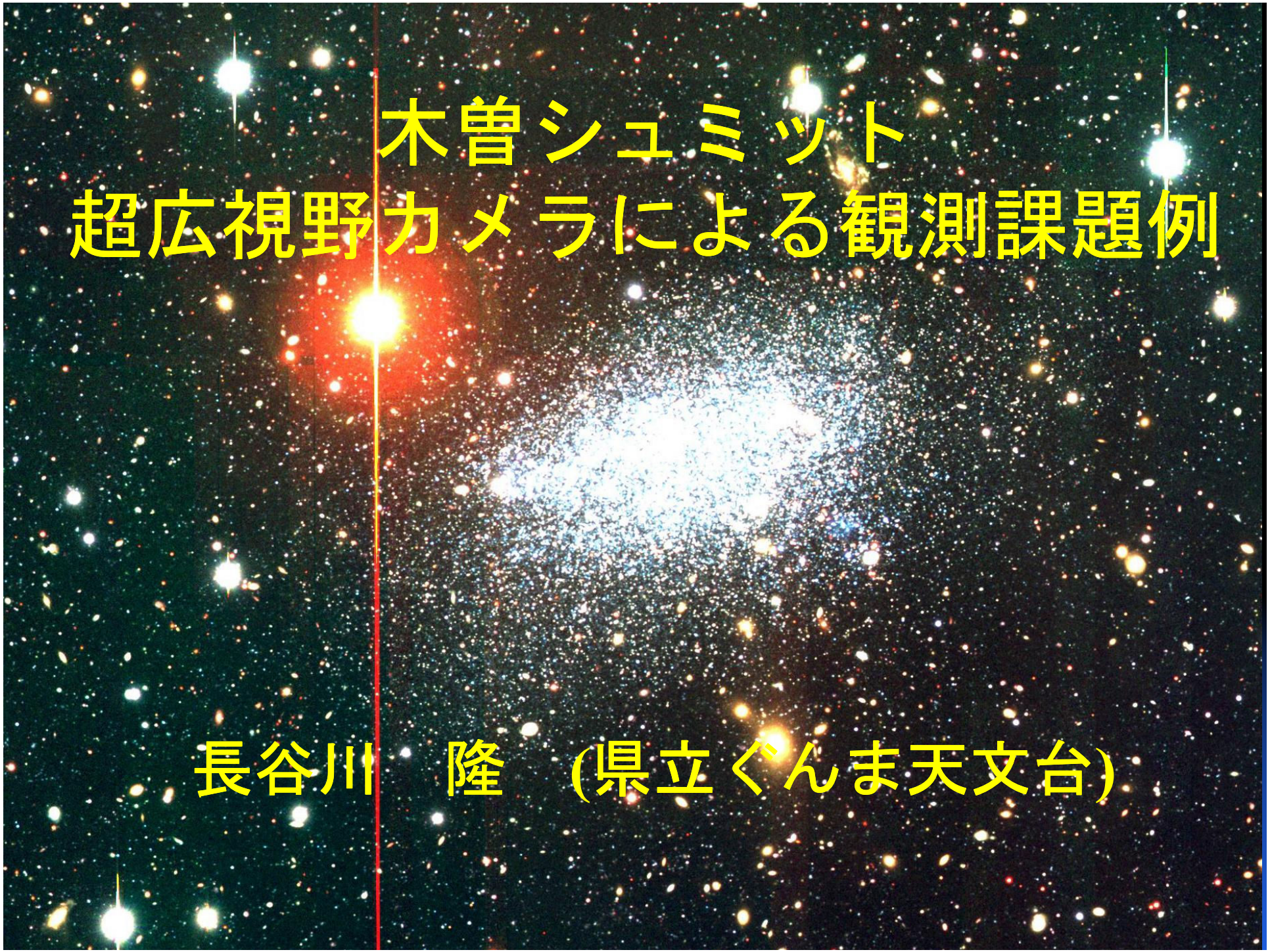

木曽シュミット
超広視野カメラによる観測課題例
長谷川　隆　(県立ぐんま天文台)

KisoWFCの性格

▼ 2kCCD スペック

[CCD受光器の性能]

検出器	米国SITe社製 2048×2048 TK2048E 裏面照射 ARコーティング
画素サイズ	24μm×24μm
受光面サイズ	48mm×48mm（シュミット主焦点で50′×50′）
データサイズ	FITS形式 8MB/フレーム
露出時間制限	5秒 ＜ 露出時間 ＜ 60分（虹彩絞り型シャッター、宇宙線）
動作温度	～170K
暗電流	1 electron /60min/pixel（170K）
ペデスタル	4,270ADU
読み出し雑音	23 e^-
変換効率	3.4 e^- /ADU
直線性	γ=0.998642（500<ADU<40,000）

[観測時の性能]

バンド	U	B	V	R	I
スカイ（mag/sec²）	21	22	21	19	18
限界等級（mag）（S/N=10，15分露出，シーイング=3″）	20	21	22.5	21	21
スループット（%）（望遠鏡光学系込み）	3.1	17	30	32	20

- Kiso SDSS
  - bad seeing, photometric condition
  - V22.5 (15min exp., SN10) はSDSSに近い限界等級
  - 十分な望遠鏡時間をいかして、2-band 1000□°の探査
    - 300point * 2band * 20min = 40days
- Kiso Hyper-Suprime Cam
  - small telescope
  - 2度角はHyper Suprimeに匹敵する視野
  - 分光なら暗い天体はできない　→　WFMOSとの連携

可能なサイエンスの性格

- SDSSのサイエンスの低銀緯版
  - seeingが問題にならない範囲で
- HSCのサイエンス
  - local calibrator
  - 分光準備

- リンク（多波長サイエンス、将来への布石）
  - 2MASS
  - JASMINE, GAIAの準備データ
    - 固有運動基準データ

KWFCならではの独自性の確保

- フィルターシステムの工夫
  - 感度の高い波長でgunnシステム(g', r', i')を利用
    - SDSSとの整合性
  - Stromgrenによる星の種族の分類付きデータ
  - Hα等の狭帯域の広視野サーベイは未開拓(?)
- 超低分散分光(グリズム、プリズム)

観測課題例

- 広がった球状星団の探査　SDSS, HSC
- 球状星団のテイルの探査　SDSS
- 低銀緯の超低表面輝度矮小銀河の探査　SDSS
- 矮小銀河ハロー
- 銀河面(第2-3象限)の探査　SDSS
  - 散開星団の探査および年齢距離マッピング
  - 超遠方星形成領域
- 銀河系ハロー構造　SDSS
- 変光星による銀河系構造の解明
- 超低分散分光で星形成領域輝線天体の検出

Near-field cosmology

z = 0 をみて high-z を知る

KisoWFCの主戦場

Population	M_V	M_V+2	D(M_{lim}=20)	D(M_{lim}=22)
MSTO(10^8yr)	–1.0	1.0	63kpc	150kpc
MSTO(1Gyr)	2.0	4.0	16kpc	40kpc
MSTO(10Gyr)	4.5	6.5	5kpc	15kpc
TRGB	–2.0	0.0	100kpc	250kpc
CHeb	0.0	2.0	40kpc	100kpc
L_0 銀河	–20.0	–18.0		(M_{lim}=21) z ≈ 0.2

銀河系のハロー、円盤最外縁部

広がった球状星団の探査（MW）

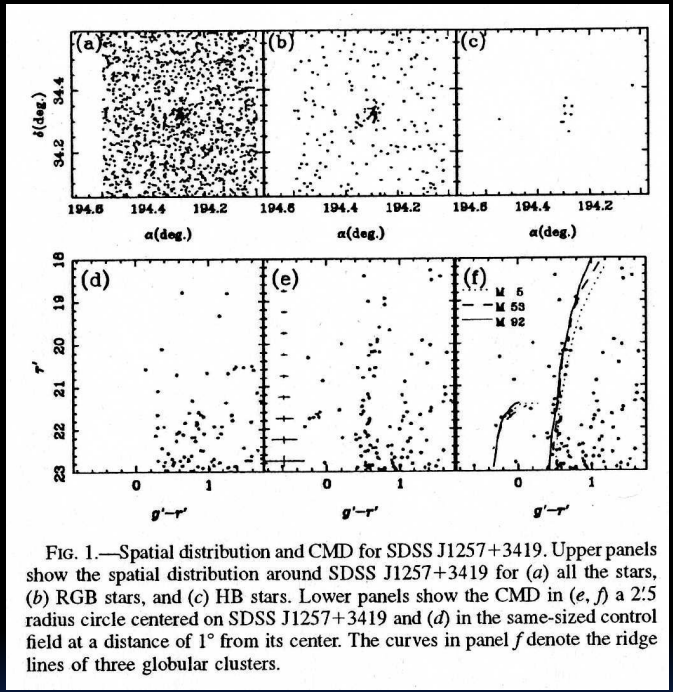


FIG. 1.—Spatial distribution and CMD for SDSS J1257+3419. Upper panels show the spatial distribution around SDSS J1257+3419 for (*a*) all the stars, (*b*) RGB stars, and (*c*) HB stars. Lower panels show the CMD in (*e*, *f*) a 2.5 radius circle centered on SDSS J1257+3419 and (*d*) in the same-sized control field at a distance of 1° from its center. The curves in panel *f* denote the ridge lines of three globular clusters.

