Distances and stellar population properties in galaxies from

Surface Brightness Fluctuations (SBF) analysis

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Accurate galaxy distances remain of fundamental importance to most astrophysical applications. Errors in distance estimates generally translate into equal or larger fractional uncertainties in derived quantities such as masses (of everything from central black holes to dark matter haloes), linear sizes, dynamical timescales, star formation rates, and ages. Thus, accurate distance estimation is essential for inter-comparing the physical properties of galaxies in the local volume where redshift is not a reliable indicator of distance and for comparing the properties of nearby galaxies to those at high redshift. Of course, they are also essential for mapping local three-dimensional structures and velocity fields. (Blakeslee et al., 2010)

SBF 101

The basic idea…

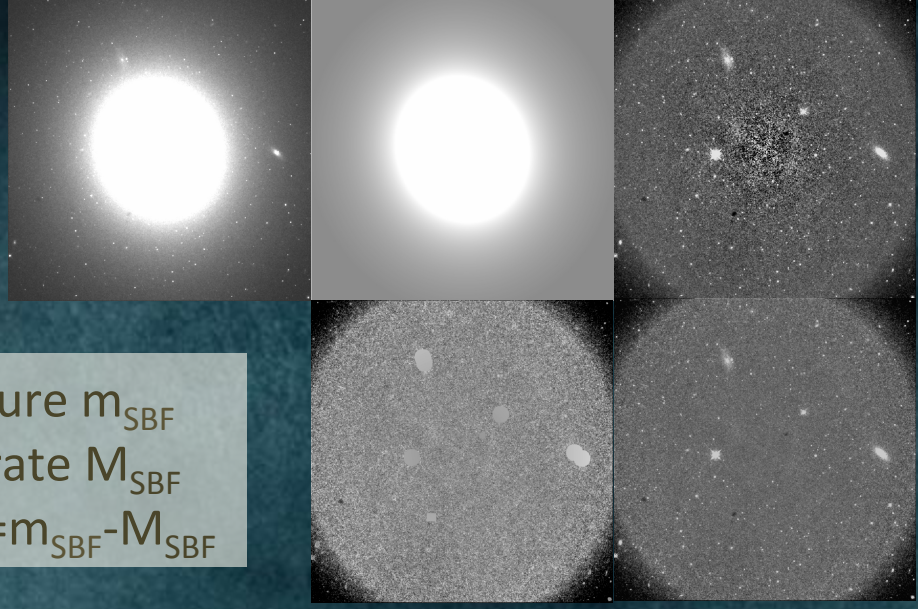
Closer => mottled light profile

