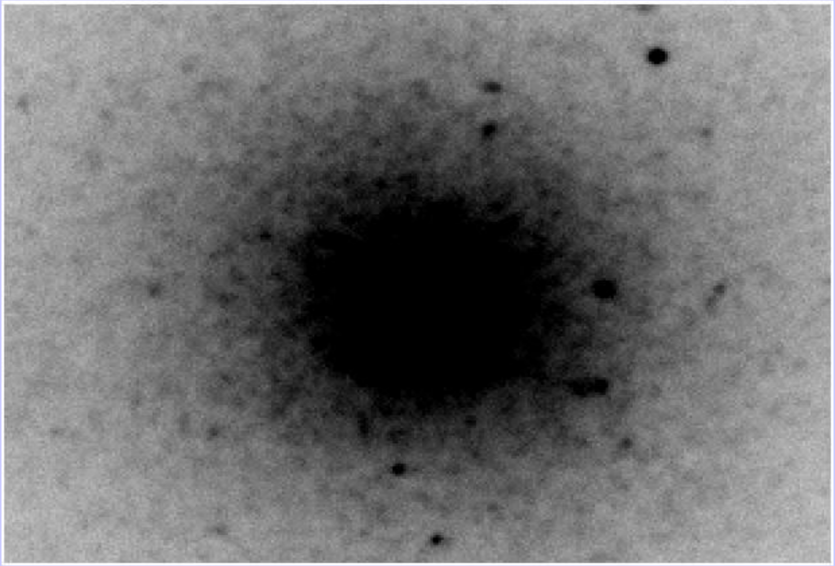
Cosmic flow studies with the ELT: How far does the SBF method reach?



(courtesy K. Flint)

Steffen Mieske
ESO

Towards the European ELT. 27th Nov - 1st Dec 2006, Marseilles.

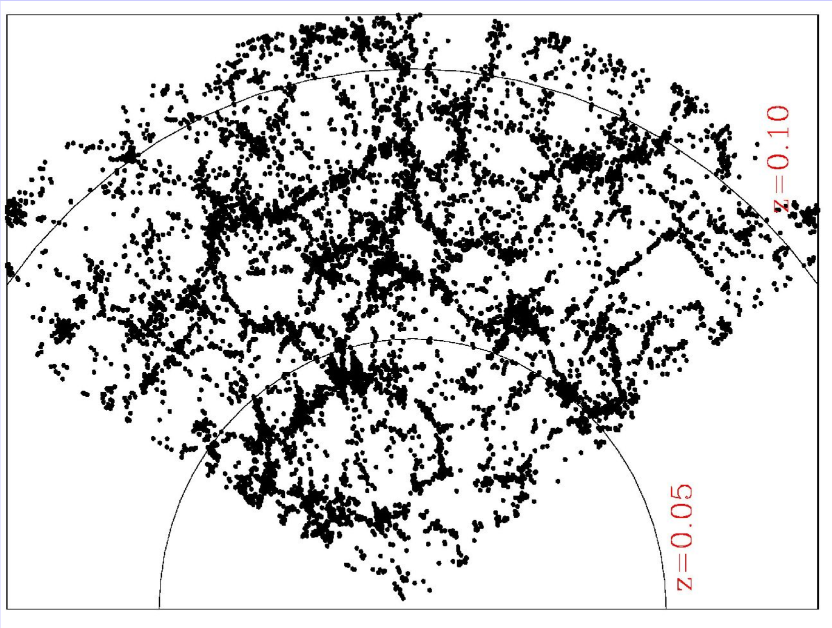
Outline:

1. Scientific background
2. Principle of Surface Brightness Fluctuations (SBF)
3. Limits for accurate SBF distances with a 42m ELT
4. Conclusions

1. Scientific Background

Aim of nearby galaxy distance measurements:

- **Calibration of local Hubble constant (H_0)**
- **Anisotropies in flow field ("Great Attractor"):**
  Test for structure formation theories



z=0.1:

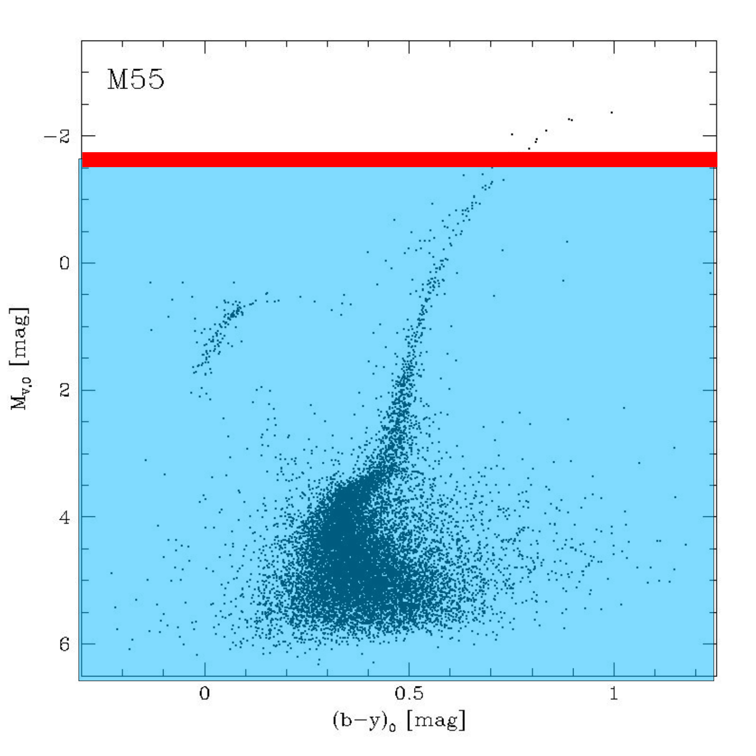
(m-M)=38 mag

d=400 Mpc

Rosenbaum et al. 2004

1. Scientific Background

The fundamental limit of most primary distance indicators is the need to resolve the stellar population of a galaxy into single stars.



DETECTION LIMITS TRGB:

VLT: (m-M)=28 mag (4 Mpc)

HST: (m-M)=31 mag (16 Mpc)

ELT: (m-M)=35 mag (100 Mpc)

Even at 100 Mpc:

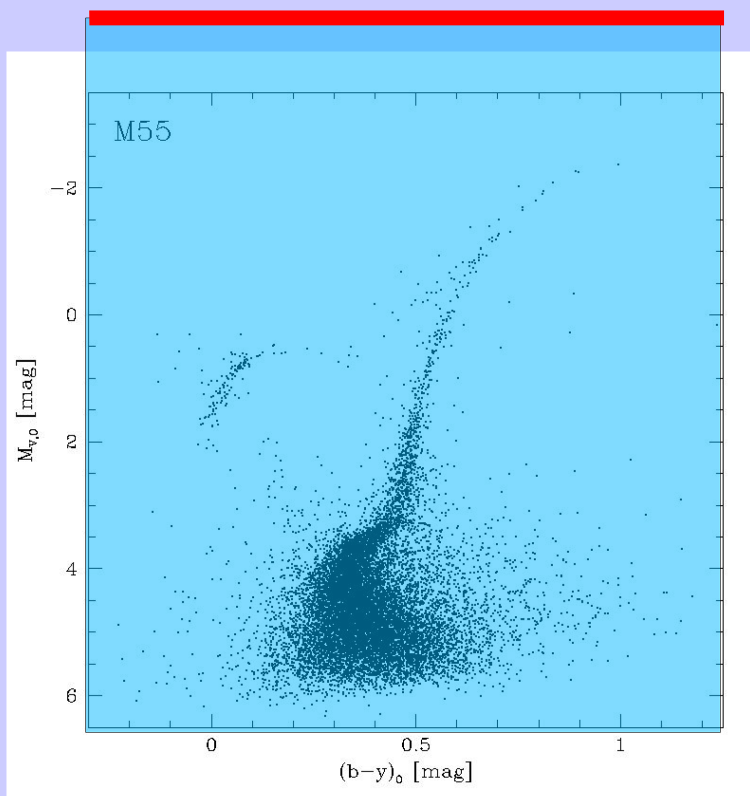
Peculiar velocity level ~10%.

Hilker, private comm.

1. Scientific Background

Wouldn't it be great to go even further?

