

# SSH: the Smallest Scale of Hierarchy Survey

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## **The Survey team:**

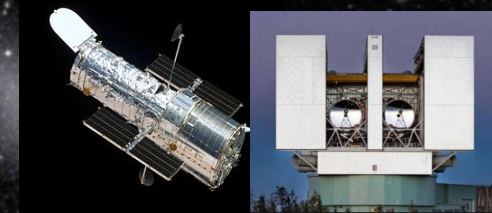
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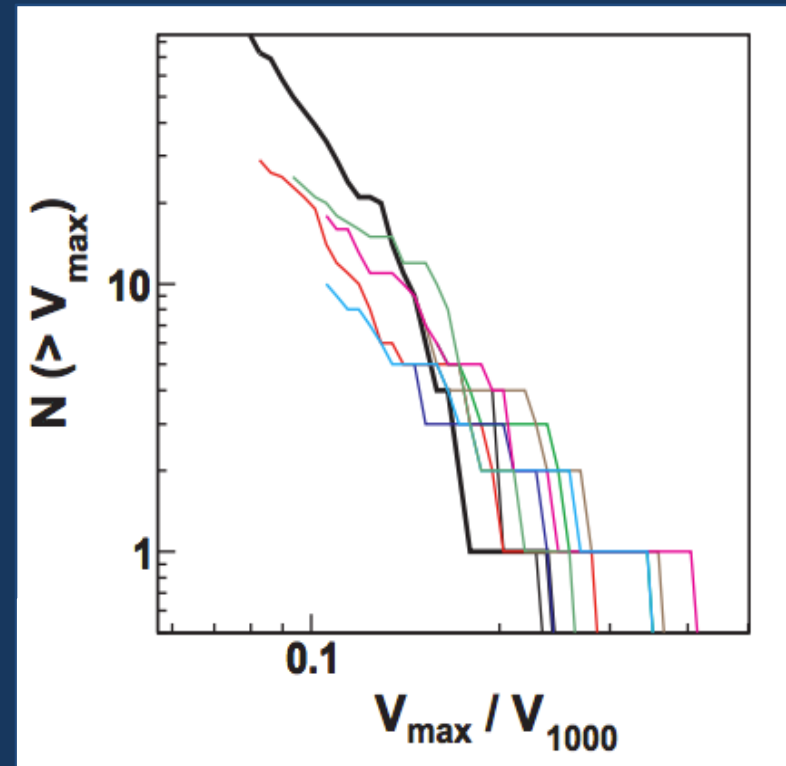
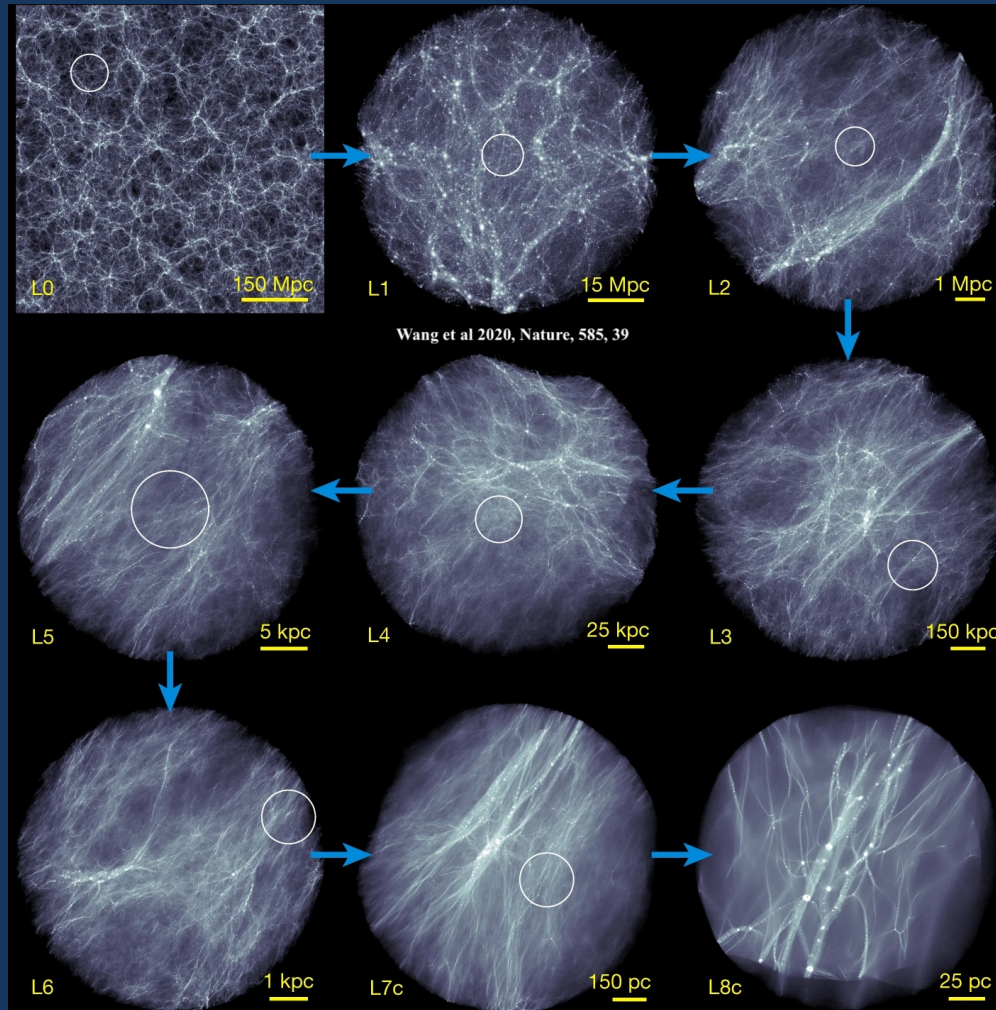


The Milky Way Assembly Tale  
BOLOGNA MAY 27-31, 2024





In  $\Lambda$ CDM DM haloes are self-similar in their shape and distribution of associated structures down to very small scales (Earth mass – solar system size)...



DM halos and sub-halos have the same relative abundance of substructures  
 (Diemand + 08, Nature 454, 735  
 Wang+20, Nature, 585, 39)

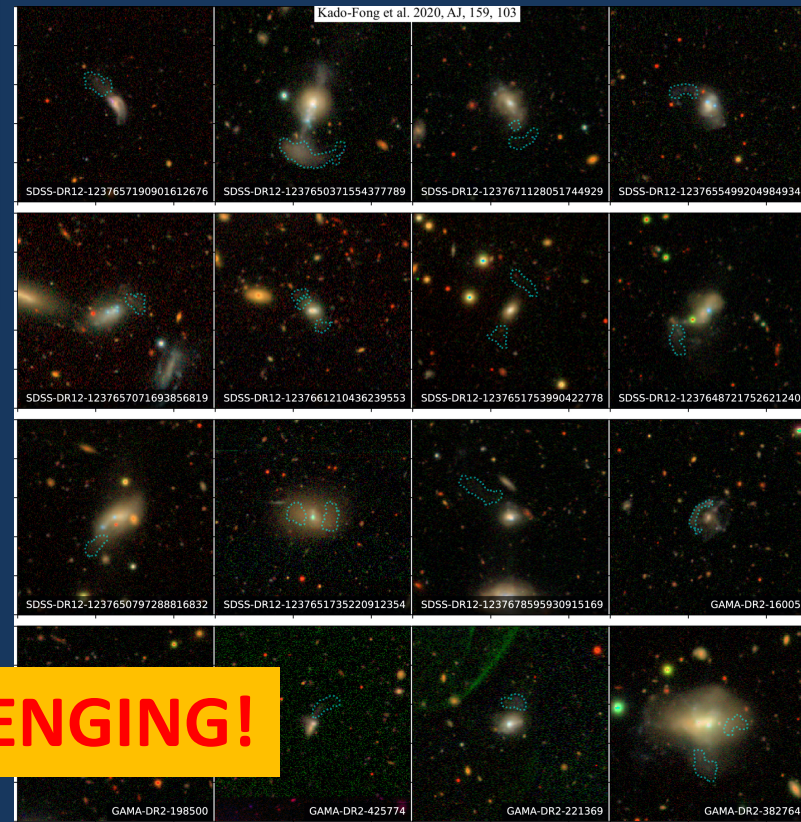


... hence satellites of dwarf galaxies should exist as well as the signature of interaction/merging of dwarfs with their satellites



Testing the hierarchical process of galaxy formation at the smallest scales

A few local cases  
Some systematic investigation starting/ongoing



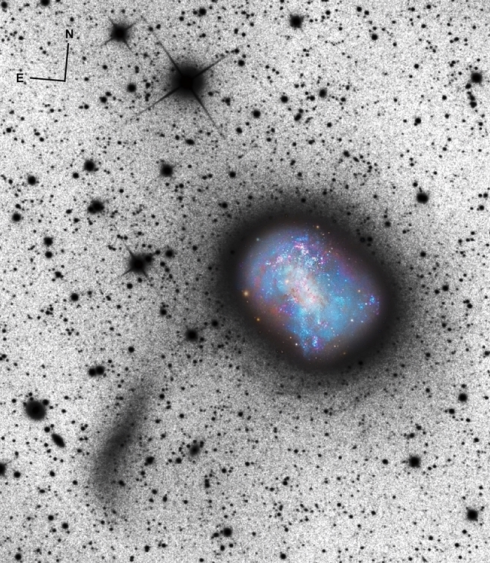
Kado-Fong et al. 2020, AJ, 159, 103

SDSS-DR12-1237657190901612676 SDSS-DR12-1237650371554377789 SDSS-DR12-1237671128051744929 SDSS-DR12-1237655499204984934

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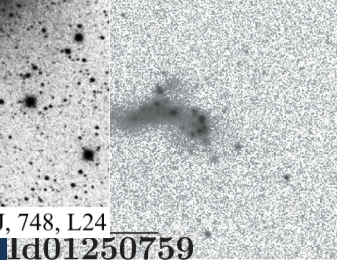
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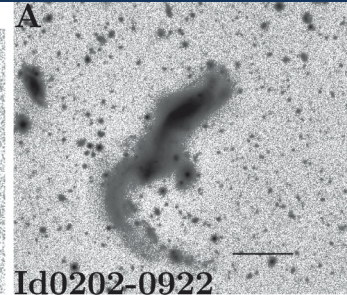


NGC4449: Martinez-Delgado+12, ApJ, 748, L24

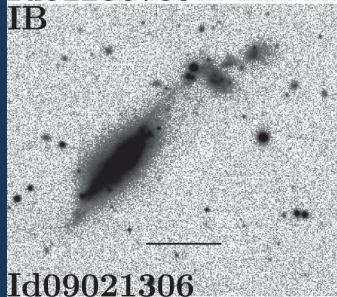
Paudel+18, ApJS, 237, 36



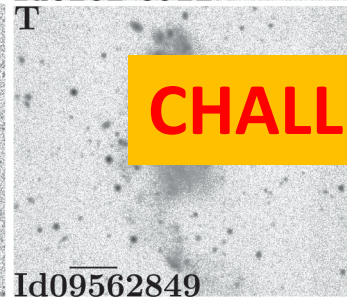
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CHALLENGING!