Farther => Smoother light profile

Smoothness $\propto$ distance

SBF How-to…

$$[n, f] \Rightarrow f_{SBF} \equiv \sum_i n_i f_i^2 / \sum_i n_i f_i$$



NGC1399 WFC3/IR

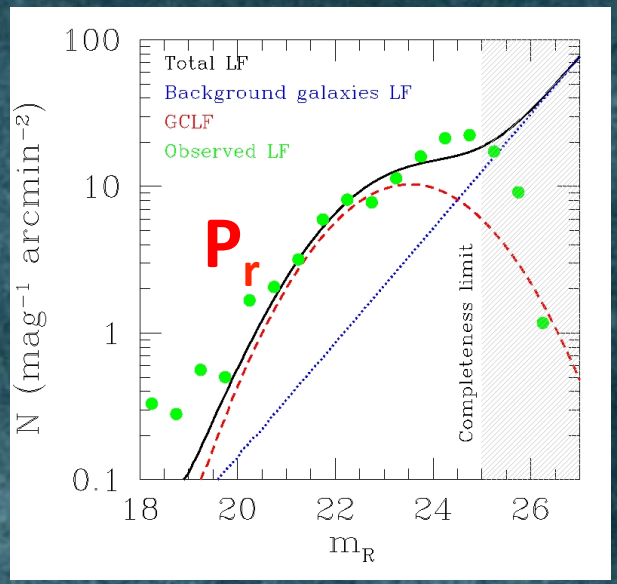
SBF Measurement

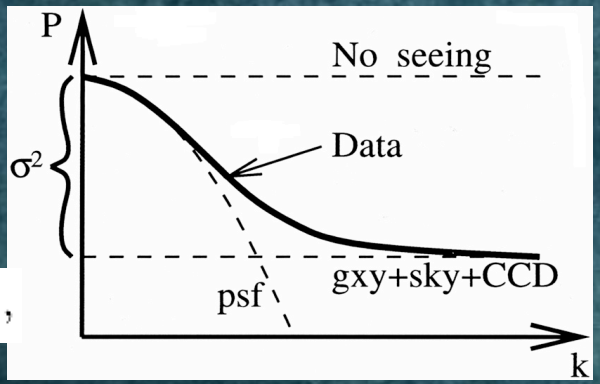
(Tonry & Schneider, 1988; Tonry et al., 1990)

1. Model the galaxy
2. Original minus Model
3. Mask all internal (GCs, dust) and external sources of non-stellar fluctuations.
4. Estimate the amplitude of the fluctuation in the Fourier domain
5. Subtract to the total fluctuation flux the contribution from un-excised sources

- ✓ Measure m_{SBF}
- ✓ Calibrate M_{SBF}
- ✓ $m-M=m_{SBF}-M_{SBF}$

$$\bar{m}_X = -2.5 \log (P_0 - P_r) + m_{zero}^X,$$





$$P(k) = P_0 E(k) + P_1,$$

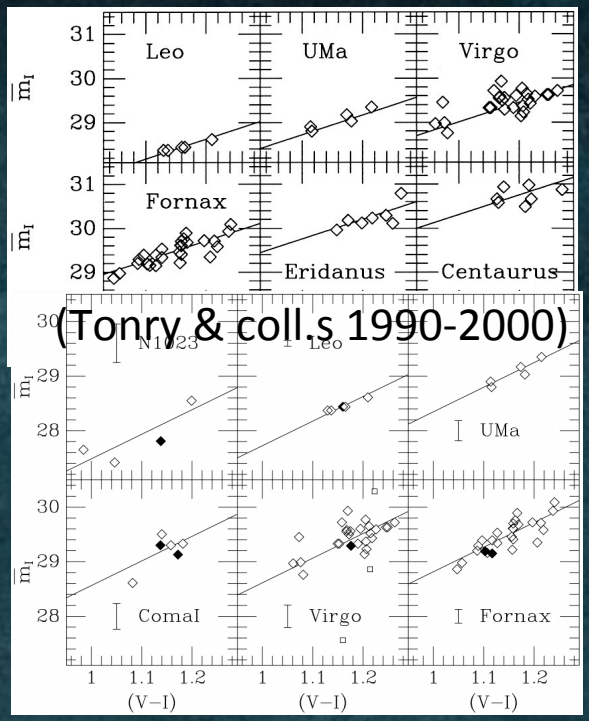
Calibrations

$$[n, f] \Rightarrow f_{SBF} \equiv \sum_i n_i f_i^2 / \sum_i n_i f_i$$

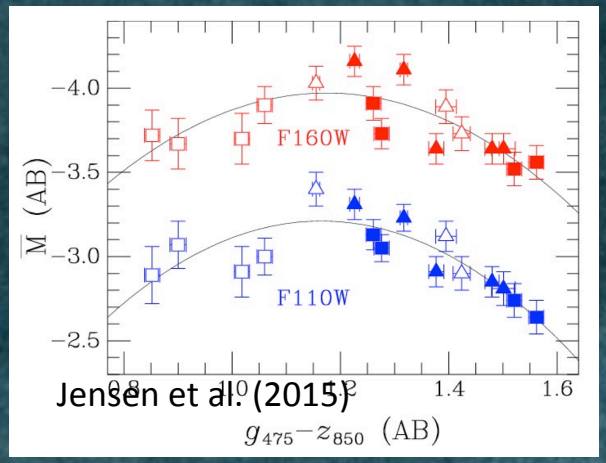
M_{SBF} ~ mean luminosity of RGB stars

First I-band Calibration:
M_{SBF}=-1.74(±0.16)+4.5(±0.25)[(V-I) -1.15]

