# A statistical investigation of the MIGHTEE-HI content in quiescent galaxies at 0.2<z<0.5

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*with*

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The Fourth National Workshop on the SKA Project

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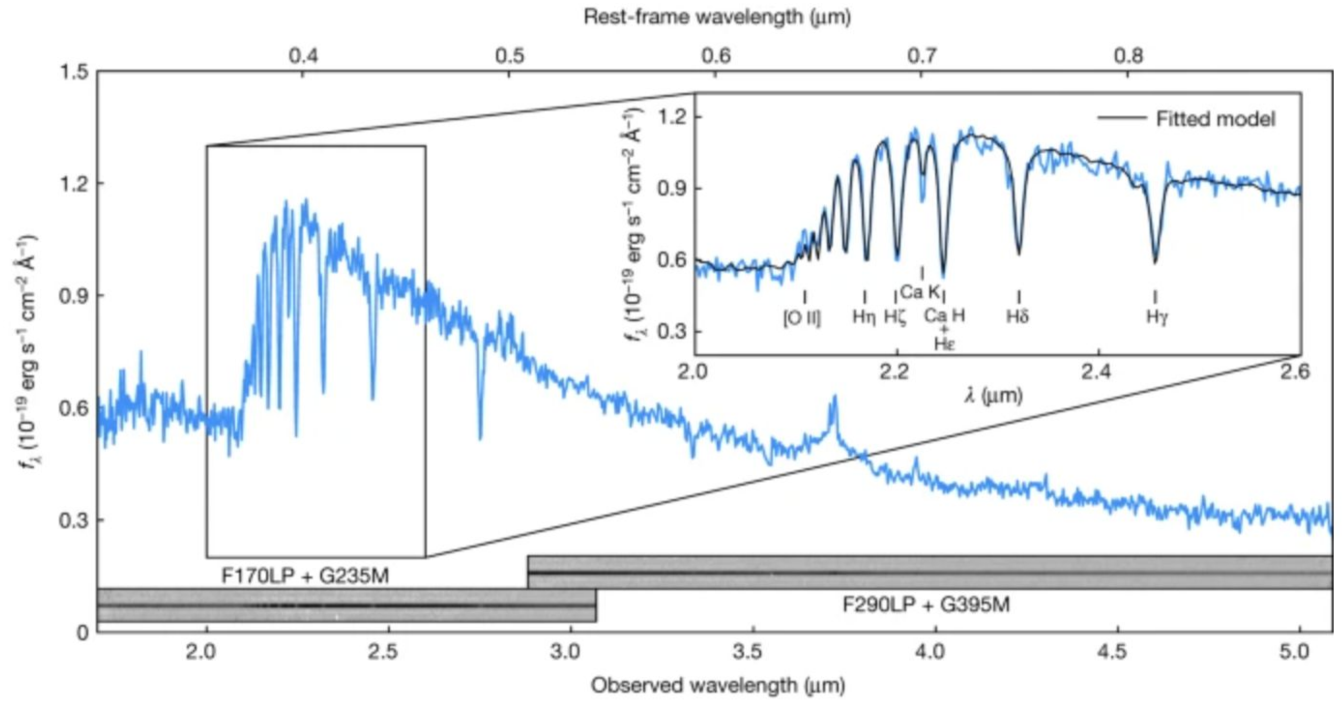
# A *z~5* rest-frame optical spectrum of a passive and quenched galaxy from JWST

**Fig. 1: JWST NIRSpec observations of GS-9209.**




*A. Carnall et al. (Nature, 2023)*

# HI content in early type galaxies in the local Universe

*a long history since the '60s*

The **ATLAS-3D** (*Cappellari+2011*) **HI survey** (*Serra+10*) still provides a reference volume-limited, complete sample of 166 nearby early-type galaxies (ETGs, but see also Morganti+06, Serego Alighieri+07, Oosterloo+10 among many others)

Main finding 1 - **strong dependence with environment**

H I detected in ~ 40% of all ETGs outside the Virgo galaxy cluster
H I detected in ~ 10% of all ETGs inside it.

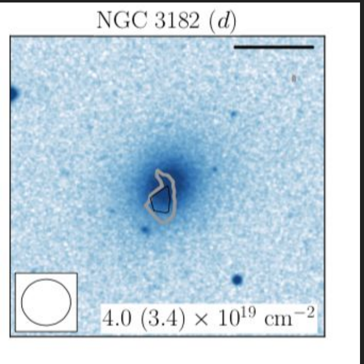
⇒ high probability for non-cluster ETGs to host H I at z~0.

Main finding 2 - **compared to spirals, ETGs host much less H I as a family. However, a significant fraction of all ETGs are as H I-rich as spiral galaxies.**

# HI morphology in local ETG from ATLAS-3D: a large variety!

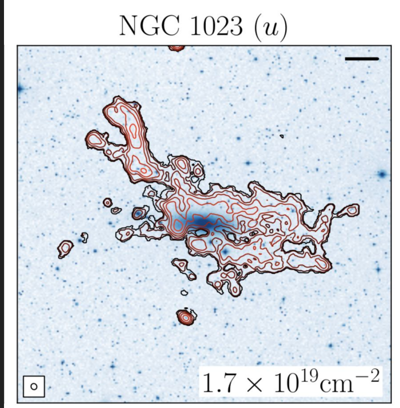
**SETTLED CONFIGURATIONS**

**UNSETTLED CONFIGURATIONS**

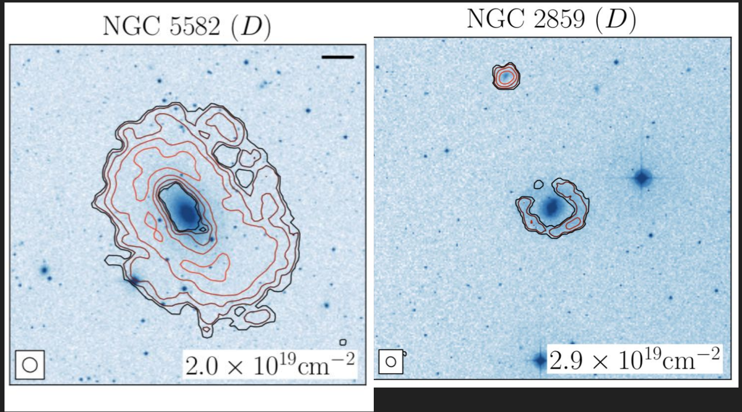



**small discs**: M(H I)< 10^8 M⊙, which are confined within the stellar body and share the same kinematics of the stars

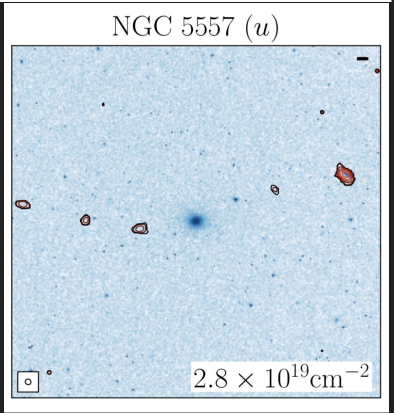
**unsettled gas distributions** (including tidal- or accretion tails)