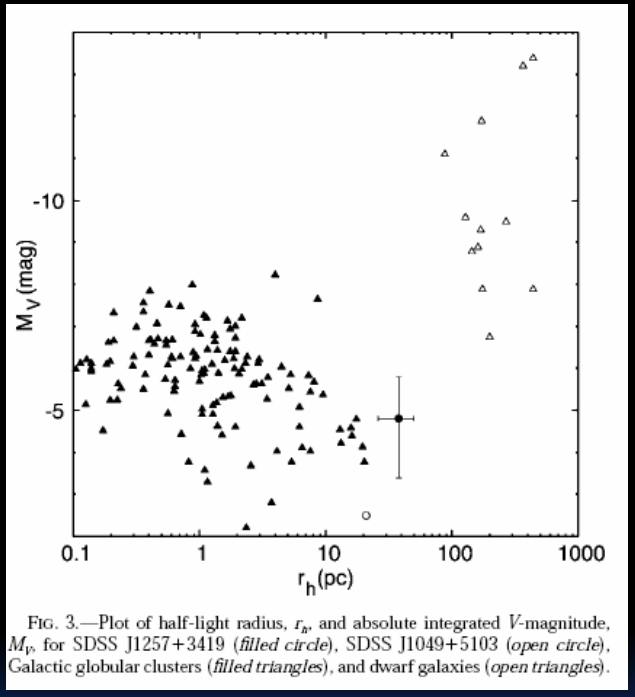


FIG. 3.—Plot of half-light radius, r_h, and absolute integrated V-magnitude, M_V, for SDSS J1257+3419 (*filled circle*), SDSS J1049+5103 (*open circle*), Galactic globular clusters (*filled triangles*), and dwarf galaxies (*open triangles*).

- SDSS + RGB星の分布で探査
- r_{GC} = 150 kpc（65cm+CCD+gunnが活躍）
- $M_V = -4.8 \pm 0.5$、r_{hl} = 38 pc

Sakamoto & Hasegawa 06

広がった球状星団の探査 (M31)

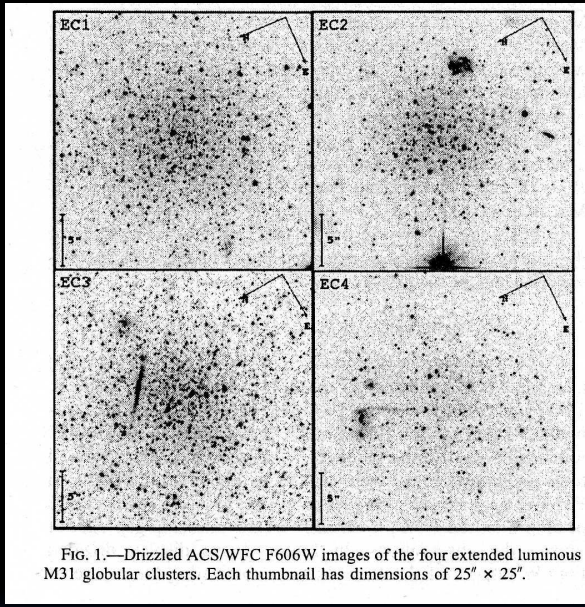


FIG. 1.—Drizzled ACS/WFC F606W images of the four extended luminous M31 globular clusters. Each thumbnail has dimensions of 25″ × 25″.

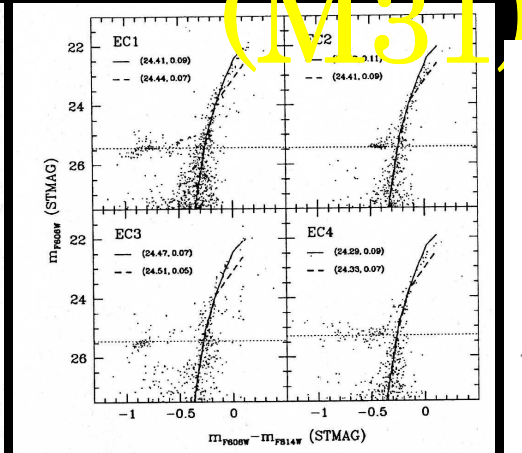
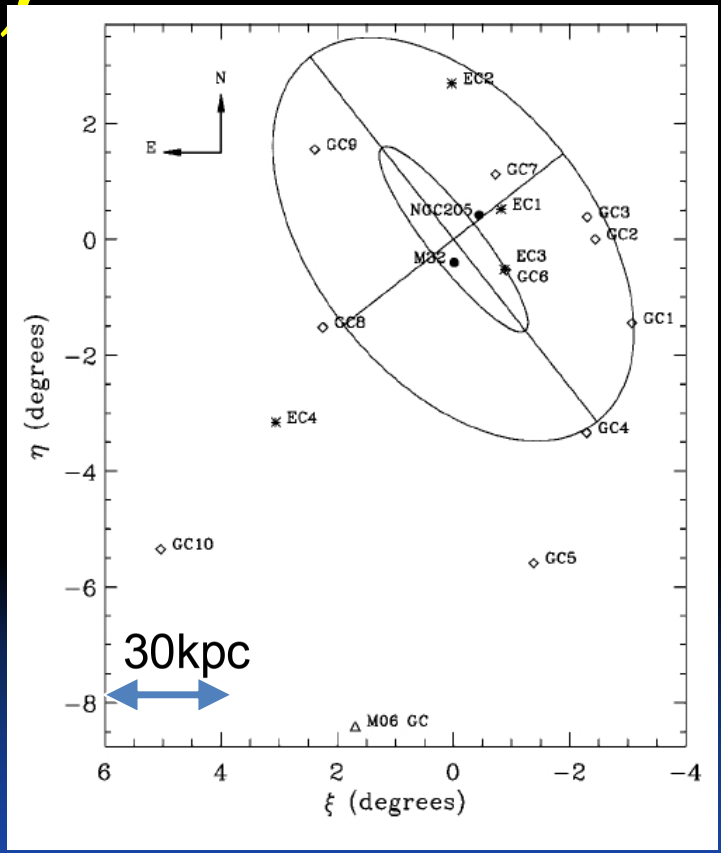
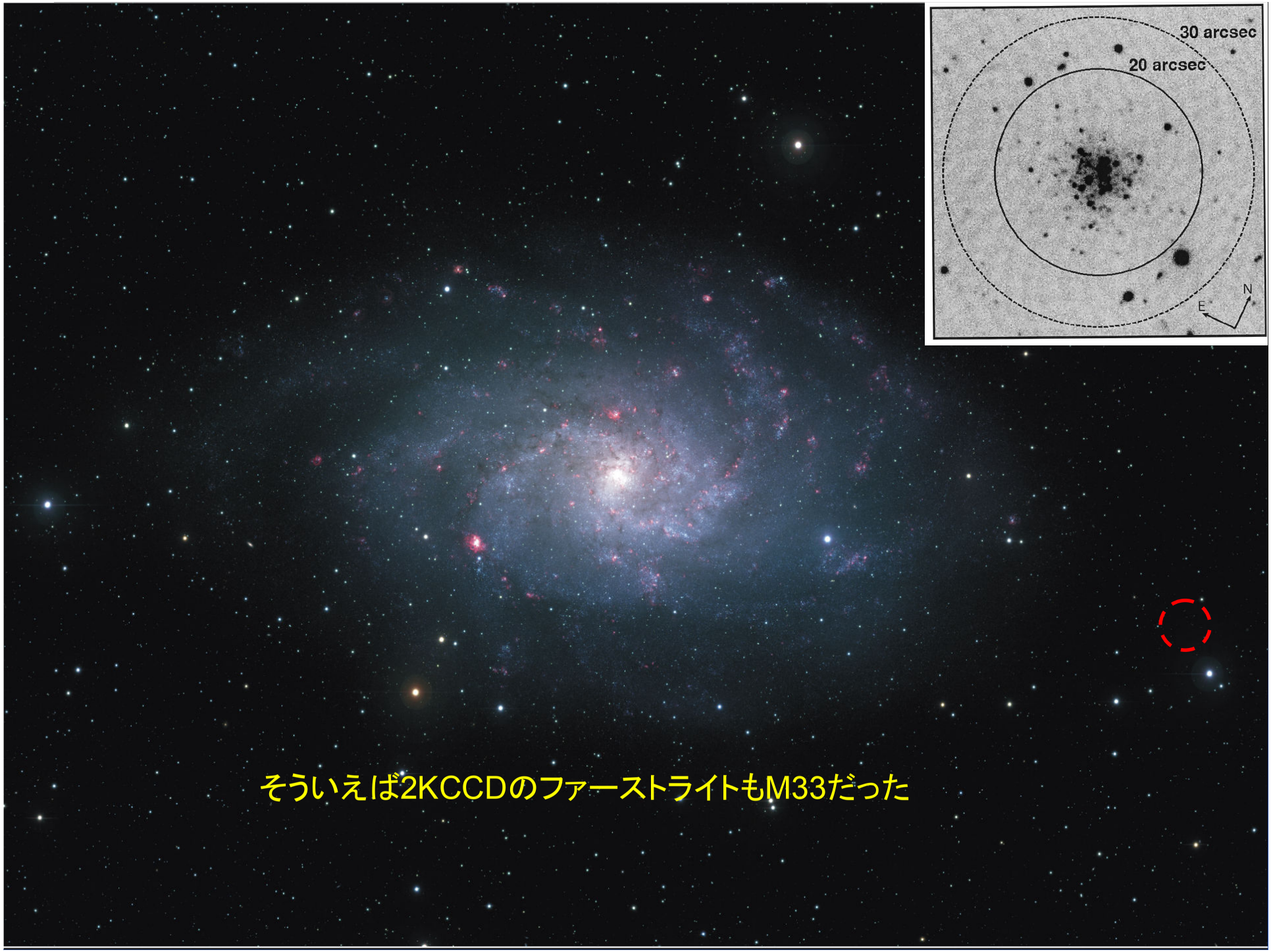


FIG. 3.—Results of fitting the Galactic globular cluster fiducials from Brown et al. (2005) to the observed CMDs. All four clusters are metal-poor, and hence have RGBs bracketed by that for NGC 6341 (M92) at [Fe/H] = −2.14 (*solid lines*), and that for NGC 6752 at [Fe/H] = −1.54 (*dashed lines*). EC3 is the most metal poor cluster, with the M92 fiducial providing a close fit. The horizontal dotted lines represent the adopted HB levels. The numbers in the upper left indicate the best fitting $(m - M)_0$ and $E(B - V)$ for the marked fiducials. Photometry has been transformed to STMAG to match the Brown et al. (2005) fiducials.



