Morphological transformation in the

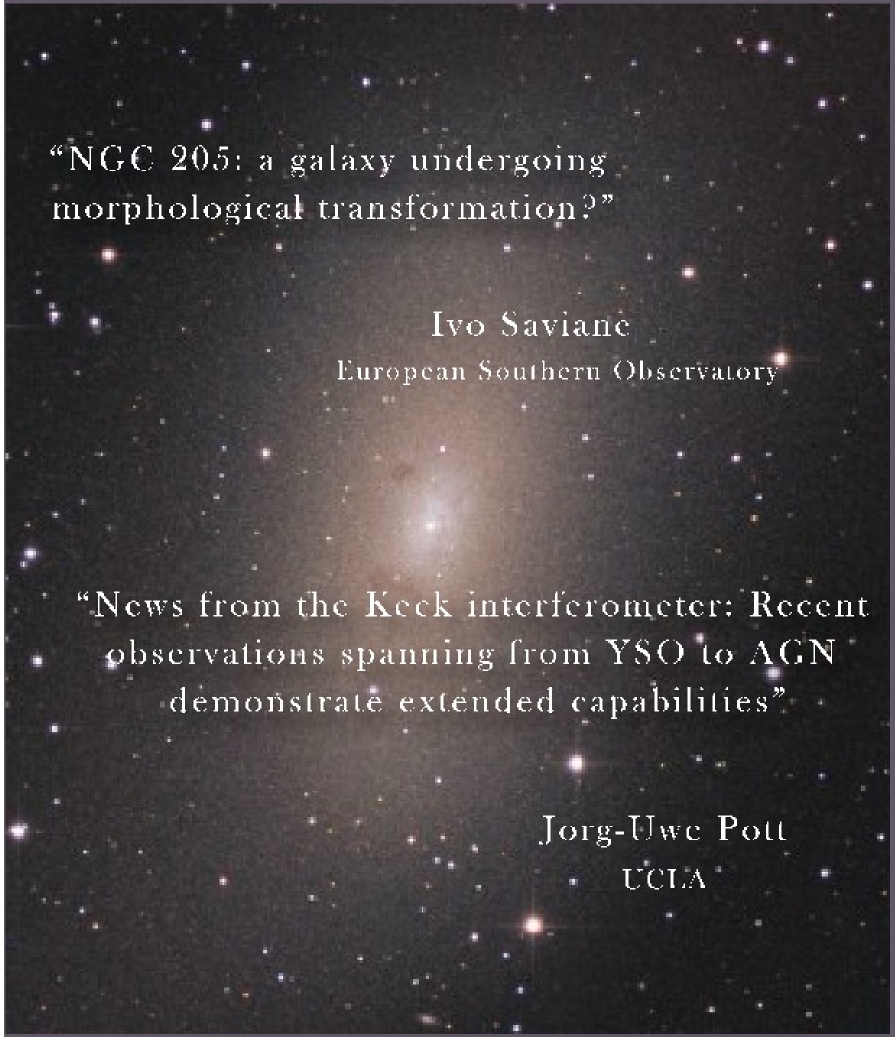
Local Group?

or...

The true identity of NGC 205

Astrophysics Journal Club

Winter 2009



"NGC 205: a galaxy undergoing morphological transformation?"

Ivo Saviane
European Southern Observatory

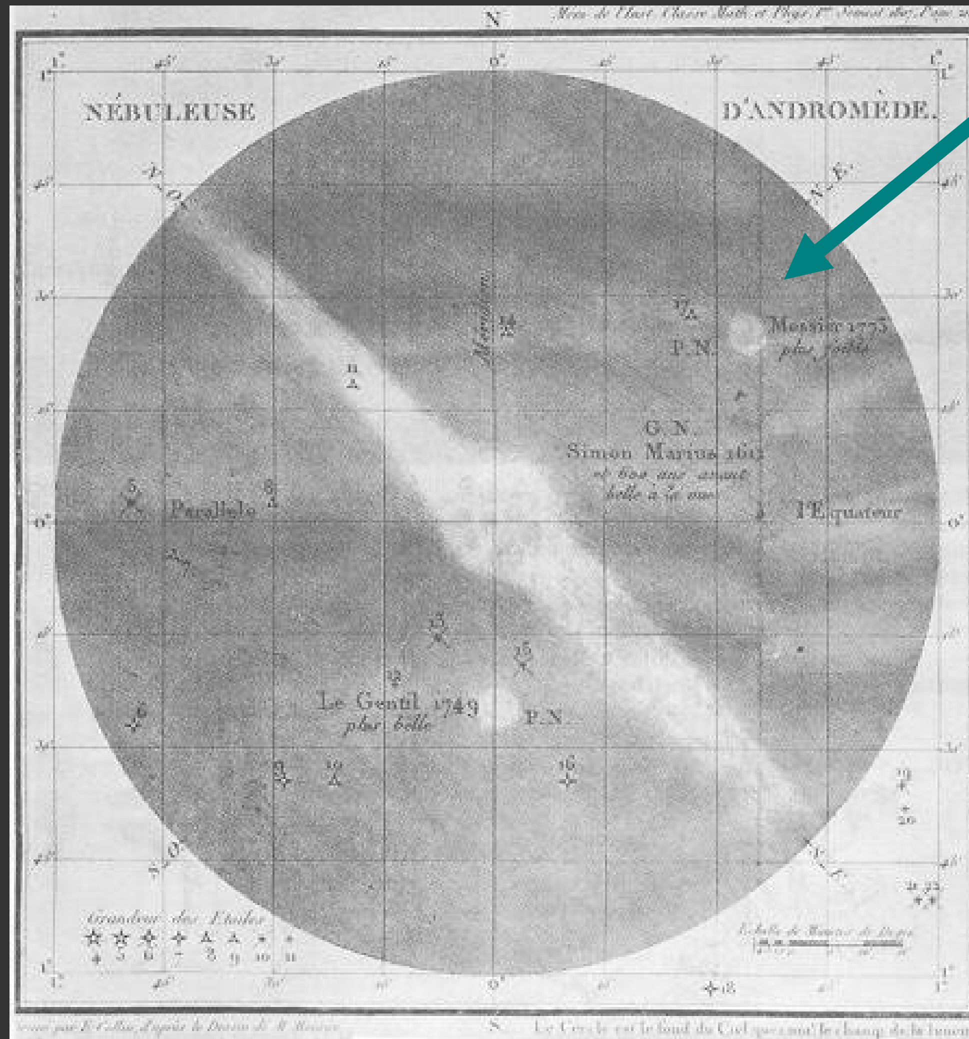
"News from the Keck interferometer: Recent observations spanning from YSO to AGN demonstrate extended capabilities"

Jorg-Uwe Pott
UCLA

2434 PAB

Tuesday, Feb 24th, 2009, 1:00pm

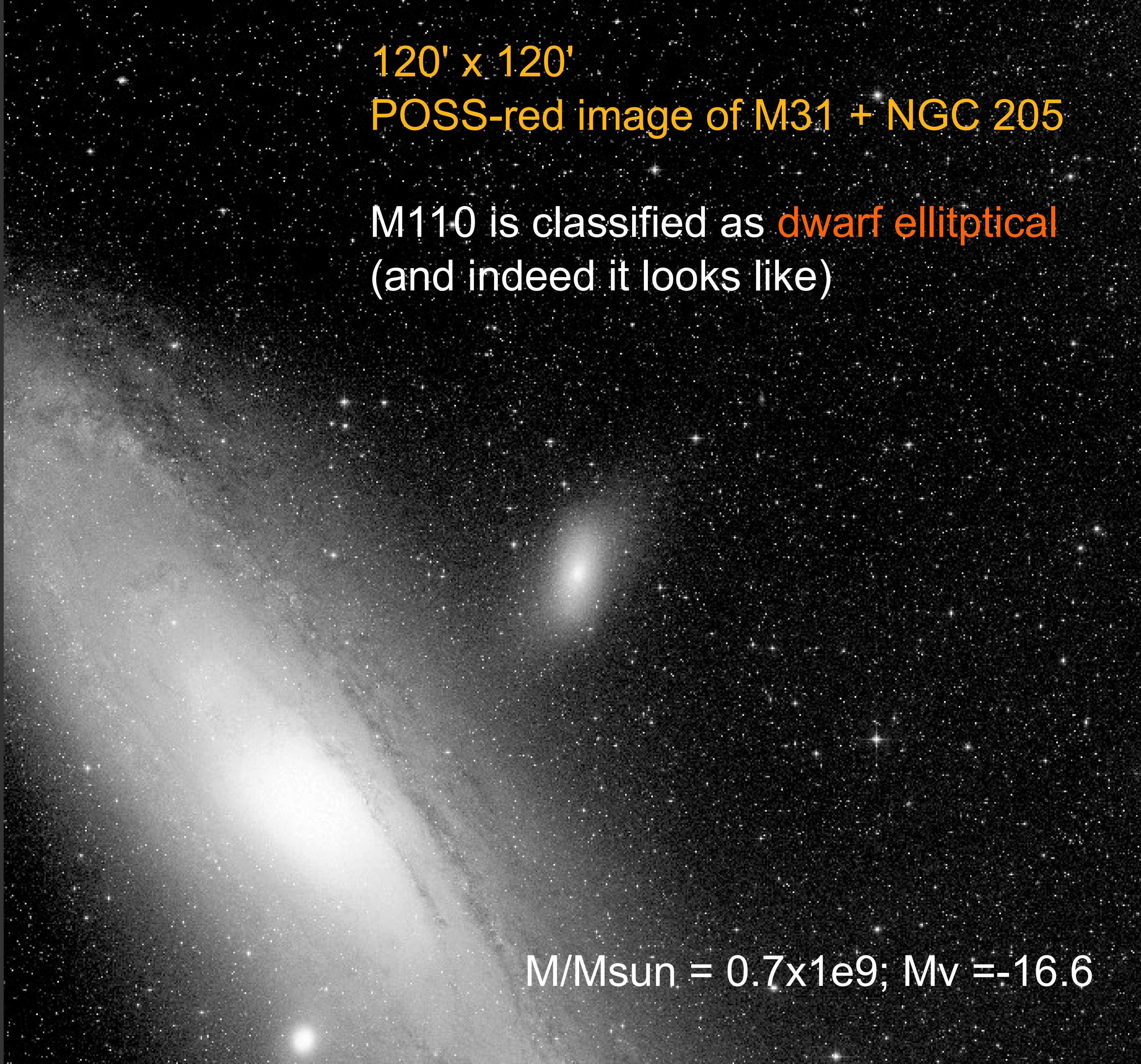
NGC 205 was discovered by Messier in 1773



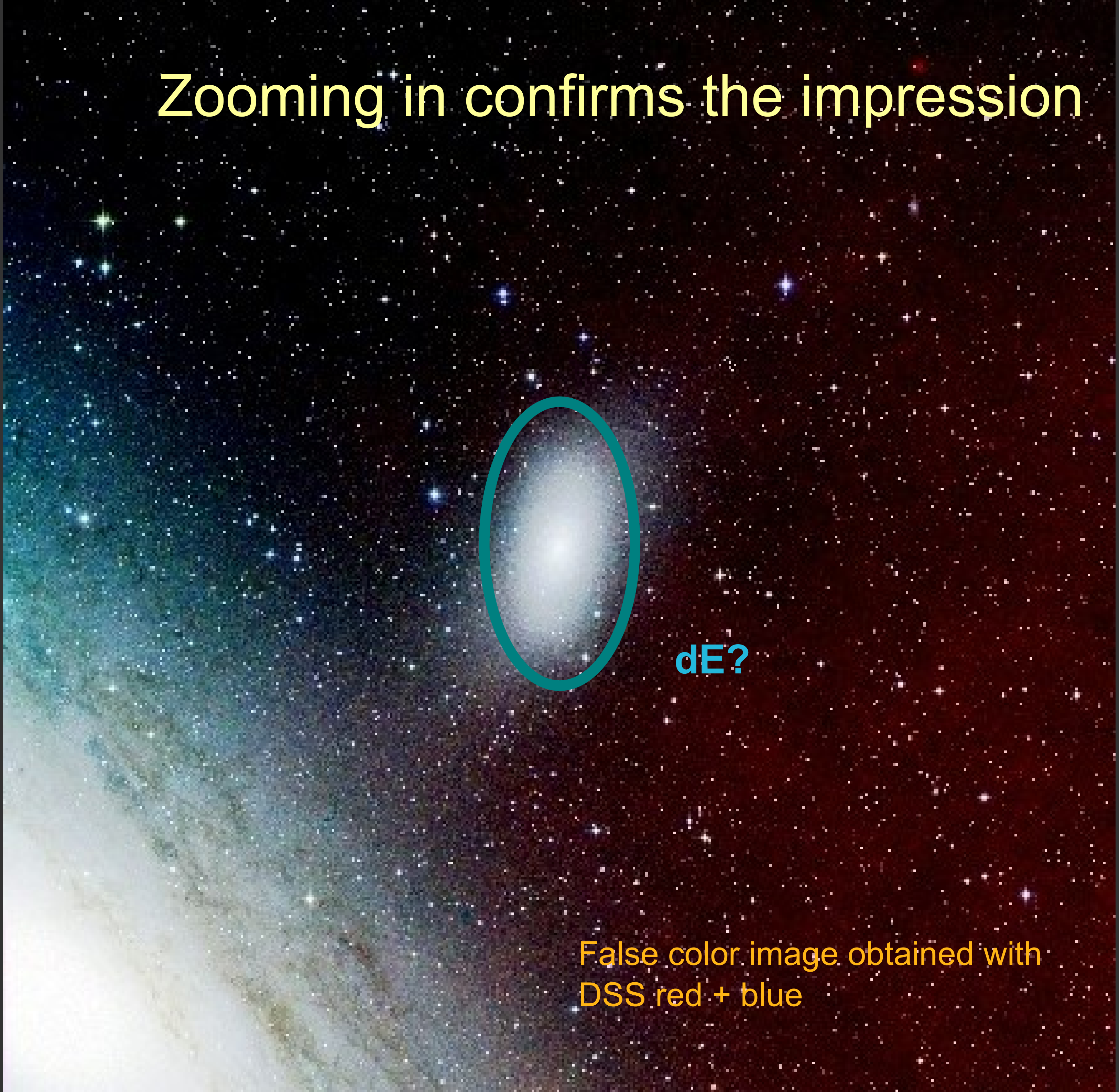
But was included in the catalog only in 1966

It's M110, the last object of the list

First resolved by Baade (1944)


120' x 120'
POSS-red image of M31 + NGC 205
M110 is classified as dwarf ellitptical
(and indeed it looks like)
M/Msun = 0.7x1e9; Mv =-16.6

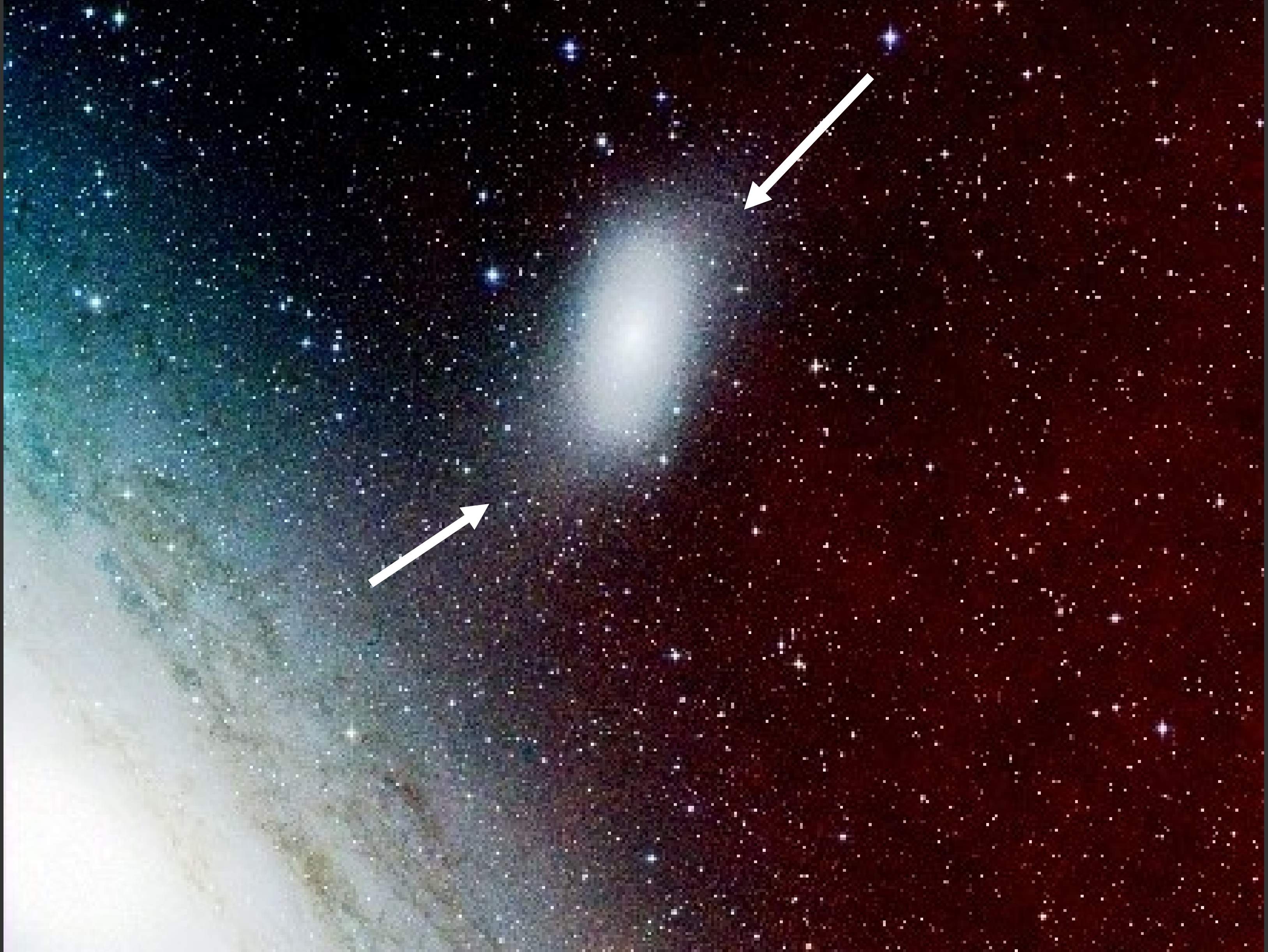
Zooming in confirms the impression



False color image obtained with
DSS red + blue

Zooming in confirms the impression

But also that there is something peculiar



It's not the only peculiarity

- specific frequency of GCs is SN = 1.8
  (Harris & van den Bergh 1981),
  in the regime of spiral galaxies

- The large scale dynamics shows
  partial rotational support
  (De Rijcke et al. 2006; Geha et al. 2006)

- 11 +/- 5 km/sec along major axis

THE ASTRONOMICAL JOURNAL, 131:332–342, 2006 January

Ⓔ

LOCAL GROUP DWARF ELLIPTICAL GALAXIES. I. MAPPING THE DYNAMICS OF NGC 205 BEYOND THE TIDAL RADIUS

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Received 2005 July 20; accepted 2005 September 18

ABSTRACT

NGC 205 is the nearest example of a dwarf elliptical galaxy and the prototype of this enigmatic galaxy class. Photometric evidence suggests that NGC 205, a close satellite of the M31 galaxy, is tidally interacting with its parent galaxy. We present stellar radial velocity measurements out to a projected radius of 20′ (5 kpc) in NGC 205 based on Keck DEIMOS multislit spectroscopic observations of 725 individual red giant branch stars. Our kinematic measurements extend from the center out to 6 times the effective radius of NGC 205, well past the expected tidal radius. The contamination in our kinematic sample from M31 field stars is estimated to be a few percent based on maximum likelihood fits to the distribution of stars in position-velocity space. We measure a maximum major-axis rotation speed for the body of NGC 205 of 11 ± 5 km s^{-1} and note that this is based on observing a definite turnover in the rotation curve; this is the first dE galaxy in which the maximum rotation velocity has been measured. Combined with the velocity dispersion, we conclude that NGC 205 is supported by a combination of rotation and anisotropic velocity dispersion. At a major-axis distance of 4.′5 (1 kpc), the velocity profile of NGC 205 turns over; stars beyond this radius are moving counter to the rotation of the inner part of the galaxy. The turnover radius is coincident with the onset of isophotal twisting and the estimated tidal radius, suggesting that the outer kinematics of NGC 205 is dominated by gravitational interactions with the nearby M31 galaxy. The motion of stars beyond a radius of ∼4.′5 implies that NGC 205 is in a prograde encounter with its parent galaxy, M31.

Key words: galaxies: dwarf — galaxies: individual (NGC 205) — galaxies: interactions — galaxies: kinematics and dynamics

Online material: color figure, machine-readable table

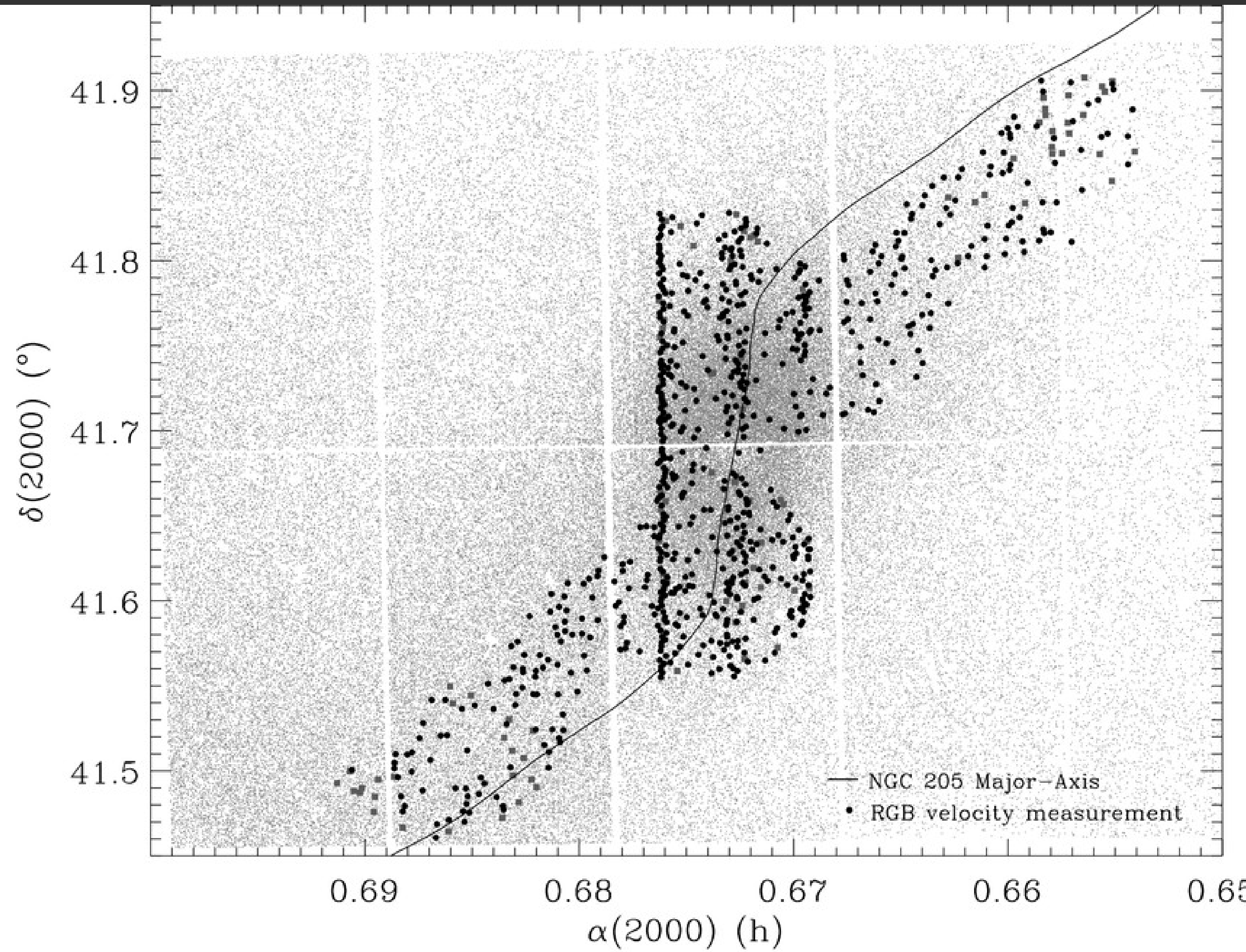


FIG. 3.—Spatial distribution of stars in NGC 205 (*small gray dots*) from Demers et al. (2003) photometry. Large circles indicate objects targeted for DEIMOS spectroscopy; the tiered pattern of slitlets can be seen in the central mask. The solid curve shows the major axis of NGC 205 determined from Choi et al. (2002) photometry.

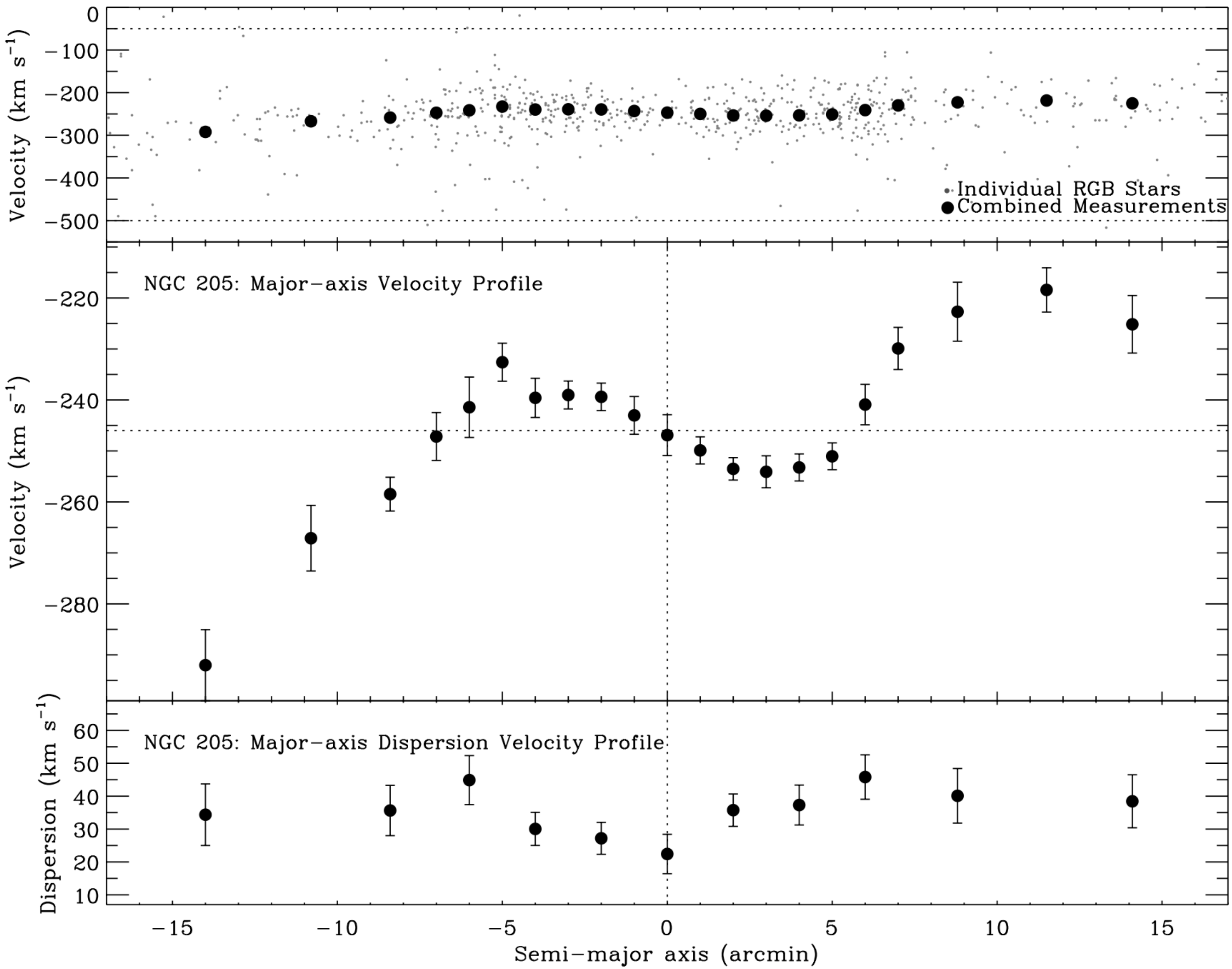


FIG. 6.—Major-axis velocity profile for NGC 205. *Top*: Small gray dots indicate Keck DEIMOS velocity measurements of individual RGB stars, and large black circles indicate the combined velocity measurements based on Gaussian fits to the velocity distribution in each radial bin. Dotted lines indicate the limits inside which the combined measurements are determined. *Middle*: Combined velocity measurements (*circles*) with a finer velocity scale. The vertical dotted line is plotted at the galaxy center, and the horizontal dotted line is plotted at the measured systemic velocity of NGC 205. *Bottom*: Velocity dispersion profile for NGC 205 determined using a coarser binning scheme than for the velocity profile.