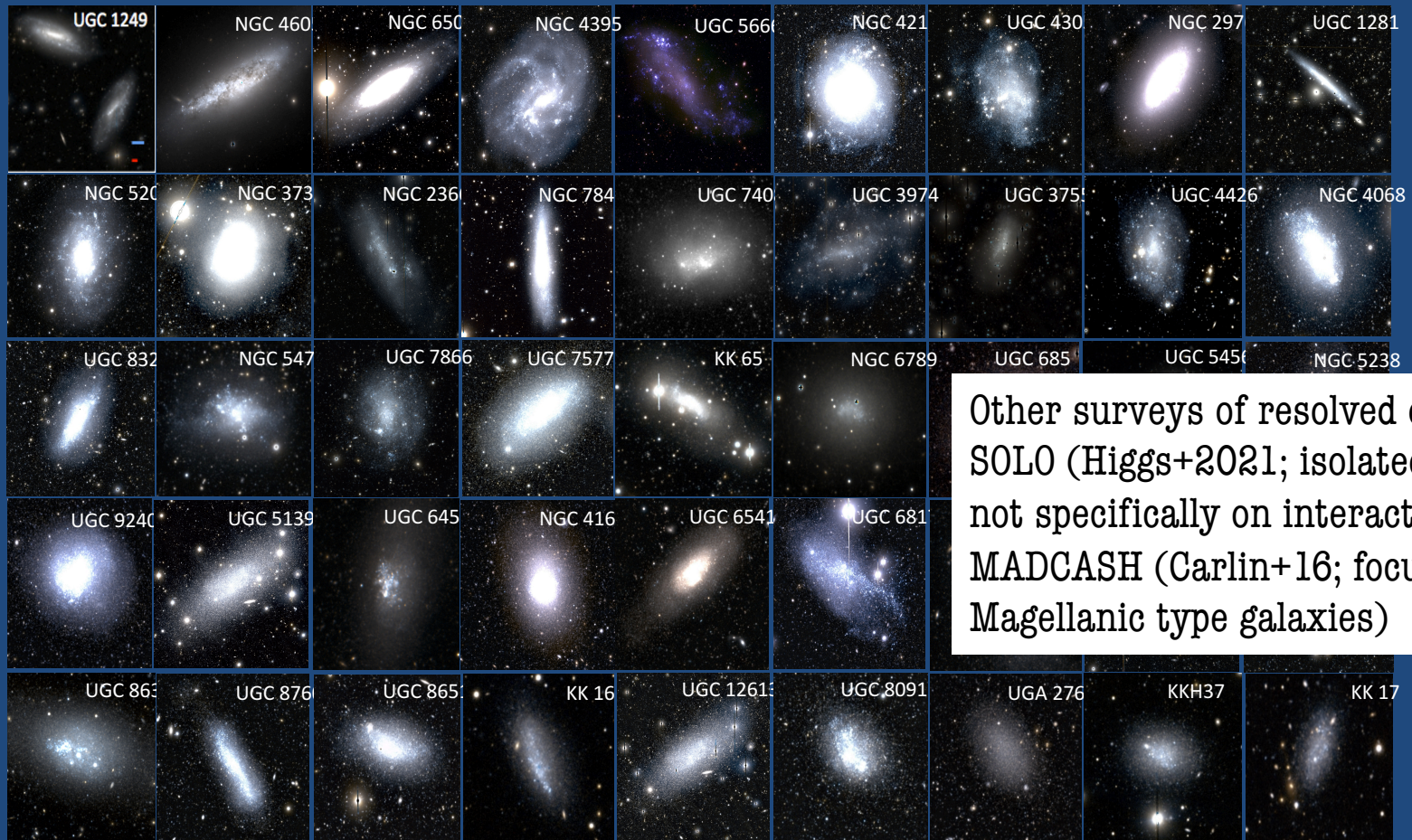
Poster by M. Pederzoli et al.  
Poster by D. Martinez-Delgado et al.



# SSH: our flavour of systematic study on hierarchical build up of dwarfs

## Getting insight into the relationship between interactions and star formation

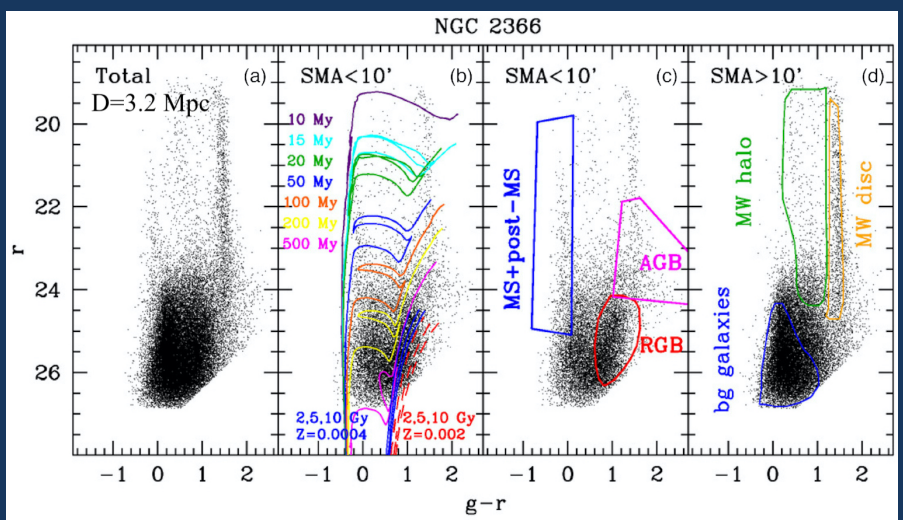
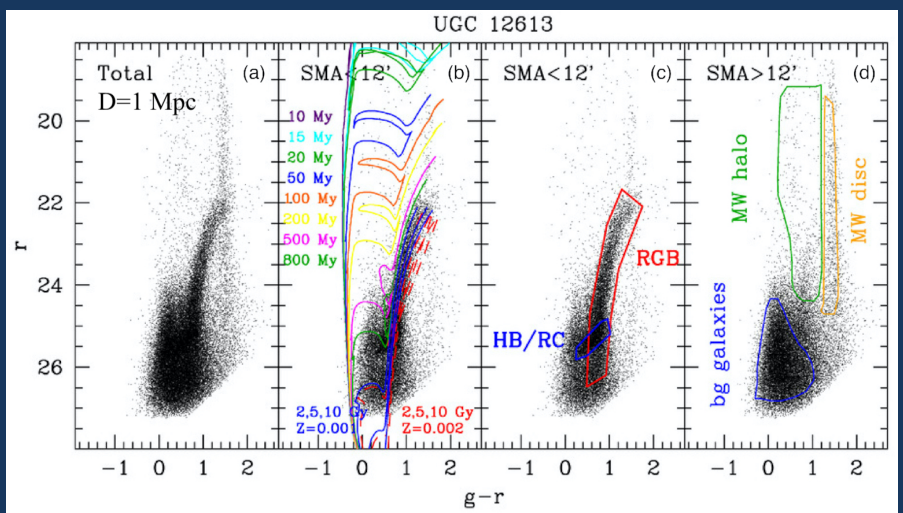
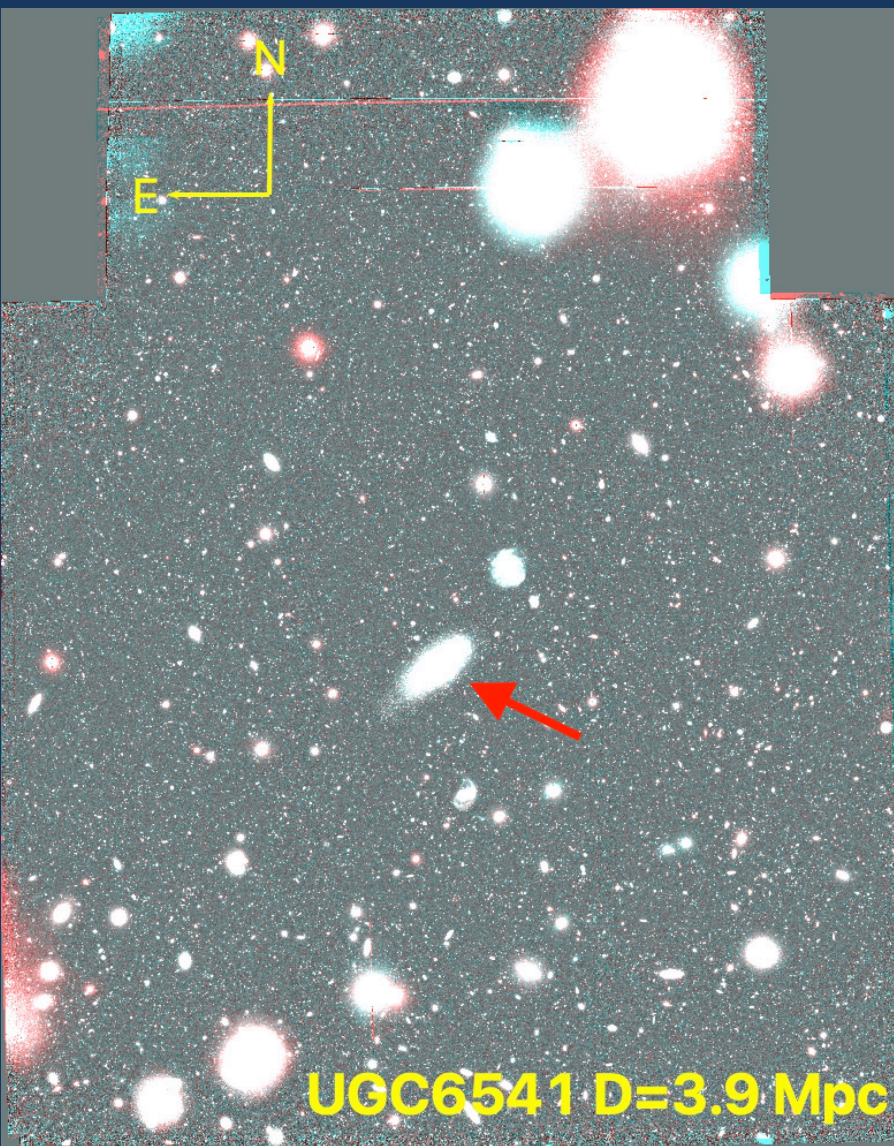
- 45 local ( $D \gtrsim 10$  Mpc) late type dwarfs, at least partially resolved (tracing density by star counts)
  - Having HST imaging in the central part (to correlate with SFH)
  - Isolated, i.e. far from large galaxies (to facilitate the interpretation of disturbances)
    - $0.002 \times L_B(\text{LMC}) \lesssim L_B \lesssim 1.0 \times L_B(\text{LMC})$





