Dwarf galaxies in groups within 5 Mpc: resolved stellar populations

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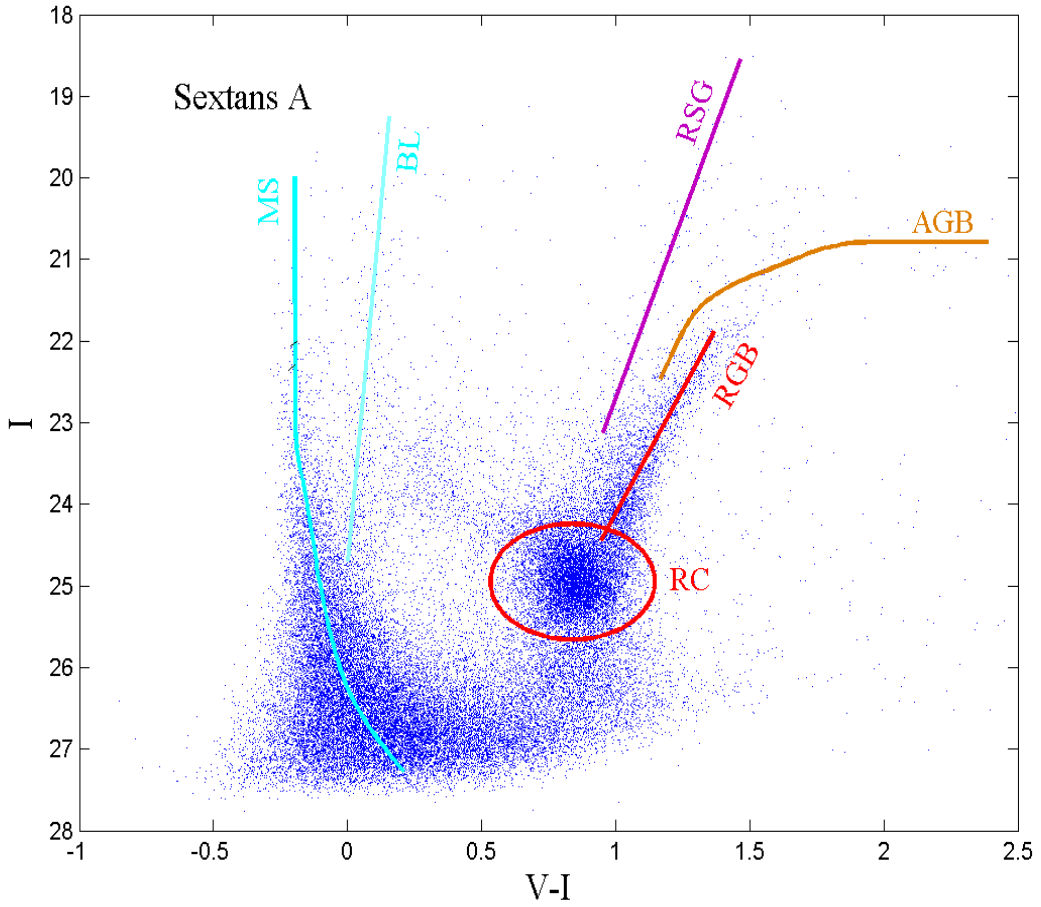
Aims and objects of our study:

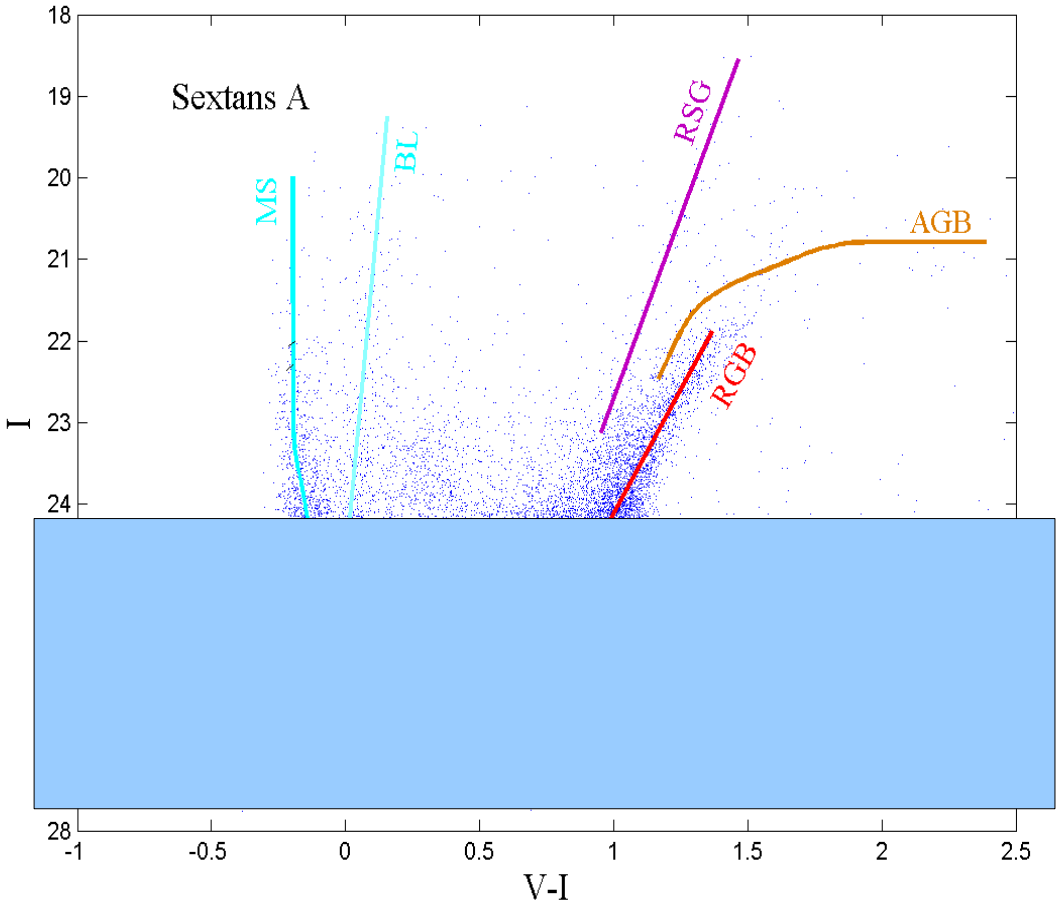
- Dwarf galaxies are the most convenient objects for galaxy evolution study: they are most numerous galaxies in the Universe, and their structure is relatively simple
- The question of star formation in dwarf galaxies is extremely important for understanding of their origin and evolution
- Nearest galaxies are resolving into individual stars, which can be studied photometrically and by spectroscopy
- The key parameter is accurate distance to a galaxy
- Tip of the red giant branch distance indicator (TRGB). Recently improved (trgbtool), new calibration
- Observations of most nearby galaxies allow us to derive their star formation history during all the galaxy's life directly

Colour-magnitude diagram



MS – main sequence stars (H burning in core), 10-300 Myr
BL – blue loop stars (He burning out of core), 10-300 Myr
RSG – red supergiants (He burning in core), 10-300 Myr
AGB – asymptotic giant branch, > 1 Gyr
RGB – red giant branch (He burning in envelope), > 1 Gyr
RC – red clump stars