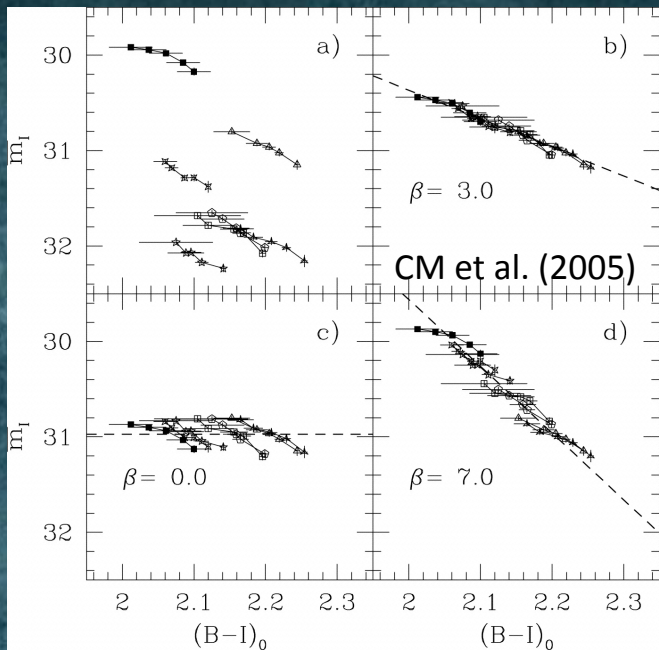
1. Measure m_{SBF}
2. **Calibrate M_{SBF}**
3. $m-M=m_{SBF}-M_{SBF}$



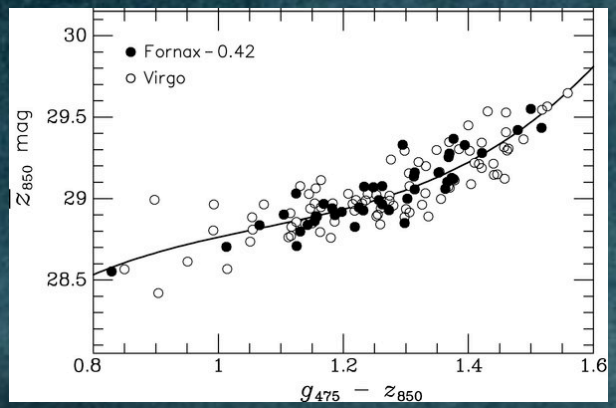
(Tonry & coll.s 1990-2000)



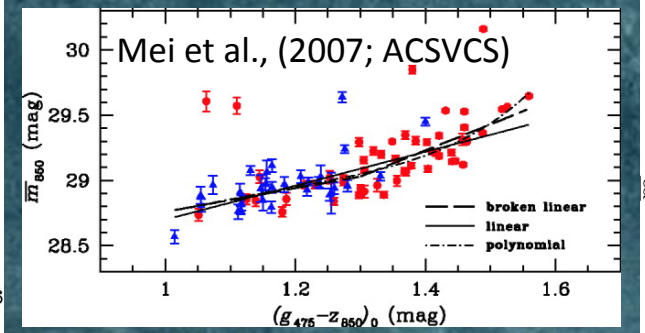
Jensen et al. (2015)



CM et al. (2005)



Blakeslee et al., (2009; ACSVCS & ACSFCS)



Mei et al., (2007; ACSVCS)