**Acquiring deep wide field g,r imaging and photometry with LBC@LBT**

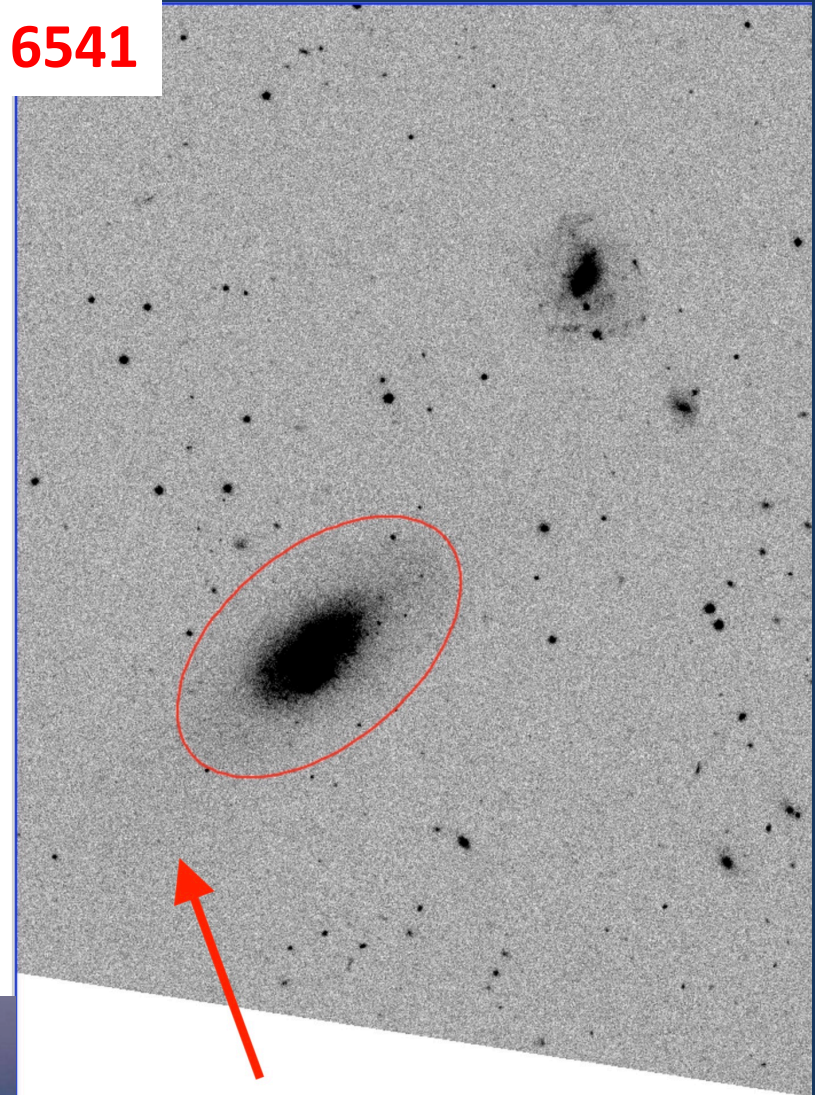
FoV  $\approx 23' \times 23'$ , subarcsec seeing  
 Reaching  $r=27.0$ , resolve RGB stars  
 Tracing stellar structures down to  $\mu_r \approx 30.5$  mag/arcsec<sup>2</sup>