- There is a significant amount of rotating molecular and atomic gas (Welch et al. 1998) (10e6 Msun)

- and dust (Marleau et al. 2006).

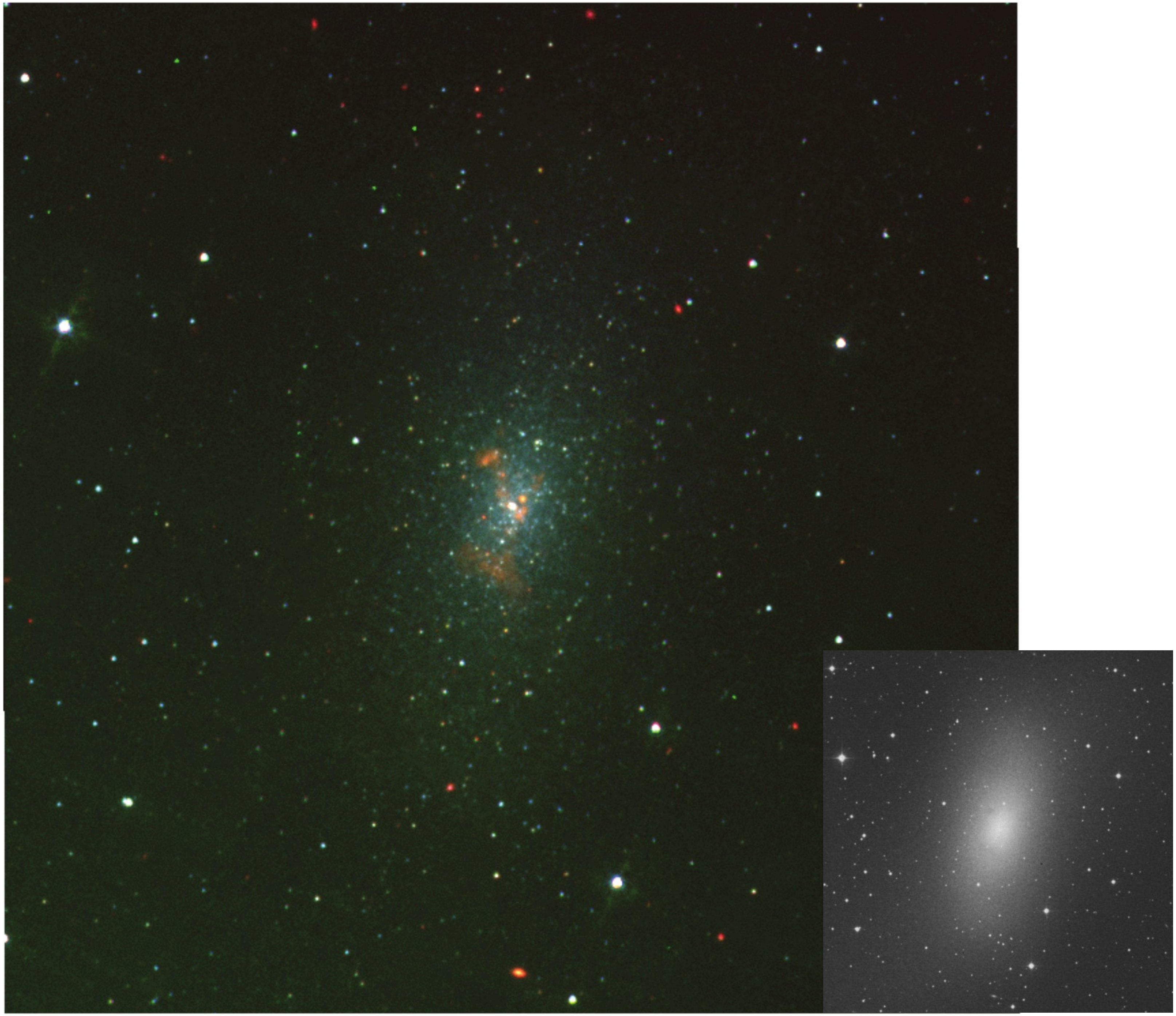


FIG. 3.—Three-color image of NGC 205 as seen by IRAC at 3.6 (*blue*), 5.8 (*green*), and 8 μm (*red*). The image emphasizes the dust cloud distribution seen at longer wavelengths over a $15' \times 15'$ region, with north up and east to the left.

- NGC 205 harbors a fairly complex stellar population

- especially in the central regions

- the presence of bright O and B stars in the center is known since Baade (1951).

- Bica et al. (1990) from integrated spectrum of nucleus:

  mean age: 100—500 Myr

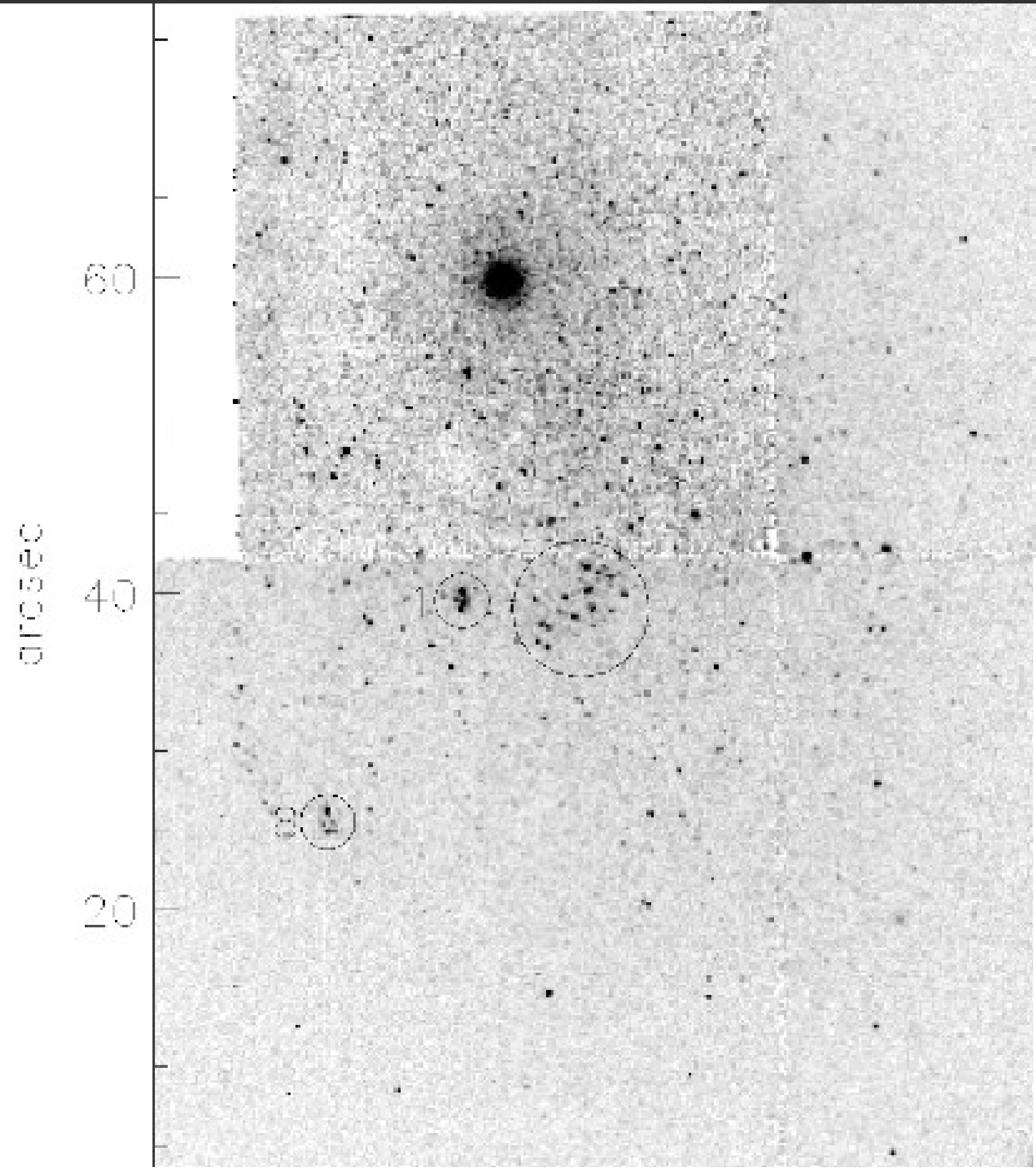
  metallicity: -1< [m/H] <-0.5
  (max [m/H]=-0.5)

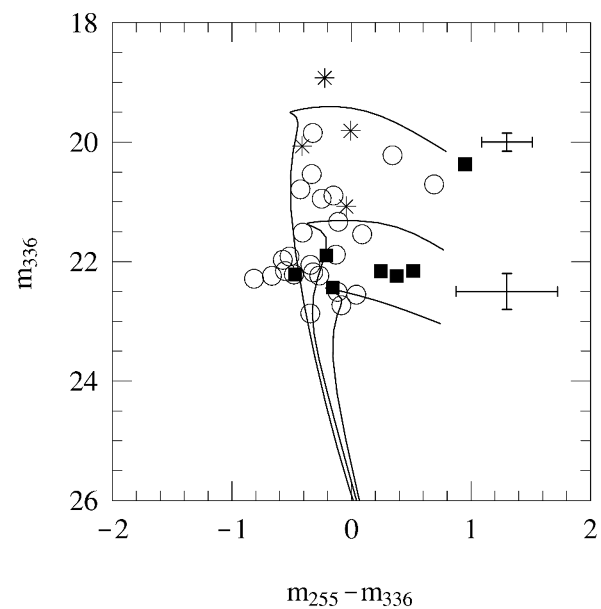
- (Cappellari et al. 1999), wfpc2 observations

- Baade's “stars” are actually multiple systems

- ages of 50 and 100 Myr for two clusters

- This centrally concentrated blue population likely represents the last episode of star formation in NGC 205





The question as to where this gas came from is not easy to answer. Possibly, as in our Galaxy, high-velocity H I clouds may be orbiting M31, and one such cloud might have been captured by the potential well of NGC 205 and squeezed above star formation threshold.

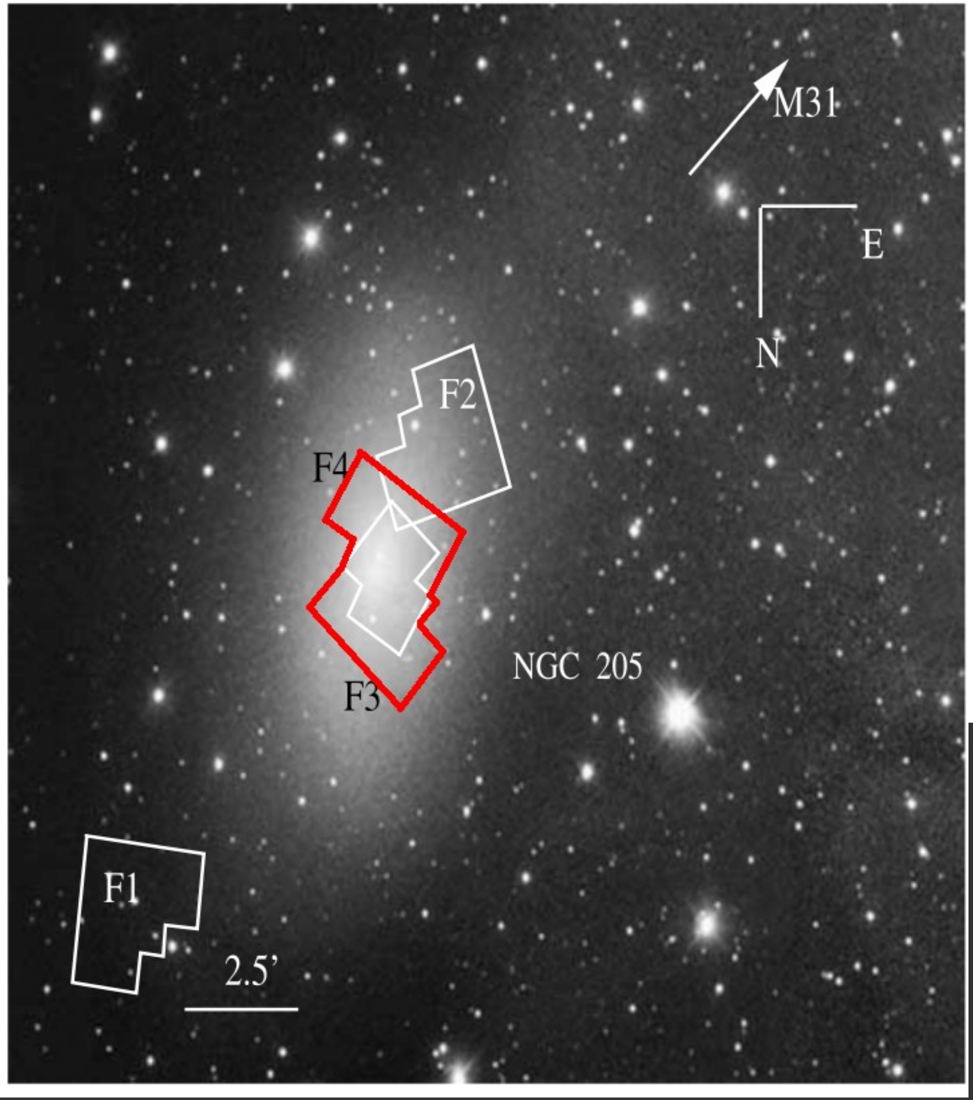
FIG. 4.—Color-magnitude diagram (m_{336} vs. $m_{255} - m_{336}$) of clusters 1 (*asterisks*) and 8 (*filled squares*) and of the Archipelago (*open circles*). Note that only the four brightest stars of cluster 1 have been included in this diagram, since the photometry of the fainter stars recognizable in Fig. 1 is affected by large errors. Mean photometric errors are shown by the error bars to the right. Overplotted are the theoretical isochrones from Bertelli et al. (1994) for the metallicity $Z = 0.02$ and ages of 20, 50, and 100 Myr, respectively. These isochrones have been transformed into the STMAG magnitude system, by adopting a true distance modulus of 24.6 mag and a reddening $E(B-V) = 0.18$. The post–main-sequence part of the isochrones has been truncated at $T_{\rm eff} = 8000$ K.

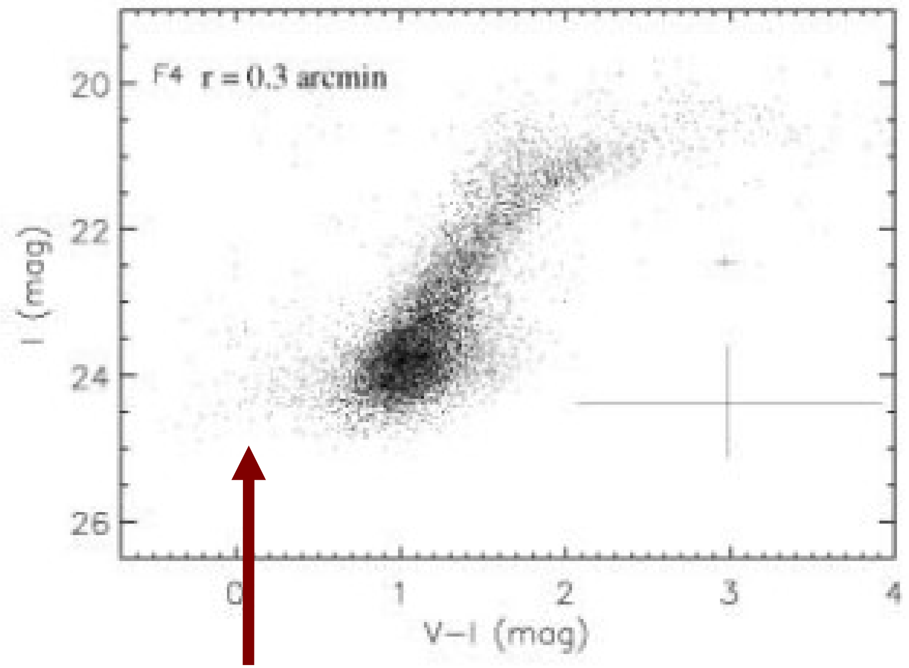
The C99 clusters/associations are not the only young population

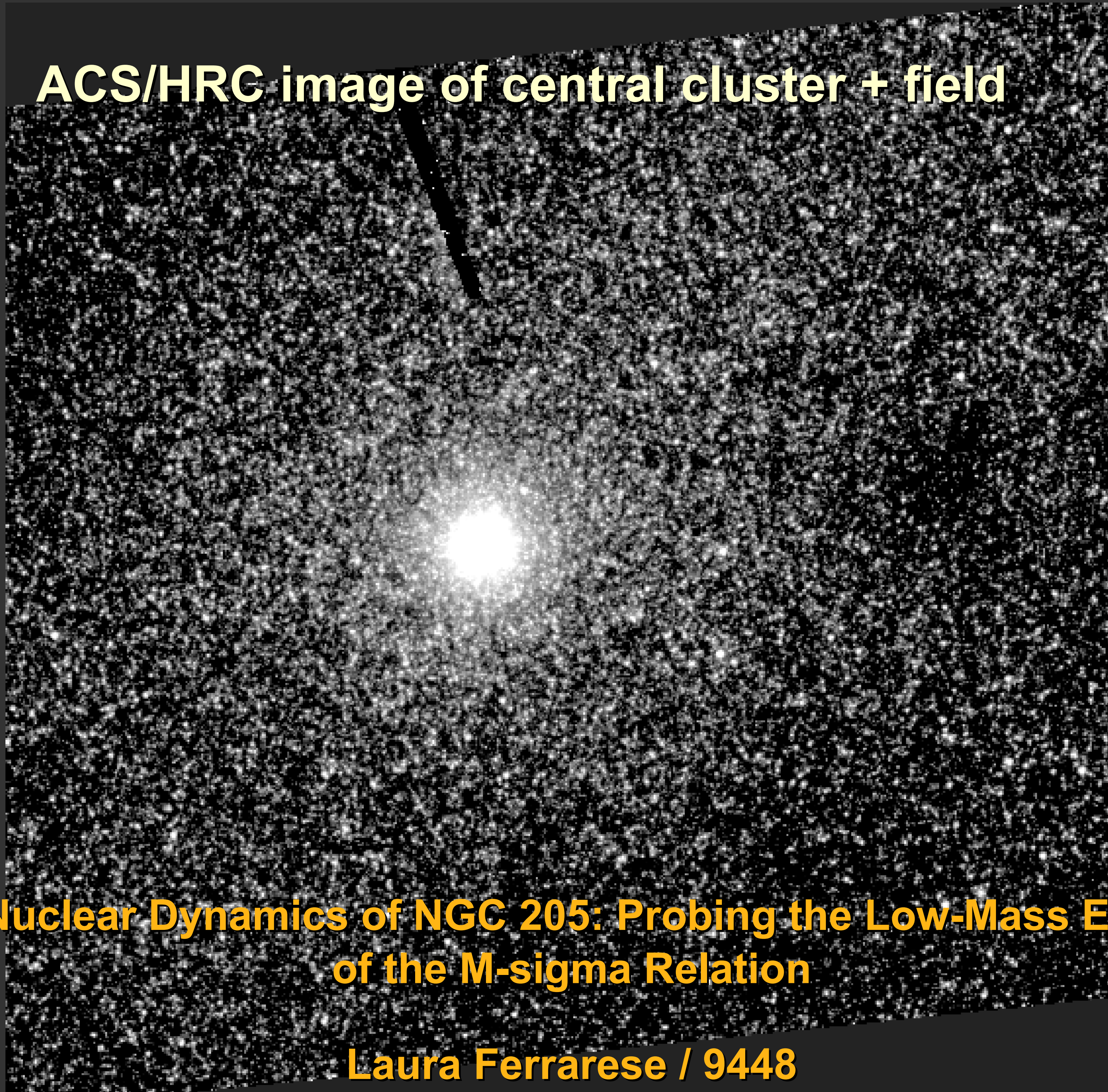
A young 'field' population is revealed by ACS/HRC in the central region

Monaco, Saviane, et al. In preparation

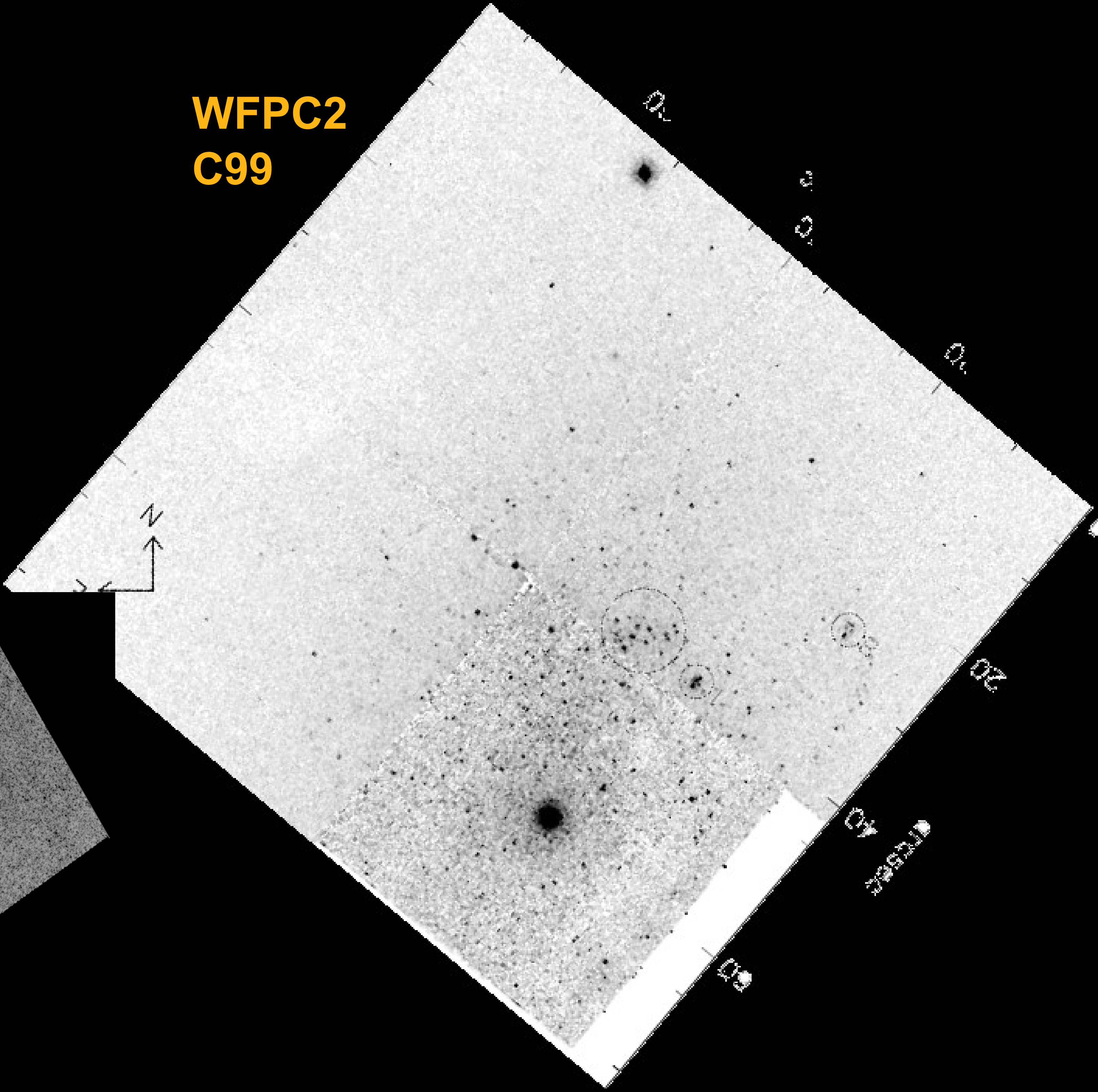
Some hint in Butler & Martinez-Delgado (2005)



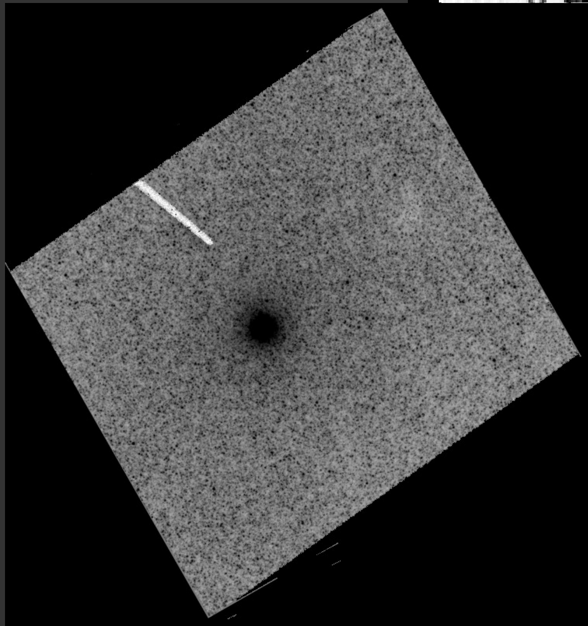


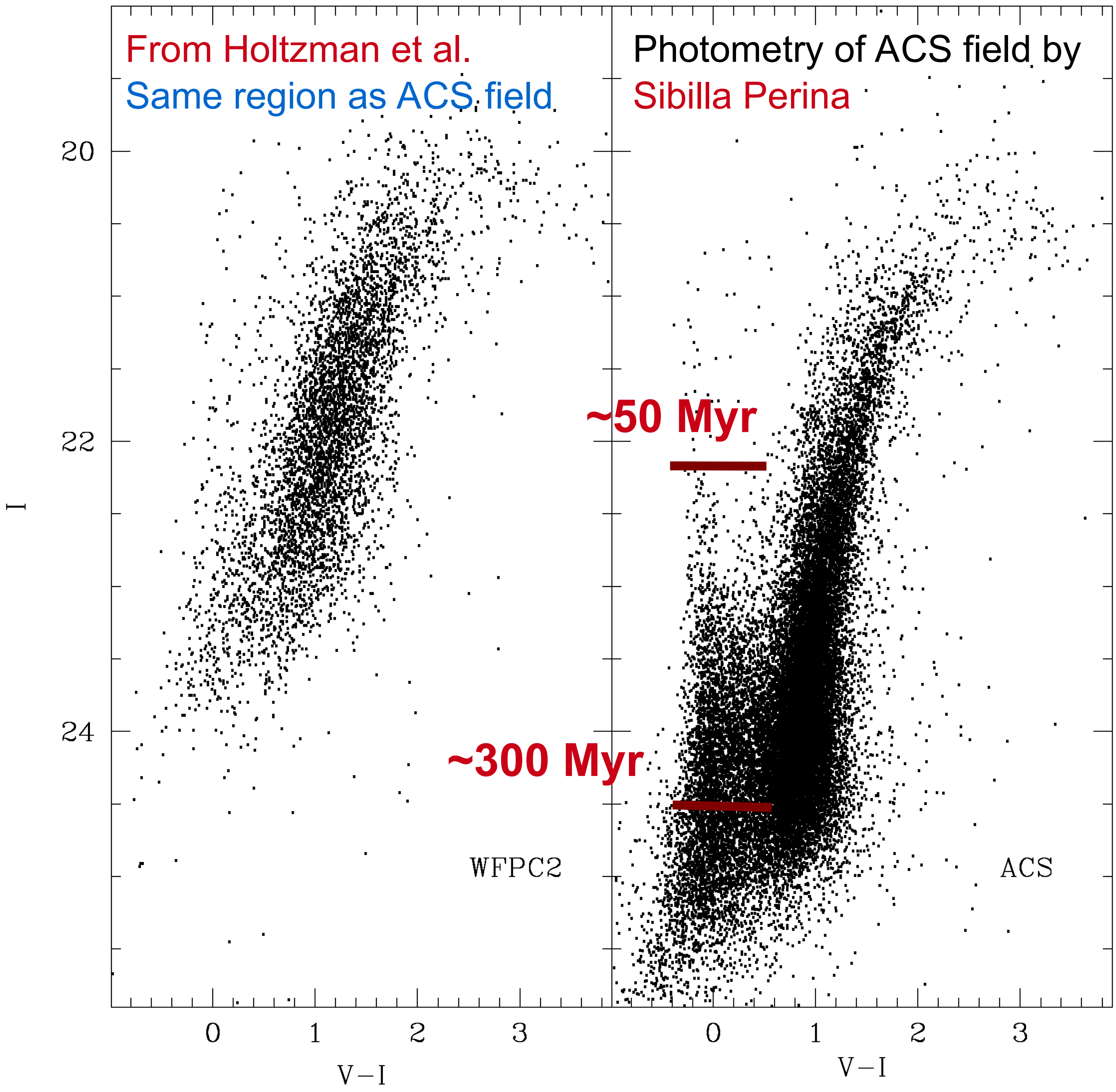

ACS/HRC image of central cluster + field
Nuclear Dynamics of NGC 205: Probing the Low-Mass End
of the M-sigma Relation
Laura Ferrarese / 9448