Taken from *LSST Science Book*

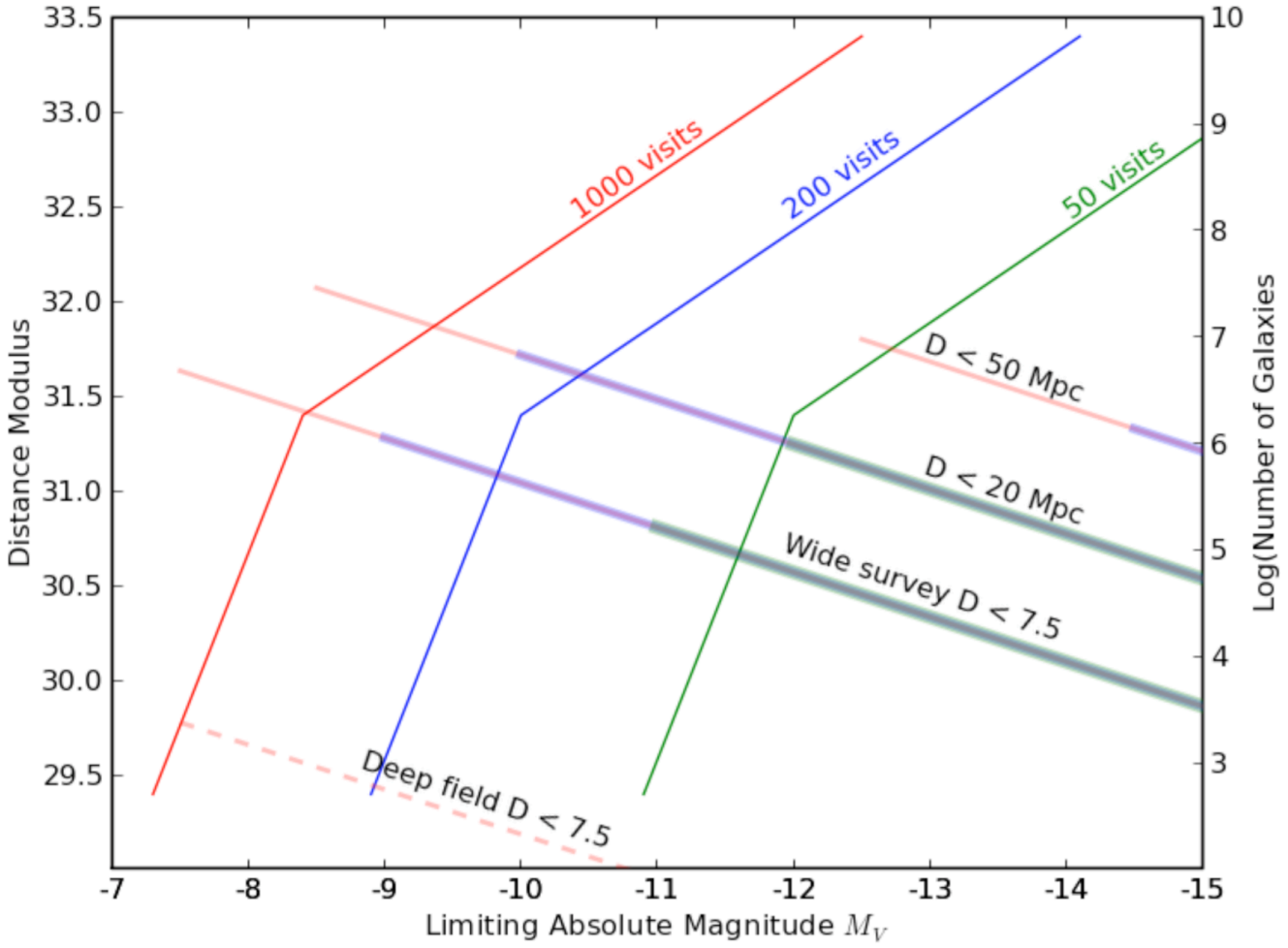
