Mapping compact groups (with Blue Muse)

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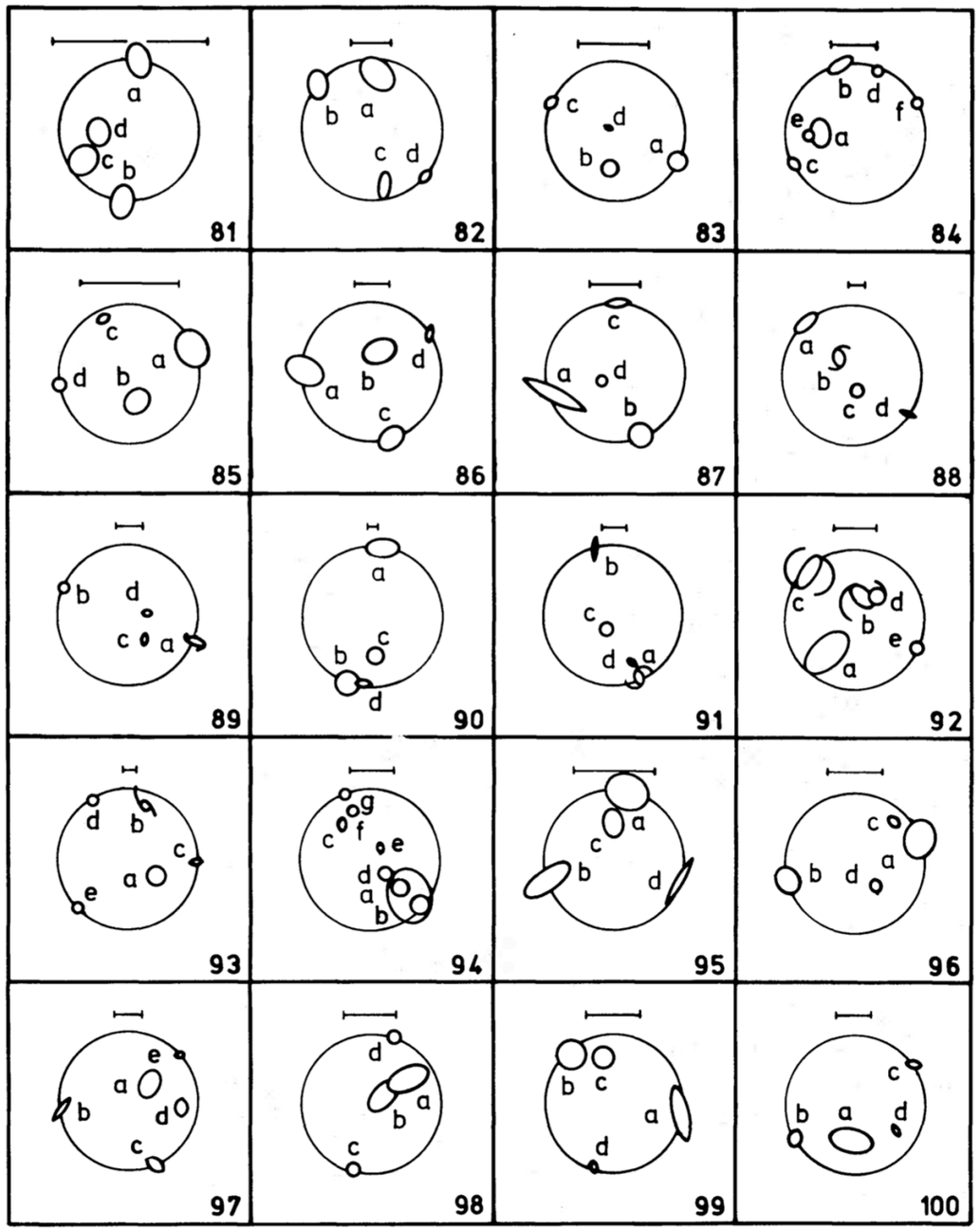
Pretty picture

- Stephan's Quintet (HCG92)
- discovered 1877 (Edourad Stephan with 40cm refractor at Observatoire de Marseille)
- NGC7320 (blue) not a member
- interacting galaxies
- shocked gas (X-rays)
- SF regions (between galaxies)
- NED references: 188(!)
- diameter of the group~ 3.2'
- location: North!

Why are CGs interesting - a bit of history

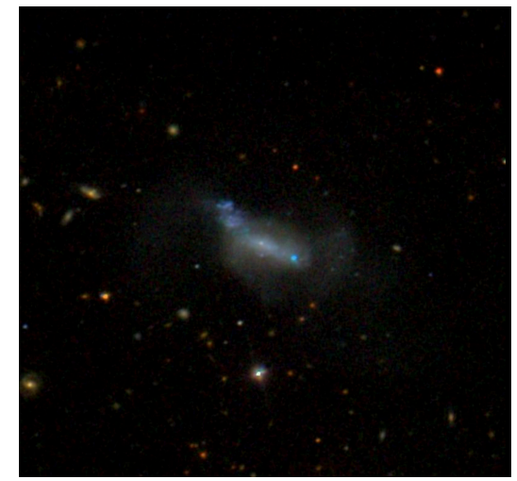
- **Compact groups**: small systems of several galaxies in a compact configuration on the sky
  - 1st discovered in 1877, 2nd in 1948(!)
  - Palomar Observatory Sky Survey
  - Atlas of Interacting Galaxies (Vorontsov-Velyaminov 1959, 1975)
  - Atlas of Peculiar Galaxies (Arp 1966)
- such **small groups** were expected to **quickly merge**
  - short dynamical timescales ~**100 Myr** (Hickson et al. 1977)
- 1st **redshifts** (60s and 70s):
  - **not** all members of the group are **at the same distance**
  - **high** group **velocity dispersion** (are the systems bound?)
- prime locations for studying galaxy evolution

Hickson (1982)

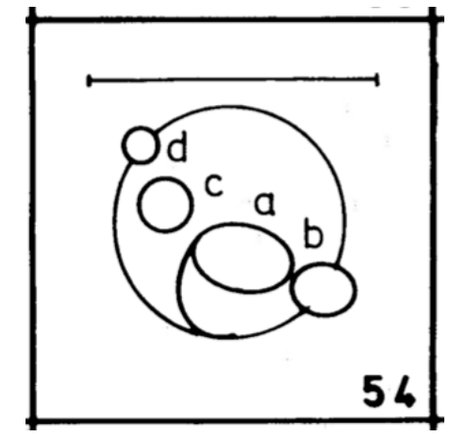


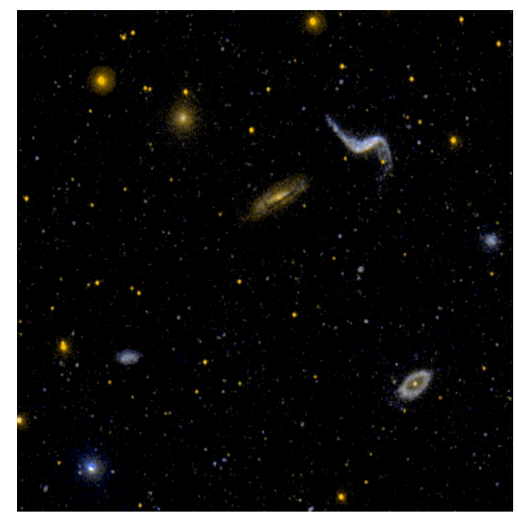
What are compact groups

- Hicksons' 1982 definition
  - 1) **number**
    - number of galaxies within 3 mag of the brightest: **N≥4**
  - 2) **isolation**
    - **$\theta_N \geq 3\theta_G$**, θ_G - angular diameter of galaxies, θ_N - angular diameter of the smallest circle that contains on other galaxies within the magnitude range (or brighter)
  - 3) **compactness**
    - **$\mu_G < 26.0$**, μ_G< is the sum of total magnitudes of galaxies averaged over their θ_G
  - somewhat arbitrary but: (2) and (3) exclude cluster of galaxies, (1) is of course problematic if no distances are available