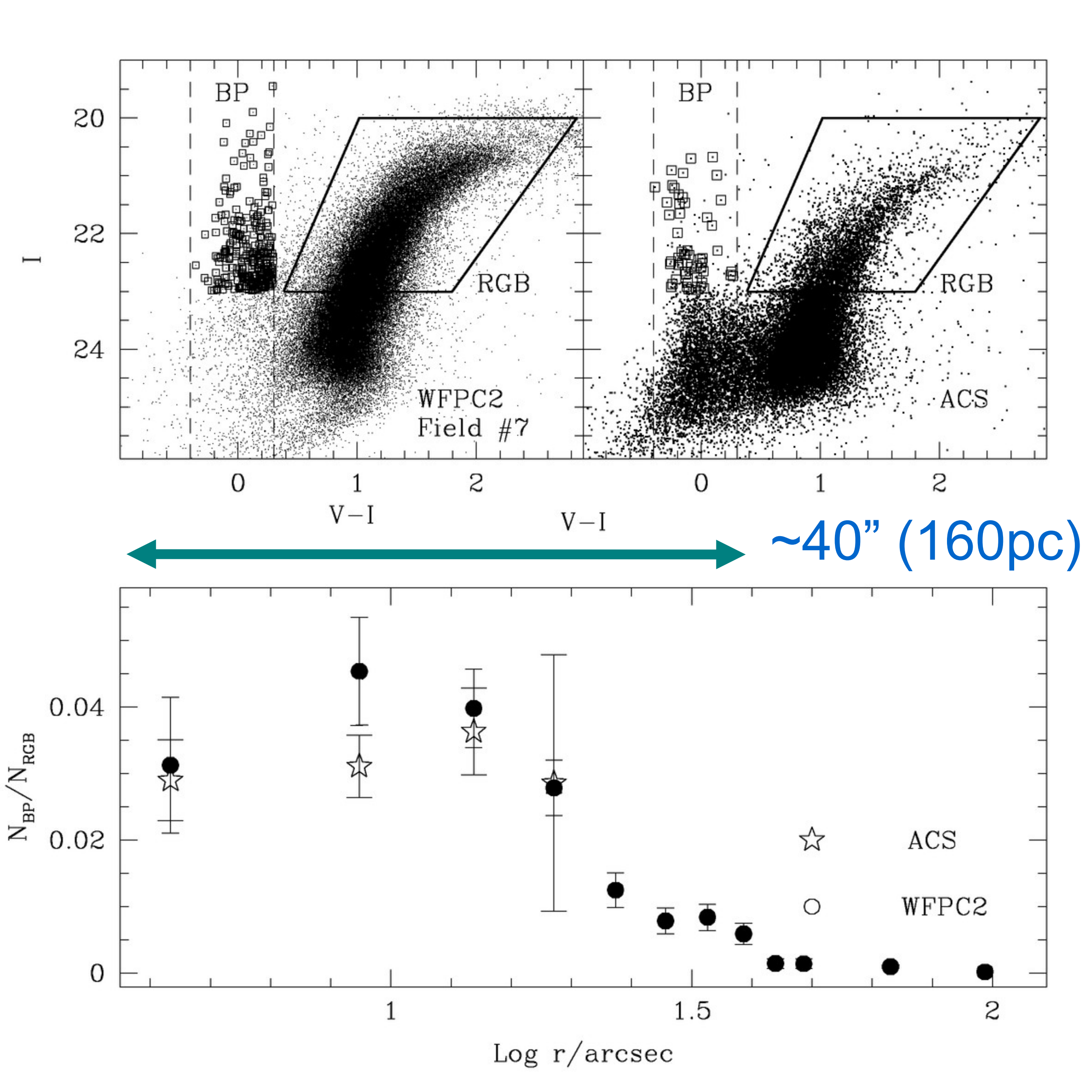
WFPC2
C99



ACS
(PI=Ferrarese)




From Holtzman et al.
Same region as ACS field
Photometry of ACS field by
Sibilla Perina
~50 Myr
~300 Myr
WFPC2
ACS
20
22
24
I
0
1
2
3
V−I



S.B. Profile from Valluri, Ferrarese et al. (2005)

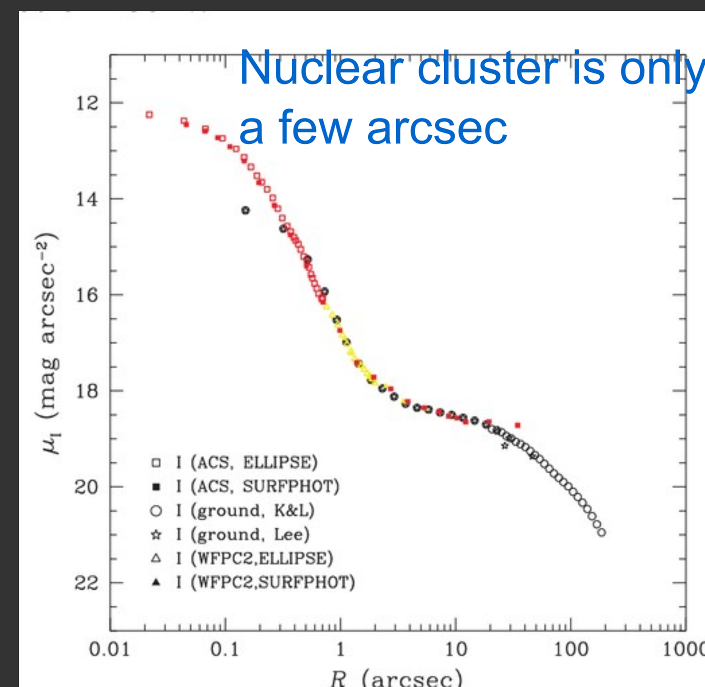
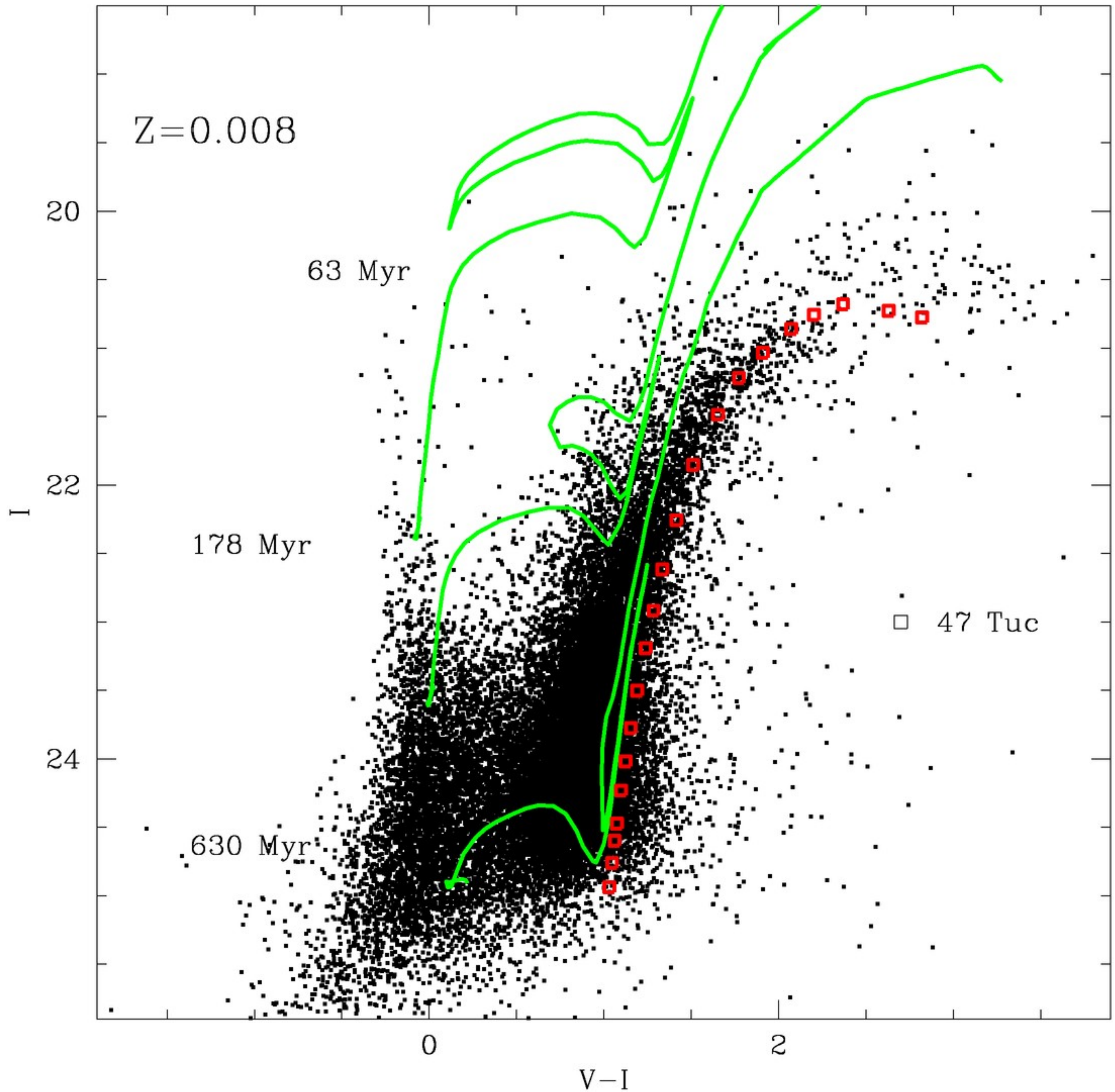
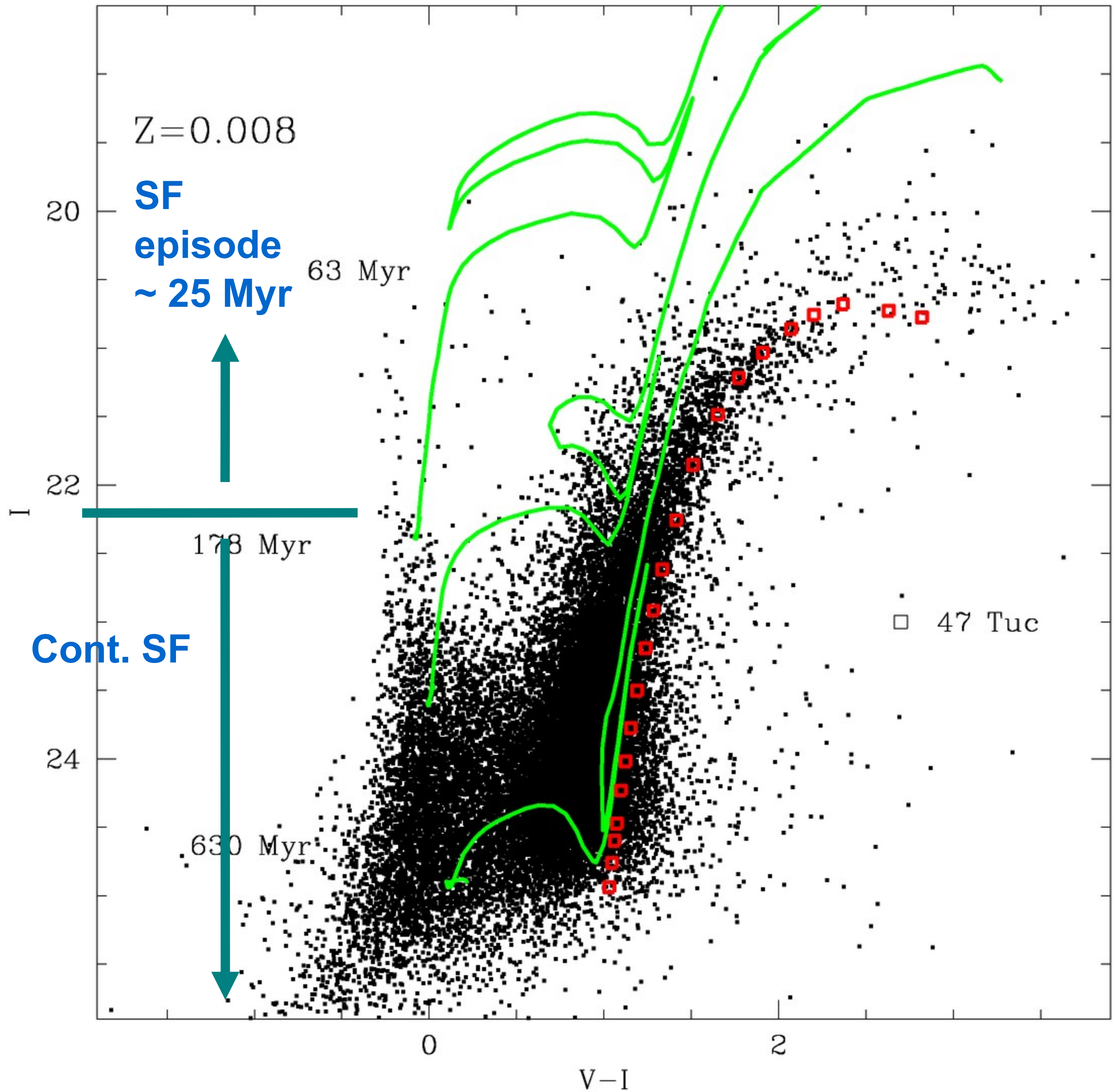


FIG. 4.—Surface brightness profile of NGC 205 in the *I* band, obtained by combining the *HST* ACS observation discussed in this paper with the ground-based data of Kim & Lee (1998) and Lee (1996). The radius is the effective radius, given by $r = r_{SMA}[1 - \epsilon(r)]^{1/2}$, where r_{SMA} is the galaxy semimajor axis and ϵ is the ellipticity.



Z=0.008
63 Myr
178 Myr
630 Myr
47 Tuc
20
22
24
I
0
2
V−I


Z=0.008
SF
episode
~ 25 Myr
63 Myr
178 Myr
Cont. SF
630 Myr
47 Tuc
20
22
24
I
0
2
V−I

SFR= 5e-4 Msun/yr during 220 Myr => 1.2e5 Msun generated

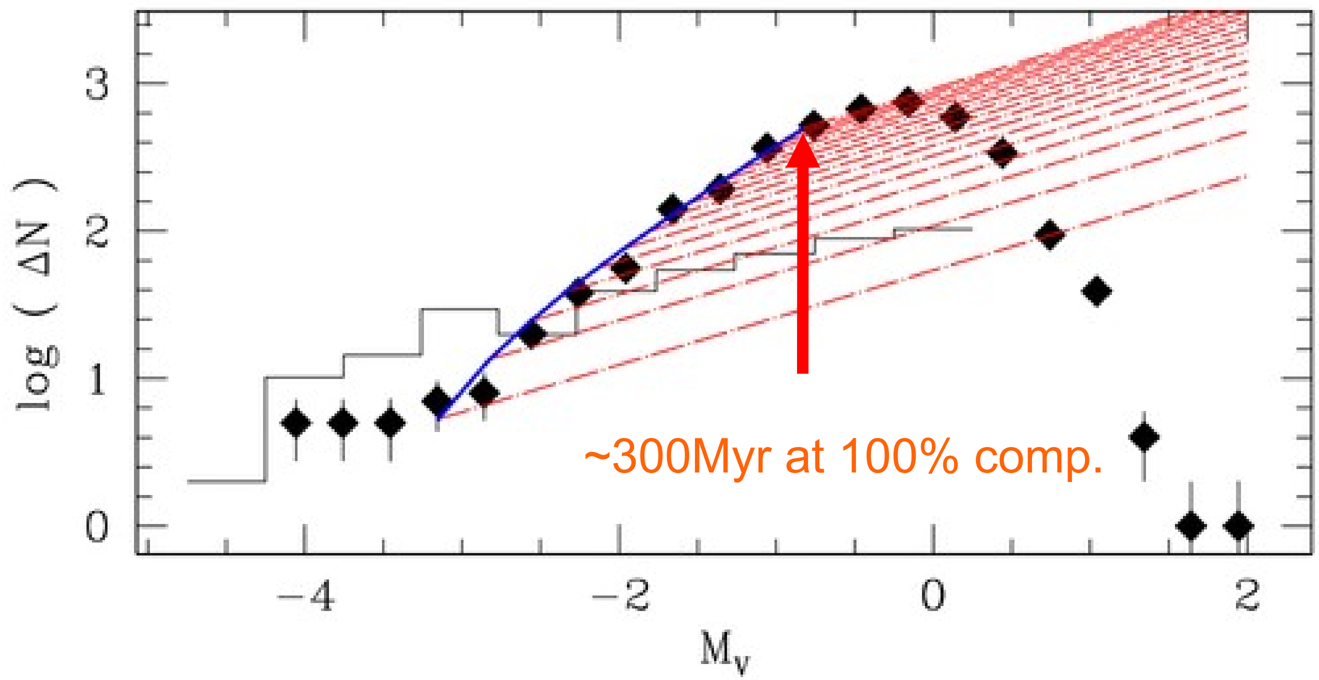


Fig. 4. Logarithmic integrated LF of young MS stars stars (filled diamonds). The LF is reproduced by the sum (thick continuous line) of 17 LFs (dot-dashed lines) of simple stellar populations. It is assumed here that the slope of the single LFs is equal to that of NGC 2004 (a young populous cluster of the Large Magellanic Cloud, histogram) and that the simple stellar population contains 0.35 times the number of stars in NGC 2004. The populations were generated at a constant rate during ~220 Myr, and all stars now evolved off the main sequence were removed from the LFs. See SHR04 for details.

APOD, Jan 24, 2008


© Tony Hallas / astrophoto.com

Galaxy body made from 10 frames, each frame 7 - 8 hours LRGB.

Telescope : 14.5 " f/8 RCOSCC

Camera : SBIG STL - 11K

Background made from 9 frames, each frame 5 - 6 hours LRGB.

Telescope : Stellarvue 6" f/8

and TeleVue 4" f/5.

