

# The Void Galaxy Survey: morphology and star formation properties of void galaxies

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with

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and natural sciences

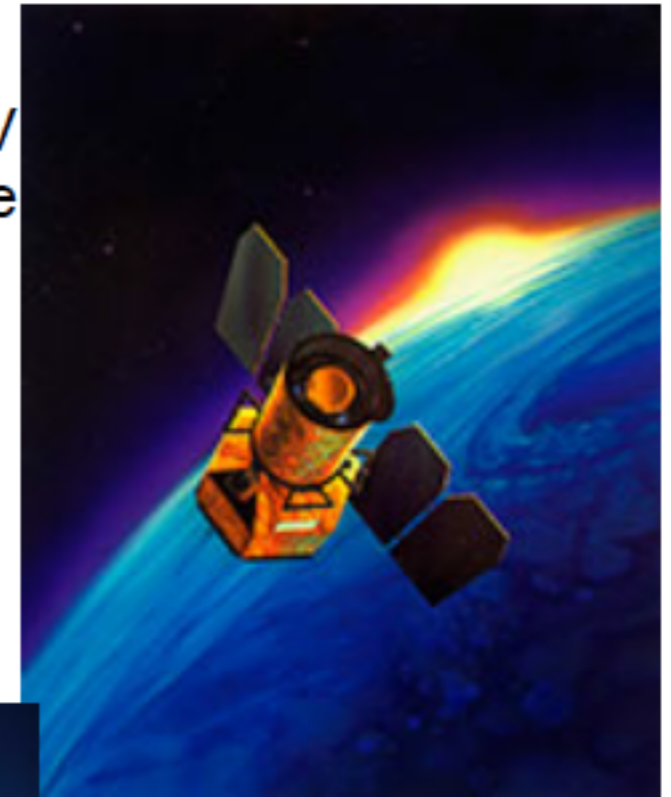
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institute

# The Void Galaxy Survey (VGS)



21 cm  
Westerbork  
Synthesis  
Radio  
Telescope

Near-UV  
GALEX Telescope



H- $\alpha$   
MDM 2.4m Hiltner Telescope

3.6 & 4.5  $\mu\text{m}$   
Spitzer

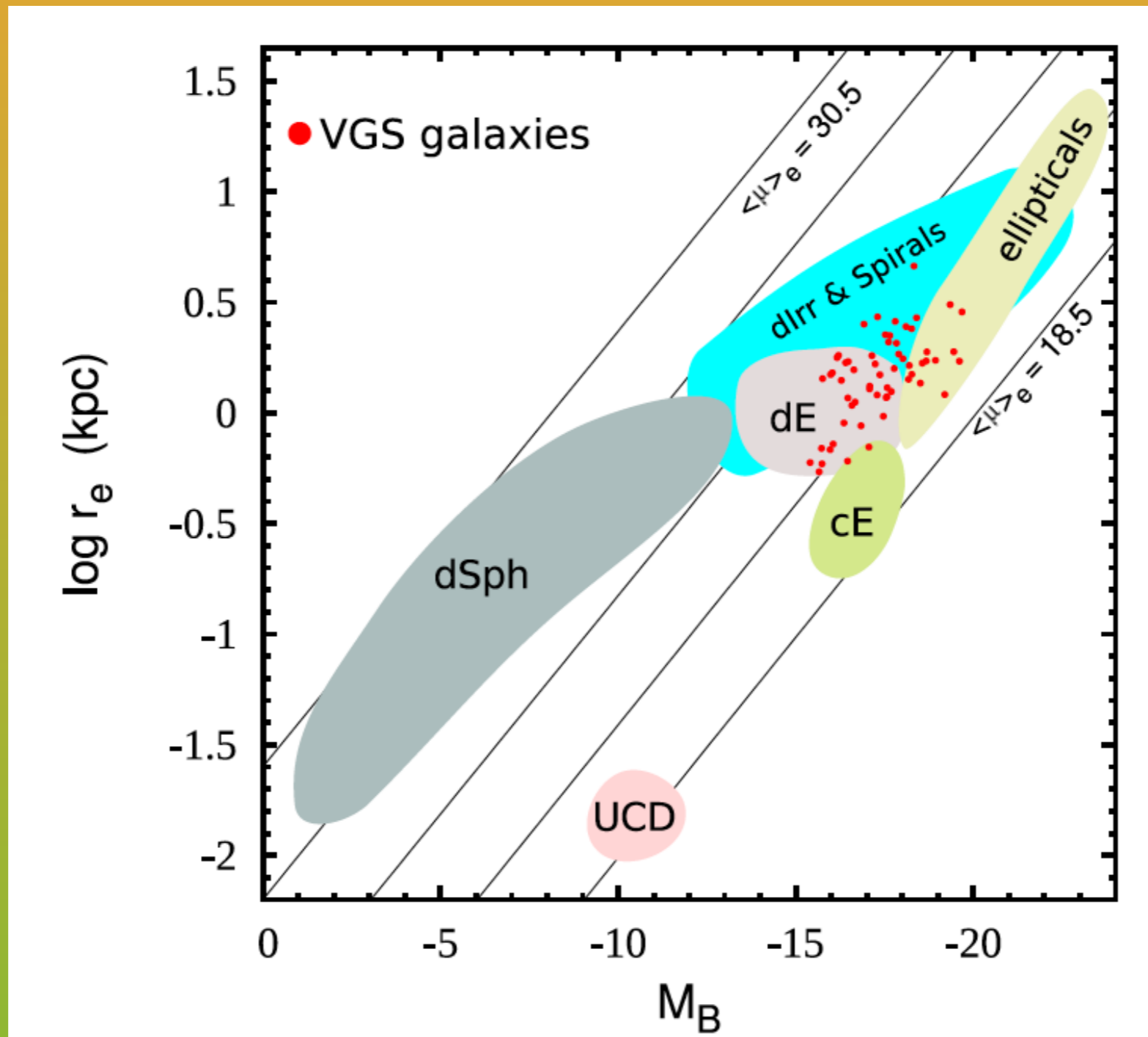


B & R -band  
INT 2.5m



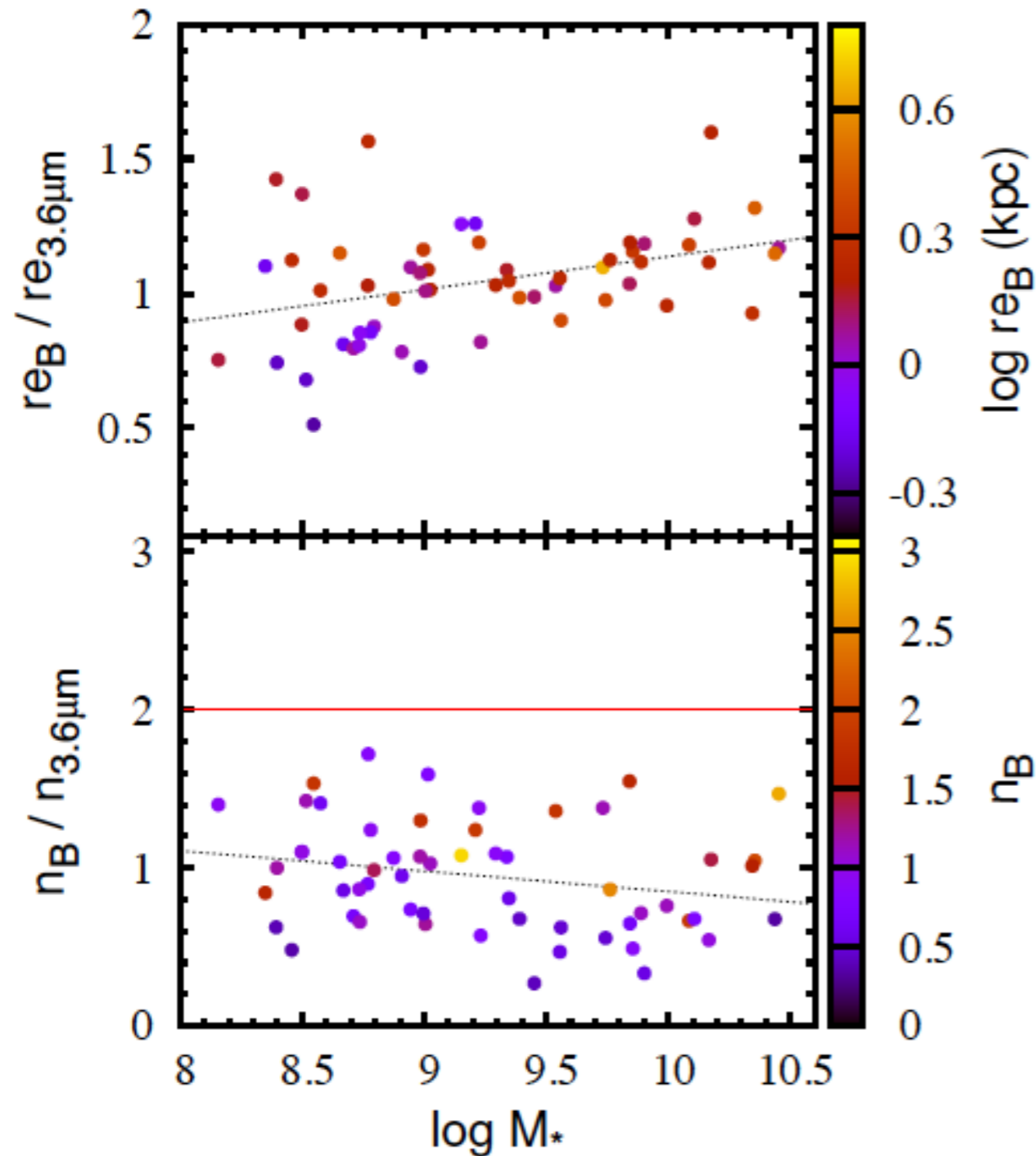
- Color - magnitude; *B-band* & *Spitzer 3.6  $\mu$*
- Morphology: structural parameters; *n, r<sub>e</sub>, h*
- Star formation properties: *H $\alpha$*  & *near-UV*
- Are they a separate class of galaxies?
- How different are their observed properties compared to other galaxies?

# VGS galaxies: their identities



- **VGS galaxies** in the parameter space of  $r_e$  and  $M_B$  in B-band, adopted from Mo et al. (2010)

# VGS galaxies: structural parameters and stellar mass



- Ratio of  $r_e$  of different bands, Sérsic indices and stellar mass

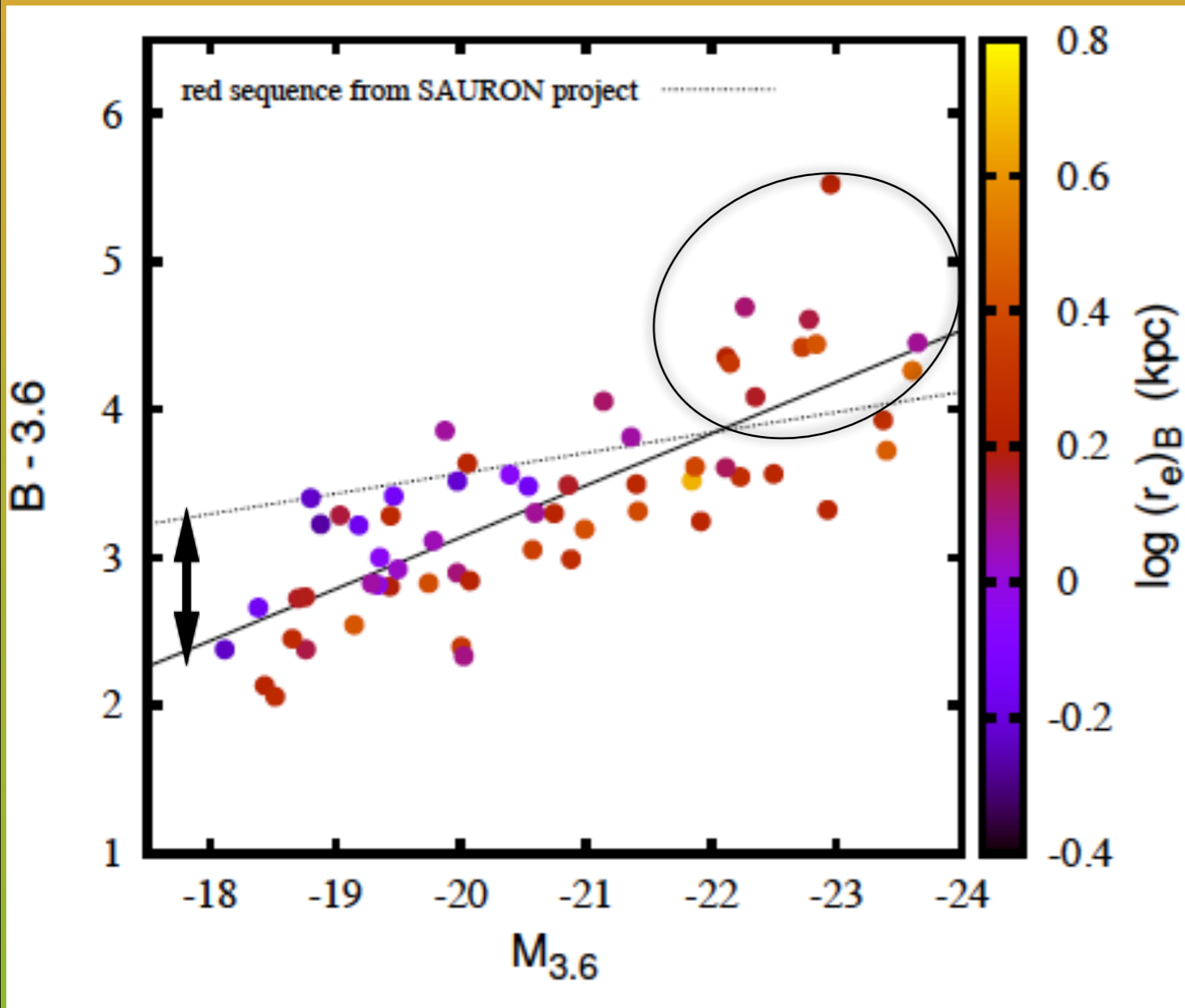
- $re_B / re_{3.6\mu m} \nearrow M_* \nearrow re_B$
- This shows that light in the smaller galaxies is more concentrated in B

- Also, SF is more concentrated in the smaller galaxies, or more in the outer parts of the larger objects. Extinction could contribute as well.

