Red-sequence galaxies at z<1

Atsushi J. Nishizawa (Nagoya Univ.),
M. Takada, A. Leauthaud, S. More, K. Bundy, S. Huang (Kavli IPMU),
M Oguri(U. Tokyo), H. Miyatake(JPL), M. Strauss(Princeton),
Y. Lin(ASIAA), HSC-collaboration

観測的宇宙論ワークショップ@京大基研

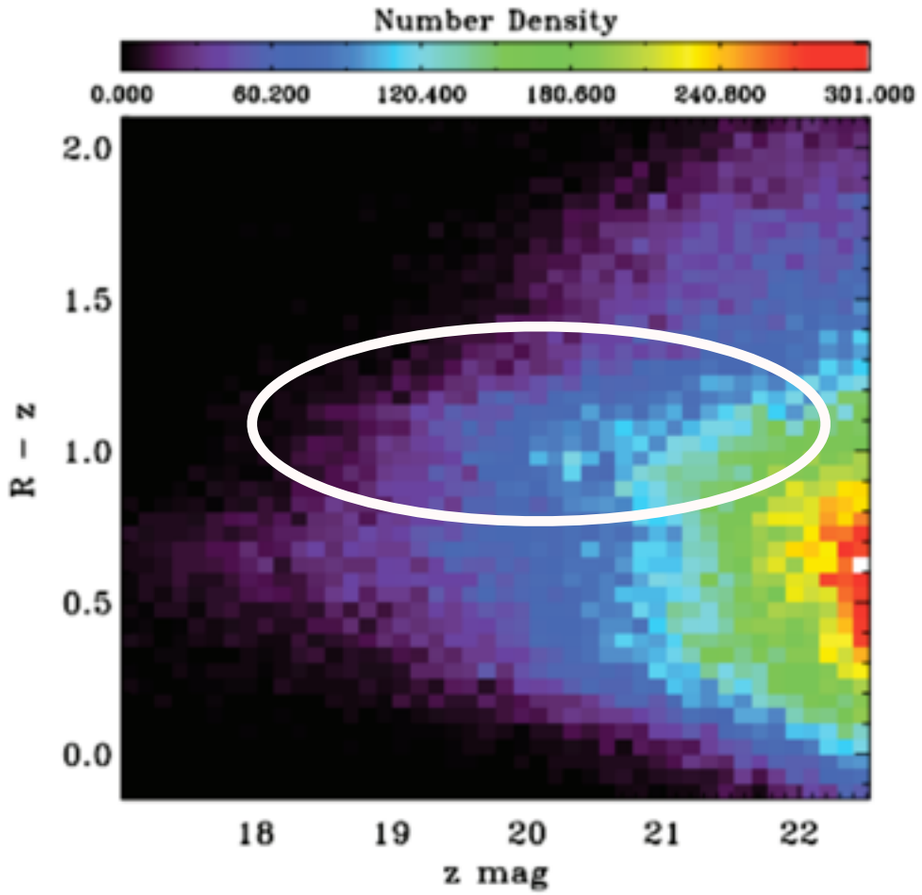
2015/11/18-20

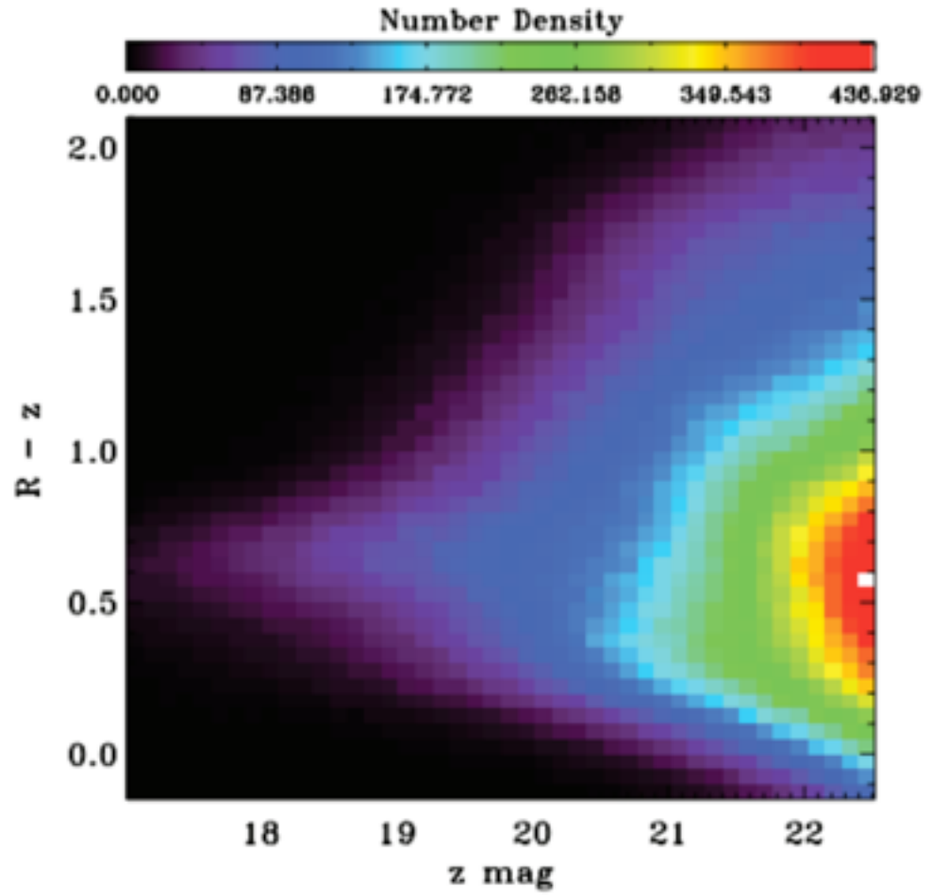
Talk Plan

- Introduction
  - Red-sequence (RS) galaxies
  - HSC survey
- Application of RS galaxies
  - Testing Photometry for extended source
  - cluster finder comparison
  - faint end behavior of the RS
  - population of galaxies in cluster
  - cluster outer mass profile
- Summary

red-sequence (RS) galaxies

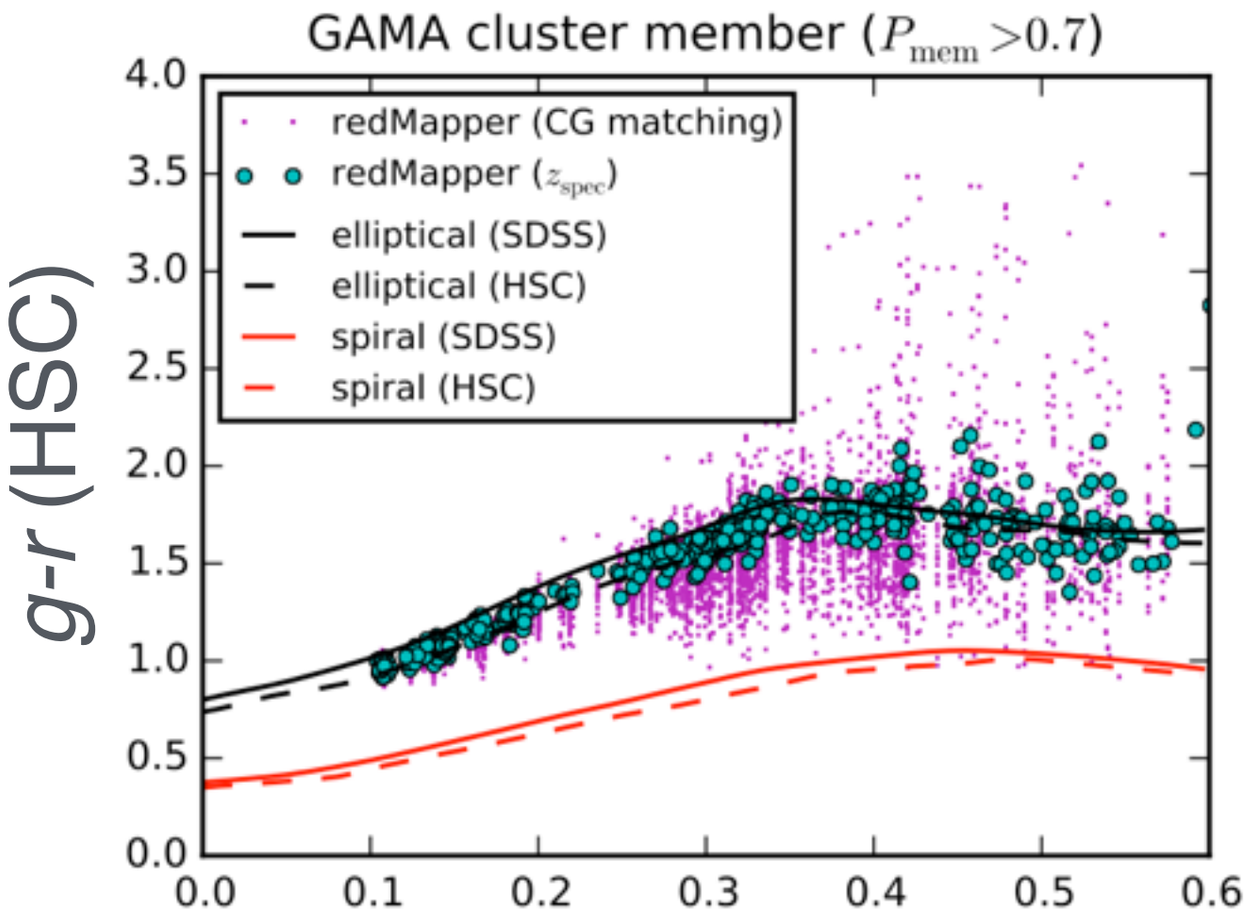
Loh++ 2008

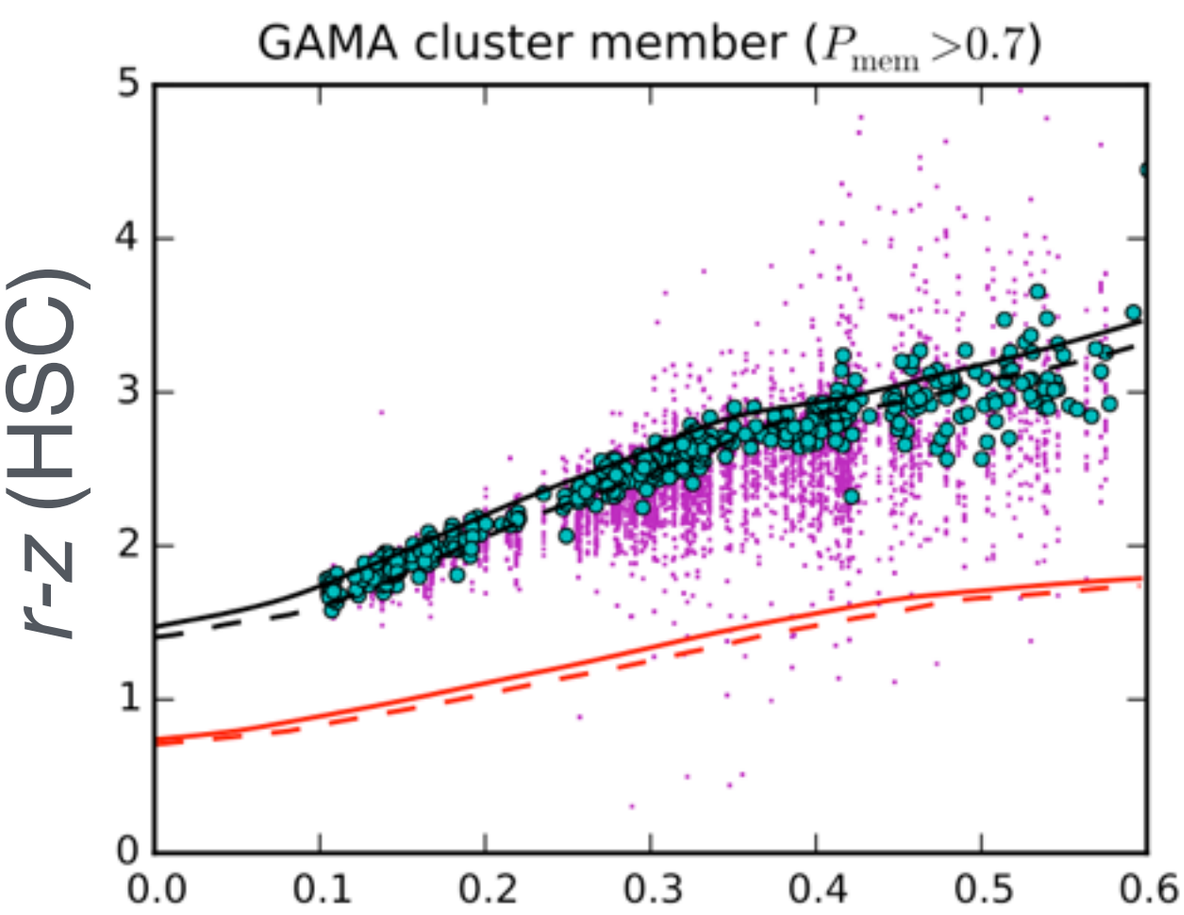




- Tight distribution in the color-mag plane
- Probes of the precision of the photometry for extended sources
- Mainly located in a cluster of galaxies
- $\sigma = \sigma_{int} + \sigma_{photo}$