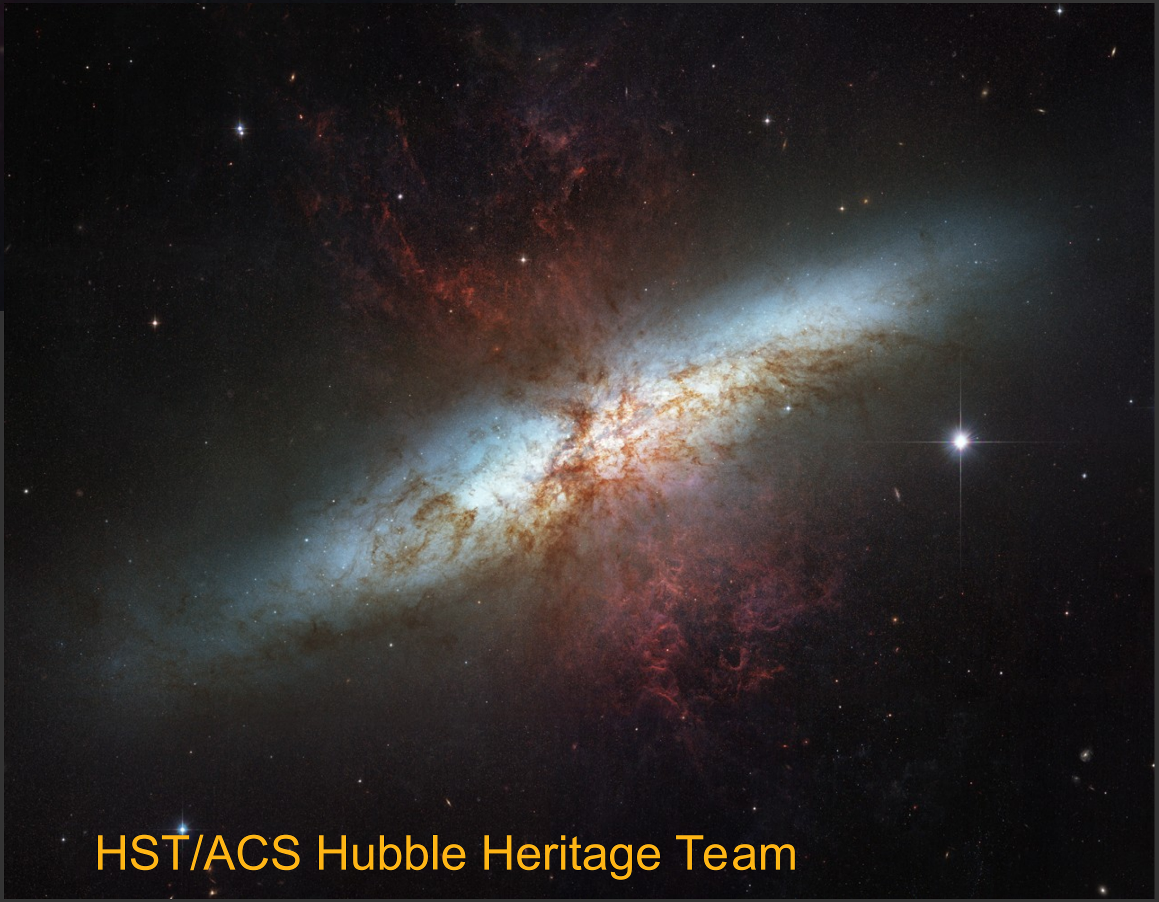
Camera : SBIG STL-11K

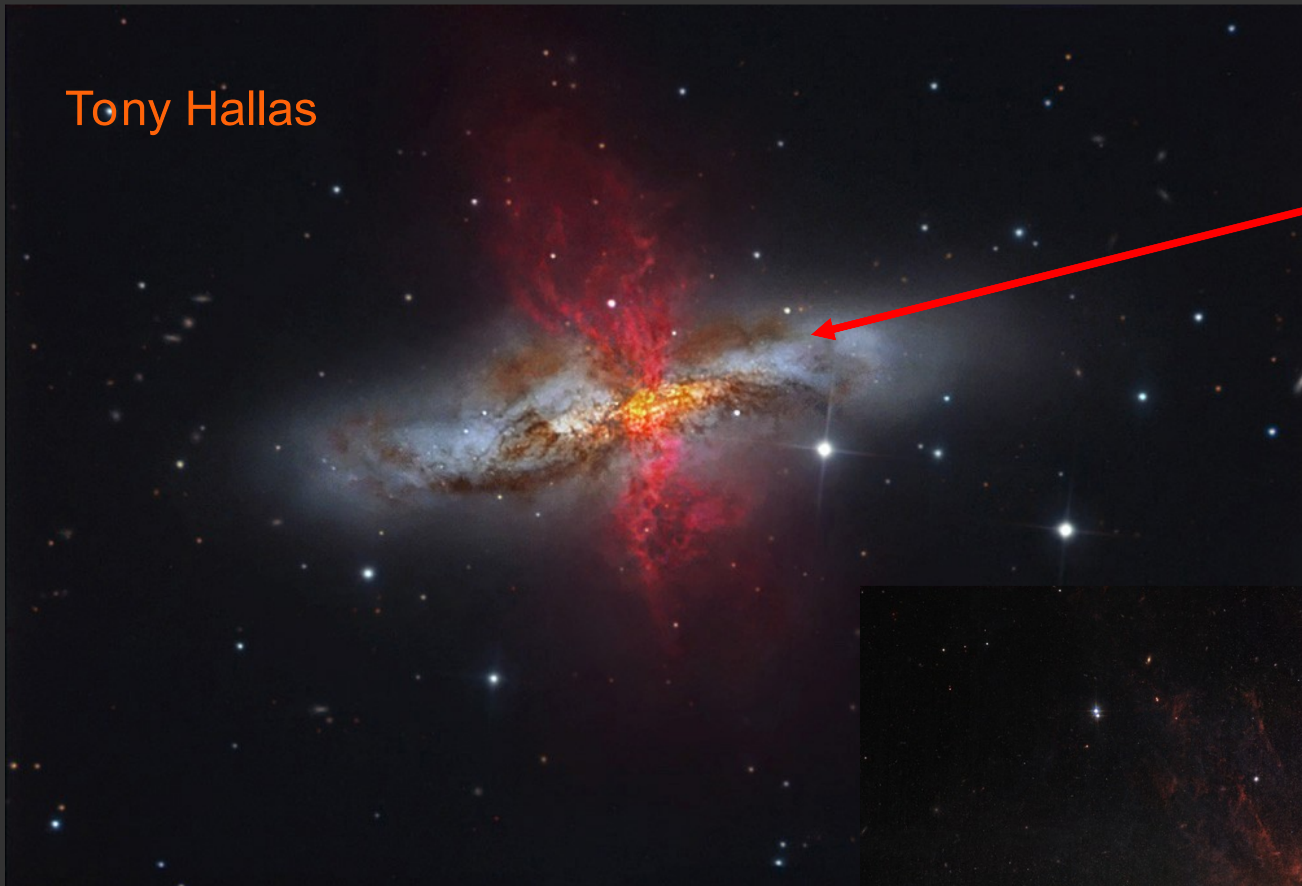
AstroDon and SBIG filters

A/P 1200 GTO mount

Taken Fall 2007 from Foresthill,CA

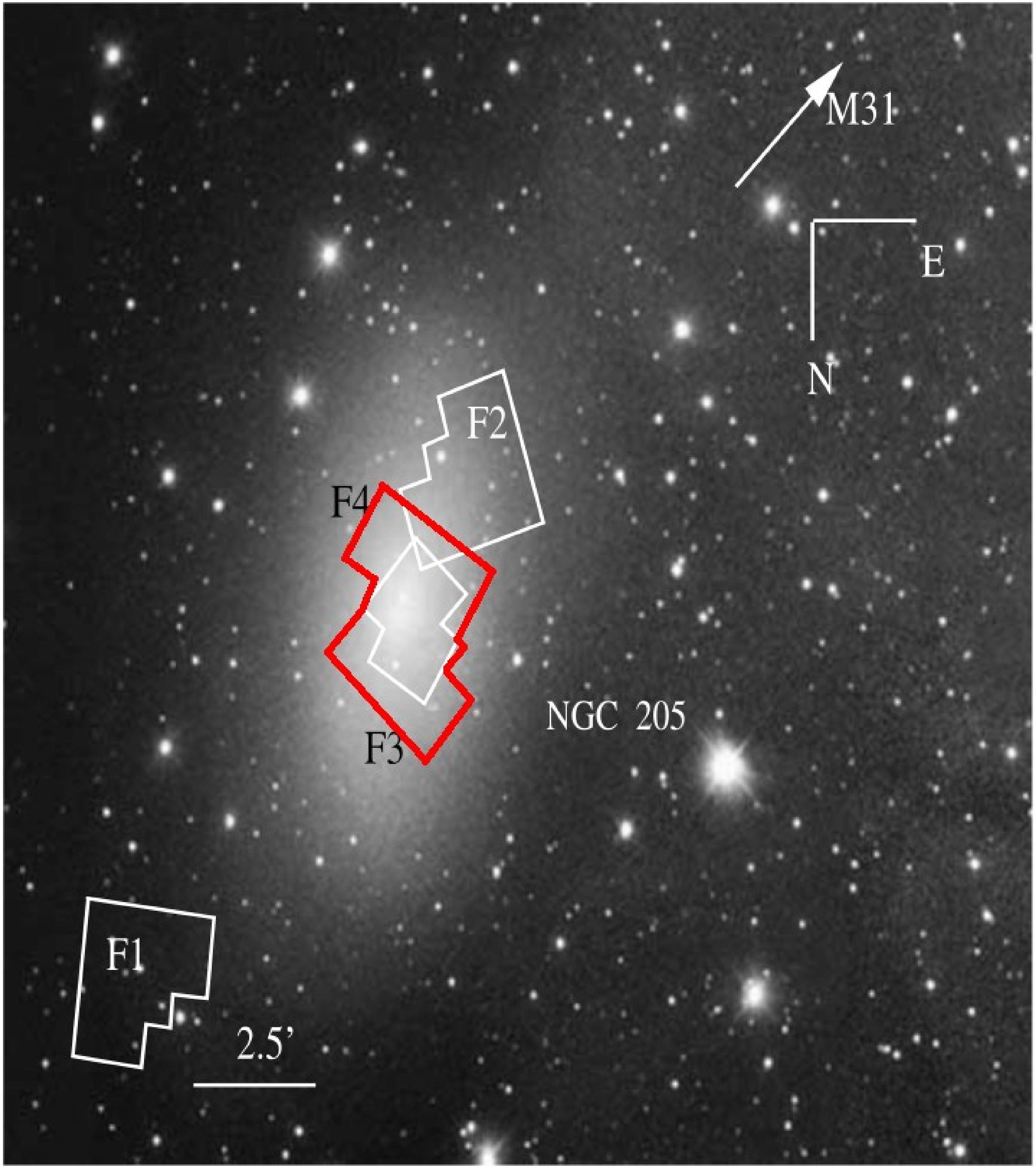
M 82

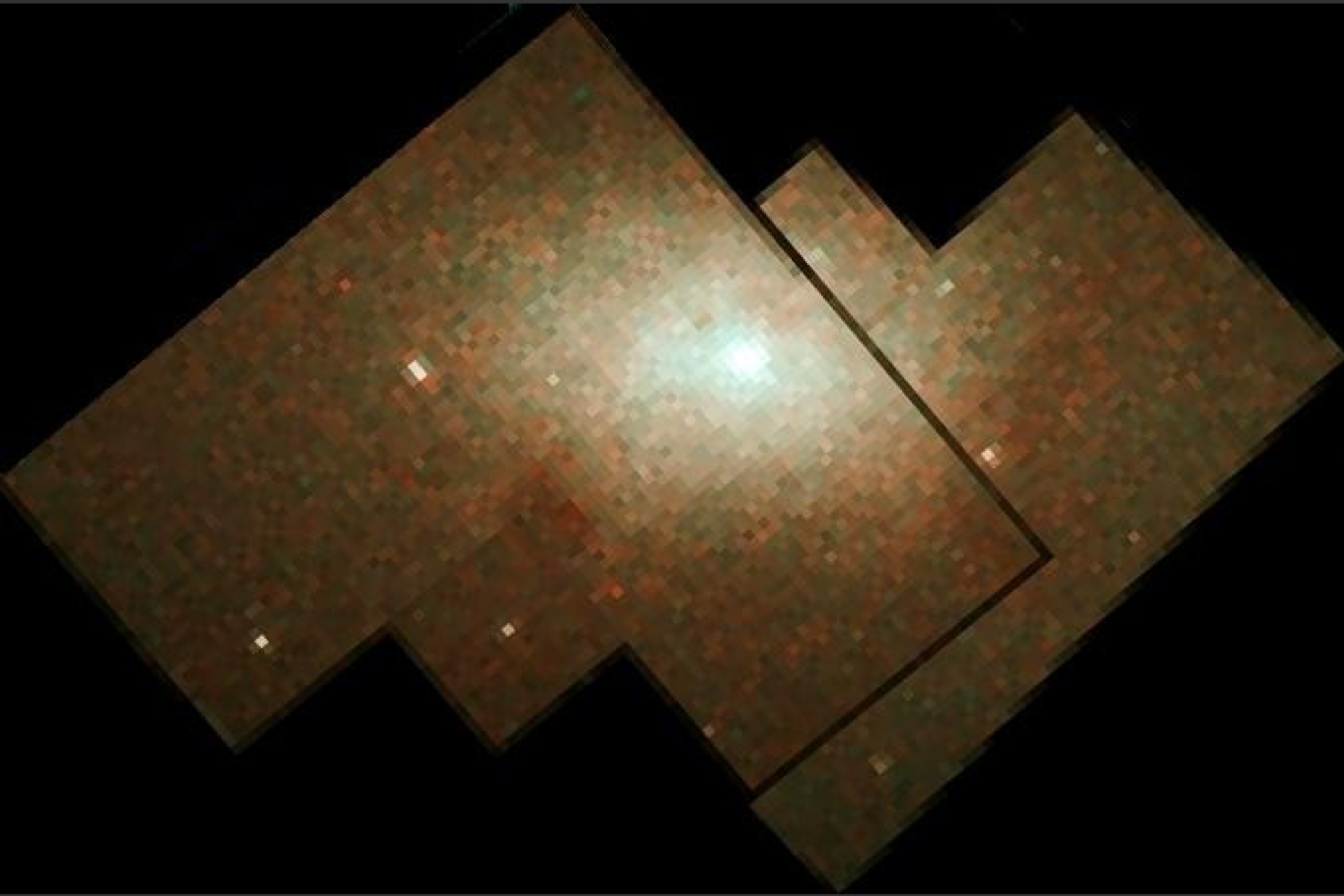

Tony Hallas

HST/ACS Hubble Heritage Team

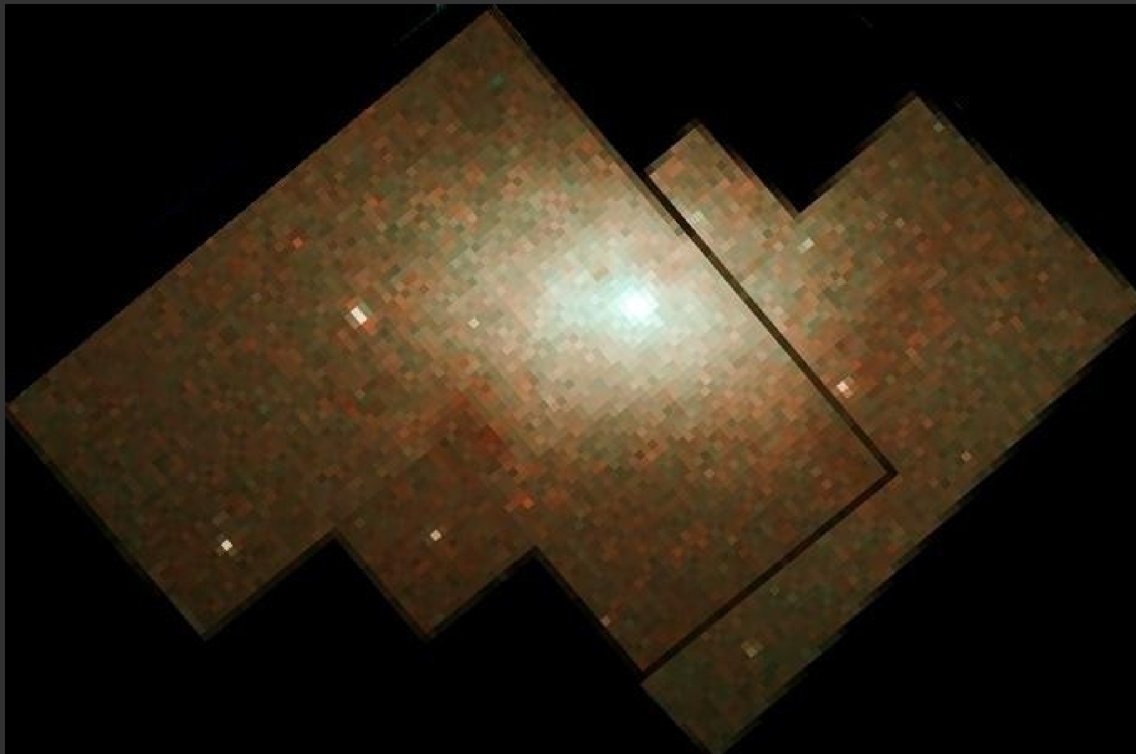


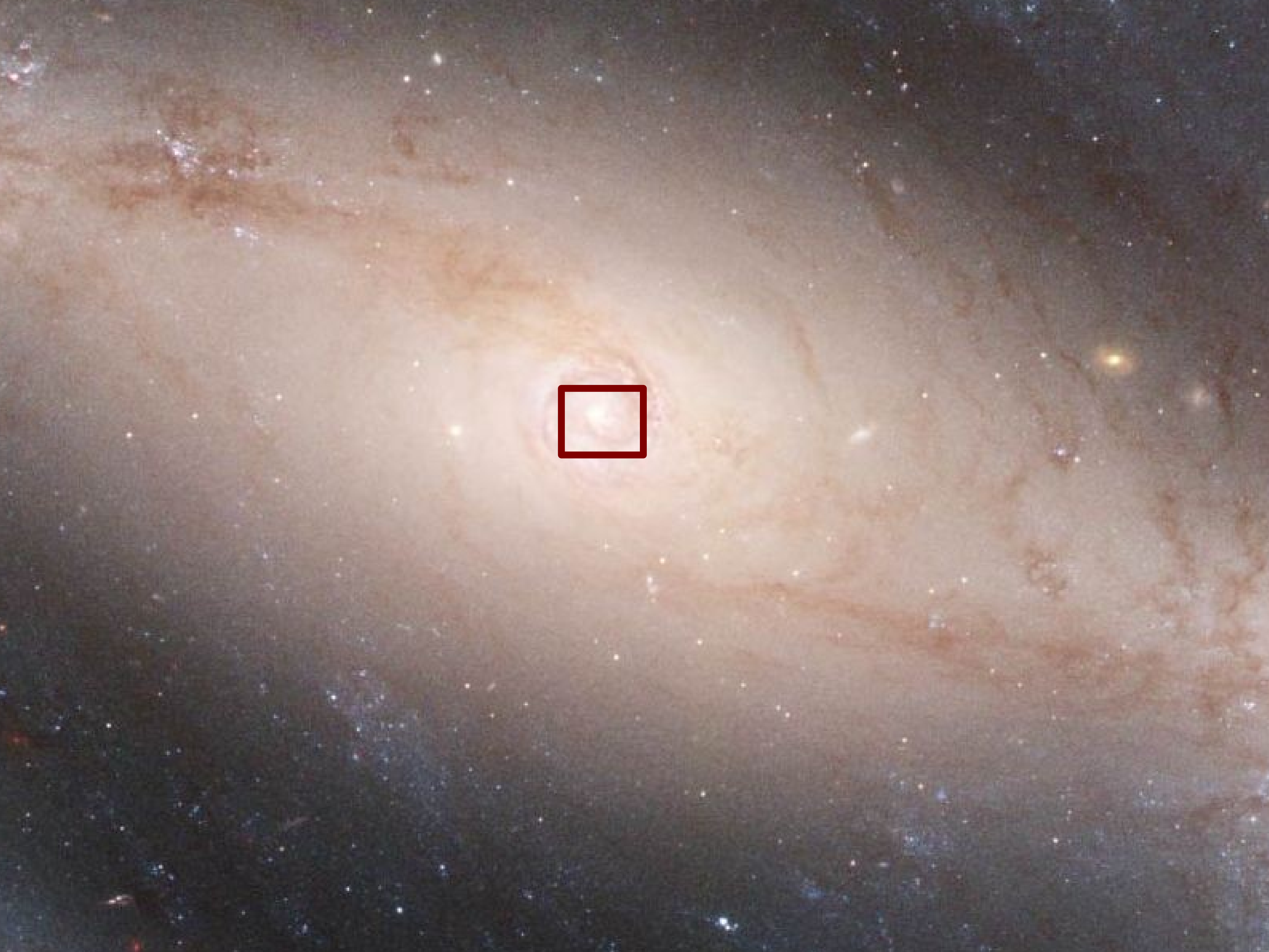
Dust features better revealed in the groundbased image

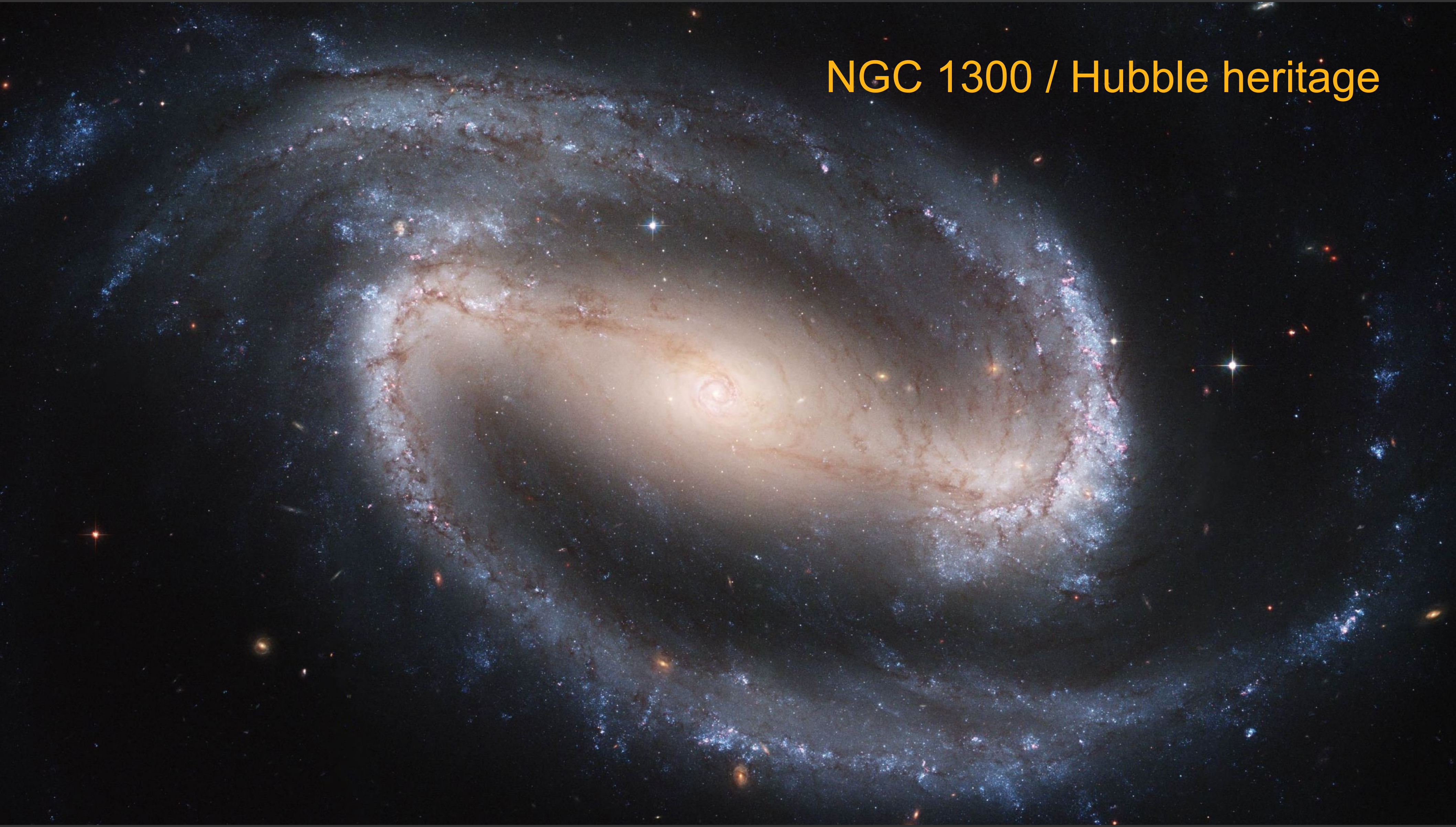

N
E



M31
E
N
F2
F4
F3
NGC 205
F1
2.5’





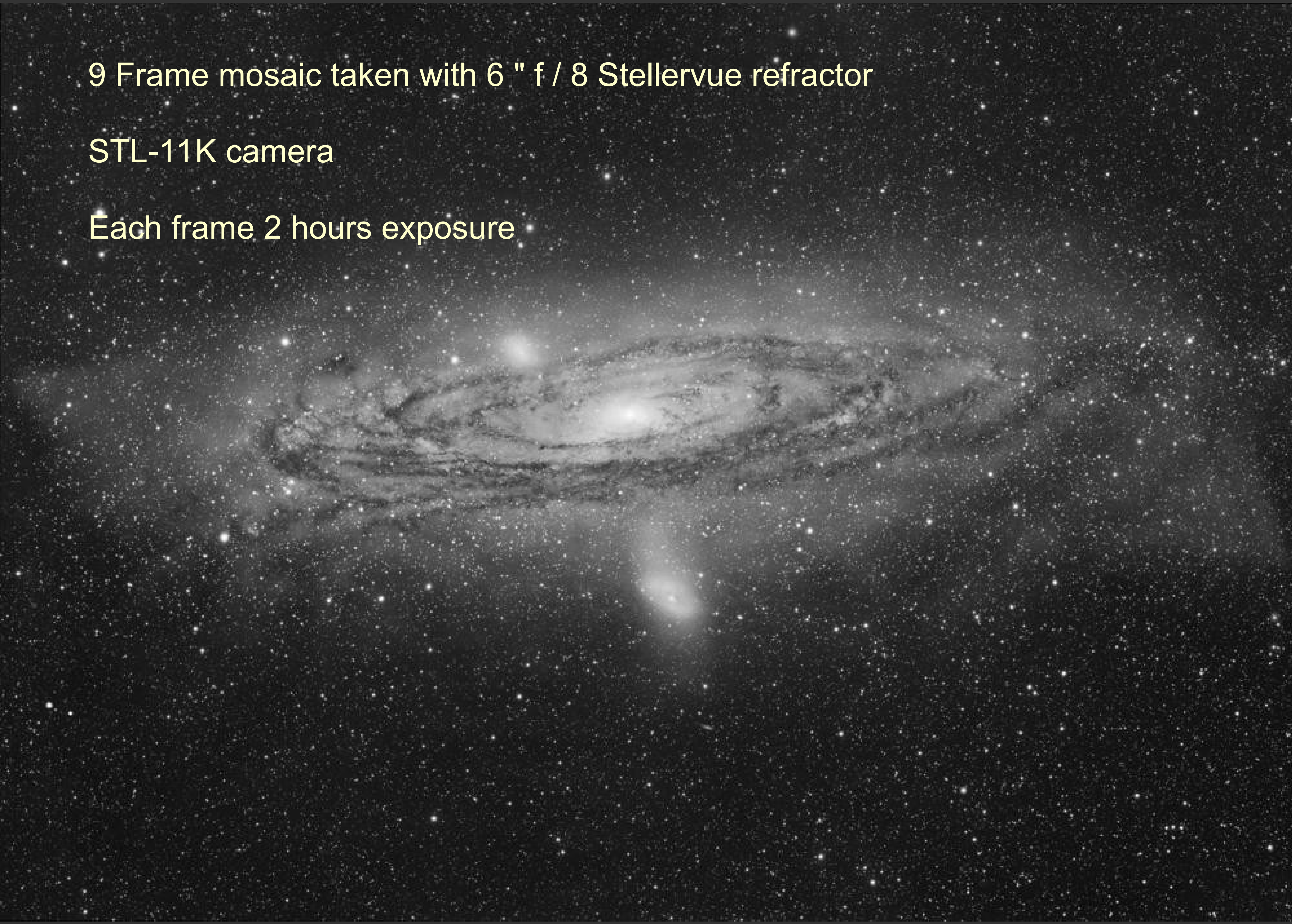




NGC 1300 / Hubble heritage

9 Frame mosaic taken with 6 " f / 8 Stellervue refractor

STL-11K camera

Each frame 2 hours exposure

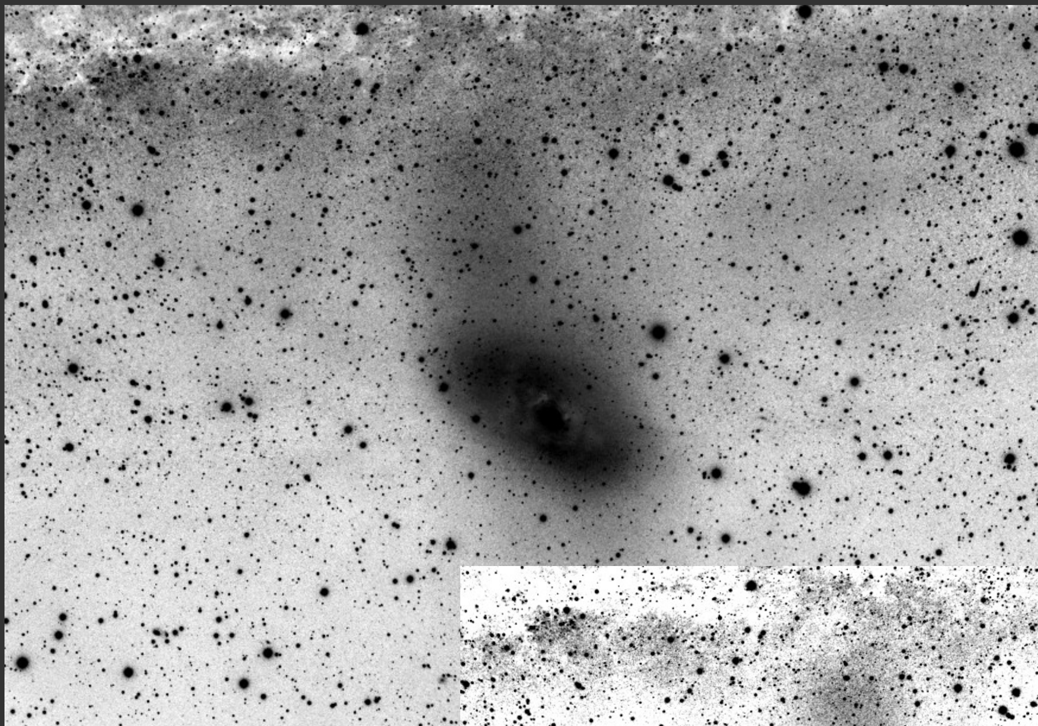


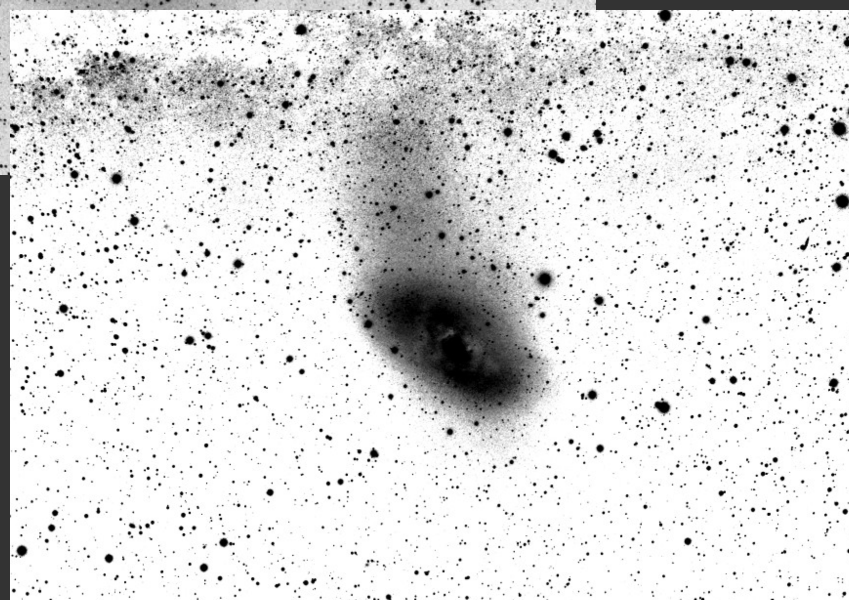

Tony Hallas, priv. comm.

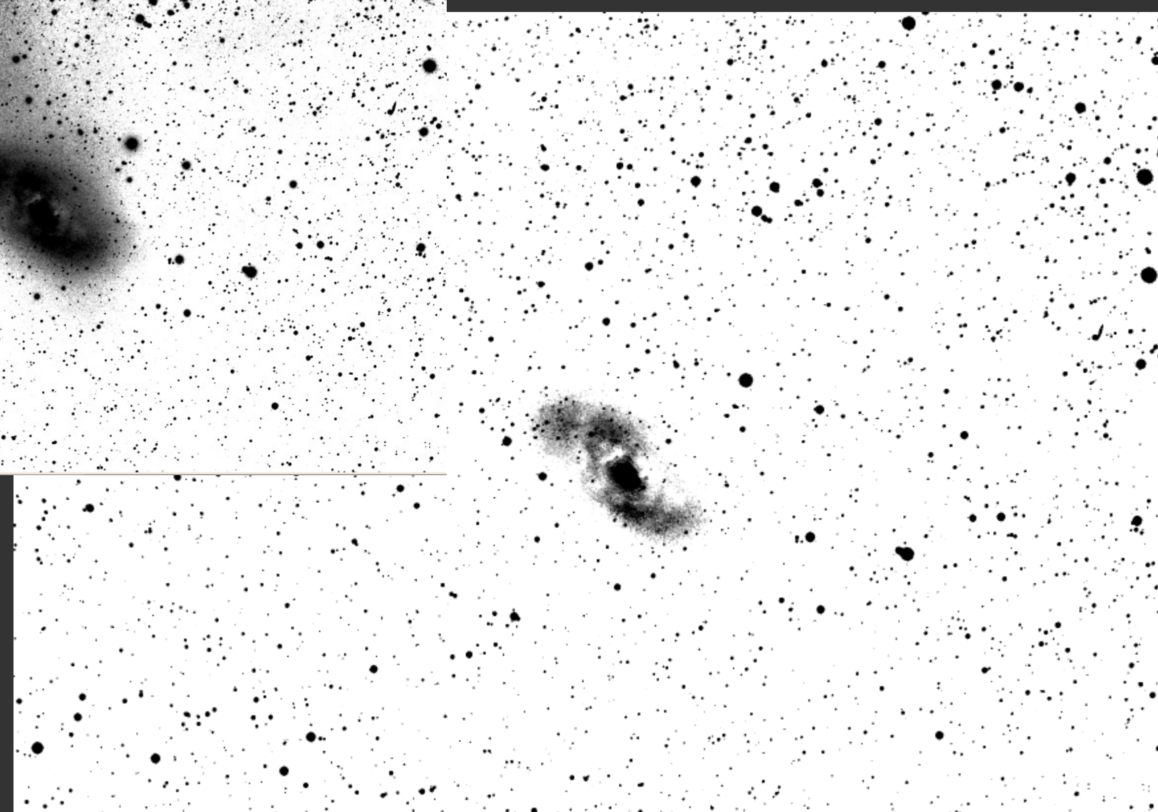
Diffuse light component subtracted

Unsharp masking technique (10px smoothing length)

White-light image with different cut levels







The spiral structure

Typical feature of a rotating disk

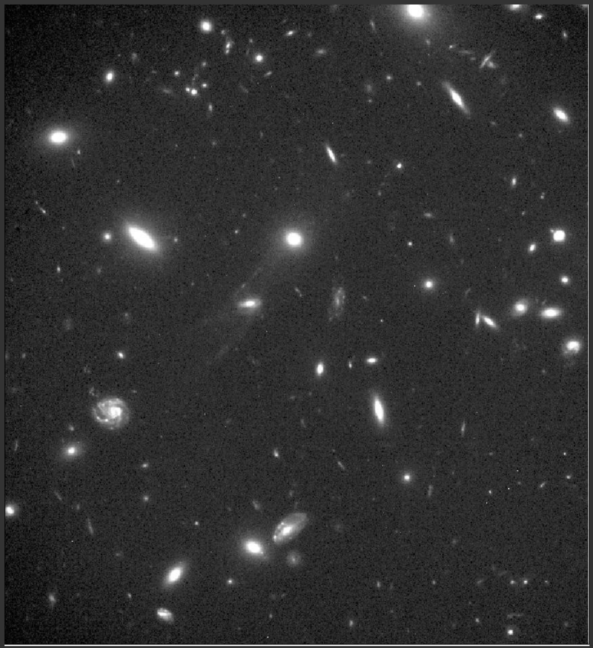
Jerjen et al. 2000; Barazza et al. 2002; Graham et al. 2003

-> hidden spiral and bar features discovered in early-type dwarfs of the Virgo cluster

-> interpreted as the result of galaxy harassment (Moore et al. 1996).