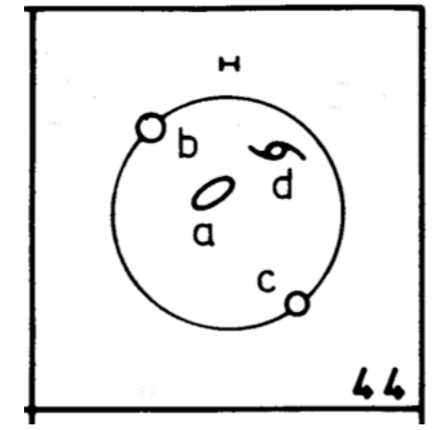


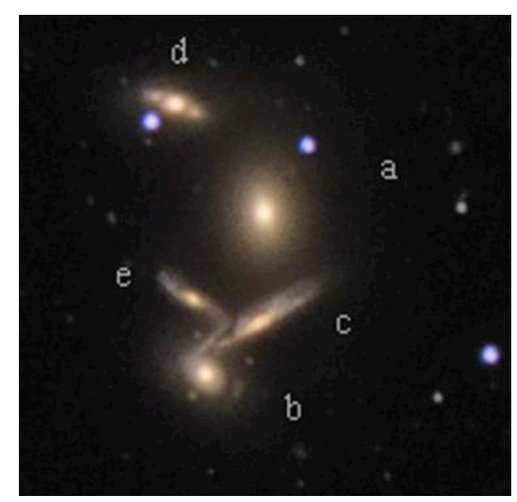
HCG 54 - smallest



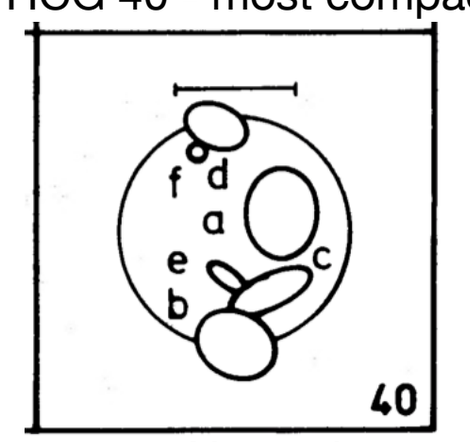


HCG 44 - largest



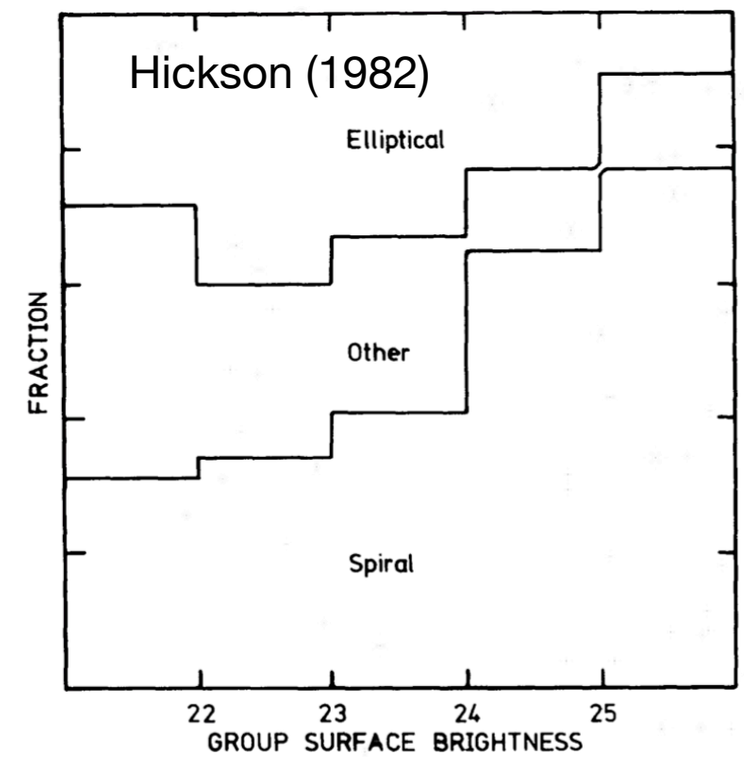


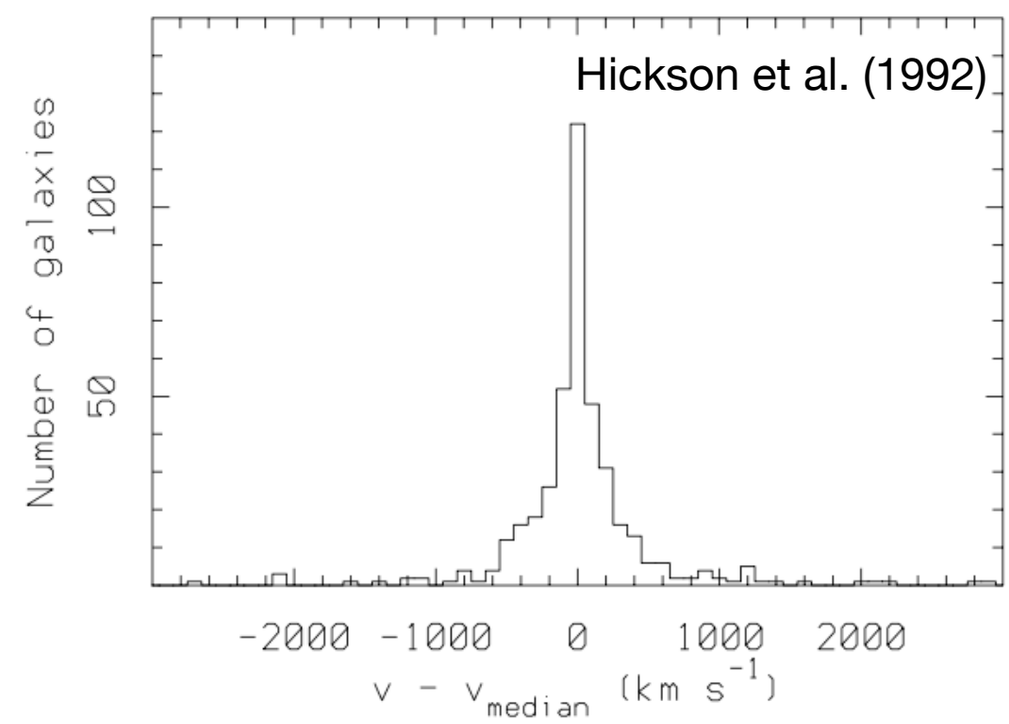
HCG 40 - most compact



General properties of Hickson Compact Groups

- **morphology** of galaxies: **spirals** 43%, **S0** 26%, **E** 31 %
  - **fraction of spirals** in HCG is **smaller than** in the **field**
- **less compact groups** have **more spirals**
- **half** of all **first-ranked galaxies** are **spiral**
- groups with **bright Es** appear to contain **fewer** relatively **faint galaxies** (than groups with a bright spiral)
- distribution of **discordant redshift** is consistent with **chance orientations**
- **1/3 of HCGs** have "**outlying**" members,
  - not clear if CG are really dense (e.g. Mamon 2008)