Colour-magnitude diagram



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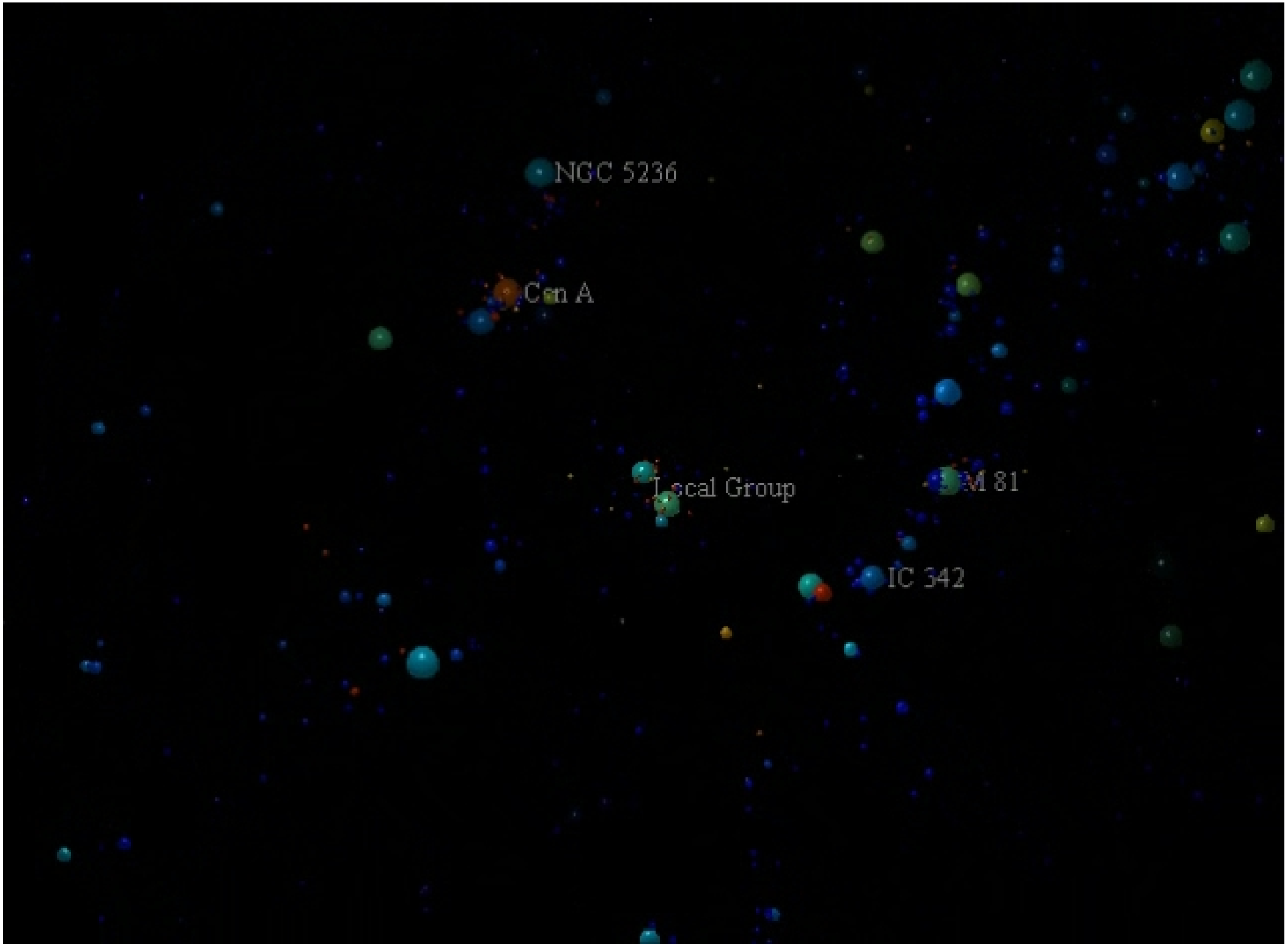
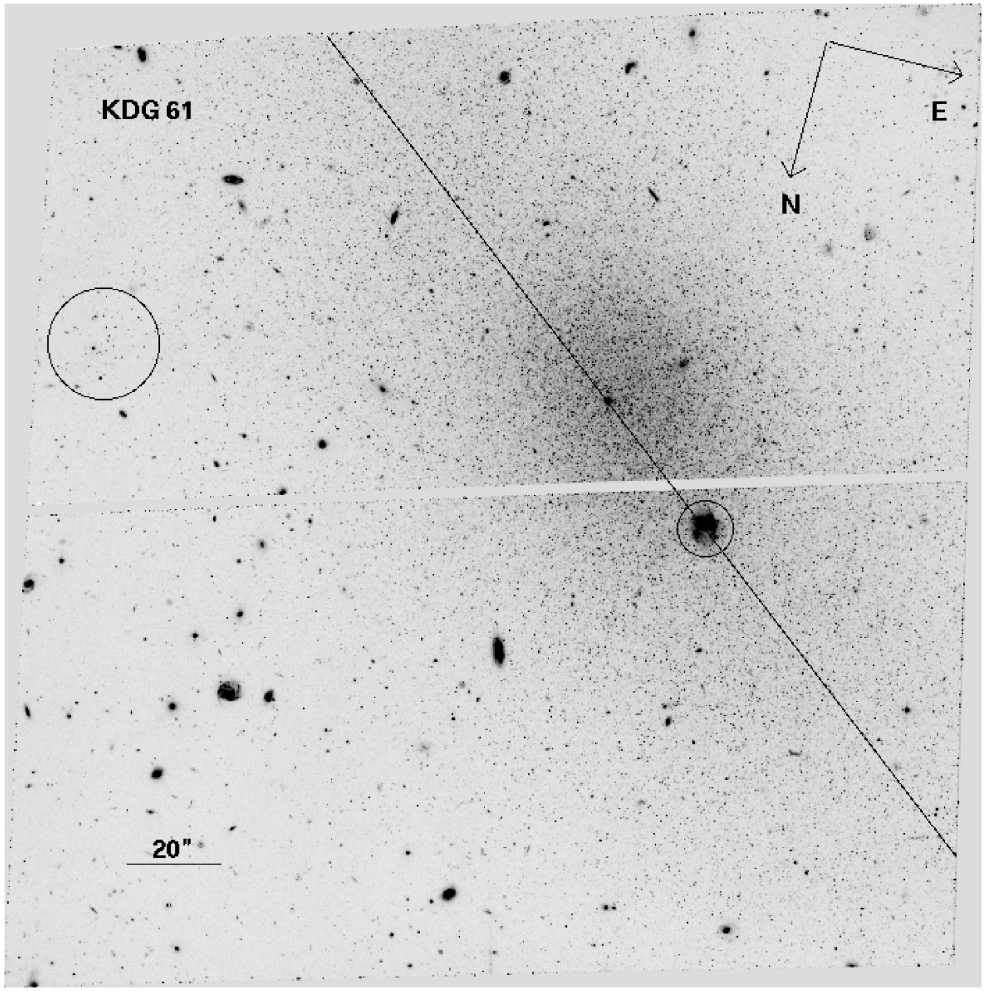
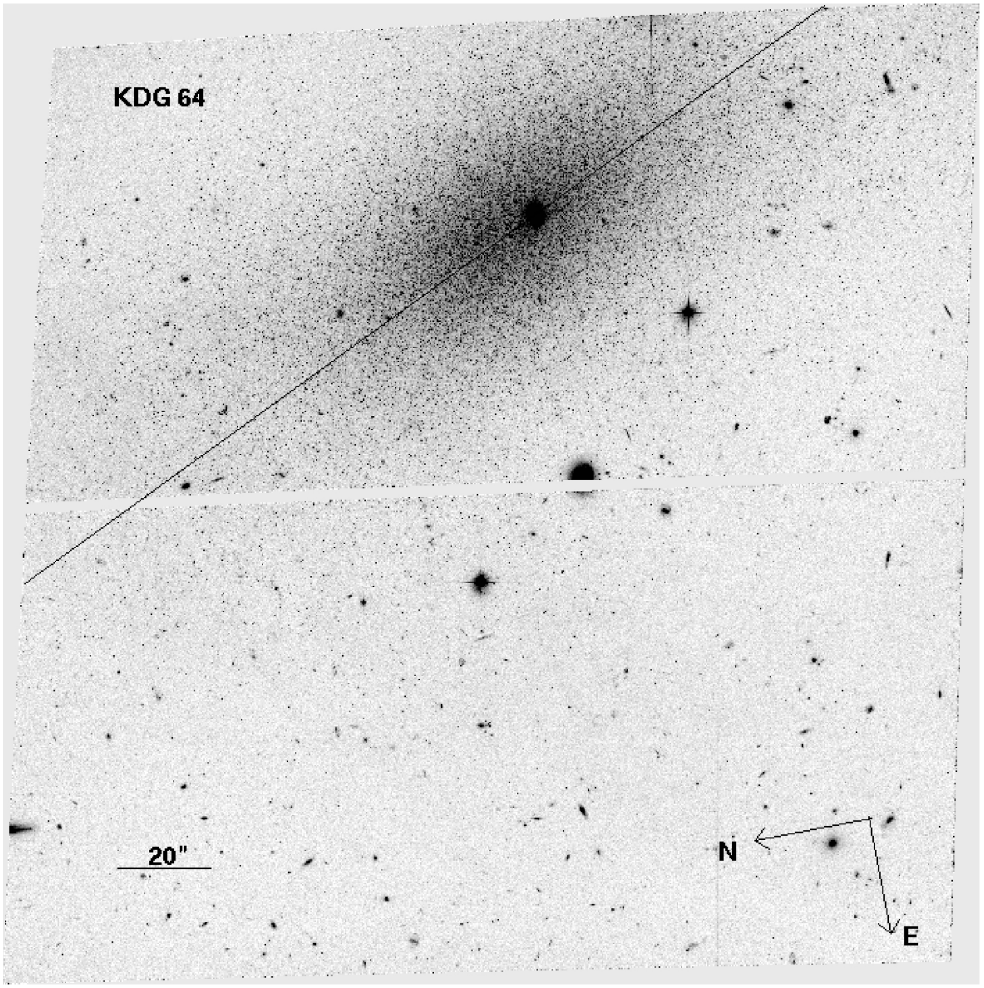

NGC 5236
Cen A
Local Group
M 81
IC 342

The method

- Quantitative approach to SFH determination: Tosi et al. 1989, Aparicio et al. 1997, Dolphin 2000
- We have created a program StarProbe to analyze our large and homogeneous sample of nearby galaxies (Makarov and Makarova 2004). The objects are situated outside the Local Group. Only brightest part of their stellar populations appears at the CMDs.
- We construct synthetic color-magnitude diagrams from theoretical stellar isochrones taking into account the initial mass function, galaxy distance, external extinction and photometric errors. We use the Padova stellar isochrones set.
- Photometric uncertainties and completeness values were added using results of artificial star tests, that are the accurate way to solve the problems of photometric errors, blending and incompleteness
- A linear combination of synthetic CMDs of different ages and metallicities forms a model CMD
- For SFH determination we have to find a best linear combination of partial model CMDs to match the observed data. We construct a maximum-likelihood function for this task.