**large discs/rings**: M(H I) up to 5 × 10^9 M⊙, which extend to tens of kpc from the host galaxy and are in half of the cases kinematically decoupled from the stars




**gas clouds scattered around the galaxy**



# ATLAS-3D ⇒ a biased targeted sample?
# Moving to a statistical sample of SF and ETG galaxies
# DINGO stacking experiment at z~0 based on a colour selection *(Rhee+22)*

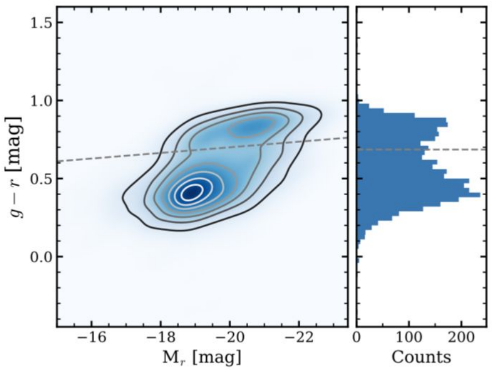
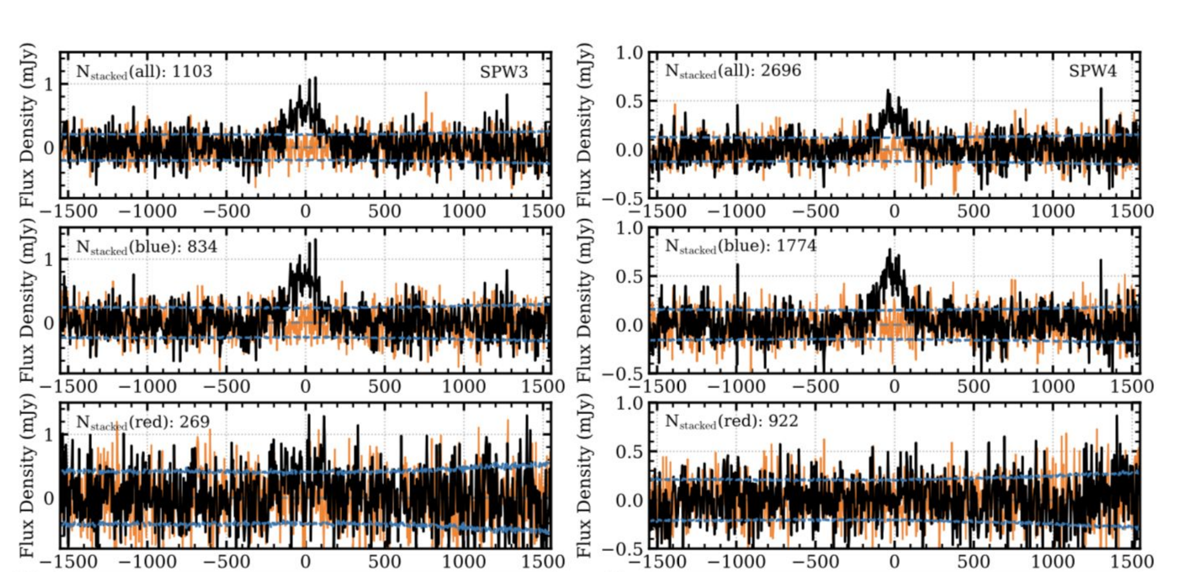



**Figure 12.** The colour-magnitude diagram (CMD) contour of galaxies in SPW3 and SPW4. The dashed line denotes the colour cut to distinguish between blue and red galaxies. The right panel shows the histogram of $g - r$ colour, indicating the bi-modality of the sample.

*Rhee+22*

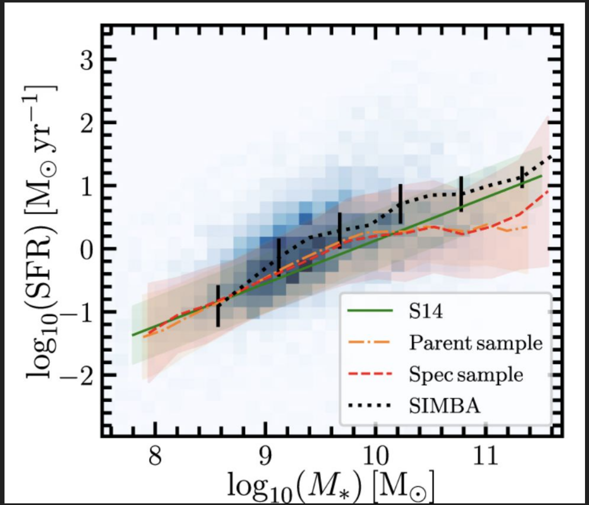



No detection of HI in red sources, independently of environment

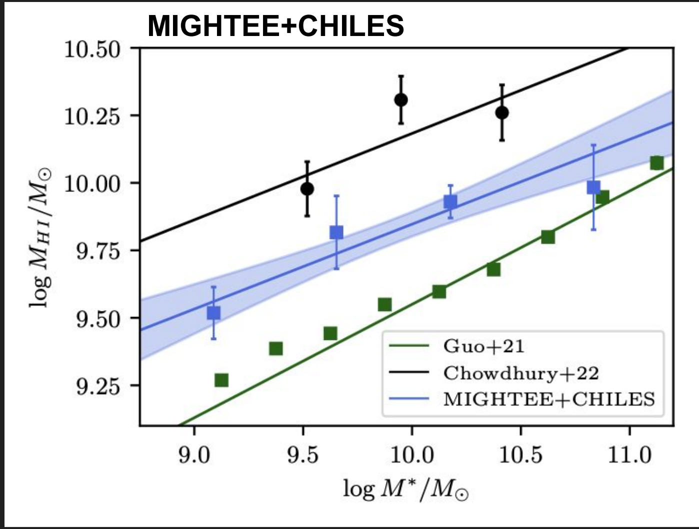
Real, physical? Or mix of selections, including low mass systems, that dilute the signal

