopic Surveys (Steidel et al.)
    - ⇒ Serendipitous redshift "spikes"
    - ⇒ Redshifts for both field and protocluster
  - ⇒ **24μm *Spitzer*/MIPS imaging, surface overdensities of star-forming galaxies**
    - ⇒ **Example of 4C23.56 at z=2.48**
- ⇒ Studying Protocluster Galaxies
  - ⇒ Multi-wavelength to build SED of protocluster gals.
  - ⇒ NIR spectroscopy for the brightest objects (K <~ 19.5)
    - ⇒ Requires imaging of large fields
  - ⇒ **NIR imaging follow-up, evolution of the red-sequence**
    - ⇒ **Example of MRC1138-262 at z=2.16**

The Mpc-Scale Environment of $1 < z < 4$ Radio Galaxies

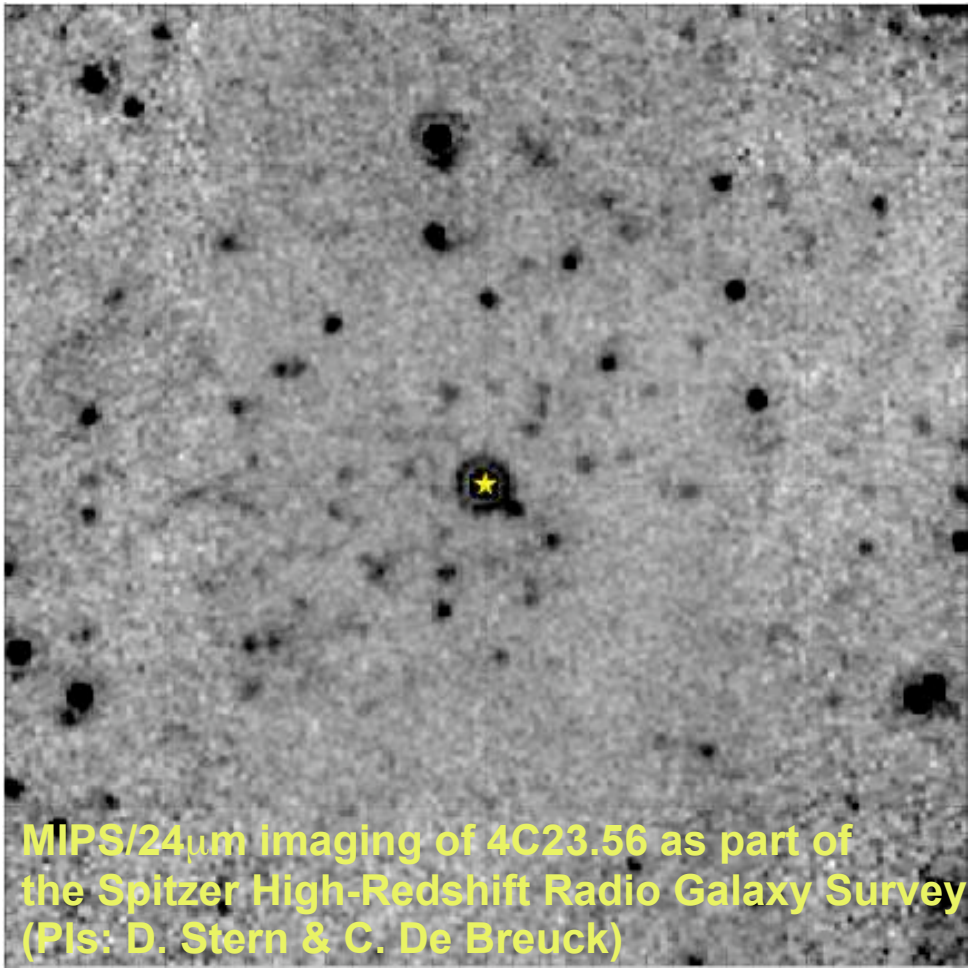
- ⇒ Diversity of companion galaxies detectable at these redshifts
  - ⇒ Star-forming (both continuum and line-selected)
  - ⇒ AGN
  - ⇒ Quiescent, near-infrared selected galaxies
- ⇒ Spans the epoch of virialization from protoclusters to X-ray luminous clusters
- ⇒ A redshift gap ($1.5 < z < 2.0$) still exists for observed (proto) clusters (but some on-going efforts, Galametz's talk this conference)
- ⇒ Imaging surveys of a few Mpc surrounding the RG
  - ⇒ Therefore, not a complete survey of galaxies which will end up in the cluster (cf. Roderik's talk)
  - ⇒ More complete for z~1 clusters where spectroscopy is much more efficient ("outskirts" surveys)
  - ⇒ Follow-up spectroscopy of line-emitting candidates at $z > 2$ and of quiescent (early-type galaxies) at z~1