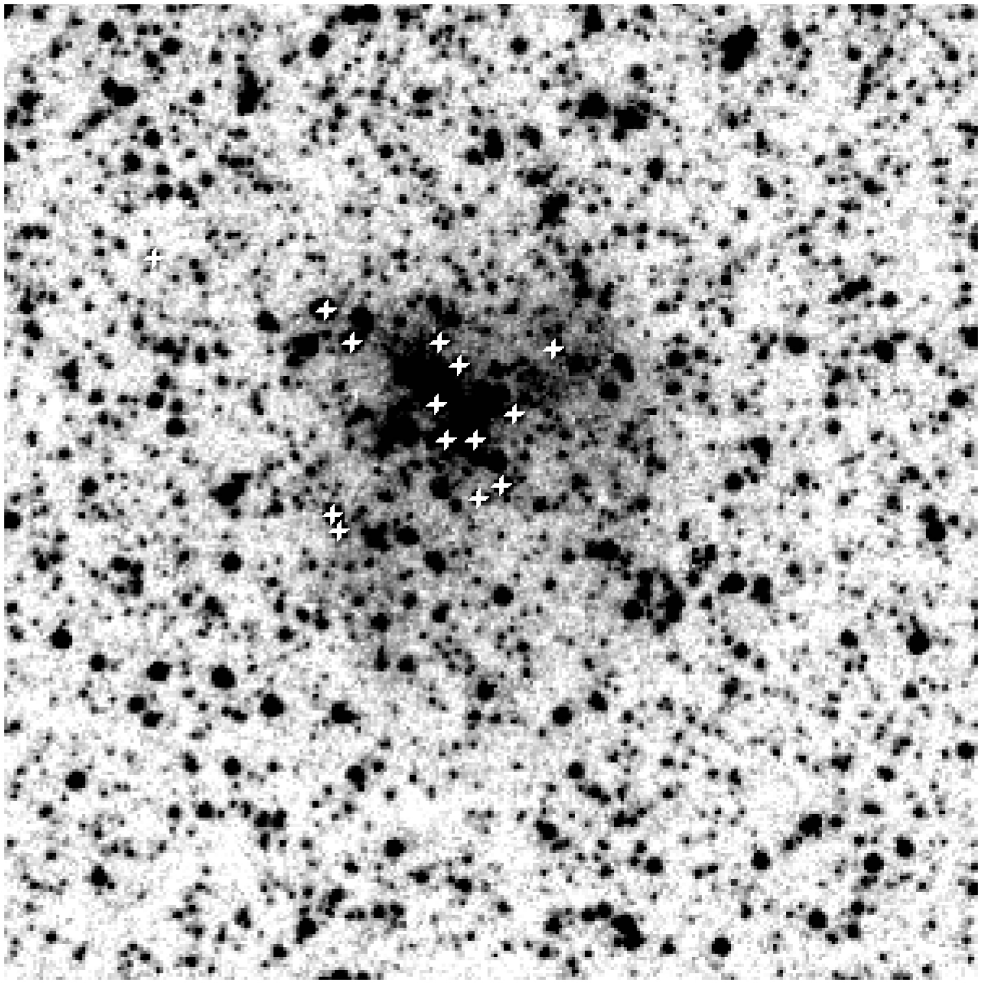
Two dwarf spheroidals in the M81 group





HST/ACS image of KDG 61 and KDG 64 in F606W filter

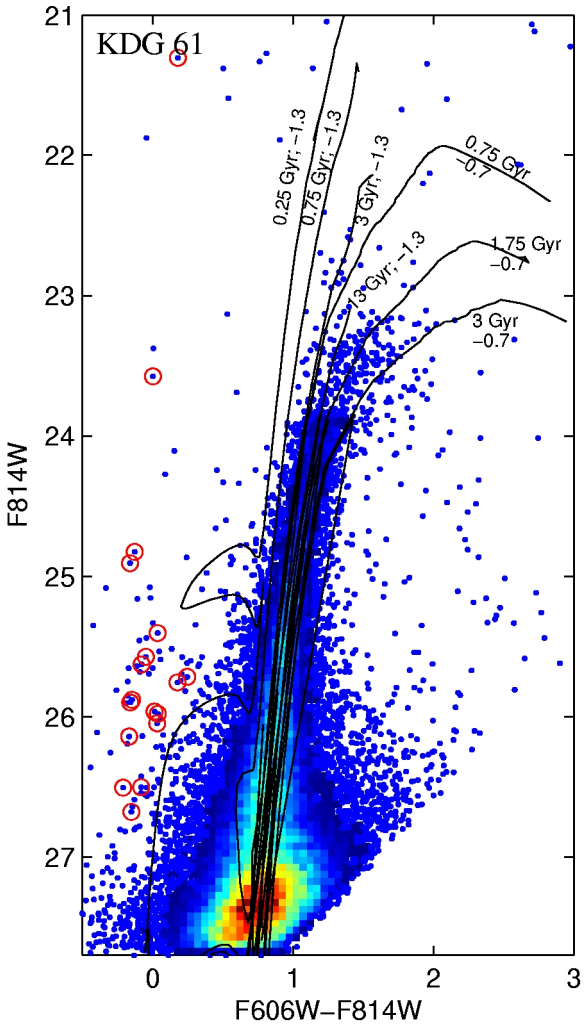
Detailed picture of HII region



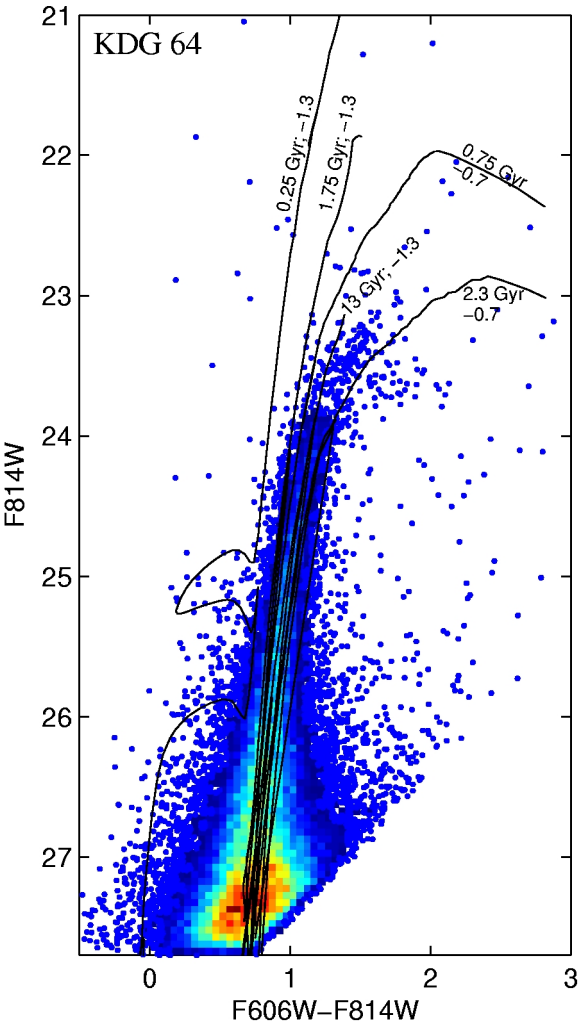
The size of the smaller picture is 15 arcsec (250 pc). We mark with crosses the resolved blue stars at this region. We have found, that the HII knot previously suggested to belong to KDG61 is in fact a wind-blown superbubble associated to a HI tidal stream projected on the line-of-sight.

