Past and future of CG J1720-67.8: Constraints from Observations and Models

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Talk Outline

- Motivation
- CG J1720-67.8: Main properties
- The group's history:
  - Observational constraints
  - Evolutionary synthesis models
  - First results from hydrodynamical simulations
- Conclusions

Motivation

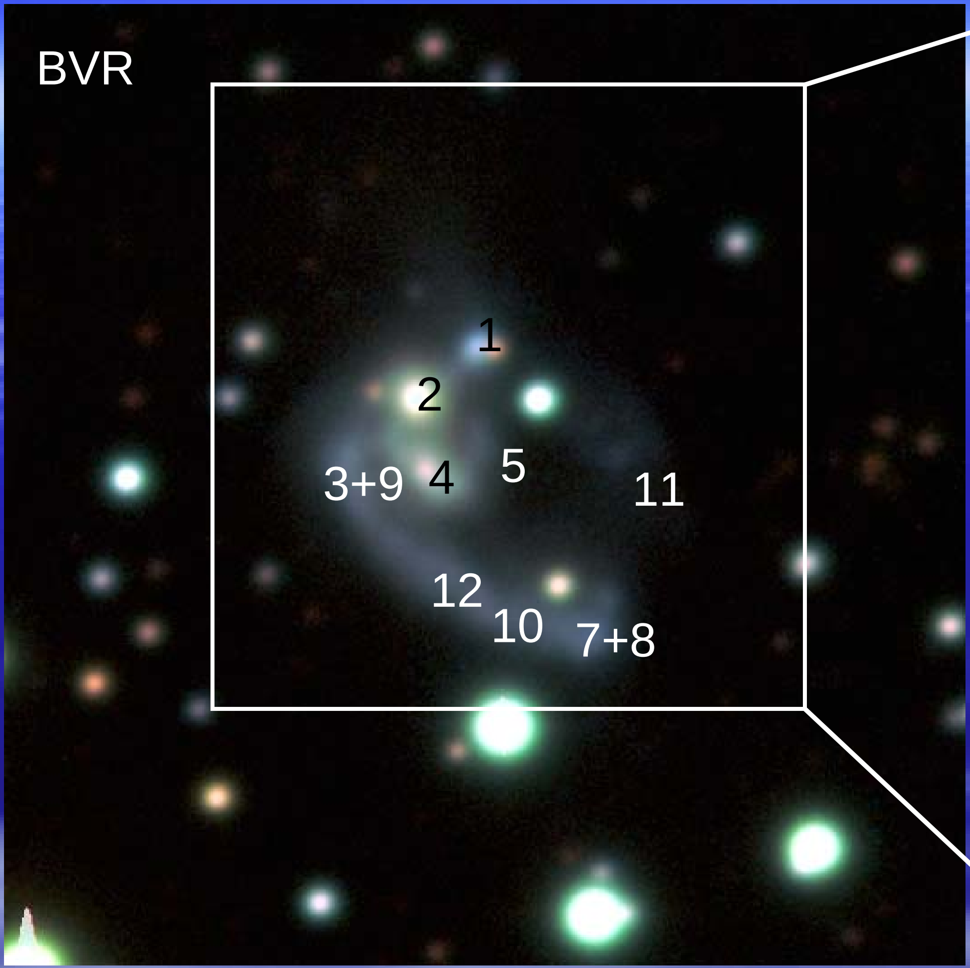
Several catalogues of CGs have been compiled during the last 20 years (see talk of Vince Eke).
Many studies have been/are devoted to understand the nature of CGs and their evolution from both an observational and a theoretical point of view (see e.g. talks of Emanuela Pompei, John Hibbard, Gary Mamon, …).
New related projects are in progress, although not necessarily strictly focussed on CGs (e.g. GEMS, see talk of Duncan Forbes).

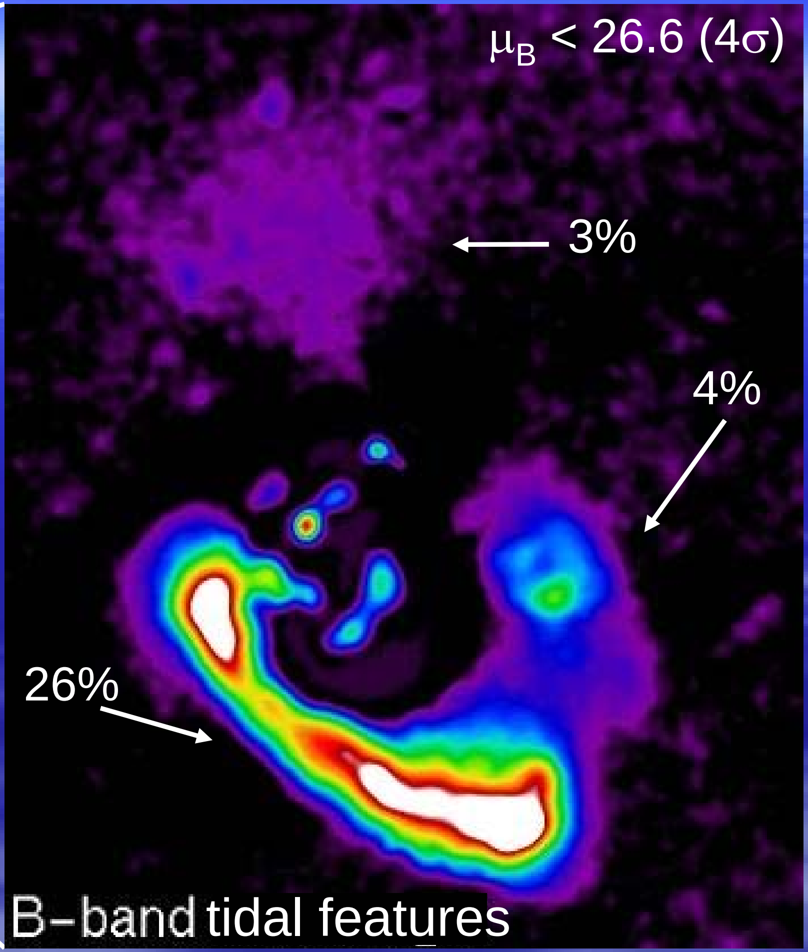
Nevertheless, we do not have yet a clear mind on how groups evolve and what is the product of their evolution.

Even the study of individual groups in differing evolutionary phases might be useful in this respect, in particular for those phases which are more rare to observe as is the case for extremely compact systems that appear to be in a pre-merging state.

This is the main reason why we have decided to study in as much detail as we could such a compact system, CG J1720-67.8.
I will summarize here our past and most recent results.