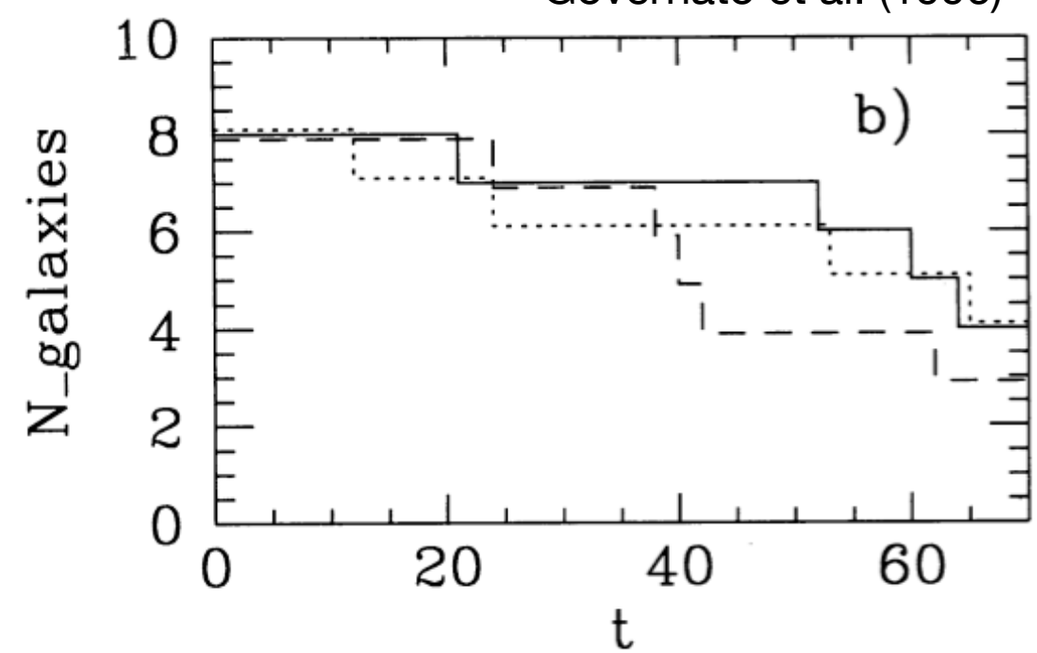




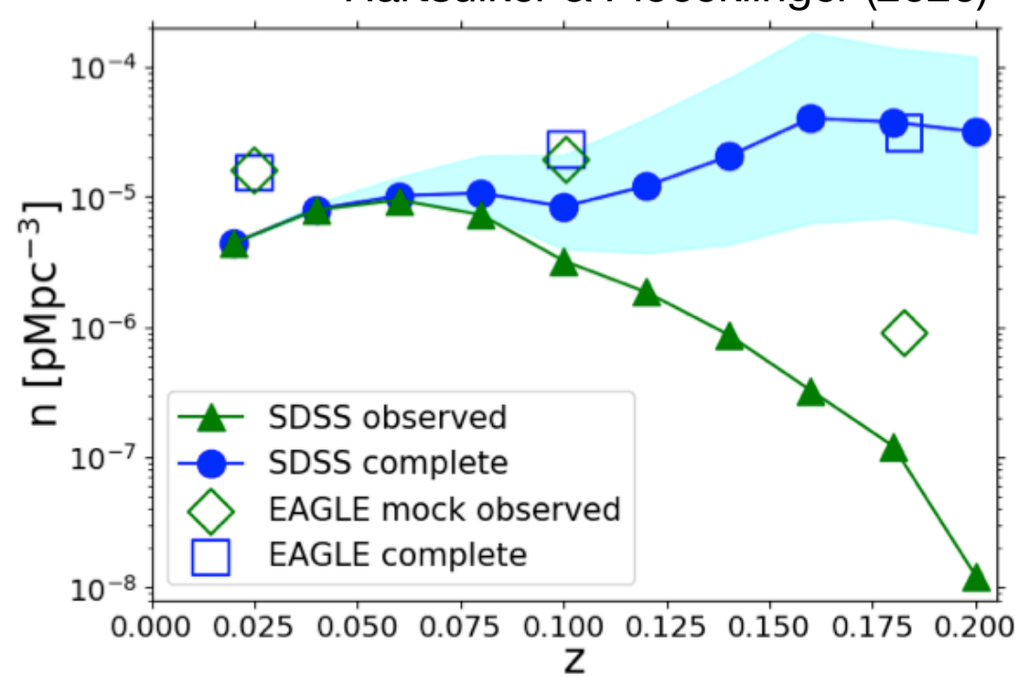
Physical nature of groups

- **transient** dense **configurations** (Rose 1977)
  - **chance alignments** in loose groups (Mamon 1986)
    - ~ 40% of CG are chance projections (Diaz-Gimenez & Mamon 2010)
  - **filaments seen end-on** (Hernquist et al. 1995)
- **isolated bound** dense configurations (Sulentic 1987)
- **bound dense** configurations **within loose groups** (Diaferio et al. 1994)
  - galaxies in CG **merge**, but are **continuously replenished** from surrounding galaxies that infall
- if CG **bound & dense**, they should be **short lived**, end up as "**fossil groups**"
  - isolated ETG (surrounded by some small galaxies) + extended X-ray halo)
  - only **~36% of FG were CG** at some previous point (Farhang et al. 2017)
  - **mergers** (and disappearance of CG) can be **quick** (<1 Gyr), but are on **average >2-3 Gyr** (in EAGLE simulations)

Governato et al. (1996)



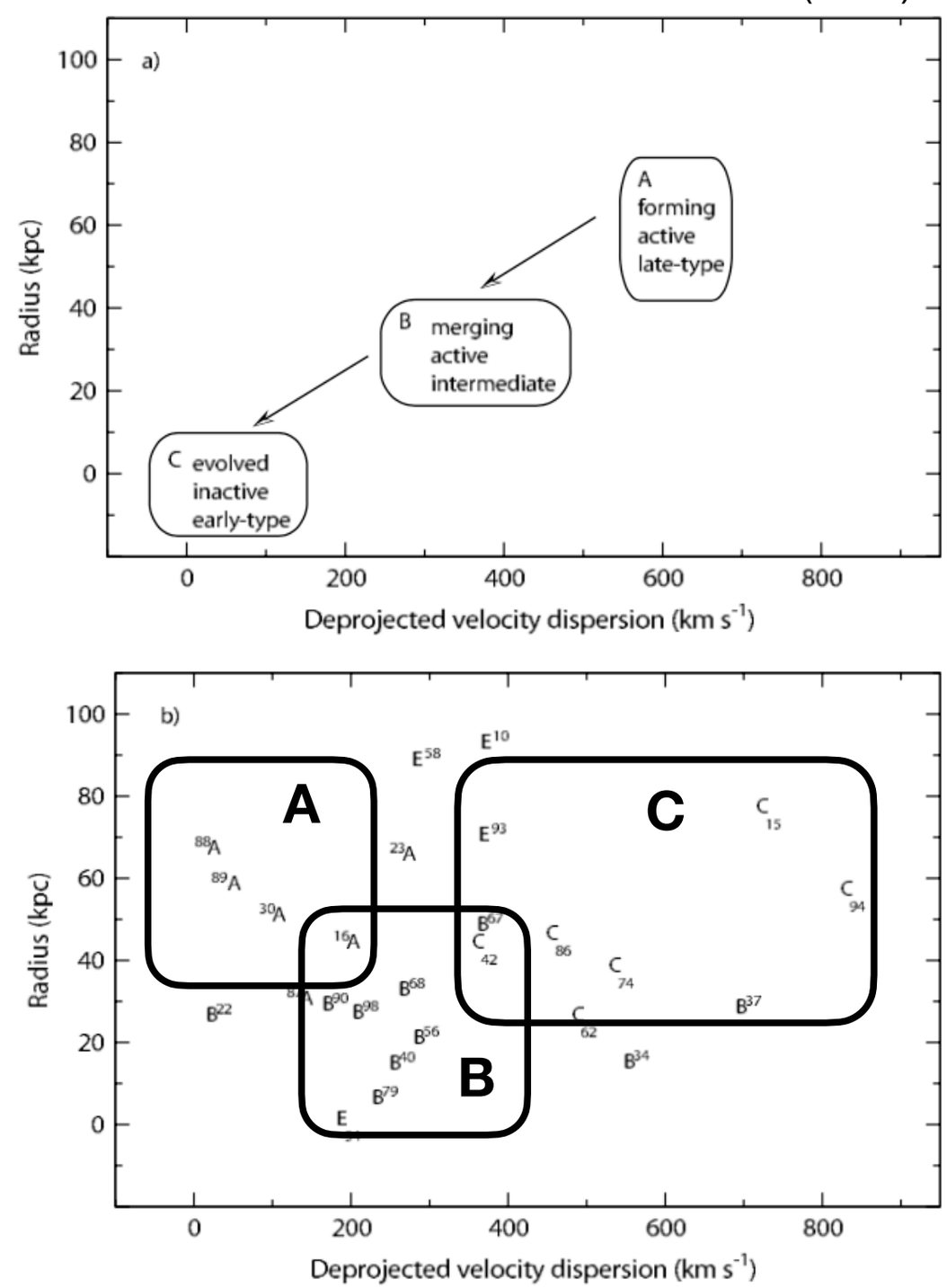
Hartsuiker & Ploecklinger (2020)



Comparing with observations

- Simulations (**fast merging** models):
  - densely located galaxies should **merge quickly**
  - more **"evolved" systems** should have **smaller group velocity dispersions**
- Observations (limited sample!):
  - **no evidence** for "fast merging models"
  - a number of galaxy properties correlate with group velocity dispersions
  - **increasing** σ_v:
    - **increase** in **mass** with group types (A->B->C)
    - **increase** in **# of surrounding galaxies** (outside of the CG): A~8, C~18
    - **increase** in **X-ray** luminosity