(Not the case here!)

Harassment = 1 encounter/Gyr with an L* galaxy, within 50kpc



CL0939 @z=0.42

Coma cluster @z=0.0023

A&A 391, 823–831 (2002)
DOI: 10.1051/0004-6361:20020875

Astronomy & Astrophysics

More evidence for hidden spiral and bar features in bright early-type dwarf galaxies*

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Received 25 February 2002 / Accepted 31 May 2002

Abstract. Following the discovery of spiral structure in IC 3328 (Jerjen et al. 2000), we present further evidence that a sizable fraction of bright early-type dwarfs in the Virgo cluster are genuine disk galaxies, or are hosting a disk component. Among a sample of 23 nucleated dwarf ellipticals and dS0s observed with the Very Large Telescope in *B* and *R*, we found another four systems exhibiting non-axisymmetric structures, such as a bar and/or spiral arms, indicative of a disk (IC 0783, IC 3349, NGC 4431, IC 3468). Particularly remarkable are the two-armed spiral pattern in IC 0783 and the bar and trailing arms in NGC 4431. For both galaxies the disk nature has recently been confirmed by a rotation velocity measurement (Simien & Prugniel 2002). Our photometric search is based on a Fourier decomposition method and a specific version of unsharp masking. Some "early-type" dwarfs in the Virgo cluster seem to be former late-type galaxies which were transformed to early-type morphology, e.g. by "harassment", during their infall to the cluster, while maintaining part of their disk structure.

Key words. galaxies: general – galaxies: fundamental parameters – galaxies: photometry – galaxies: structure

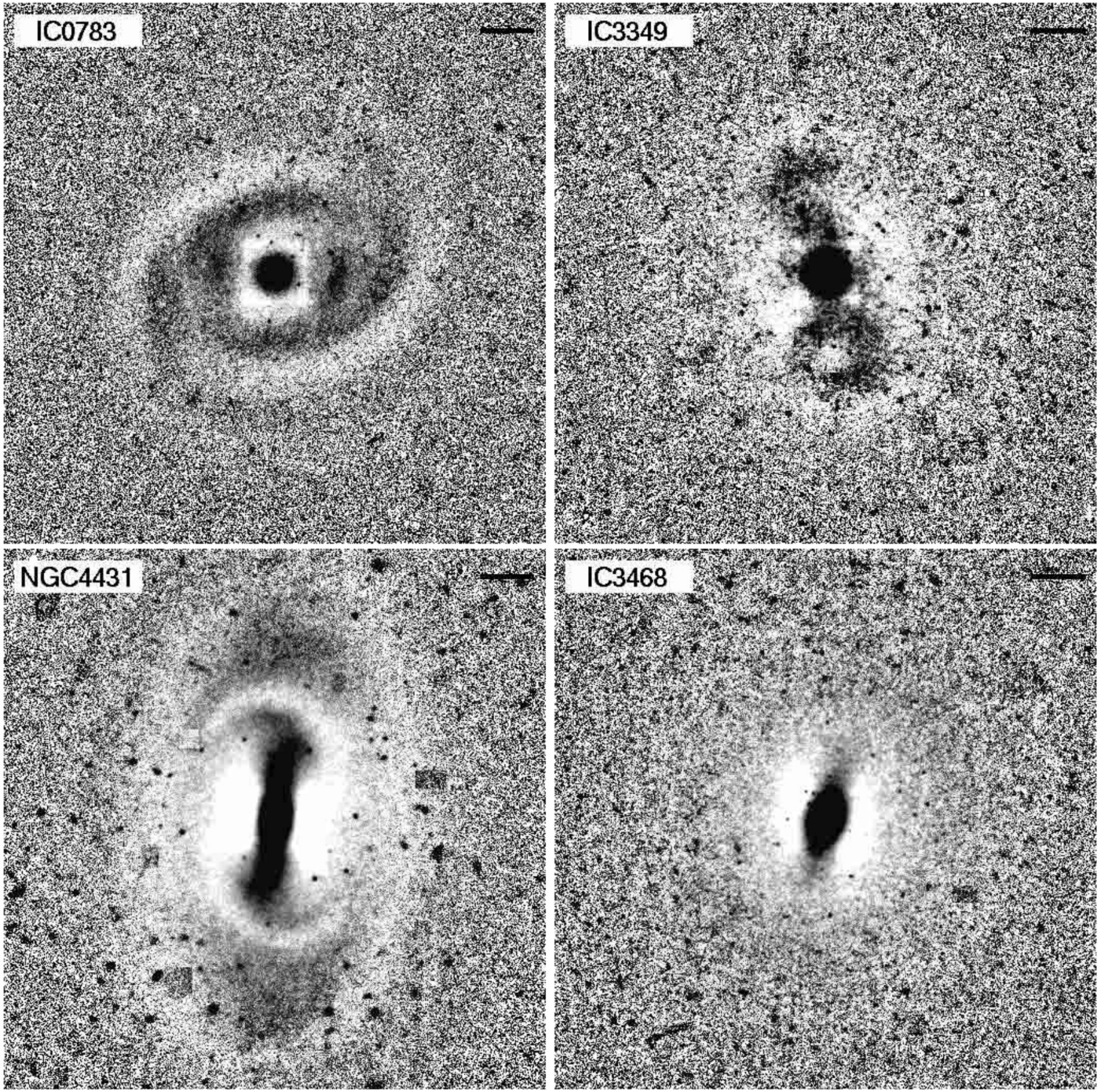

Fig. 3. Result of unsharp masking for the four galaxies. The images are negatives. Size and orientation as in Fig. 1.

The big picture:

morphological evolution in the LG?

Galaxy threshing

The Astrophysical Journal, 557:L39–L42, 2001 August 10

A NEW FORMATION MODEL FOR M32: A THRESHED EARLY-TYPE SPIRAL GALAXY?

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Received 2001 June 12; accepted 2001 July 2; published 2001 July 17

ABSTRACT

The origin of M32, the closest compact elliptical galaxy (cE), is a long-standing puzzle of galaxy formation in the Local Group. Our *N*-body/smoothed particle hydrodynamics simulations suggest a new scenario in which the strong tidal field of M31 can transform a spiral galaxy into a compact elliptical galaxy. As a low-luminosity spiral galaxy plunges into the central region of M31, most of the outer stellar and gaseous components of its disk are dramatically stripped as a result of M31's tidal field. The central bulge component, on the other hand, is just weakly influenced by the tidal field, owing to its compact configuration, and retains its morphology. M31's strong tidal field also induces rapid gas transfer to the central region, triggers a nuclear starburst, and consequently forms the central high-density and more metal-rich stellar populations with relatively young ages. Thus, in this scenario, M32 was previously the bulge of a spiral galaxy tidally interacting with M31 several gigayears ago. Furthermore, we suggest that cE's like M32 are rare, the result of both the rather narrow parameter space for tidal interactions that morphologically transform spiral galaxies into cE's and the very short timescale (less than a few times 10^9 yr) for cE's to be swallowed by their giant host galaxies (via dynamical friction) after their formation.

Subject headings: galaxies: bulges — galaxies: elliptical and lenticular, cD — galaxies: formation — galaxies: interactions

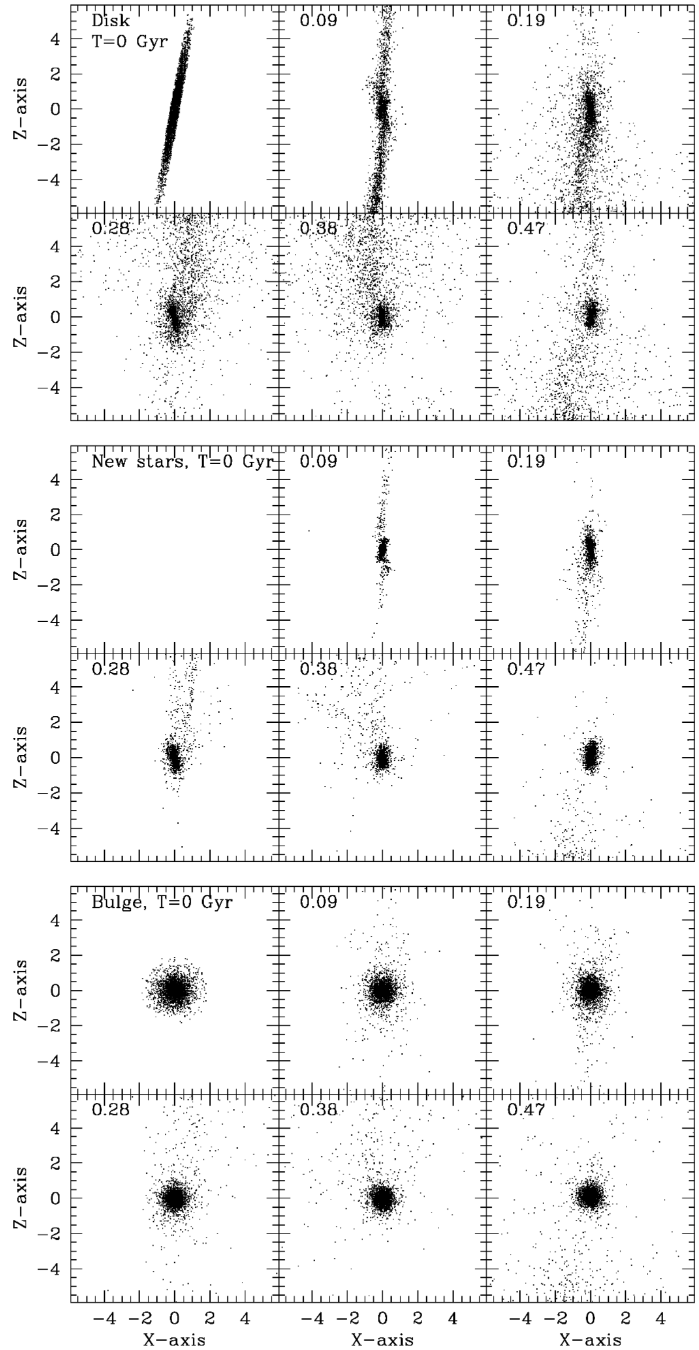

FIG. 2.—Morphological evolution projected onto the *x-z* plane (edge-on) for the stellar disk (*top six panels*), the new stars formed from gas (*middle six panels*), and the bulge (*bottom six panels*) in the simulated spiral galaxy. The time indicated in the upper left-hand corner of each frame is given in gigayears, and each frame measures 9.4 kpc on a side.

Disk stars

New stars

Bulge

M32: from disk to spheroid

n-body/smoothed particle hydrodynamics simulations

Started several Gyr ago as a low-luminosity spiral galaxy (M/Msun=4e9

later stripped of its outer stellar and gaseous disk by M31's tidal field

In the course of the transformation, gas rapidly transferred to the central region

nuclear starburst is triggered =>
  => central high-density, more metal-rich stellar populations
  => with relatively young ages

Tidal stirring

Mayer et al. 2001, 2006, 2007

Klimentowski et al. 2008

Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 17 March 2008 (MN LaTeX style file v2.2)

Tidal evolution of a disky dwarf galaxy in the Milky Way potential: the formation of a dwarf spheroidal

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17 March 2008

ABSTRACT

We conduct a high-resolution collisionless N-body simulation to investigate the tidal evolution of a dwarf galaxy on an eccentric orbit in the Milky Way (MW) potential. The dwarf originally consists of a low surface brightness stellar disk embedded in a cosmologically motivated dark matter halo. During 10 Gyr of dynamical evolution and after 5 pericentre passages the dwarf suffers substantial mass loss and its stellar component undergoes a major morphological transformation from a disk to a bar and finally to a spheroid. The bar is preserved for most of the time, as long as angular momentum is transferred outside the galaxy. A dwarf spheroidal (dSph) galaxy is formed only after the last pericentre when the average angular momentum per stellar particle increases. Despite the strong tidal perturbations and mass loss, for most of the time the 1D stellar velocity dispersion, σ, follows the maximum circular velocity, $V_{\rm max}$, and they are both good tracers of the bound mass. Specifically, we find that $M_{\rm bound} \propto V_{\rm max}^{3.5}$ and $V_{\rm max} \sim 2\sigma$. The latter relation is based on directly measuring the stellar kinematics of the simulated dwarf and may thus be used to map the observed stellar velocity dispersions of dSphs to halo circular velocities when formulating the missing satellites problem. We also study the properties of tidal tails formed during the evolution of the dwarf. We report on an interesting phenomenon of 'tidal tail flipping': on the way from the pericentre to the apocentre the old tails following the orbit are dissolved and new ones pointing towards the MW are formed over a short timescale. Contrary to common belief, we find that in the vicinity of the dwarf (where they are most likely to be detectable) the tails are typically oriented towards the MW and not along the orbit. We also find a linear relation between the velocity of stars in the tidal tails and their distance from the dwarf.

Key words: galaxies: Local Group – galaxies: dwarf – galaxies: fundamental parameters – galaxies: kinematics and dynamics – cosmology: dark matter

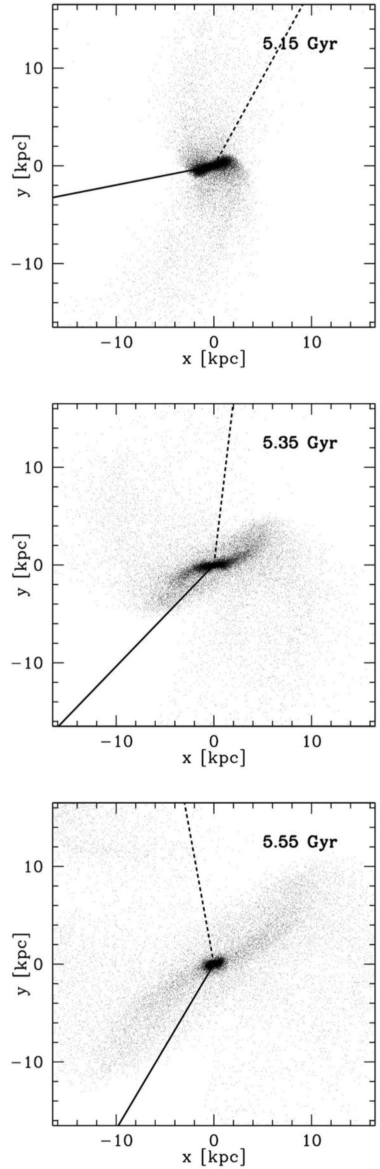

Figure 13. Tidal tail flipping. The three panels show three snapshots from the simulation at 5.15, 5.35 and 5.55 Gyr from the start. Only the positions of stellar particles are shown projected onto the orbital plane. The solid line indicates the direction to the host galaxy while the dashed one is parallel to the velocity vector. Old tidal tails oriented almost along the orbit decay and new ones pointing radially towards the host galaxy are formed.

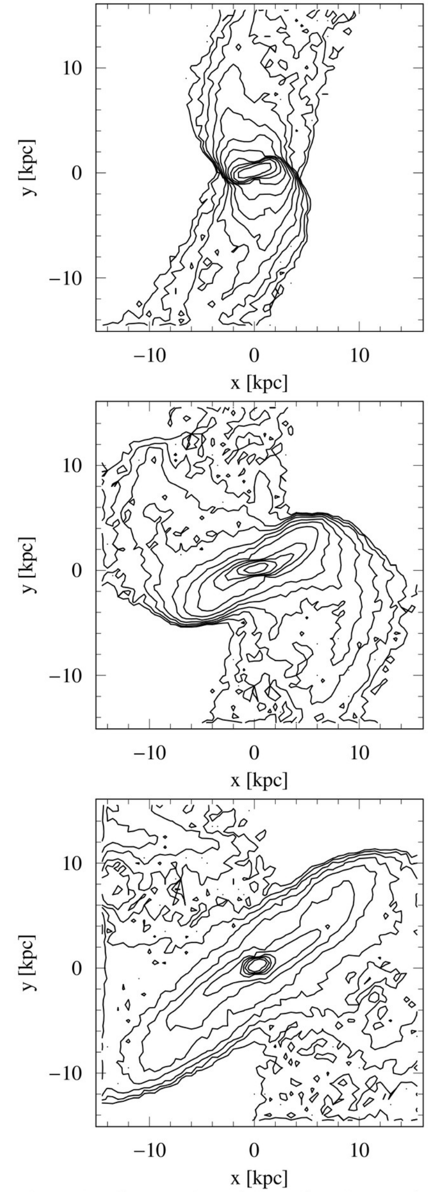

Figure 14. Contour plots of the surface density of stars corresponding to the three stages shown in Fig. 13. Each contour marks the density twice lower than the previous one. Assuming the stellar mass-to-light ratio of 3 solar units, the innermost contour corresponds to 2 $L_\odot$ pc^{-2}, while the outermost to 0.002 $L_\odot$ pc^{-2}.

In any case, interaction with M31 is clear

Davidge (2003):

- multiple episodes of star formation in the most central region

- with a time spacing compatible with the putative NGC 205 orbital period (Cepa & Beckman 1988)

Demers et al. (2003)
-> extra-tidal carbon stars

Ibata et al. 2001; McConnachie et al. 2004
-> tidal streams of stars in M31 halo
- possibly related with NGC 205 and/or M32

Hodge 1973; Choi et al. 2002
-> isophotes twisted at radii larger than ~ 4'
- incipient tidal tails

De Rijcke et al. 2006; Geha et al. 2006
- stars beyond that radius are apparently moving in the opposite direction with respect to the inner galaxy

Note that NGC 205 is also the prototype of nucleated dwarf ellipticals
-> usually considered as tracers of high density environments (interactions favor the nucleation process)

The four nucleated galaxies in the Local Group (M33, Sagittarius, M32, and NGC 205; Kormendy & McClure 1993; Majewski et al. 2003; Ibata et al. 2001; McConnachie et al. 2004) have all been suggested to be in the process of tidal disruption

Mon. Not. R. Astron. Soc. **351,** L94–L98 (2004) doi:10.1111/j.1365-2966.2004.08076.x

The tidal trail of NGC 205?

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ABSTRACT

Using data taken as part of the Isaac Newton Telescope Wide Field Camera (INT WFC) survey of M31, we have identified an arc-like overdensity of blue, presumably metal-poor, red giant branch stars in the north-west quadrant of M31. This feature is $\sim 1^\circ$ (15 kpc) in extent and has a surface brightness of $\Sigma_{V'} \simeq 28.5 \pm 0.5$ mag arcsec^{-2}. The arc appears to emanate from the dwarf elliptical galaxy NGC 205, and the colour of its red giant branch is significantly different from the M31 disc population but closely resembles that of NGC 205. Further, using data taken with the Deep Imaging Multi-Object Spectrograph (DEIMOS) on Keck II, we identify the radial velocity signature of this arc. Its velocity dispersion is measured to be $\simeq 10\,\mathrm{km\,s^{-1}}$, similar to that of the central regions of NGC 205 and typical of stellar streams. Based upon the spatial coincidence of these objects, the surface brightness, the velocity dispersions and the similarity in colour of the red giant branches, we postulate that the arc is part of a stellar stream, the progenitor of which is NGC 205.

Key words: galaxies: dwarf – galaxies: general – galaxies: interactions – Local Group.

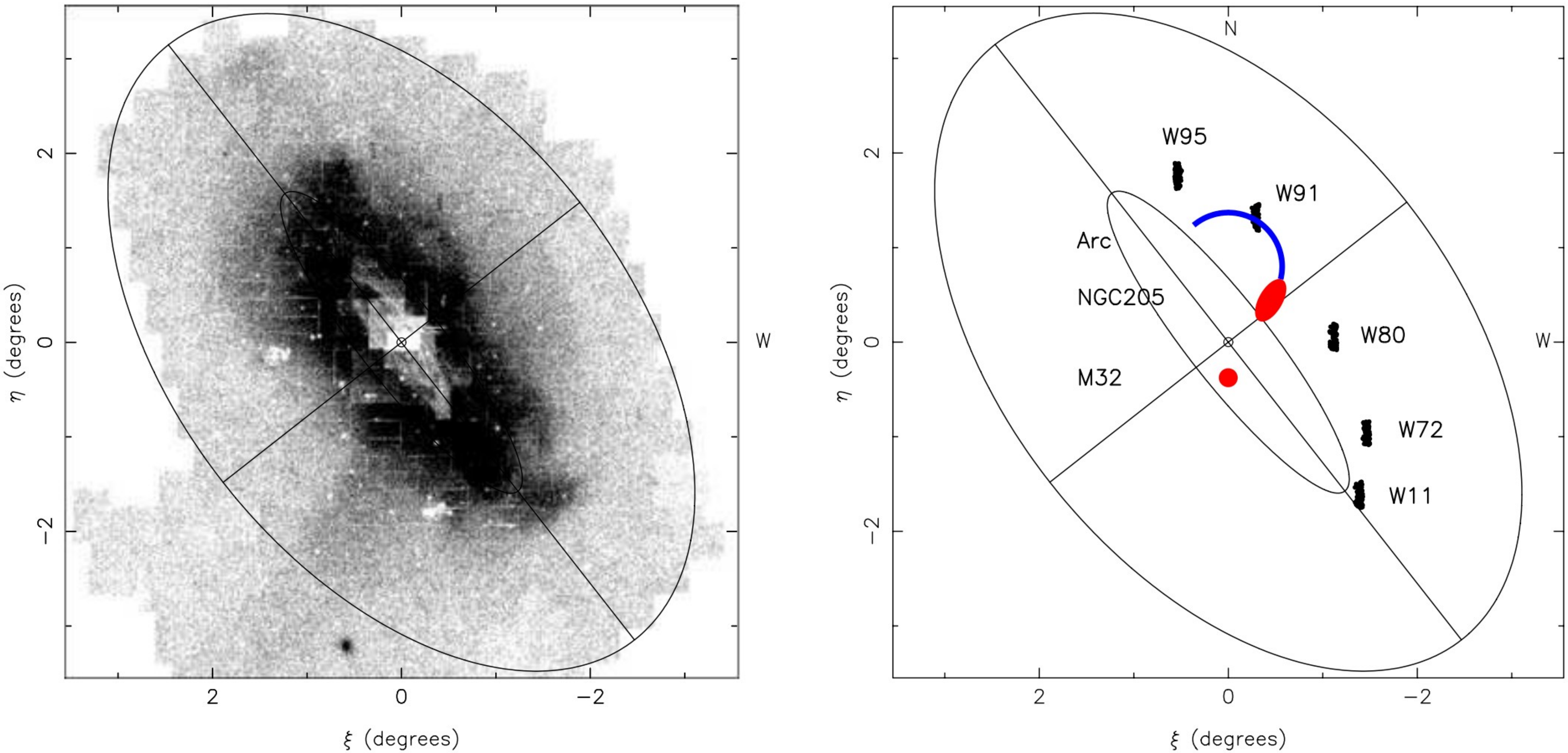
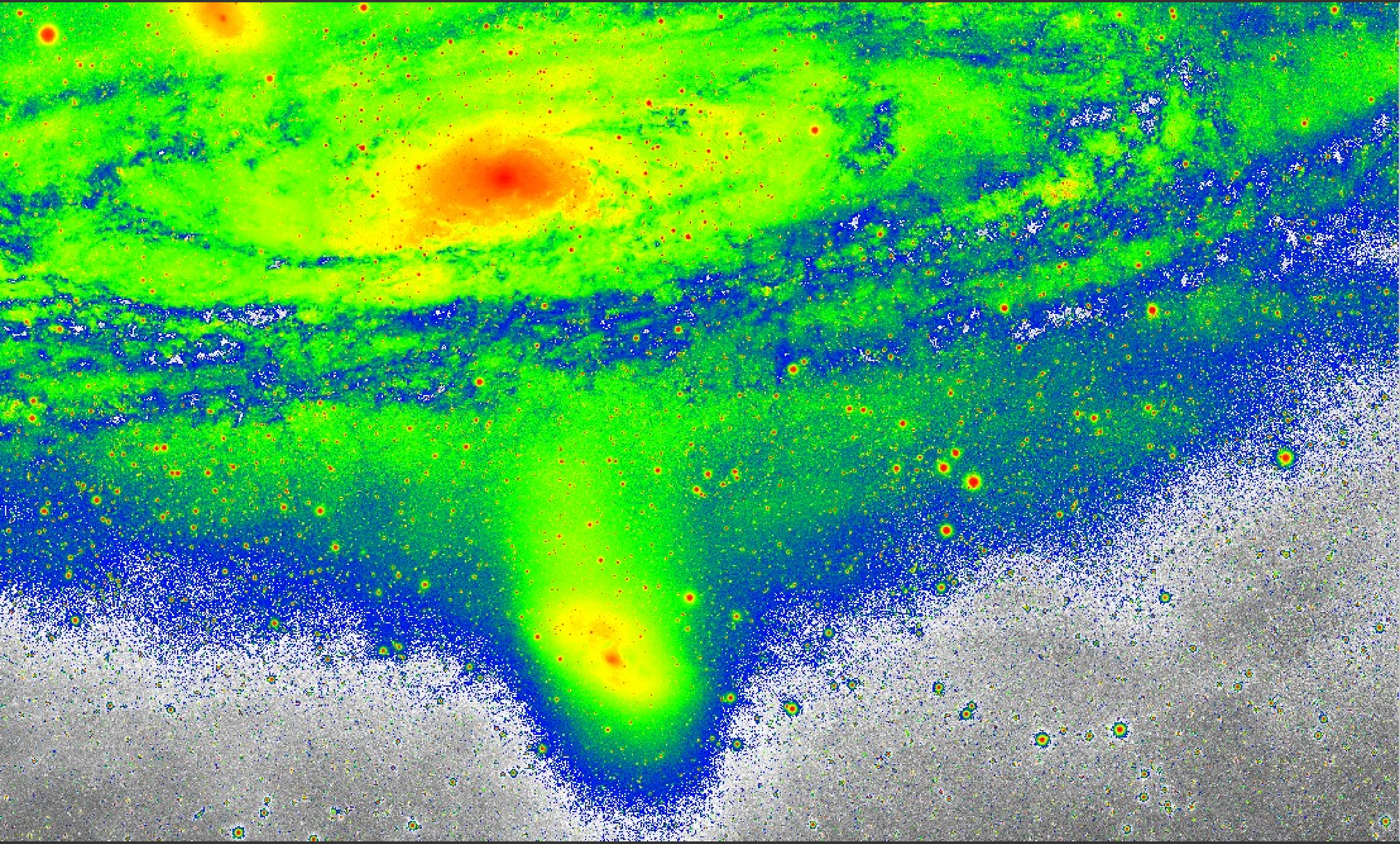
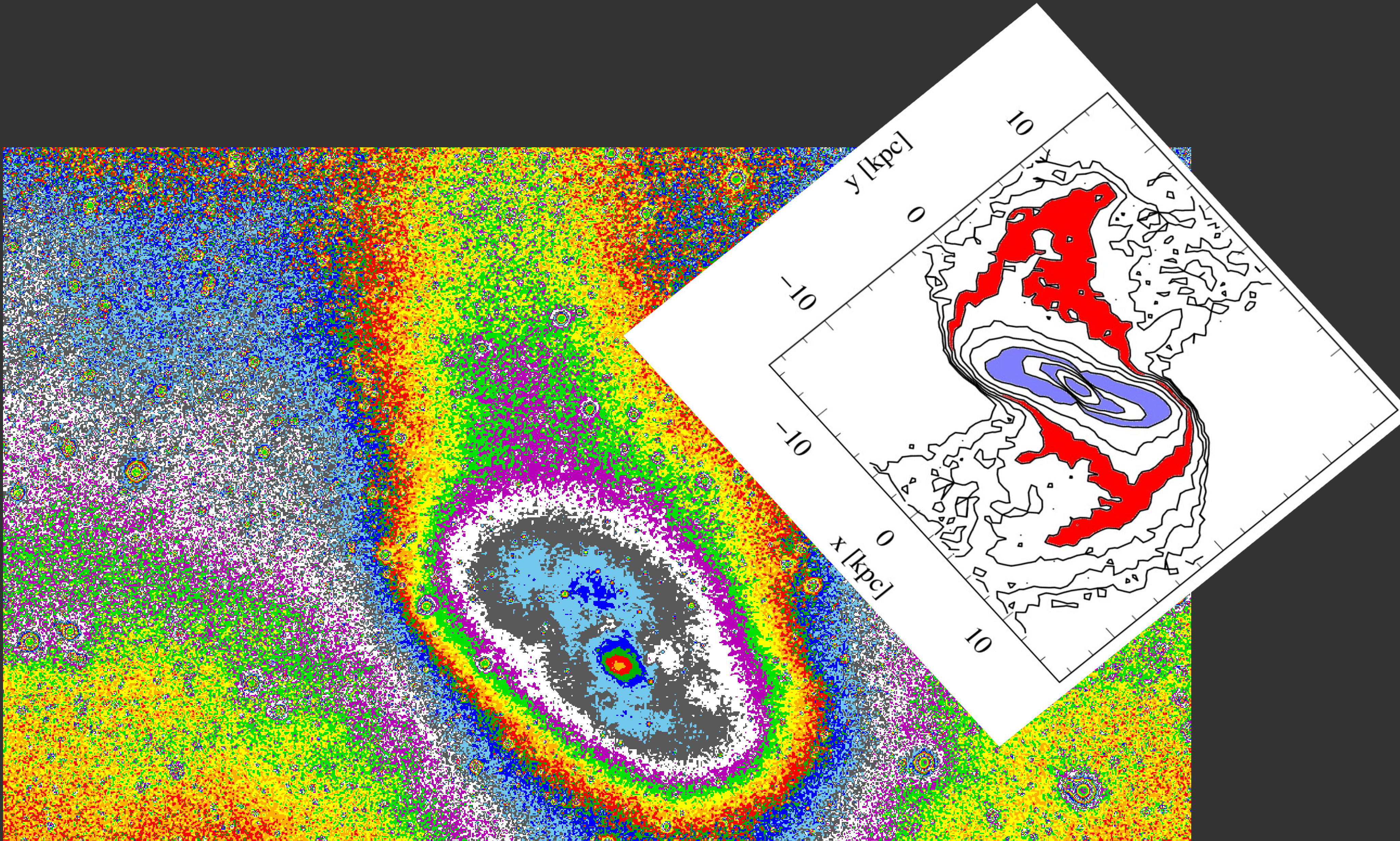