- $n < 2$  in both bands : late type galaxies

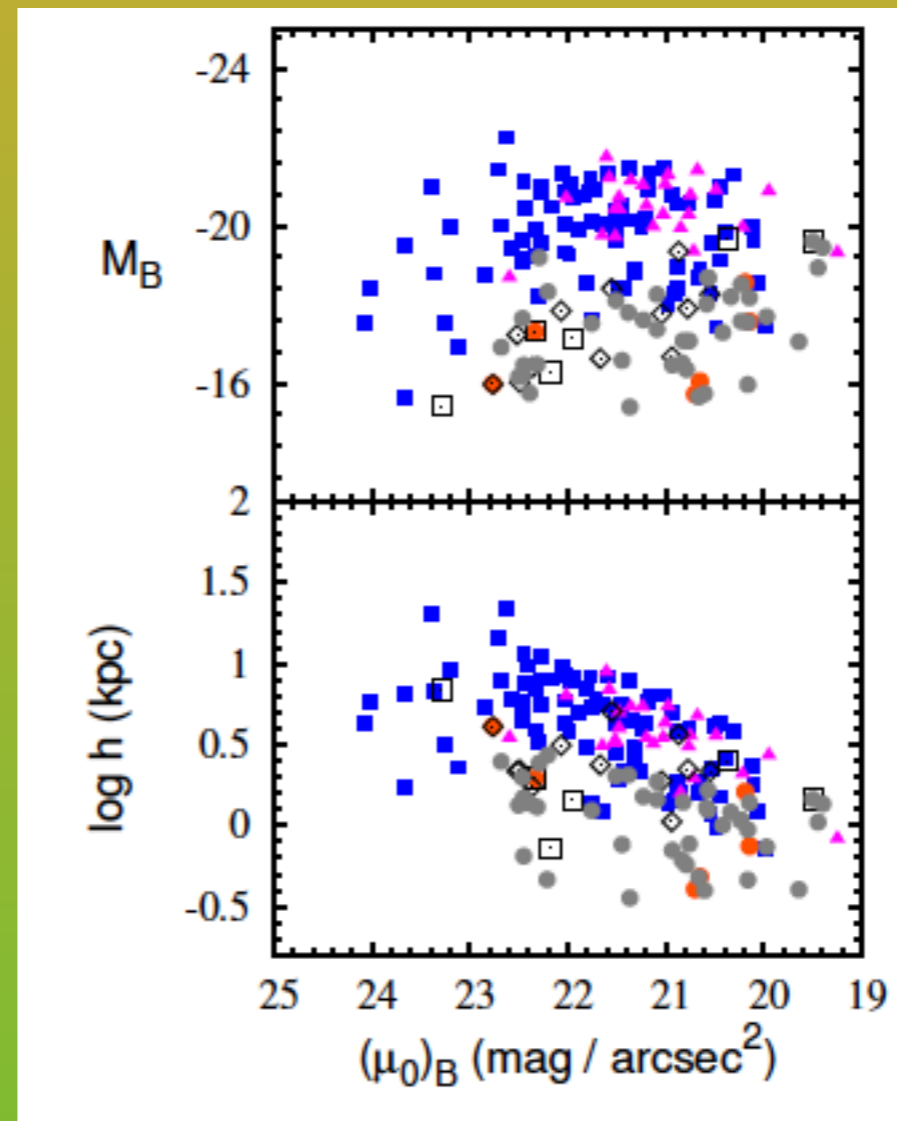
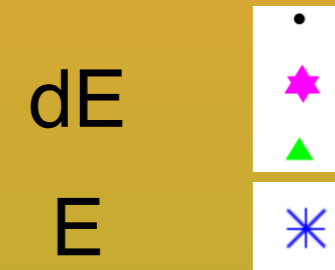
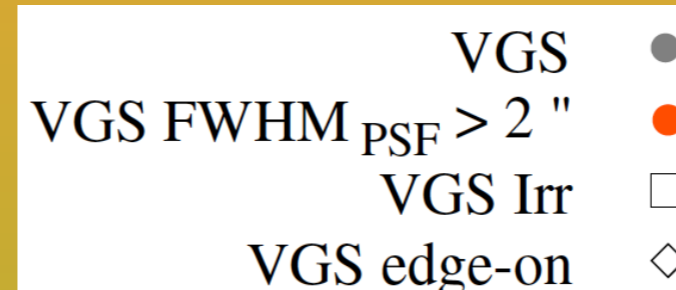
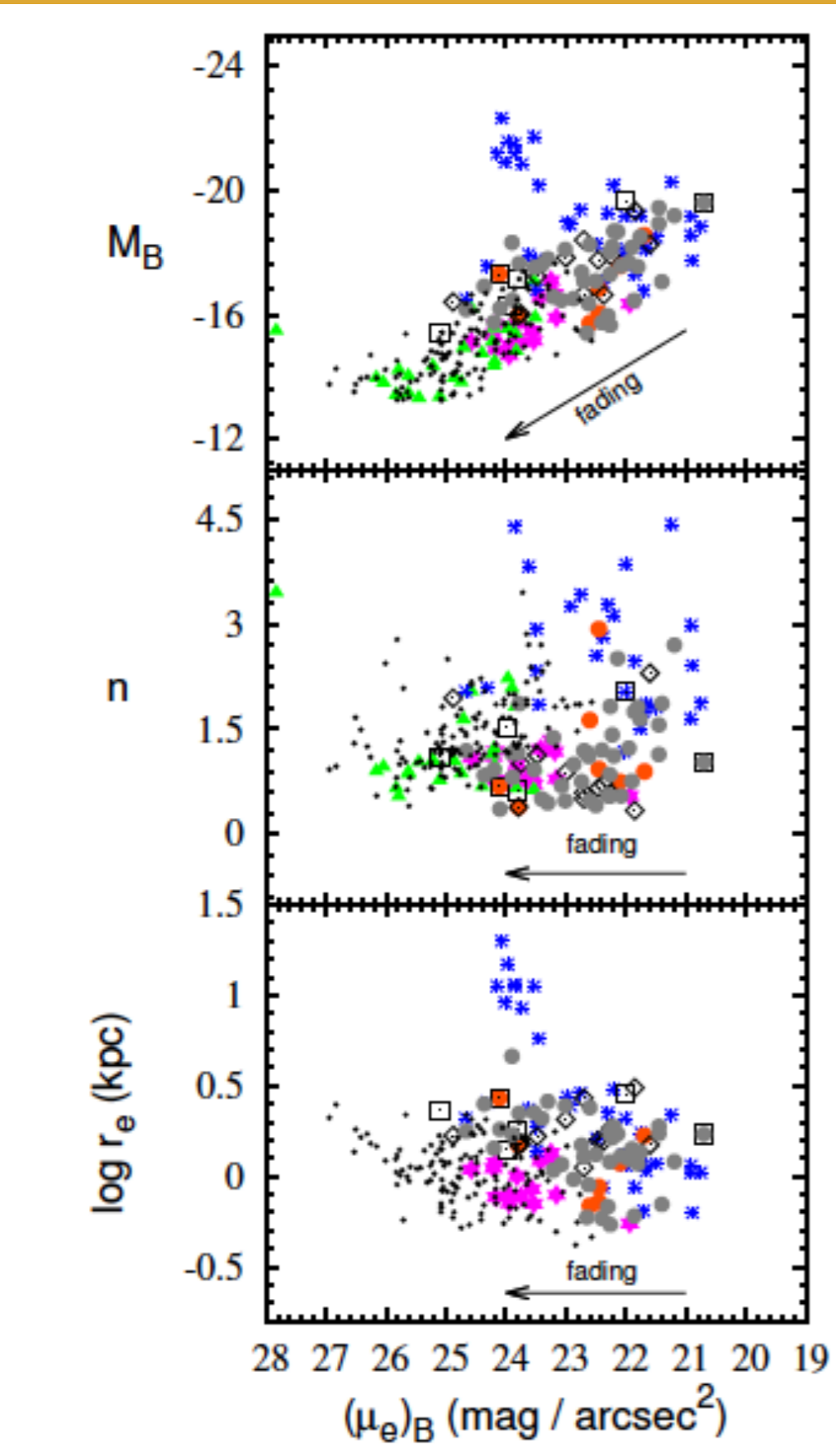
- $n_B / n_{3.6\mu m} \sim 1$

# VGS galaxies: color



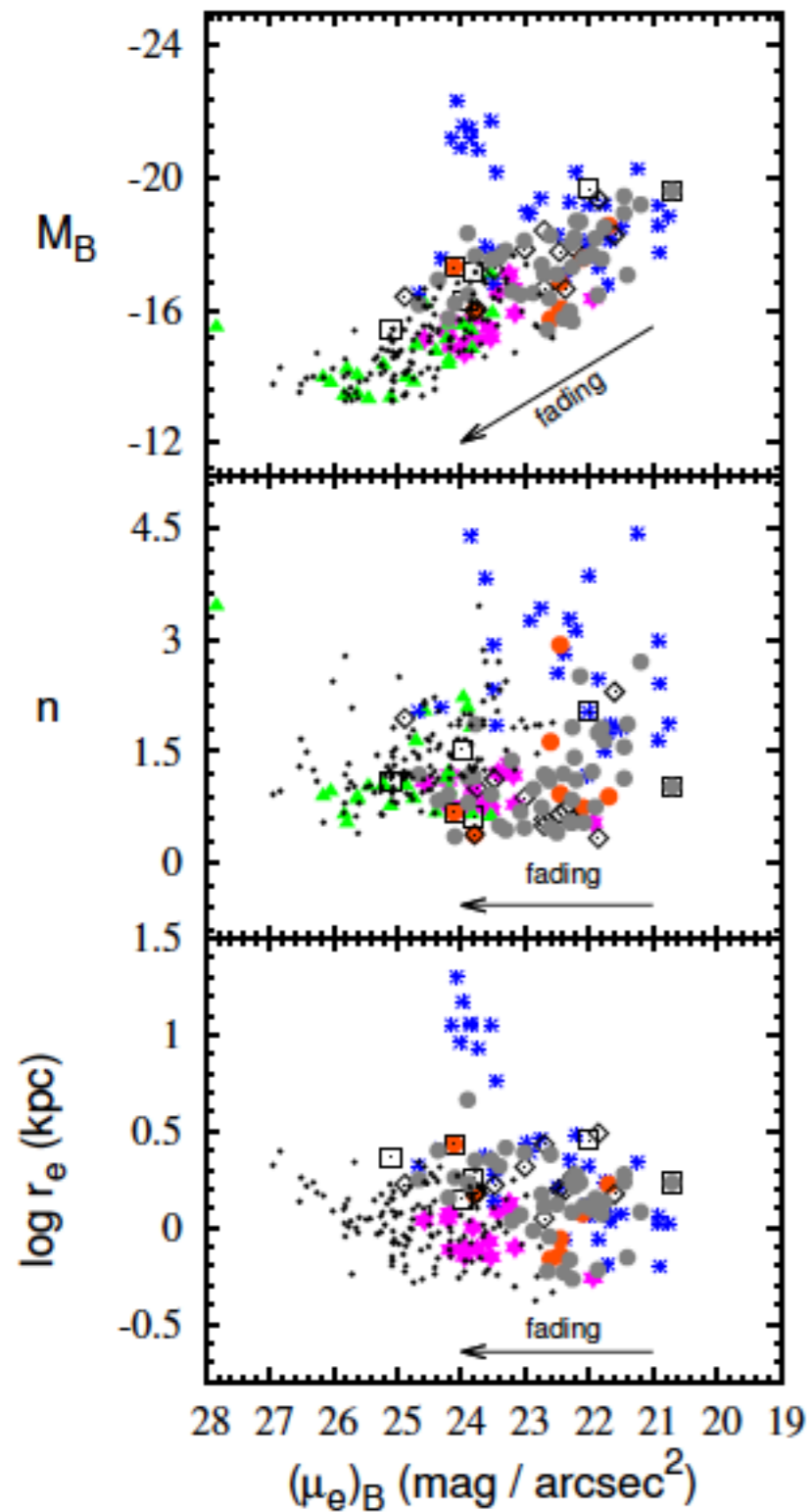
- color - magnitude -  $r_e$
- SAURON red sequence (Falcón-Barroso et al. 1011), elliptical, old stars
- faintest galaxies are the youngest
- massive VGS galaxies are reddened by dust