redshift evolution of the red-sequence galaxies

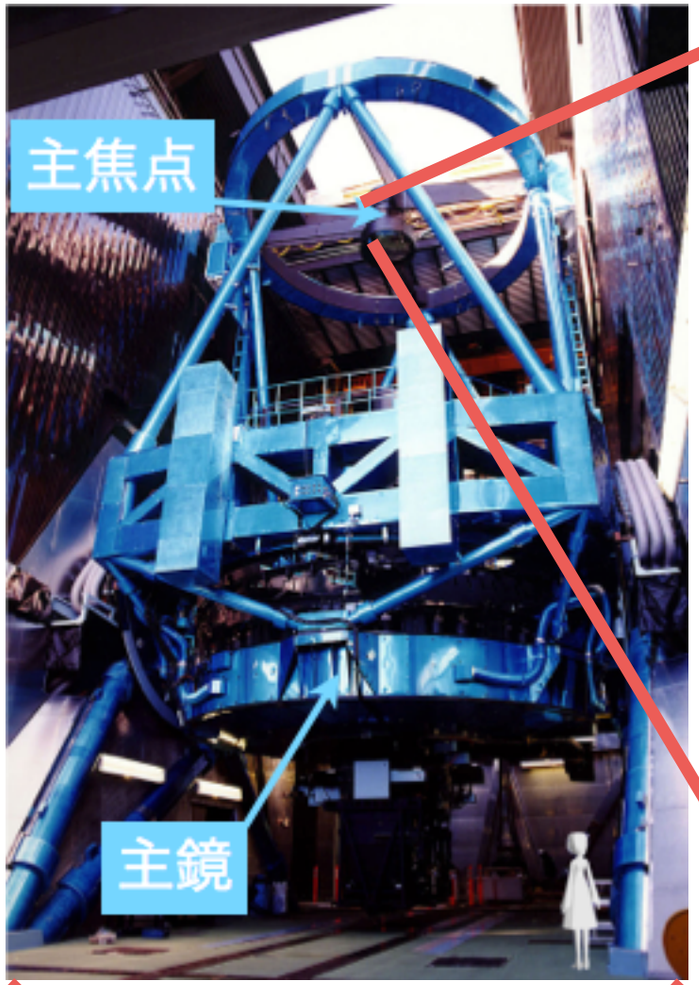


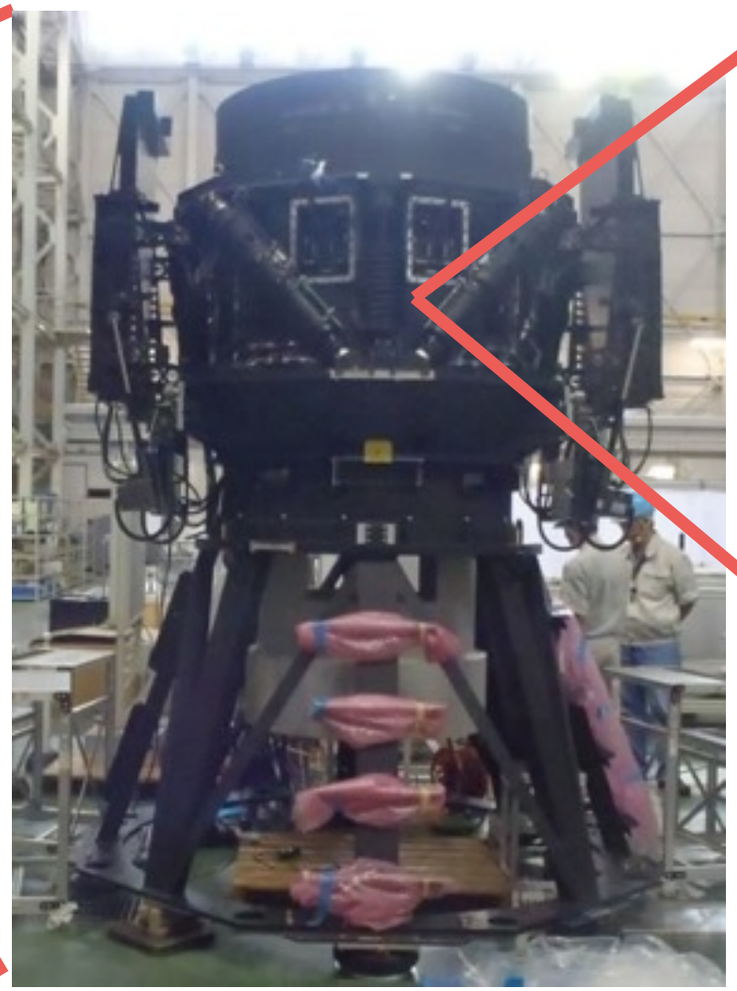


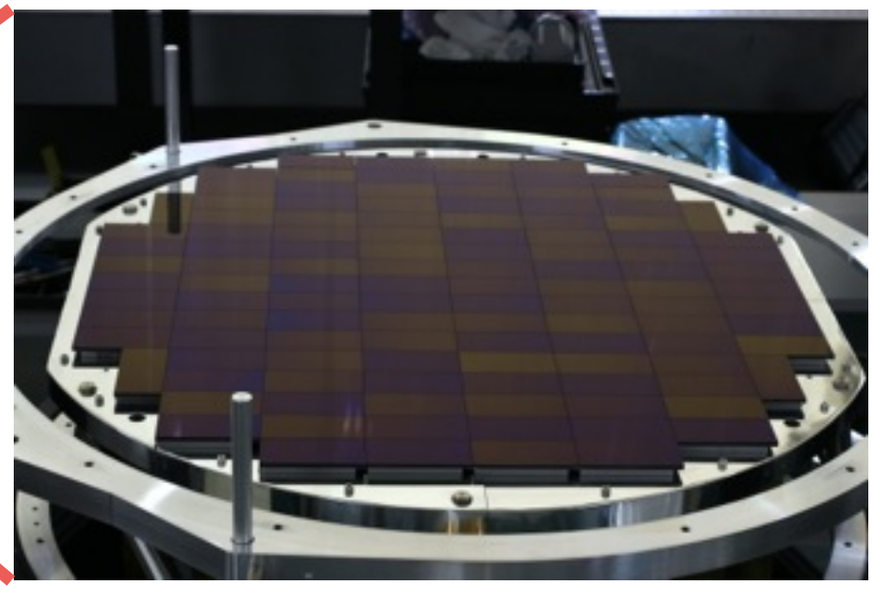
- cluster members from SDSS
- object matching by RA, DEC to assign HSC colors.
- K-correction or narrow z-bin

- RS galaxies beautifully follow the E-type galaxy evolutional track.
- Optimal color choice to define the RS naively depends on the location of the 4000A break.

Hyper Suprime-Cam (HSC)





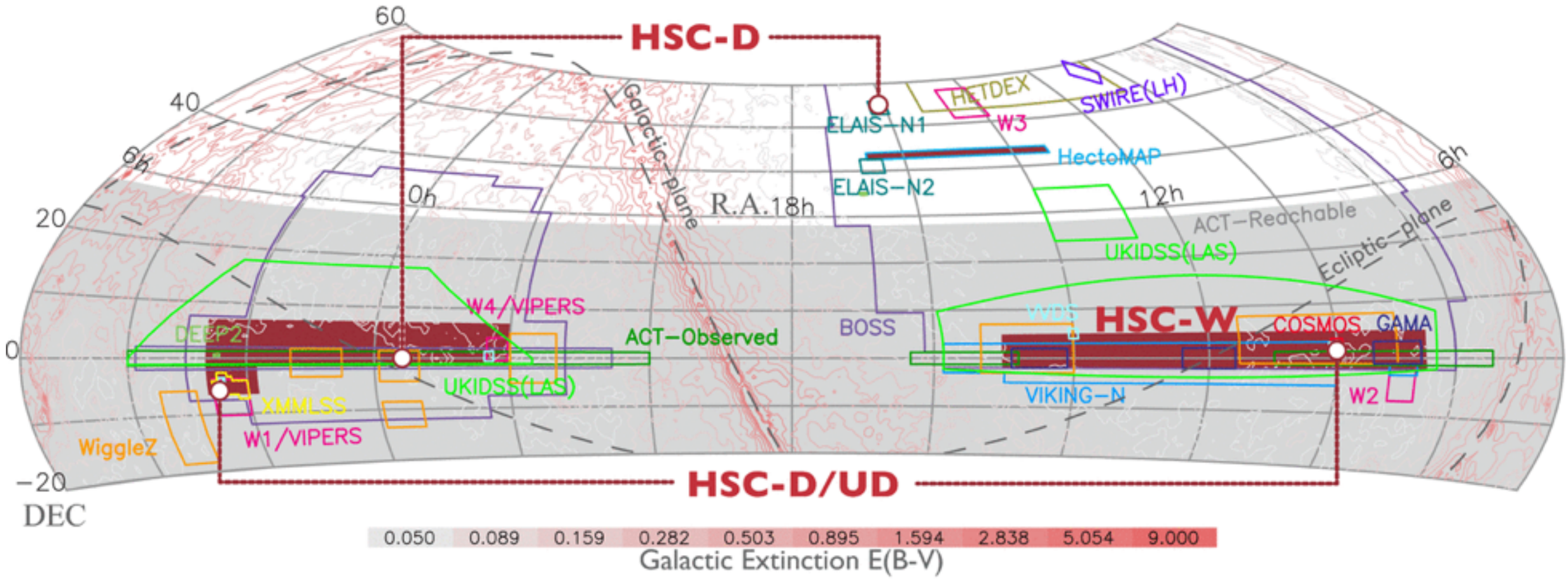


- HSC is a large CCD detector installed on the Subaru 8m telescope in Hawaii.
- 1.77 deg^2 FoV
- 6 filters available in the filter slot
- Actuator controls 3.2t weight in um accuracy
- 2.3GB/exposure

HSC survey

- Three strategies
  - HSC-W:1,400 deg2, i<25.9
  - HSC-D:25 deg2, i<26.8
  - HSC-UD: 3.5 deg2, i<27.4
- 300 nights over 5 years
- started Feb. 2014
- ~60 nights finished

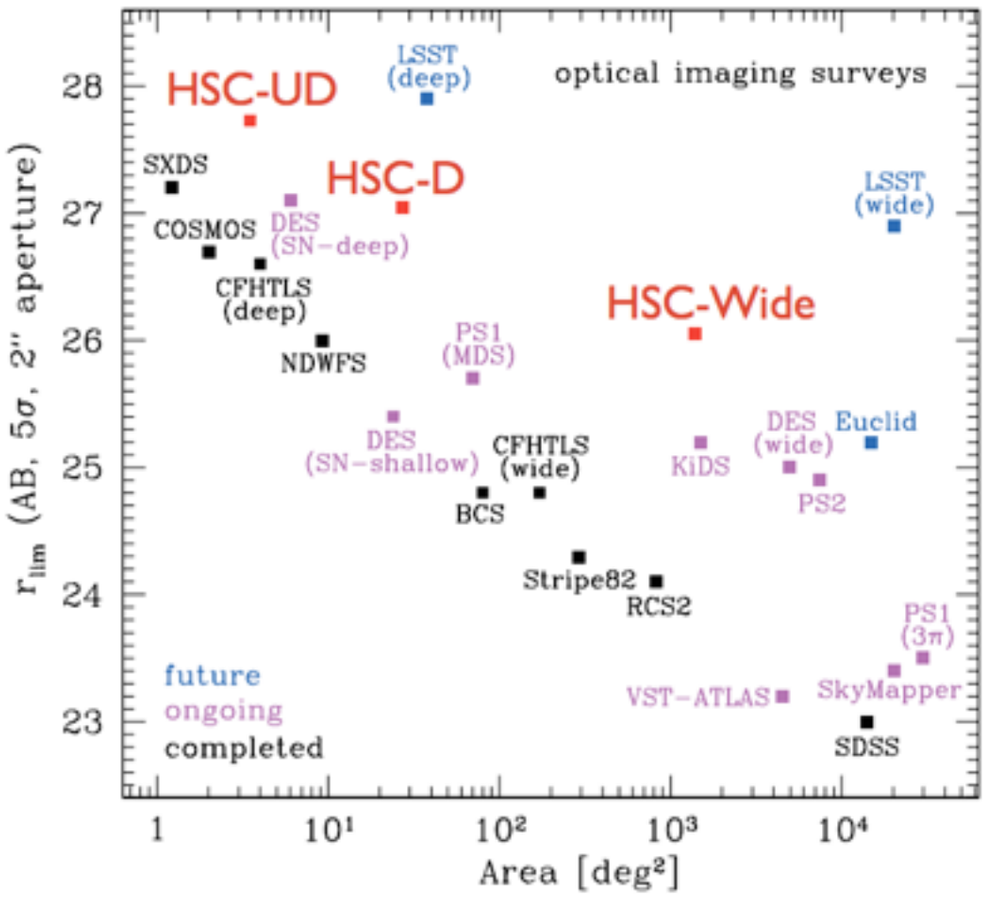
- Main science : Gravitational Lensing
  - Cosmic shear, g-g lensing, strong lens
  - cluster and galaxy sciences
  - SN, AGN, transients, solar system
- 300 nights over 5 years
- started Feb. 2014
- ~60 nights finished