# Looking beyond the local Universe with MIGHTEE

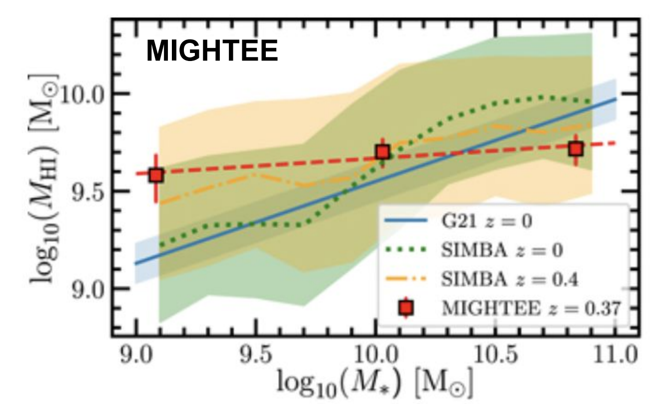
Scaling relations for star-forming galaxies at 0.2<z<0.5 (selected as blue and/or main sequence sources), still debated in the literature




*Sinigaglia+22*



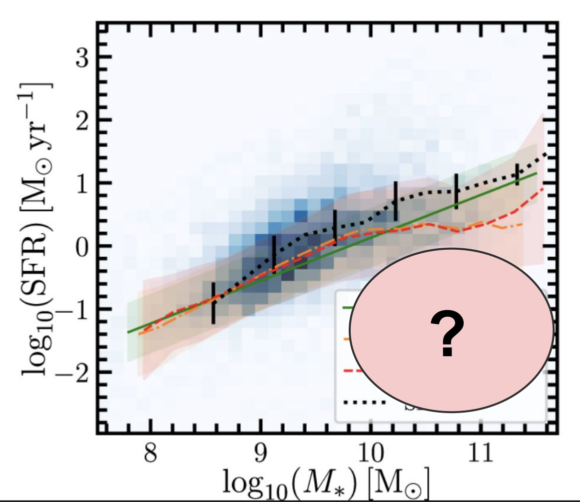

*Bianchetti+24 (in prep)*



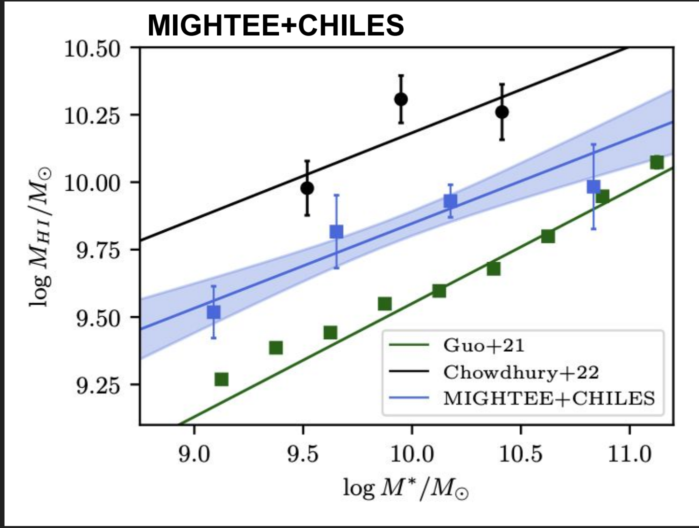

*Sinigaglia+22*

# Looking beyond the local Universe with MIGHTEE

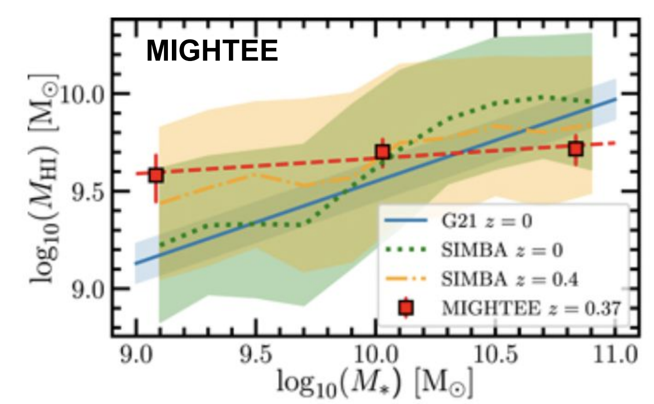
What about red/quenched sources at the same cosmic epoch??
Similar trends as at z=0?




*Sinigaglia+22*




*Bianchetti+23 (in prep)*




*Sinigaglia+22*

# Sample selection

- **hCOSMOS** spectroscopic survey *(Damjanov+18)*
- targets: UltraVISTA galaxies with $17.8 < r < 21.3$
- Hectospec: a 300-fiber optical spectrograph with an ~ 1 deg2 field of view (FoV) and a fiber diameter of 1.5″. In total, hCOSMOS survey observed ~ 1.5 deg2.
- The hCOSMOS catalogue includes 4362 galaxies with a science quality spectra. The galaxies are identified across the redshift range of $0.01 < z < 0.7$.
- Large benefit of the rich multiwavelength ancillary photometry in COSMOS (UV-to-mm)

# Selection of Quiescent Galaxies

**on the basis of the spectral indicator Dn4000:** Dn4000 measures the strength of the 4000 Å break produced by a large number of absorption lines where ionised metals are the main contributors to the opacity. Because the strength of the 4000 Å break increases with the population age, it is always used as an indicator of a quiescence. Insensitive to reddening!

***Dn4000 > 1.5*** (1737 sources in total, Donevski+23).

"dusty QGs" : by imposing source detections in the IR with S/N ≥ 3 in at least four photometric bands in the mid-IR-to-FIR range (8 μm < λ <500 μm).

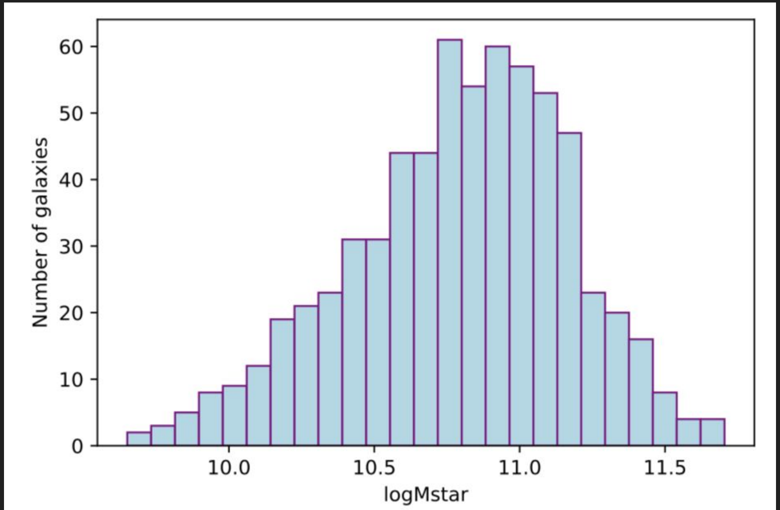
**detectable dust in 618 out of 1737 Quiescent Galaxies (35% of total)** at