# VGS galaxies: structural parameters

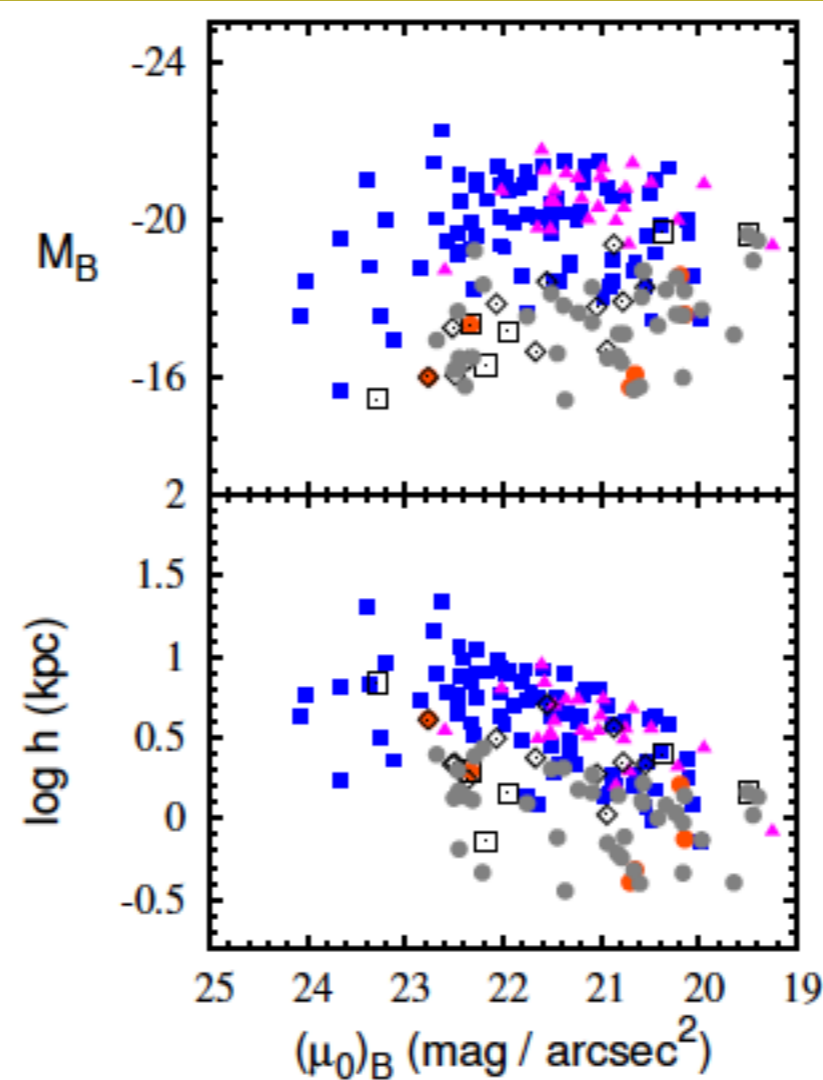


Spirals ■

- $h_{\text{VGS}} < h_{\text{Spirals}}$ ,  $M_{\text{B VGS}} > M_{\text{B Spirals}}$  but  $\mu_0$  is in similar range
- $M_{\text{B VGS}} > M_{\text{B dE}}$ ,  $\mu_{0 \text{ VGS}} < \mu_{0 \text{ dE}}$  but  $n$  and  $r_e$  in similar order



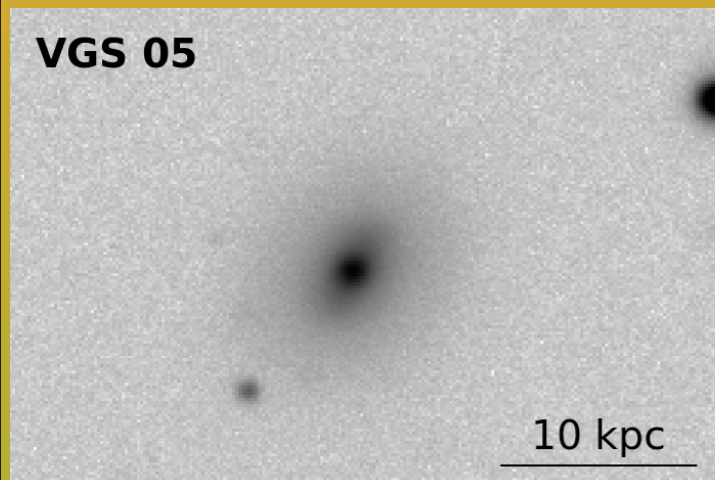
- VGS similar to late types in terms of disk presence and  $\mu_0$  but smaller and fainter.
- VGS similar to dE in terms of size but they are brighter.



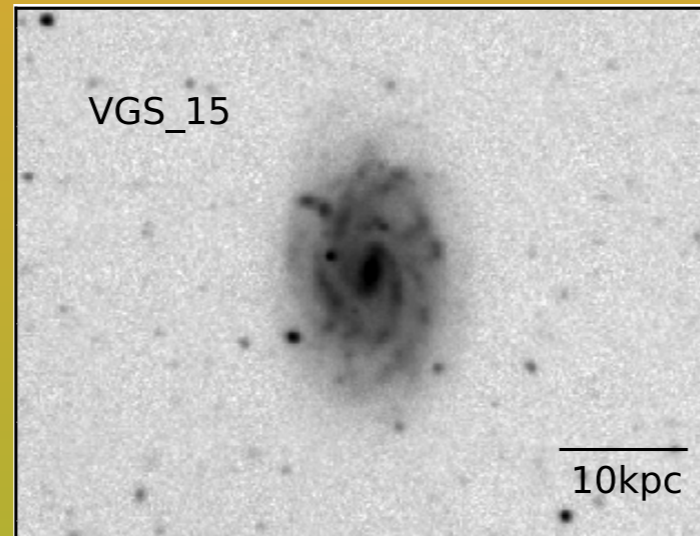


# How do they look like?

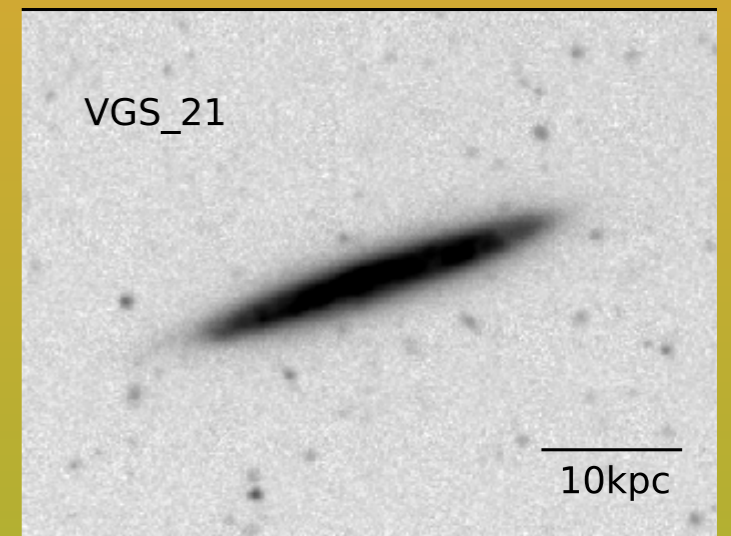
## Early type



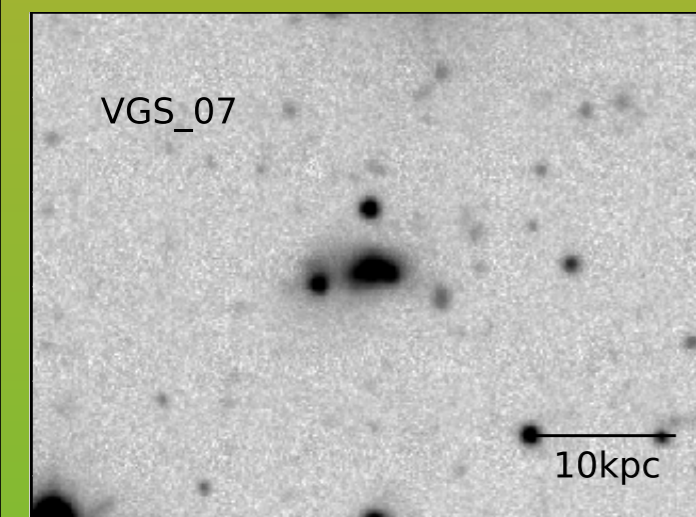
## Spiral



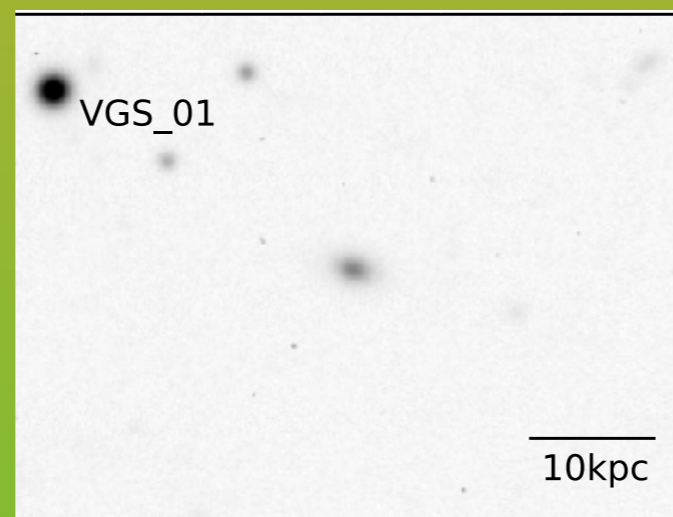
## Edge-on



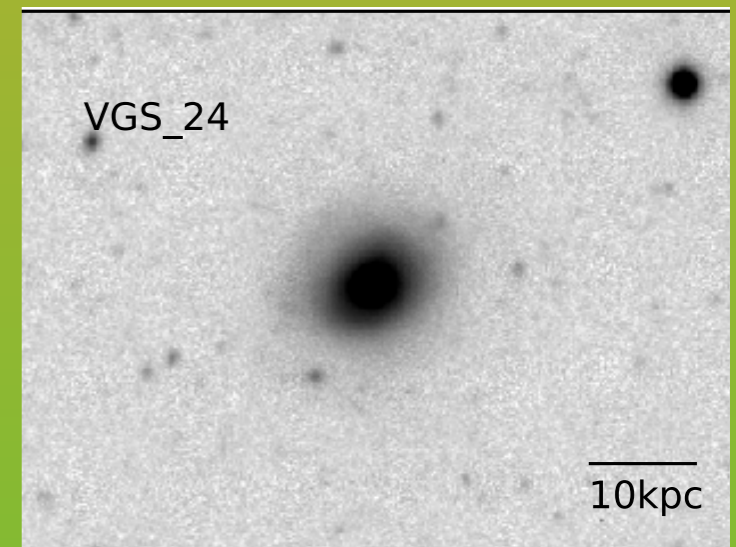
## Irregular



## Compact

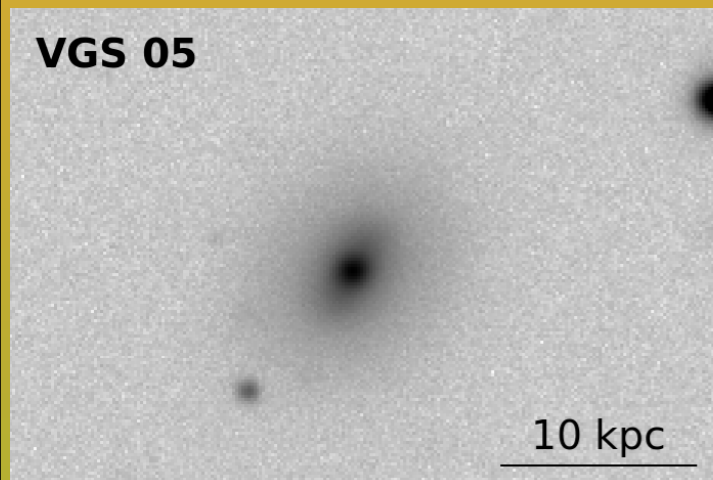


## AGN



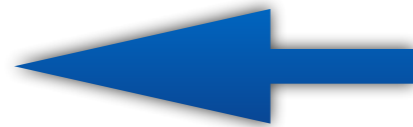
# How do they look like?