CG J1720-67.8: Group components and properties





2 Sc (1 and 4) + 1 S0 (2) + TDG candidates

D ~ 180 Mpc R ~ 6.9 kpc

Tail length ~ 29 kpc

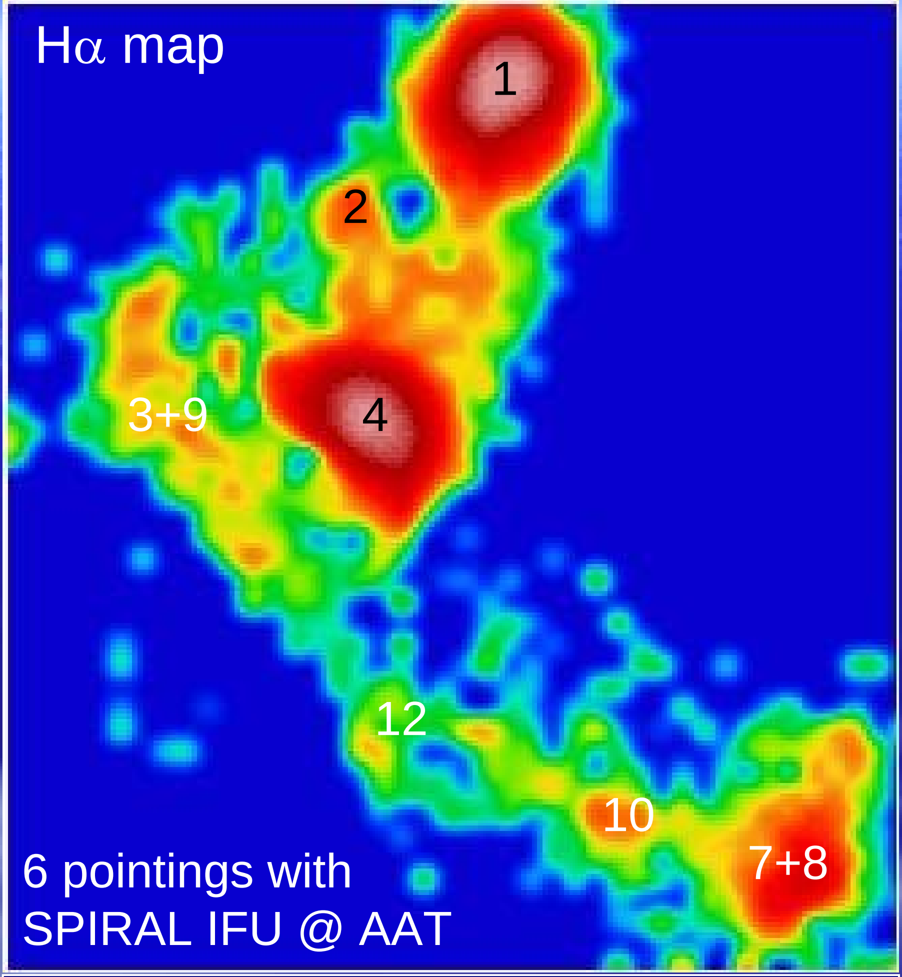
σ_V ~ 65 (149) km s^{-1} H_0t_c ~ 0.0067

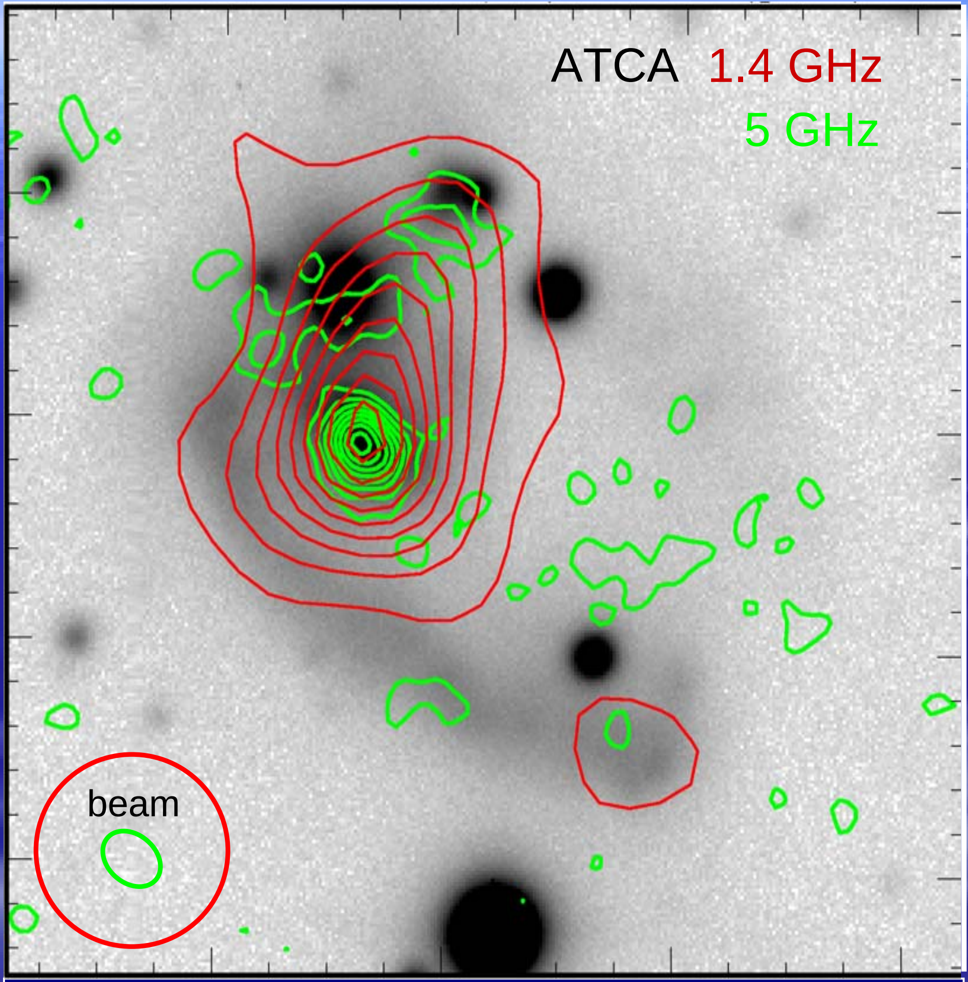
$M_V \sim 7.0\text{x}10^{11}\ M_\odot$ $M_P \sim 2.6\text{x}10^{11}\ M_\odot$

Temporin et al. 2003, ApJ, 584, 239
Temporin et al. 2003 ApJ, 587, 660
Temporin et al. 2005, MNRAS, 356, 343