Figure 1. Left-hand panel: the spatial distribution of 'bluer' RGB stars, defined by the the colour cut described in the text. This cut is designed to highlight the arc-like density enhancement centred at approximately ($-0\overset{\circ}{.}6$, $1\overset{\circ}{.}1$). The dwarf elliptical galaxy NGC 205 is located at ($-0\overset{\circ}{.}6$, $0\overset{\circ}{.}4$). The metal-poor dwarf spheroidal galaxy and I stands out to the south of the plot, in addition to other complex substructure around the outer south-west disc. Right-hand panel: cartoon showing the location of our outer disc DEIMOS fields with respect to M32, NGC 205 and the stellar arc. In both panels, the 2°-radius ellipse marks the outer boundary of the optical disc of M31, whereas the outer ellipse has a semimajor axis $\simeq 55$ kpc and flattening 0.6. This corresponds to the original limit of the INT survey.




y [kpc]
10
0
−10
−10
0
10
x [kpc]

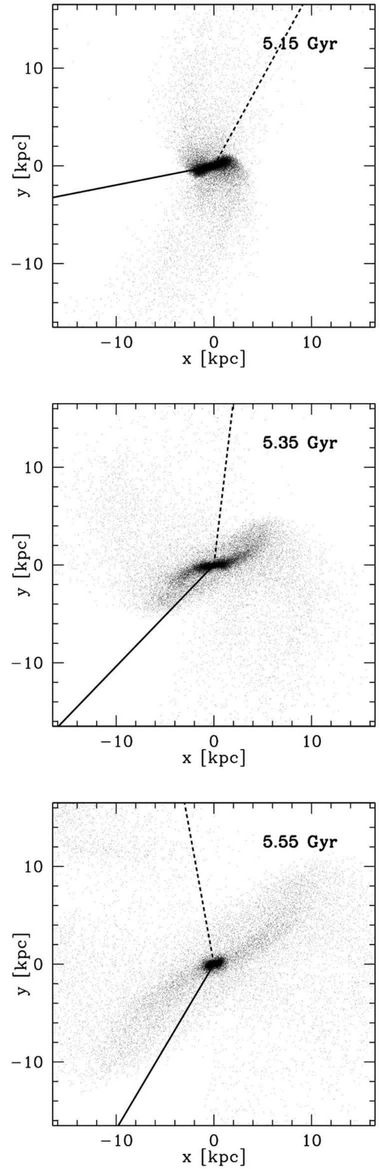


Figure 13. Tidal tail flipping. The three panels show three snapshots from the simulation at 5.15, 5.35 and 5.55 Gyr from the start. Only the positions of stellar particles are shown projected onto the orbital plane. The solid line indicates the direction to the host galaxy while the dashed one is parallel to the velocity vector. Old tidal tails oriented almost along the orbit decay and new ones pointing radially towards the host galaxy are formed.

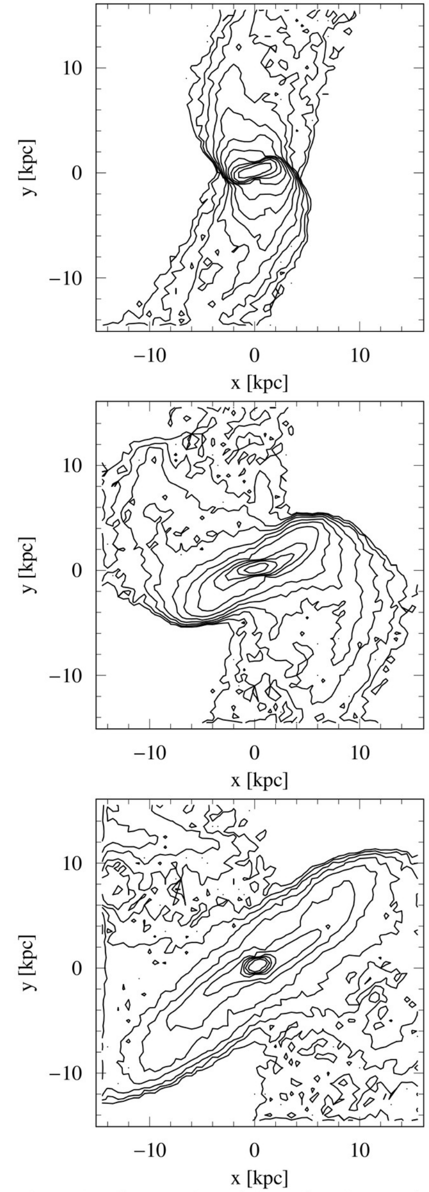
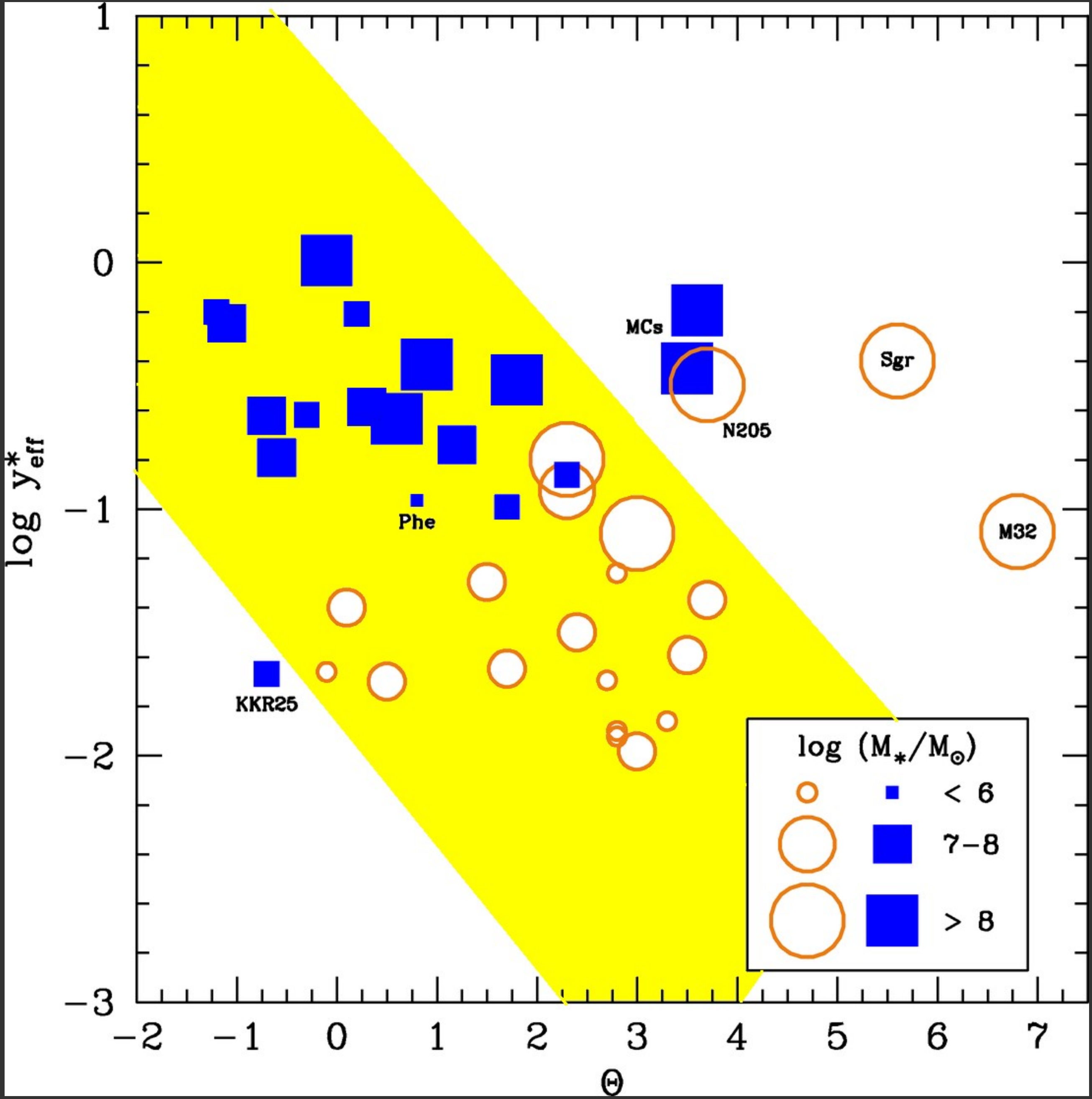


Figure 14. Contour plots of the surface density of stars corresponding to the three stages shown in Fig. 13. Each contour marks the density twice lower than the previous one. Assuming the stellar mass-to-light ratio of 3 solar units, the innermost contour corresponds to 2 $L_\odot$ pc^{-2}, while the outermost to 0.002 $L_\odot$ pc^{-2}.

the inescapable conclusion seems to be
that NGC 205 is a disk galaxy disguised as an elliptical because its old stars have been stirred up by the tidal field of M31, and they have been distributed in a spheroid.

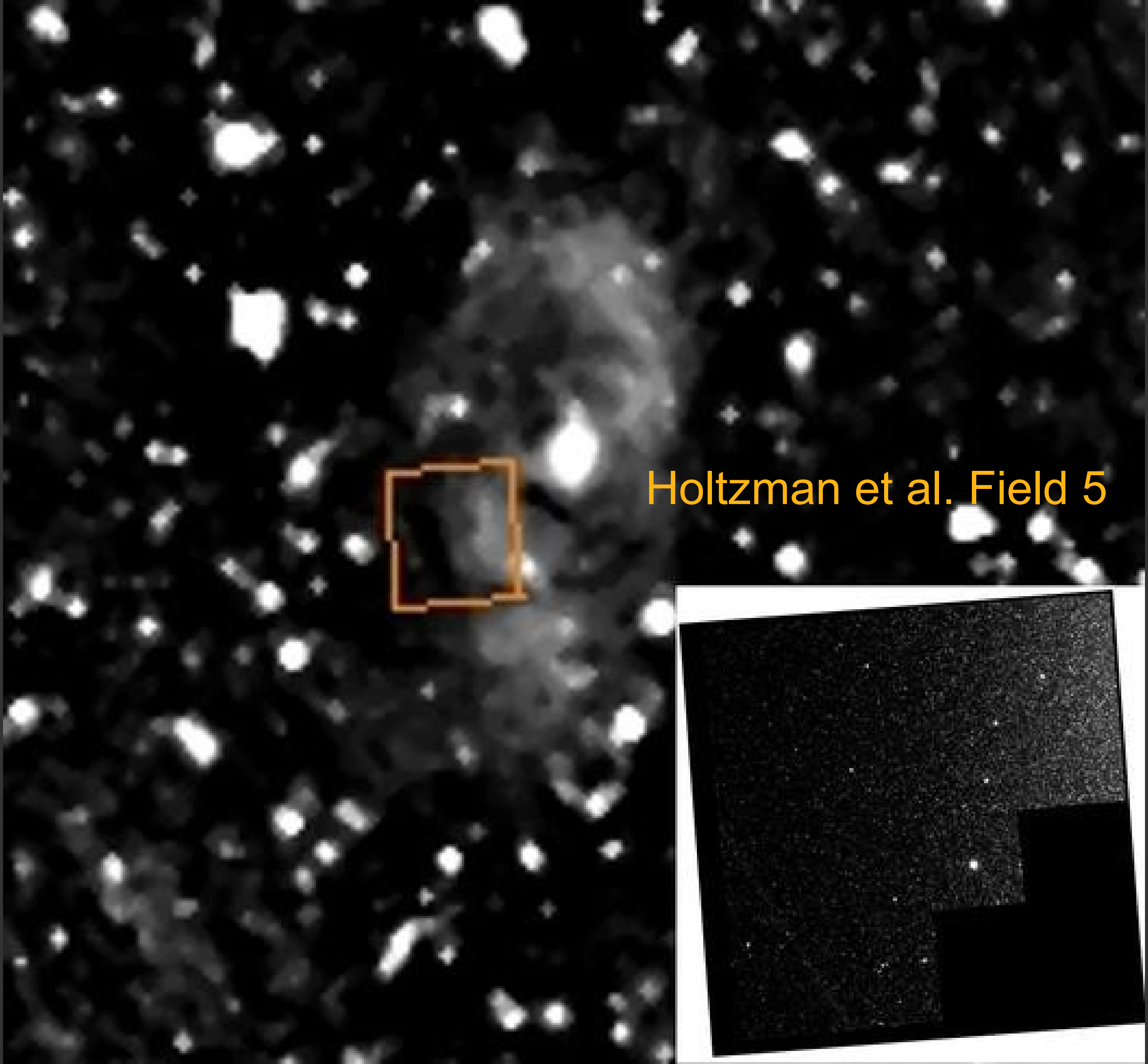
What next...

From Lee et al. (2009)

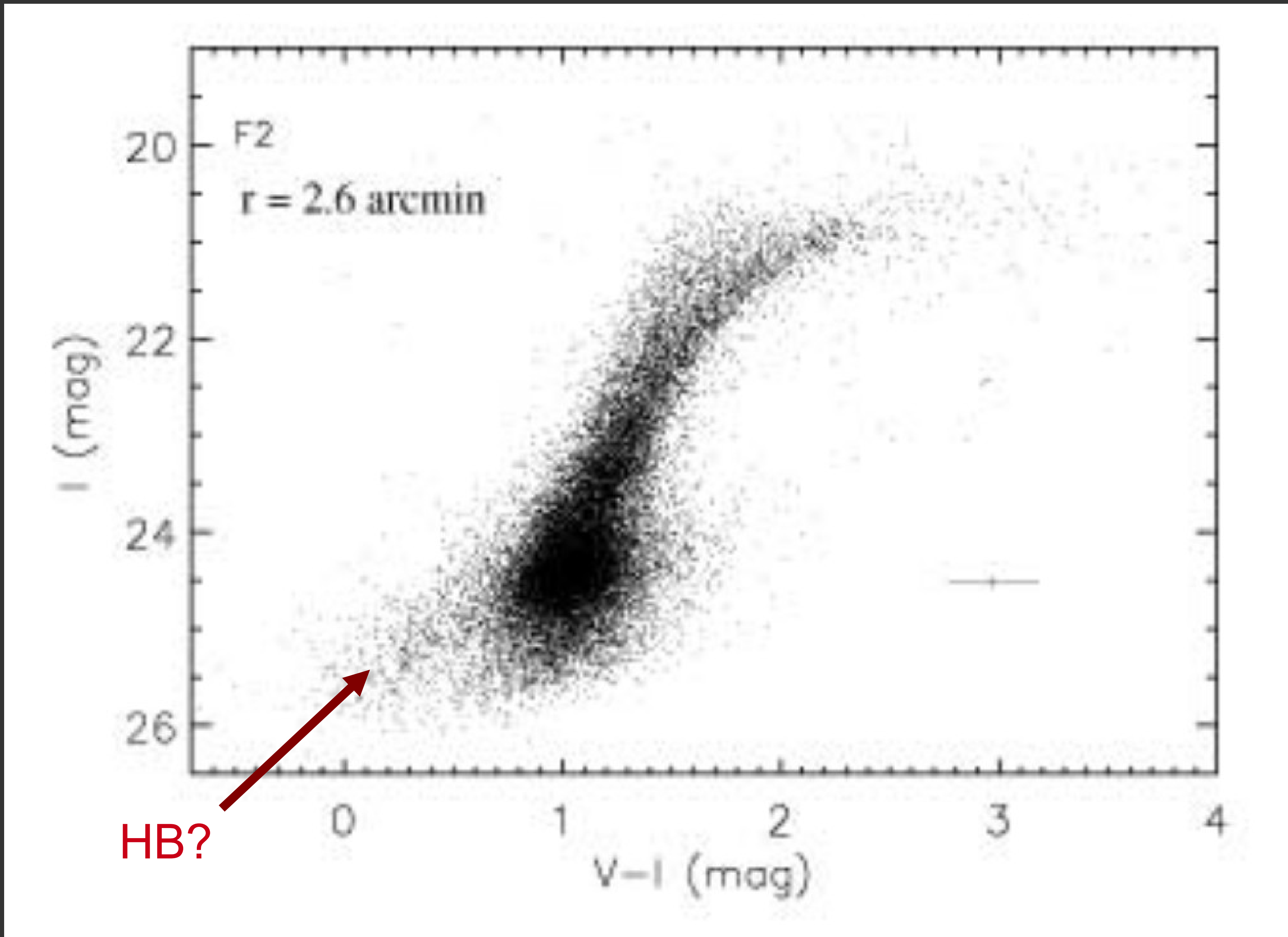


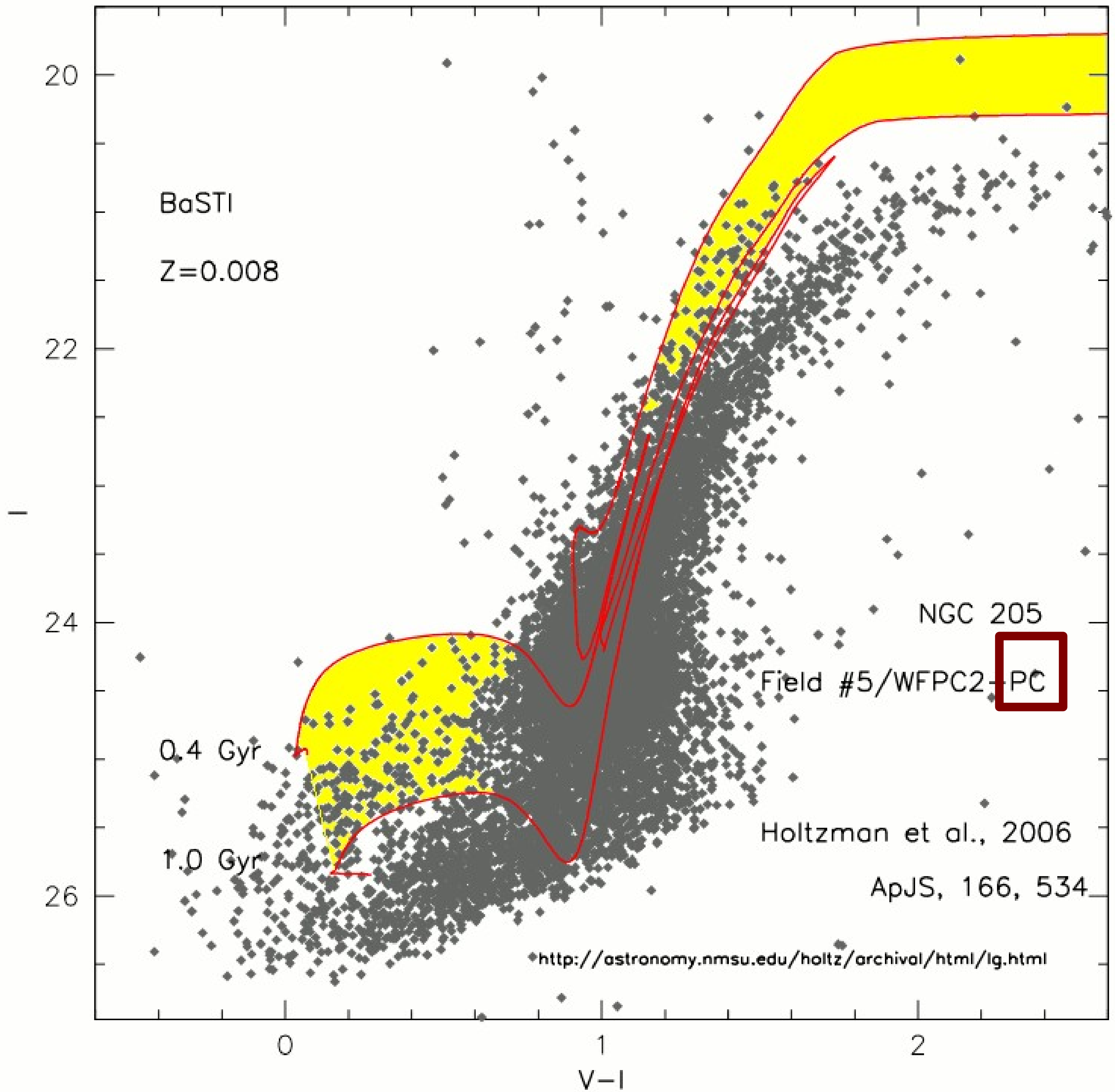
Wide-area, deep imaging:

- HST/ACS
- LBT/LBC
- Subaru/SuprimeCam

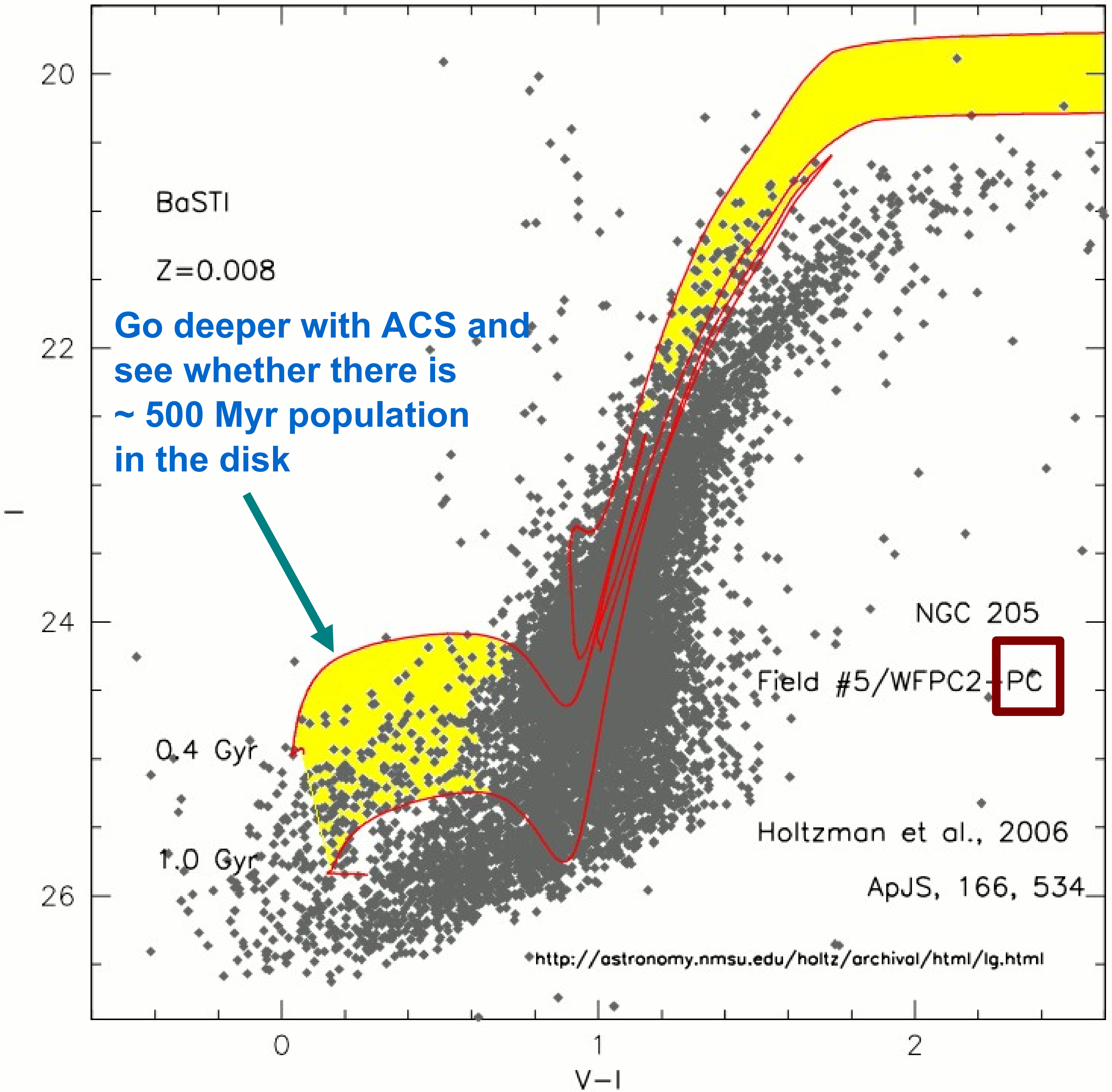

Holtzman et al. Field 5

BD05 Field 2 (=Holtzman Field 5)