Finding Protoclusters

- ⇒ Identify rare, highly-luminous AGN
  - ⇒ Precise emission-line redshifts
  - ⇒ Host galaxy properties (K-z)
- ⇒ Color-select candidate companion galaxies
  - ⇒ Include narrow-band(s) for prominent emission lines
  - ⇒ Use broad-band colors, Lyman-break Galaxies ($z >\sim 2.5$)
  - ⇒ Near-infrared imaging used to select 4000A/Balmer break objects
- ⇒ X-ray imaging to identify AGN
- ⇒ *Spitzer*/MIPS 24μm imaging of dusty star-forming galaxies (and hot dust from AGN) at $2 < z < 3$

24μm selection of protoclusters?

⇒ Example of 4C23.56 at z=2.48



⇒ Protocluster candidate from Knopp&Chambers 1997

⇒Factor ~2 surface overdensity

⇒ At this redshift, 24μm band is sensitive to PAH emission in star-forming galaxies

⇒ flux distribution of companion candidates peaked around 100 -200 μJy which corresponds to SFR~100-200 $M_{\odot}$ yr^{-1}, so not crazy

⇒Too faint for IRS spectroscopy

⇒ IRAC "bump" sources, 1.6μm peak of stellar emission in IRAC 5.8μm band at z~2.5, will need deeper ch. 3 and 4 IRAC data (some soon to be public)

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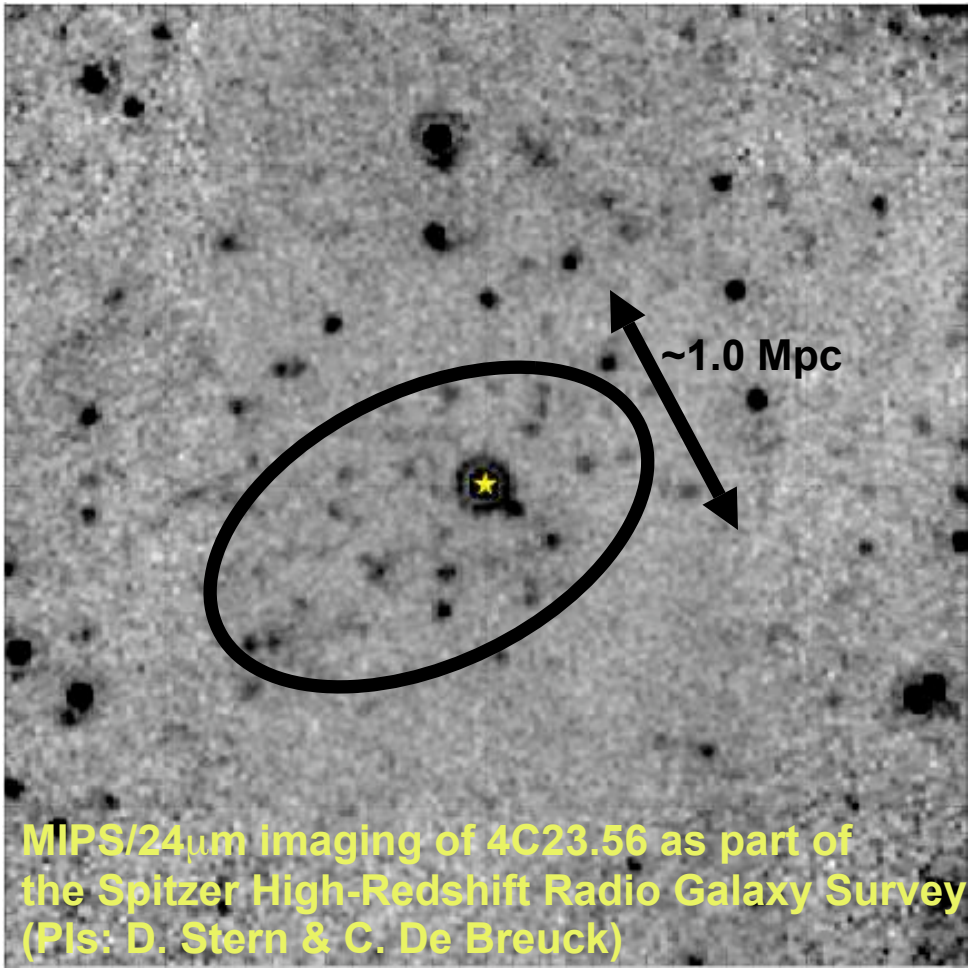