Present day star formation

Temporin et al. 2005, MNRAS, 356, 343



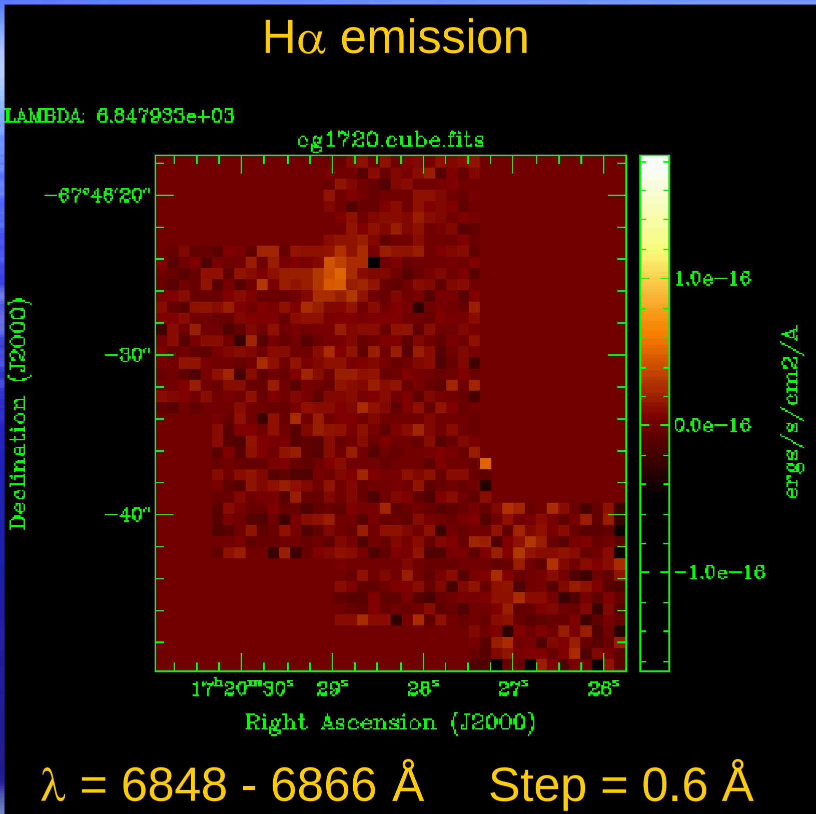


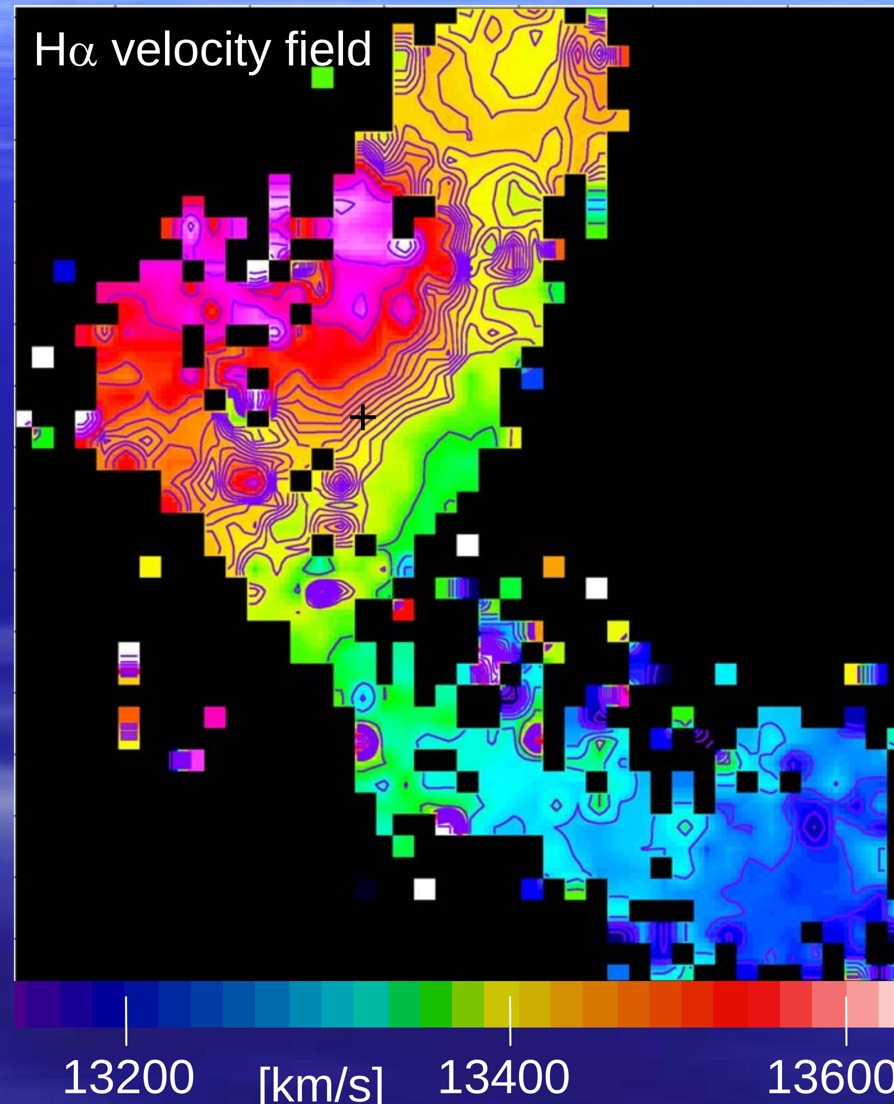
L(Hα) ~ 3.7 x 10^{41} ergs s^{-1} (uncorrected)
31% of Hα from tidal tail
After correction for <E(B-V)> = 0.5 mag
→ Total SFR(Hα) ~ 10 $M_{\odot}$ yr $^{-1}$

S(1.4 GHz) = 4.2 mJy S(5 GHz) = 1.1 mJy
SFR(1.4GHz) ~ 18 $M_{\odot}$ yr^{-1}
HI (3σ) < 0.3 Jy km s^{-1} M_{HI} < 2.3x10^9 $M_{\odot}$
M_{HI}/L_B < 0.02 $M_{\odot}$ $L_{\odot}^{-1}$ Def_{HI} > 0.3

Group dynamics

Temporin et al. 2005, MNRAS, 356, 343





- Presence of global kinematic structure
- Kinematic center offset from G4 center
- G1 has distorted velocity field
- $M_{G4}(5'') \sim 2\times10^{10}\ M_{\odot}$ $V_c \sim 150$ km s^{-1}
- Age of tail 29 kpc / $\Delta V_{max} \sim 200$ Myr

Possible interaction scenarios suggested by observations

- G4 and G1 experienced a prograde-retrograde close encounter < 200 Myr ago. The strong tidal tail, the bridge between the two gals. and possibly the cone-like plume were issued during the encounter. Strong SF episodes were triggered across the bodies and in the centers of both gals.
  Recent SF (< 10 Myr) has taken place in condensations of gas and stars formed under action of self-gravity within the tidal tail (TDGs?). G2 might be involved in the interaction with both G1 and G4 (presence of bridges). The low level of SF in the center of G2 might be a fading burst triggered by a previous merging process (origin of the faintest tail?).