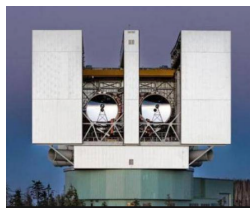


**Acquiring deep wide field g,r imaging and photometry with LBC@LBT**

**UGC 6541**



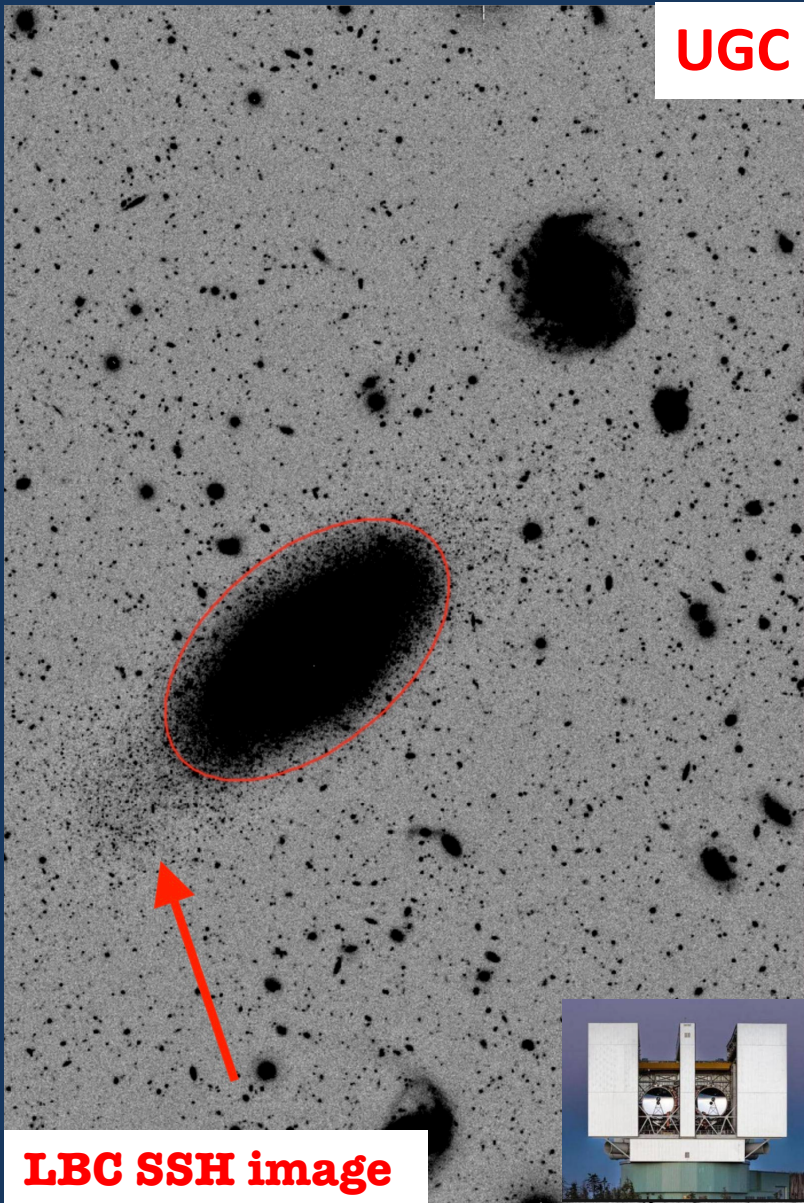
**SDSS DR12 r**



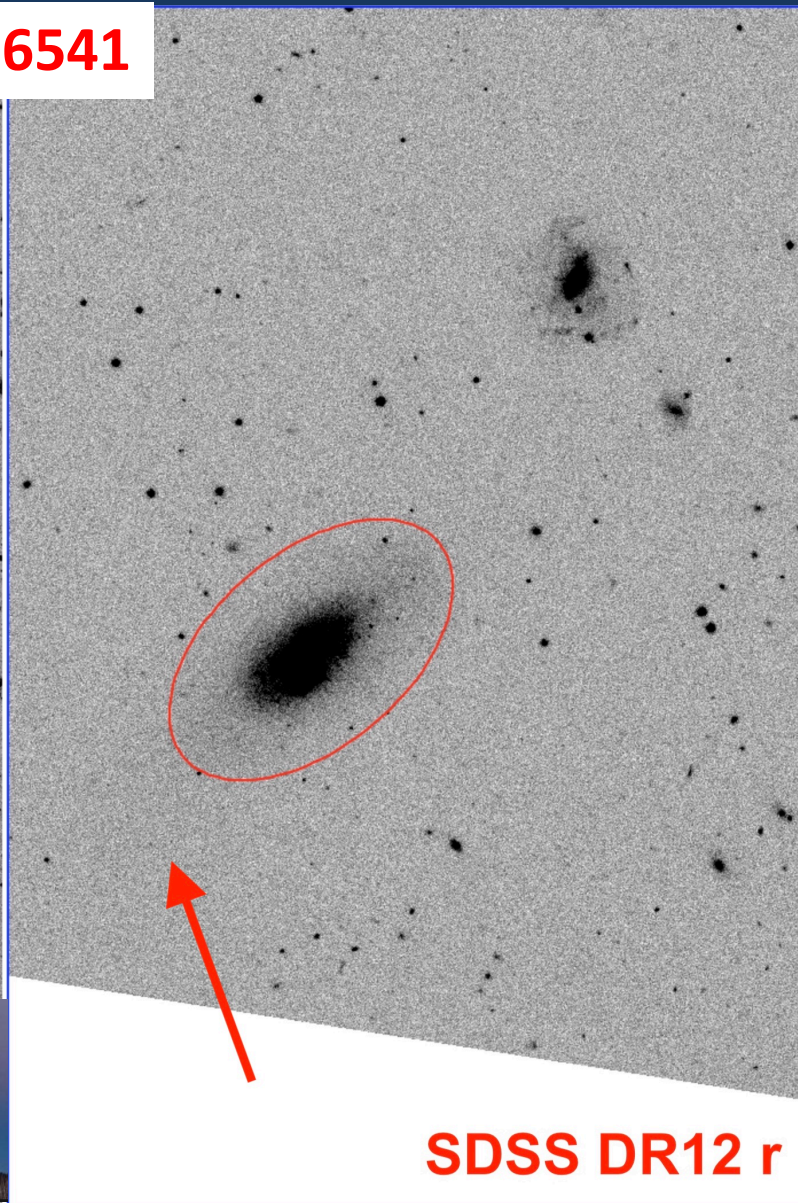


**Acquiring deep wide field g,r imaging and photometry with LBC@LBT**

**UGC 6541**



**LBC SSH image**



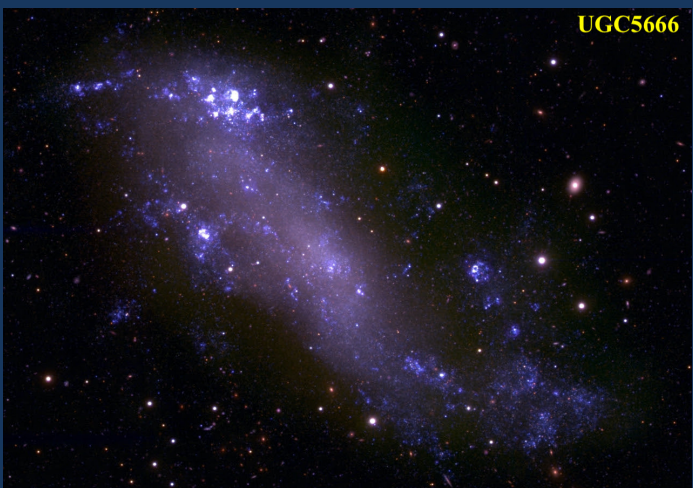
**SDSS DR12 r**





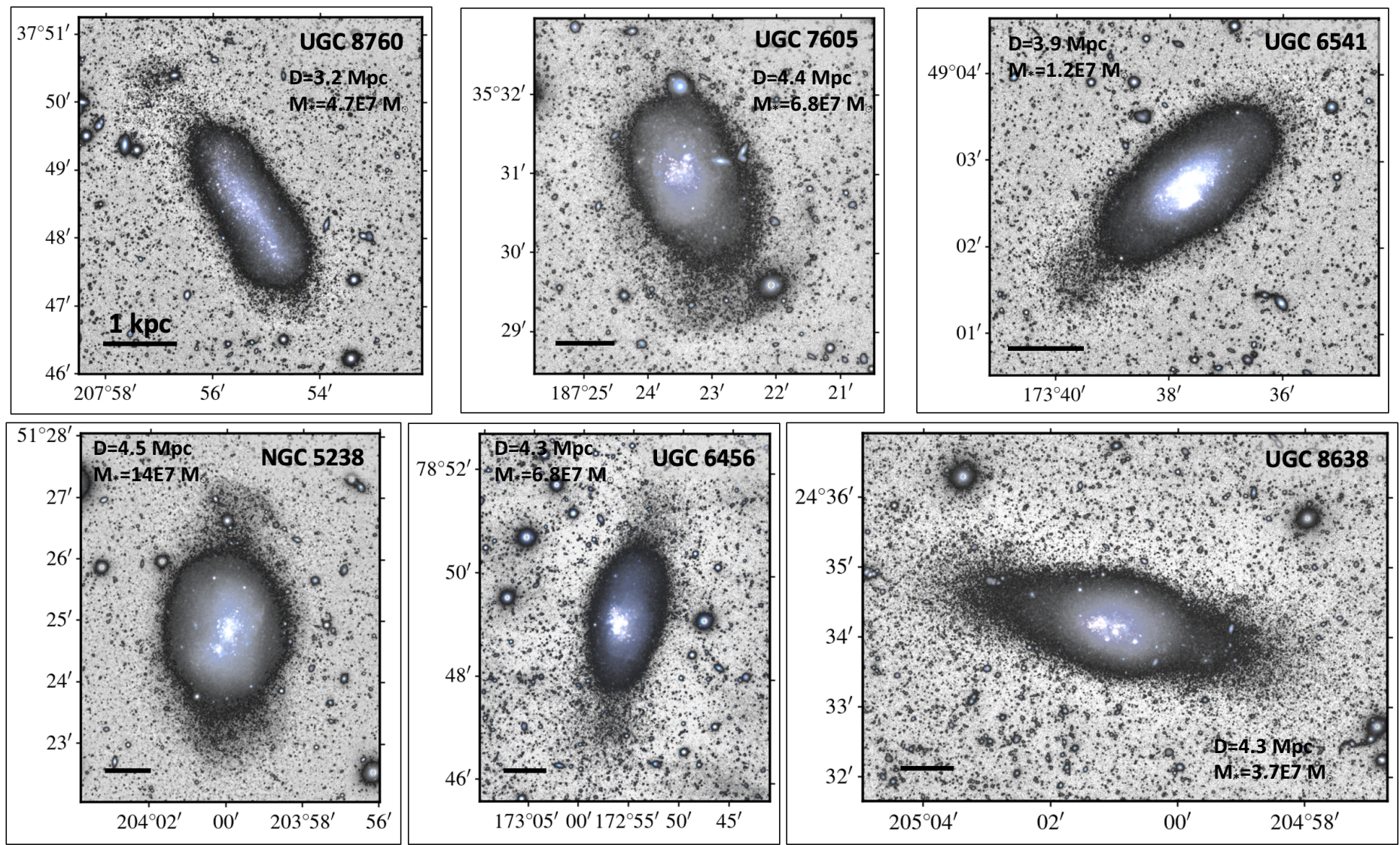
We know Star Formation may occur in very asymmetric configurations in dwarfs mimicking disturbance.

For this reason we consider only features dominated by old stars (RGB; age  $\gtrsim 2$  Gyr) that must trace genuine perturbations of the gravitational potential



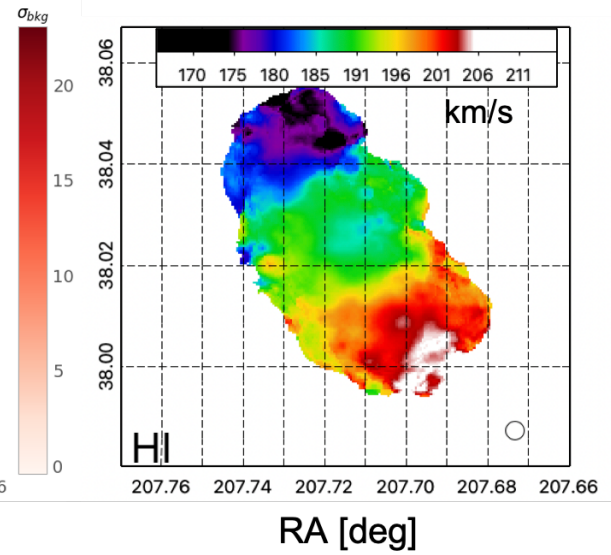
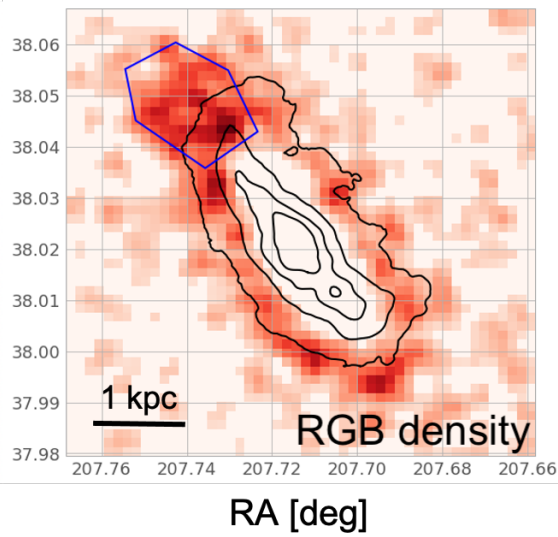
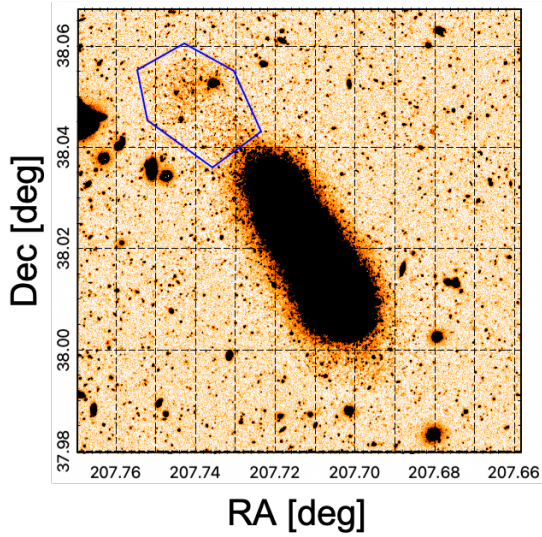


Asymmetric LSB features beyond the main body resembling the tidal features classified by Martínez-Delgado+2010

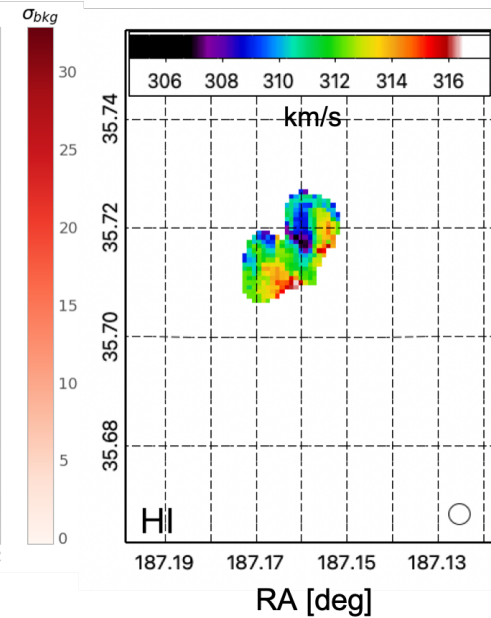
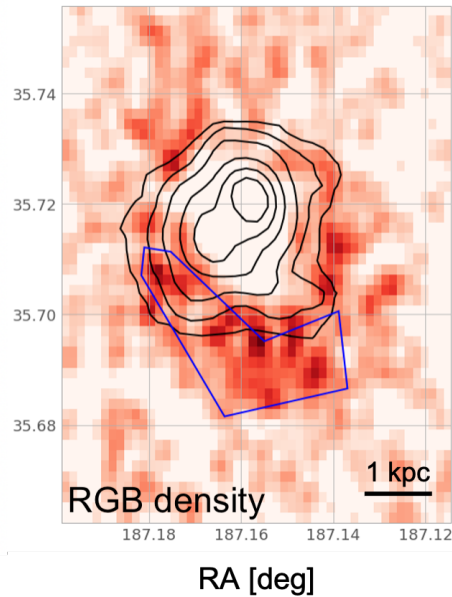
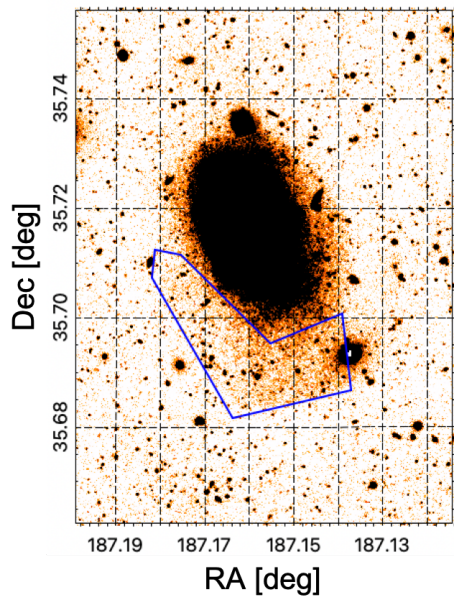