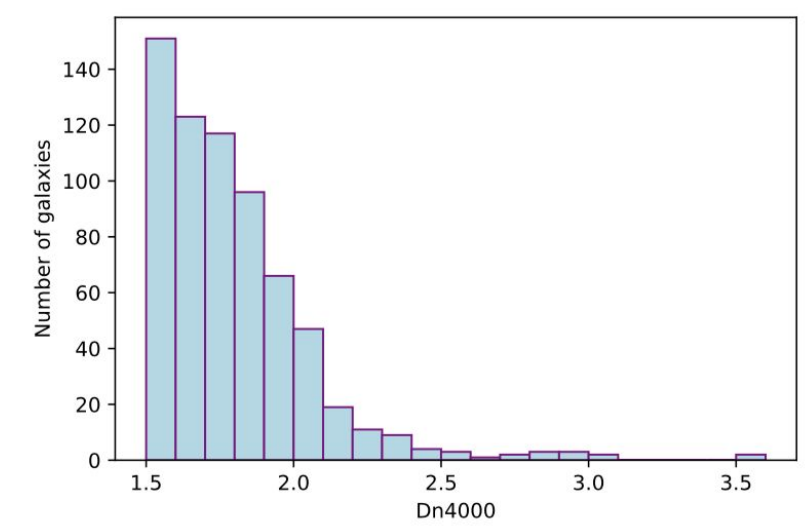
$0.1 < z < 0.6$

**our final total sample ~440 galaxies at 0.23<z<0.49 after RFI masking**

⇒ includes a mix of morphologically elliptical galaxies (¾) and red spiral (¼)

# physical properties of the overall QGs sample:



# Overall HI stack in dusty vs non-dusty QGs

*Rodighiero+ (in prep)*

***log(HI/Msun)=10.2+/-0.05***

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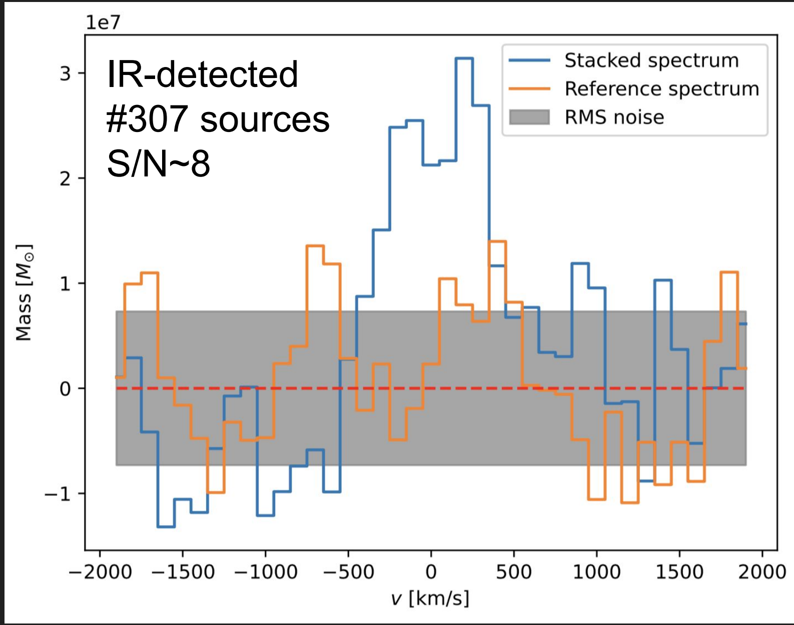
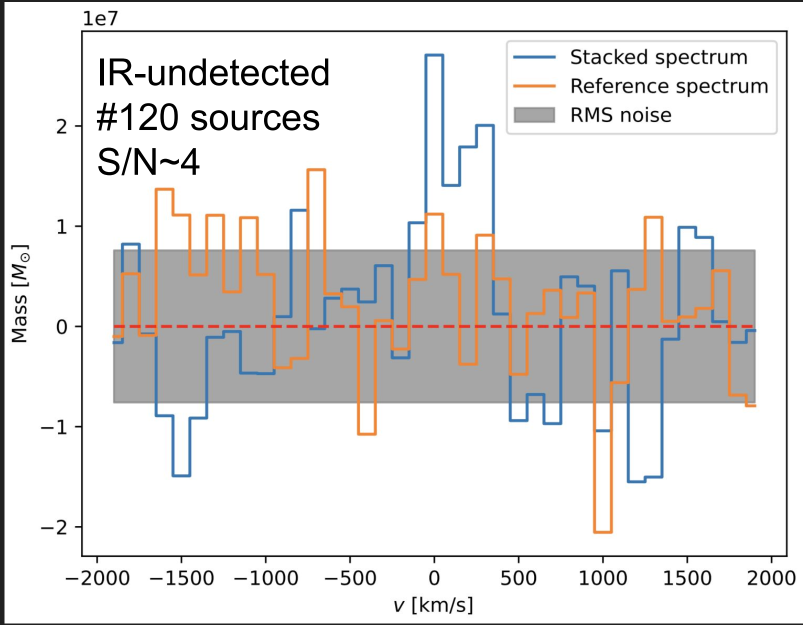
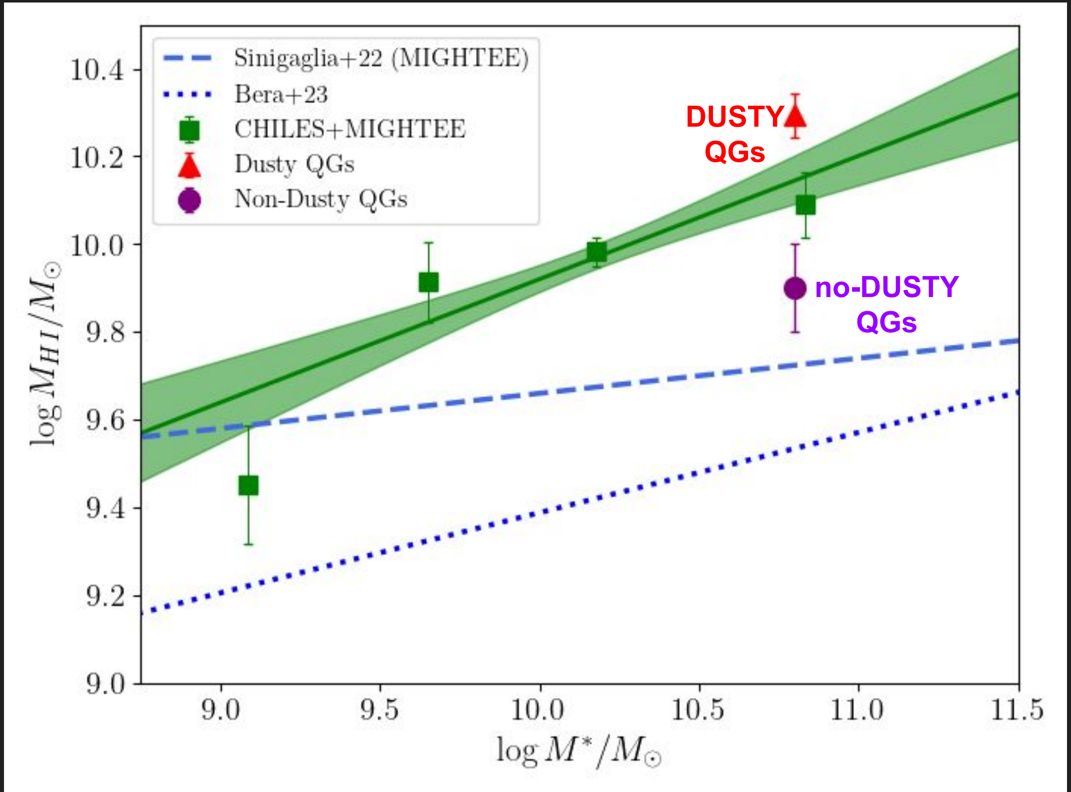