Colour-magnitude diagrams

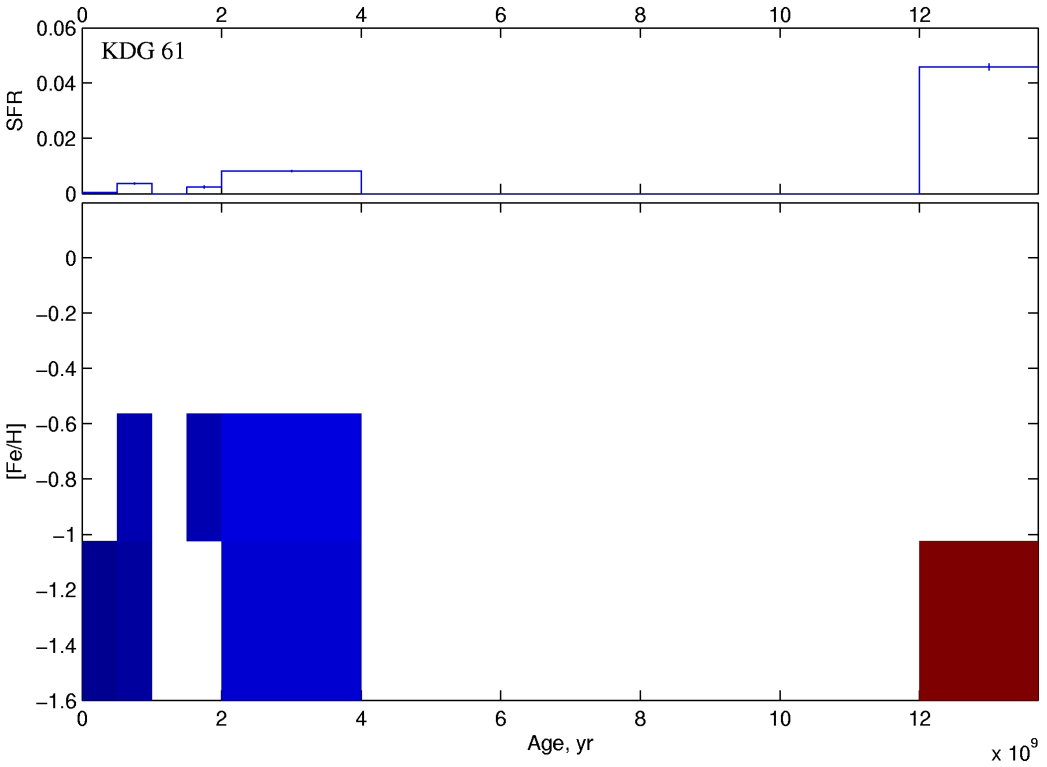
KDG 61

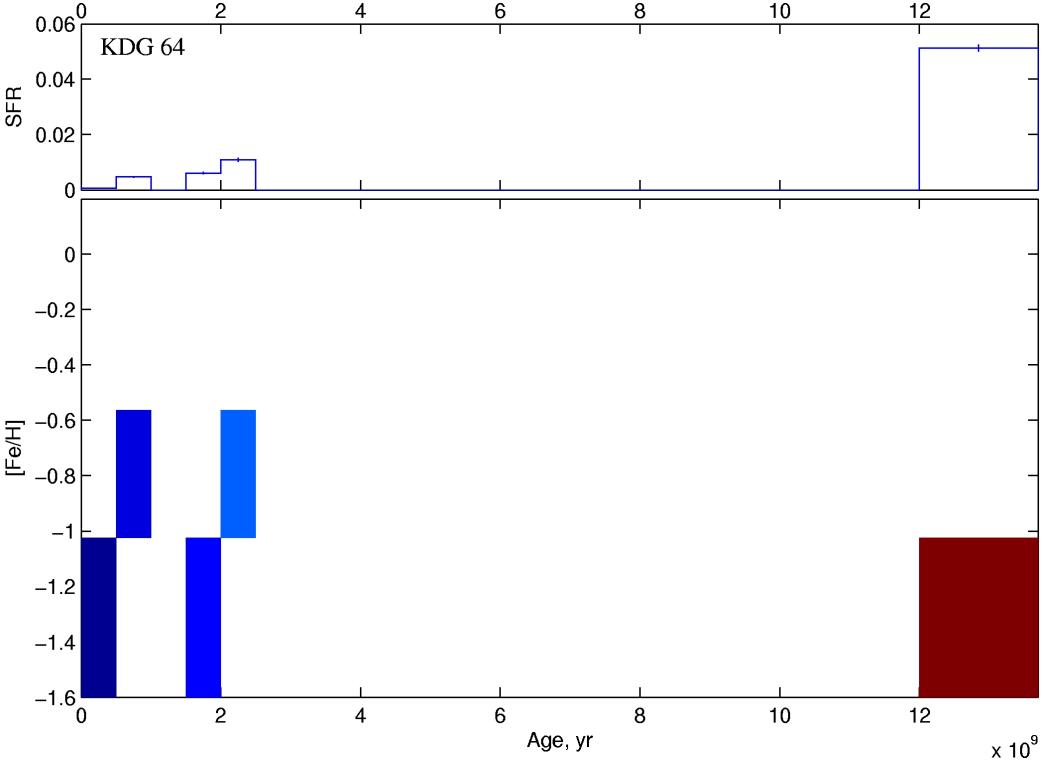


KDG 64



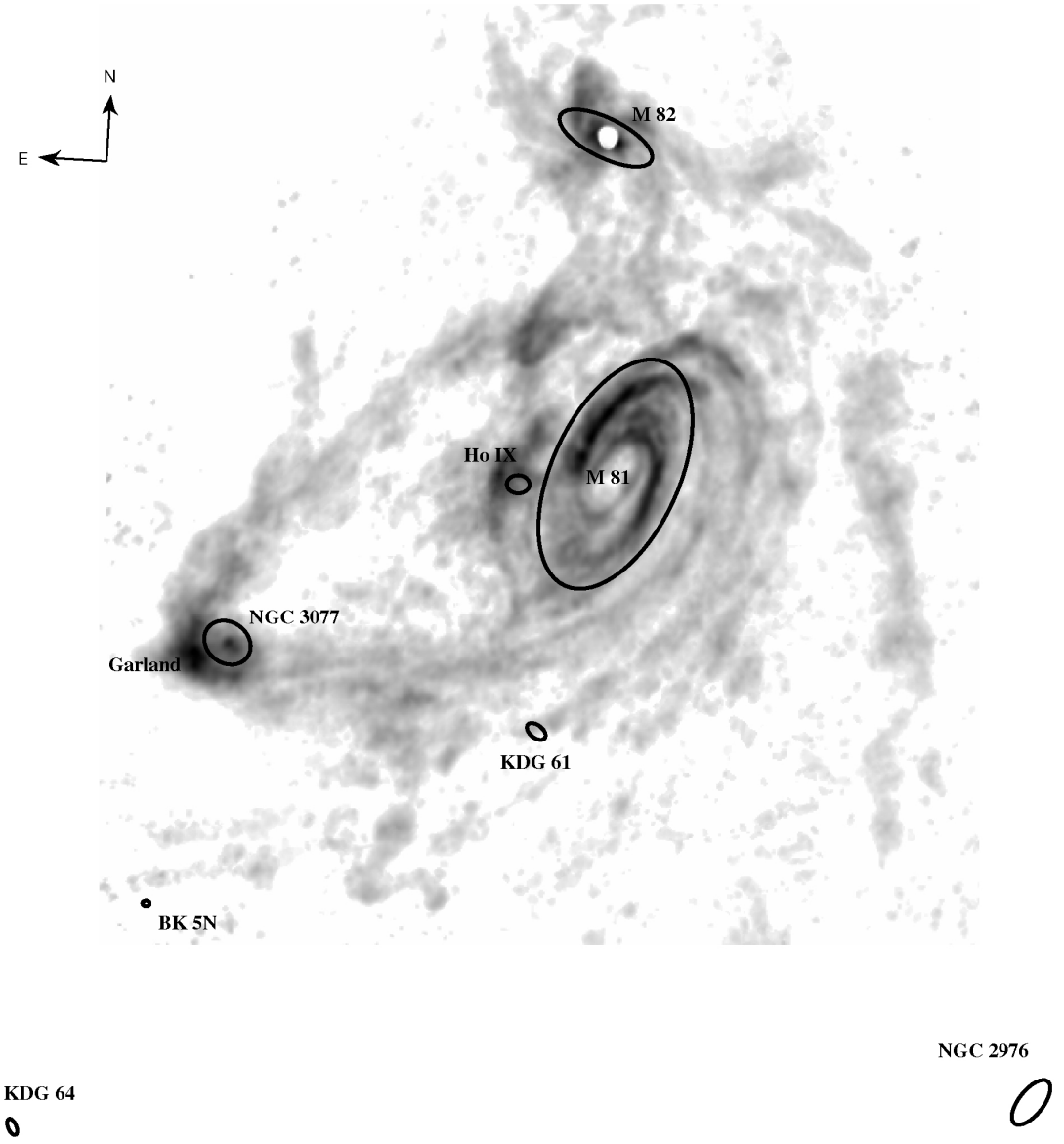
Star Formation History





The main star formation event occurred between 12 and 14 Gyr. These initial bursts account for 82-86 and 72-89 % of the total mass of formed stars for KDG 61 andKDG 64. [Fe/H] of these old stars is about -1.5 dex for KDG 61 and -1.6 dex for KDG 64. There are intermediate age star formation in the both galaxies.

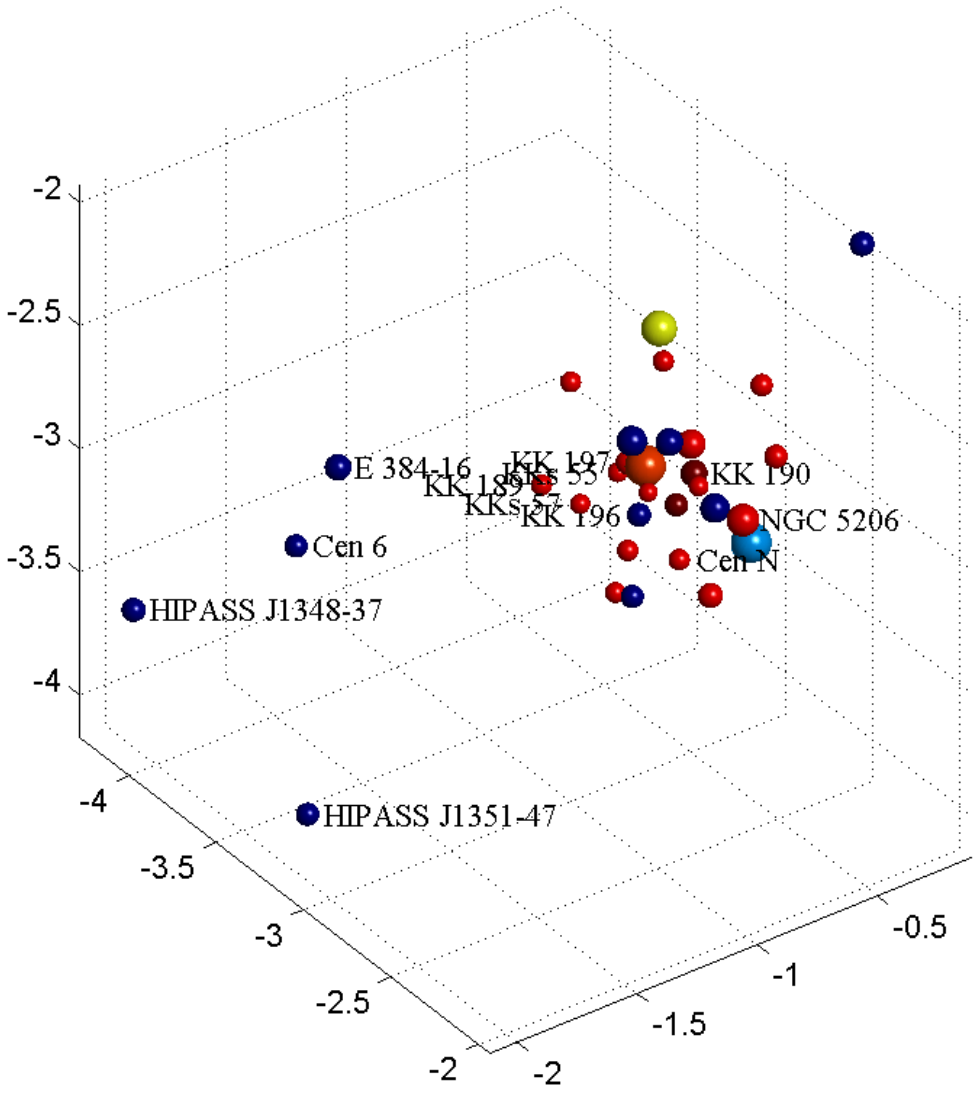
Integrated HI map of the central part of the M 81 group (Yun et al. 1994).