- G2 was an early-type gal. to start with and has recently undergone a close interaction with G1 and G4. As a consequence, G4 launched a strong tidal tail and bridge, G1 launched a faint tail (retrograde encounter?) and a small bridge, G2 gave origin to the cone-like plume. Some gas was driven from the disk to the center of the gas-poor G2 starting a small episode of SF, while stronger SF episodes were triggered in the gas-rich G1 and G4.

Evolutionary synthesis models

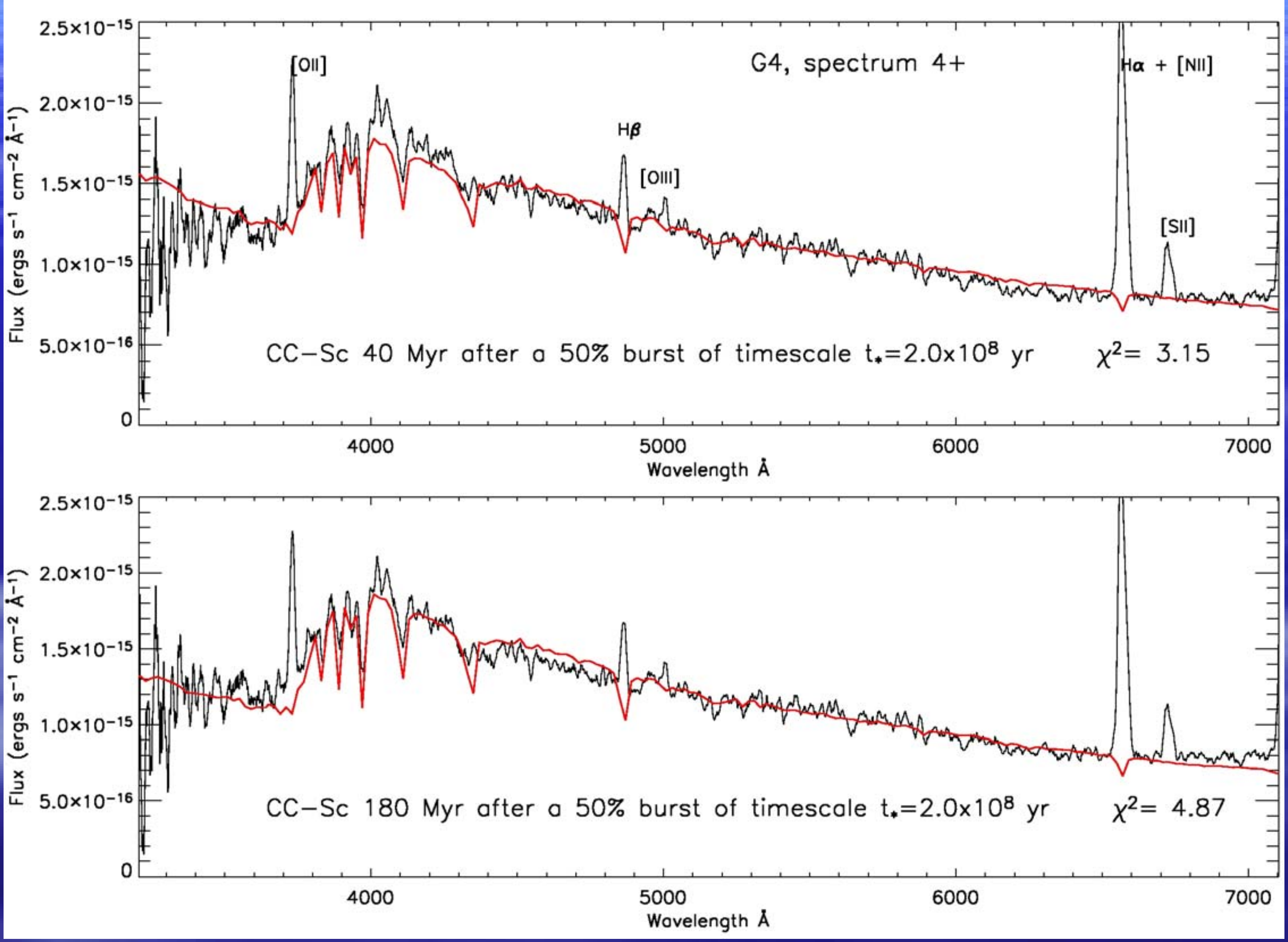
Temporin & Fritze-v. Alvensleben 2005, A&A, in press (astro-ph/0509905)

Application of code GALEV (Fritze-v. Alvensleben & Gerhard 1994; Schulz et al. 2002) to optical-NIR photometry and optical spectra under closed-box assumption and simulating recent burst on top of normal evolution.
Nebular emission is not included.

→G1 and G4 consistent with Sc galaxies that experienced a moderate to strong (25% - 50%) burst of SF 40 to 180 Myr ago.
Stellar mass increase 9 – 24%.
Burst age consistent with estimated age of the tidal tail.
SFR @ best fit age consistent with observations.
Estimated masses: $M_{G4} \sim 2x10^{10}\ M_{\odot}$ $M_{G1} \sim 5x10^{9}\ M_{\odot}$

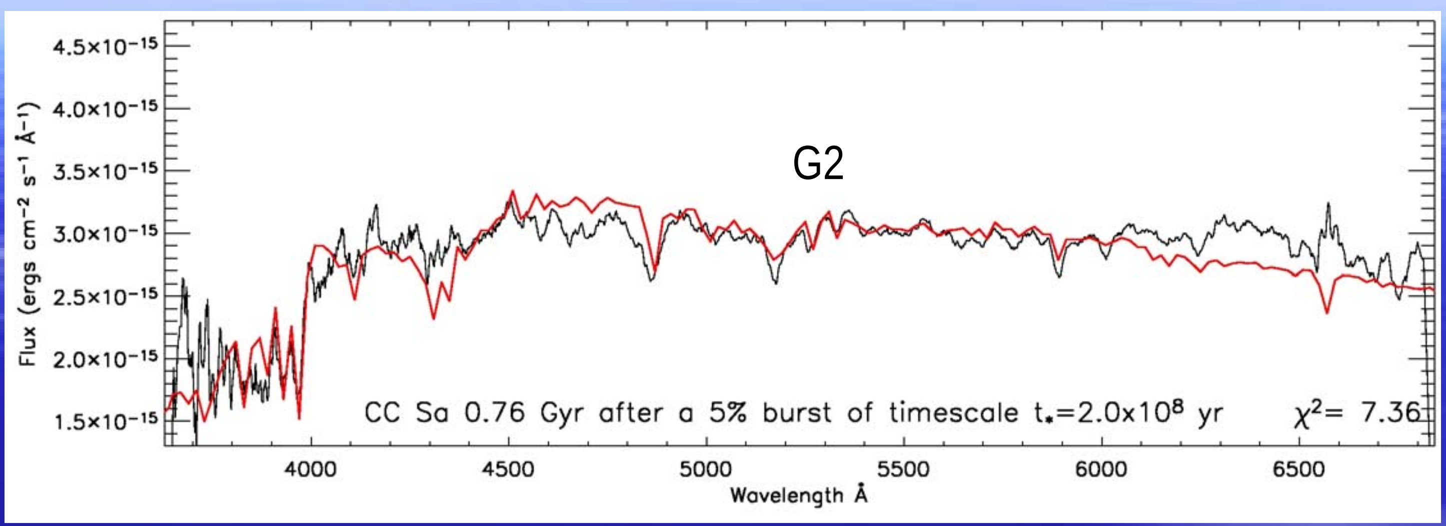
→G2 consistent with
either merger of 2 early-type spirals (Sa) < ~ 1 Gyr ago
burst age ~ 0.7 – 0.9 Gyr, stellar mass increase 5%
estimated mass ~ $3.4x10^{10}\ M_{\odot}$
or early-type with central episode of SF due to interaction-induced gas inflow
burst age ~ 0.9 – 1.0 Gyr, stellar mass increase 8%
estimated mass ~ $7x10^{10}\ M_{\odot}$