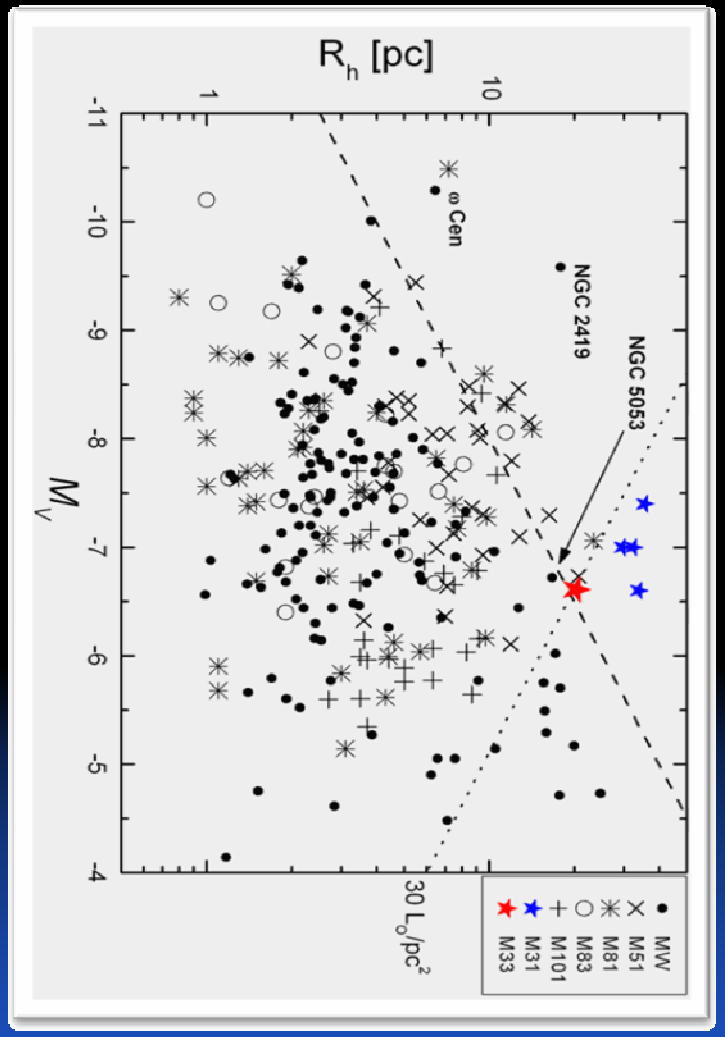
- Huxor 05, Mackey 06
  - 円盤外部でみつかる
  - 降着起源か
    - 球状星団どうしの合体起源か



そういえば2KCCDのファーストライトもM33だった

広がった球状星団の探査（M33）

- M33-EC1
- r_{GC} = 12.5 kpc
- ≥ 7 Gyr, [Fe/H] ≤ −1.4
- r_{hl} = 20 pc
  - 他の星団は $r_c \leq 2$ pc
- 複雑なmerging history
  - RGB stream
  - ハローの速度成分をもつGC
  - eGC（降着起源？）
  - cf. 星の分布にハローはない？
- とにかく遠い！
  - 銀河のeGC探査はKWFCに適する



Rima,Vladas,
Hasegawa, Arimoto et al. 07

低銀緯の超低表面輝度矮小銀河

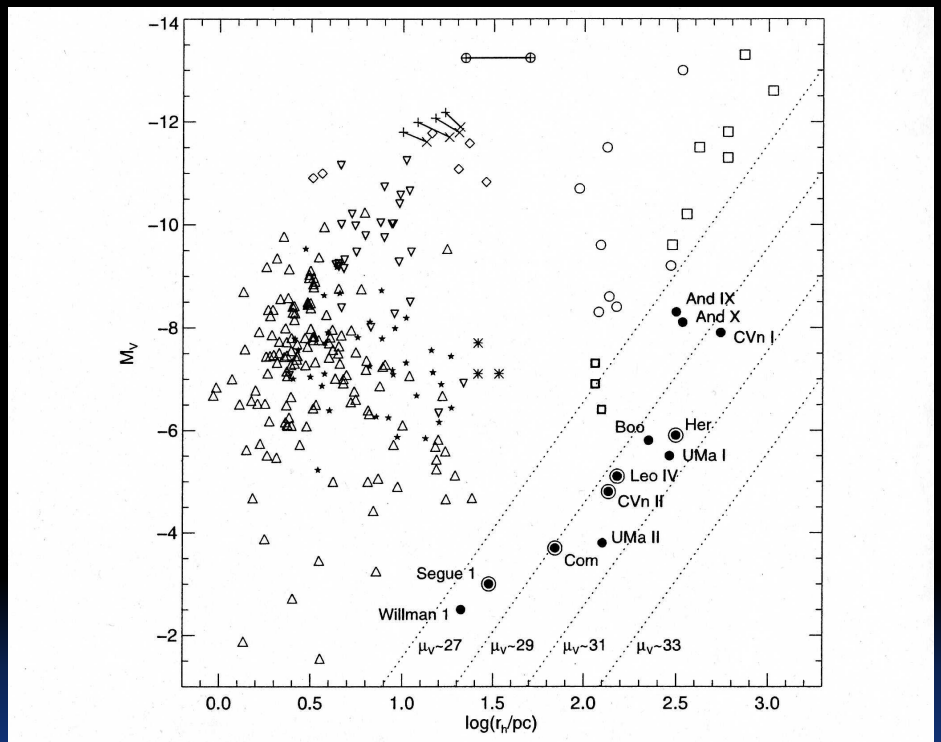


FIG. 8.—Location of different classes of objects in the plane of absolute magnitude vs. half-light radius. Lines of constant surface brightness are marked. Filled circles are the SDSS discoveries including the 10 Milky Way satellites (Willman et al. 2005a, 2006; Zucker et al. 2006a, 2006b; Belokurov et al. 2006b), as well as And IX and X (Zucker et al. 2004, 2006c). Open circles are eight previously known Milky Way dSphs with Sgr omitted (Irwin & Hatzidimitriou 1995; Mateo 1998), squares are the M31 dSphs (McConnachie & Irwin 2006), bold squares are three new M31 dSphs recently discovered by Martin et al. (2006), and triangles are the Galactic globular clusters (Harris 1996). A variety of other extragalactic objects are also plotted: asterisks are the extended M31 globular clusters discovered by Huxor et al. (2005), plus signs and crosses are UCDs in Fornax from Mieske et al. (2002) and De Propris et al. (2005), respectively, diamonds are the so-called Virgo dwarf–globular transition objects (Hasegan et al. 2005), and filled stars and inverted triangles are globular clusters from the nearby giant elliptical NGC 5128 from Harris et al. (2002) and Gómez et al. (2006), respectively. Different measurements of the same object are connected by straight lines. The straight line connecting the Earth symbols refer to measurements by Mieske et al. (2002) and Drinkwater et al. (2003) of UCD3 in Fornax.

- SDSSのRGB星の分布から検出
- $r_{GC} \leq 420$ kpc
- Missing dwarf 問題の観測的解決の一つ
- まだまだ足りない
- 球状星団と矮小銀河には分類しにくい new population か？

Belokurov 07

銀河団(群)に落ち込む銀河

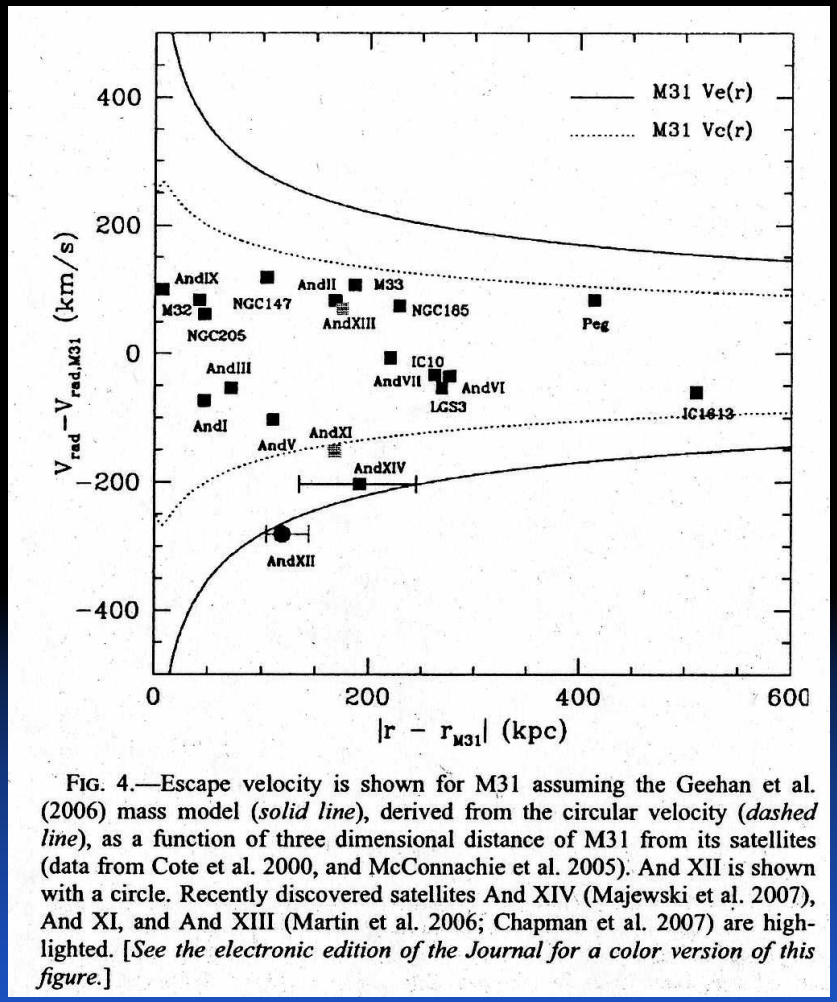


FIG. 4.—Escape velocity is shown for M31 assuming the Geehan et al. (2006) mass model (*solid line*), derived from the circular velocity (*dashed line*), as a function of three dimensional distance of M31 from its satellites (data from Cote et al. 2000, and McConnachie et al. 2005). And XII is shown with a circle. Recently discovered satellites And XIV (Majewski et al. 2007), And XI, and And XIII (Martin et al. 2006; Chapman et al. 2007) are highlighted. [*See the electronic edition of the Journal for a color version of this figure.*]