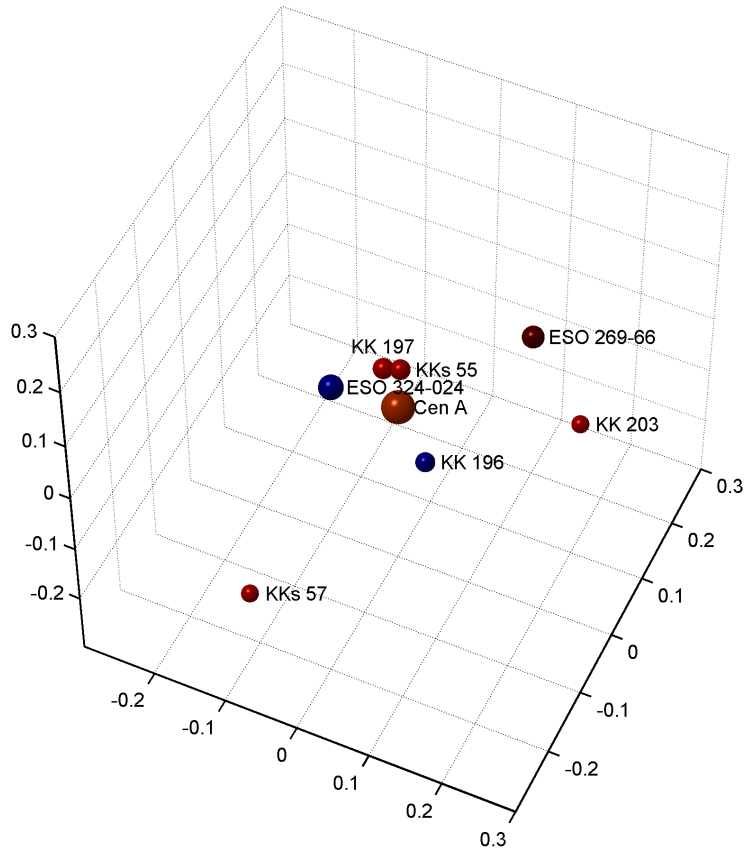


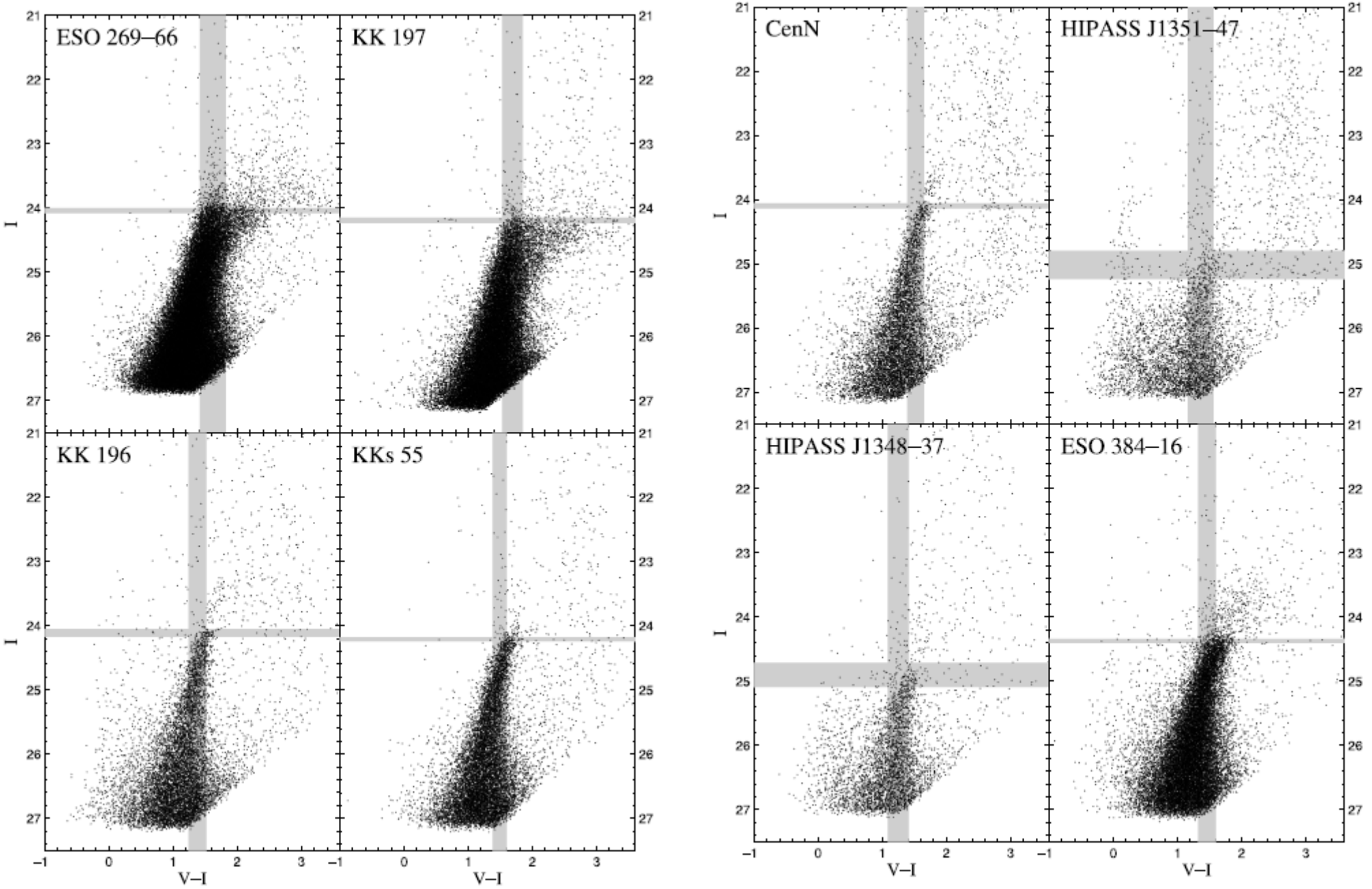
Evolution scenario

- The environment is often proposed to be responsible for the evolution of the gas-rich small galaxies into dE/dSph through a transition-type phase. The M81 group is an excellent site to catch these phenomena in the act, due to the intense interactions between its members.
- Arguing on the presence of HI gas, KDG61 was proposed in several occasions to be such a transition type object. But as we have seen above, this gas is not related to the stellar population.
- The well-known numerical simulations by Yun (1999) gives the time since nearest approach between M81–M82–NGC3077 of about 300 Myr ago. Recent star formation events in these and tidal dwarf galaxies agree well with this age. But signs of earlier approaches and, therefore, earlier common star formation events are probably “erased” by the recent interaction, and, therefore, we could not relate the recent star formation event in KDG61 and KDG64 (1–4 Gyr ago) to the large scale star formation event in the M81 group.

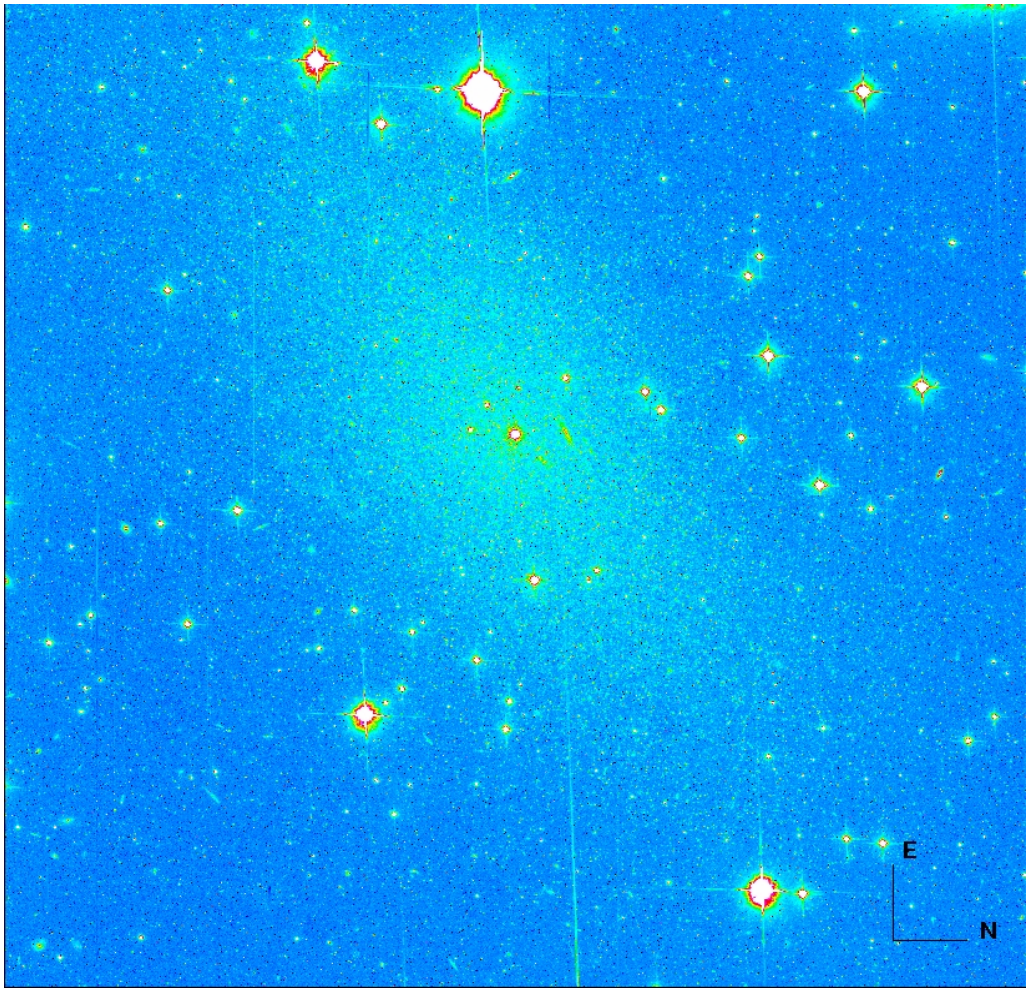
3D structure of the Cen A group



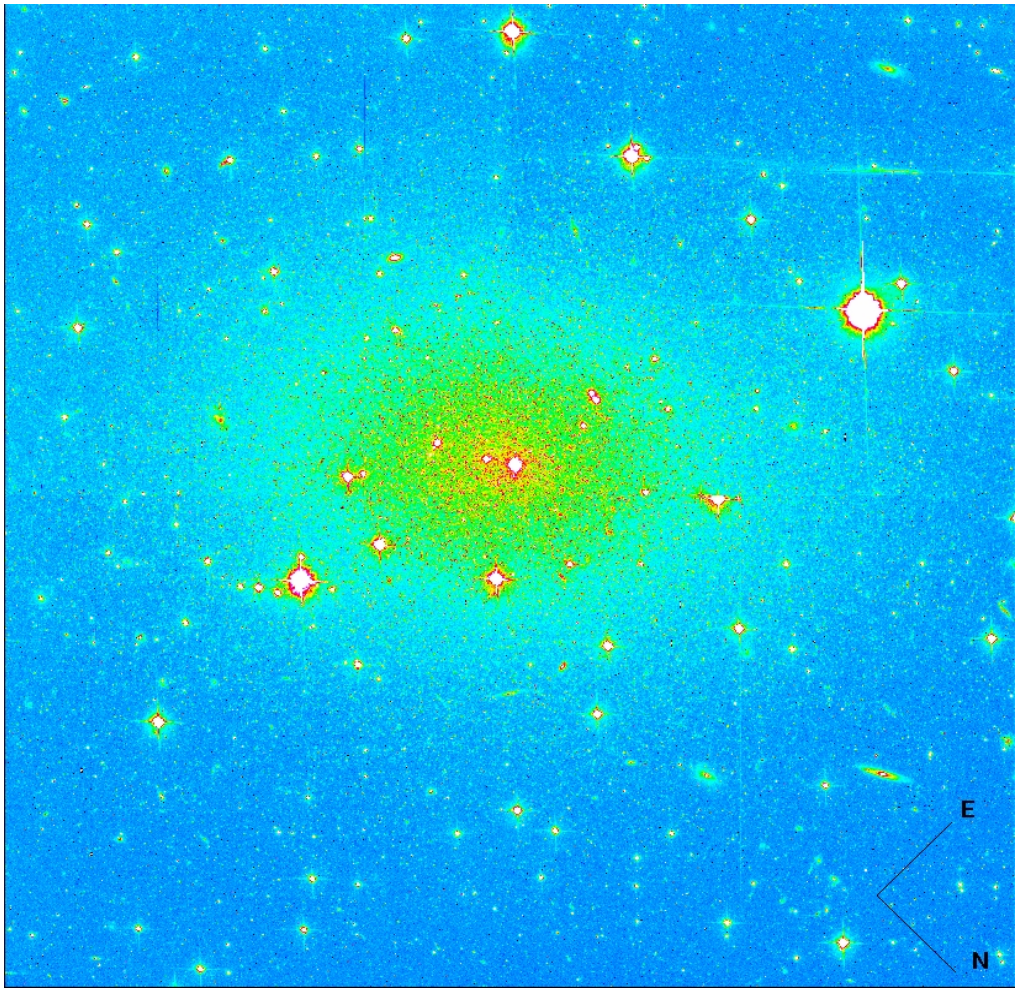



ESO 269–66
KK 197
KK 196
KKs 55
CenN
HIPASS J1351–47
HIPASS J1348–37
ESO 384–16
I
V–I

KK 197 (F814W)