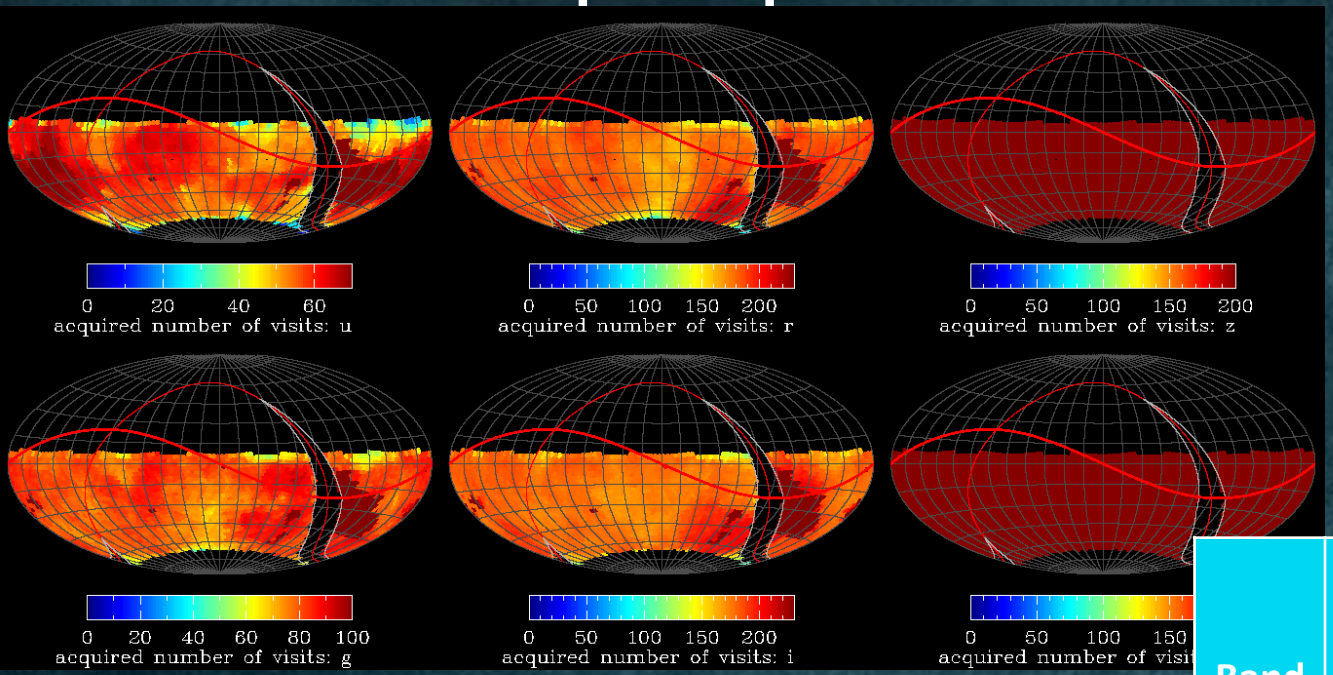