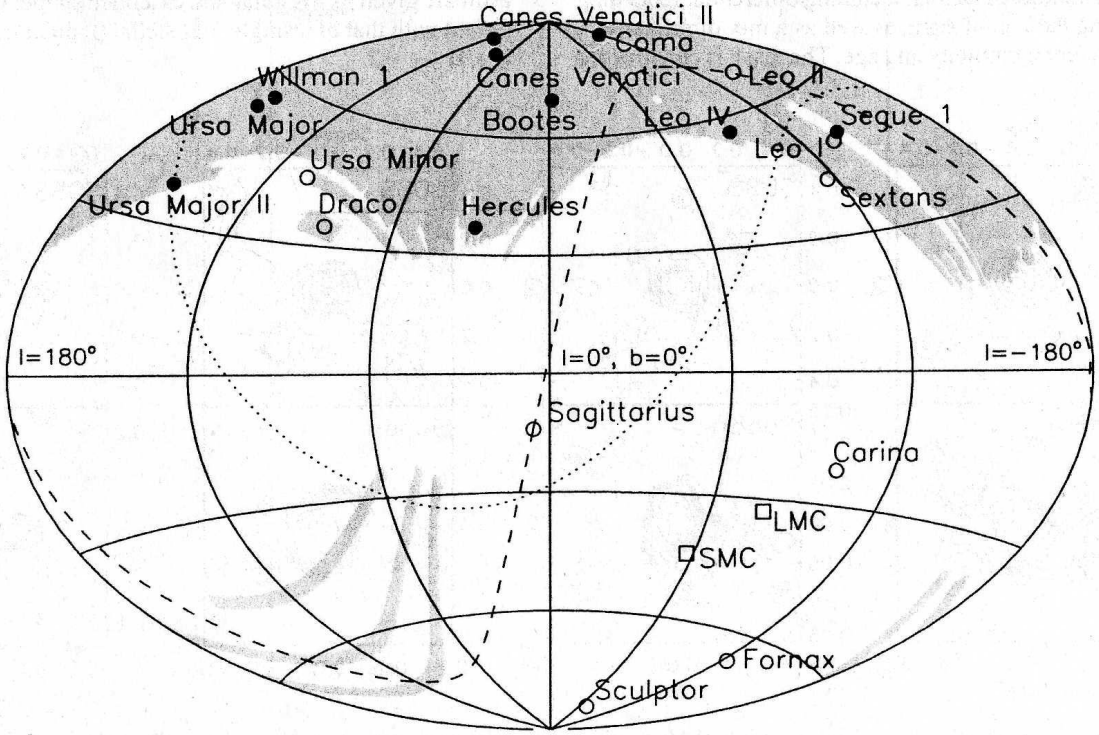
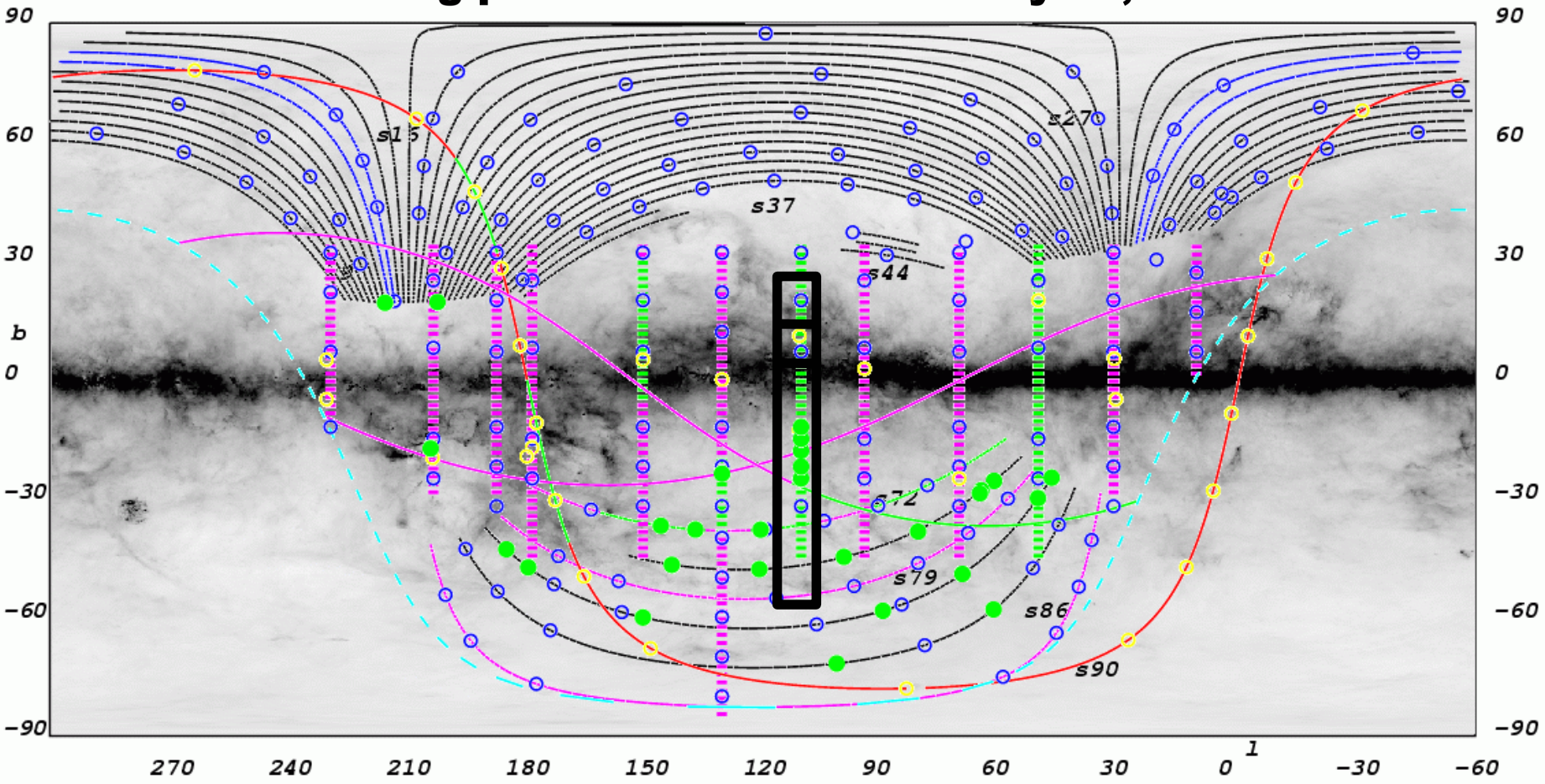


FIG. 7.—Locations of Milky Way satellites in Galactic coordinates. Filled circles are satellites discovered by SDSS, and open circles are previously known Milky Way dSphs. The light gray shows the area of sky covered by the SDSS and its extensions to date. The dashed and dotted lines show the orbital planes of the Sagittarius and Orphan Streams, taken from Fellhauer et al. (2006) and Fellhauer et al. (2007), respectively.

- SDSS → 低銀緯度では今のところ未開拓
- 15銀河/10000□ → 2銀河/1500□ くらい?
  - 球状星団のテイルの探査にも

SEGUE observing plan and status as of May 12, 2005



SDSS Imaging scan

Planned SEGUE scan (3500 sq deg)

Sgr stream planned scan

Completed SEGUE imaging

Declination = -20 degrees

Planned SEGUE grid pointings (140)

Planned targeted SEGUE pointings(60)

Completed SEGUE plate pointing

銀河円盤外縁の研究

- 中西et al. 探査の延長
  - 最外縁星団/星形成領域の探査
  - （星団の）金属量勾配
    - Smooth-gradient vs. 10 kpc break

- Canis-Major overdensity
  - 2MASS M型巨星の分布で検出
  - CMa / southern arc/ northern arc
  - 降着した矮小銀河?
  - 銀河円盤のwarp?
  - 広域のV22程度の星のカタログが必要

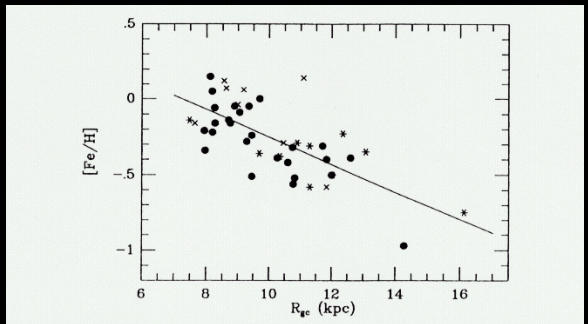


Figure 7 Radial abundance gradient for the old open clusters, with metallicities from Table 1. Filled circles are points from Friel & Janes (1993) or Thogersen et al (1994). Starred symbols are preliminary metallicities from Friel et al (1995). Crosses are data taken from Lynga (1987).