## Early type

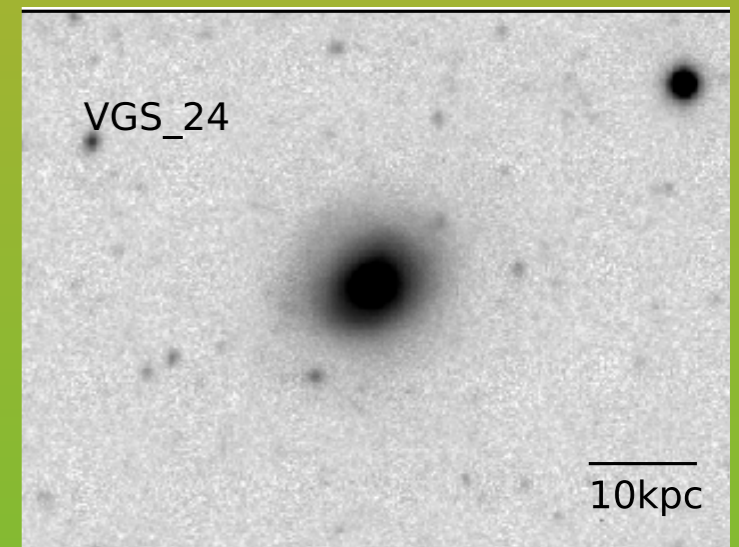


  $\delta = -0.93$

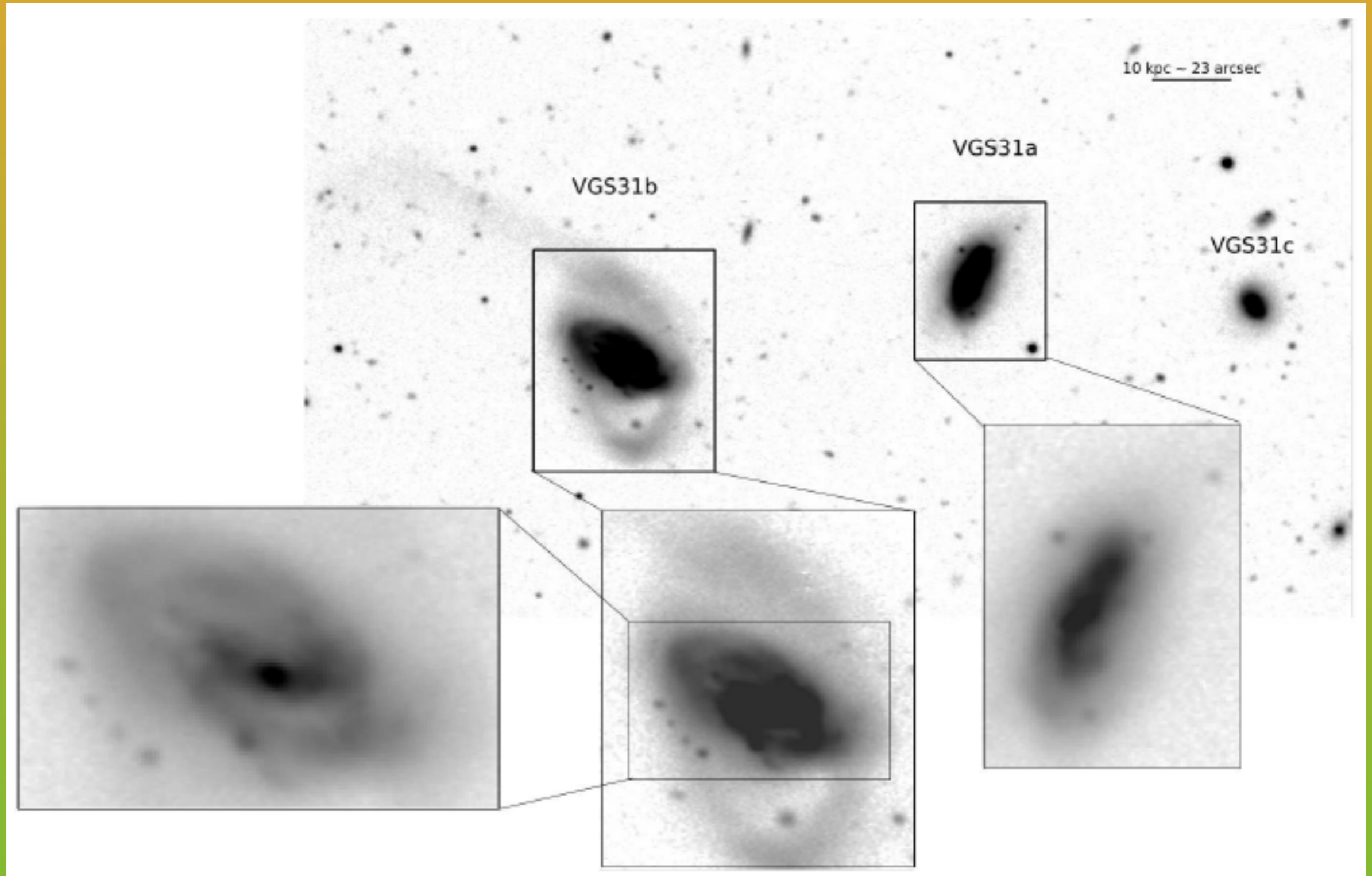
$\delta = -0.80$



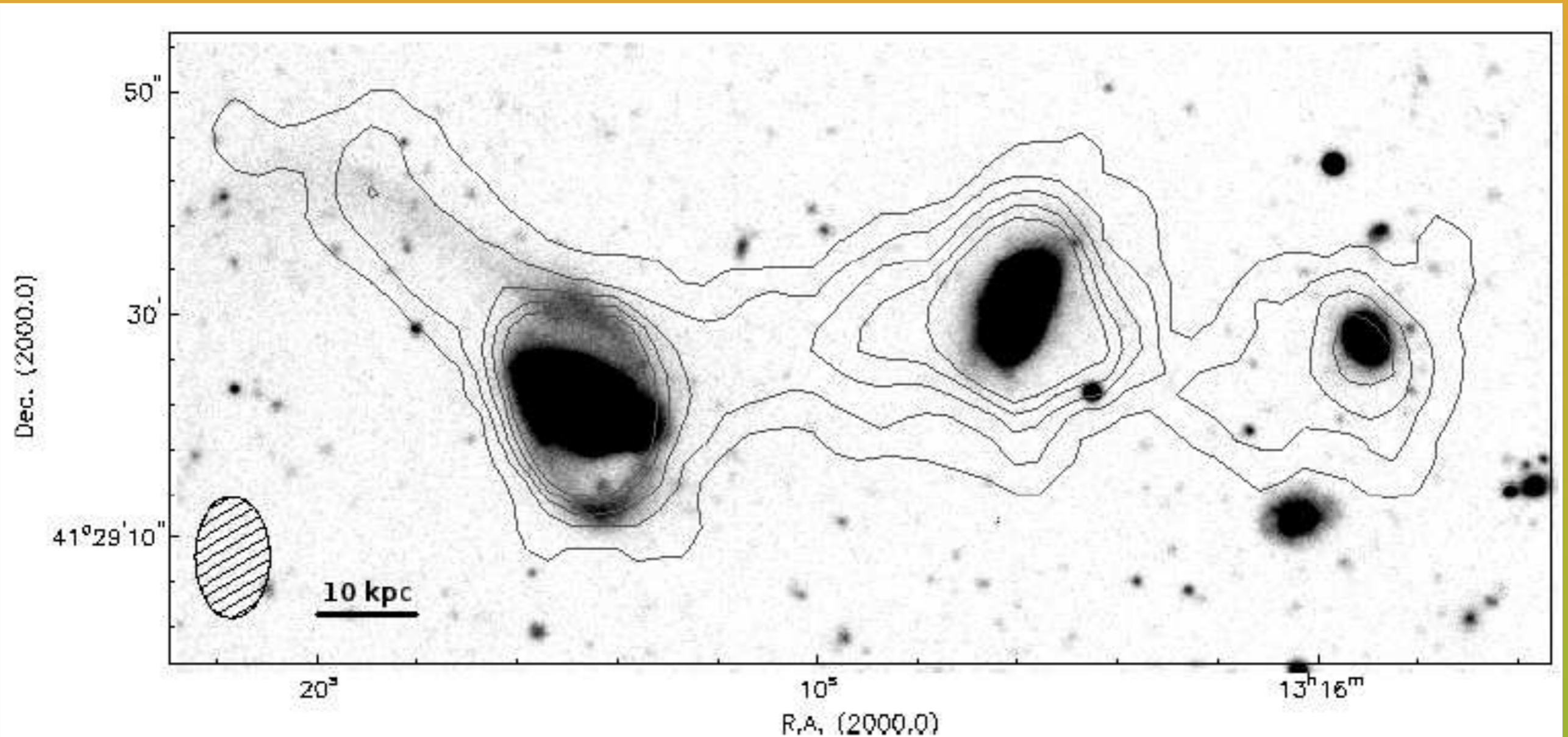
## AGN



# VGS 31: an interacting galaxy system along a filament in a void

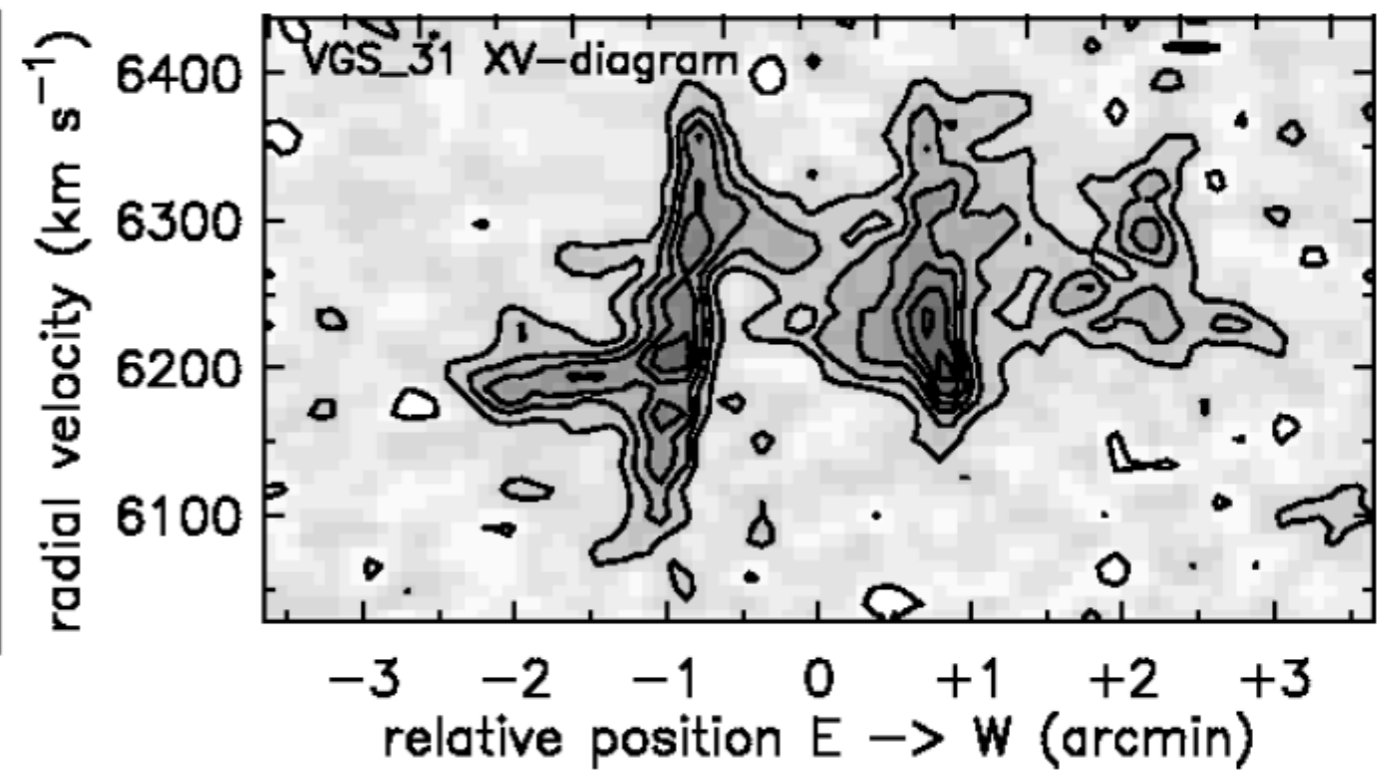
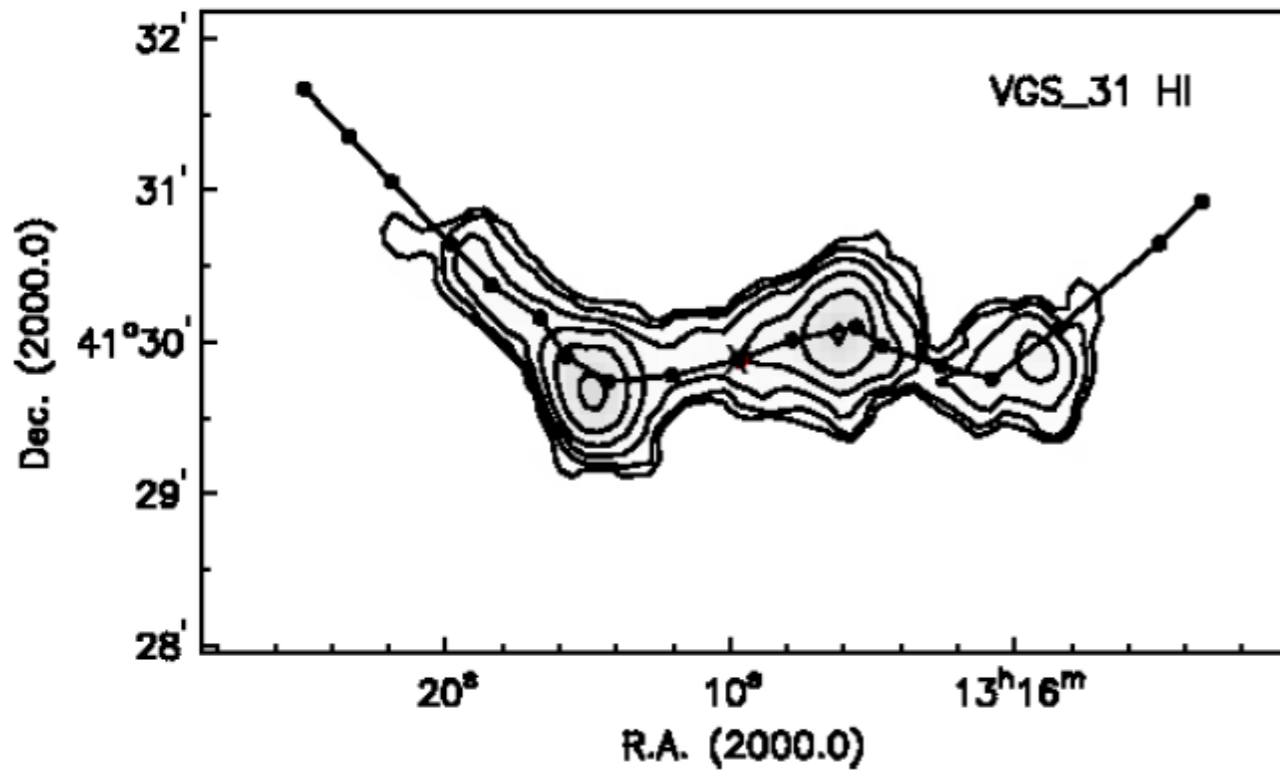