Figure 9.12: LSST surface brightness fluctuations, whereby mottling of the galaxy image due to the finite number of stars in each pixel is a measure of the distance to the galaxy. The curves moving upwards to the right show distance modulus vs. absolute magnitude for distance modulus determination to a precision of 0.5 mag for 50, 200, and 1,000 r-band visits (the latter appropriate to the deep drilling fields). This is derived by scaling from the realistic image simulations of Mieske et al. (2003), which include the effects of photon statistics, resolution, and image size. The curves moving upwards to the left show the expected number of galaxies in a 20,000 deg^2 survey (solid lines) or a 10 deg^2 deep-drilling field with 1,000 visits (dashed line near the bottom). Numbers are based on the luminosity function of Croton et al. (2005).

The LSST perspective



Number of Visits for the Deep & Wide survey

$T_{exp} \sim 5 \times 10^{0.4(DM-M_{sbf}-ZP_{mag})}$

(Blakeslee et al.,1999)

- ✓ M_{sbf} ~5/2.2/0.6/-0.5/-1.8/-2.4 u/g/r/i/z/y_N
  (Teramo SPoT models, G. Raimondo & E. Brocato)
- ✓ ZP_{mag} LSST web-pages

Instrumental Zeropoints

We can also use the above formula to calcula
magnitude which would produce one count p
DU = c

u	26.50
g	28.30
r	28.13
i	27.79
z	27.40
y	26.58

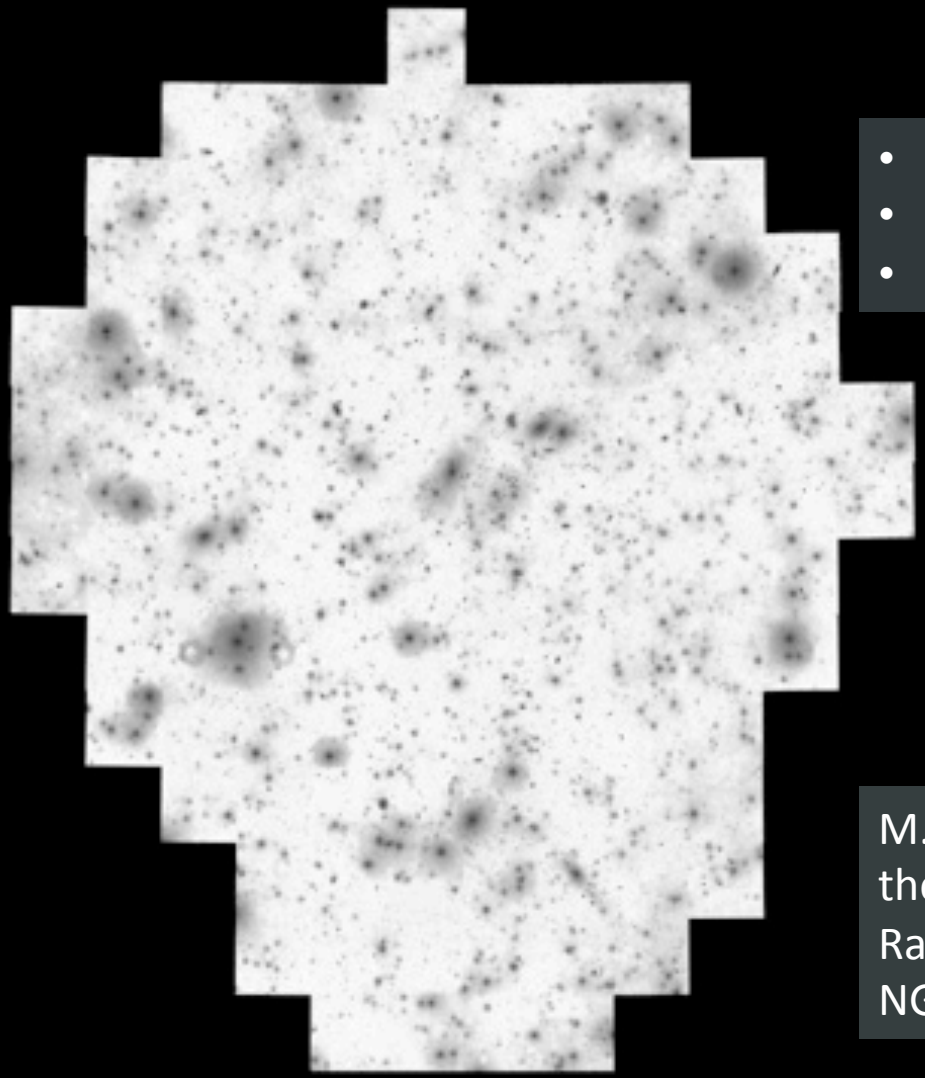
Number of targets reached? >>10^5

Band	N. of visits (15s)	Max Distance modulus	Max D (Mpc)
u	70	28-30?	4-10?
g	100	>32	>25
r	230	~35	~100
$r_{D.D.}$	1000	~36.5	~200
i	230	~36	~150
z	200	>36	>150
y	200	>36	>150