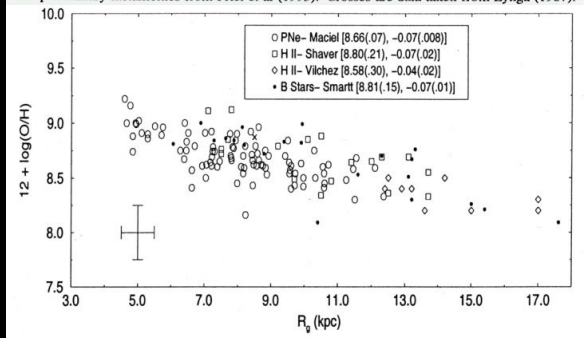
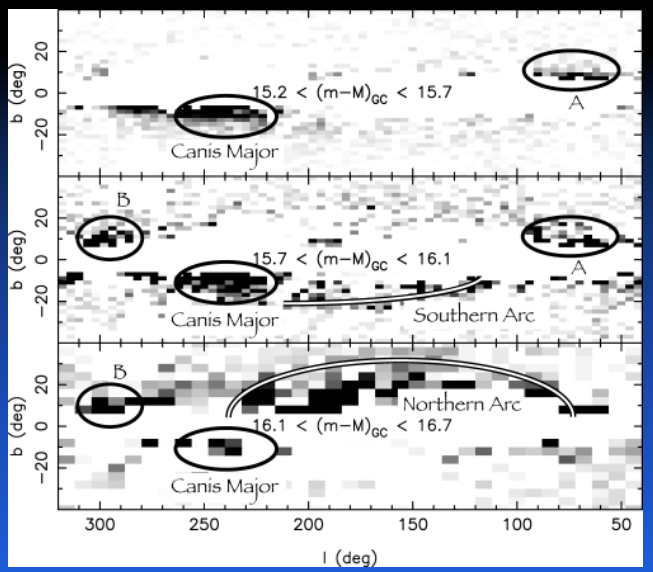


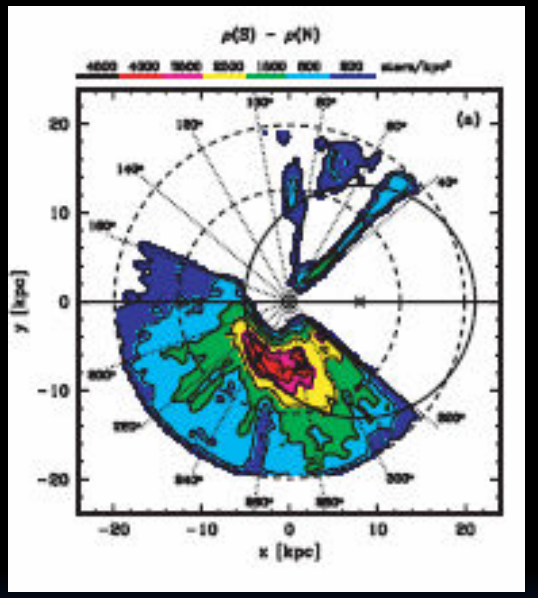
Figure 1. 12 + log(O/H) versus galactocentric distance in kpc for the four data sets indicated in the legend, where parameters (and uncertainties) for least squares fits for each data set are included (see text).



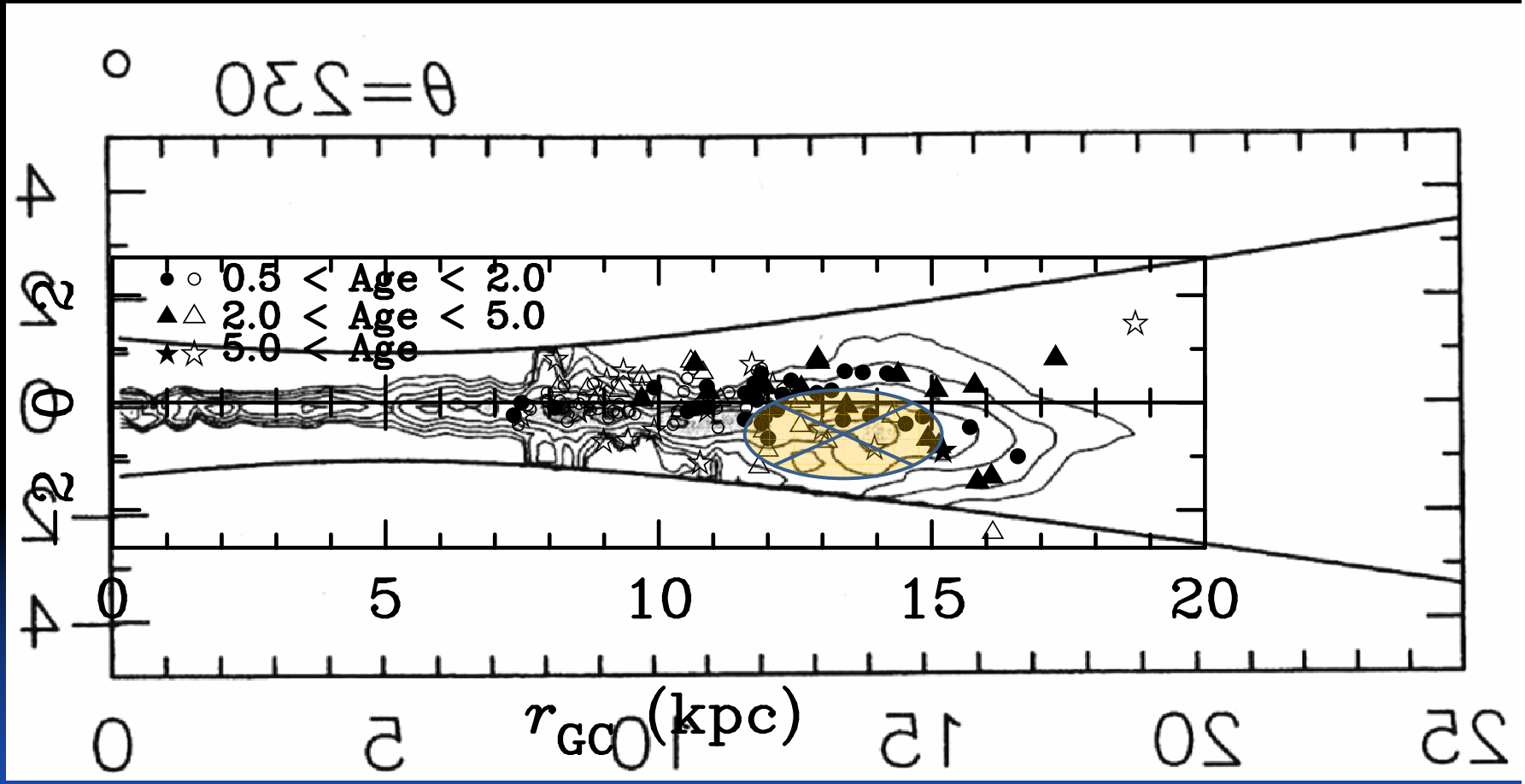
Martin et al. 04

降着した矮小銀河？

- Canis Major dwarf galaxy
  - 2MASS-RC星でも確認
    - 中心は反銀河中心方向 r_{sun}～ 8 kpc
    - LOS depth 4 kpc
    - AM2, To2が中心星団 （～5 Gyr）
  - ほぼ銀河面内の軌道で矮小銀河とarcsを説明できる
  - Dyanamicalにもあう星団が複数
- But, warp ？ （Carraro 07）
- 星団の観測も重要な役割
  - 距離、運動(固有/視線)、年齢、金属量がよく推定できる



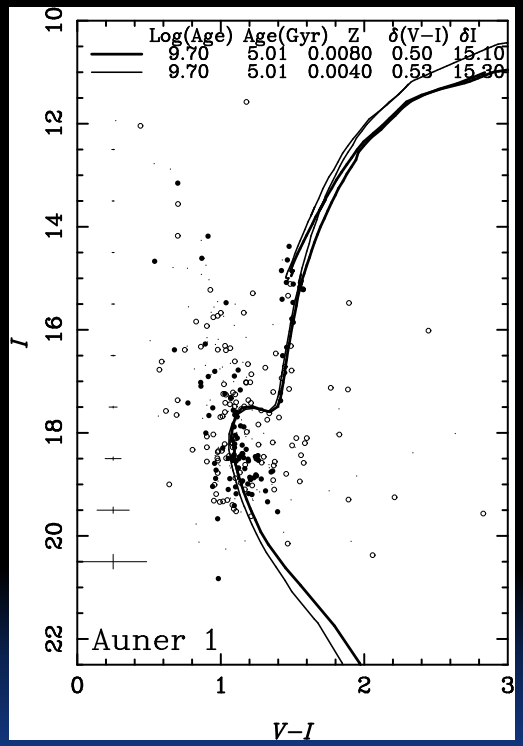
散開星団の年令距離マッピング (GAO65cm他)

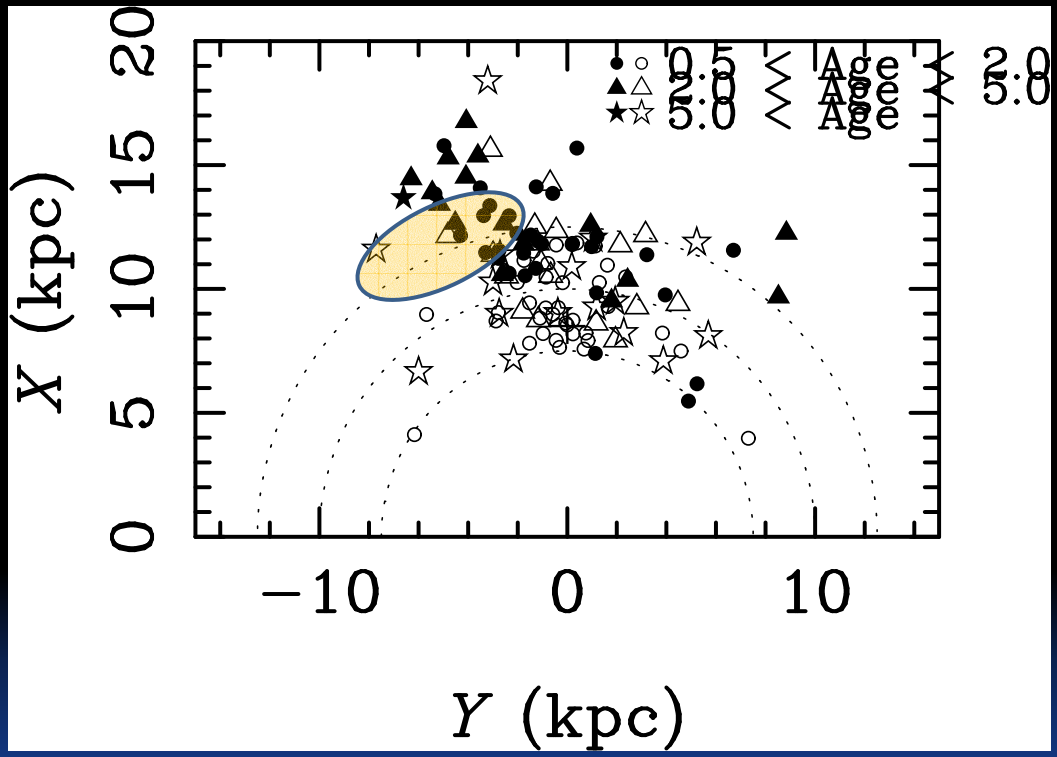


OCs from Hasegawa et al 04 +

HI from Nakanishi & Sofue (2003)