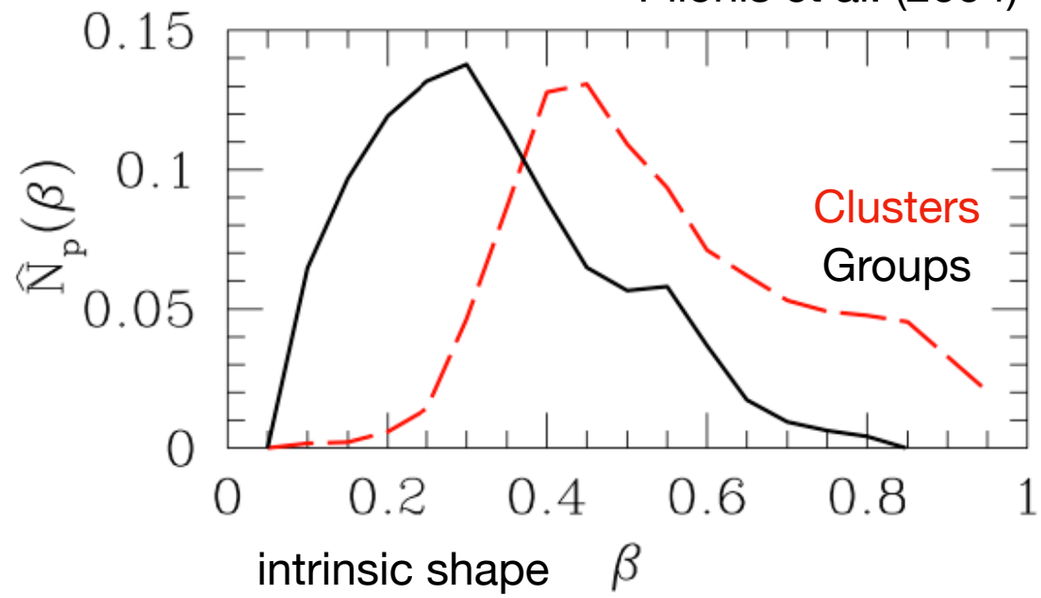
Coziol et al. (2004)



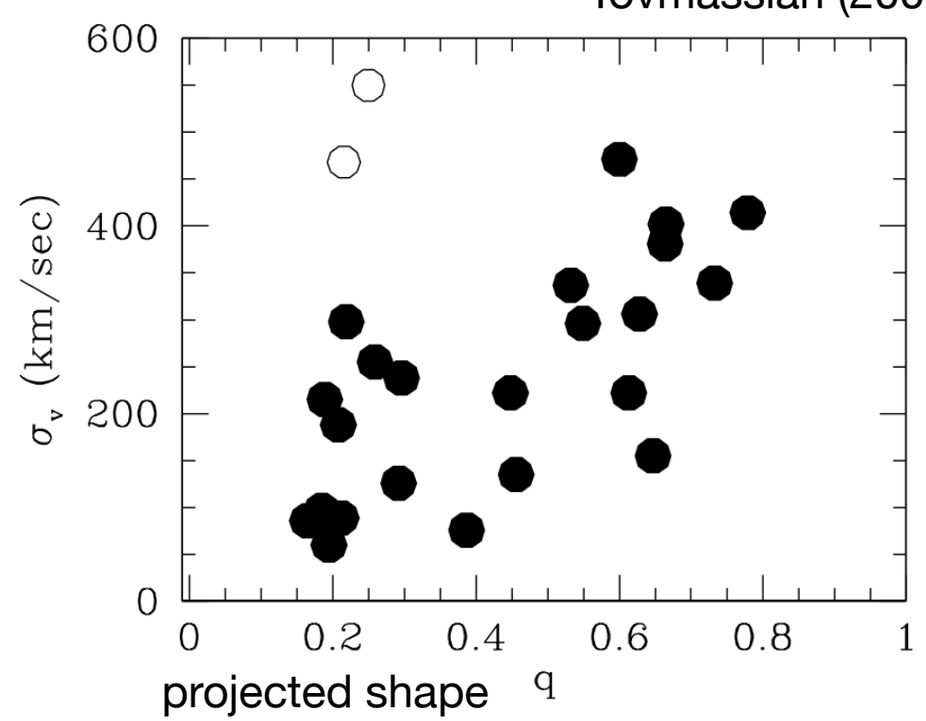
Structure of groups

- groups (in general) have typically **a nearly prolate shape** (elongated along the line of sight)
- consistent with **formation along filaments**
- **galaxies** move **on** (nearly) **radial orbits** around the group gravitational centre
- CG: just **normal groups** observed in a **special moment**:
  - when (some of) its **members happen to be close** to each other along their radial orbits
  - group is **oriented close to the line-of-sight** (its members project over a small angle on sky)
- **CG** show a specific **dynamical trend** (limited sample of Tovmassian 2006):
  - **group velocity dispersion** (σ_v) **correlates** with
    - (projected) **shape** of the group
    - **X-ray luminosity**
    - higher **fraction of ETG**s
    - lower f**raction of SF** or **AGNs**
  - **high σ_v** are more **"evolved" groups**

Plionis et al. (2004)



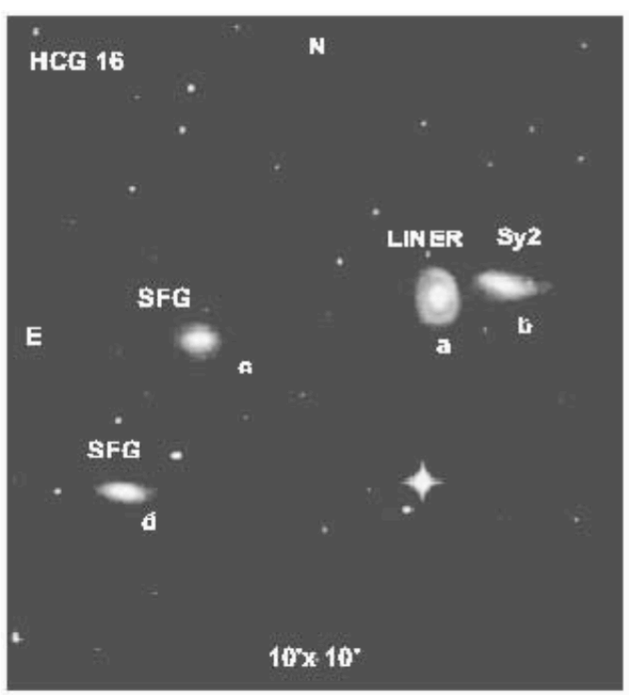
Tovmassian (2006)



An evolutionary sequence

- based on: **activity** (AGN, SF) & **morphology** of galaxies, **spatial configuration** of galaxies in CG
- **type A** - low σ_v, rich in LTGs, rich in AGN and SF galaxies
- **type B** - intermediate σ_v, large fraction of interacting and merging galaxies
- **type C** - high σ_v, dominated by ETGs
- physical origin: related to the masses of structures in which CGs are embedded
- evolutionary sequence: **A⇒B⇒C**

Coziol et al. (2004)



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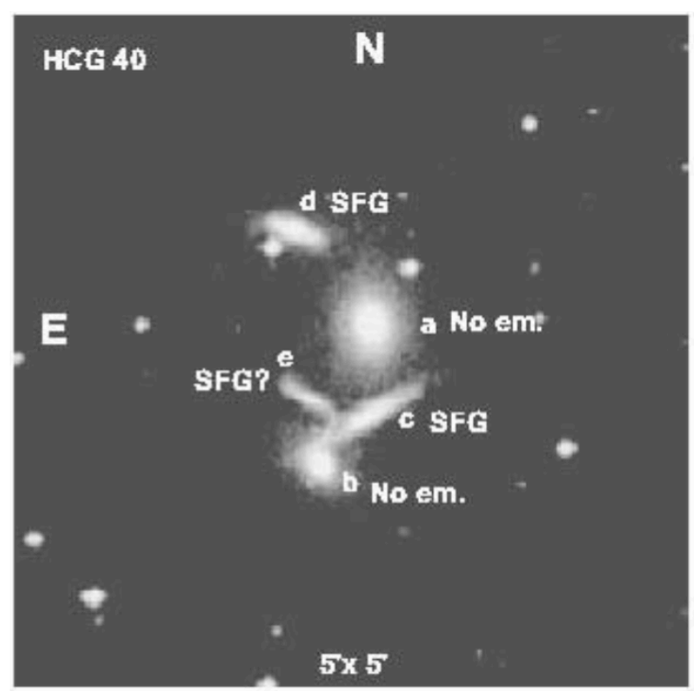