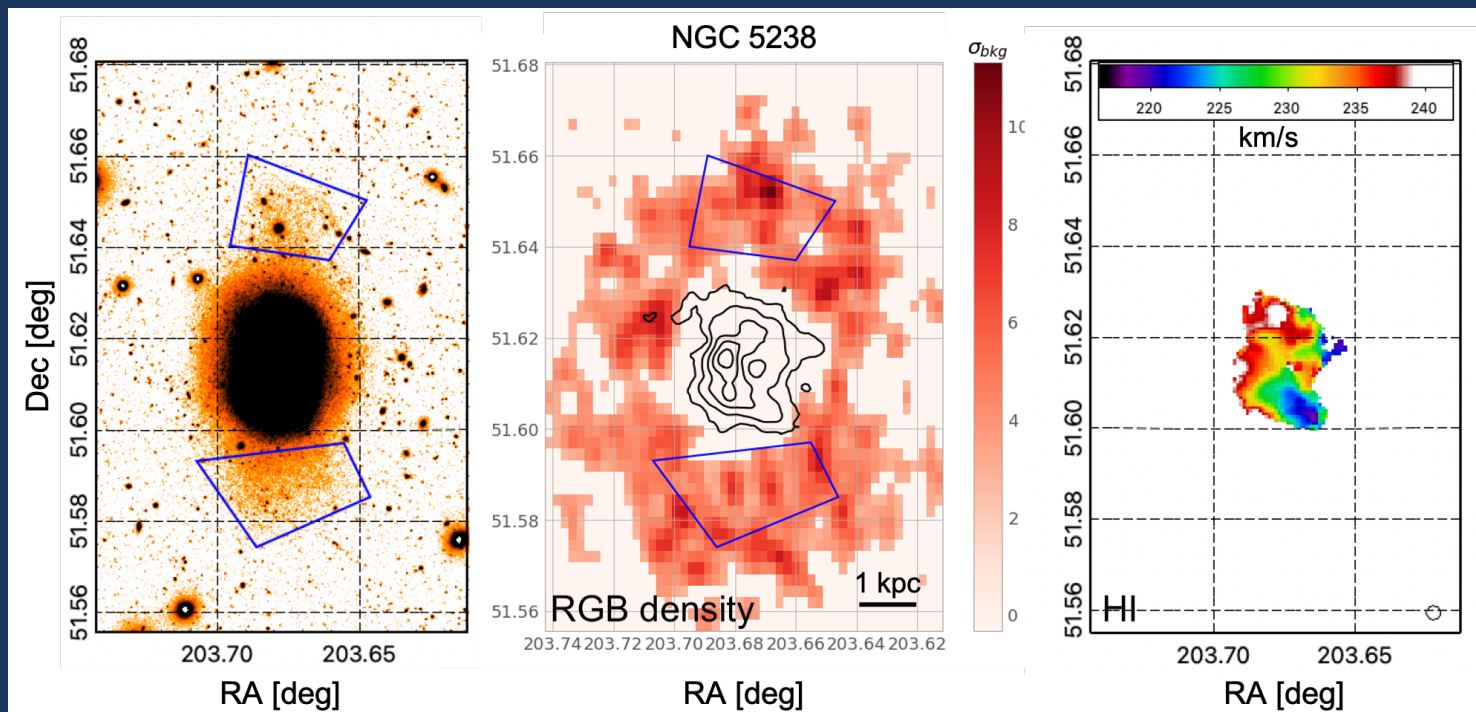
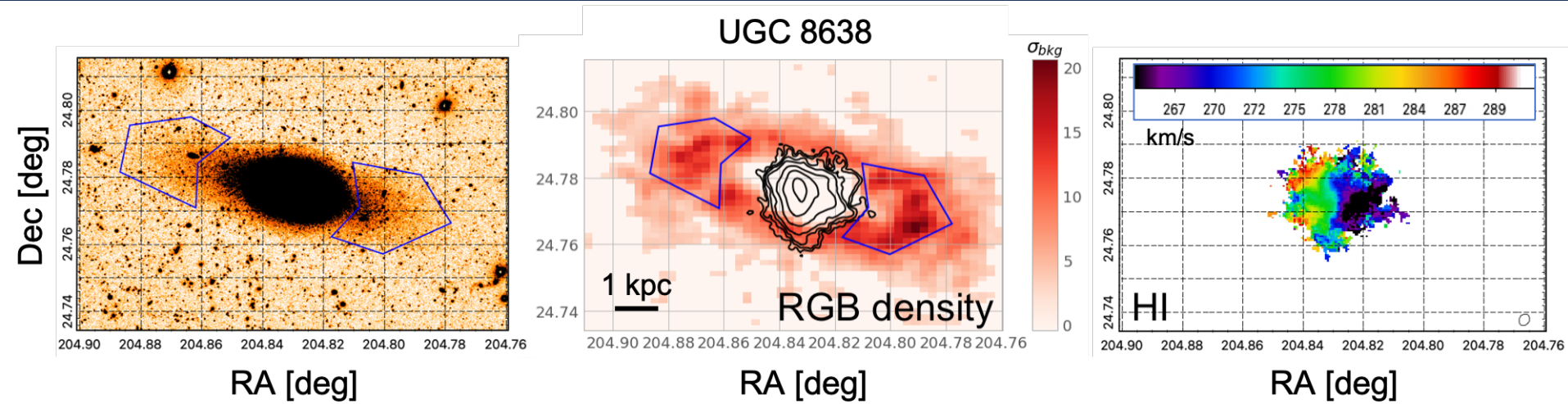
UGC 8760



UGC 7605



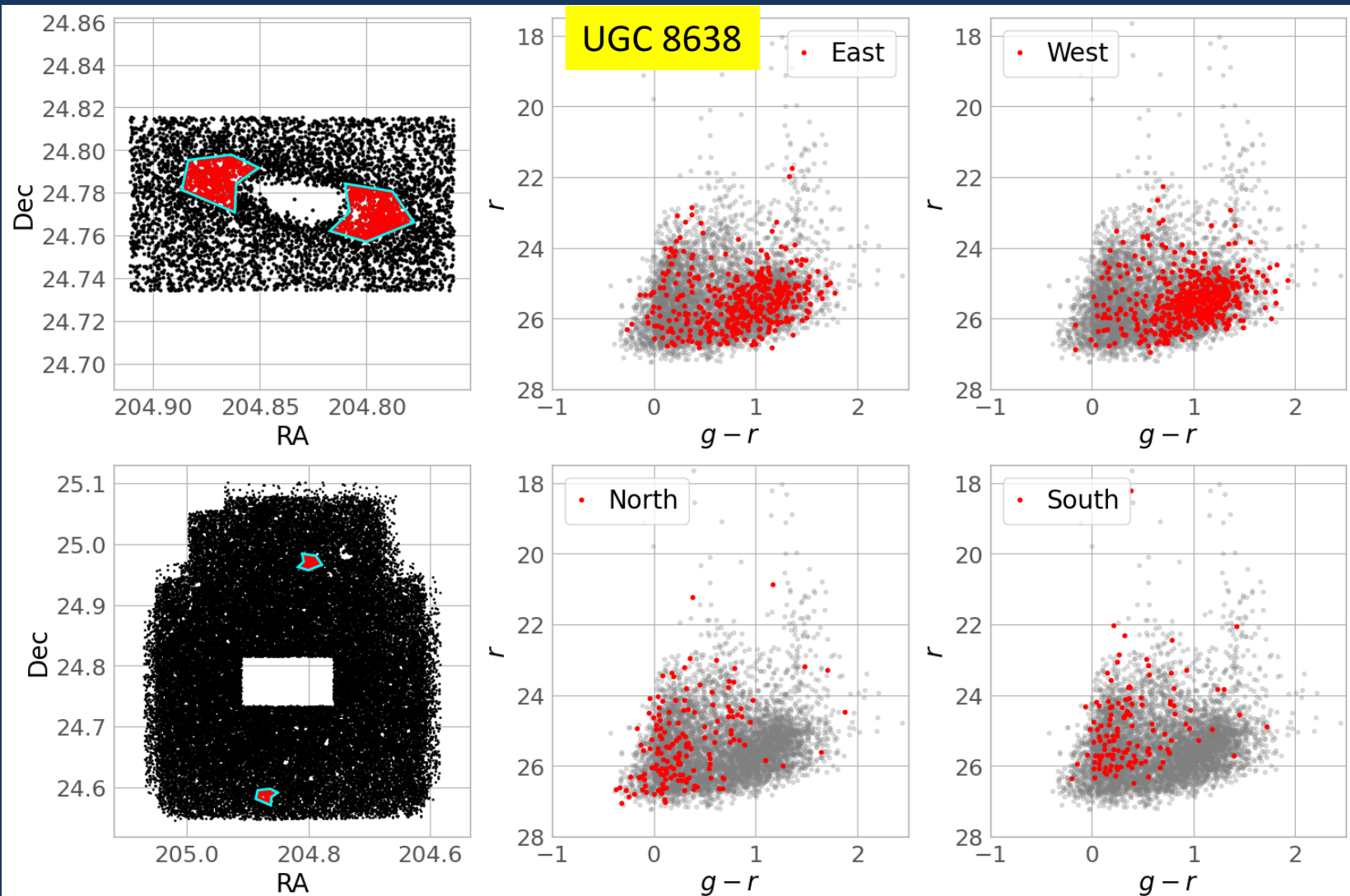






# Real RGB stars

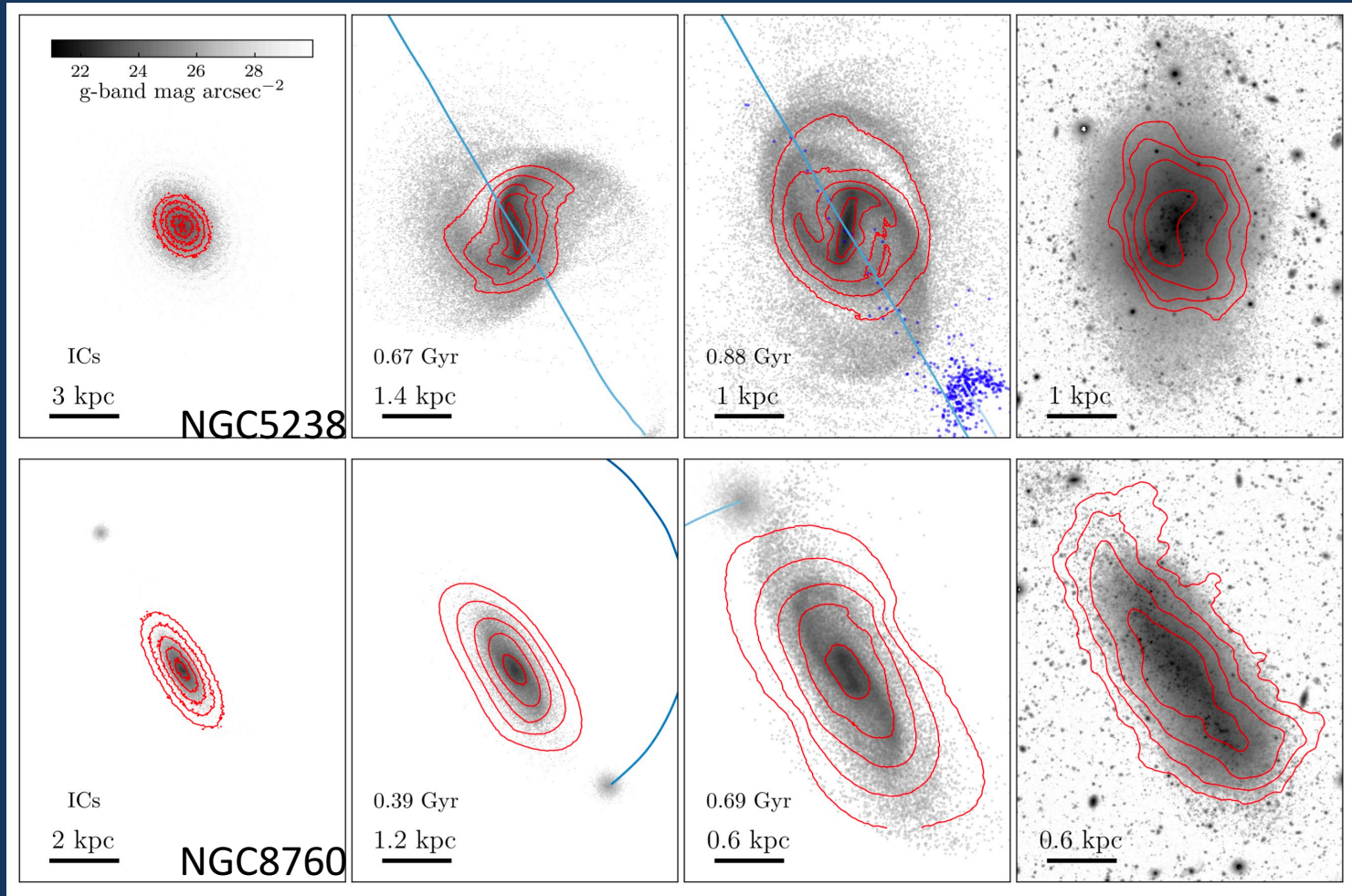
Our CMDs are very effective in classifying stars – Validated on HST data





**Can the observed distributions of stars and HI (+ HI kinematics) be produced by the interaction with a satellite? Individual cases investigated with N-body + hydrodynamical simulations (AREPO)**

Pascale+2024, A&A, in press (arXiv:2405.12284)



no claim of uniqueness in the proposed solutions: a “feasibility analysis”



# Summary 1

**SSH:** a survey aimed at finding signs of interactions with satellites in local star-forming dwarf galaxies

Deep wide-field high-resolution LBC imaging and photometry acquired for all the 45 selected targets – **data reduction completed**

Distribution of RGB stars used as tracer of features genuinely due to interactions

**Analysis ongoing:** looking for less evident tidal features, correlations with SF, surface brightness profiles etc.

We are finding clear extended tidal features in several target dwarfs. Following them up with additional observations and hydro-dynamical models.