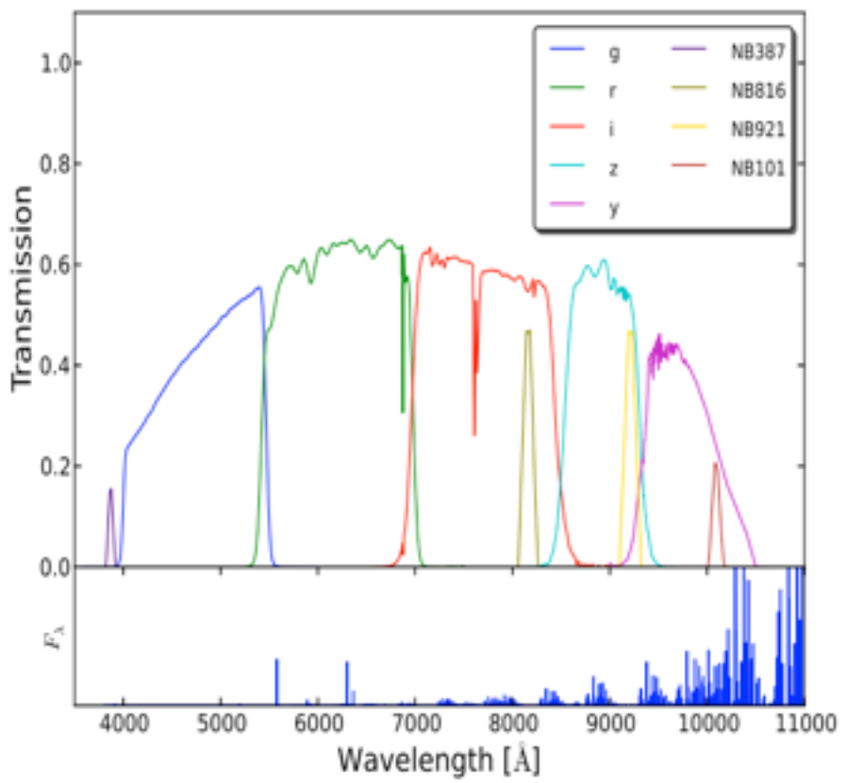


HSC survey

- Three strategies
  - HSC-W:1,400 deg2, i<25.9
  - HSC-D:25 deg2, i<26.8
  - HSC-UD: 3.5 deg2, i<27.4
- 300 nights over 5 years
- started Feb. 2014
- ~60 nights finished

- Main science : Gravitational Lensing
  - Cosmic shear, g-g lensing, strong lens
  - cluster and galaxy sciences
  - SN, AGN, transients, solar system
- 300 nights over 5 years
- started Feb. 2014
- ~60 nights finished





HSC first science paper

PASJ: Publ. Astron. Soc. Japan , 1–??,

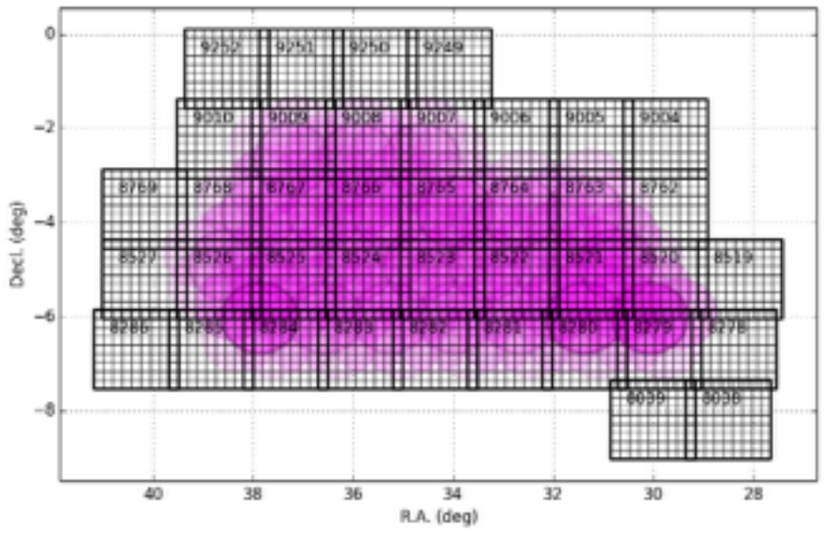
Hyper-luminous Dust Obscured Galaxies discovered by the Hyper Suprime-Cam on Subaru and WISE*

Yoshiki TOBA [1], Tohru NAGAO [1], Michael A. STRAUSS [2], Kentaro AOKI [3], Tomotsugu GOTO [4], Masatoshi IMANISHI [3,5,6], Toshihiro KAWAGUCHI [7], Yuichi TERASHIMA [8], Yoshihiro UEDA [9], James BOSCH [2], Kevin BUNDY [10], Yoshiyuki DOI [3], Hanae INAMI [11], Yutaka KOMIYAMA [5,6], Robert H. LUPTON [2], Hideo MATSUHARA [12,13], Yoshiki MATSUOKA [5], Satoshi MIYAZAKI [5,6], Tomoki MOROKUMA [14], Fumiaki NAKATA [3], Nagisa OI [12], Masafusa ONOUE [5,6], Shinki OYABU [15], Paul PRICE [2], Philip J. TAIT [3], Tadafumi TAKATA [5,6], Manobu M. TANAKA [16], Tsuyoshi TERAI [3], Edwin L. TURNER [2,10], Tomohisa UCHIDA [16], Tomonori USUDA [5,6], Yousuke UTSUMI [17], Shiang-Yu WANG [18], Yoshihiko YAMADA [5]

[1] *Research Center for Space and Cosmic Evolution, Ehime University, Bunkyo-cho, Matsuyama, Ehime 790-8577*
toba@cosmos.phys.sci.ehime-u.ac.jp
[2] *Princeton University Observatory, Peyton Hall, Princeton, NJ 08544, USA*
[3] *Subaru Telescope, 650 North A'ohoku Place, Hilo, HI 96720, USA*
[4] *Institute of Astronomy and Department of Physics, National Tsing Hua University, No. 101, Section 2, Kuang-Fu Road, Hsinchu 30013, Taiwan*
[5] *National Astronomical Observatory of Japan, Osawa, Mitaka, Tokyo 181-8588*
[6] *Department of Astronomy, School of Science, SOKENDAI (The Graduate University for Advanced Studies), Mitaka, Tokyo 181-8588*
[7] *Division of Physics, Sapporo Medical University, S1 W17, Chuo-ku, Sapporo 060-8556*
[8] *Department of Physics, Ehime University, 2-5, Bunkyo-cho, Matsuyama, Ehime 790-8577*
[9] *Department of Astronomy, Graduate School of Science, Kyoto University, Kitashirakawa-Oiwake cho, Kyoto 606-8502*
[10] *Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU, WPI), Todai Institutes for Advanced Study, the University of Tokyo, Kashiwa 277-8583*
[11] *National Optical Astronomy Observatory, 950 North Cherry Avenue, Tucson, AZ 85719, USA*
[12] *Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210*
[13] *Department of Space and Astronautical Science, SOKENDAI (The Graduate University for Advanced Studies), 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210*
[14] *Institute of Astronomy, Graduate School of Science, The University of Tokyo, 2-21-1 Osawa, Mitaka, Tokyo 181-0015*
[15] *Graduate School of Science, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8602*
[16] *High Energy Accelerator Research Organization (KEK), Institute of Particle and Nuclear Studies, 1-1 Oho, Tsukuba*

HSC Data (fully overlapped with SDSS)

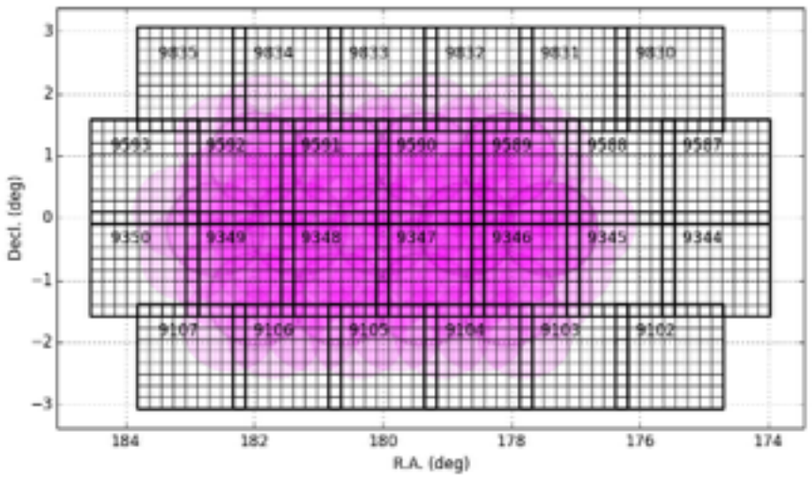
- XMMLSS region (ver. S15A_pre)

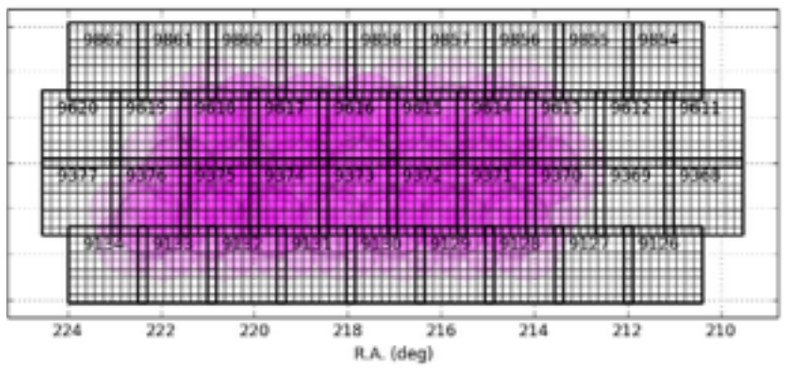


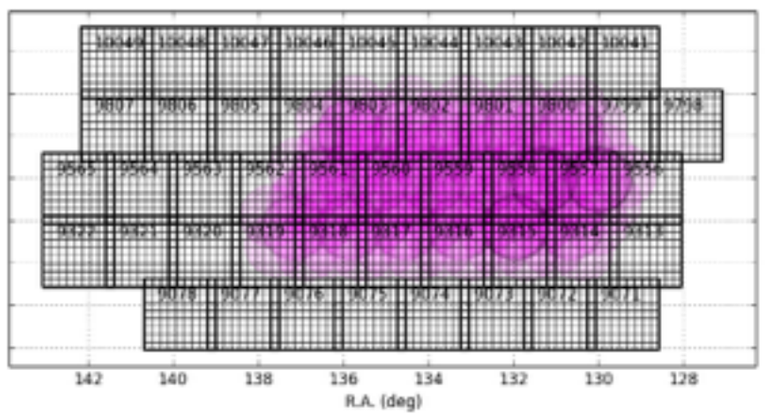
- Data released at Feb. 10, 2015
- Cmodel mags at the crowded regions unavailable (deblending, model fitting issues)
- Large photometric error (at bright end)
- 30 clusters at z<0.6 (SDSS cluster)
- 500 clusters at z < 1.1 (HSC clusters)

- Three GAMA regions (ver. S15A prelim.)