***log(HI/Msun)=9.9+/-0.1***



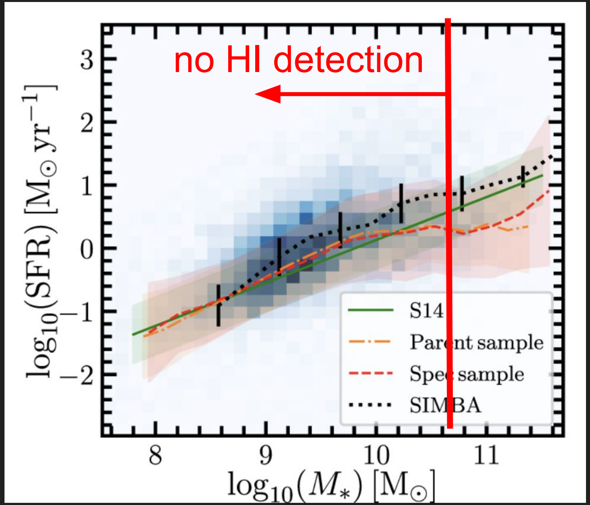
# Comparison to star-forming scaling relations at $z\sim0.37$




*adapted from A. Bianchetti+ (in prep)*

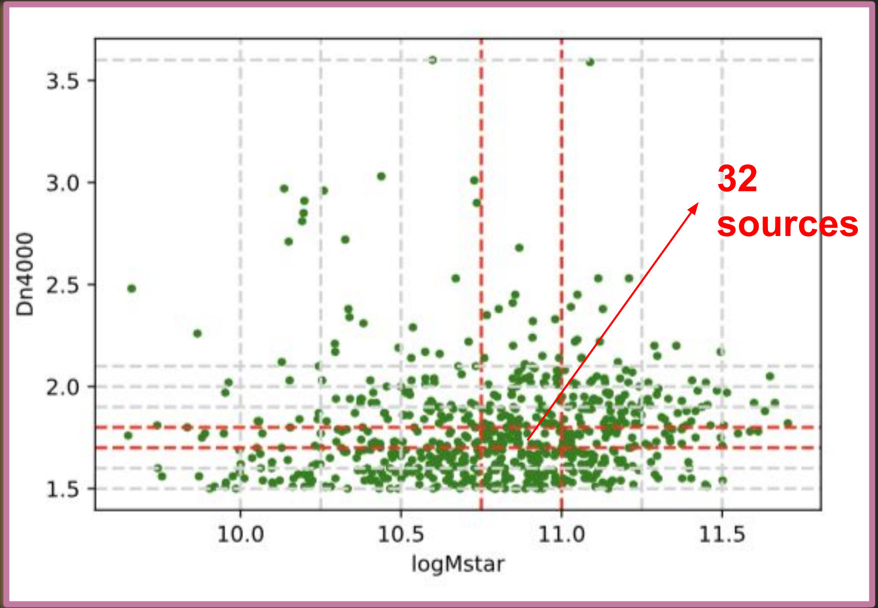
1. **Dusty QGs are HI gas richer (x2.5) than non-dusty QGs**
2. **Dusty QGs have an HI gas content in excess with respect to main sequence galaxies at fixed stellar mass**
3. **a colour selection for passive sources (from COSMOS2020) returns an HI mass consistent with that of no-dusty QGs**

# Stacks as a function of M* and Dn4000




**as a function of stellar mass (M*):**

A strong limit for HI detection from the MIGHTEE sensitivity is observed for ***log(M*/Msun)>10.6***




**as a function of Dn4000:**

S/N increases with increasing Dn4000

*Dn4000<1.8 S/N~4*

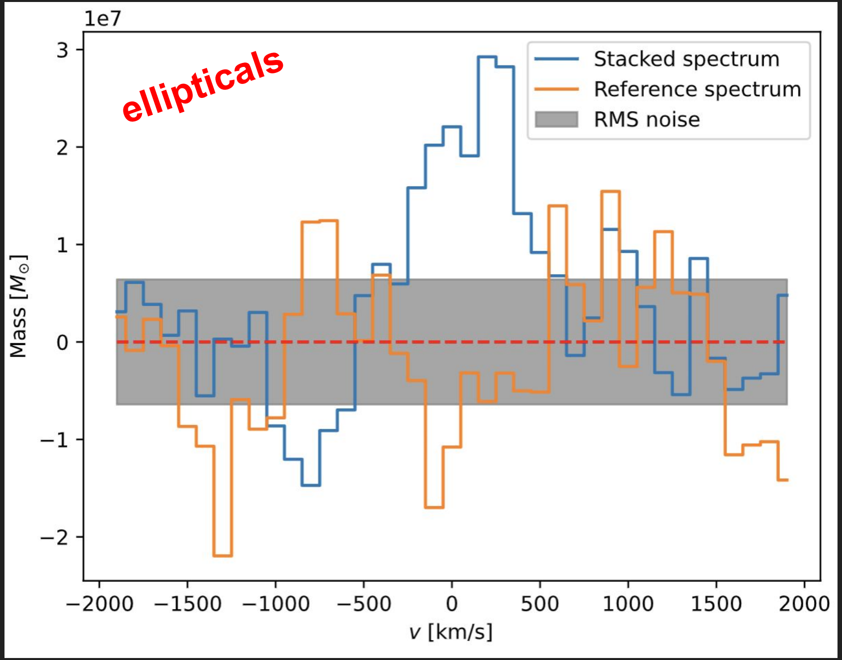
*Dn4000>1.8 S/N~7* (with similar number statistics)