NGVS

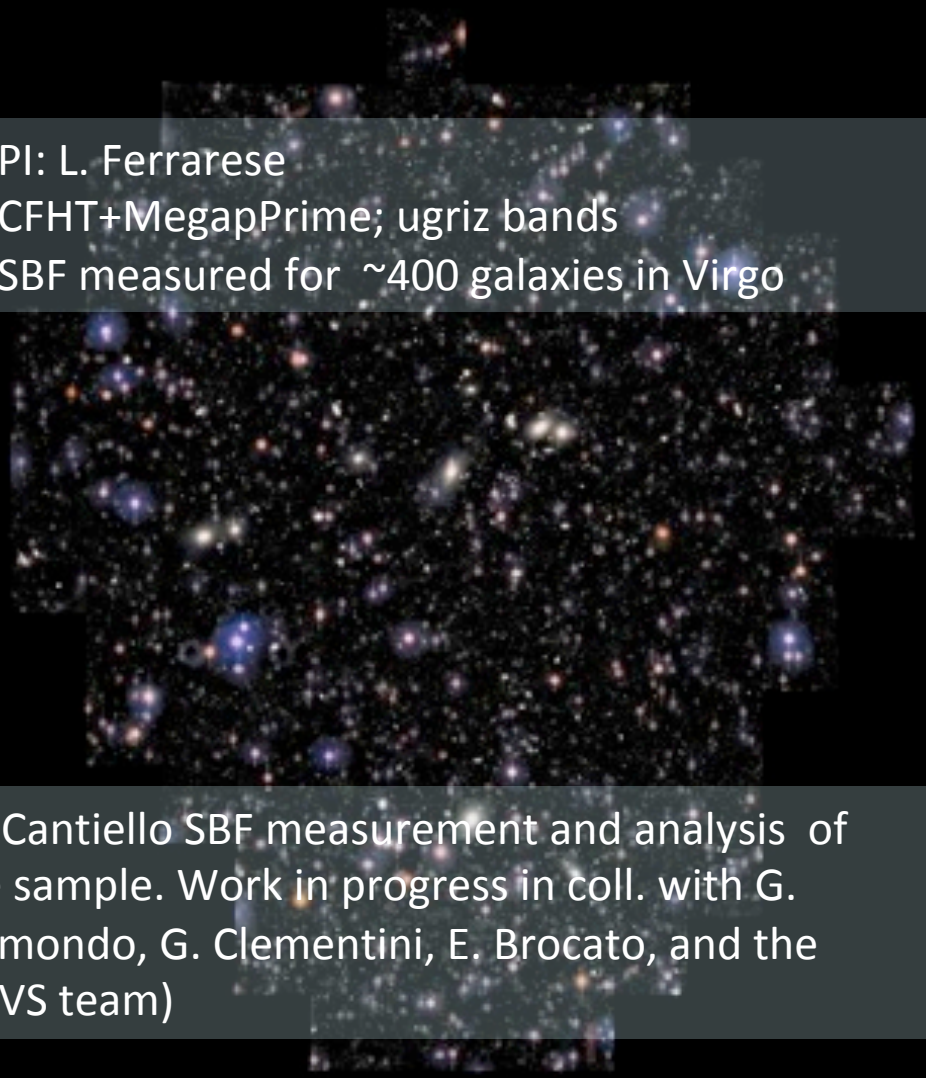
The Next Generation Virgo Cluster Survey

The NGVS is five-year large program with MegaCam on CFHT (2009/2013)



Completed 104 sq. deg. mosaic in MegaCam g'-band
Image quality: 0.8", 53 mn integration per 0.187" pixel
Point source detection at SNR=5: g'=26.2

- PI: L. Ferrarese
- CFHT+MegapPrime; ugriz bands
- SBF measured for ~400 galaxies in Virgo



Completed 104 sq. deg. mosaic in MegaCam g'i'z' bands
Image quality: 0.8", 0.6", 0.7" (53/34/64 mn per pixel)
Point source detection at SNR=5: g'=26.2 i'=24.9 z'=24.2

M. Cantiello SBF measurement and analysis of the sample. Work in progress in coll. with G. Raimondo, G. Clementini, E. Brocato, and the NGVS team)

Conclusions - Pros & Cons

- **USER DATA PRODUCT**: (u)grizy SBF for:
  - ✓ Distance estimates out to ~150 Mpc. Even deeper for the “drilled” fields
  - ✓ Stellar population characterization, via SBF colors & gradients
  - ✓ 3D-mapping of southern sky galaxies within ~150 Mpc with accuracy <5%
  - ✓ Gaia+2-color calibration
- Automatized procedure for measuring SBF to tens of thousands (or way more) galaxies