©Naoki Yasuda



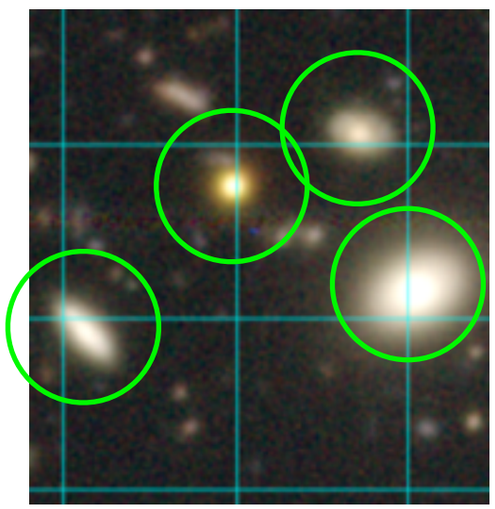




- Data released at Sep. 1, 2015
- Cmodel mags, photometric errors seem improved (thanks to software team)
- 200 clusters at z<0.6 (SDSS), ~1000 clusters at z<1.1 (HSC)

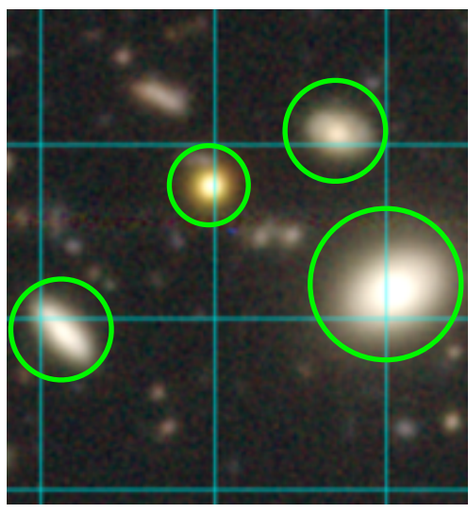
Flux measurements of galaxies

Aperture mag



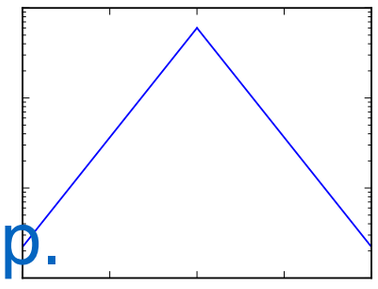
- apt. size fixed
- easy to implement
- noisy
- never total mag

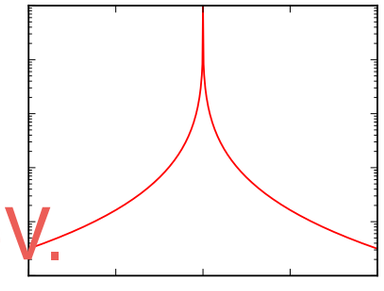
Kron mag



- apt. size adaptive
- easy to implement
- $2R_k$ contains >90% fluxes
- TH func. doesn't fit the light profile

Model mag



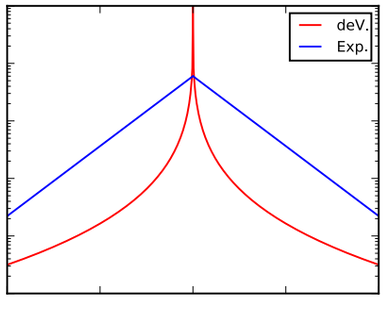


- fit the profile by either deV. or Exp.
- size and amplitude
- allow ellipticity

PSF mag

- should be optimal for point sources

C-model mag



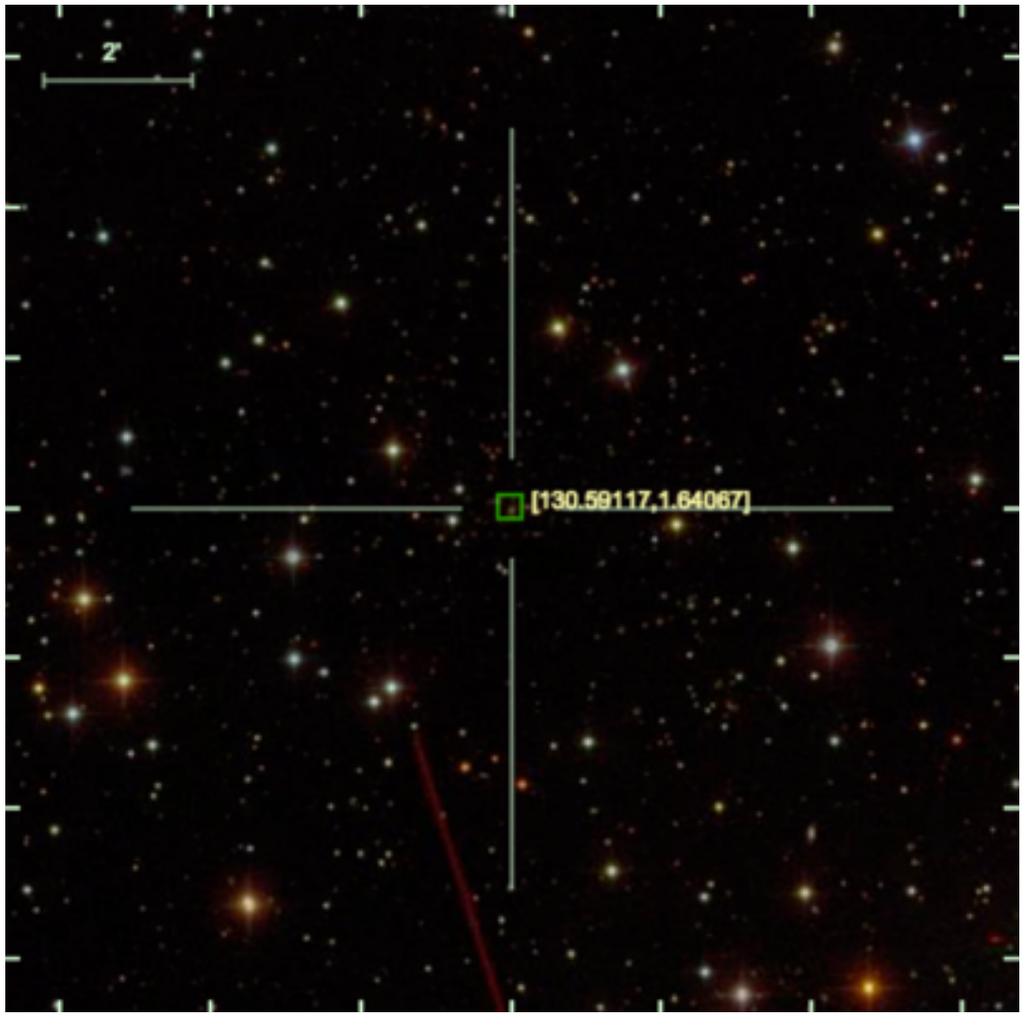
- fit with composite model
- should be optimal for extended sources

SDSS(model_mag) vs HSC(cmodel_mag)

- color-term correction with CWW Elliptical galaxy template
- $\sigma_{SDSS} = 0.14$, $\sigma_{HSC} = 0.09$ $(0.30 < z < 0.35)$
- $\sigma_{SDSS} = 0.26$, $\sigma_{HSC} = 0.17$ $(0.35 < z < 0.40)$
- almost intrinsic scatter for HSC

SDSS vs HSC - visual inspection -

rich cluster at z=0.41, λ=101
(RA,DEC)=(130.591168, +1.640672)



SDSS composite image(r'<21)

http://skyserver.sdss.org/dr12/en/tools/chart/navi.aspx

HSC composite image (i<25)

https://hscdata.mtk.nao.ac.jp:4443/hsc_ssp/dr_early/skymaps-s15a/

HSC(**cmodel_mag**) vs HSC (other mag system)

C_MODEL_MAG

σ=0.06

KRON_MAG

σ=0.05

PSF_MAG

σ=0.16

HSC(**cmodel_mag**) vs HSC (other mag system)

C_MODEL_MAG

σ=0.10

KRON_MAG

σ=0.11

PSF_MAG

σ=0.13

HSC(**cmodel_mag**) vs HSC (other mag system)

C_MODEL_MAG

σ=0.18

KRON_MAG

σ=0.21

PSF_MAG

σ=0.19

HSC(**cmodel_mag**) vs HSC (other mag system)