Best-fit models for G4:
Chemically-consistent-Sc models 40-180 Myr after a 50% burst

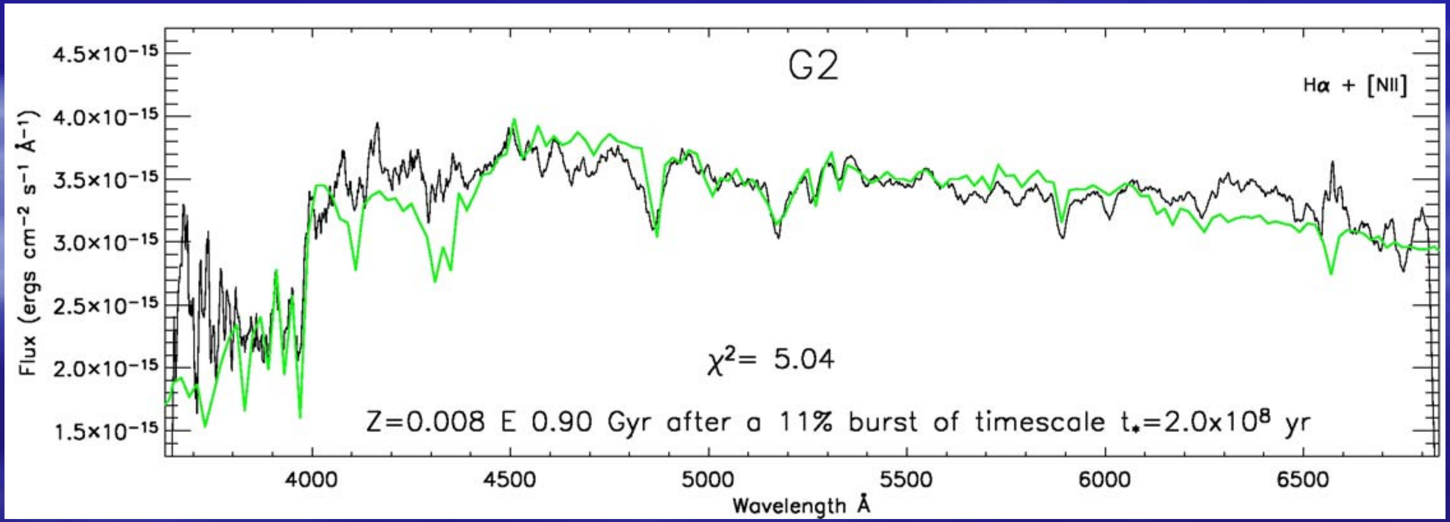


Two possible models for G2:

1) Chemically-consistent-Sa+Sa merger model, seen 0.7 Gyr after a 5% burst



2) Z = 0.008 E model seen 0.9 Gyr after an 11% burst



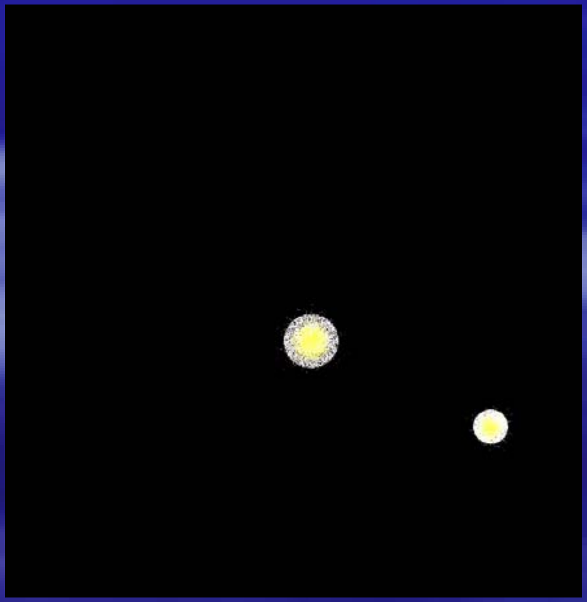
Hydrodynamical simulations

Can the observed galaxy configuration be explained with an interaction between the two spiral galaxies? Or is this a 3-galaxy interaction?

→ Comparison of observations with combined N-body/hydrodynamical simulations (provided by W. Kapferer), obtained with GADGET2 (Springel 2005, astro-ph/05).

For assumptions and technical details see Kapferer et al. 2005, A&A, 438, 87 and references therein.