From the six obvious cases we identified:

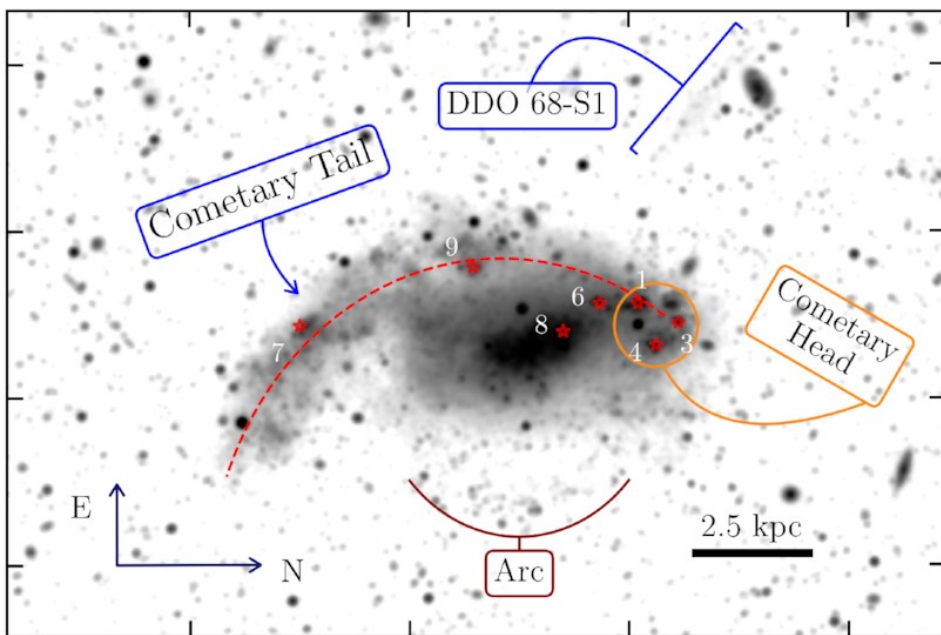
Fraction of tidally disturbed dwarfs in the SSH sample  $10\% \approx \mathbf{F} \approx 20\%$ , in broad agreement with the results of other surveys (Kado-Fong+20; Lazar+2024 – for late type galaxies) and with the available theoretical predictions in a  $\Lambda$ CDM framework (Deason+2014, 2022; Martin+2021)

See Sacchi+2024 for further discussion and more details

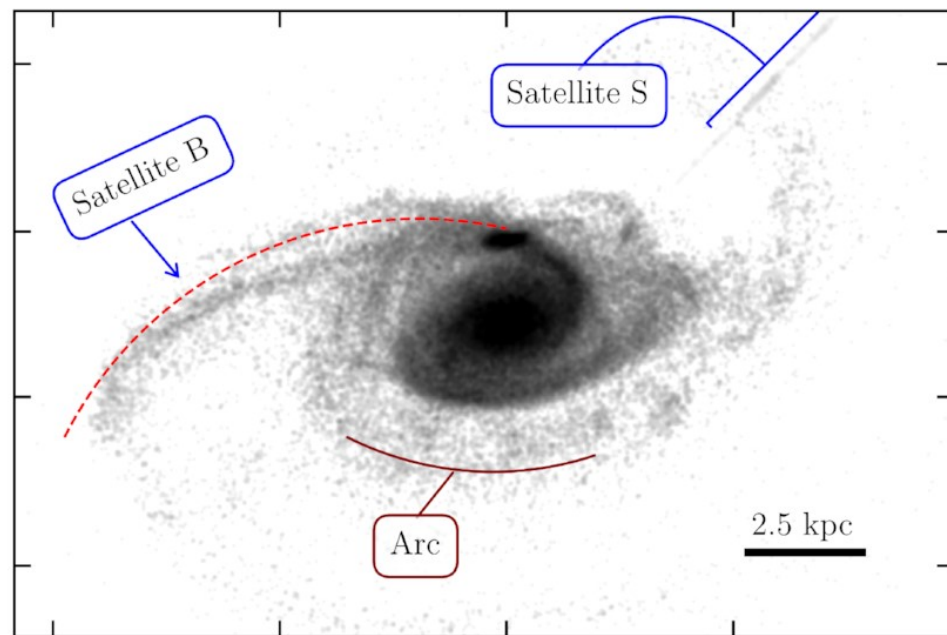


# SSH. A glance to what's coming. The **DD068** system

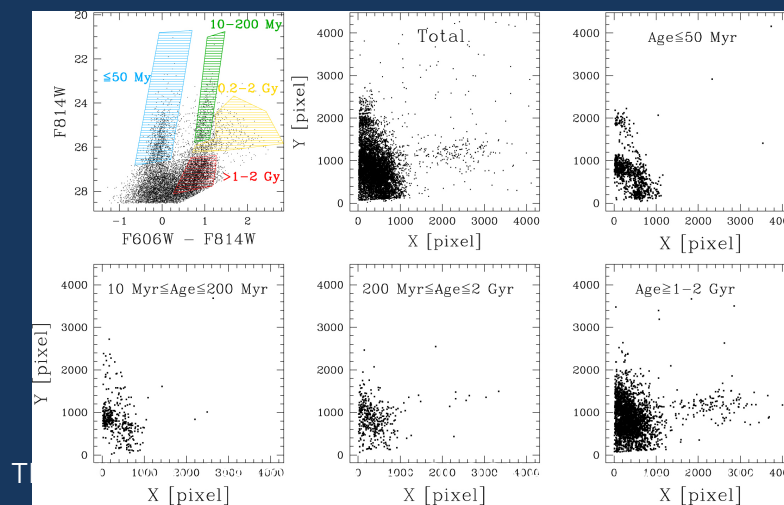
Observations



Simulation



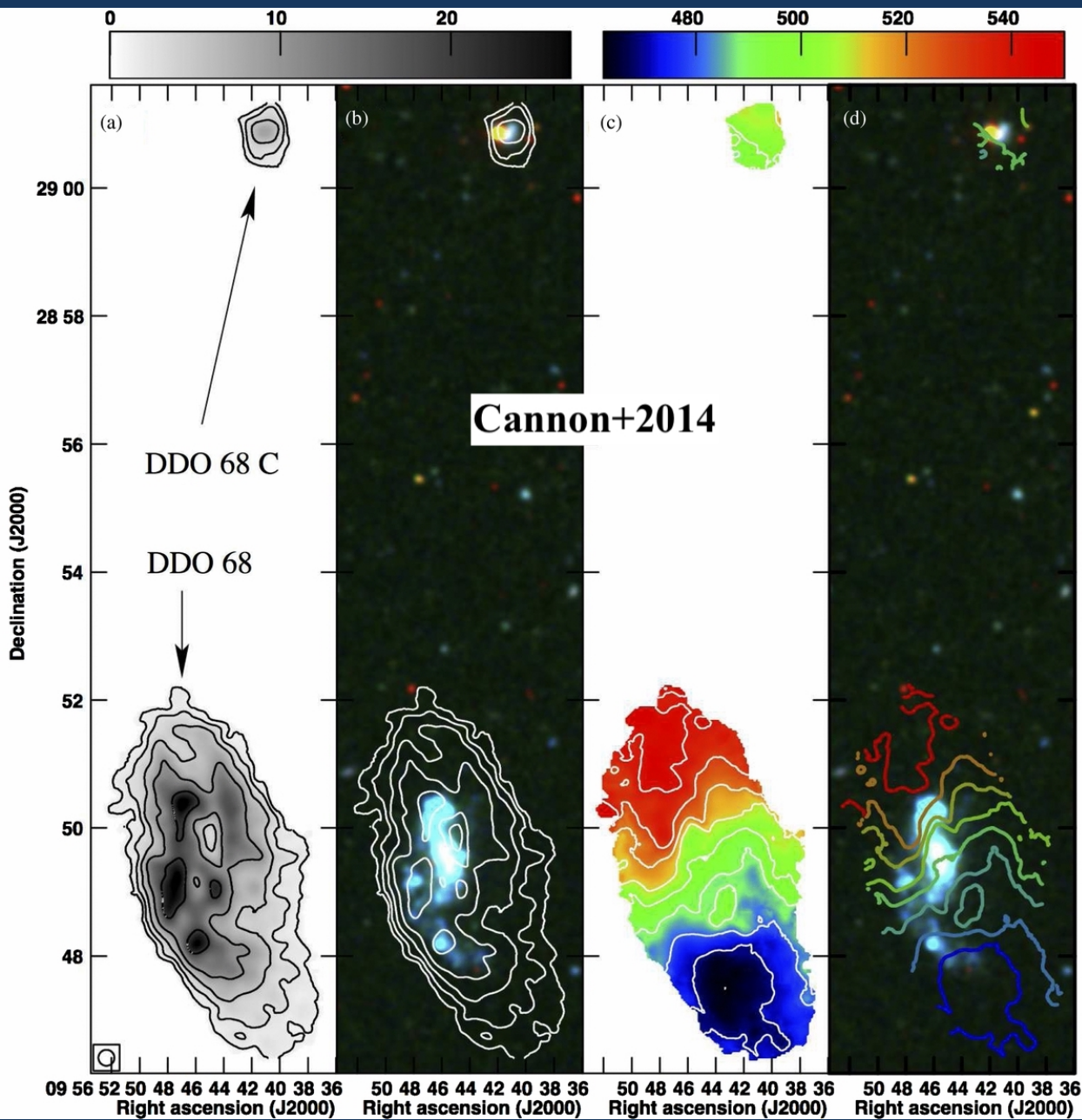
DD068 – A multiple merger dwarf. See Annibali+16,19a,19b; Pascale+2022