Looking for eventual **morphology dependence**:

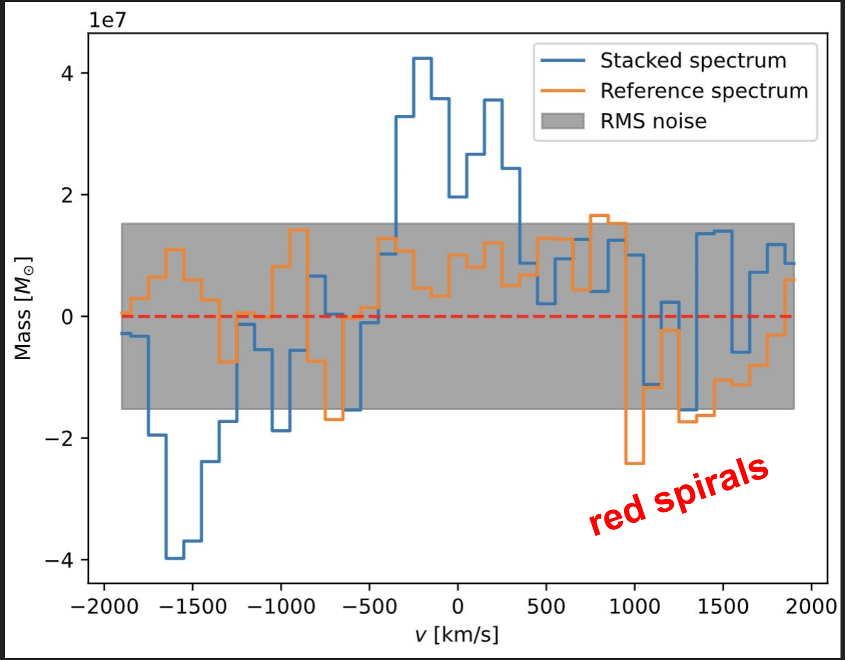
⇒ pure dusty spheroids have HI masses consistent with the global dusty QGs population