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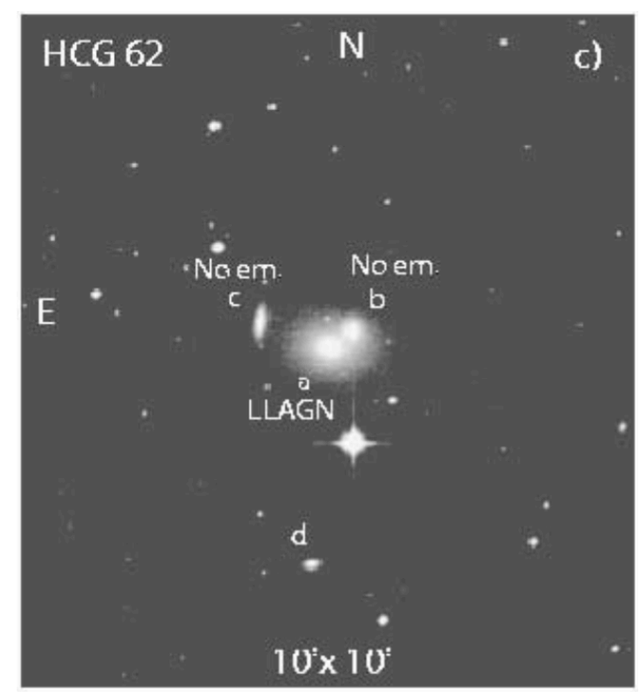
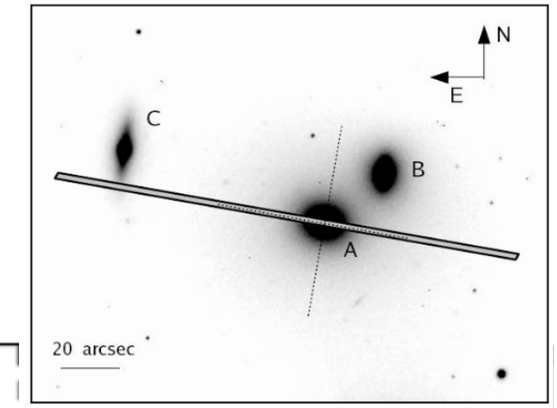
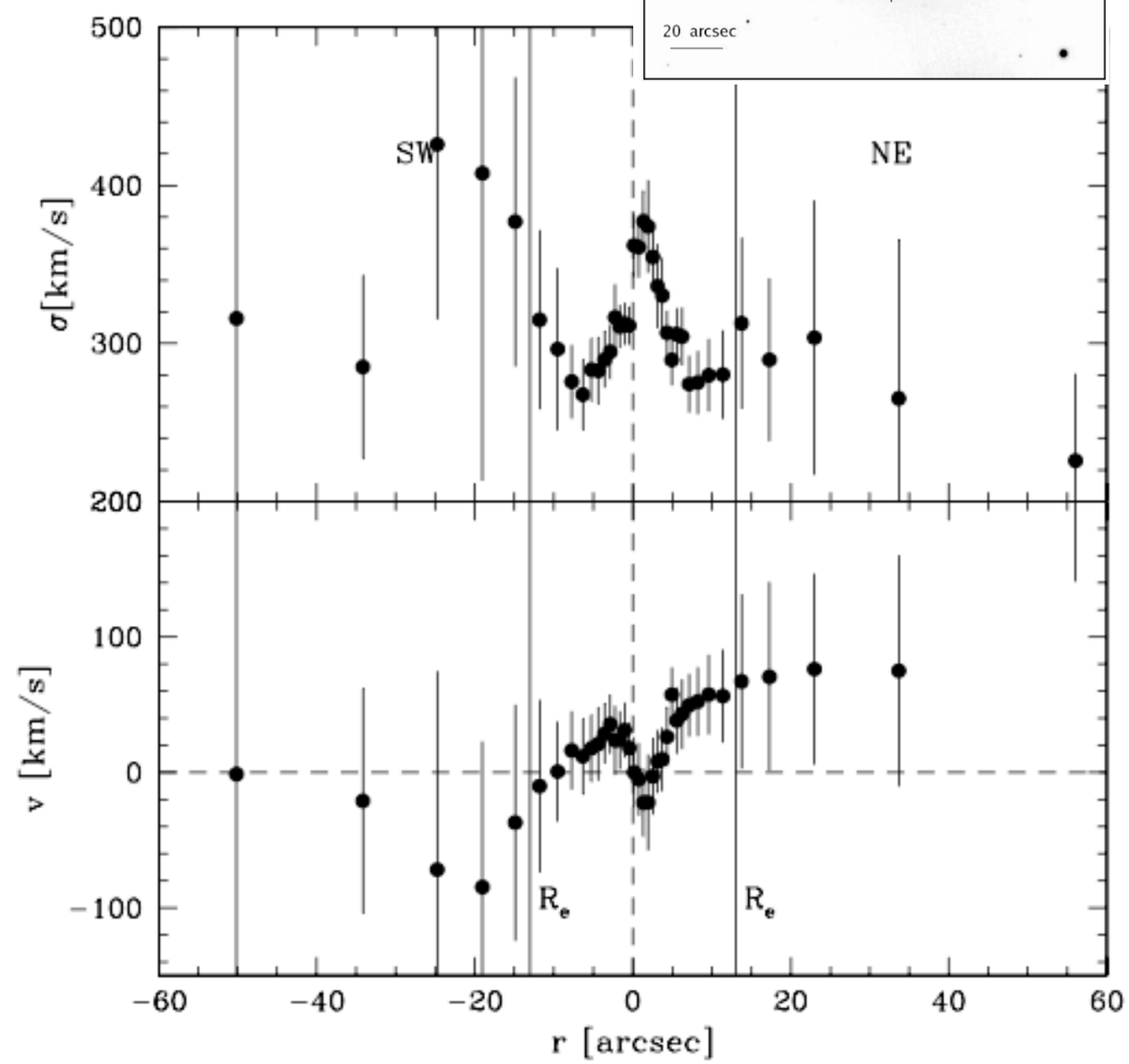


Galaxies in CGs: dynamics

- internal **kinematics** and **dynamics** of CG galaxies **linked** to their evolution
- prime targets: groups of **type C** (dominated by ETGs)
  - **fossil records** of evolution
- only a **few** groups investigated (long slits!)
  - morphological evidence for mergers are known, but not kinematic are still lacking
- **complex kinematics** found (counter-rotating core), providing evidence for interactions and merging
  - evidence for **minor merging** in case of HCG62 (NGC4778)
- **dynamical models** + **stellar populations properties** needed of a **sample of CG** to better constrain evolution