散開星団の年令距離マッピング





- r_{GC} > 15kpc 以遠の星団リストは不完全で、Kiso-WFCによる深いサーベイで銀河外縁の理解が深まる。

矮小不規則銀河　LeoA　～800kpc

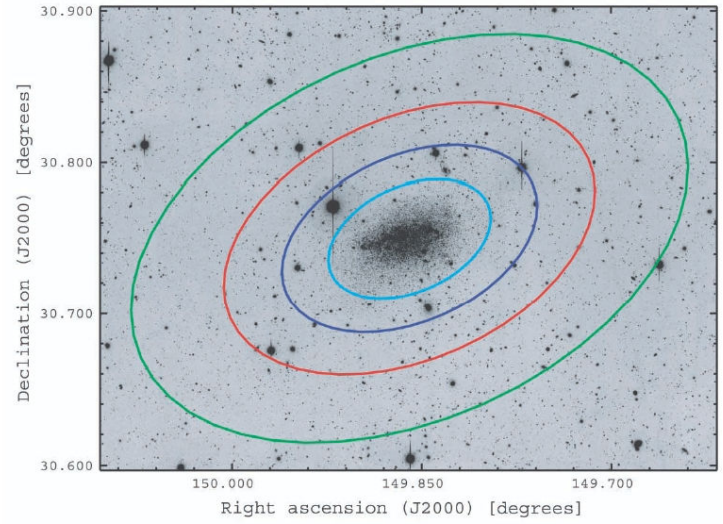
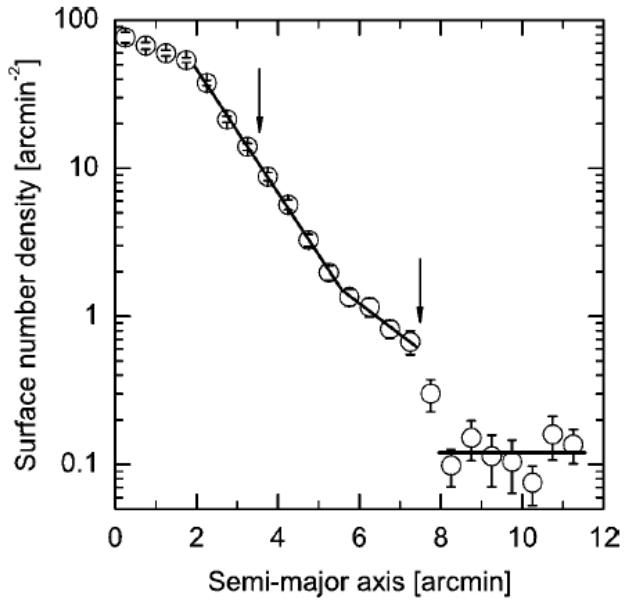


FIG. 1.—Suprime-Cam *V*-band image of the galaxy Leo A. The ellipses ($b/a = 0.6$, a = semimajor axis) indicate the Holmberg's radius ($B = 26.5$ mag arcsec^{-2}), $a = 3'.5$ (*cyan*); the radial distance where the discovered halo becomes prominent, $a = 5'.5$ (*blue*); the size of Leo A established in this work, $a = 8'.0$ (*red*); and the zone used for background source surface number density determination, $a = 12'.0$ (*green*).



ハローの検出

矮小銀河でも過去のmergingを示唆

Leo I など、1mクラスでもハローの探査に適した矮小銀河は他にもある。

Kiso-WFCは Near-field Cosmologyにも 貢献できるカメラである。

- 銀河面
- 中銀緯サーベイ

超低分散分光による
星形成領域輝線天体の検出

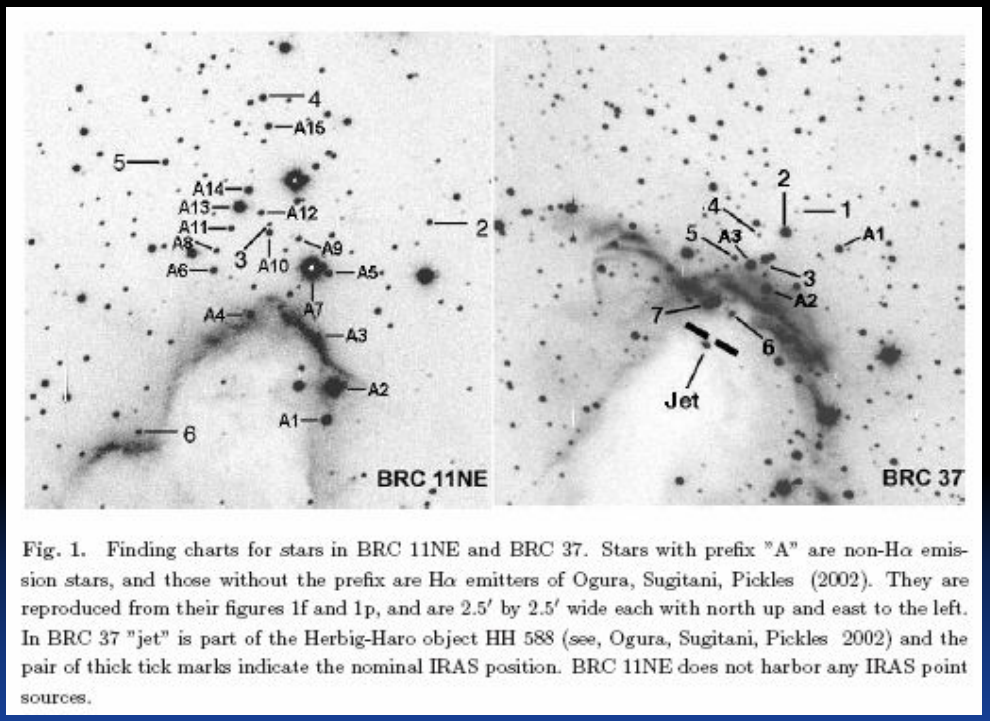
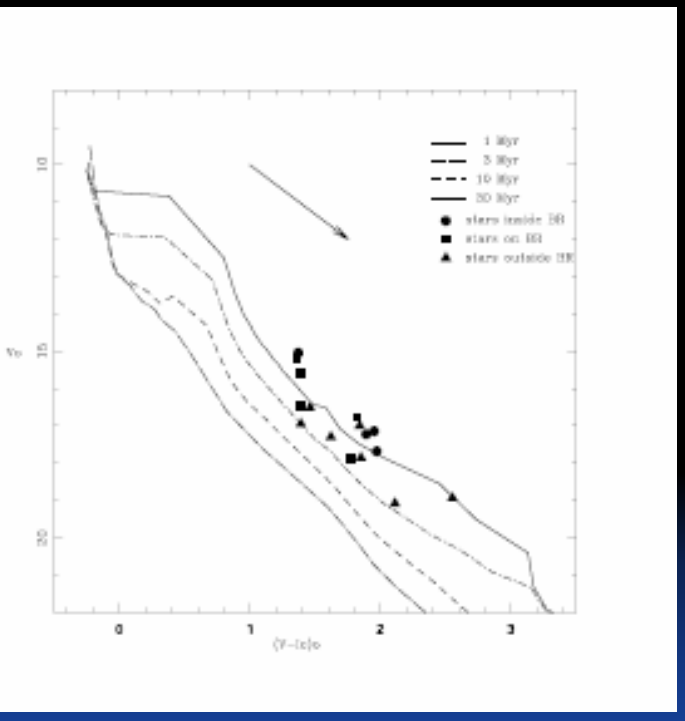


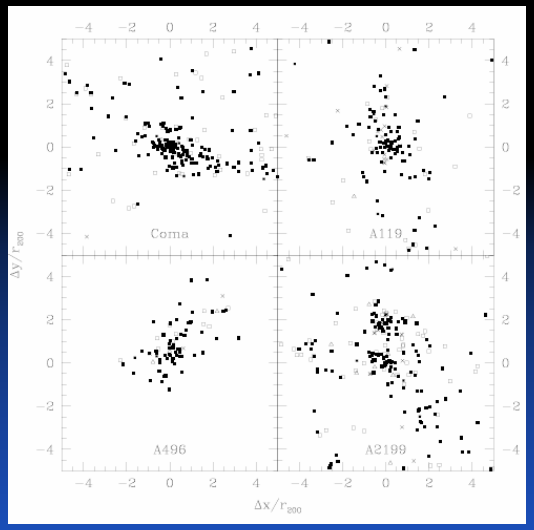
Fig. 1. Finding charts for stars in BRC 11NE and BRC 37. Stars with prefix "A" are non-Hα emission stars, and those without the prefix are Hα emitters of Ogura, Sugitani, Pickles (2002). They are reproduced from their figures 1f and 1p, and are 2.5′ by 2.5′ wide each with north up and east to the left. In BRC 37 "jet" is part of the Herbig-Haro object HH 588 (see, Ogura, Sugitani, Pickles 2002) and the pair of thick tick marks indicate the nominal IRAS position. BRC 11NE does not harbor any IRAS point sources.