BaSTI
Z=0.008
NGC 205
Field #5/WFPC2-PC
0.4 Gyr
1.0 Gyr
Holtzman et al., 2006
ApJS, 166, 534
http://astronomy.nmsu.edu/holtz/archival/html/lg.html
20
22
24
26
I
0
1
2
V−I


Go deeper with ACS and
see whether there is
~ 500 Myr population
in the disk
BaSTI
Z=0.008
NGC 205
Field #5/WFPC2-PC
0.4 Gyr
1.0 Gyr
Holtzman et al., 2006
ApJS, 166, 534
http://astronomy.nmsu.edu/holtz/archival/html/lg.html
20
22
24
26
I
0
1
2
V−I

The Large Binocular Cameras (LBC)

- Two wide-field, high-throughput imaging cameras

- Prime Focus stations of the LBT

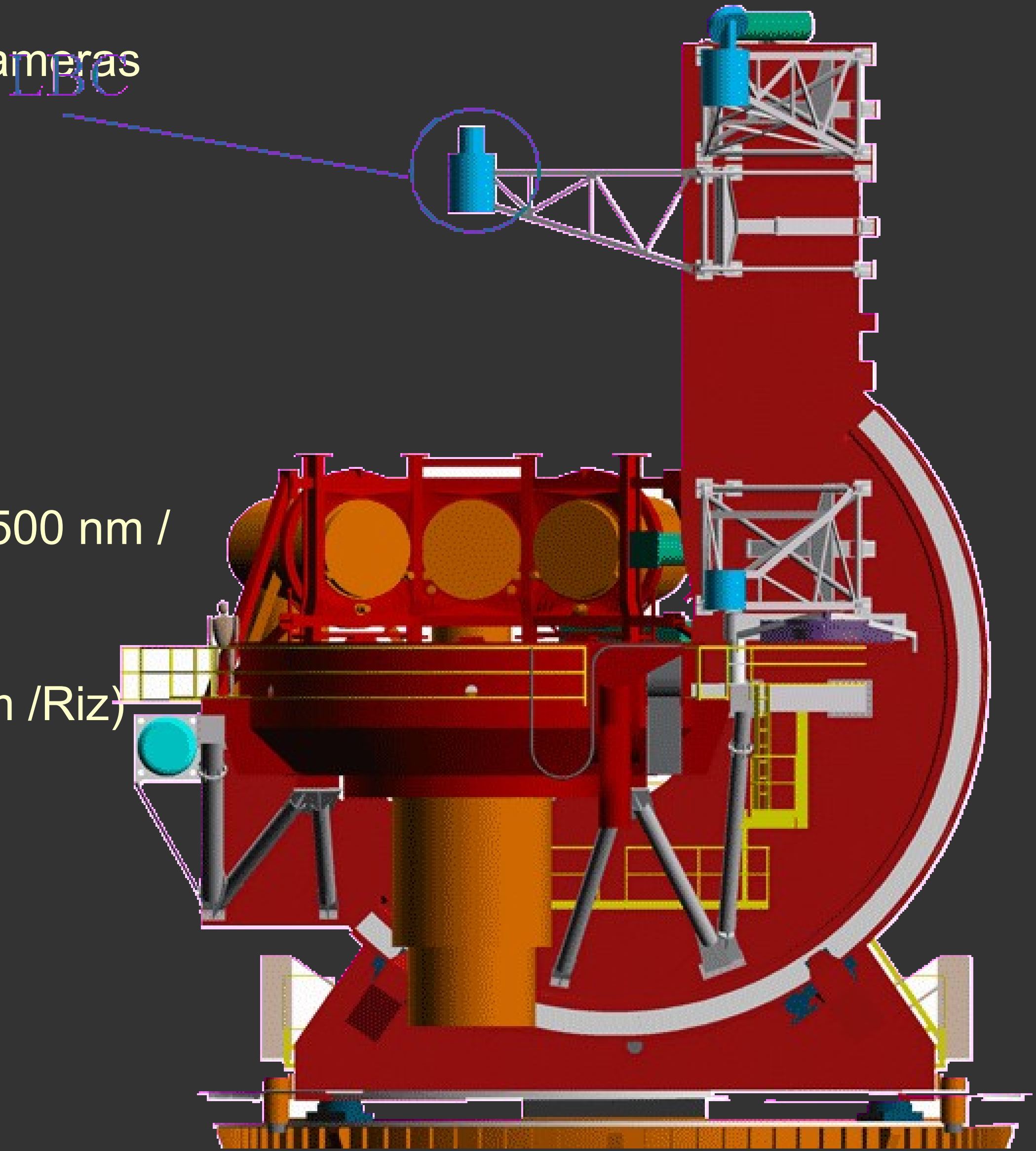
- 23'x23' / 0.23"/pixel

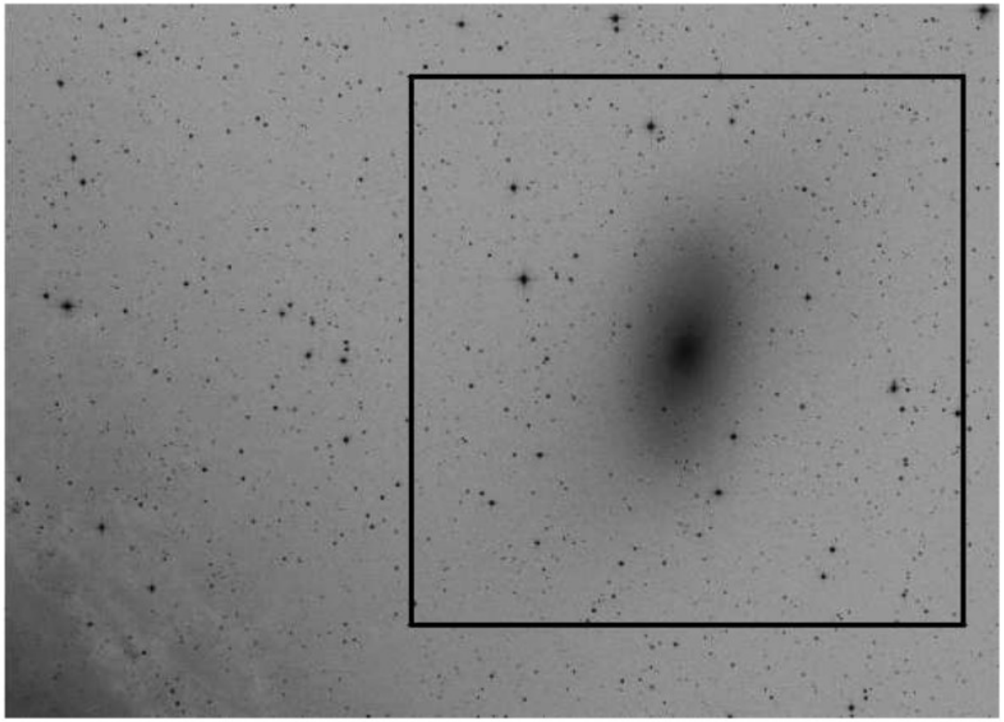
- Optics and detectors optimized for

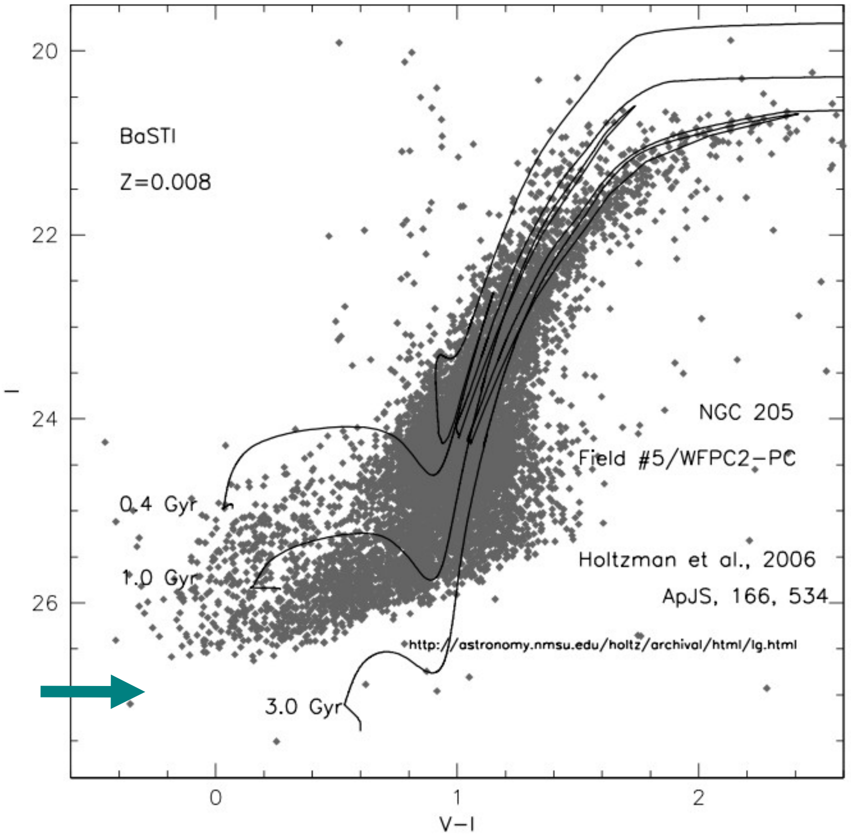
  - UV-blue wavelengths (from 320 to 500 nm / UBV)

  - Red-IR bands (from 500 to 1000 nm /Riz)

- Both channels available simultaneously







7.4h in I => SN R = 5 @ I =27 (89x300sec)

(B − I) ≃ 0.8 on MS

4.8h in B => SNR =5 @ B =27.8

2min in V to obtain (V-I)=> [Fe/H]

To be observed, hopefully, between 20 and 24 Feb.

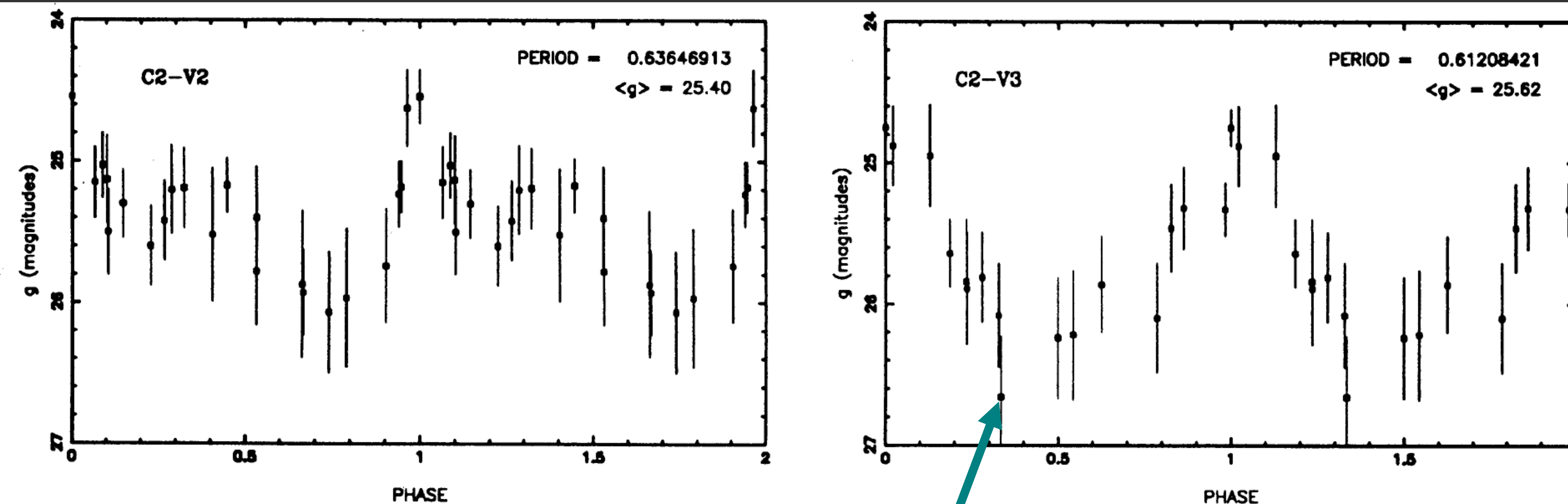


FIG. 3. Light curves, mean magnitudes, and periods for variable stars discovered.

From Saha et al. (1992)

g passband of Thuan & Gunn (1976)

=> g(lim) > 26.5

g-band avoids e.g., [OI] 5577

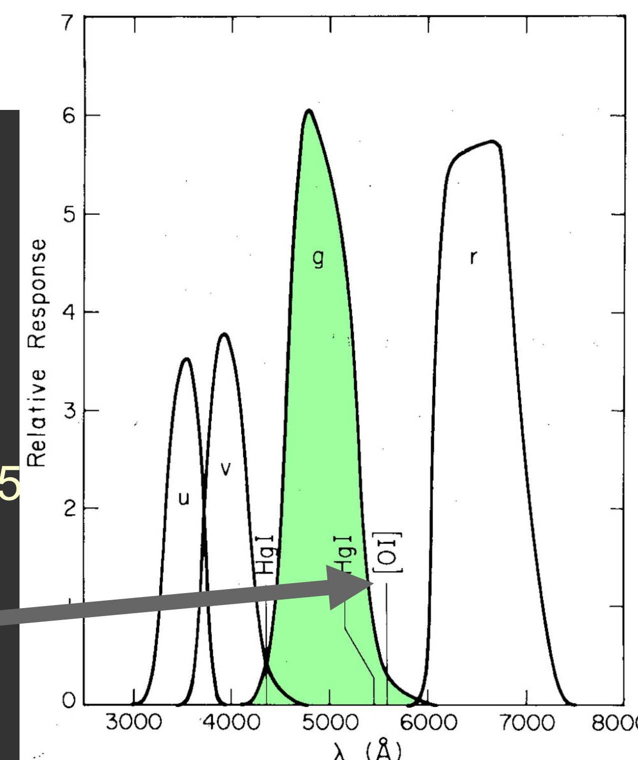
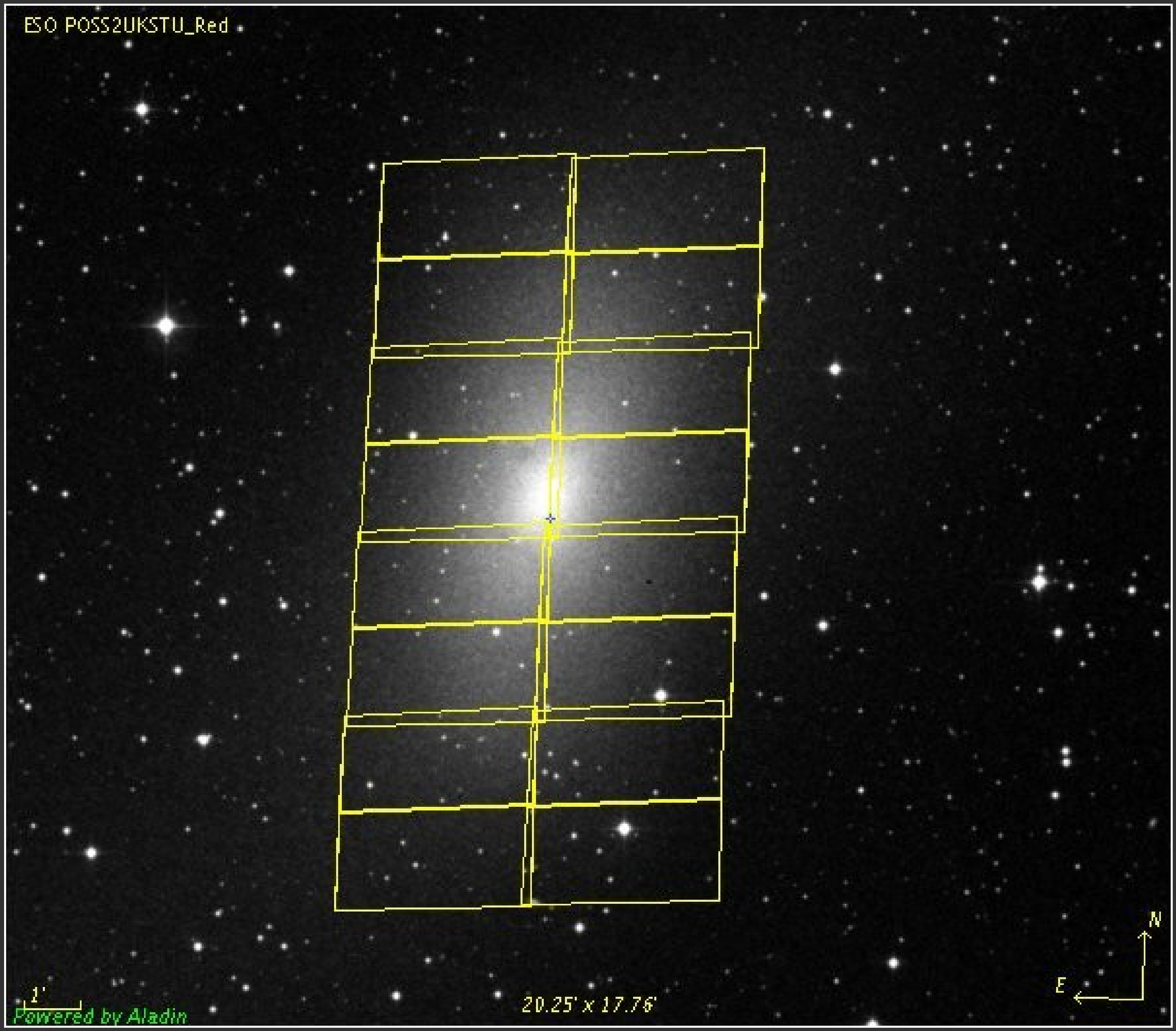
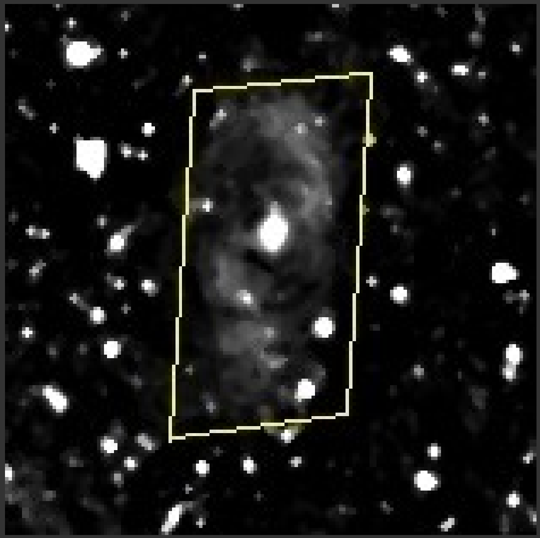


FIG. 1—The transmission function S(λ) for the filters, S-20 photocathode, and one reflection from aluminum.

HST / ACS



16 orbits + 2 control field



An exciting possibility, to be confirmed by a really sound body of evidence

A panoramic view of this key member of the Local Group is needed

Need to resolve stars as faint as I=27 (get MS stars as old as 3 Gyr)
=> mosaic of ACS/WFC images
- -> resolution to distinguish the subtle morphological features
- -> sensitivity to reconstruct the recent SFH of the disk
- -> trend of SFH over several orbits (P=0.1 Gyr, CB88): enhanced in close passages to M31?
- -> spatial trends of SF? Tidal stripping?

Should be one of the top galaxies that should be part of the HST legacy

The mosaic of ACS frames will cover the whole spiral pattern

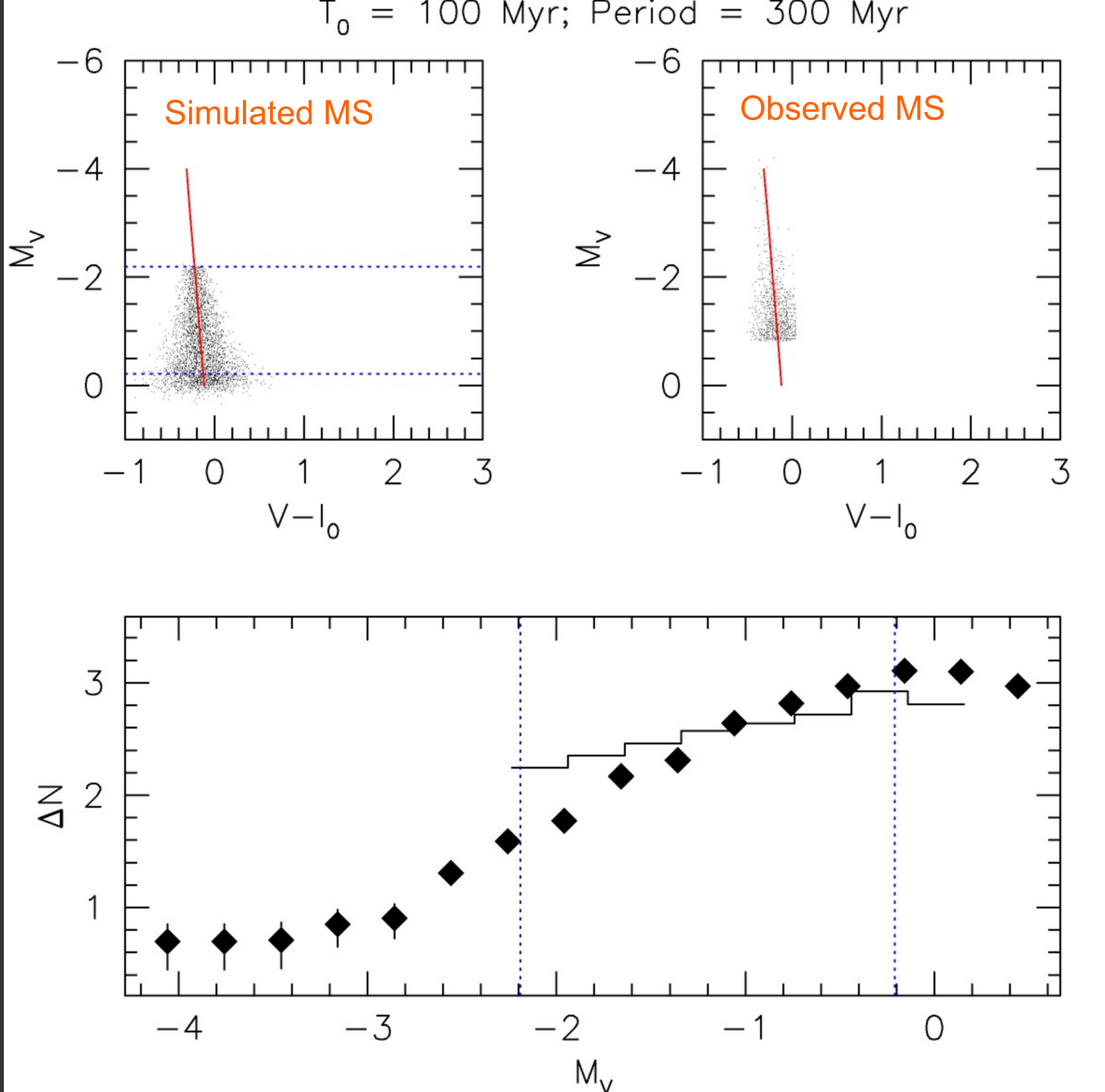
=> confirm the morphology of NGC 205

To enhance the large-scale features
- rebin the images
- use matched filter techniques
  => map spiral arms to larger distances using resolved stars
  (e.g. Walsh et al. 2007; Ondekirchen et al. 2001; Willman et al. 2002).