C_MODEL_MAG

σ=0.11

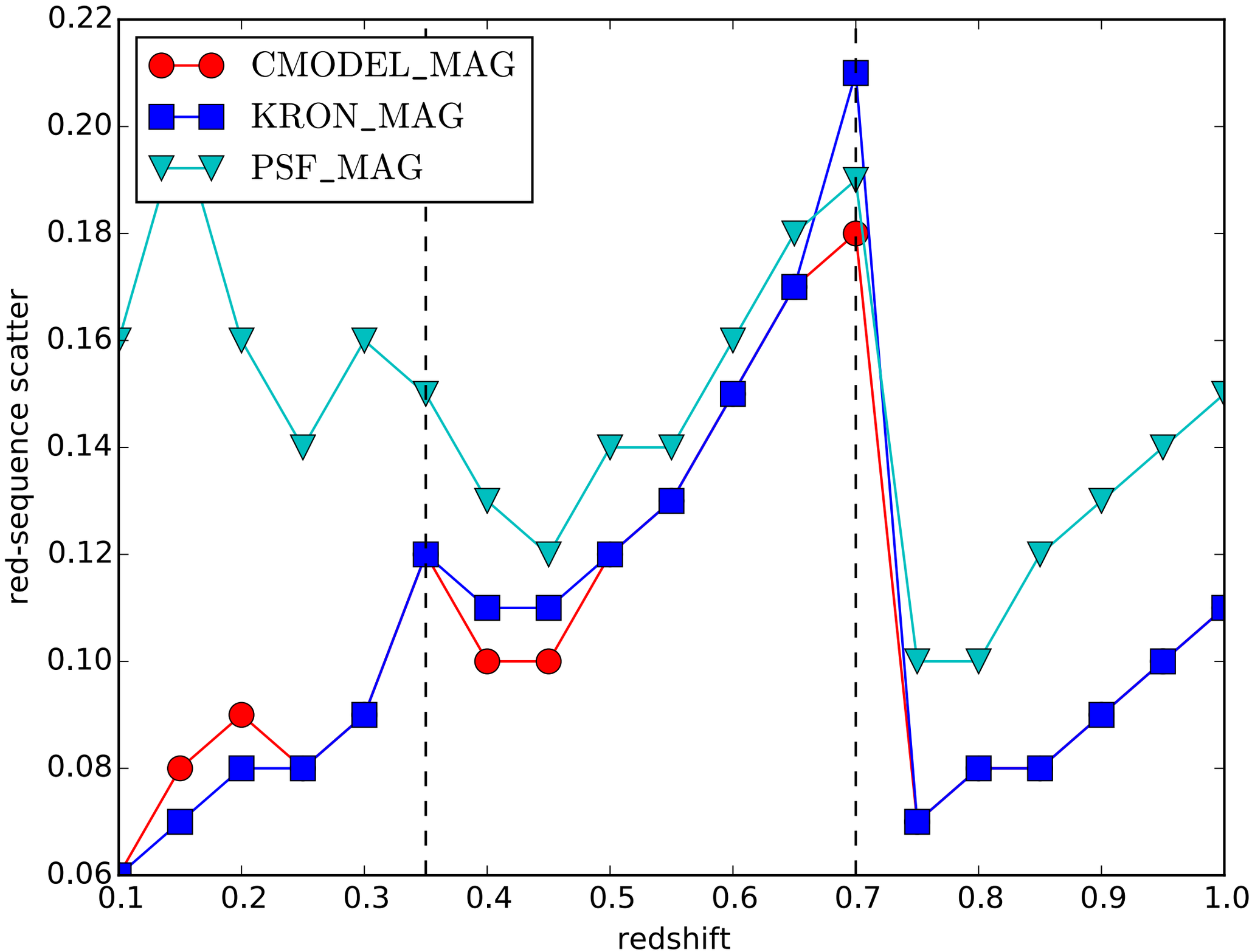
KRON_MAG

σ=0.11

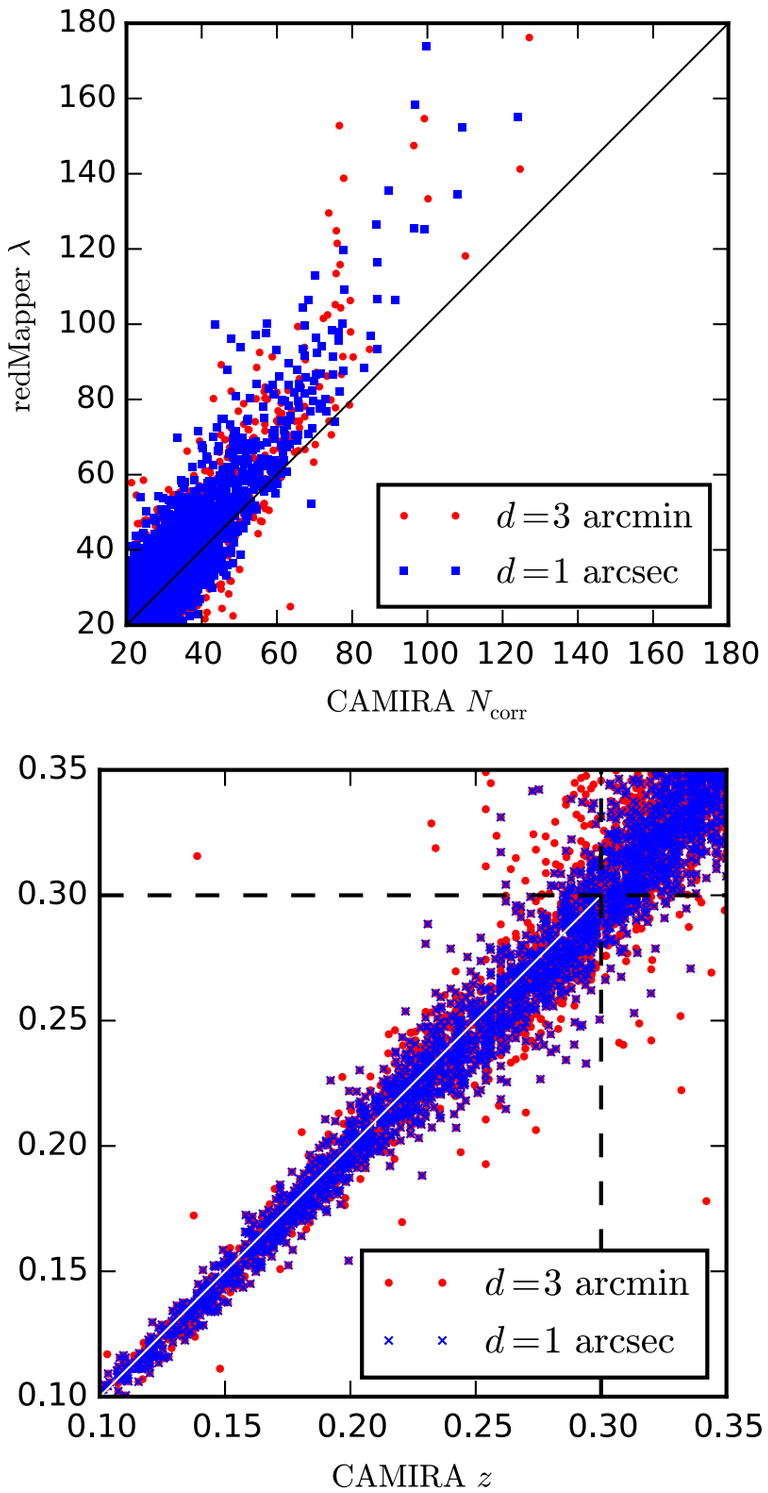
PSF_MAG

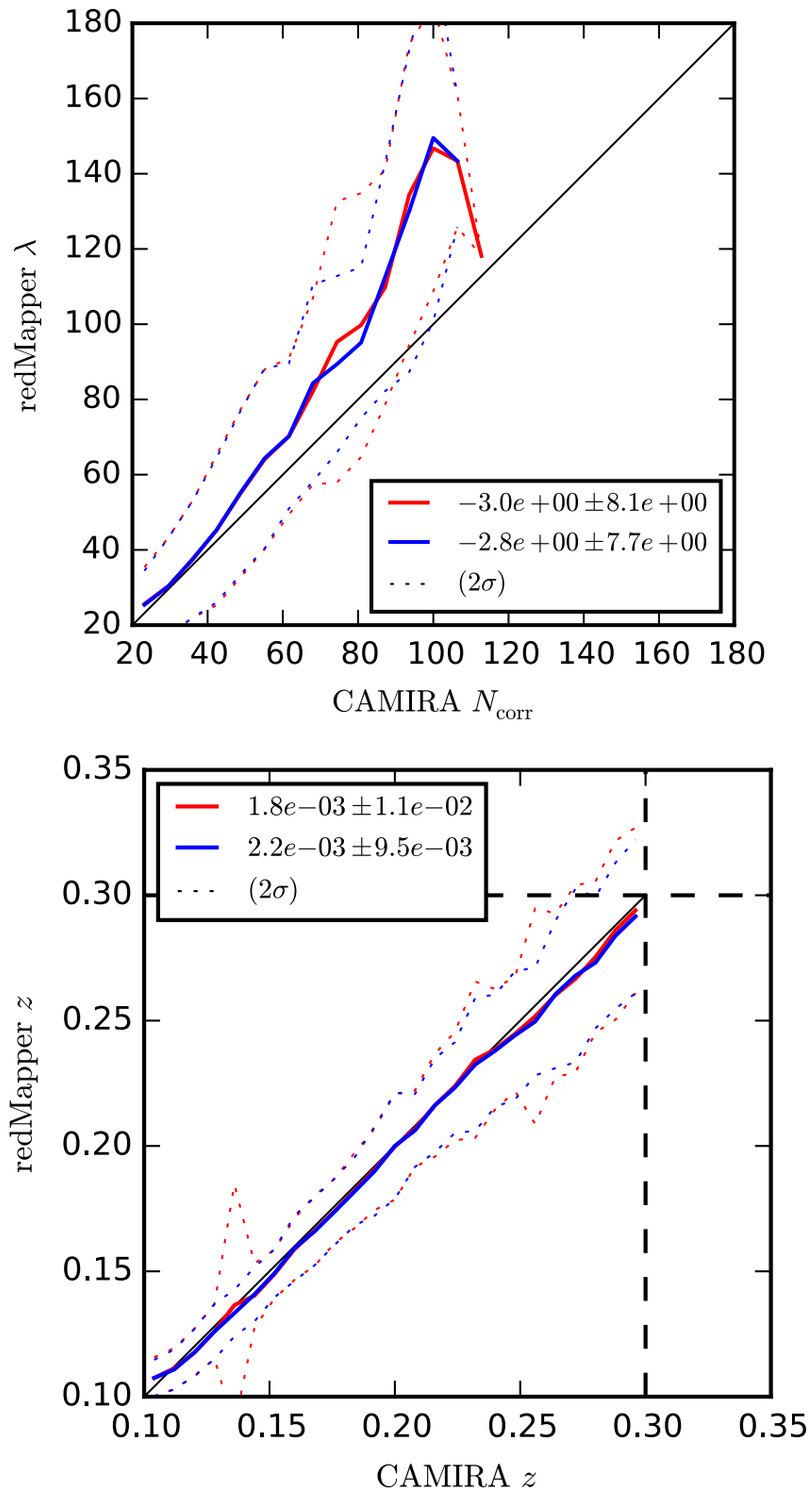
σ=0.15

HSC(cmodel_mag) vs HSC (other mag system)

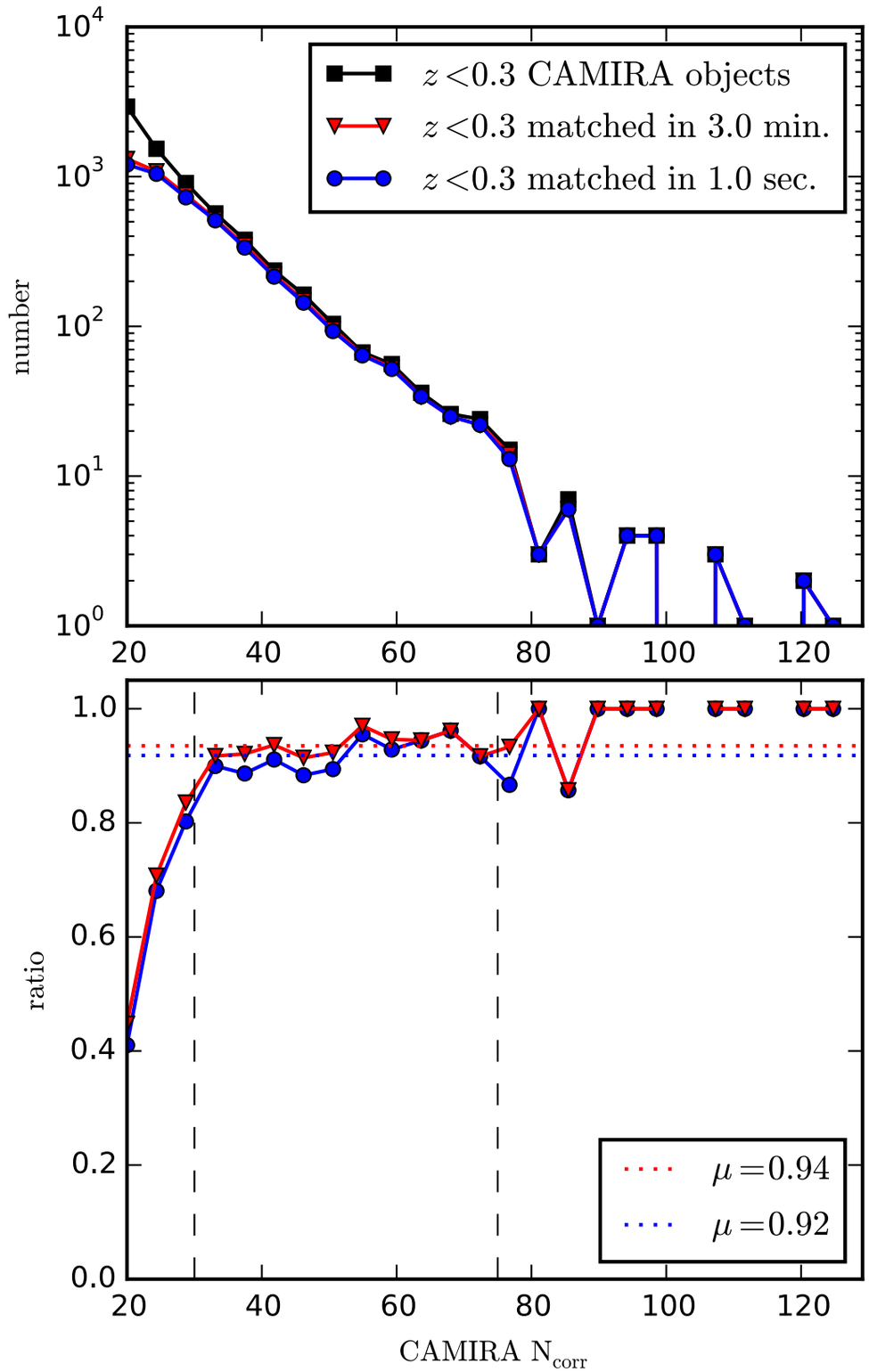


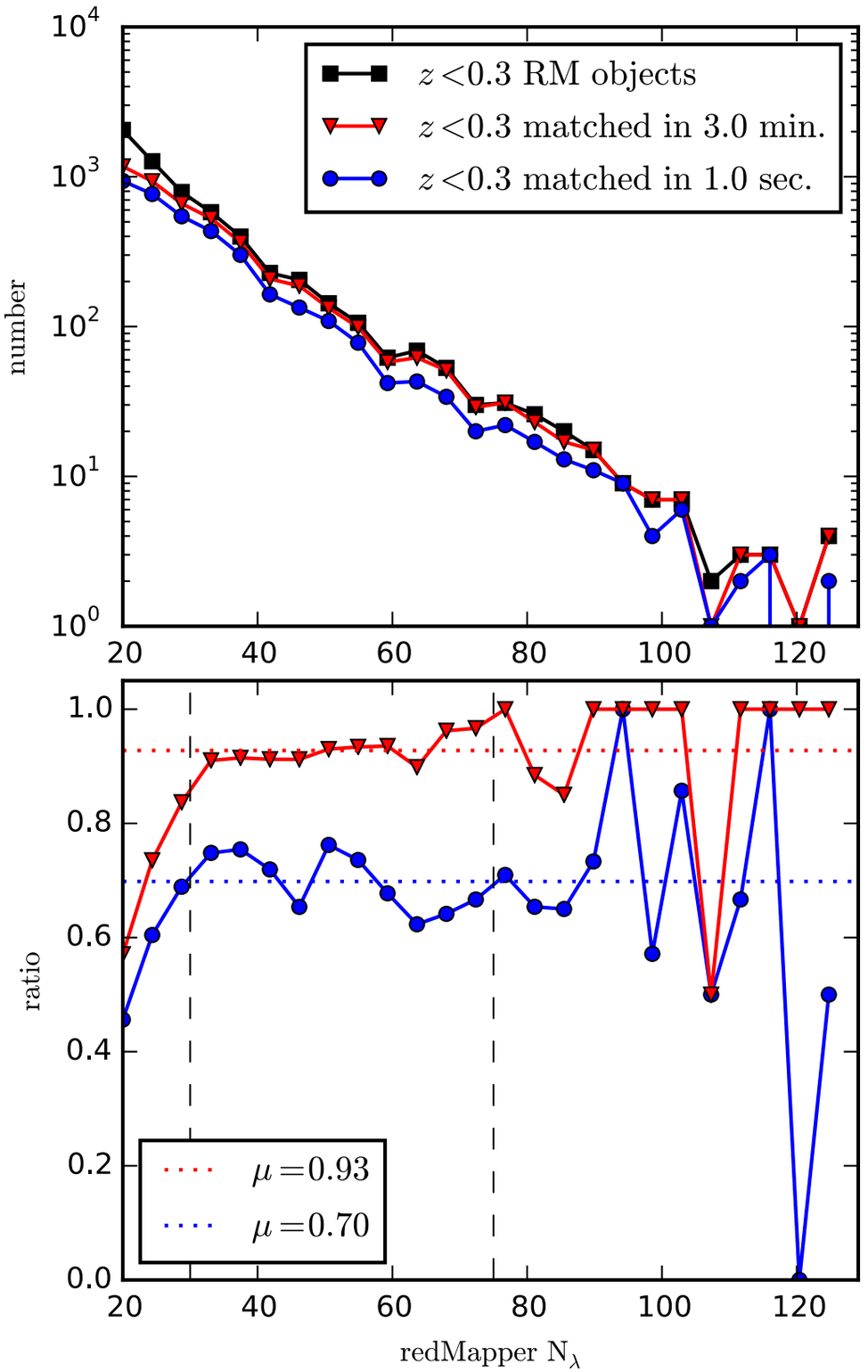
beyond the red-sequence : Is cluster finder robust?