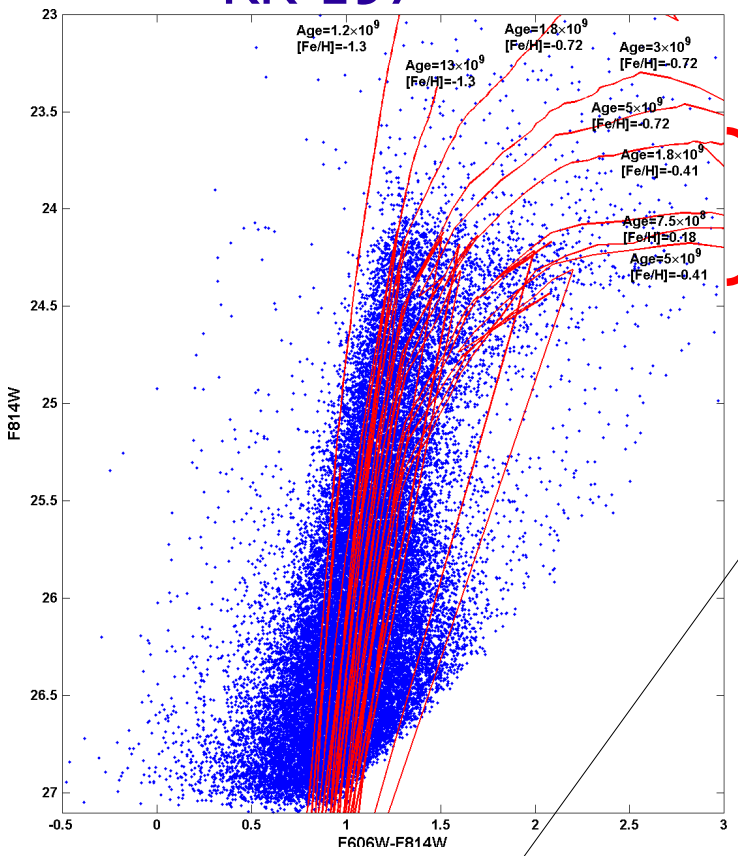


ESO 269-066 (F814W)



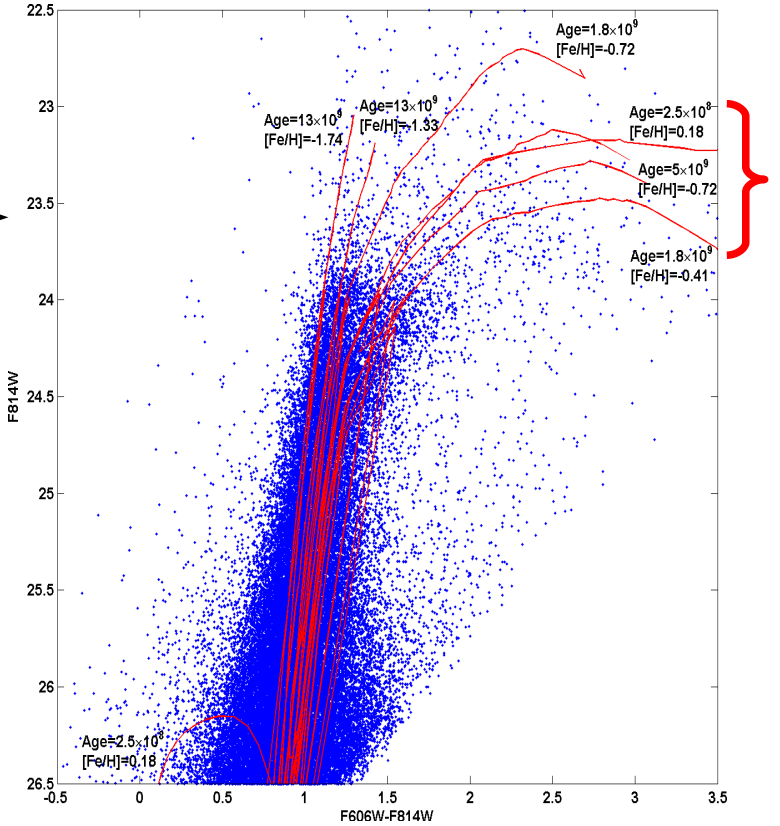
Photometry of resolved stars in the galaxies was made with the DOLPHOT package (Dolphin 2002) for crowded field photometry. Photometric distances were determined using our implementation of ML algorithm for the TRGB distance indicator (Makarov et al. 2006).

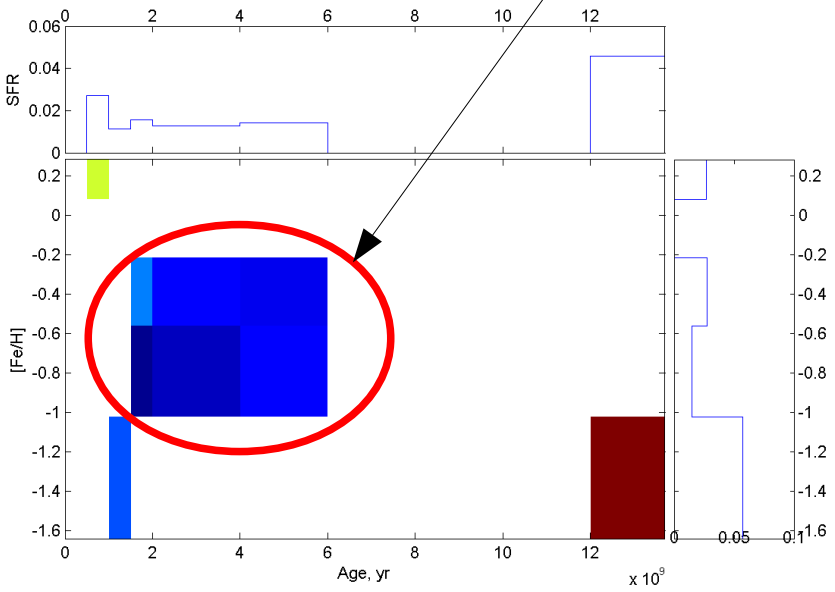
KK 197

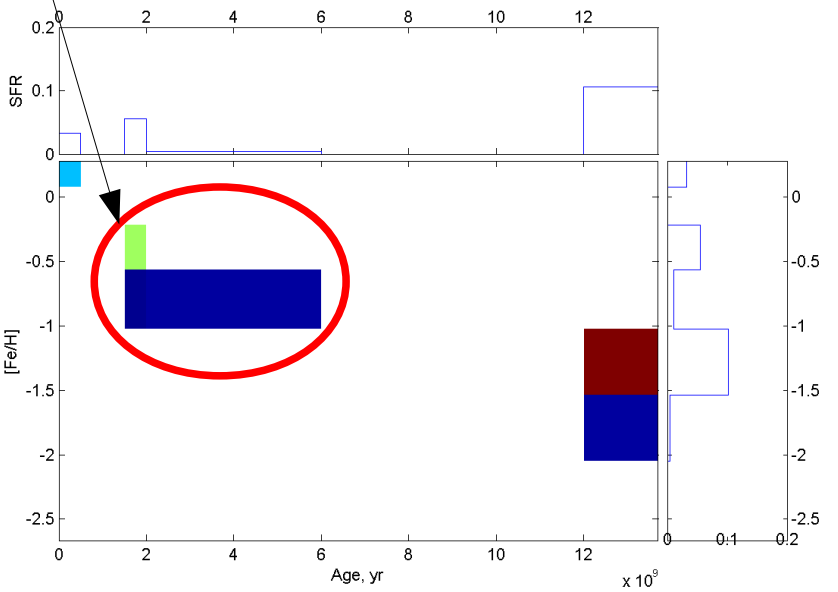


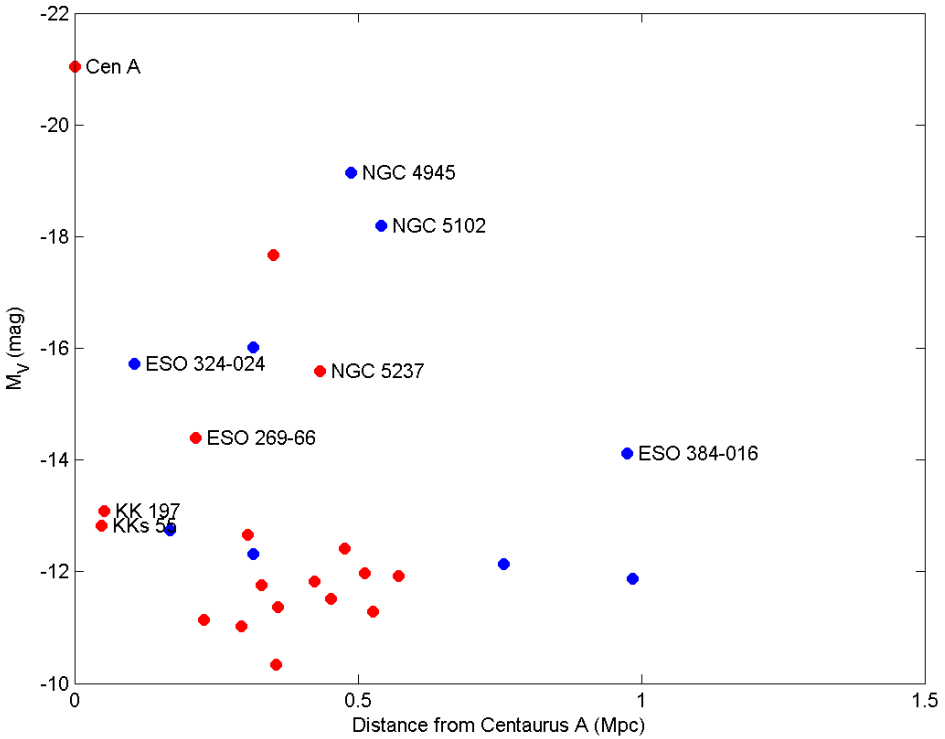
Longer Intermediate-age star formation with higher metallicity tail