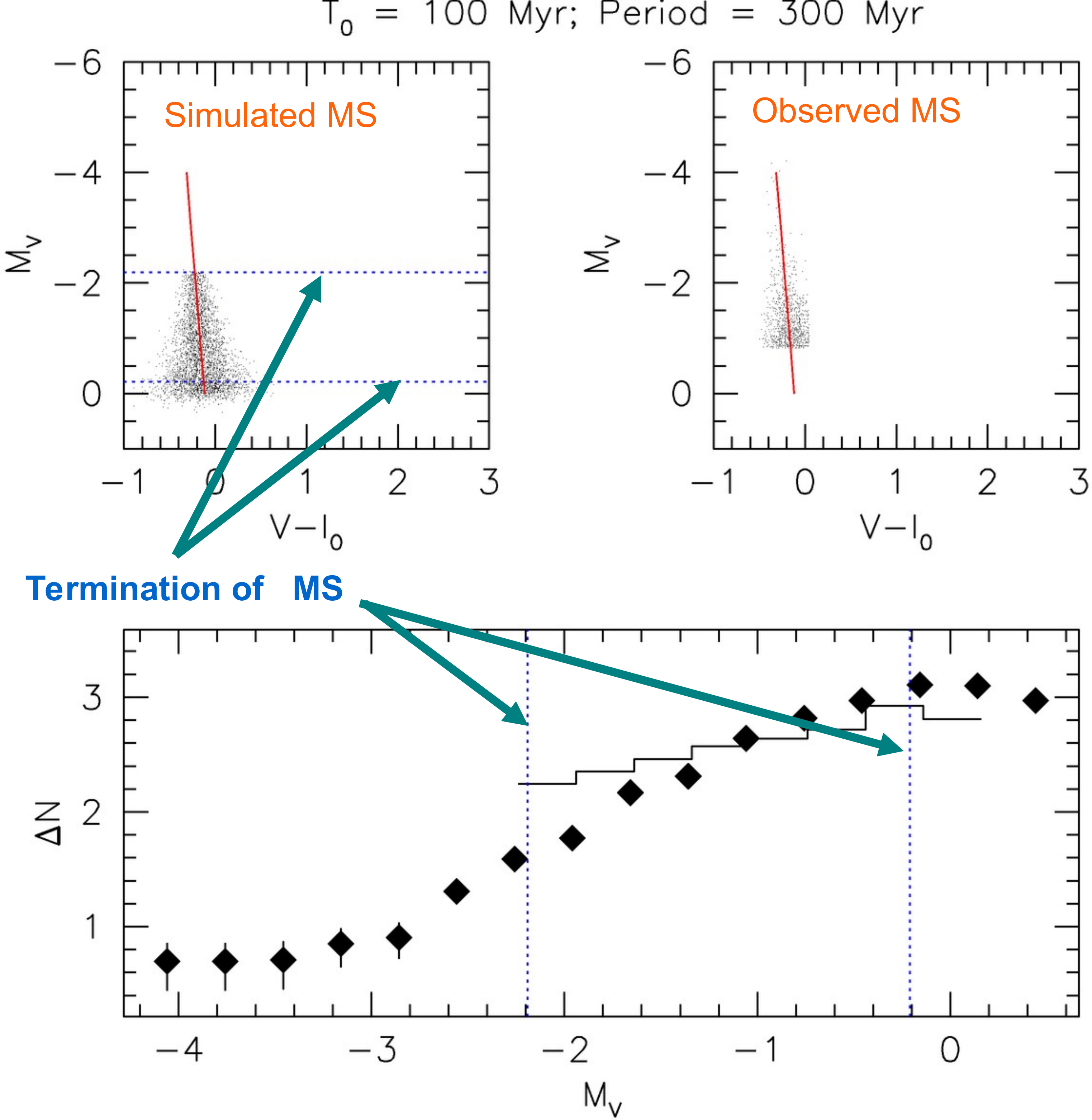
The blue filter will ensure the best contrast of the spiral arms with respect to the diffuse population

and enhance the dust patches => gas is more extended than thought before?

resolved stars CMDs for the entire GCs system of this keystone galaxy

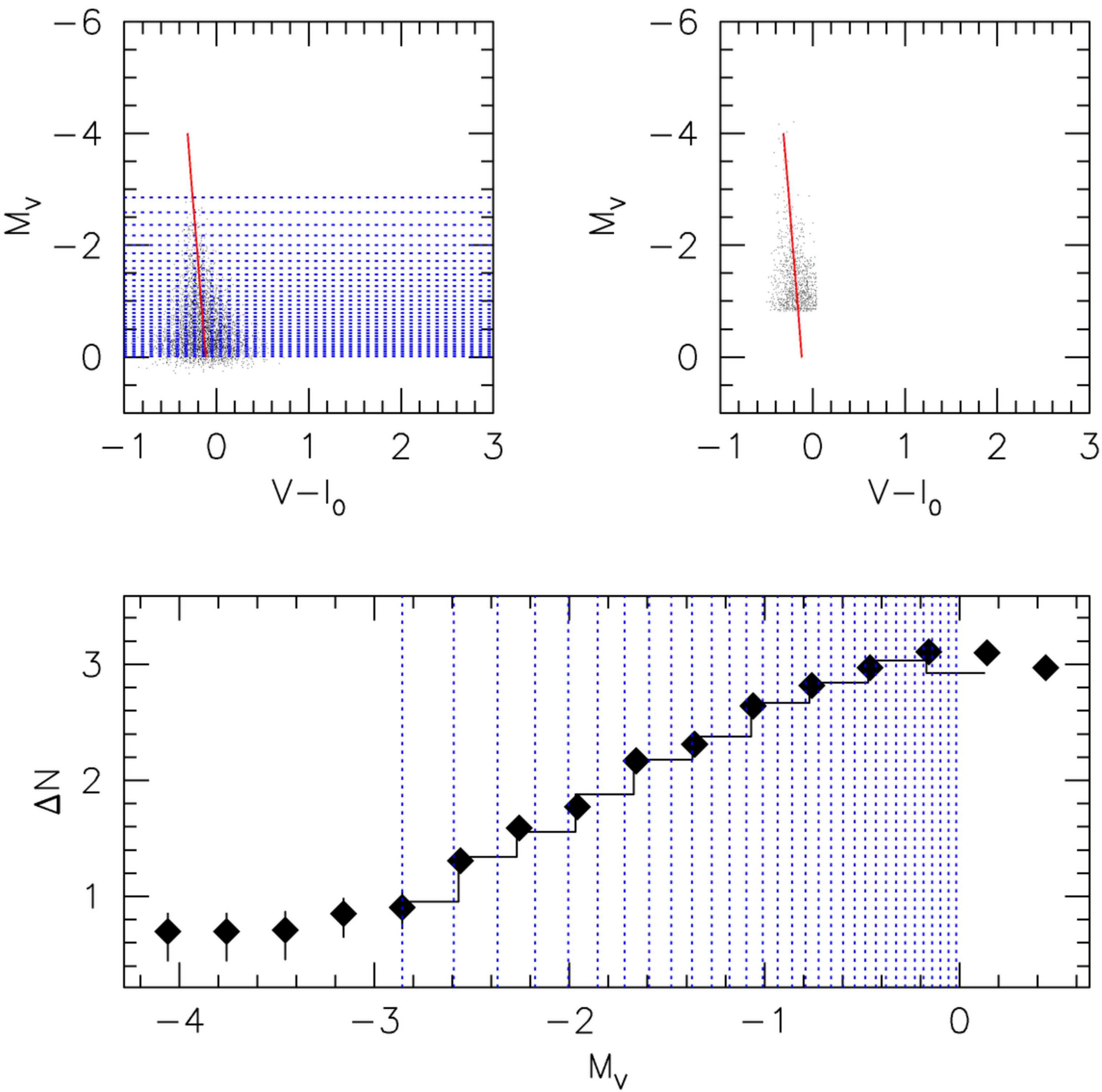


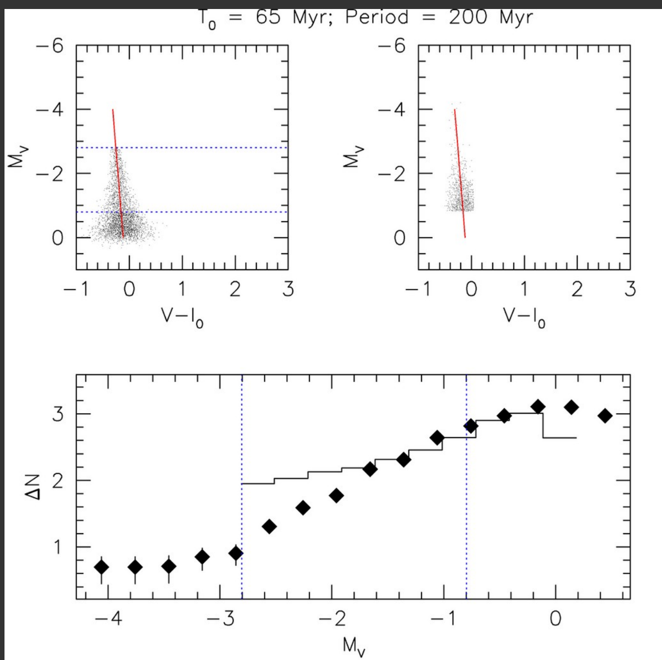
T_0 = 100 Myr; Period = 300 Myr
Simulated MS
Observed MS
M_V
$V-I_0$
ΔN
M_V

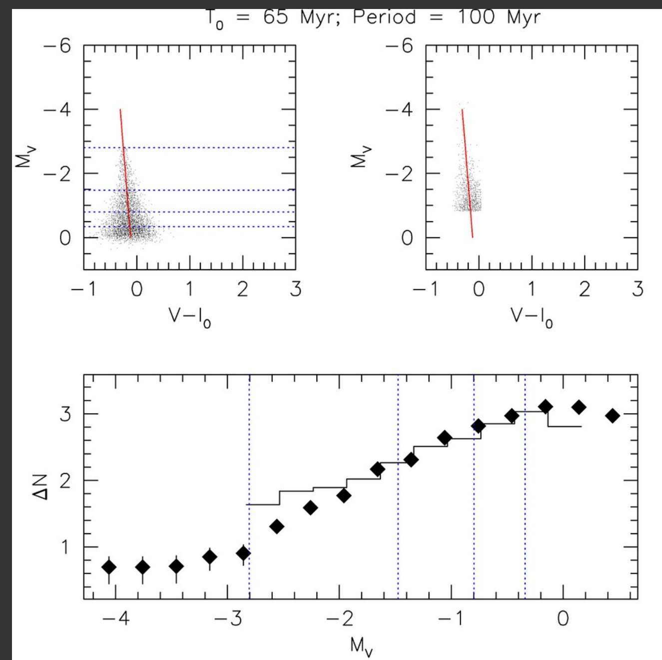


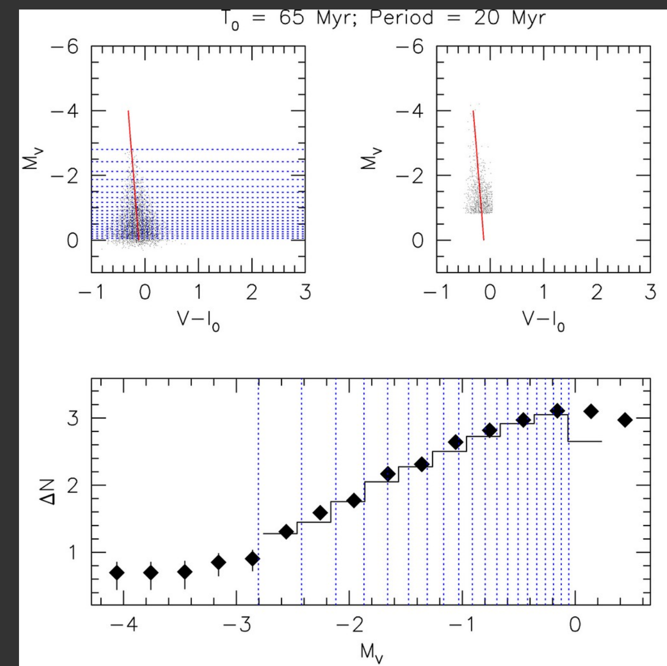
T$_0$ = 100 Myr; Period = 300 Myr
Simulated MS
Observed MS
M_V
$V-I_0$
Termination of MS
ΔN
M_V

T_0 = 62.7 Myr; Period = 12.75 Myr




T0 = 65 Myr; Period = 200 Myr
Mv
V−I0
ΔN
Mv


T0 = 65 Myr; Period = 100 Myr
Mv
V−I0
ΔN
Mv

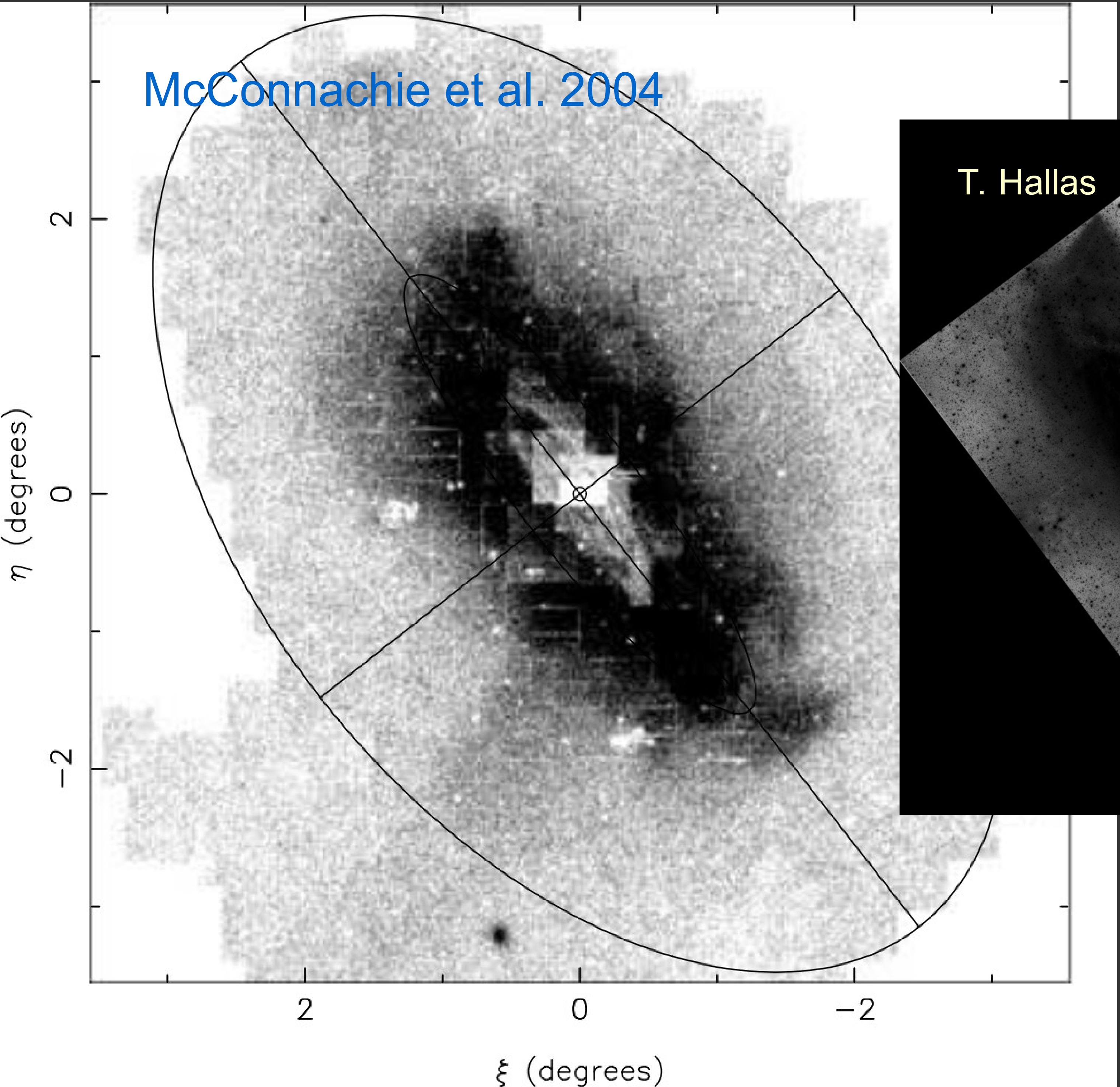

T0 = 65 Myr; Period = 20 Myr
Mv
V−I0
ΔN
Mv

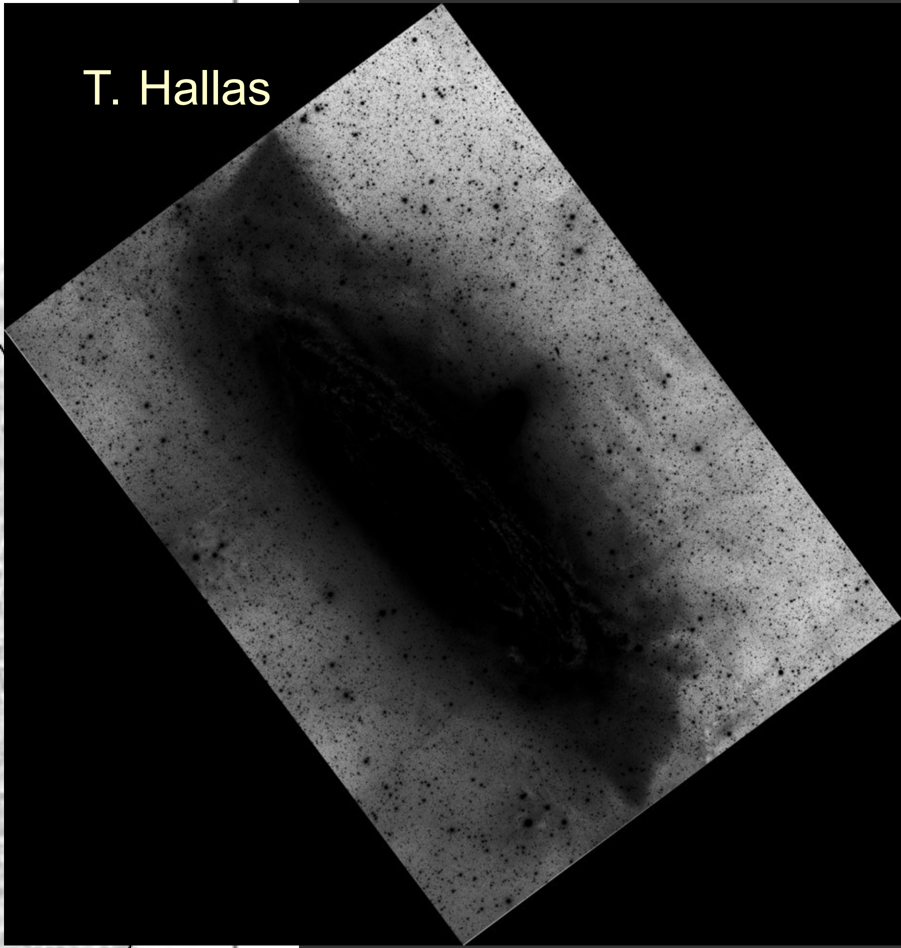
Simulations:

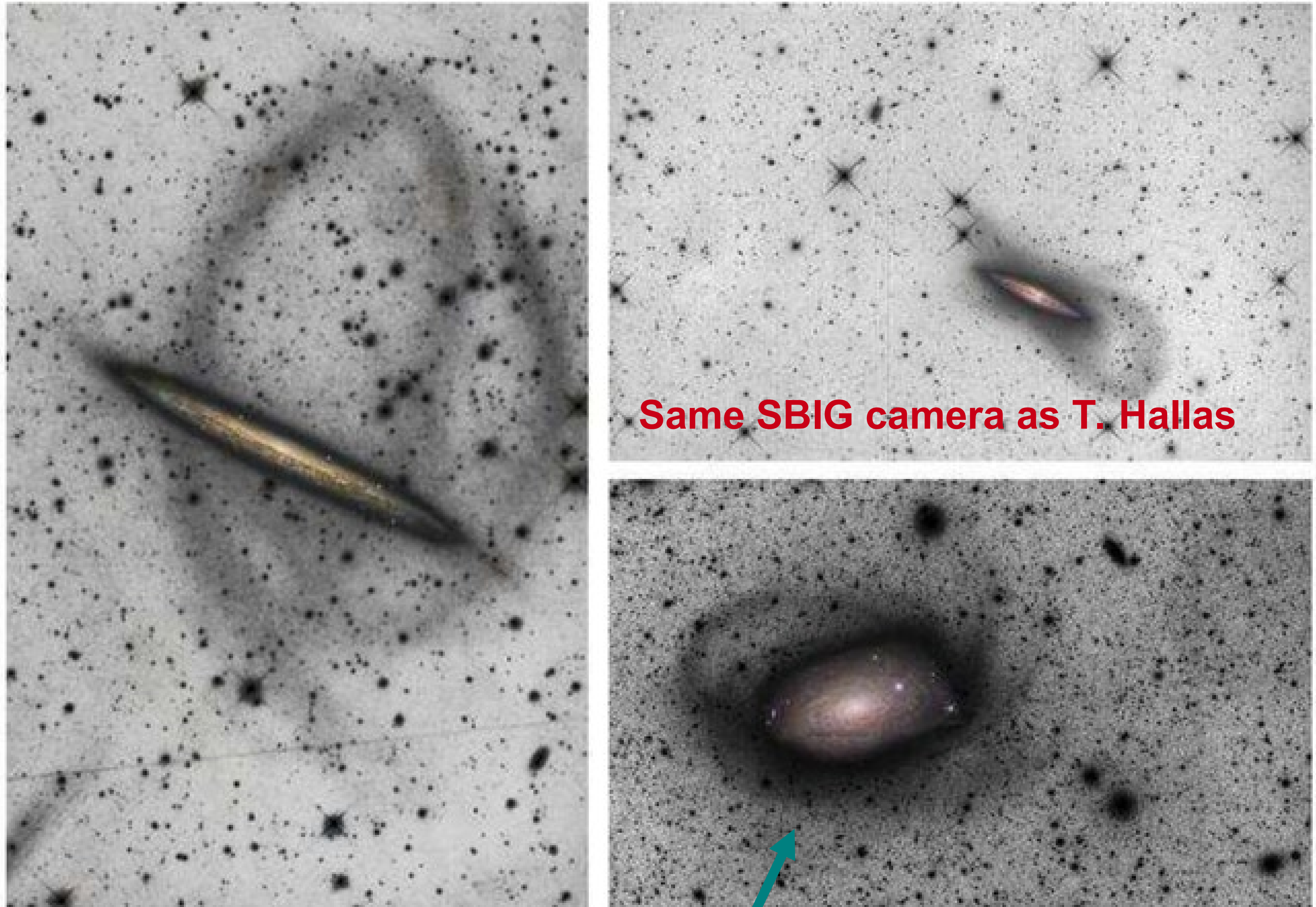
-- Take observed MS and interpolate with fiducial line
(red line in top panels)

-- Take errors from photometry and interpolate with exponential law vs. mag.
-- Multiply by three... (errors underestimated or MS has intrinsic width)

-- Each burst contains the same number of stars
-- Normalize sum of bursts to reproduce observed number of stars


McConnachie et al. 2004
2
0
−2
η (degrees)
ξ (degrees)


T. Hallas



Martinez-Delgado (2009)

Fig. 1 *(left)* Deep image of the stellar tidal stream around NGC 5907 obtained with the 0.5-meter Black Bird Observatory (BBO) telescope (Martinez-Delgado et al 2008a). A N-body model of this structure is shown in Fig. 2; *(right, top)* A low-galactic latitude stellar tidal stream of NGC 4013, discovered by our team from deep images taken with the BBO telescope; *(right, bottom)* Deep images taking with a FSQ-106ED telescope of only 10cm aperture allowed the discovery of a giant tidal stream in the halo of the spiral galaxy Messier 63 (Martinez-Delgado et al. 2009, in preparation). A colour inset of the disk of each galaxy has been inserted with reference purpose.


M110
M32

The Astronomical Journal, 129:2217–2231, 2005 May

ON THE STELLAR POPULATIONS IN NGC 185 AND NGC 205 AND THE NUCLEAR STAR CLUSTER IN NGC 205 FROM *HUBBLE SPACE TELESCOPE* OBSERVATIONS[1]

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Received 2004 August 5; accepted 2005 February 6

ABSTRACT

We present the first detailed analysis of resolved stellar populations in the dwarf galaxies NGC 185 and NGC 205 based on archival *V*- and *I*-band WFPC2 pointings. For NGC 185 we deduce from the brightest main-sequence and blue-loop stars that star formation was probably still active about 4×10^8 yr ago and have three key abundance-related results: (1) We identify ancient stars with $[\mathrm{Fe/H}] \lesssim -1.5$ dex by a well-defined horizontal branch (HB). (2) We find a prominent clump/bump-like feature along the red giant branch/faint asymptotic giant branch (RGB/faint AGB) with the same mean *V*-band magnitude as in the HB, within uncertainties [i.e., $\Delta V(\mathrm{bump} - \mathrm{HB}) = 0$]; from a comparison with theory, the implication is that ancient stars have $[\mathrm{Fe/H}] \sim -1.5$ dex, with a higher abundance level for intermediate-age stars. (3) From color information we infer that the median $[\mathrm{Fe/H}] > -1.11 \pm 0.08$ dex for ancient stars [assuming $E(B-V) = 0.18$ mag]. For NGC 205 we record a new distance modulus, $(m-M)_0 = 24.76 \pm 0.1$ mag, taking $E(B-V) = 0.11$ mag, based on the RGB tip magnitude method in the *I* band. We find that stars were probably still forming less than 3×10^8 yr ago in NGC 205, which is compatible with star formation triggered by an interaction with M31. There are three key abundance-related results for NGC 205: (1) The RGB/faint AGB is significantly skewed to redder values than those for a control field in the outskirts of M31; this probably results from a relatively narrow metallicity and/or age range for a significant fraction of the dwarf's stars. (2) From a comparison with models, the most metal-rich RGB stars reach $[\mathrm{Fe/H}] \gtrsim -0.7$ dex ($\gtrsim 0.2\,Z_\odot$). (3) For ancient stars we infer from color information that the median $[\mathrm{Fe/H}] > -1.06 \pm 0.04$ dex [for $E(B-V) = 0.11$ mag]. We briefly compare the stellar populations of NGC 205, NGC 185, and NGC 147. Finally, we study several *V*- and *R*-band structural properties of the nuclear star cluster in NGC 205 for the first time; the apparent *V*- and *R*-band effective radii indicate a blue excess in the cluster's outer region. In terms of size, the cluster is like a typical Galactic globular cluster or a nuclear cluster in a nearby late-type spiral galaxy, but it is quite bright ($10^6\,L_{\odot,R}$), unlike an ancient globular cluster, and by matching with models, the blue color hints that its stellar population is young, up to a few times 10^8 yr old.

Key words: galaxies: dwarf — galaxies: evolution — galaxies: individual (NGC 147, NGC 185, NGC 205) — galaxies: photometry — Local Group

Online material: color figures

HOLTZMAN, AFONSO, & DOLPHIN

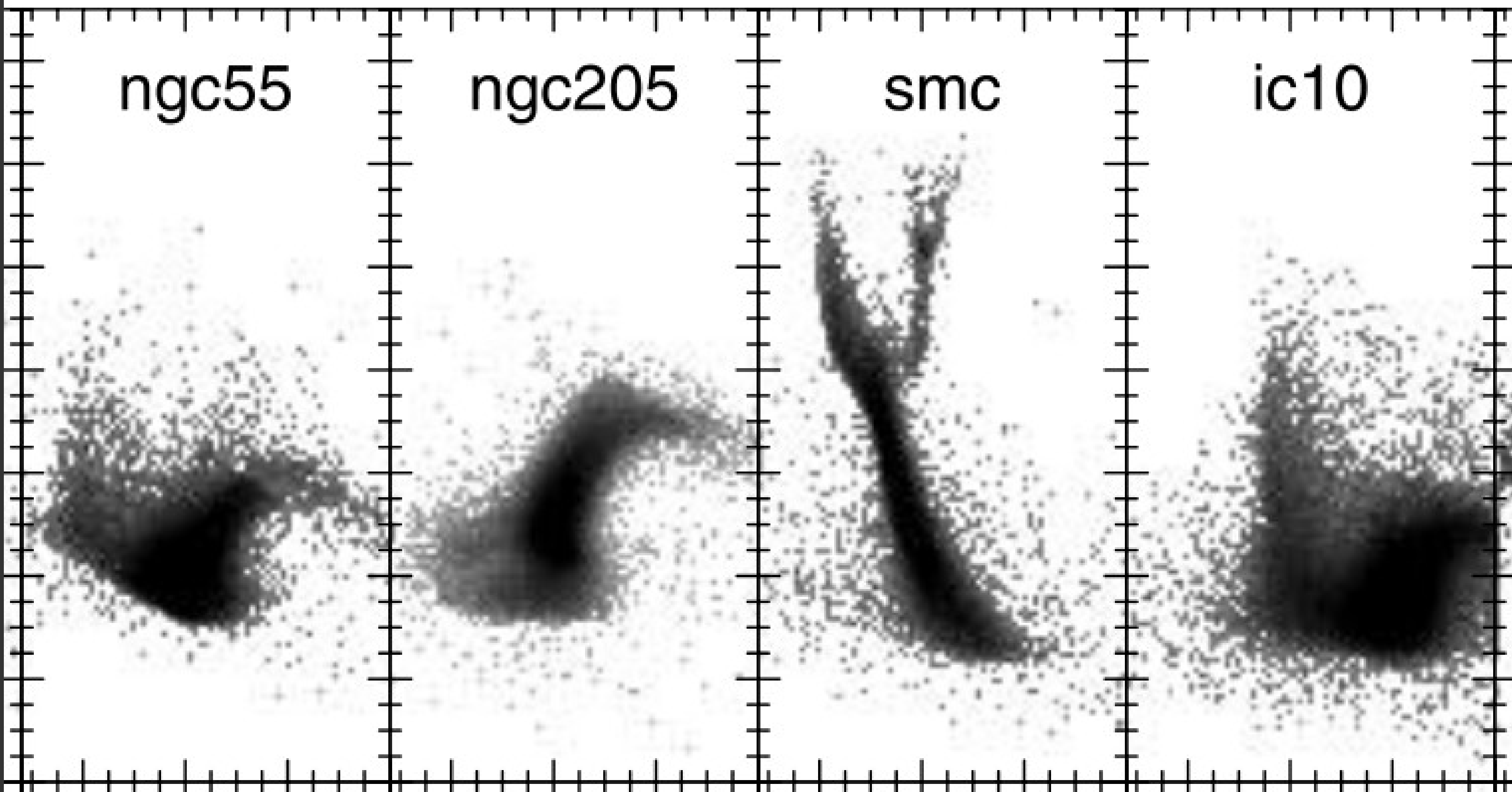

Fig.
[fig:Stellar-content-of] already hints that SF in the disk might have stopped \sim0.4 Gyr ago, which is interestingly close to the time when the central SF burst started (0.5 Gyr, see above). One might then speculate that around that time the gaseous disk was disturbed, and gas began to be fed into the central regions. The reality of this guess will be checked with the more precise photometry allowed by the ACS, and moreover, the spatial trends of SF across the galaxy disk will be studied, possibly revealing the effect of the tidal stripping. In addition, the color distribution of the RGB can be used to compute the metallicity distribution function (MDF) in different regions (e.g,. Momany et al. 2005), which will offer clues on the chemical evolution of the galaxy, to be compared to the mean age of the underlying stellar population.