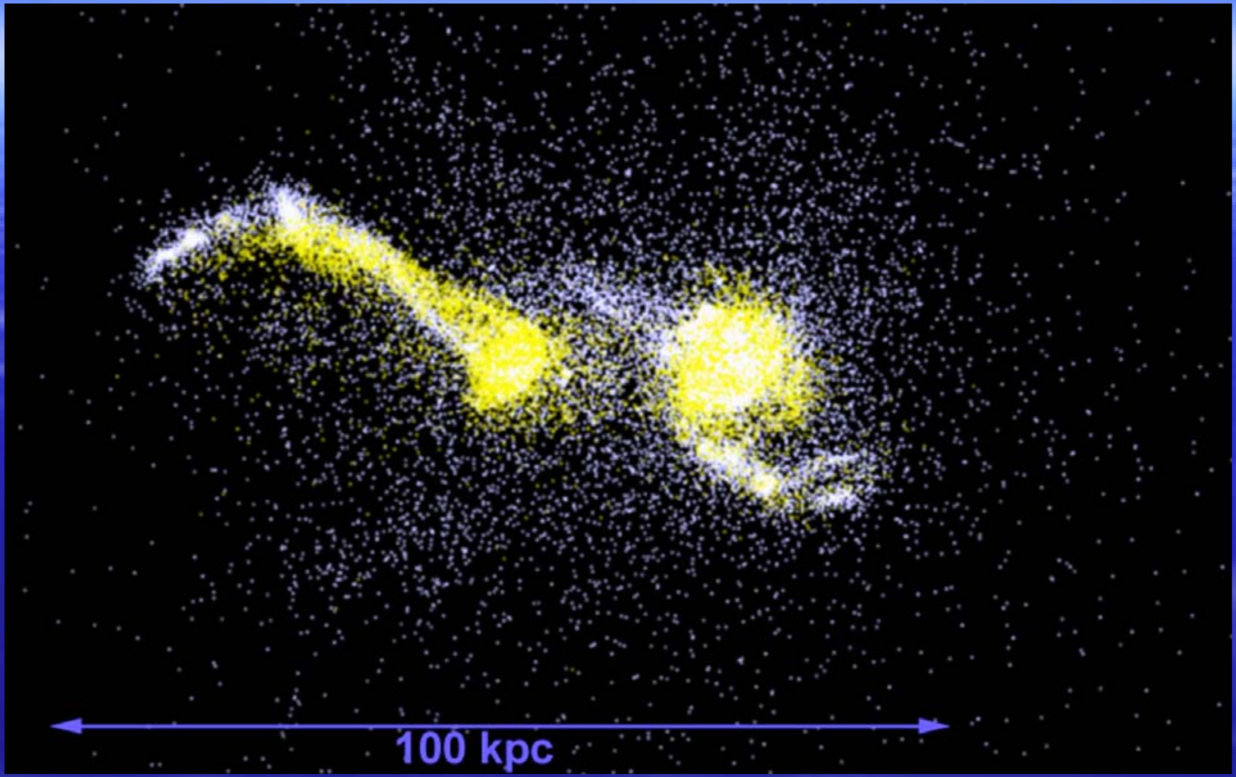
Fast prograde encounter of 2 unequal mass disks.



Properties	Galaxy A
Halo concentration[1]	5
Circular velocity v_{200} [km s^{-1}] [2]	160
Spin parameter λ[3]	0.05
Disk mass fraction[4]	0.05
Bulge mass fraction[4]	0
Bulge size[5]	0
Gas content in the disk[6]	0.25
Disk thickness[7]	0.02
HI gas mass fraction[8]	0.5
Total mass [$M_\odot$]	$1.3375 \times 10^{11}\ h^{-1}$
Disk scale length [kpc]	$4.50622\ h^{-1}$

[1] $c \equiv \frac{r_{200}}{r_s}$ (r_s scale radius for dark matter halo density profile $\rho(r) = \rho_{\rm crit} \frac{\delta_0}{(r/r_s)(1+r/r_s)^2}$).
[2] Circular velocity at r_{200}.
[3] $\lambda = J|E|^{1/2} G^{-1} M^{-5/2}$.
[4] Of the total mass (baryonic and non baryonic matter).
[5] Bulge scale length in units of disk scale length.
[6] Relative content of gas in the disk.
[7] Thickness of the disk in units of radial scale length.
[8] In comparison to the total gas mass.

Snapshot shortly after the fast prograde encounter of the 2 disks:

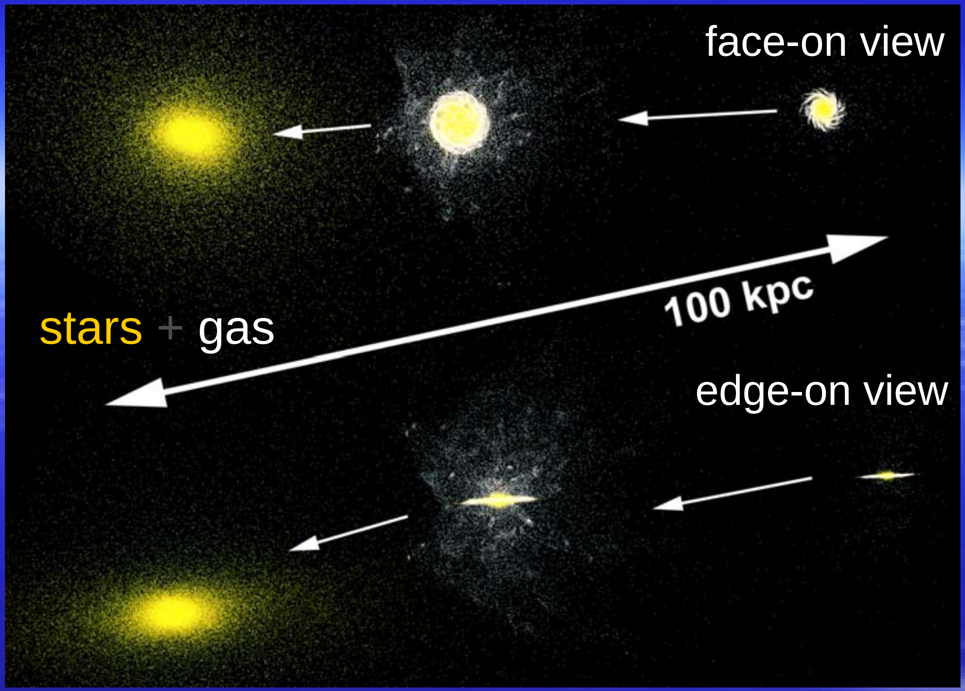


Retrograde encounters also produce a second tidal tail that we do not observe!

↓

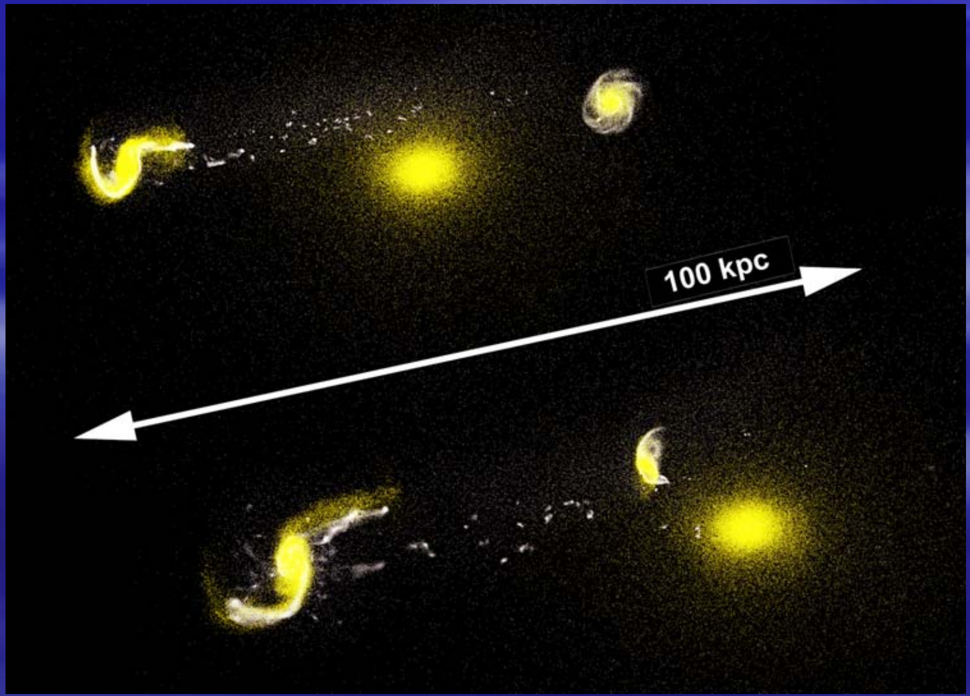
The interaction must be more complex. The S0 galaxy must play an active role.