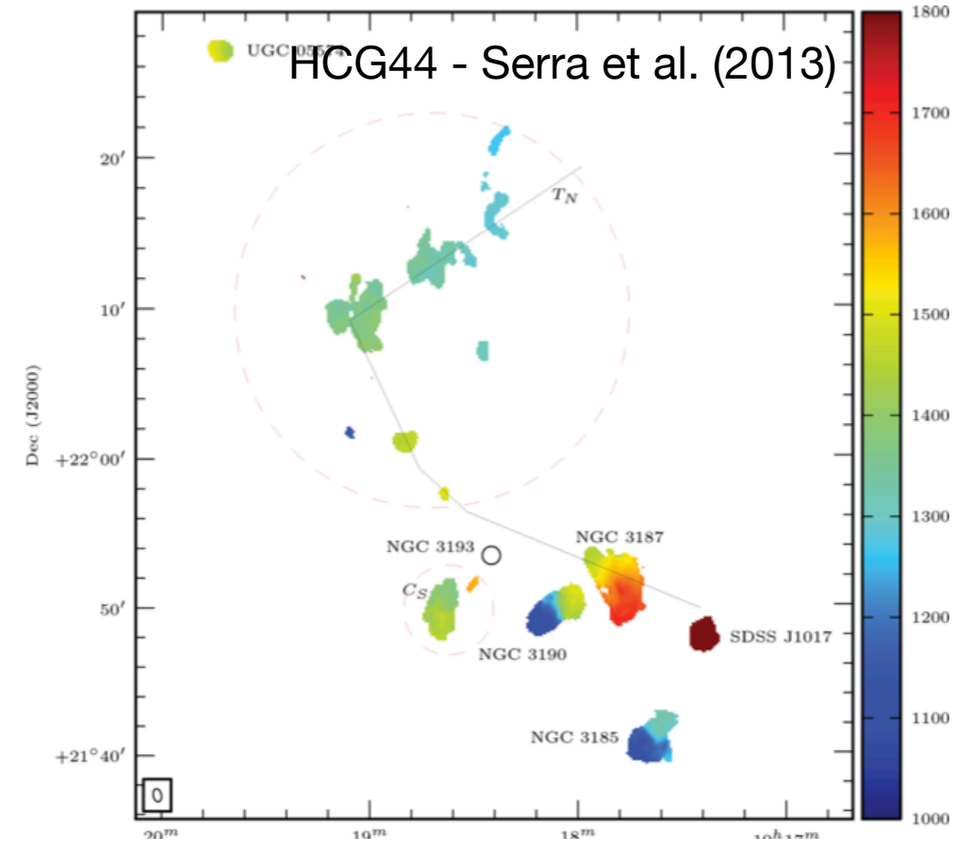
Spavone et al. (2006)
HCG62



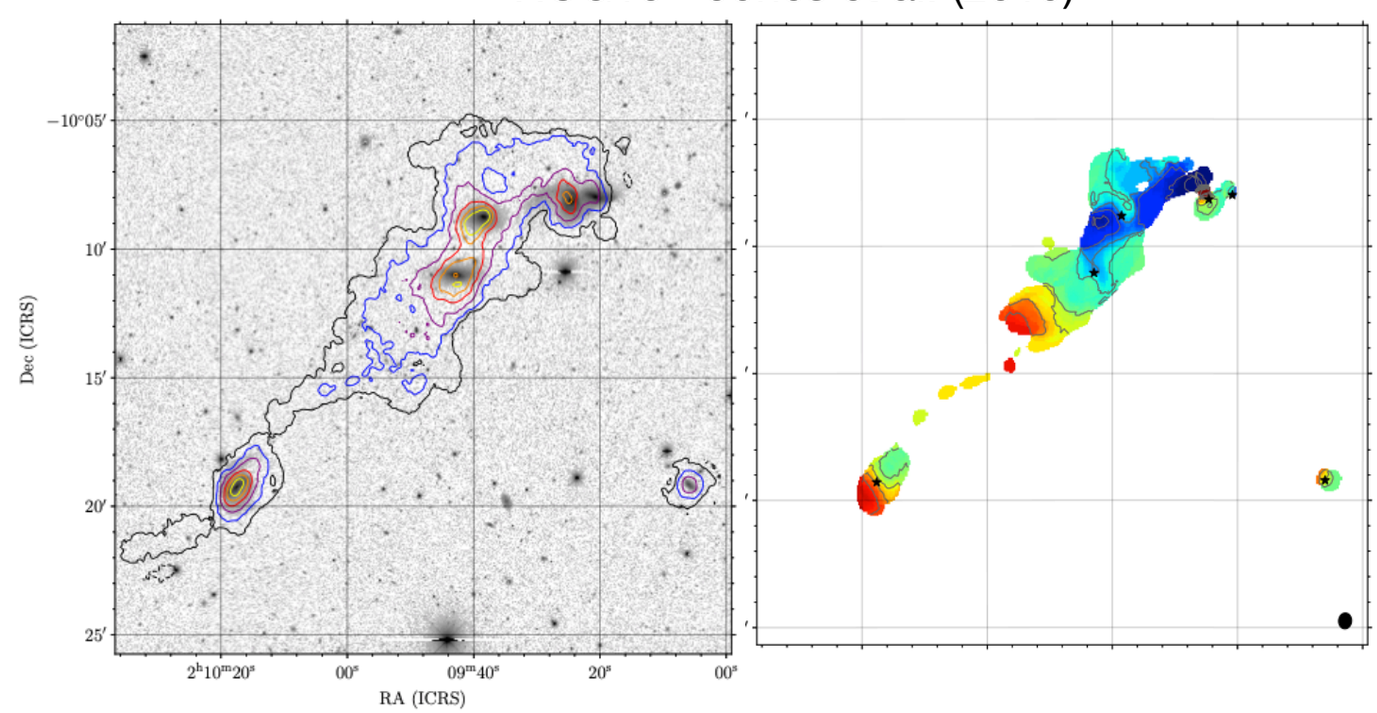


Galaxies in CG: gas

- **gravitational interaction** (dominant?)
- what about **other physical processes**, e.g. ram-pressure stripping?
- **CG galaxies** are often **HI deficient** (Verdes-Montenegro et al. 2001, Konstantopoulos et al. 2010)
    - **evolutionary sequence** traced by **HI depletion**
    - **gas** can be **consumed** (SF) + later dry merging
    - **gas** can be **stripped** from galaxies and forms hot+diffuse intra-group-medium (IGrM)
- what is the **mechanisms of gas stripping**
    - **no** clear **evidence** for **ram-pressure stripping**
    - clear **evidence** for **tidal stripping**

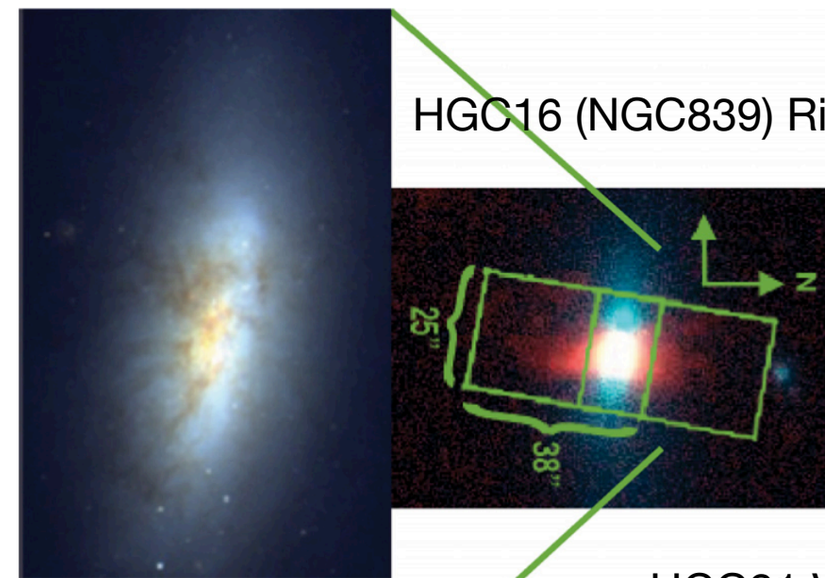


HCG16 - Jones et al. (2019)