# VGS 31: Filament inside void



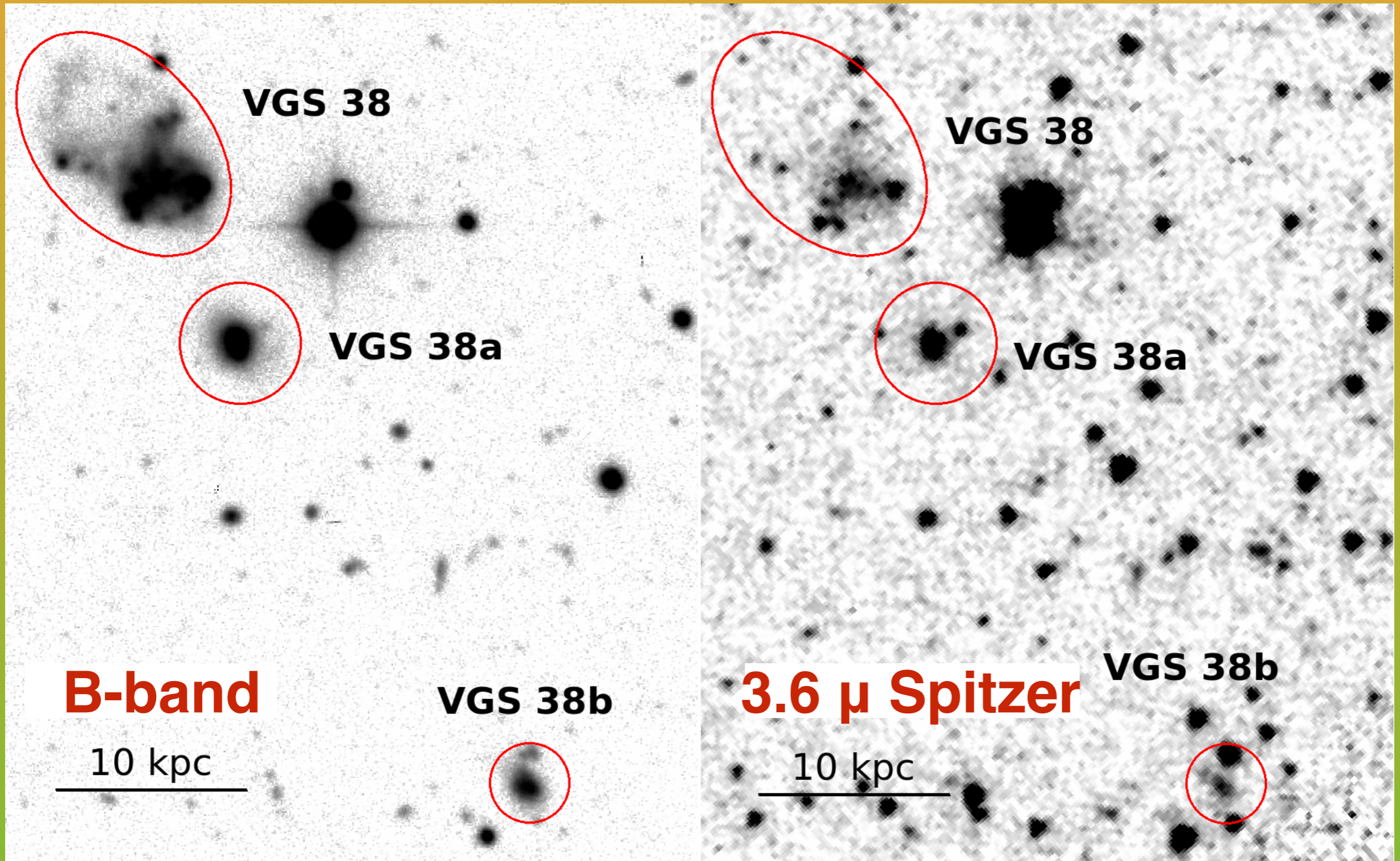
- **A density enhancement in an underlying tenuous dark matter filament?**

# VGS 31: filament inside void

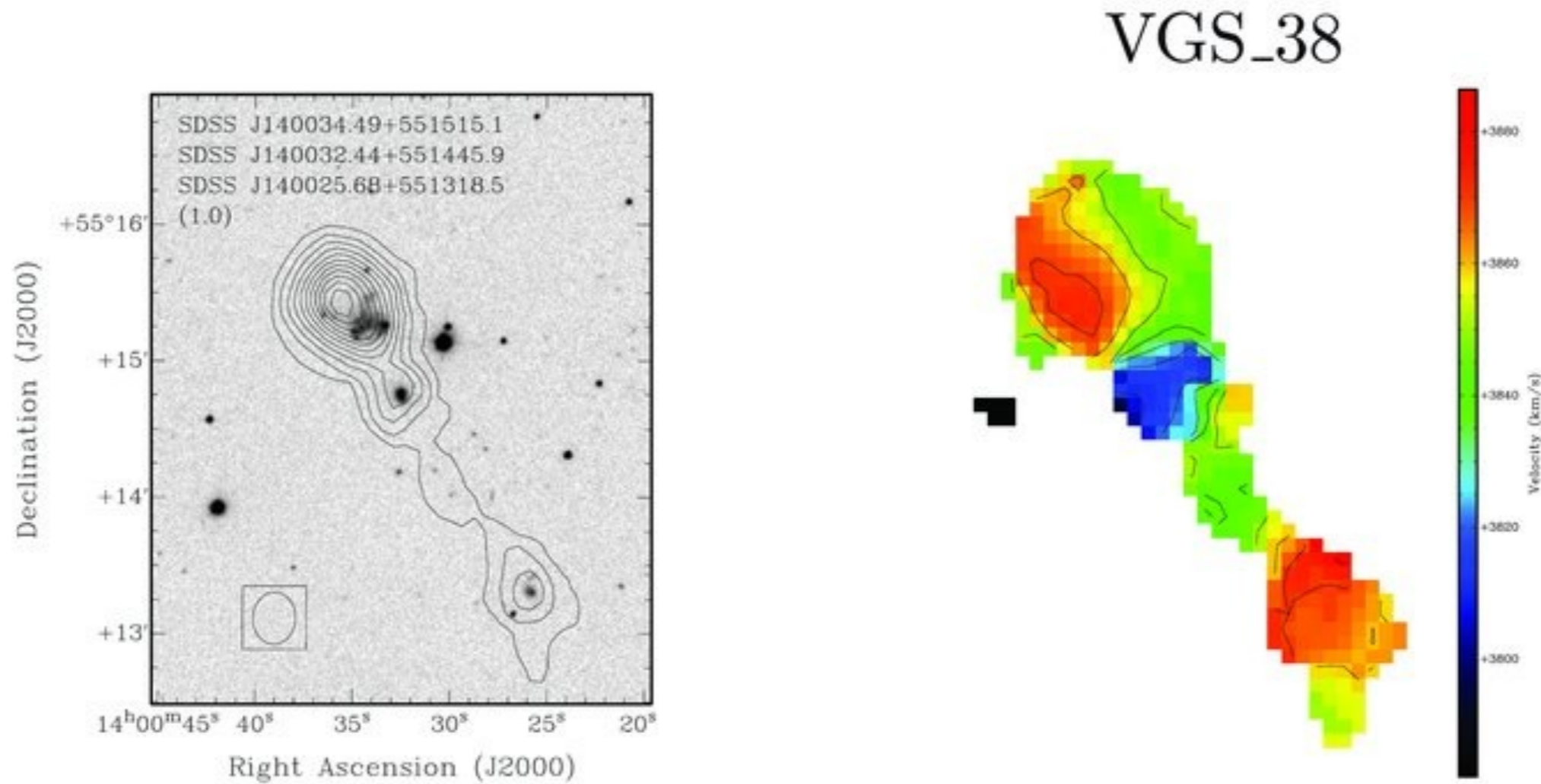


- A density enhancement in an underlying tenuous dark matter filament?

# Another filament?

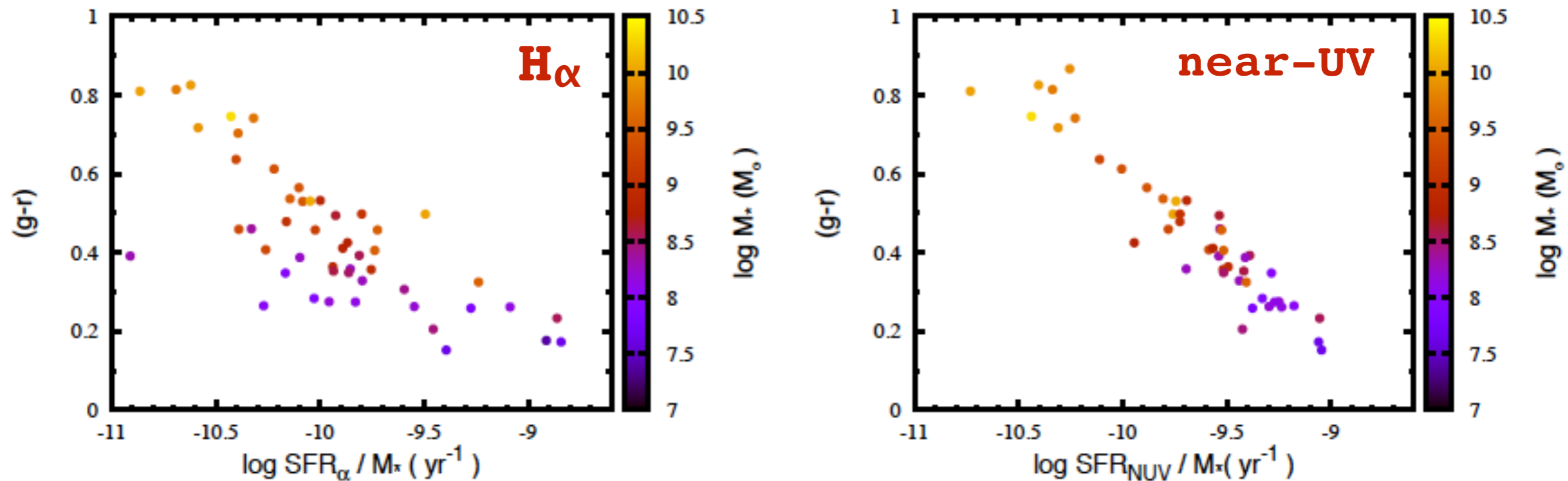


# Another filament?



- A major merger and two companions
- Common HI envelop?