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Studying Protocluster Galaxies

⇒ Spectroscopy of line-emitting candidates

  ⇒ NIR for very brightest quiescent candidates

⇒ Deeper imaging to enable color-selection of lower luminosity sources (LBGs)

⇒ Multi-wavelength studies to constrain AGN fraction

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Deep near-infrared imaging

to select quiescent (red sequence?) galaxies

Red Galaxies in the Protocluster Surrounding MRC1138-262 (z=2.16)

⇒ One of the Miley et al. protoclusters containing spectroscopically-confirmed Lyα and Hα emitters (Kurk et al. 2000, 2004a,b)

⇒ Surface-overdensity of EROs known from the ground (Kurk et al. 2004a,b)

⇒ Targeted 7 NICMOS Camera 3 pointings follow-up in J_{110} and H_{160} filters

⇒ Span the 4000A/Balmer break at z=2.16

⇒ Also, g and I band imaging with ACS and several optical and NIR ground-based datasets. (ACS+)NICMOS give accurate colors at wavelengths comparable to ACS studies of z~1 clusters. In particular, we compare to RDCS 1252.9-2927 at z=1.24 (Blakeslee et al. 2003)

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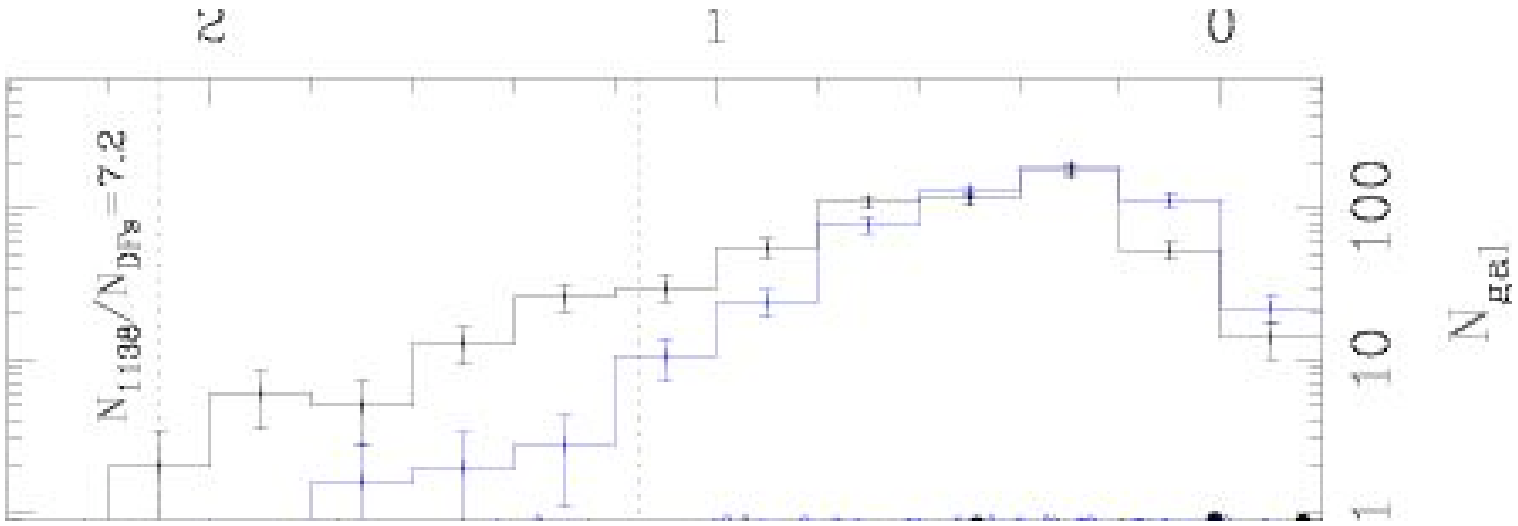
Factor of ~7x overdense compared to deep (blank) field data