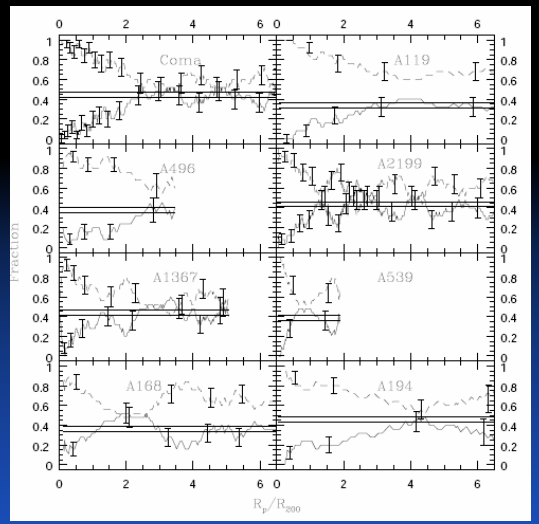


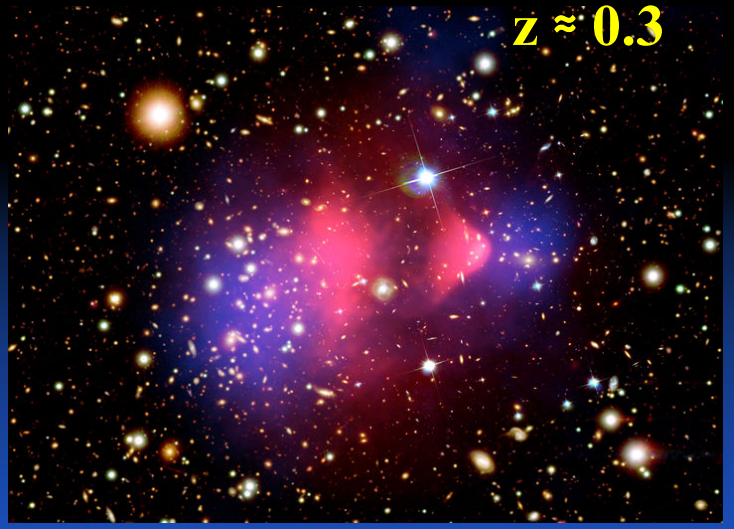
- S⁴F = Small-scale Seqencial Star formation (Ogura et al 07)

銀河団Hαマッピング

- 銀河団中に降着する時に星形成が止まる
  - LocalではSDSSが独壇場　？
    - HαはEW(Hα)を使っていて、画像はない
    - 分光データもコンプリートではない







Rines (05)　CAIRNS: The Cluster and Infall region nearby survey

球状星団のテイルの探査

- Palomar 5
  - SDSSで、星団のRGB星の分布で検出
  - 4 kpcにもおよぶtails (幅 120 pc)
  - 軌道 → Sagittarius 起源ではない

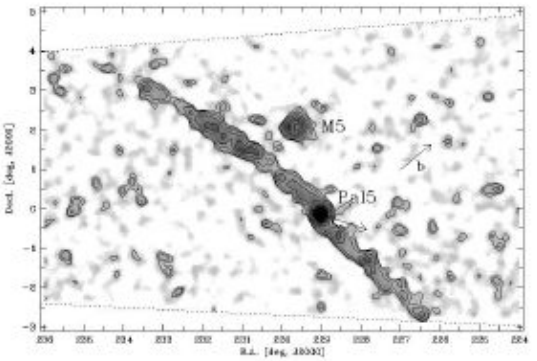


FIG. 3.—Map of the surface density of stars that are photometrically concordant with the stellar population of Pal 5 (plotted in equatorial coordinates R.A., decl.). These surface densities were derived by least-squares estimation as described in § 3.2. The lowest contours show density levels of 1.5 σ, 2 σ, 3 σ, and 5 σ above zero (*white*). Pal 5 is seen to be accompanied by two long tidal tails. The tidal debris covers an arc of almost 10° (for further details, see § 4.1). The arrow attached to Pal 5 gives an approximate indication of the direction of its Galactic motion based on the proper motion measurement by K. M. Cudworth (see § 5.2). The arrow labeled with *b* shows the direction of increasing Galactic latitude. The patch of enhanced density around (229°.6, +2°.1) is a residual feature from the cluster M5 and hence not related to Pal 5. The dotted lines mark the borders of the field.

球状星団のテイルの探査

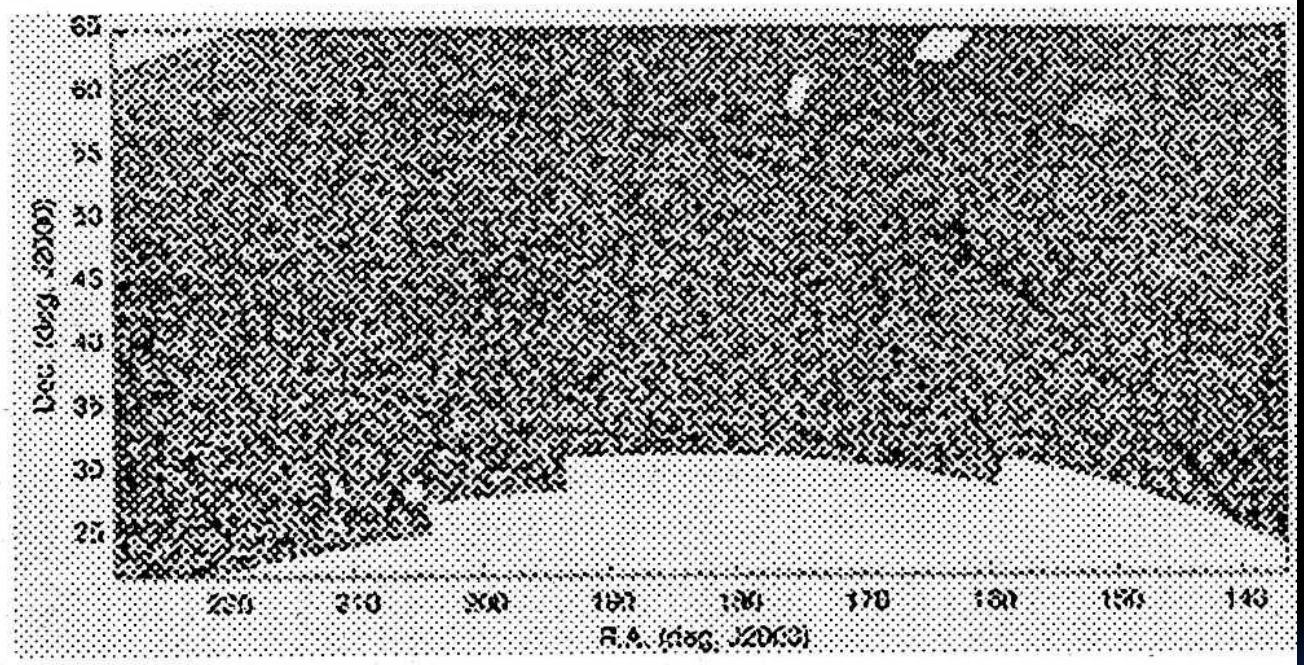


FIG. 1.—Smoothed, summed weight image of the SDSS field after subtraction of a low-order polynomial surface fit. Darker areas indicate higher surface densities. The weight image has been smoothed with a Gaussian kernel with $\sigma = 0.^{\circ}2$. The white areas are either missing data, clusters, or bright stars that have been masked out prior to analysis.

- 起源不明のテイル?

球状/散開星団の軌道

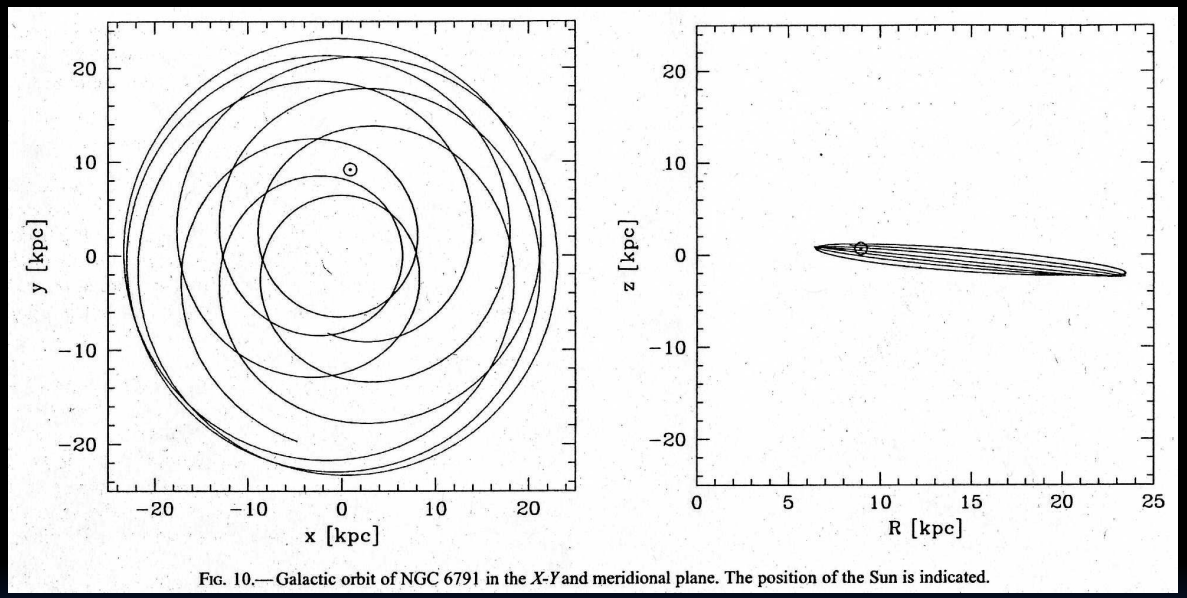
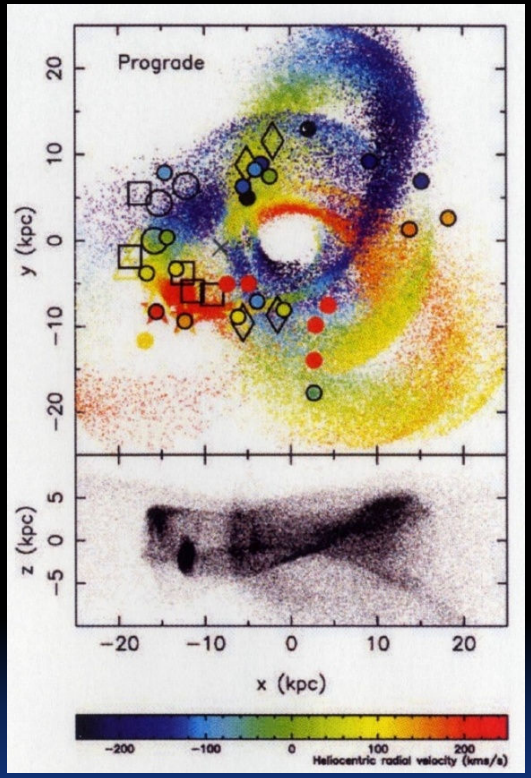