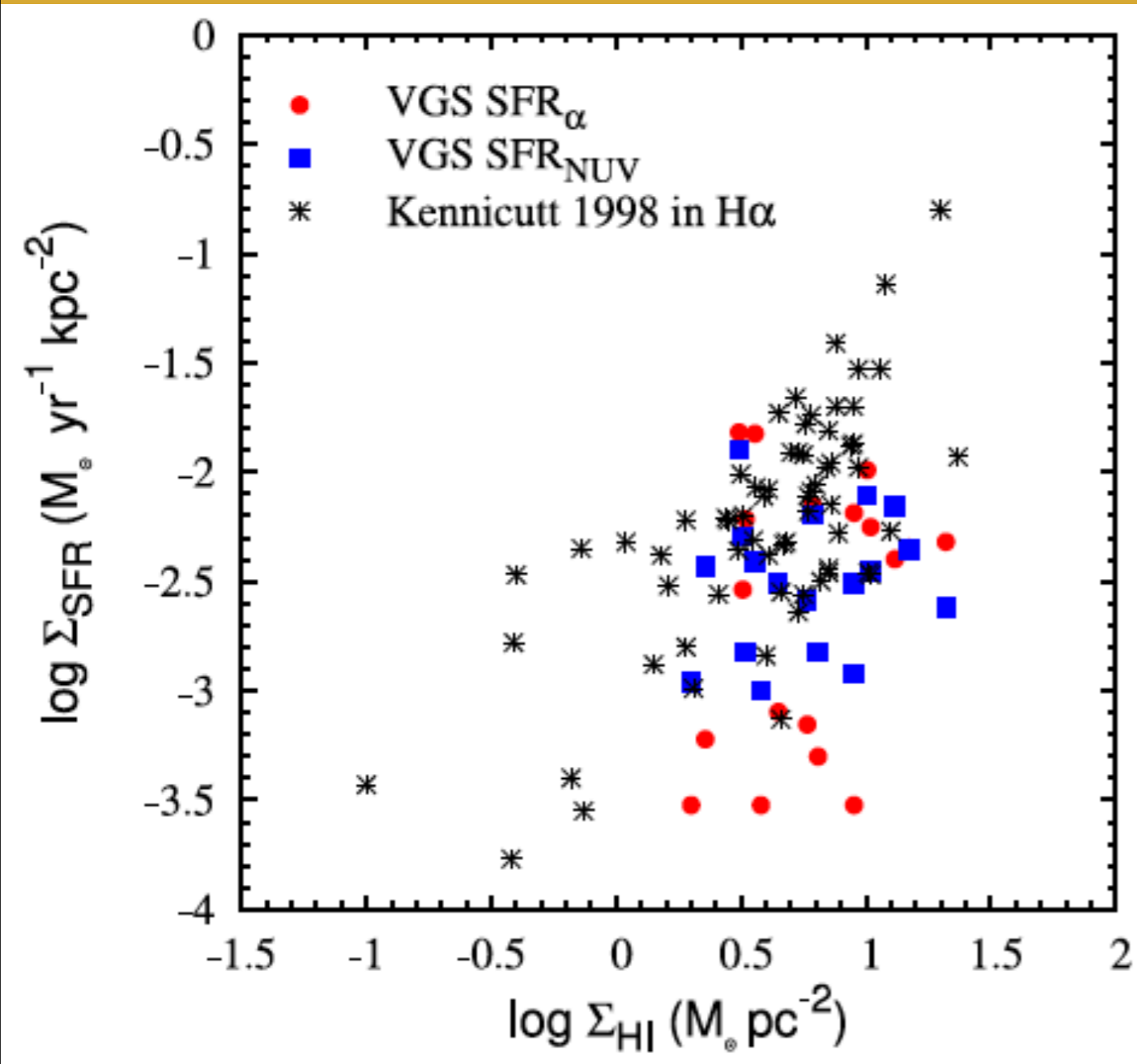
# VGS galaxies: Star formation properties



- VGS galaxies: color- specific star formation - stellar mass relation
- VGS galaxies are star forming galaxies, not starburst (occasional)
- $\text{SFR} < 1.5 M_{\odot} \text{ yr}^{-1}$  ( except VGS 31 and couple more )
- Small galaxies suffer more from stochasticity, effecting  $H_{\alpha}$  sample more as result of recent star formation.



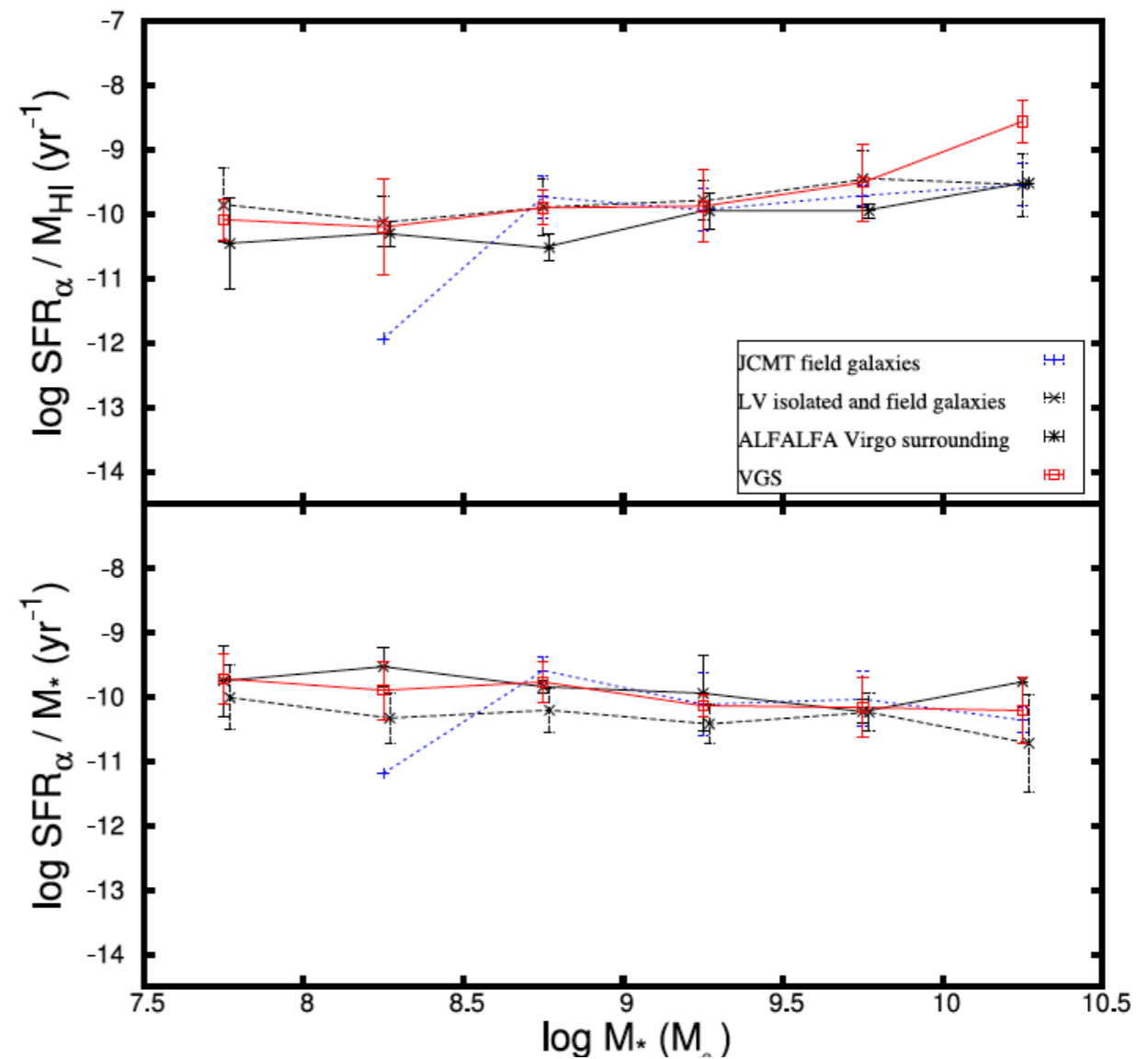
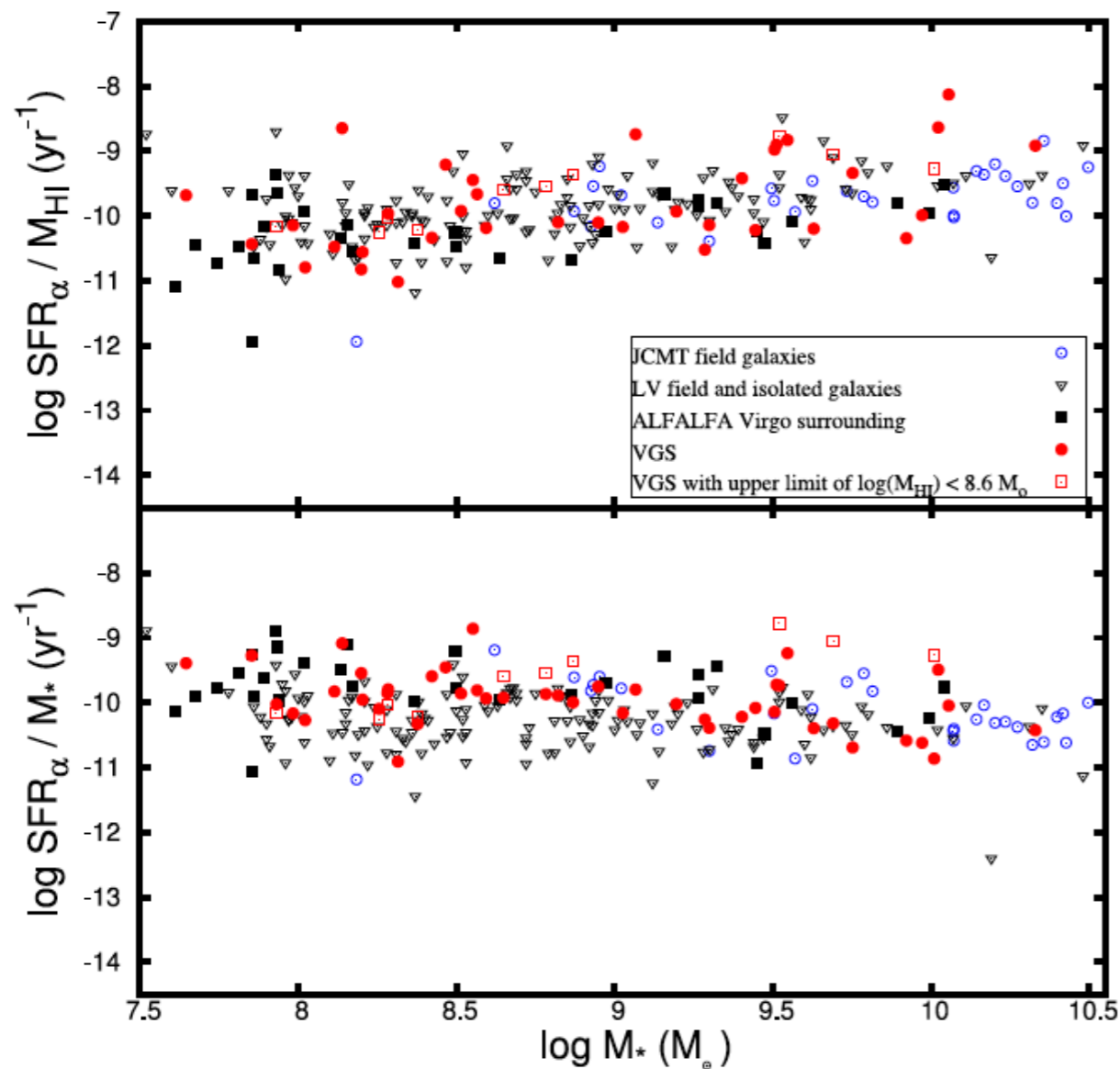
# VGS galaxies: Star formation properties