In this simulation the S0 was formed by an equal mass merger.
Two spirals with masses $3 \times 10^{10}\ M_\odot$ and $1 \times 10^{10}\ M_\odot$ interact with the S0.
The initial separation of the S0 from the 2 spirals is 100 and 200 kpc, resp.

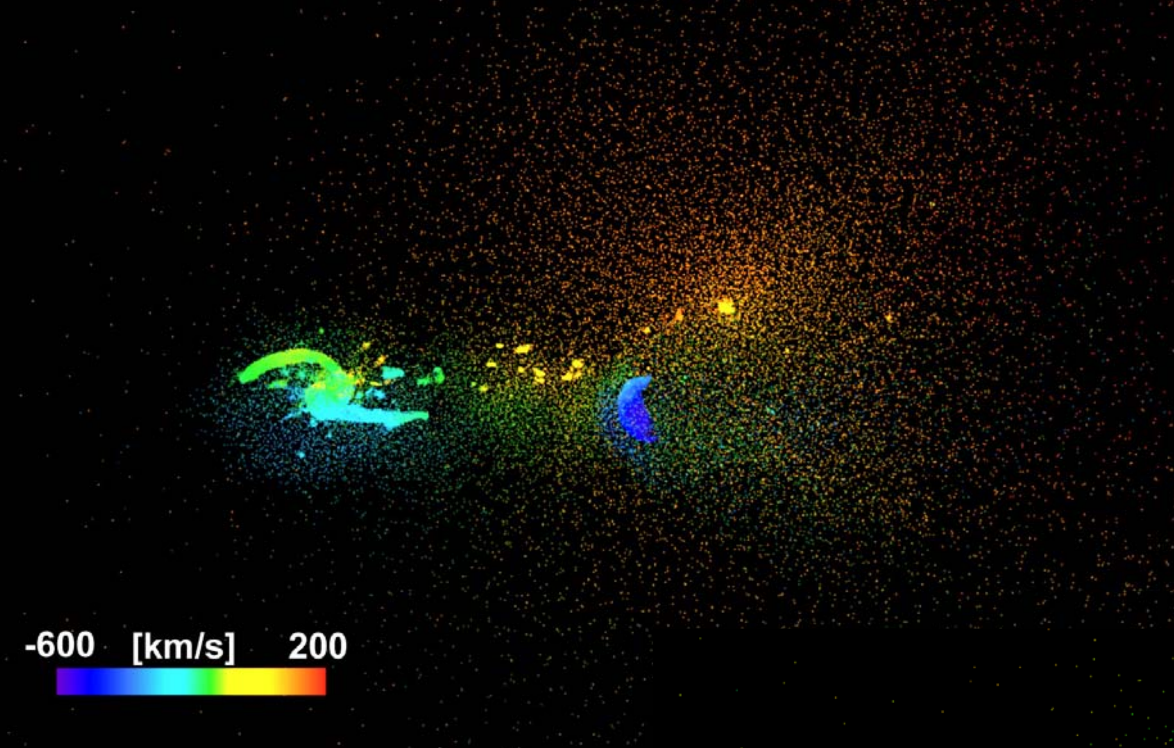


The bigger spiral has started the interaction with the S0.