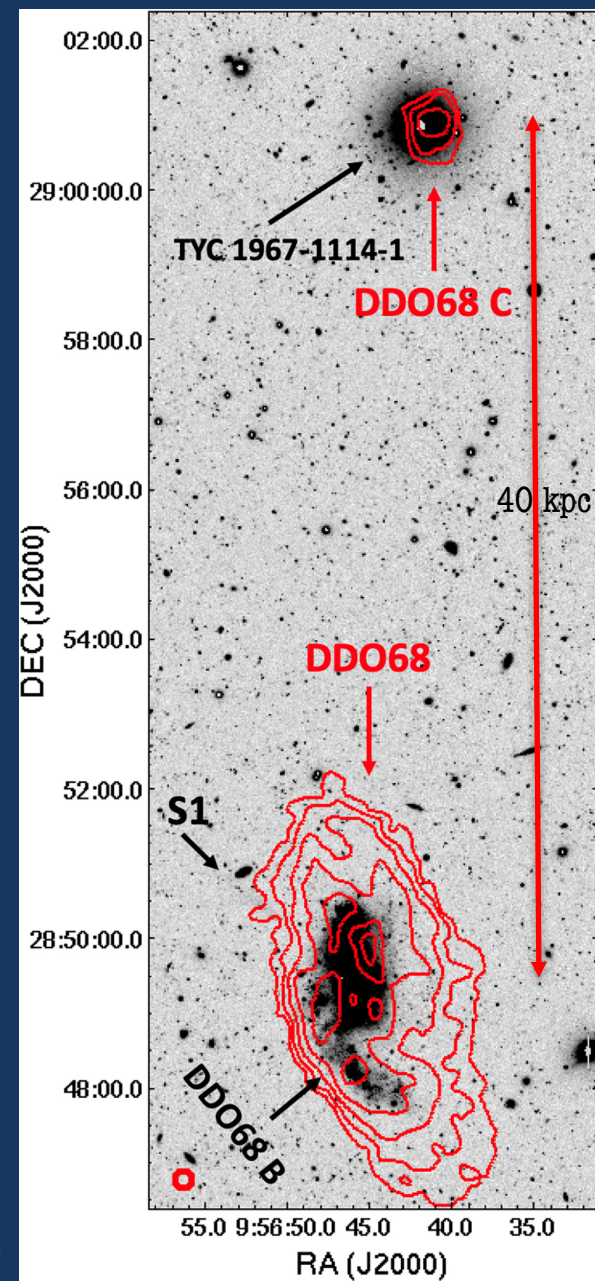
$M_* \approx 10^8 M_\odot$



# SSH. A glance to what's coming. The **DD068** system

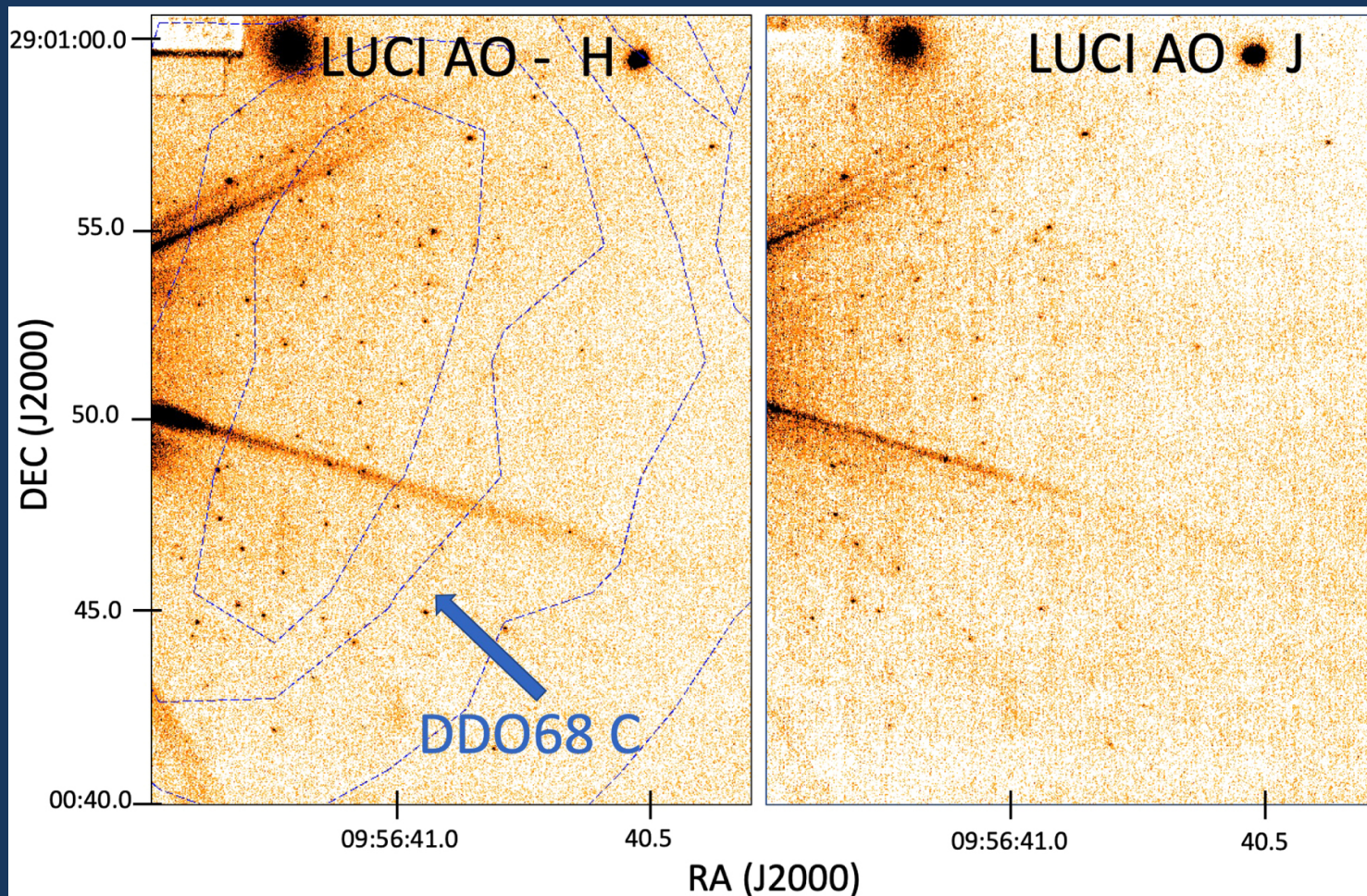


2024



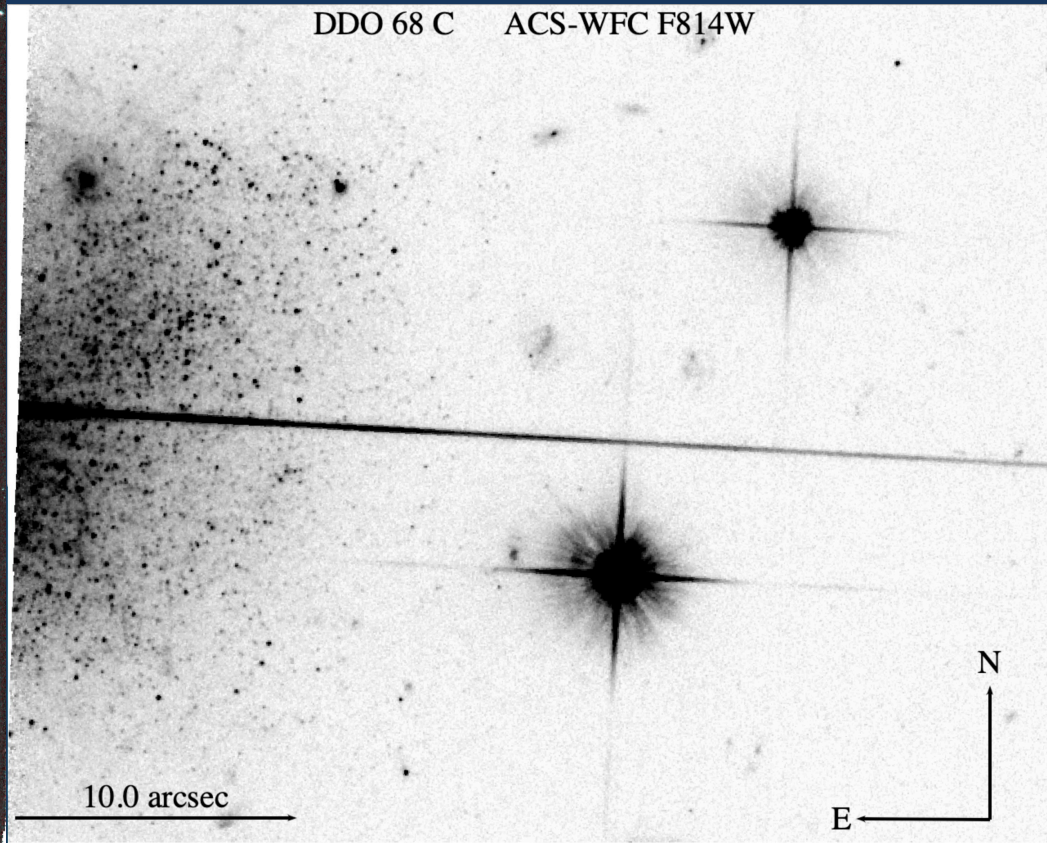
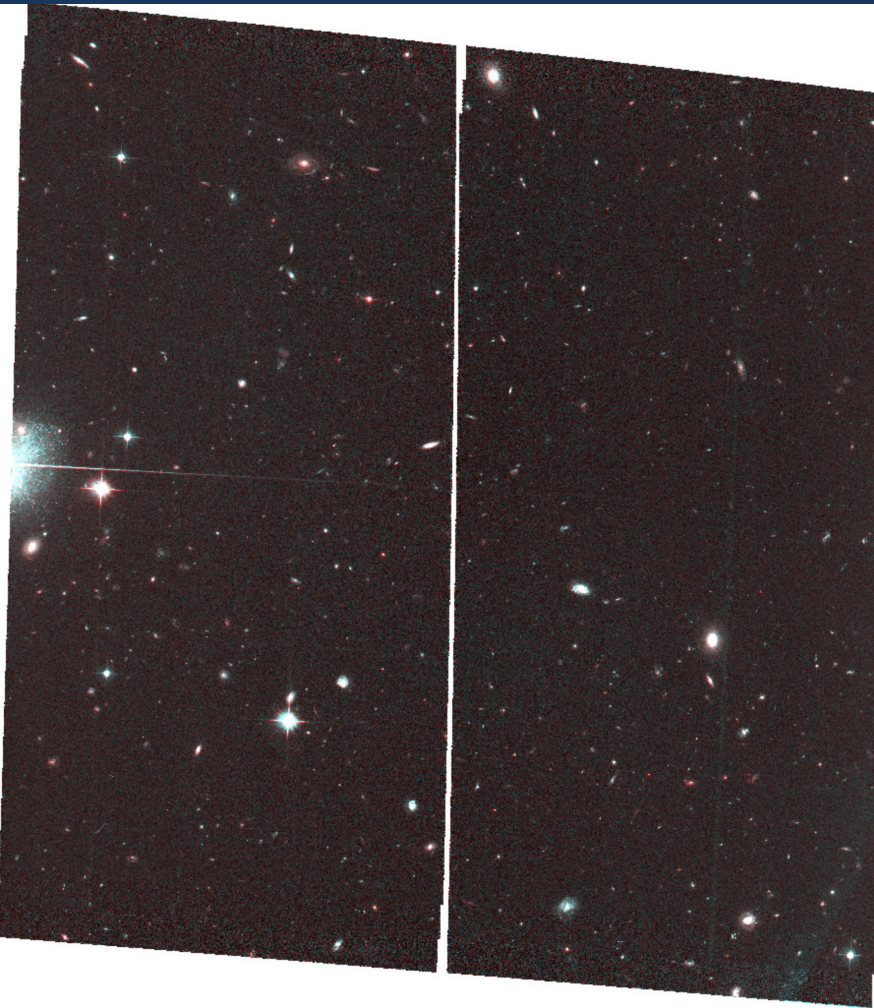