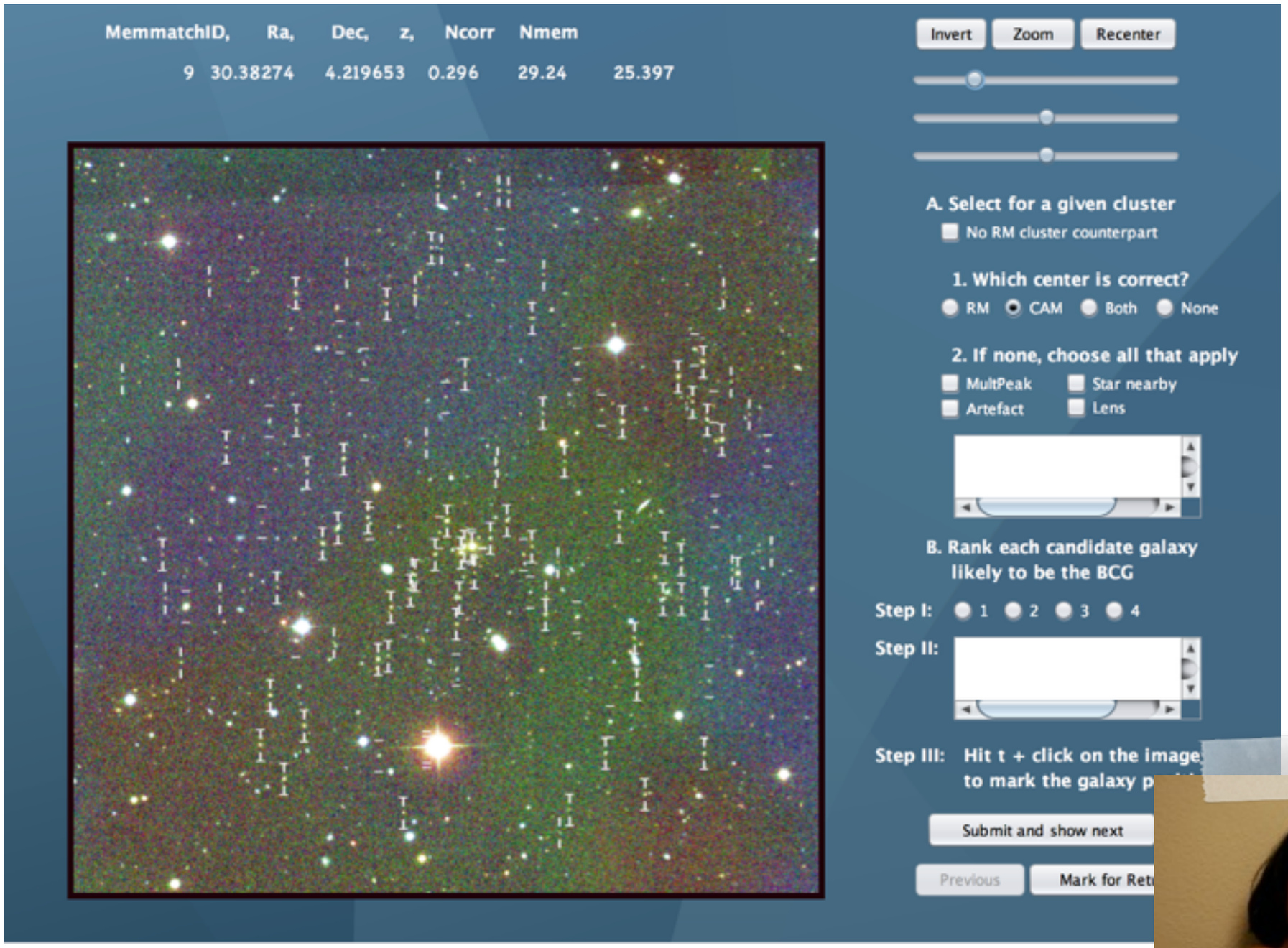


beyond the red-sequence : Is cluster finder robust?





beyond the red-sequence : Is cluster finder robust?

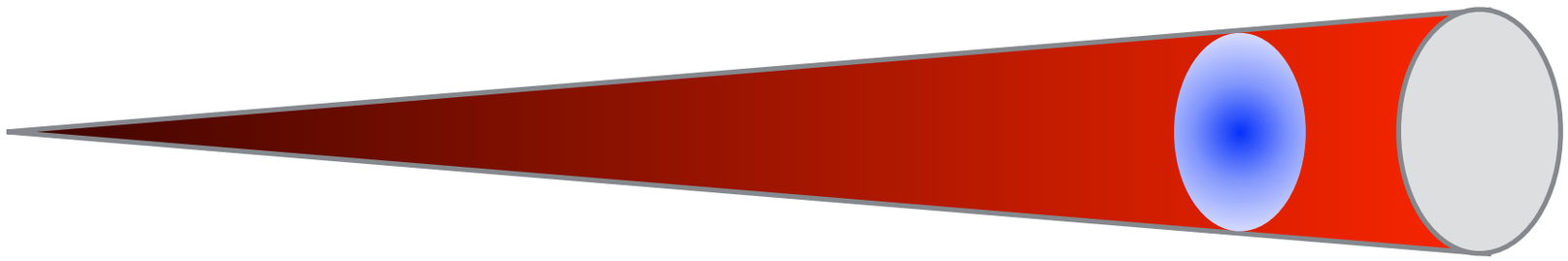


©Anu More(IPMU)

Two cluster finders point same cluster but identification of member galaxies is not always consistent with each other.

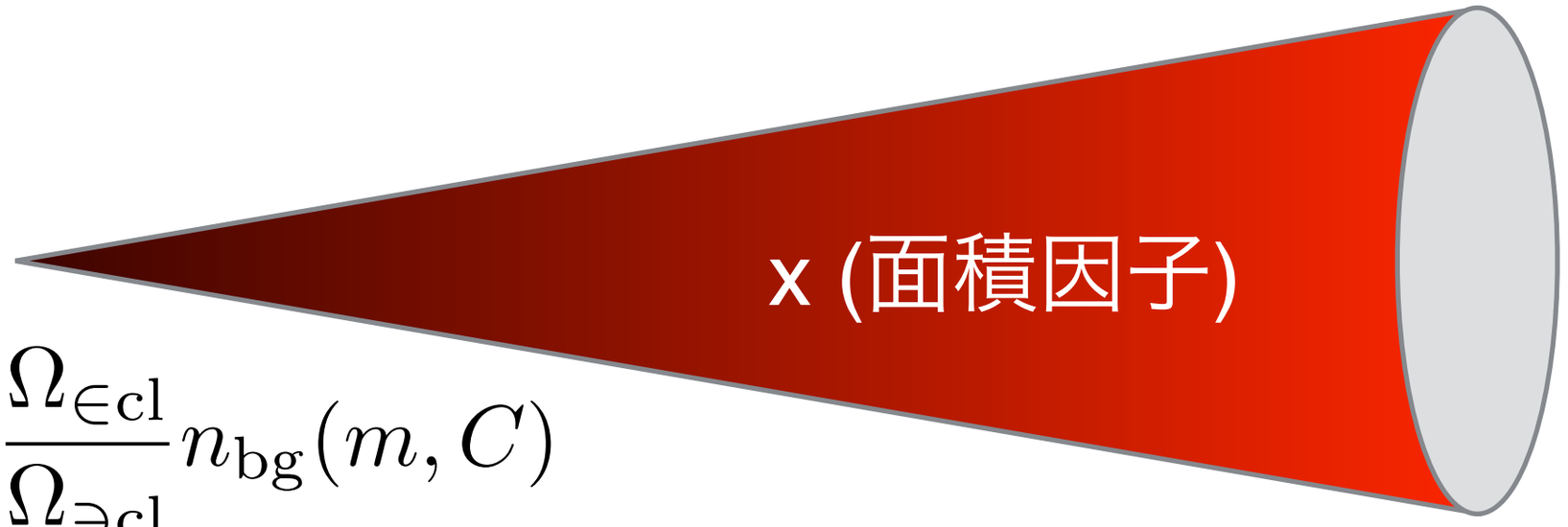
beyond the red-sequence : composite cluster

クラスタ領域



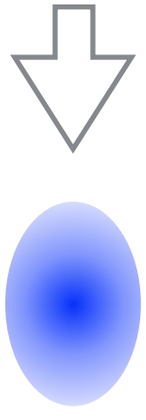
$$n_{\rm obs}(m, C, z) = n_{\rm cl}(m, C, z) + n_{\rm bg}(m, C)$$

ブランク領域



$$\tilde{n}_{\rm bg}(m, C) = \frac{\Omega_{\in {\rm cl}}}{\Omega_{\ni {\rm cl}}} n_{\rm bg}(m, C)$$

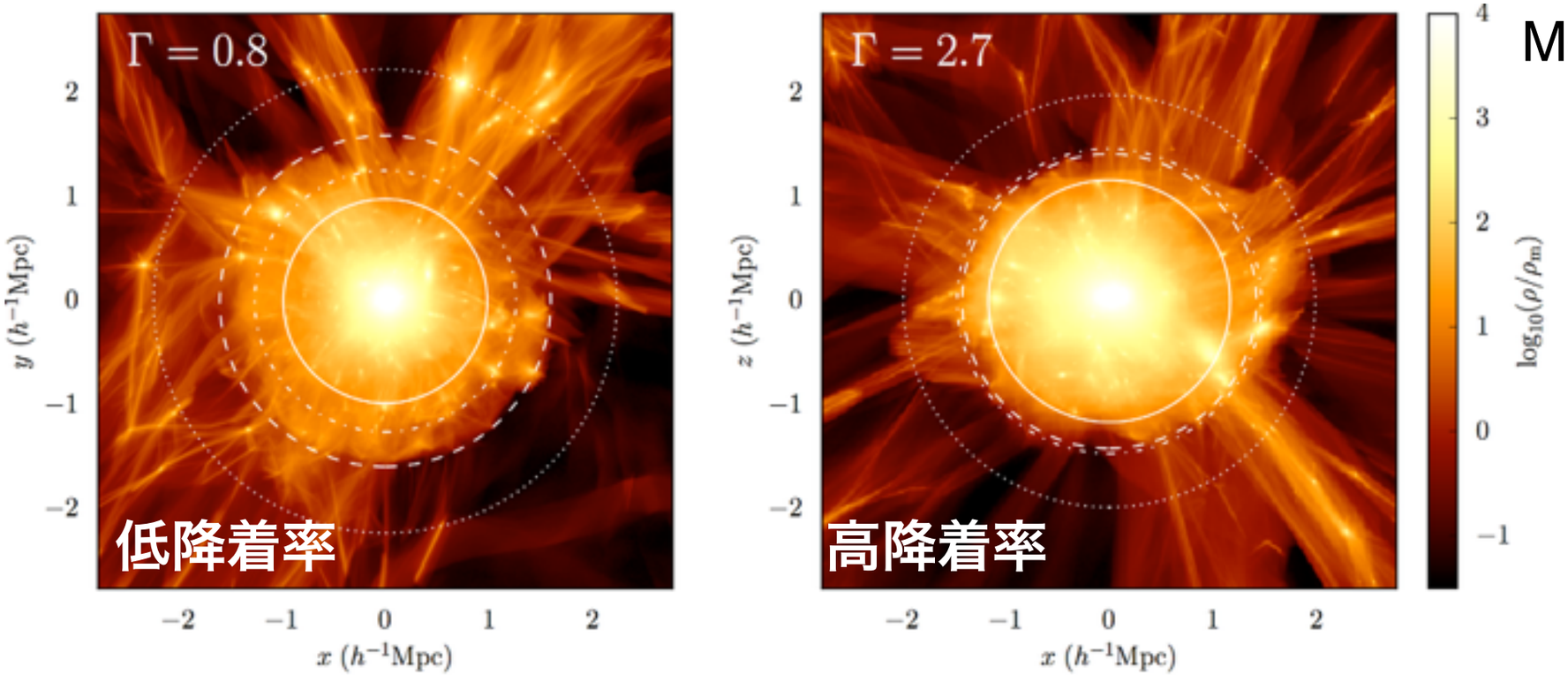
bg/fg subtraction



Hansen++ 2008
Loh++2008
Gilbank++2007
Hao++2009

galaxy population in the cluster regions (z~0.2)