1 Gyr later, the bigger spiral has undergone first encounter with S0 and formed a bridge of gas clouds.

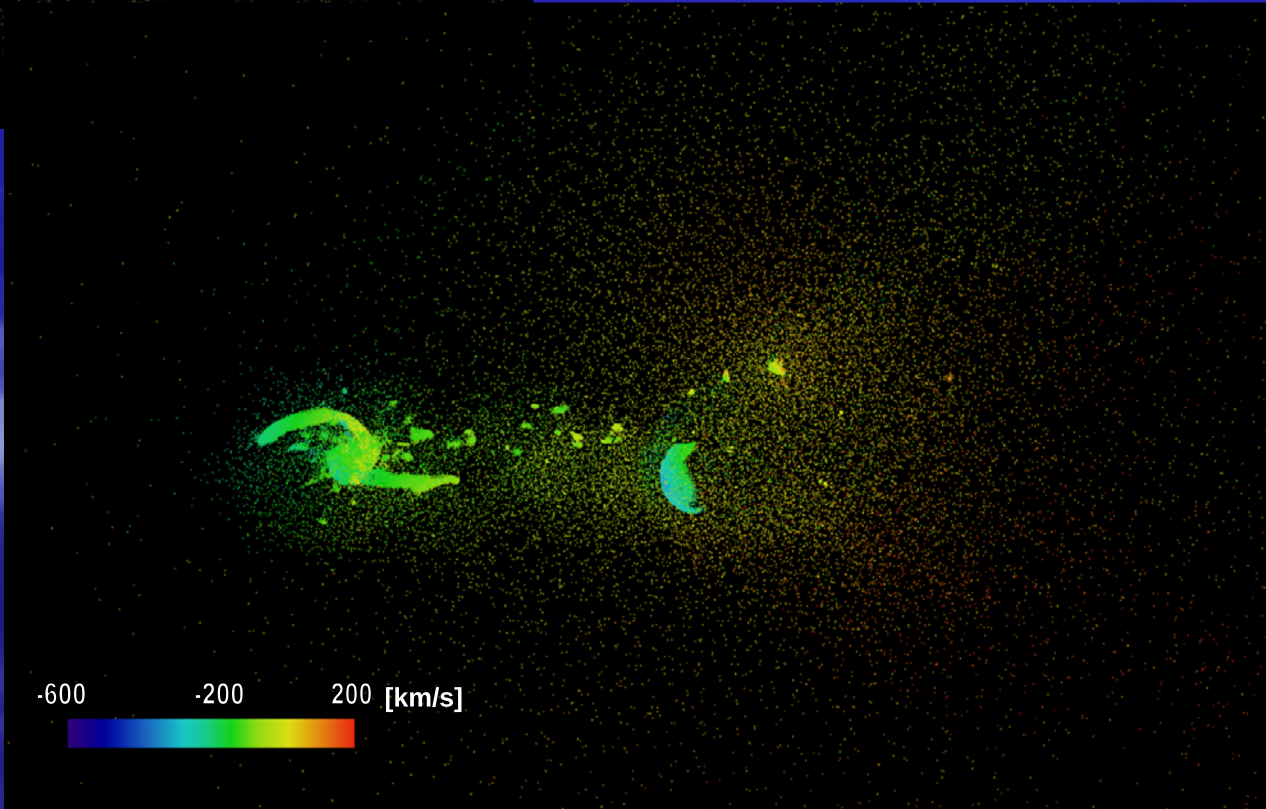


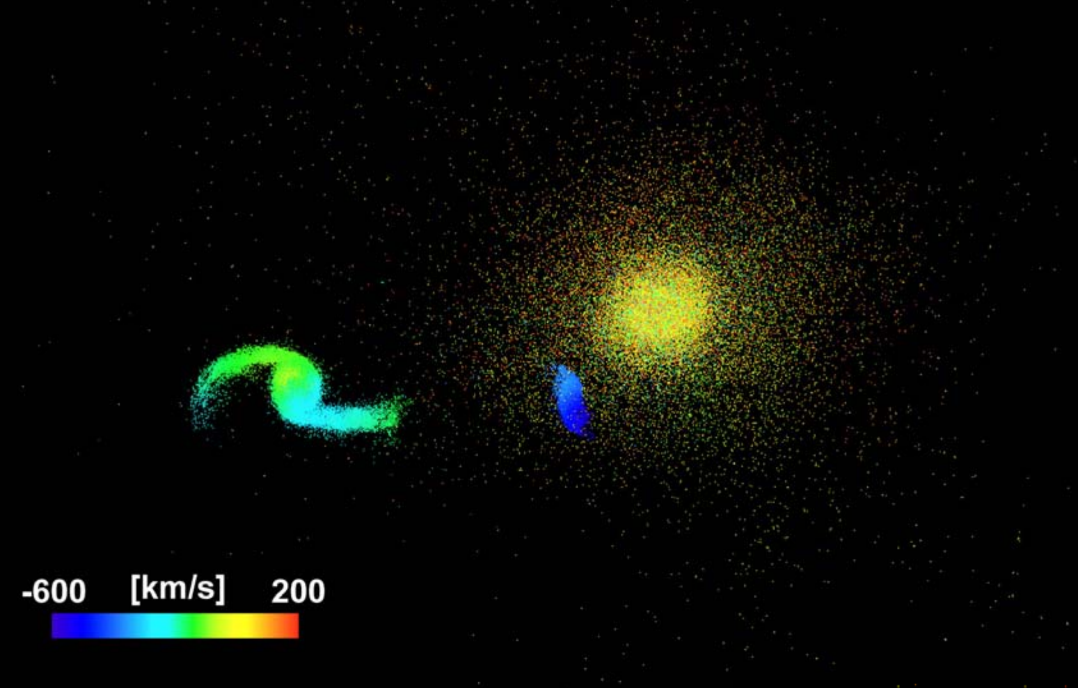
15 Myr later: the smaller spiral has undergone first encounter with S0 and is now remarkably distorted.



Velocity distribution of the gas.

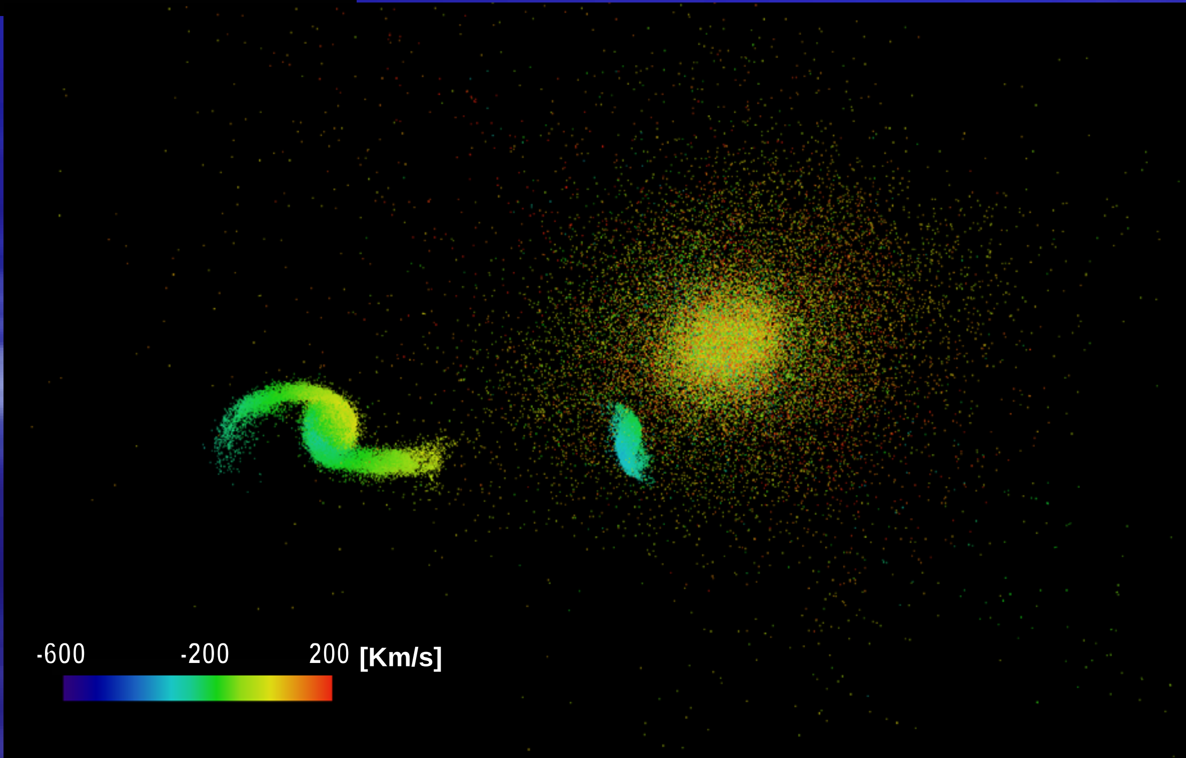
Velocity distribution of the gas seen in projection.





Velocity distribution of the stars.

Velocity distribution of the stars seen in projection.



Conclusions

- We found several observational evidences that CG J1720-67.8 is in a late pre-merging phase. The evolutionary stage of the group is probably similar to (or more advanced than) that of HCG 31, which is claimed to have started the merging process (e.g. Amram et al. 2004).
- The fit of evolutionary synthesis models to the data suggest that the latest interaction episode for the two spiral galaxies took place < 200 Myr ago. Another interaction episode (or merger event) has involved the S0 galaxy < 1 Gyr ago.
- First comparisons with N-body/hydrodynamical simulations seem to indicate that all three group members are actively involved in the interaction.
- The extreme compactness and low velocity dispersion suggest that the group coalescence will be fast.
- If CG J1720-67.8 is to be considered as representative of a late pre-merging phase in poor groups, its properties suggest that sufficiently gas-rich groups might undergo a particularly active star-forming phase before final coalescence. Comprehenseve studies of groups representative of differing evolutionary stages will greatly increase our understanding of CG evolution.

Thank you!