# SSH. **DD068 C** from **AO: SOUL+LUCI @LBT**



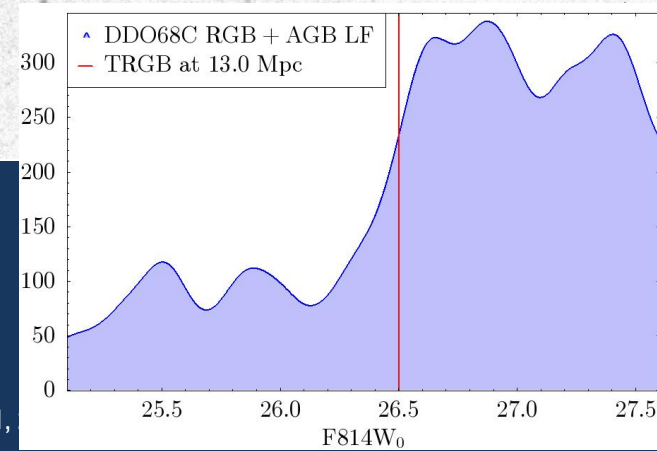
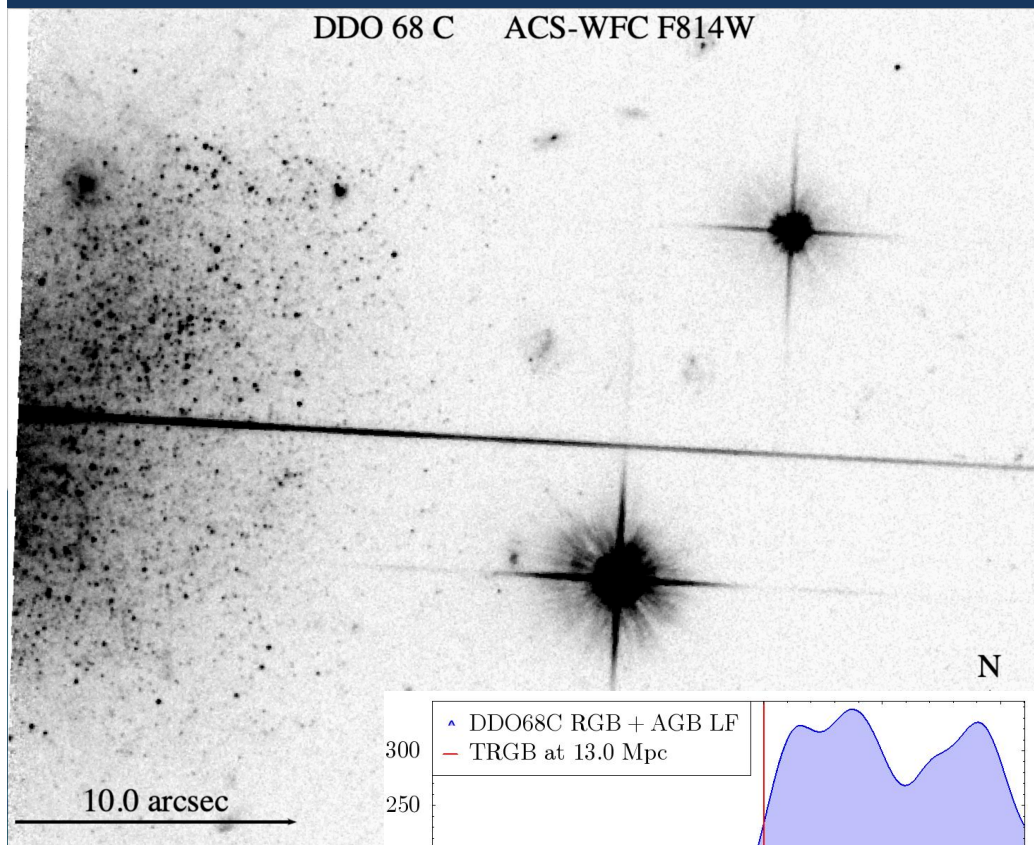
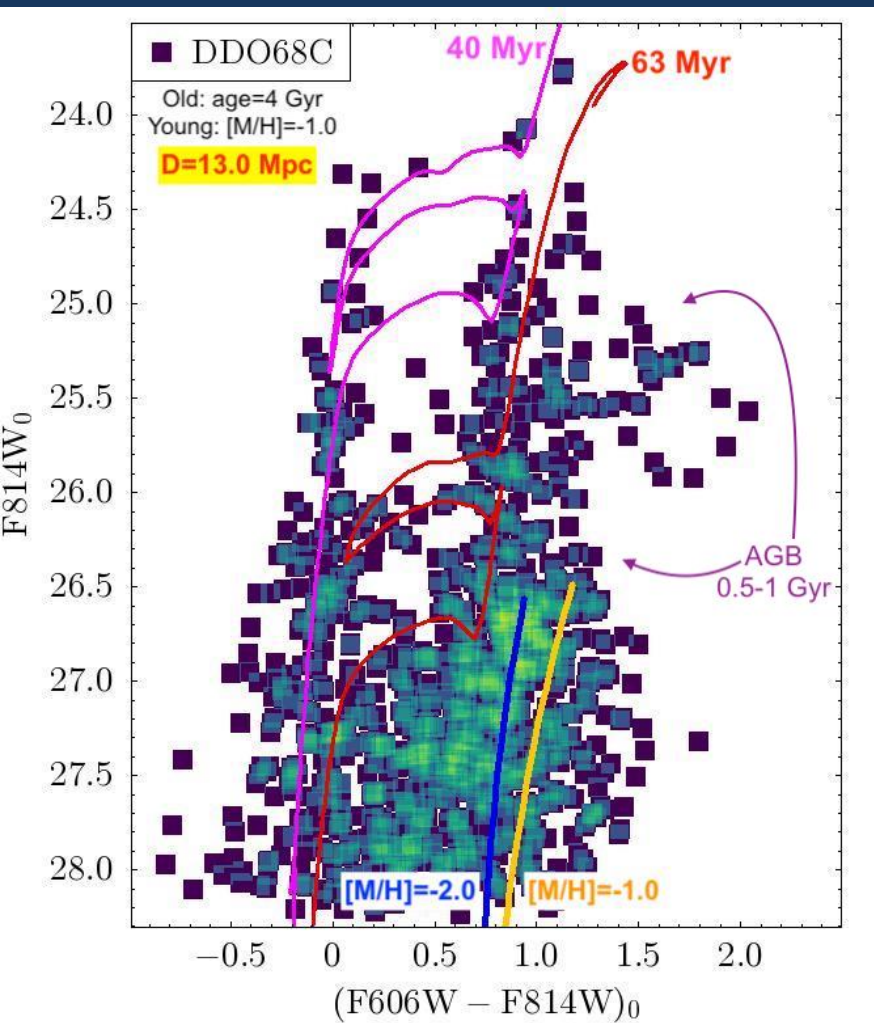


# SSH. A glance to what's coming. **DDO68C with HST**



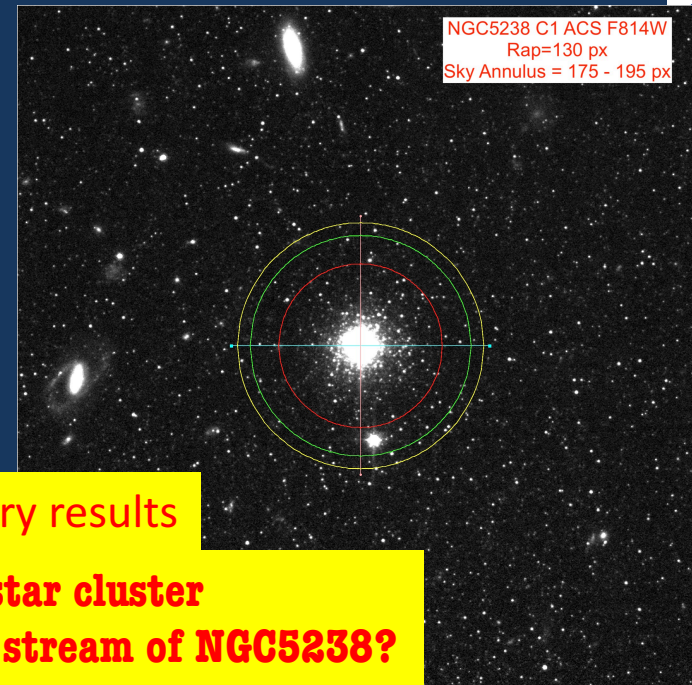
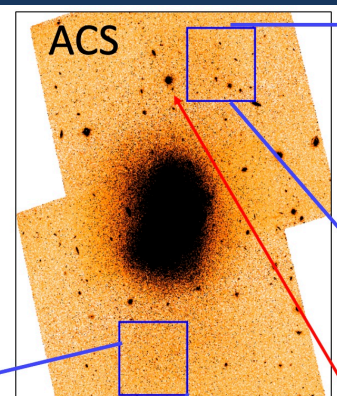
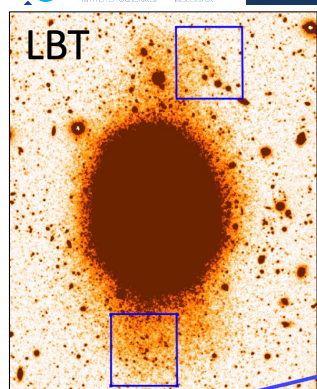


# SSH. A glance to what's coming. **DDO68C with HST**



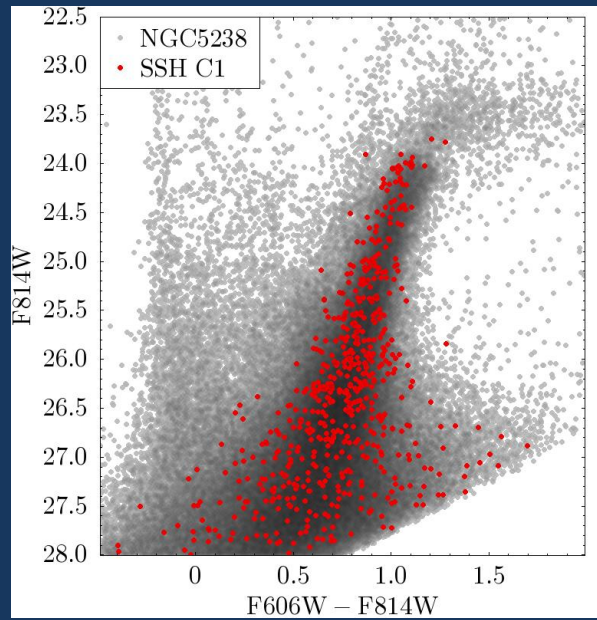
RGB Tip detected at the same distance of DDO68: D=13 Mpc





NGC 5238

**Preliminary results**  
**A nuclear star cluster**  
**in the northern tidal stream of NGC5238?**



$$M_V = -10.81 \pm 0.11$$

$$L_V = 1.77E6 \pm 0.19E6 = 1.37 \times L_V(\omega \text{ Cen})$$

$$M_* = 3.26E6 \pm 0.55E6 M_\odot$$

(adopting  $\langle M/LV \rangle_{GGC} = 1.83$  and  $\sigma_{GGC} = 0.24$  from Baumgardt+2020, PASA, 37, e046)

$$M_{*,NGC5238} / M_{*,MW} = 0.003 \rightarrow 0.3\%$$



## Summary 2

- **DD068 C is a confirmed satellite of DD068**: available evidence suggests that the DD068 system was originally formed by 4 bound dwarfs. Two merged forming the current main-body, a tiny one was disrupted (S1), and one is still alive, gas-rich and star forming (DD068 C)
- **SSH**: full analysis of the LBT data ongoing; **AO + HST + VLTI follow-up ongoing** + hydro-dynamical modelling ongoing



Stay tuned!