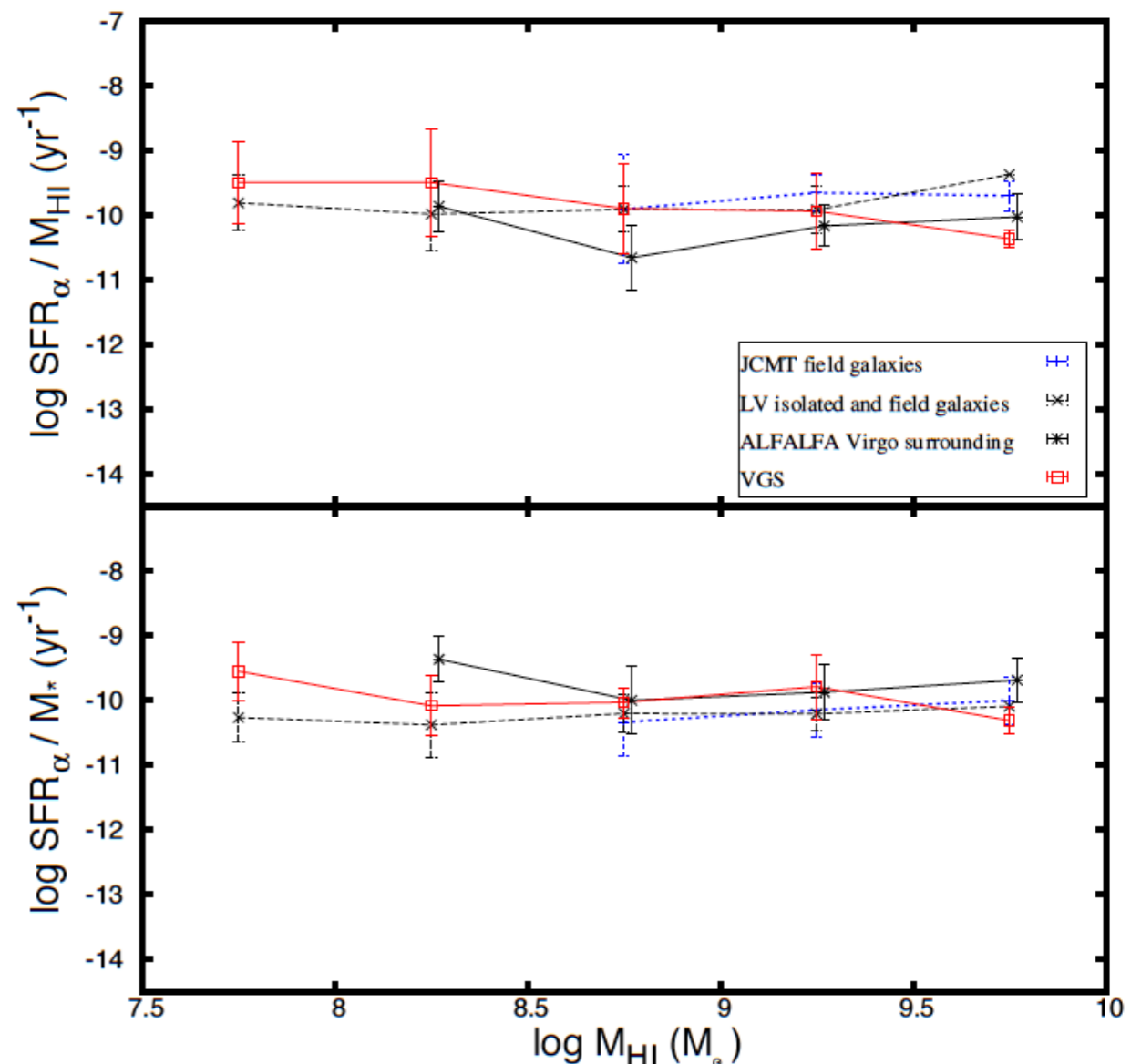
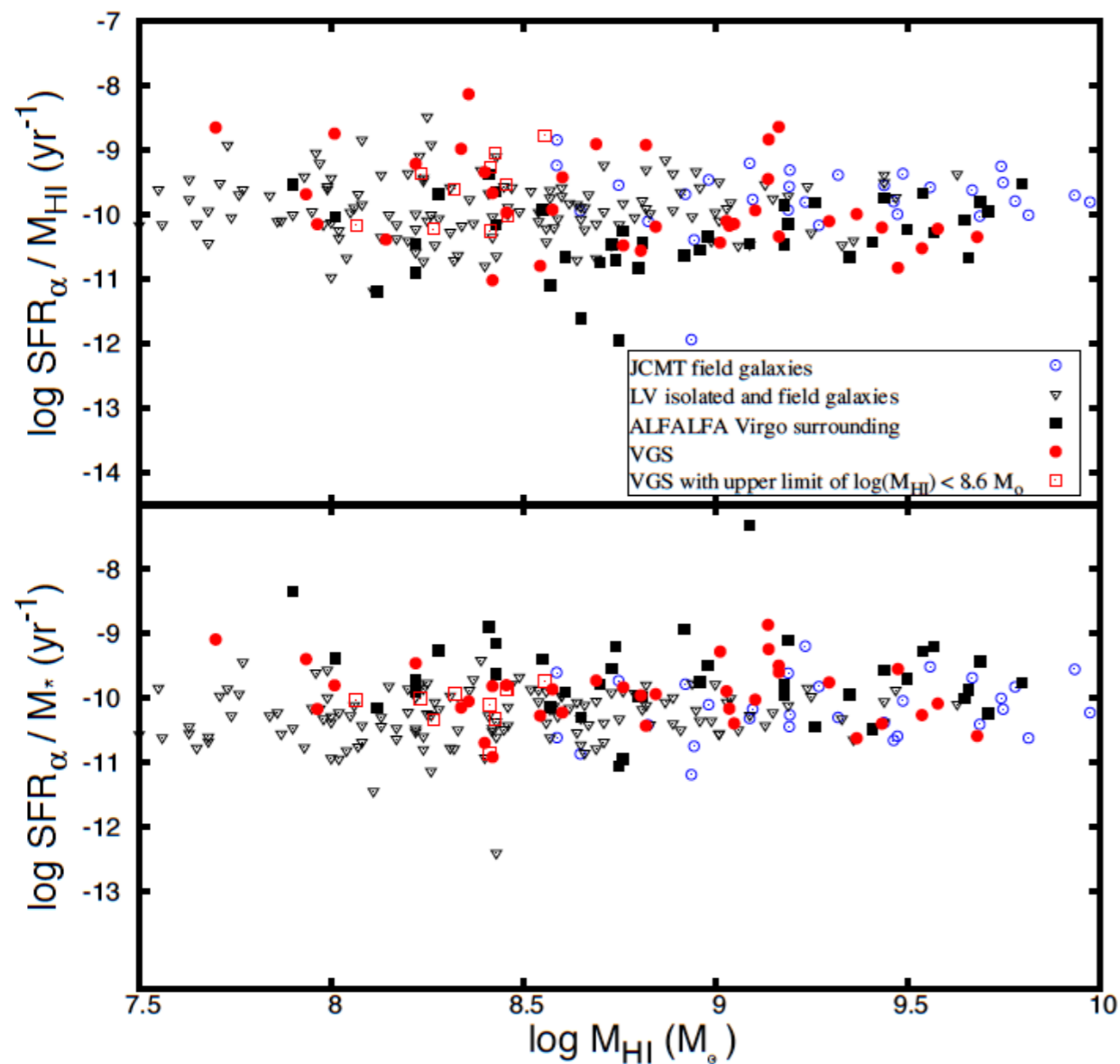
- **VGS galaxies in Kennicutt-Schmidt relation**
- **Low star formation, average HI density regime**

**Beygu et al. in prep.**

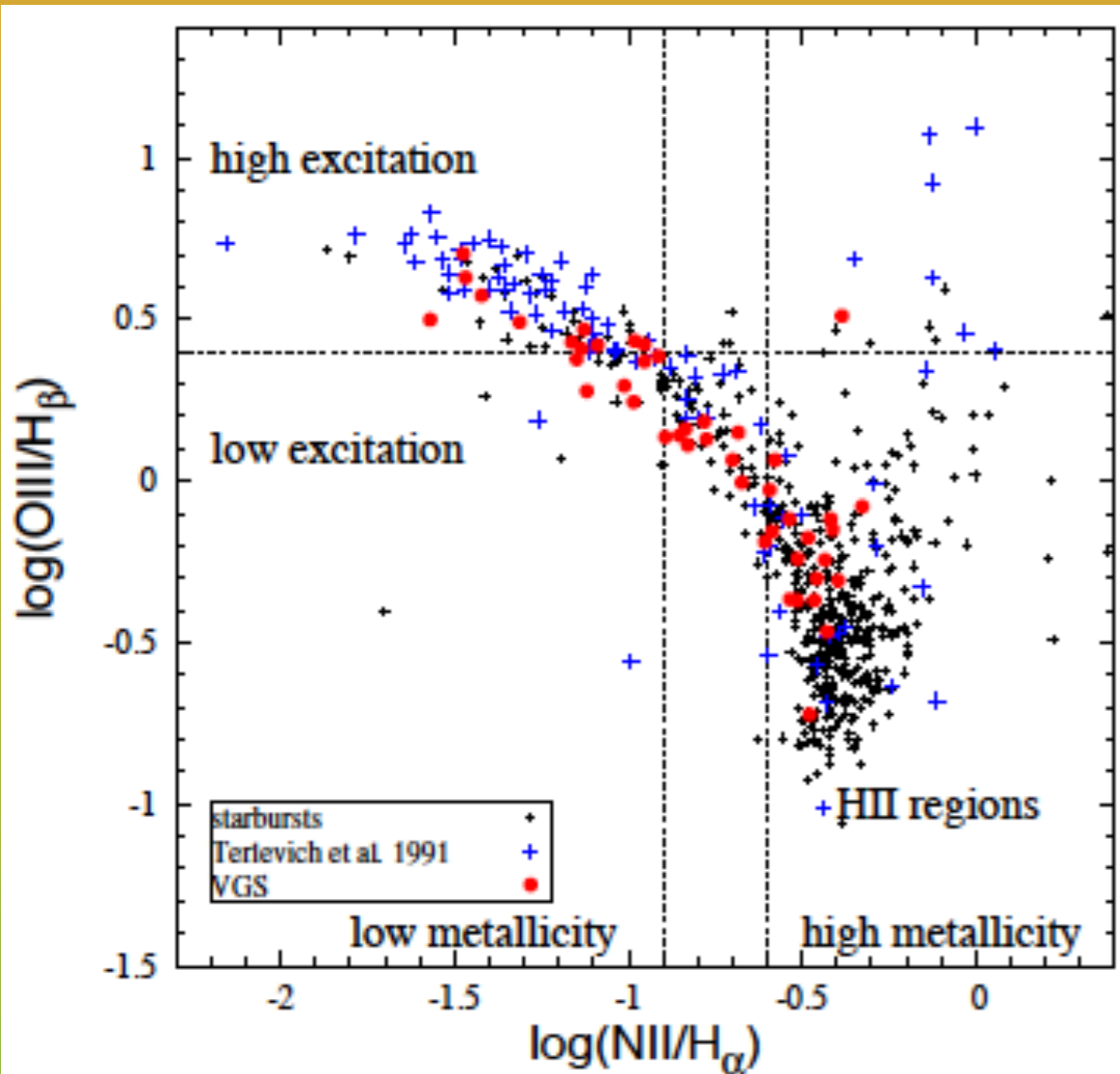
- **SFEs ( $\text{SFR}/M_{\text{HI}}$ ) and S-SFRs ( $\text{SFR}/M_*$ ) per  $M_*$**
- **compared to intermediate density environment galaxies; LV galaxies (Karachentsev et al. 2013), ALFALFA, JCMT**
- **There is no significant difference, similar trend, also not each mass bin equ.**



- **SFE (SFR/M<sub>H I</sub>) S\_SFR (SFR/ M<sup>\*</sup>) per M<sub>H I</sub>**
- **similar to previous comparison, there is no significant difference**



# Emission line properties and AGN population

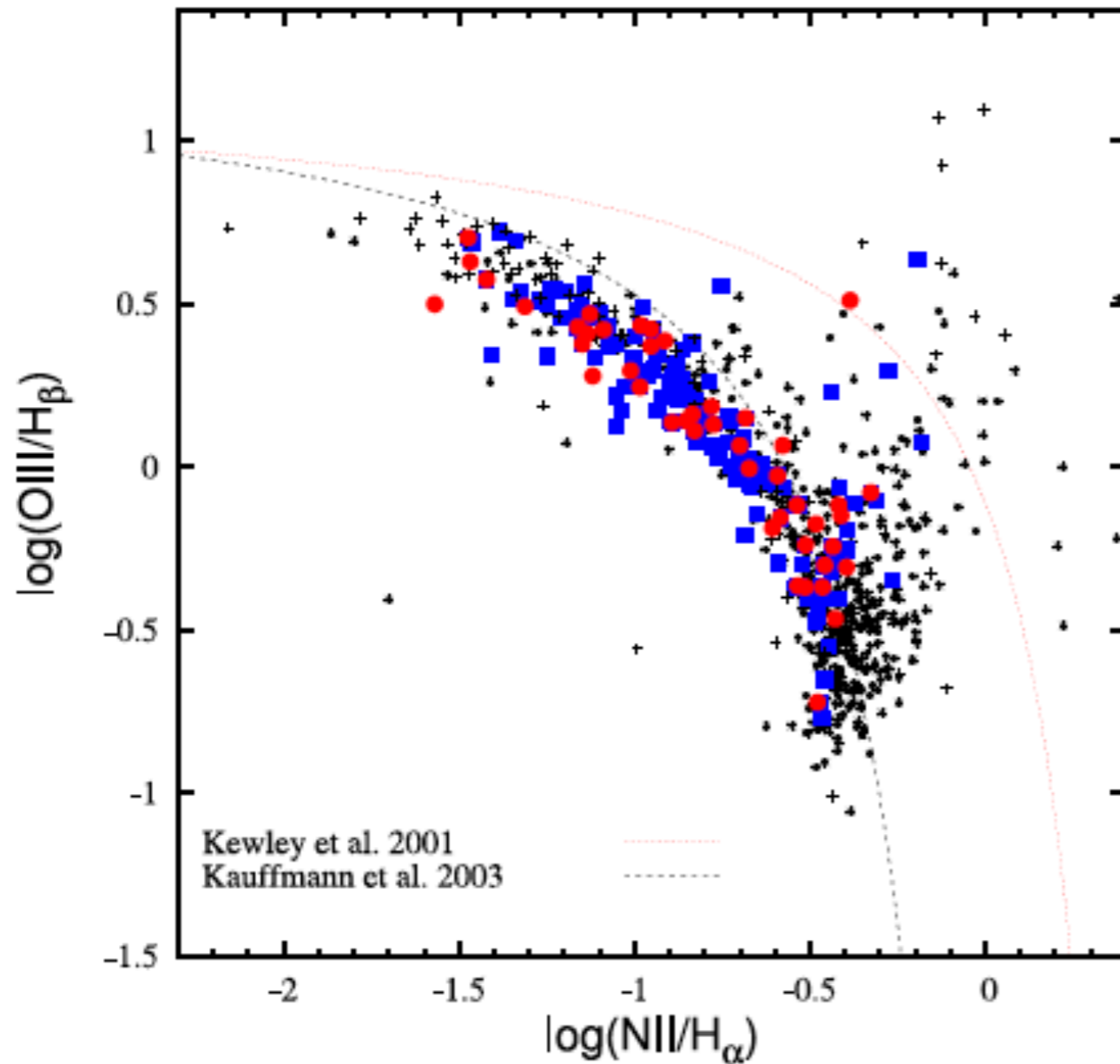


- VGS galaxies in the BPT diagram
- Based on SDSS spectra
- Star forming, HII galaxies
- 1 AGN out of 59 void galaxies