⇒ red dusty spiral seems even more extreme

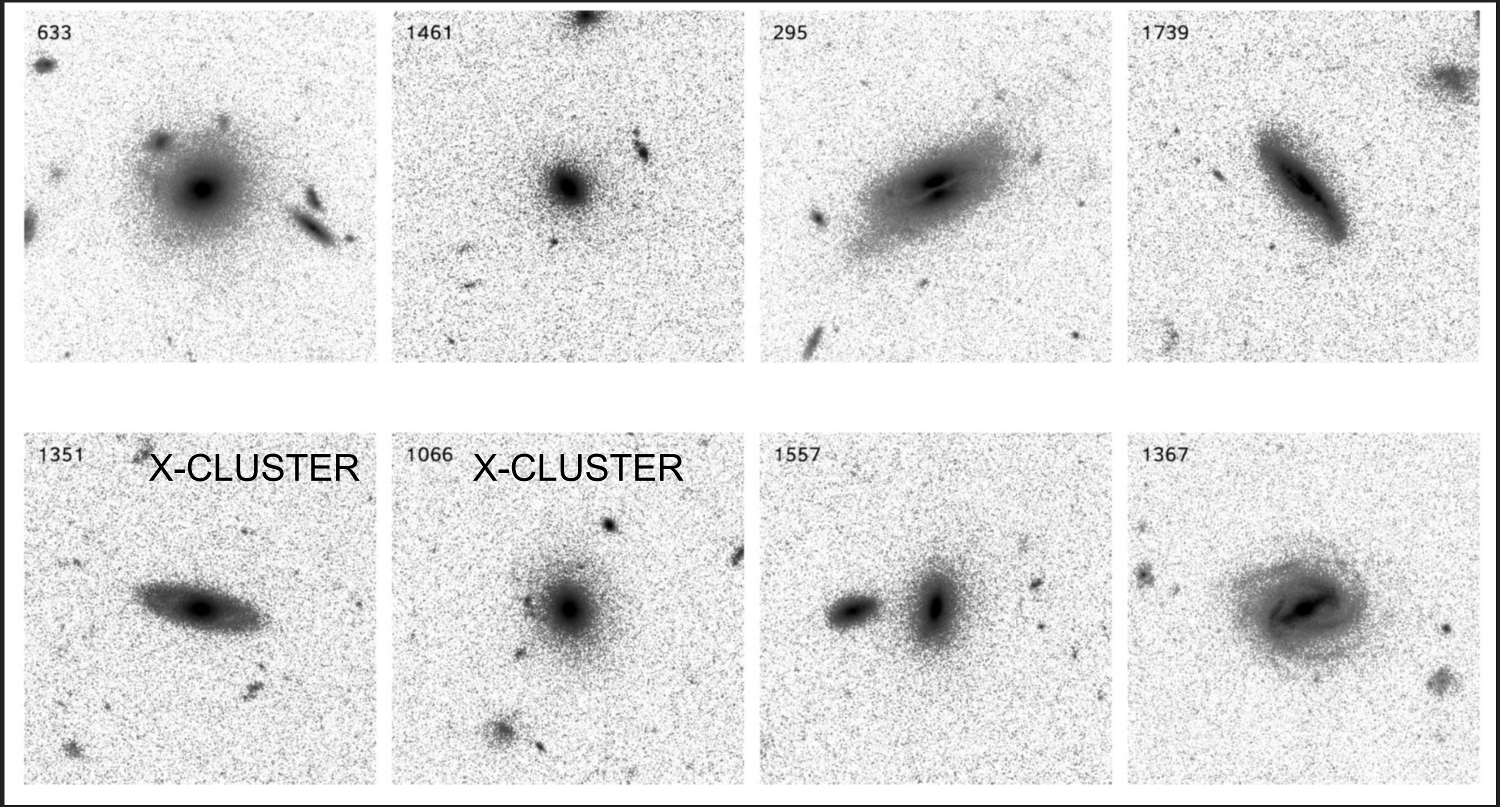
**log(HI/Msun)=10.29+/-0.05**



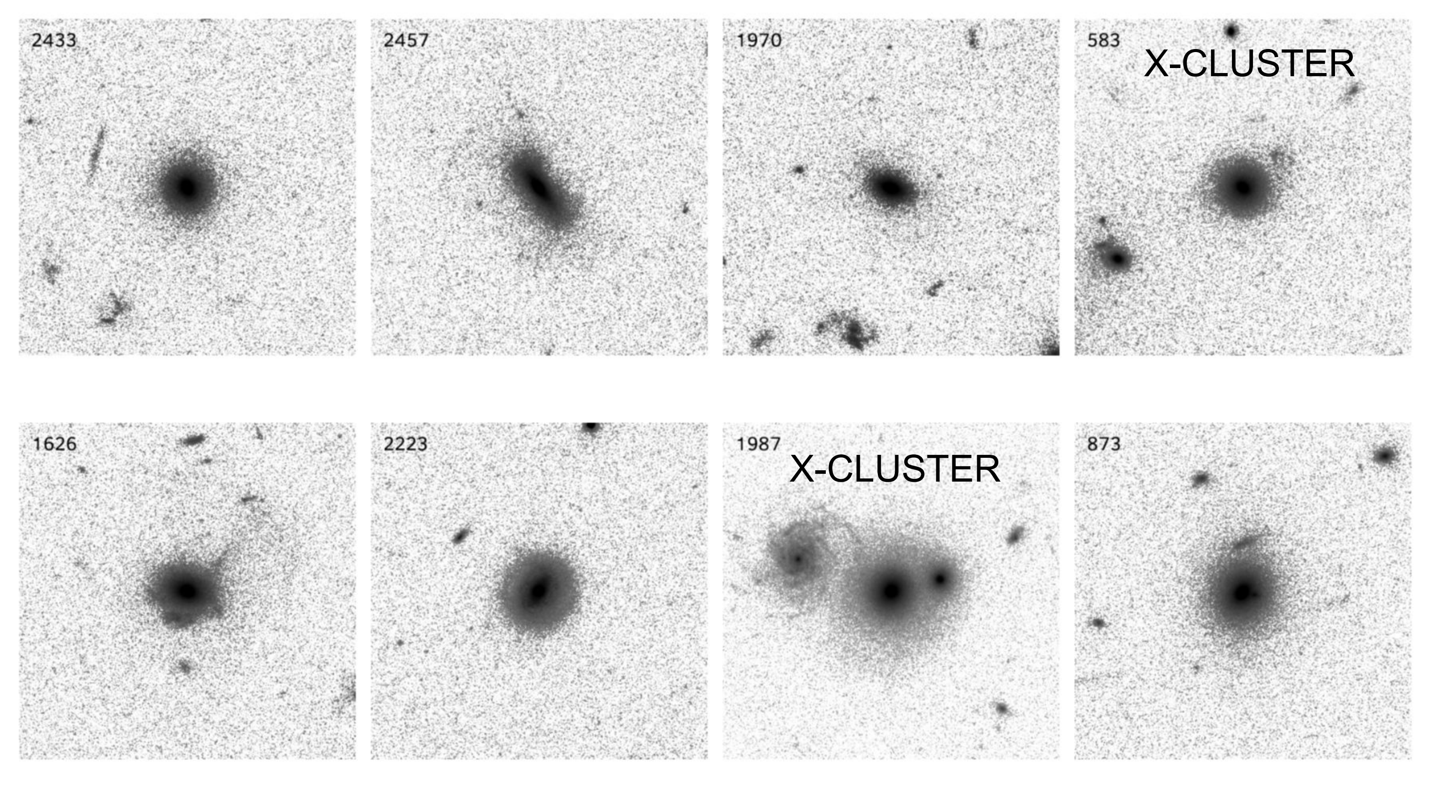

**log(HI/Msun)=10.45+/-0.10**

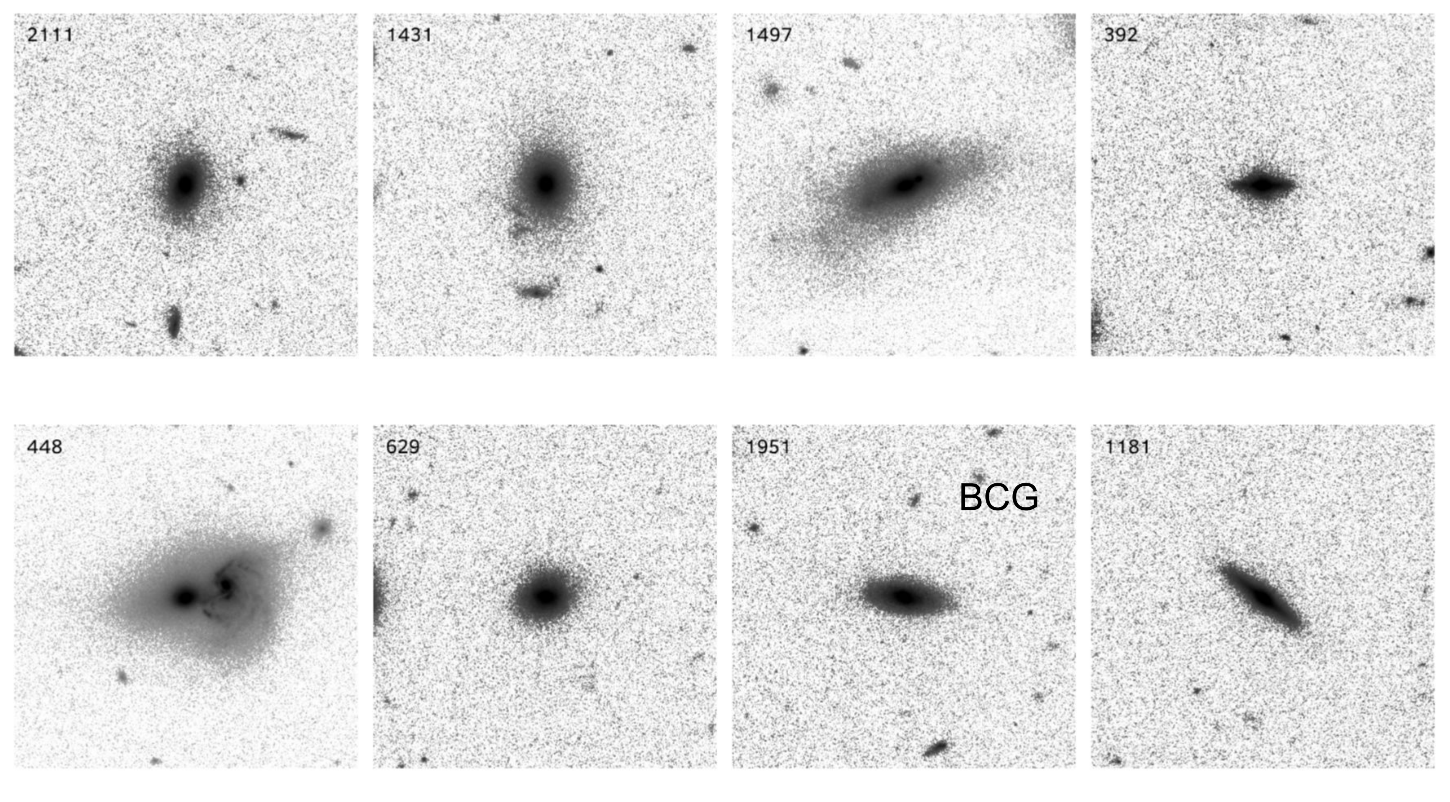


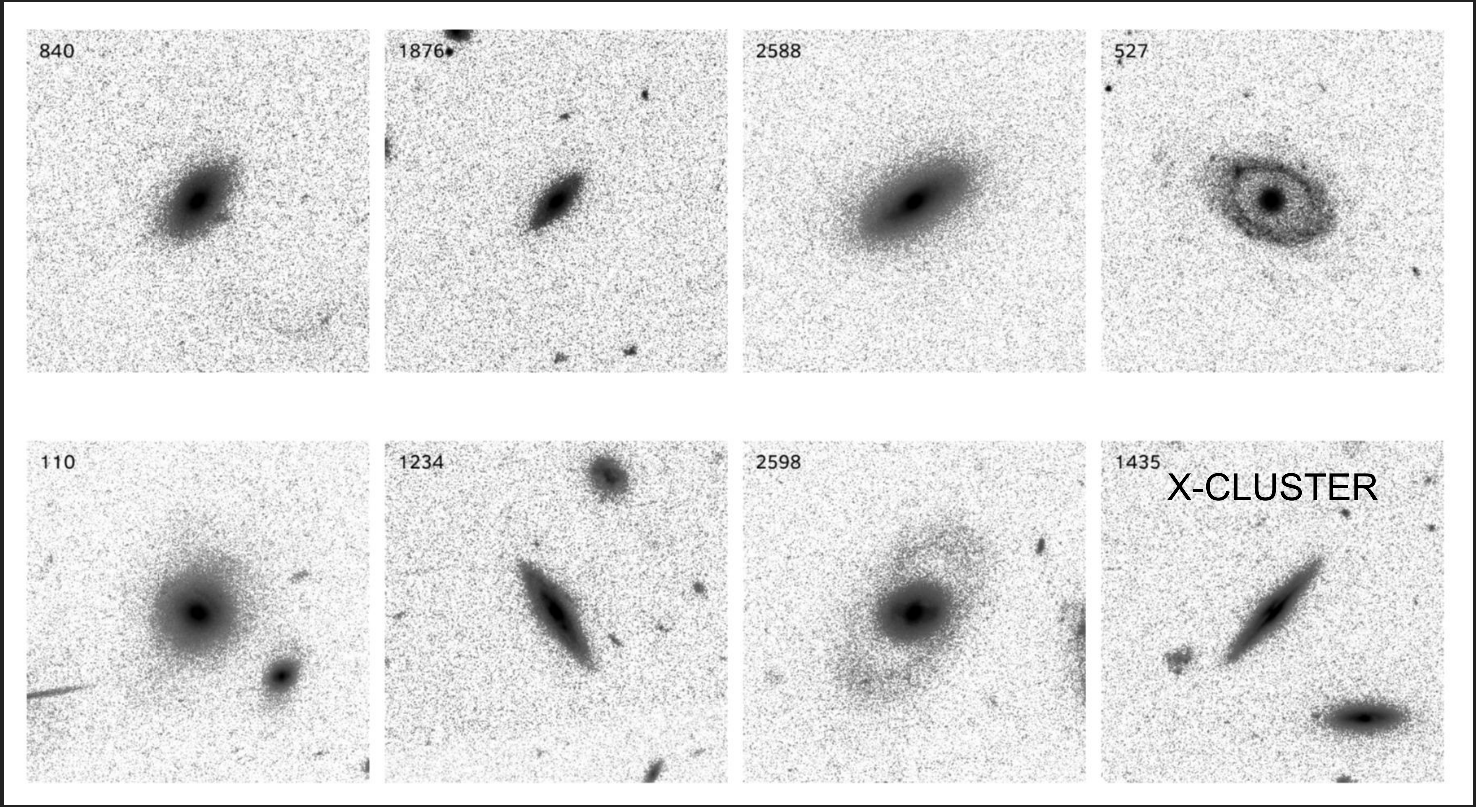
PRELIMINARY!!!! a subsample of only ~30 sources maximizes the HI stacked mass: evidence for environment dependence? ⇒ 20% of the HI boosted sources sits in X-ray clusters + evidence of companions/mergers




ACS/HST


2433
2457
1970
583
X-CLUSTER
1626
2223
1987
X-CLUSTER
873


2111
1431
1497
392
448
629
1951
BCG
1181


840
1876
2588
527
110
1234
2598
1435
X-CLUSTER

# What about the origin of HI in dusty quenched sources?

T.B.D.

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T.B.D.

local ETGs with central HI are usually CO detected (e.g. *Oosterloo+10*). Molecular gas provides fuel for ongoing SFR with respect to fully dead galaxies.

⇒

Dusty QGs at $0.2<z<0.5$ might also be filled by molecular gas, predictable assuming a metallicity dependent dust/gas ratio. HI represents the natural reservoir for $H_2$ condensation.

***Donevski+23:*** passive galaxies might re-grow dust due to efficient conversion of metals in the ISM, independently of environments

⇒ the presence of abundant atomic gas is important to support this scenario!

*priv. comm. SIMBA: higher dust-to-metal ratio in galaxies with more atomic gas.*

# Summary results

- **Overall detection of HI in massive QGs galaxies at z~0.37**
- **Dusty QGs are HI gas richer (x2.5) than non-dusty QGs**
- **Dusty QGs have an HI gas content comparable/in excess with respect to main sequence galaxies at fixed stellar mass**
- For the dusty QGs: increasing HI mass with increasing Dn4000 (older galaxies ⇒ gas richer?), exceeding typical main sequence quantities by 0.2dex
- evolution with respect to $z=0$?
- Environment might be playing a role (in progress)

# Conclusions and future perspectives

- total HI content, no spatial resolution to disentangle the main physical driver of the HI feeding (accretion from the cosmic web, merging processes, internal structures, settled - unsettled configuration??)
- possible contamination to the stacks by unidentified HI detections in the MIGHTEE cubes? not obvious…need  to check: continuum radio emission, halo relics, systematic environmental trends, AGN impact, morphological dependence
- comparison to cosmological expectations ⇒ SIMBA
- accounting for the contribution of passive sources to Omega(HI) at z>0?

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**Thank you for your attention!**