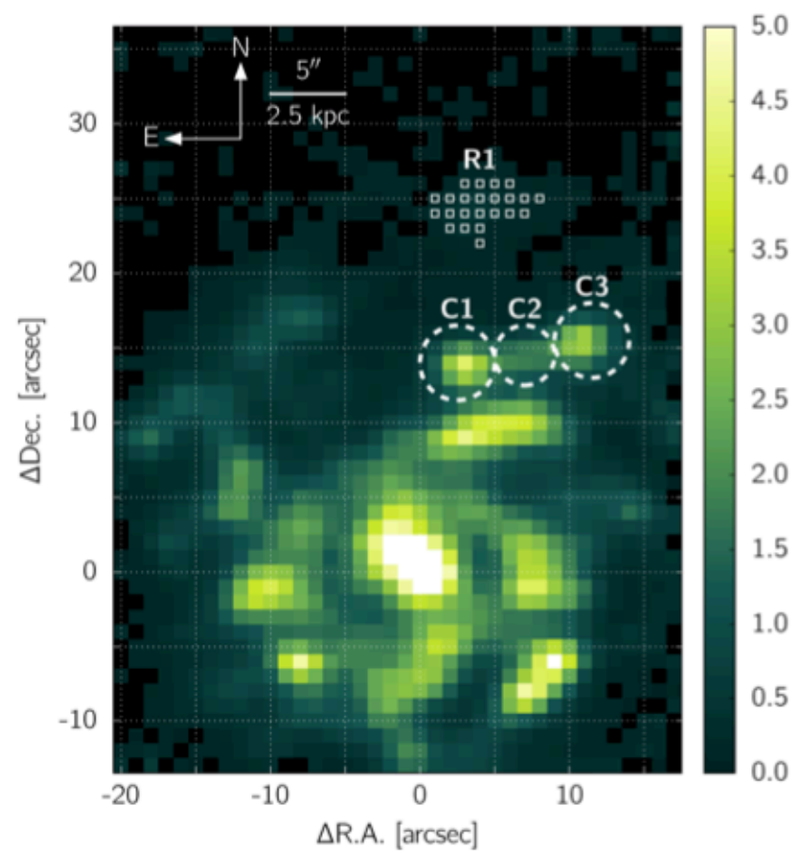


Galaxies in CGs: SFH

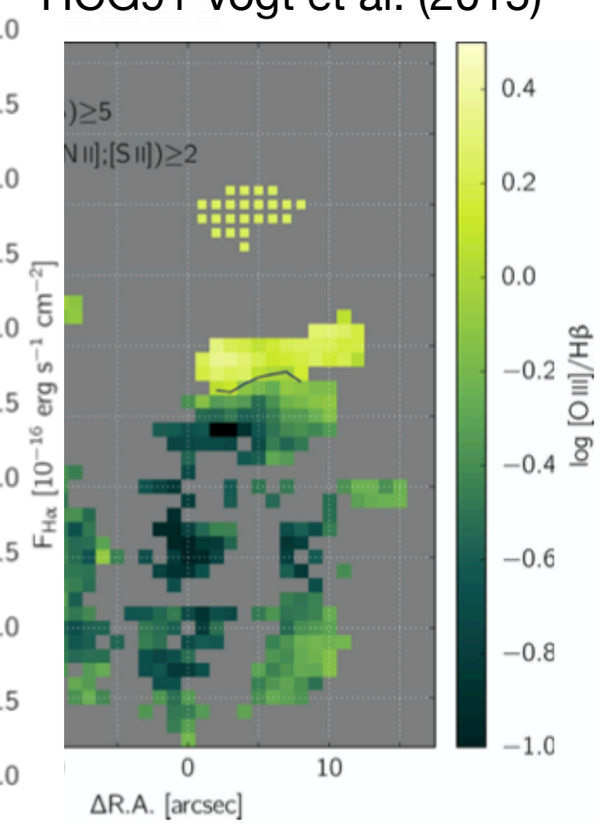
- **SF is enhanced** in CG galaxies, compared to the galaxies surrounding CGs (Tovmassian et al. 2006)
  - **not** the case for **AGN**
- **interactions** trigger **starbursts** (SB)
- SB trigger **large-scale galactic winds**:
  - **symmetric**, powered by shock (e.g. Rich et al. 2010)
  - **asymmetric**, powered by nuclear starburst (e.g. Vogt et al. 2013)
- **local SF** can show significant differences, indicating **different origin**
  - **infall of gas from halo** due to interactions/perturbations



HGC16 (NGC839) Rich et al. (2010)

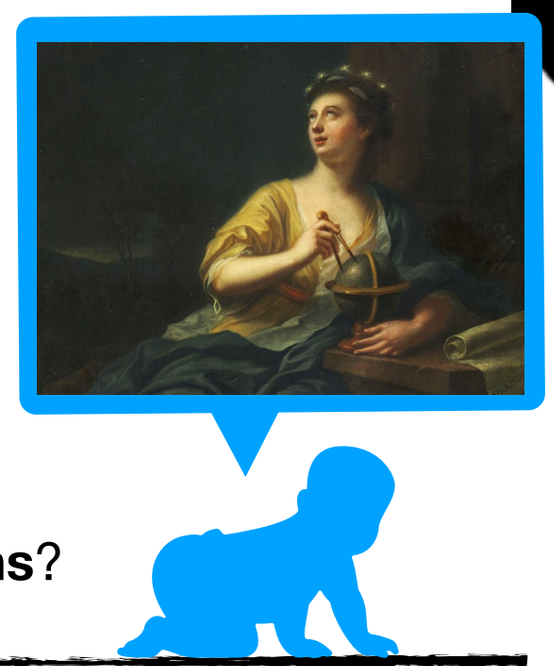


HCG91 Vogt et al. (2015)

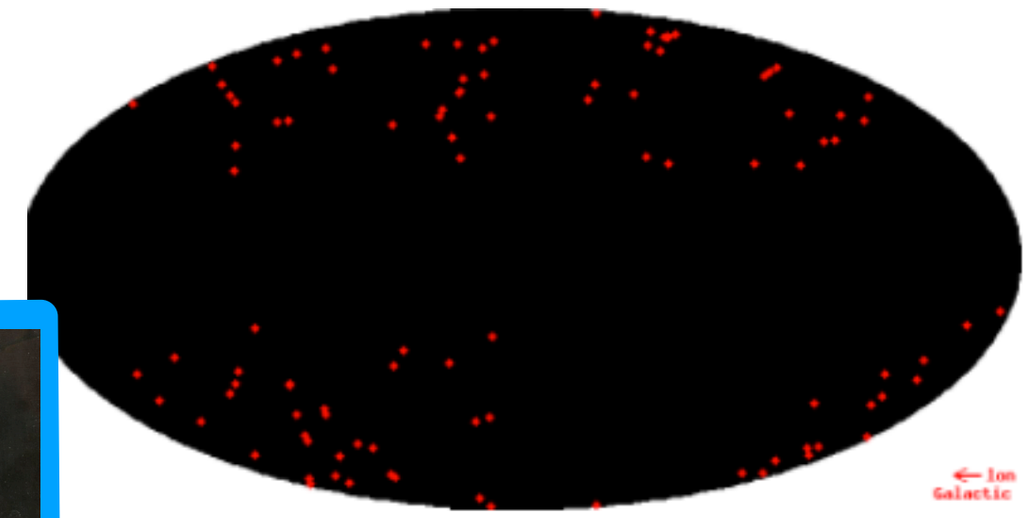


What's next?

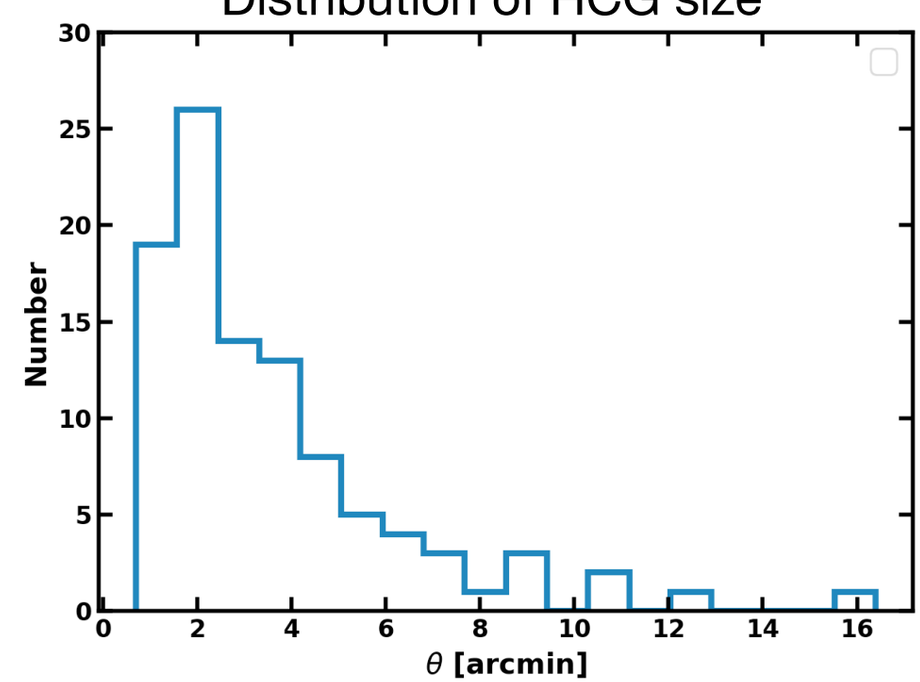
- what is the **dynamical structure** of galaxies in CG?
- what are the **SFH** of CG galaxies?
- what are the **properties** (kinematics, mass, Z) **of IGrM**?
- what are the **dynamical properties of CG**?
- properties of **tidal feature**
  - stellar populations and kinematics
  - are there **tidal dwarfs**?
- what is the **origin of CG**?
- what is the **fate of CG**?
- what is needed to **constrain simulations**?