# Summary and Discussion

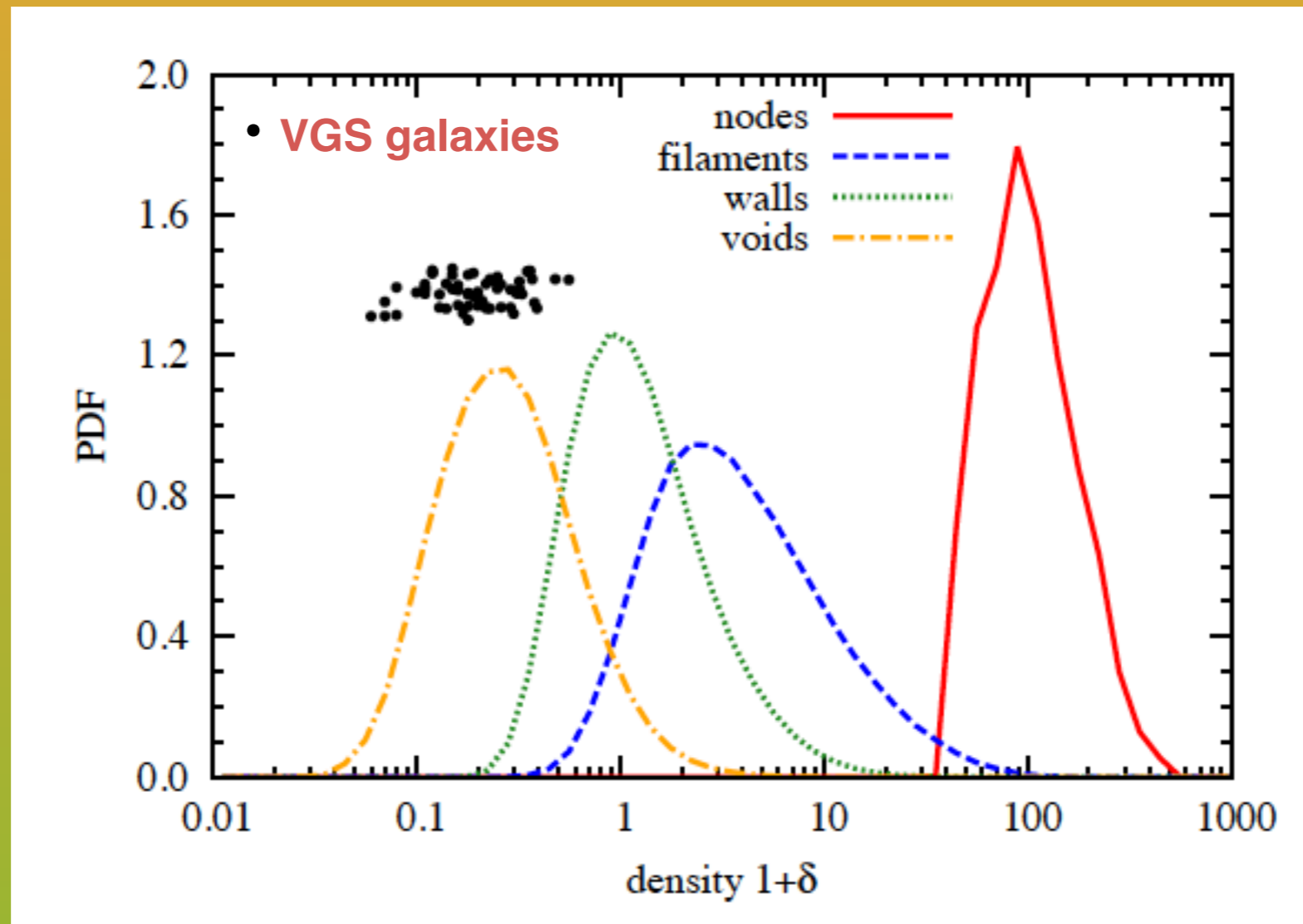
- **VGS galaxies mostly consist of blue late-type disk galaxies.  $n < 2$**
- **There are occasional red early types, AGN and irregular galaxies.**
- **There is a population of interacting/ maj. merging galaxies apart from the isolated (without companion) void galaxies**
- **VGS galaxies are star forming galaxies.**
- **S\_SFRs and SFEs per  $M_*$  and  $M_{\text{HI}}$  are similar to those of field / intermediate density environment galaxies.**
- **VGS may evolve to be large dEs**
- **Voids in our sample don't seem to be populated by a particular type of void galaxy; environment has an effect on  $M_*$  and size ?**

# Emission line properties and AGN population

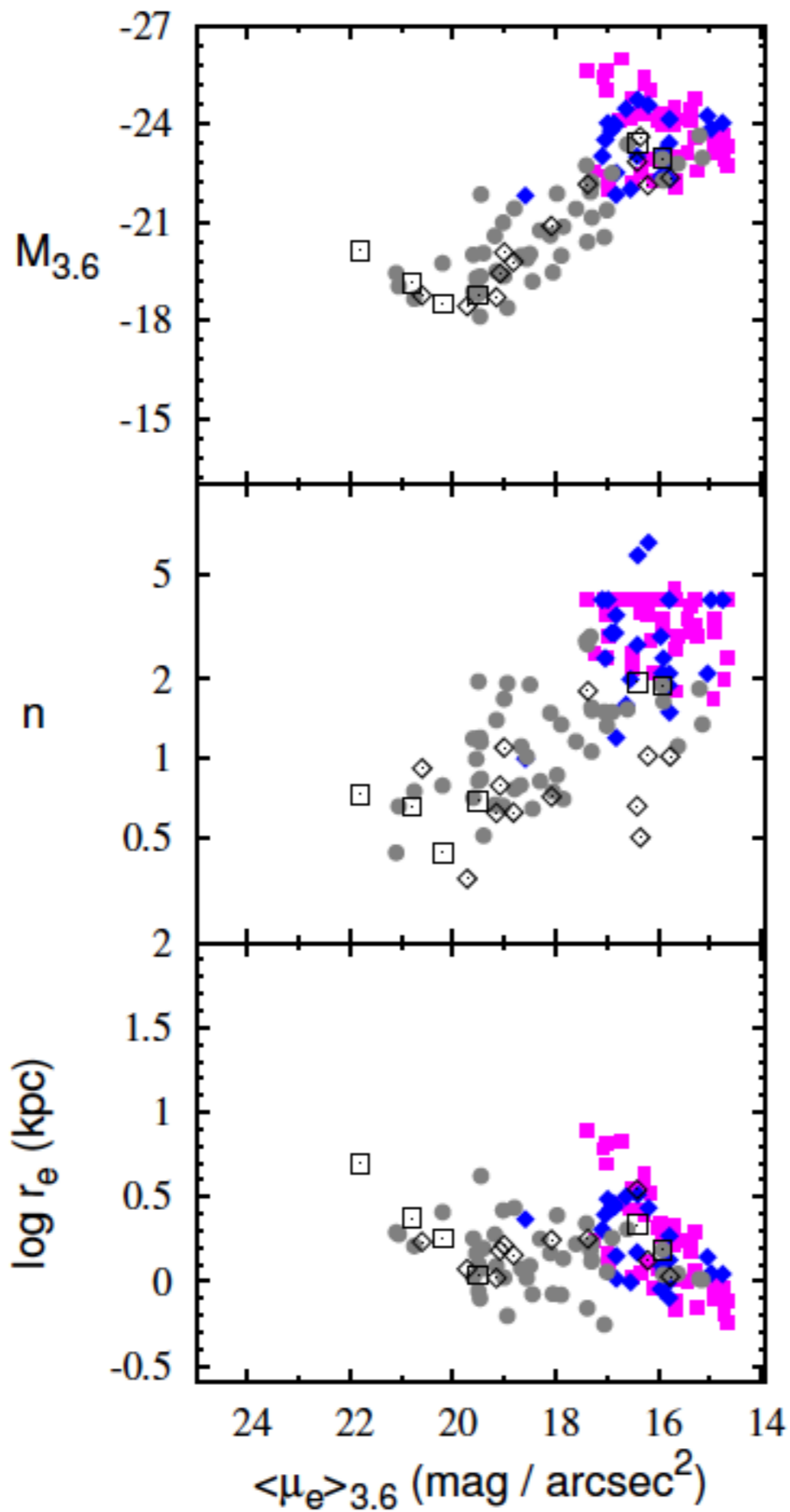


- complete void galaxy sample
- 2 AGNs
- consistent with 60 VGS

# VGS galaxies and the cosmic web

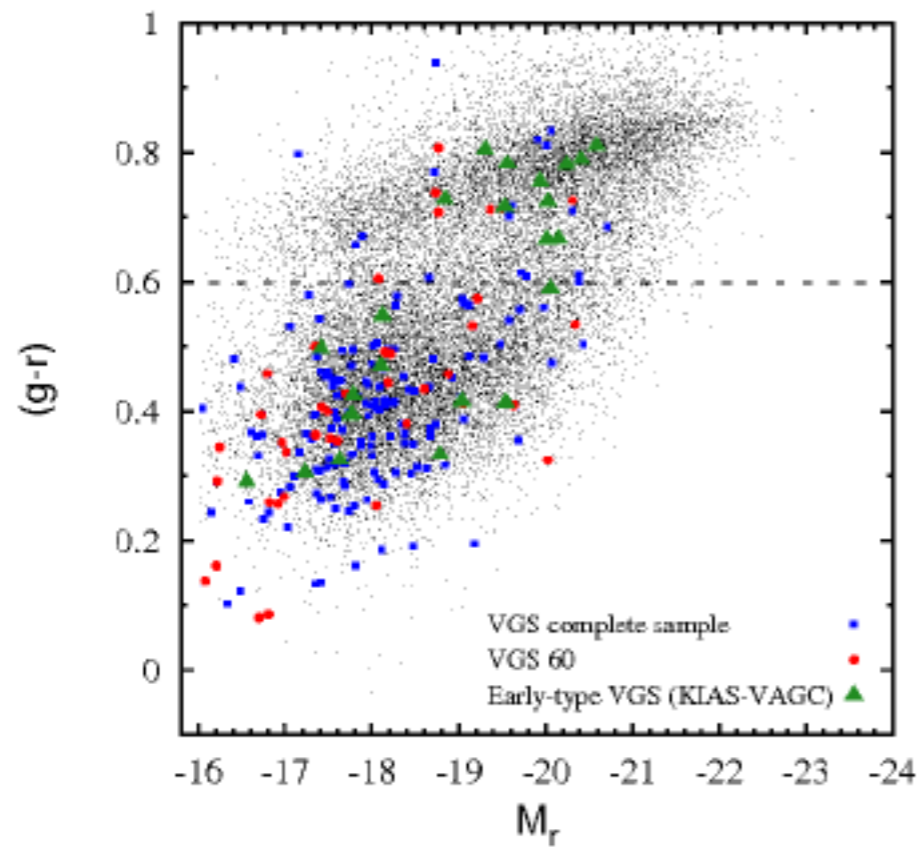


- **VGS galaxies and the density distribution over the different components of the cosmic web (courtesy of Marius Cautun)**



- VGS ●
- VGS Irr □
- VGS edge-on ◇
- Ellipticals from the SAURON project ■
- Sa galaxies from the SAURON project ◆





(a)