Color-Magnitude Diagram for MRC1138-262 NICMOS Fields

$(J_{110}\text{-}H_{160})_{AB}$



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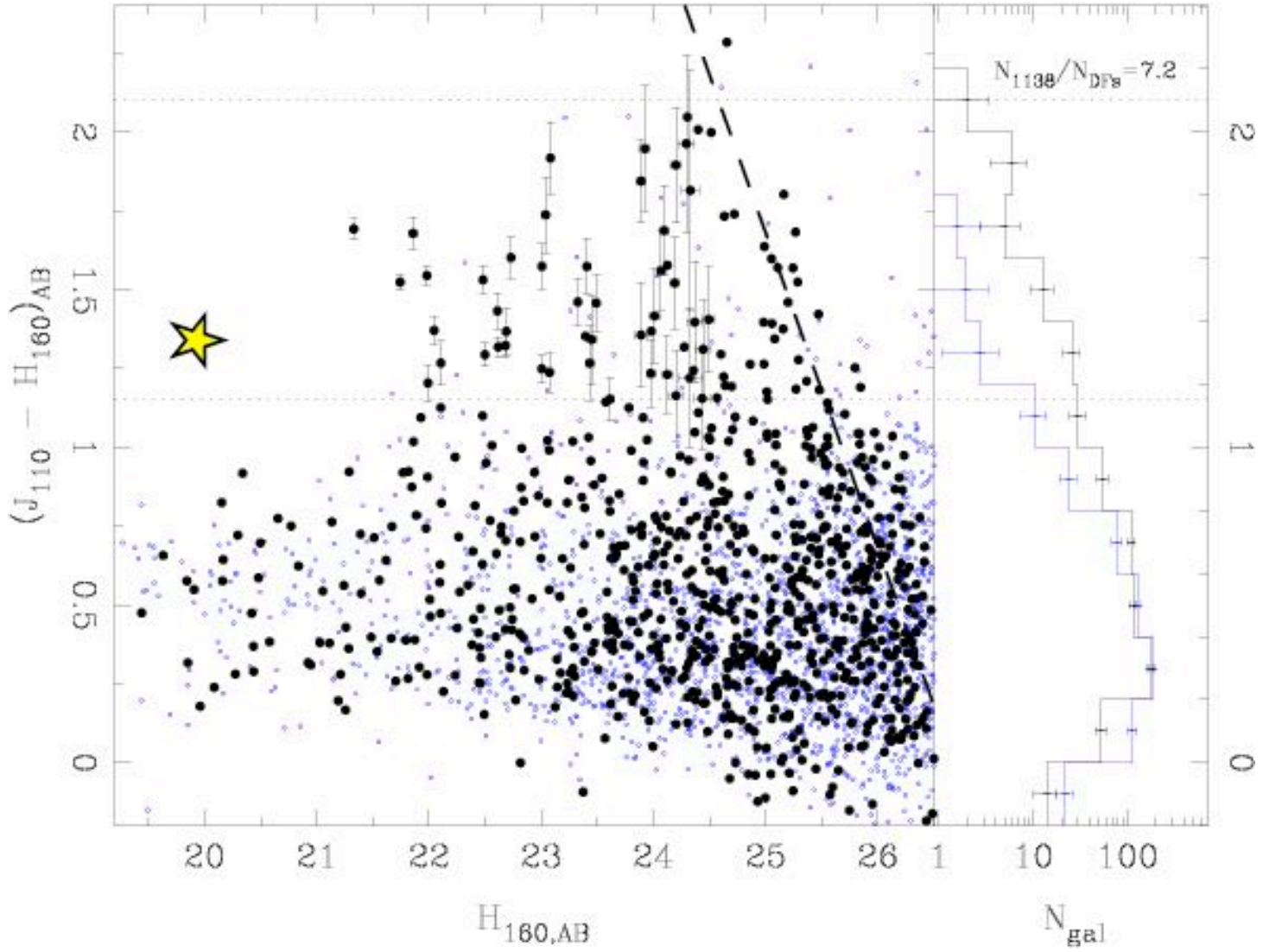