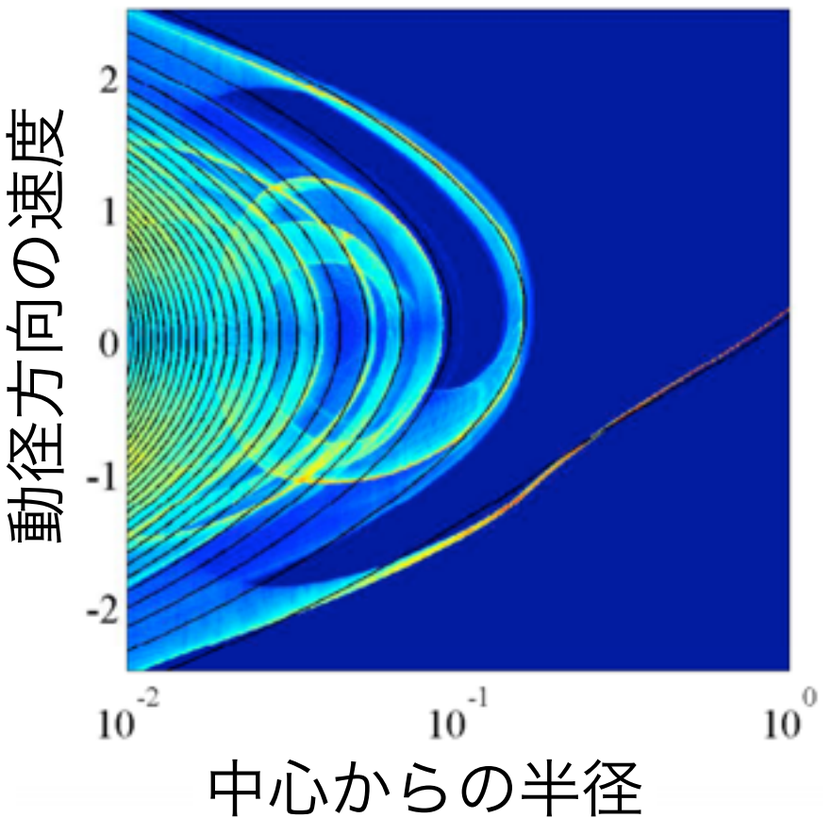
銀河団境界領域



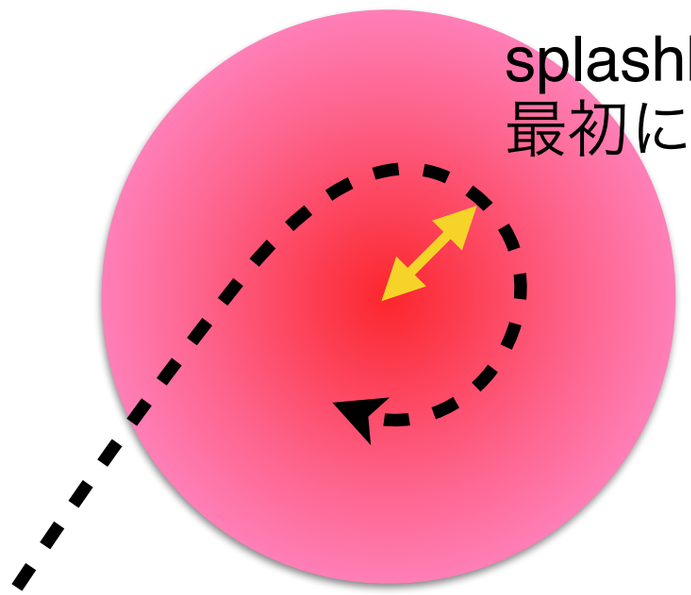
More++2015

— virial radi.

- - sprashback



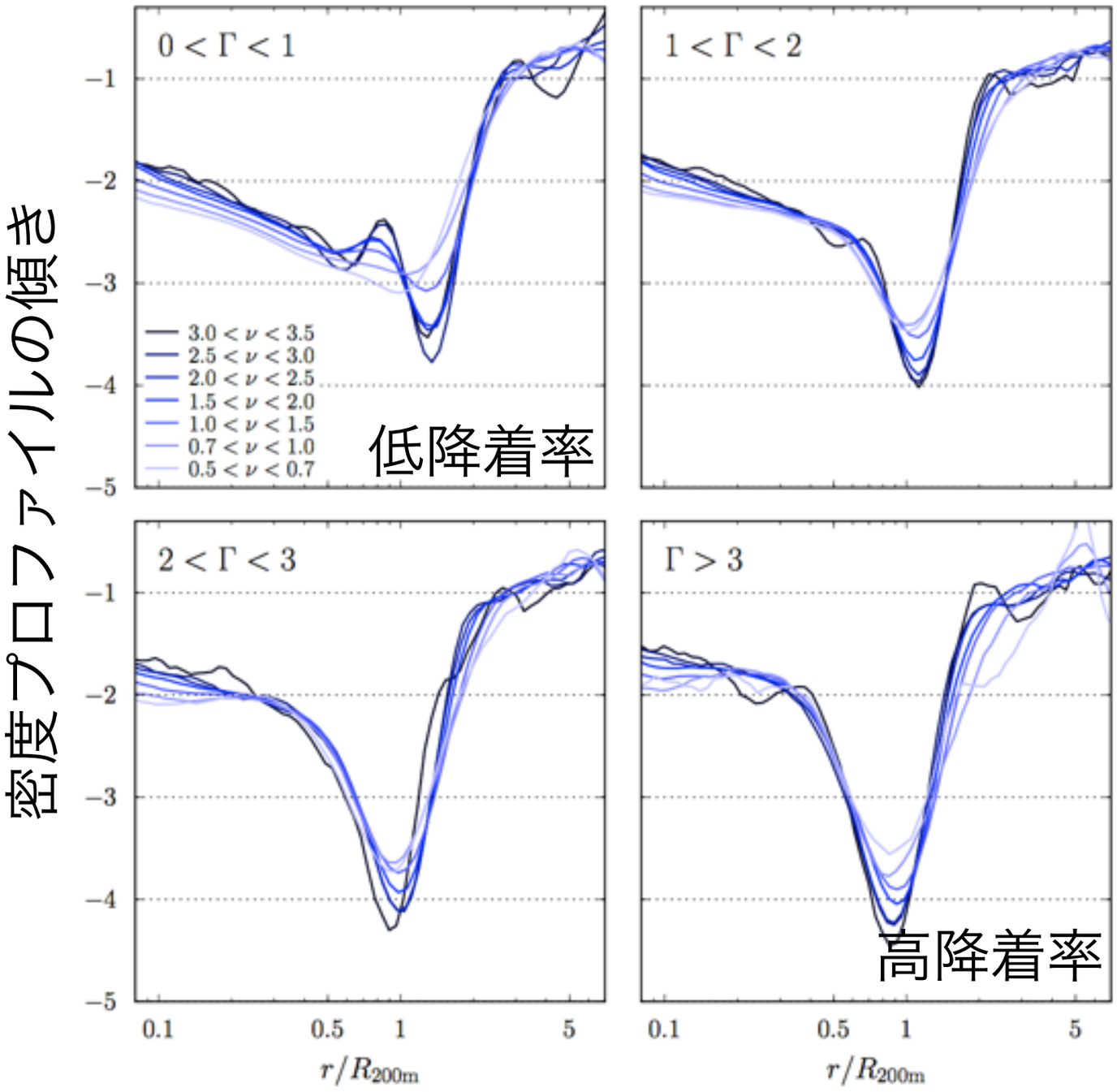
Adhikari++2014



splashback radius:
最初に到達した遠日点

銀河団境界領域の密度プロファイル

Diemer & Kravtsov 2014



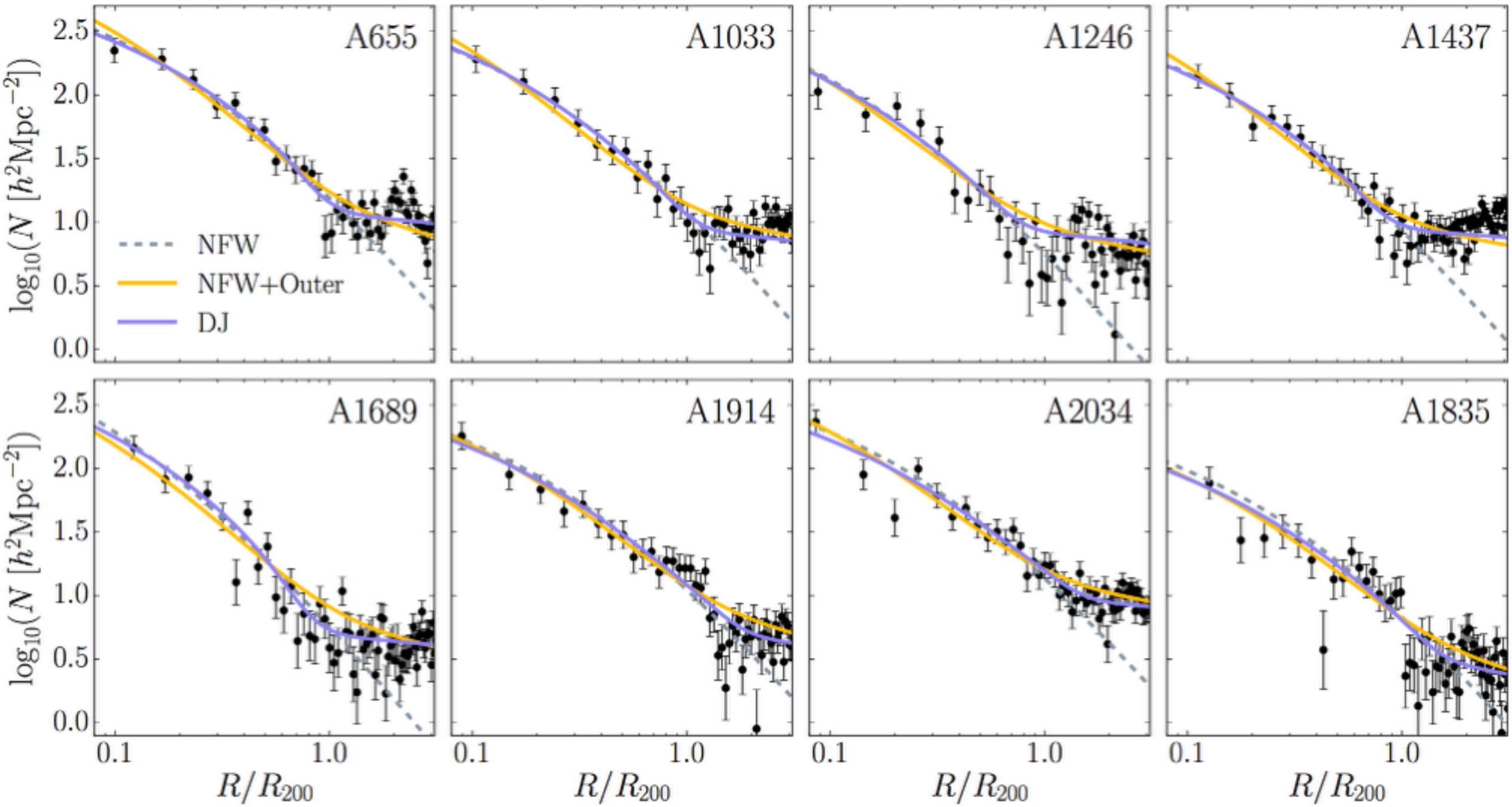
- r > Rspで急激な密度飛躍
- 密度プロファイルは質量降着率 Γ に大きく依存