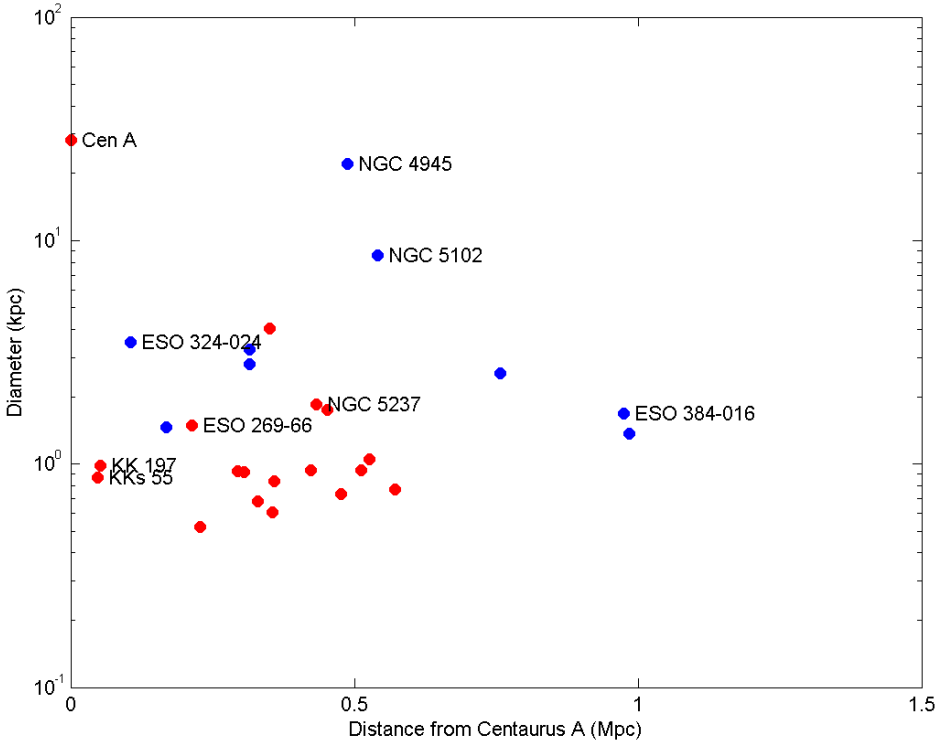
ESO 269-066







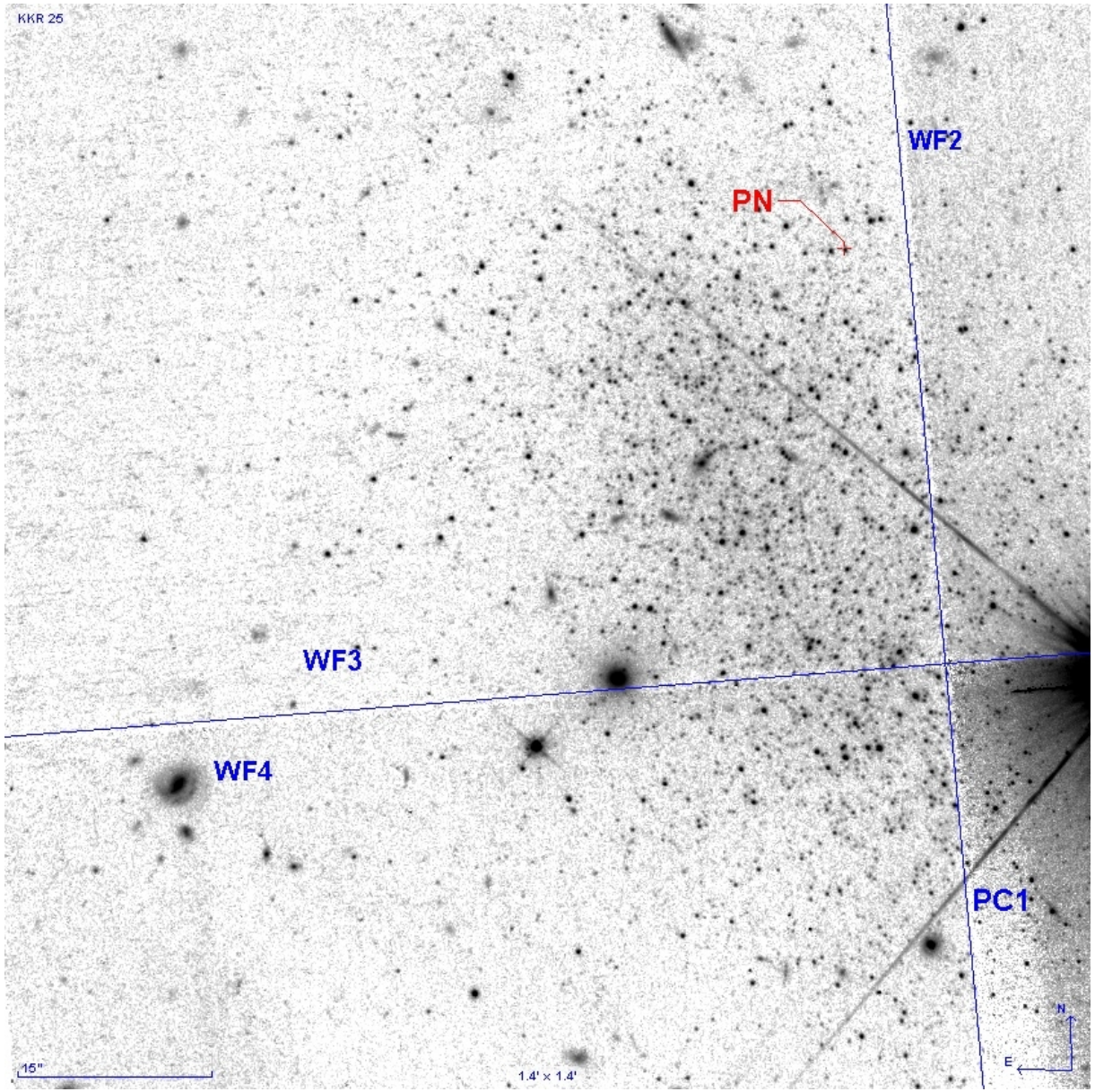


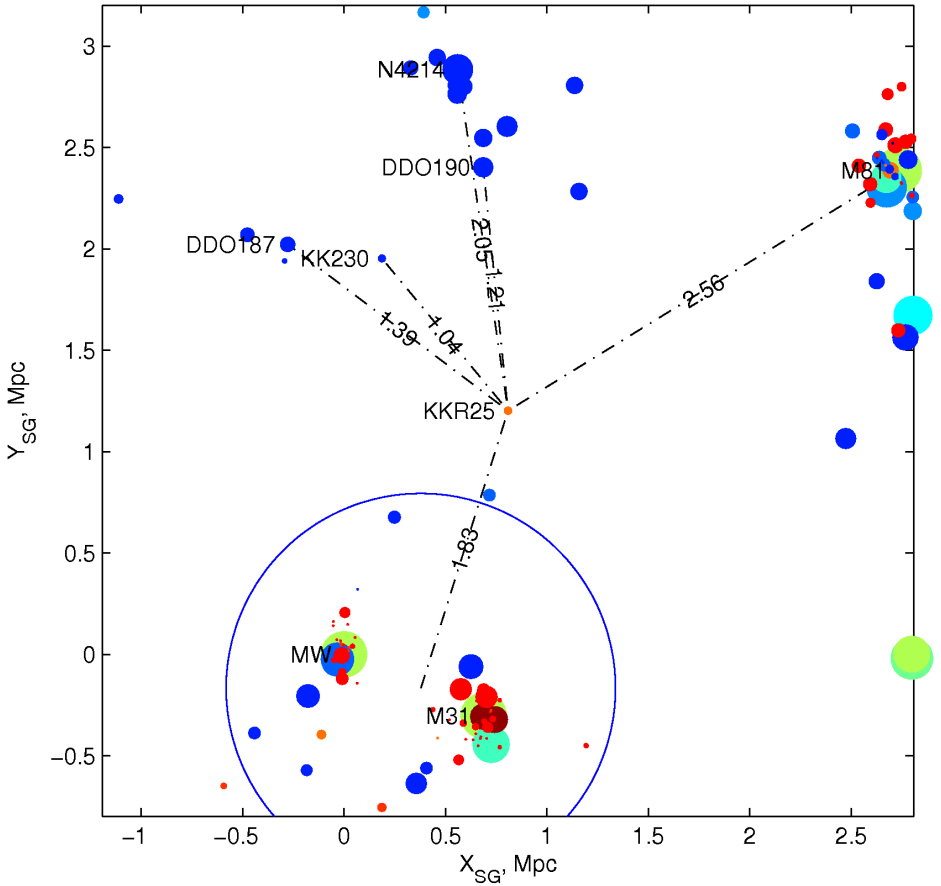


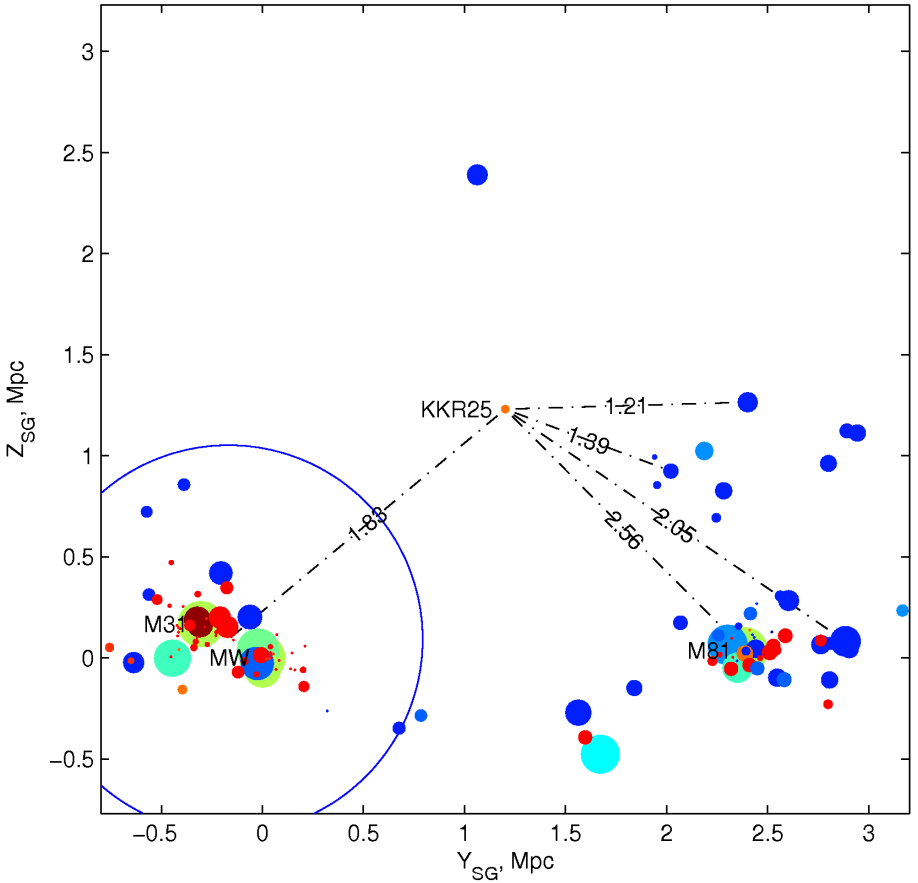
Summary

- We have found two dwarf spheroidal galaxies within Cen A group with unusual spread of the RGB population (“red flag”)
- Star formation history measurement show valuable and quite long intermediate-age star formation with higher metallicity in the both galaxies
- Both galaxies are situated close to the giant E galaxy Cen A
- There are several satellites within the distance of 300 – 400 Kpc from Cen A, including dwarf irregulars
- Whereas ESO 269-066 is brighter and larger than most of the Cen A dwarf spheroidals, KK 197 has “a twin” KKs 55, which does not show a “red flag”
- In general, the galaxies under study have not apparent peculiarities between other satellites of Cen A