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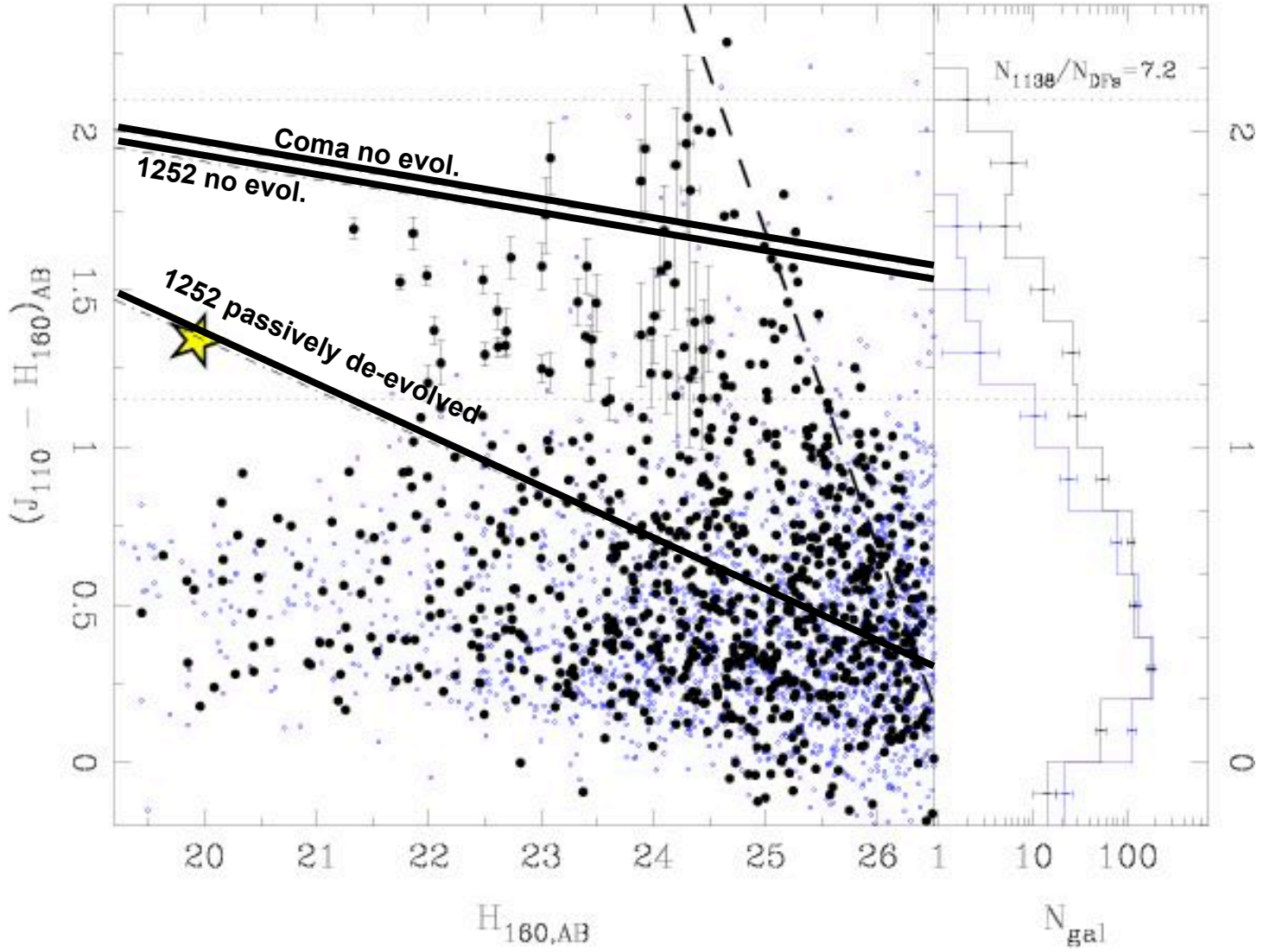
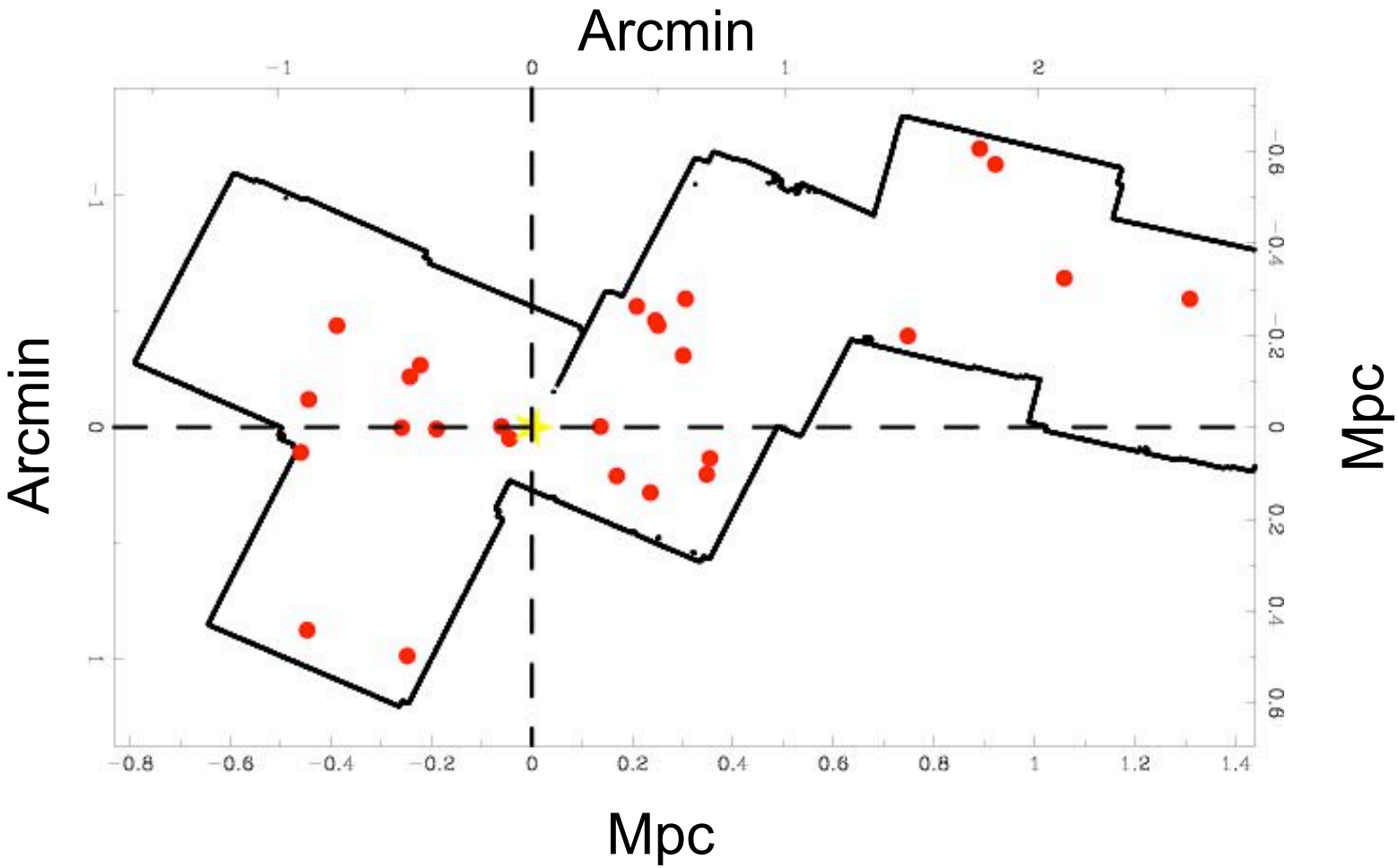


Spatial Distribution of Red Galaxies



Summary

⇒ Protoclusters exist around high-z radio galaxies and contain a variety of galaxy types, from vigorously star-forming to relatively quiescent

⇒ The “red sequence” does not exist in its low-scatter form in the case of MRC 1138

⇒ Relatively shallow MIPS/24μm imaging may provide an efficient means to detect new protoclusters

Future

⇒ Fit SEDs of 1138 galaxies to determine ages/masses (best current estimate 1.5-2.5 Gyr, few x 10^{10} $M_{\odot}$ for the red gals.)

⇒ Deeper. larger field red sequence studies for more proclusters with HST/WF3

⇒ MIPS-selected protoclusters, if confirmed, will provide ideal high-z target fields from ALMA