$$\Gamma \equiv \mathrm{d}\log M_{\mathrm{vir}}/\mathrm{d}\log a$$

$$n_{\mathrm{DK}}(r) = n_{\mathrm{in}}(r)\left[1+\left(\frac{r}{r_t}\right)^{\beta}\right]^{-\frac{\gamma}{\beta}} + n_m\left[b_e\left(\frac{r}{5R_{200}}\right)^{-s_e}+1\right]$$

$$r_t = \left(0.62 + 1.18e^{-2\Gamma/3}\right) \times R_{200}$$

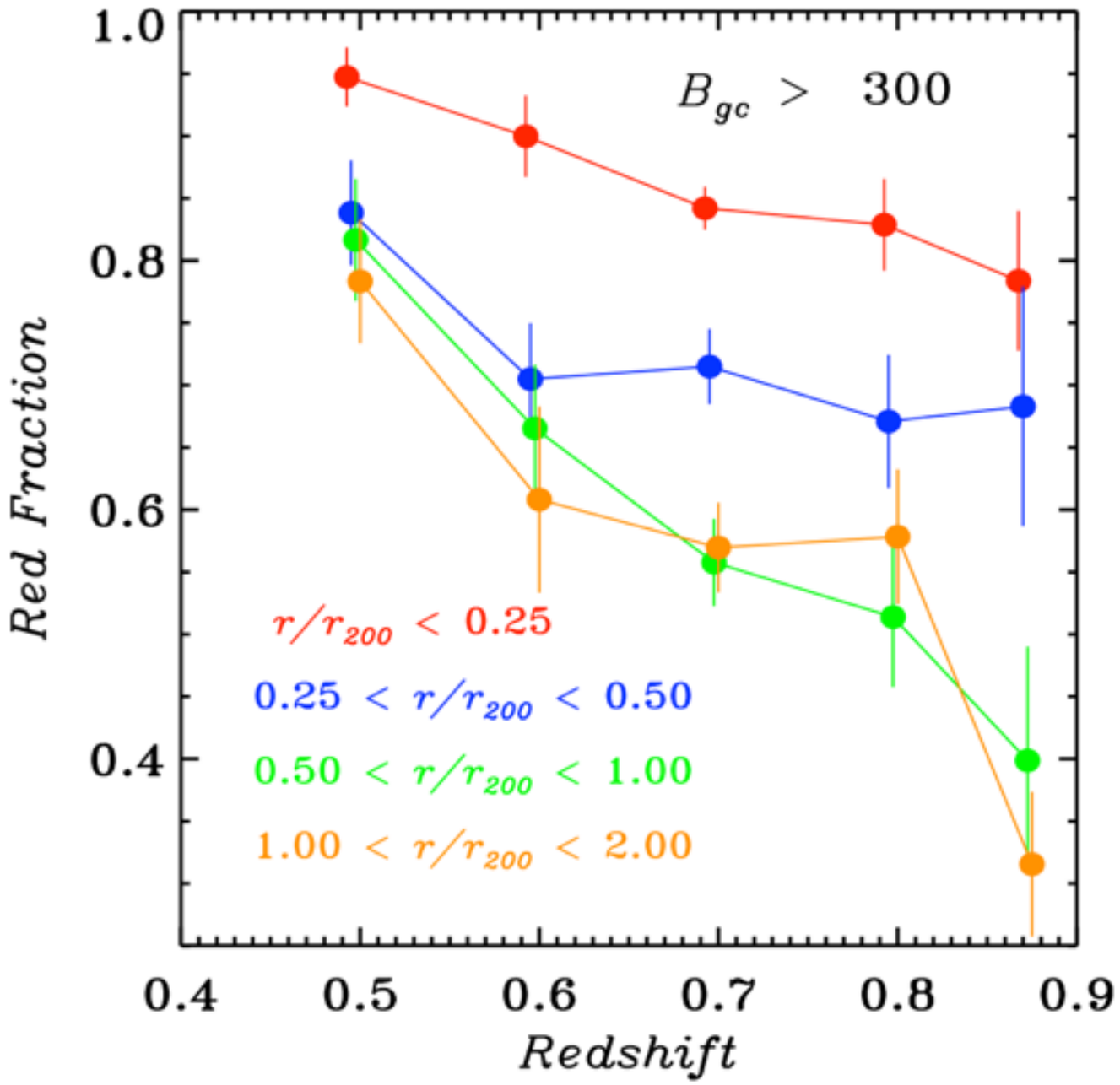
銀河団プロファイル(SDSS)



Patej & Loeb 2015

銀河団プロファイル(HSC) by スタック解析

red fraction：赤い(古い)銀河の割合

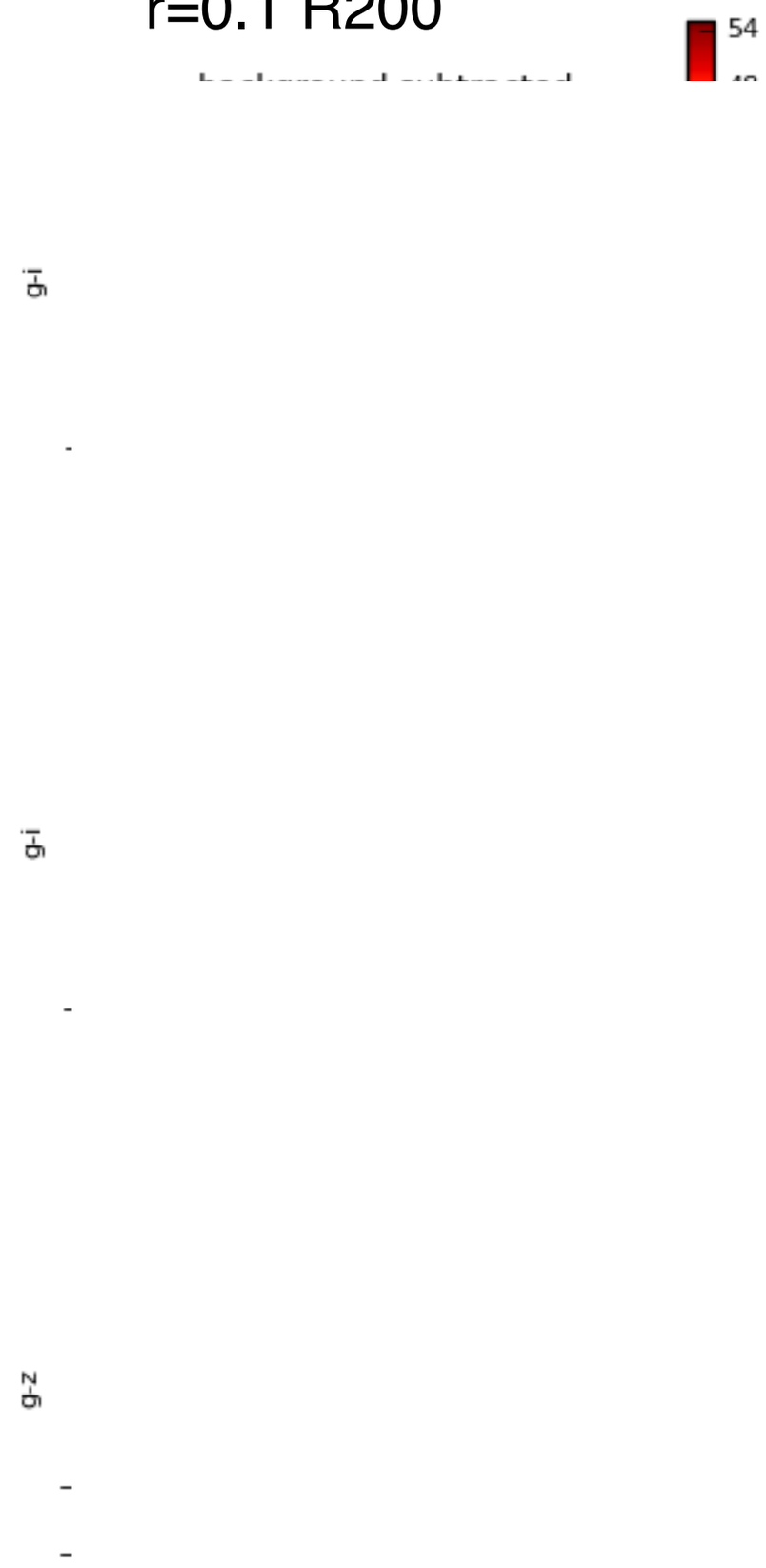


Loh++ 2008

- 赤い銀河ほどより中心部にいる
- 赤い銀河の割合はhihg-z (できて間もない)銀河団では小さい

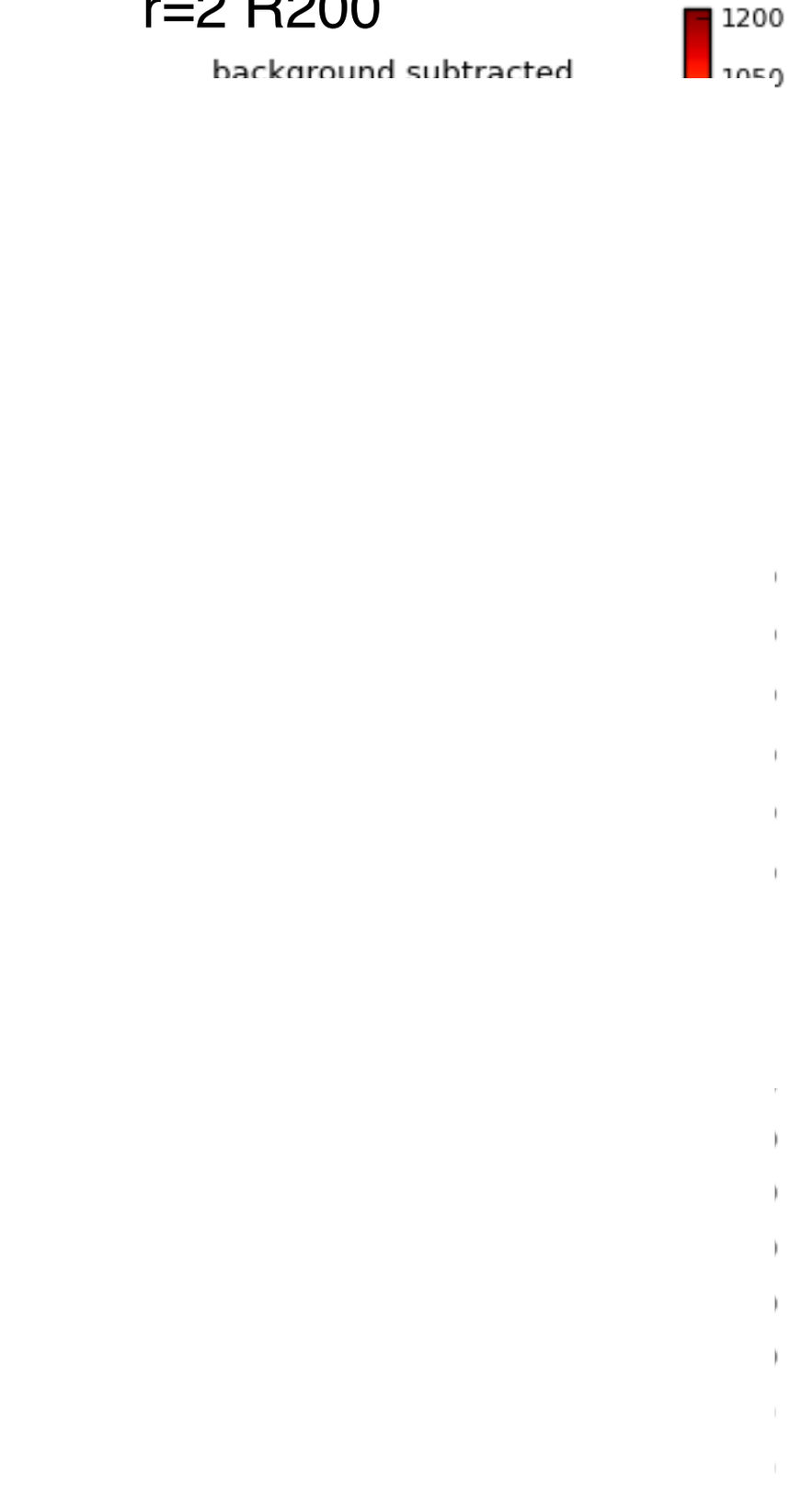
red fraction：赤い(古い)銀河の割合

r=0.1 R200



r=R200

r=2 R200



summary

- Red-Sequence (RS) galaxies are used to probe a precision of the photometry.
- Compared with SDSS, HSC shows very accurate photometry.
- Composite cluster method with background subtracted can be used for extend the analysis to fainter magnitude, higher redshifts, where HSC photometry is comparable or larger than the RS intrinsic scatter.
- Composite cluster method can be applied to measure the density profile of the cluster, red fraction…
- Density jump at ~2R_200 is found