Distribution of HCG on sky (by CDS)



Distribution of HCG size

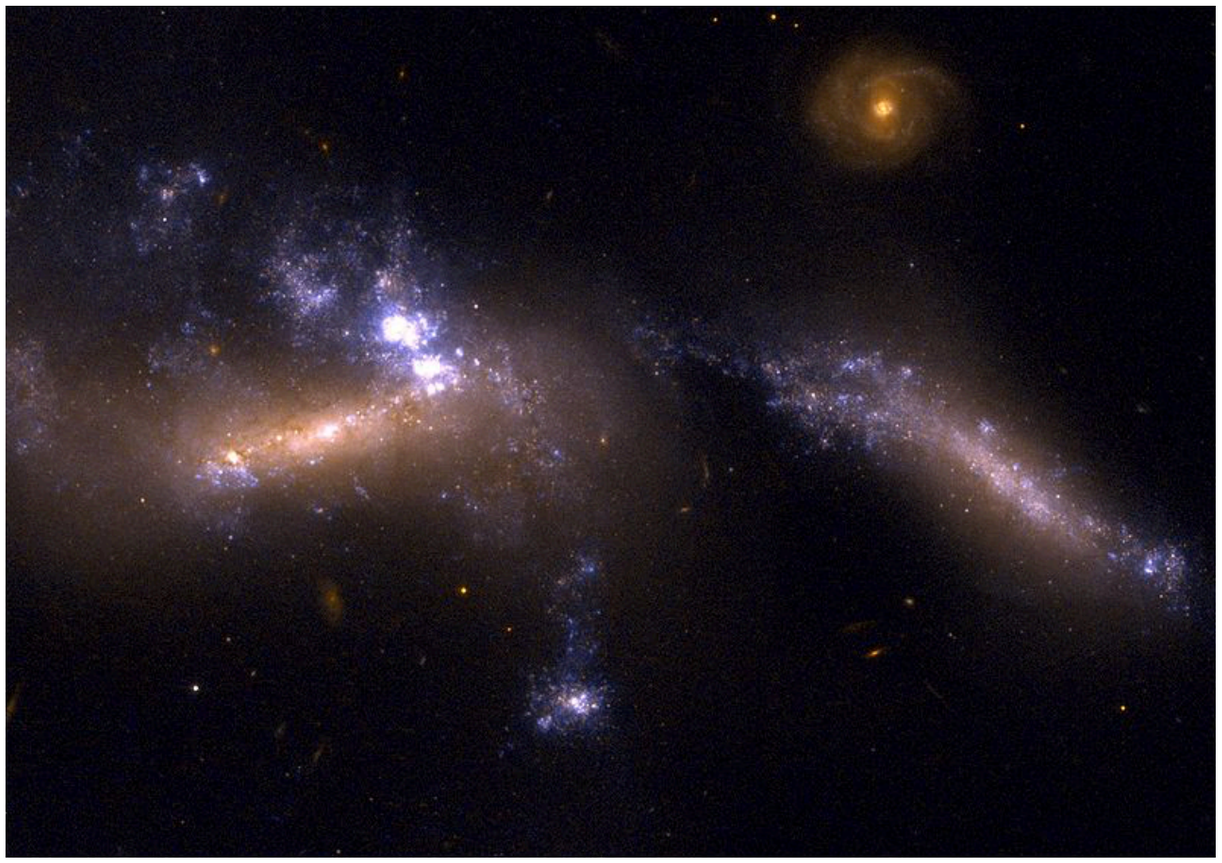


what is needed:

- a good sample (statistics)
- large FoV (spectral mapping, kinematics, dynamics)
- blue wavelengths (intense SF, better age estimates)

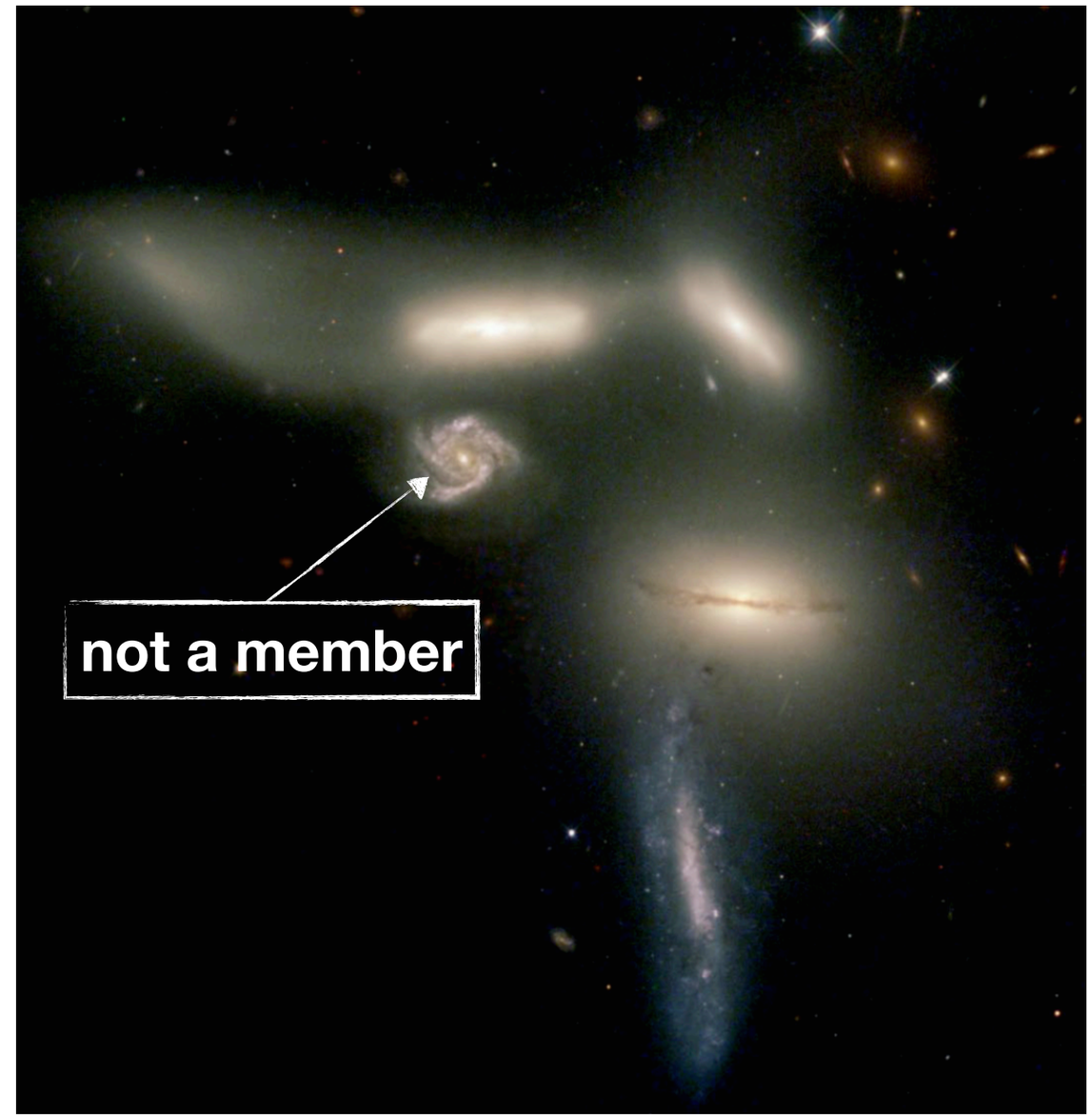
Compact groups and Blue MUSE

HCG31 (dec -4)



1 arcmin

HCG79 (dec: +20) Seyfert (1948) sextet



1.4 arcmin

- why is blue Muse competitive
  - large size
  - large (blue) wavelength range