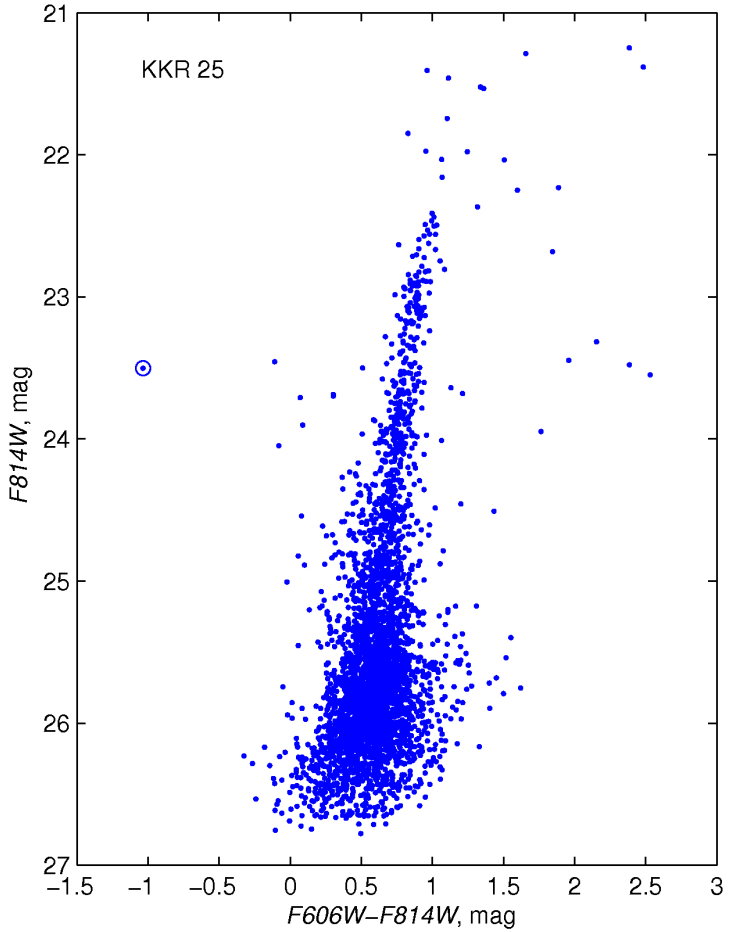
Isolated dSph KKR 25 at D=1.9 Mpc

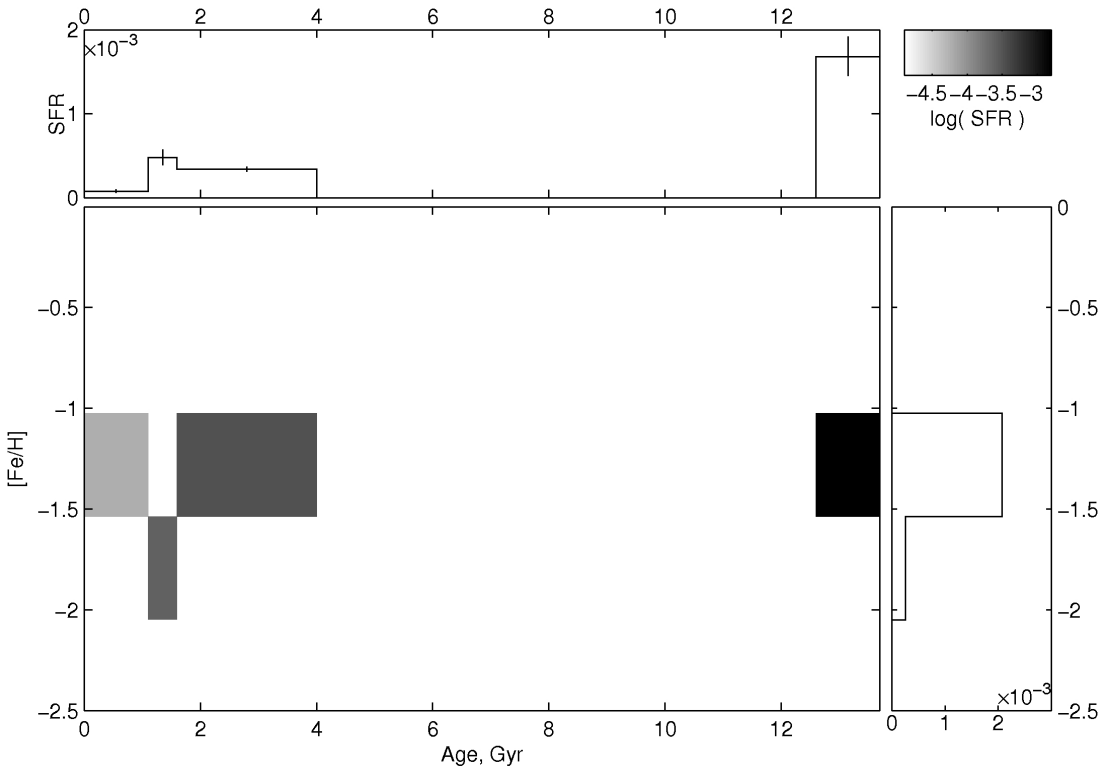



N4214
DDO190
DDO187
KK230
M81
KKR25
MW
M31
2.05
1.21
1.39
1.04
2.56
1.83
Y_{SG}, Mpc
X_{SG}, Mpc


KKR25
1.21
1.39
2.05
2.56
1.83
M31
MW
M81
Z_{SG}, Mpc
Y_{SG}, Mpc

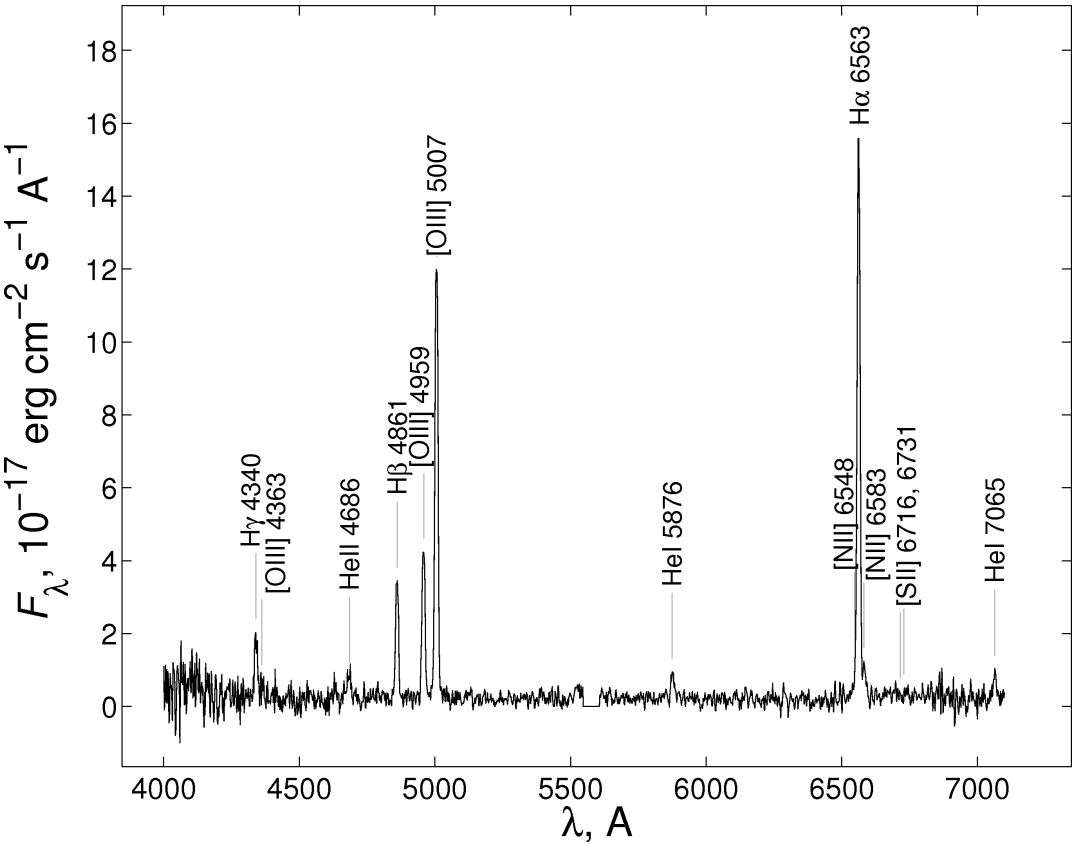
SFH of KKR 25





The main star formation event: 12.6 - 14 Gyr ago, a metallicity range: [Fe/H]=[-1.6:-1] dex. This initial burst accounts for 62 % of the total mass of formed stars. There are indications of intermediate age star formation in KKR 25 between 1 and 4 Gyr.

The spectrum of the H_α object.



The spectroscopy of H_α object in KKR 25 revealed that it is a planetary nebula with oxygen abundance 12+log(O/H) = 7.60 ± 0.07. We have derived heliocentric velocity of KKR 25 using PN emission lines V_h=-79±9 km/s and using integrated light of the galaxy V_h=-65±15 km/s.

Formation of isolated dSphs

•KKR 25 is one of the most isolated galaxies in the vicinity of the Local Group. It does not contain a detectable amount of gas and can be reliably classified as dwarf spheroidal galaxy.

• KKR 25 stays far away from any massive galaxy in the Local Volume to be affected by an interaction during its evolution. We can conclude that an evolution of KKR 25 was regulated by star formation in the galaxy itself rather than by its environment.

•The `primordial scenario' proposed that dwarf spheroidals form before the reionization in small halos $M<2\cdot10^8$ $M_\odot$.A star formation in these halos is regulated by cooling and feedback processes in the early Universe. Simulations of pre-reionization fossils explain main properties of dwarf spheroidals in the Local Group. It seems that KKR 25 is the best candidate of such a `fossil' galaxy.

Local Volume of galaxies

- Number of nearby galaxies with radial velocities < 500 km/s : Karachentsev et al. (2004) (451)
- Recent updates : 825 galaxies (Karachentsev et al., in preparation) within 10 Mpc
- HST/WFPC2 projects: 8192, 8601 «A Snapshot Survey of Probable Nearby Galaxies», cycle 8 и 9, 150 galaxies
- 9771 «The local Hubble flow and the density filed within 6 Mpc», cycle 12, I. Karachentsev (PI)
- 10235 «Dark vs. luminous matter in the CenA/M83 galaxy complex» , cycle 13, I.Karachentsev (PI), 50 galaxies