FIG. 10.—Galactic orbit of NGC 6791 in the *X-Y* and meridional plane. The position of the Sun is indicated.

- NGC6791のテイル?
  - 10Gyrと古いのに [Fe/H]～+0.2
  - 降着起源か (Carraro 07)


Prograde
y (kpc)
z (kpc)
x (kpc)
−20
−10
0
10
20
−5
5
−200
−100
100
200
Heliocentric radial velocity (kms/s)

球状星団のテイルの探査

- Palomar 5 / NGC 5466のテイル

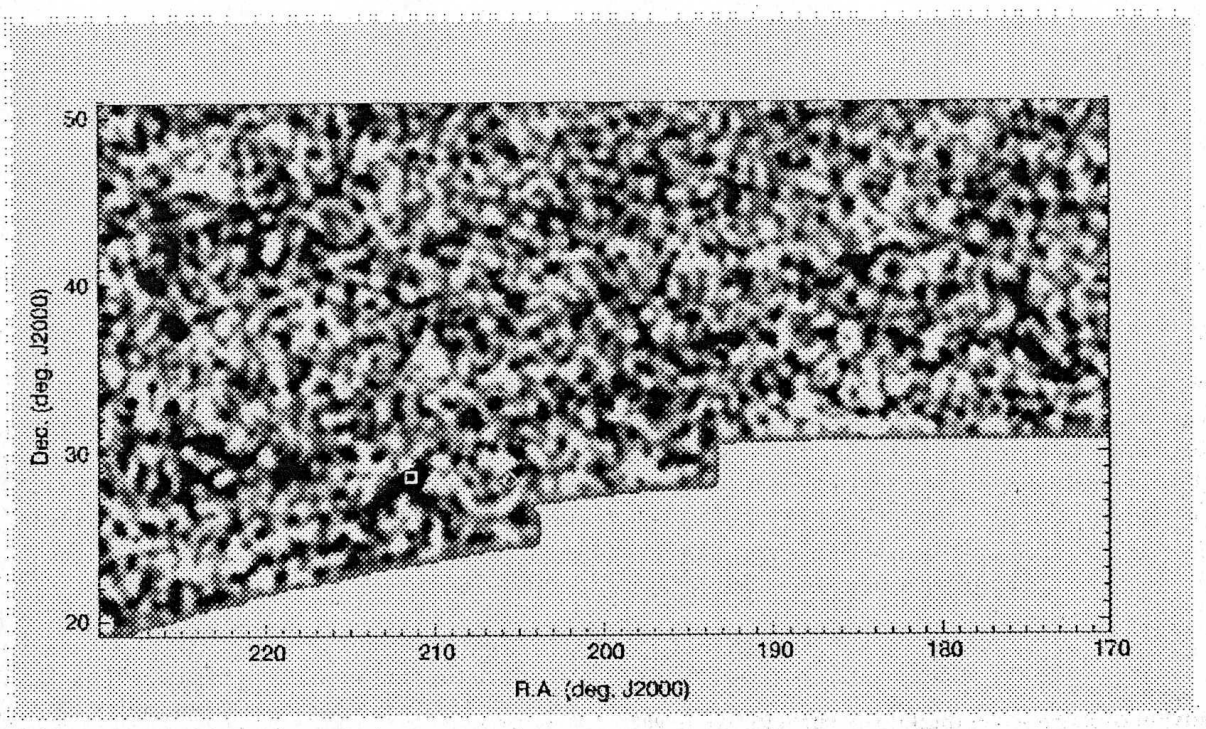


FIG. 1.—Smoothed, summed weight image of the SDSS field after subtraction of a low-order surface fit. Darker areas indicate higher surface densities. The image is the sum of weight images generated independently using the $g' - r'$ and $g' - i'$ color pairs. NGC 5466 is indicated by the open square at R.A., decl. = (211.36, +28.54), while the location of NGC 5272 (R.A., decl. = 205.55, +28.38) is shown by the open diamond. The weight image has been smoothed with a Gaussian kernel of full width 1°. The irregular southern border is defined by the limits of SDSS DR4. The faint, parallel features in the northeastern corner trace the edges of individual SDSS scans and are presumably due to variations in sensitivity and completeness at faint magnitude levels. The putative tidal stream of NGC 5466 extends from the southeastern corner of the image to roughly R.A., decl. = (180, 42).

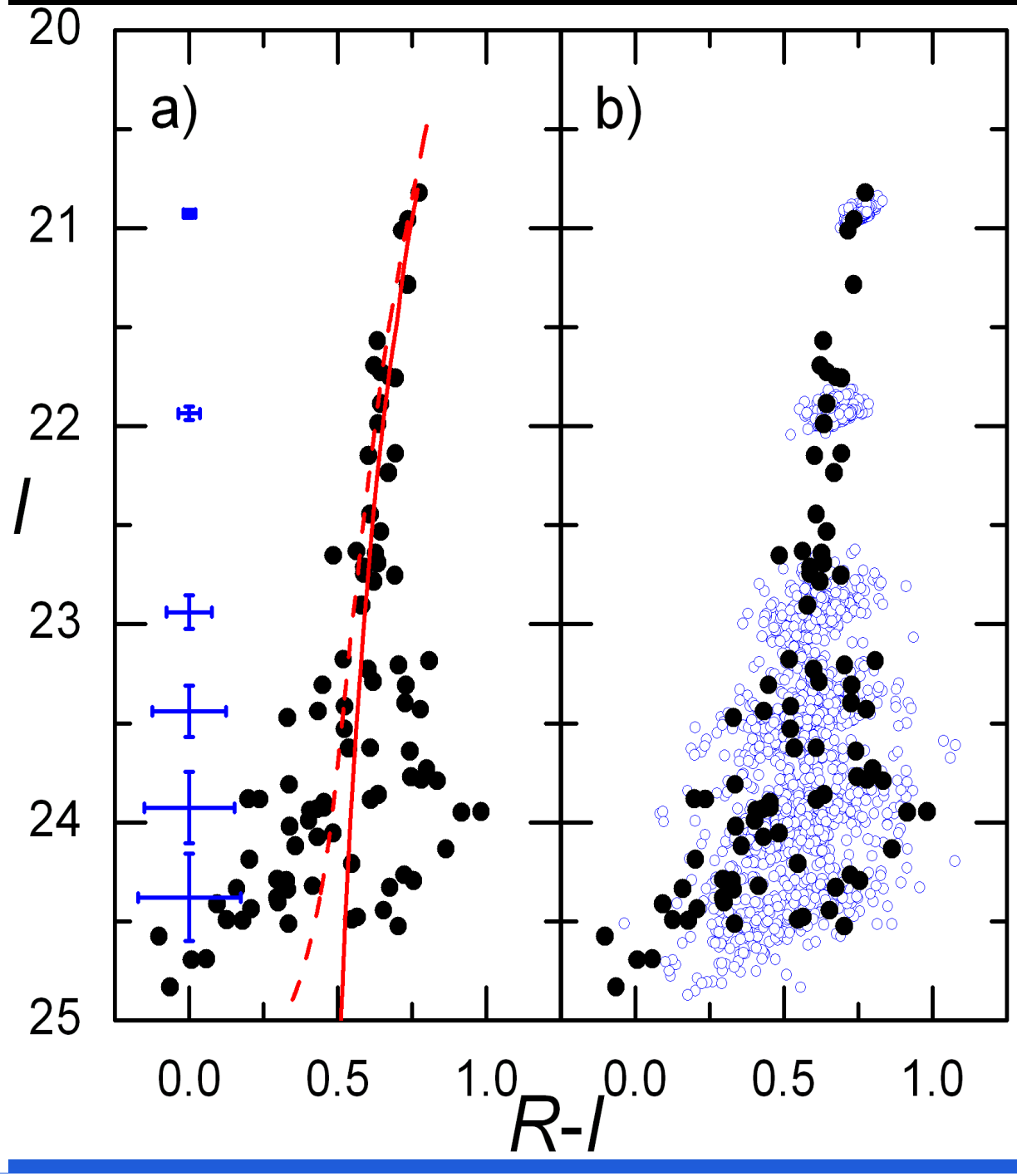


Figure 3.
The stellar-like objects in the cluster's area:
a) overlaid with the isochrone (Girardi et al. 2002) of t = 14 Gyr and [M/H] = –1.3, shifted for distance modulus of 24.75 and reddened by $A_I = 0.11$ and $E(R-I) = 0.045$ (RGB – solid, AGB – dashed lines);
b) underlaid with the artificial stars (AS; blue circles).
Error bars (blue) are