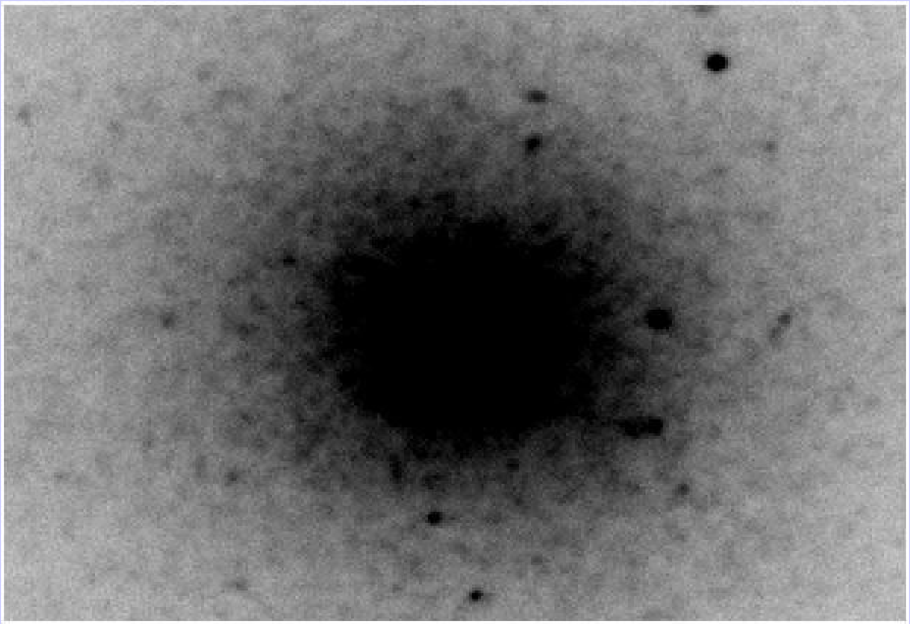
(and not have to bother measuring Cepheid light curves)



Hilker, private comm.

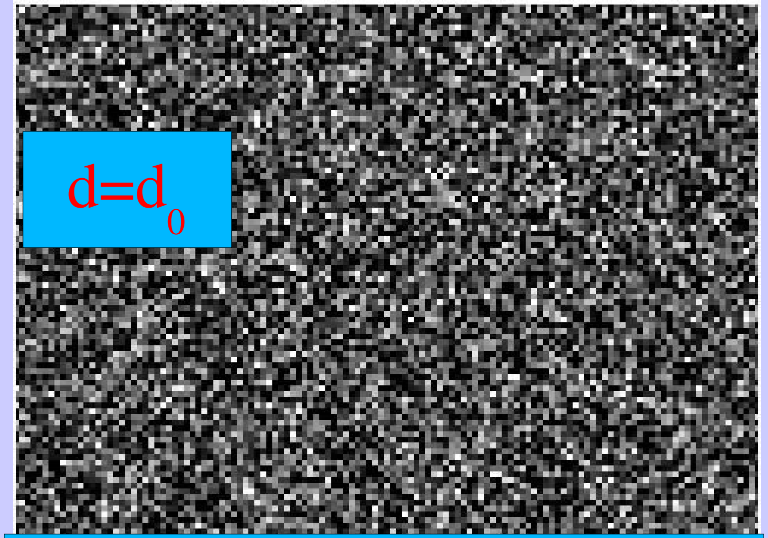
2. Principle of SBF

Surface Brightness Fluctuations are caused by the statistical fluctuation of the number of stars per resolution element (Tonry & Schneider 1988).

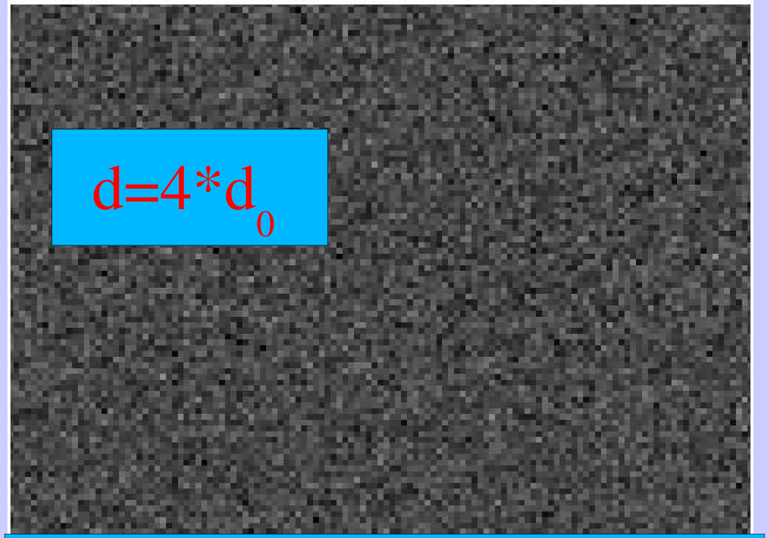


2. Principle of SBF

How can one measure distances with SBF?
Assume image of galaxy region with constant surface brightness. No atmosphere nor detector noise:



100 stars per pixel
Fluctuations ~ 10%

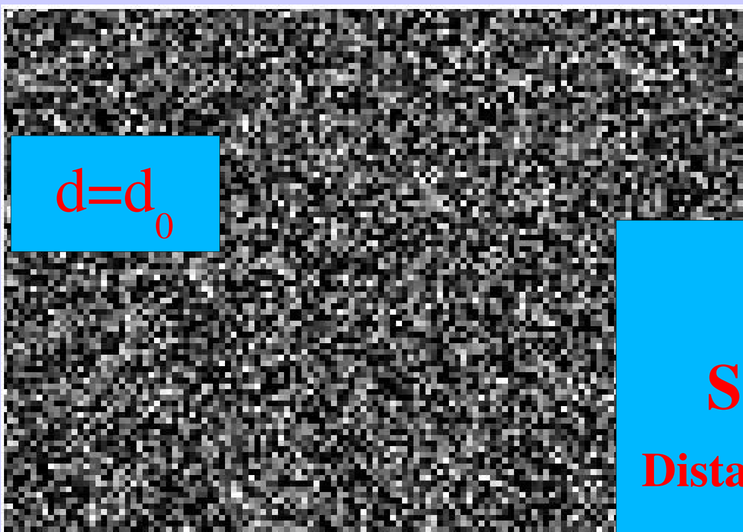


1600 stars per pixel
Fluctuations ~ 2.5%

2. Principle of SBF

How can one measure distances with SBF?

Assume image of galaxy region with constant surface brightness. No atmosphere nor detector noise:



100 stars per pixel

Fluctuations ~ 10%

$SBF \propto d^{-1}$

Distance indicator!

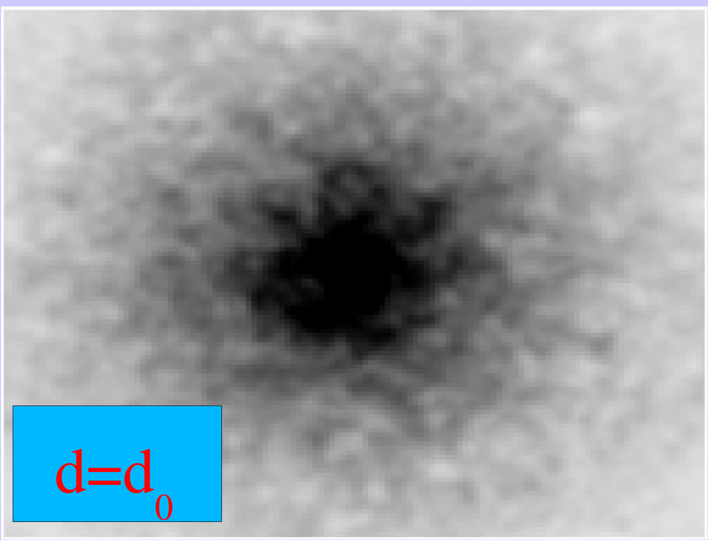
1600 stars per pixel

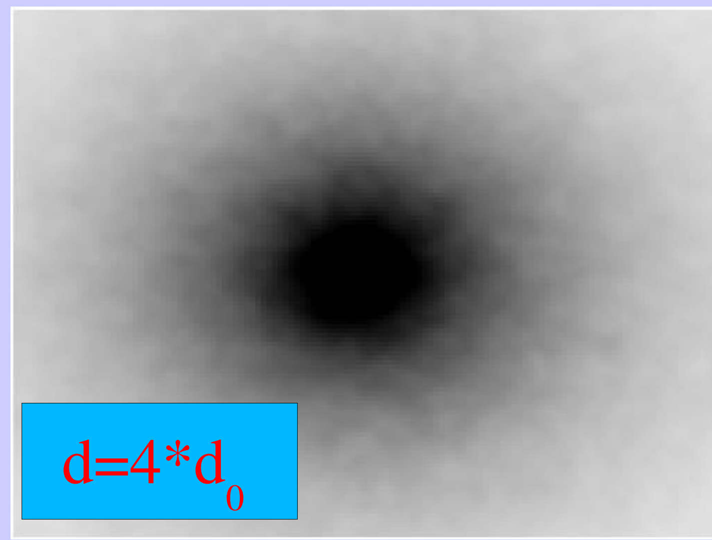
Fluctuations ~ 2.5%

2. Principle of SBF

SBF issues in practise:

1. **Atmosphere.** *Fluctuations are convolved with PSF*
2. **Galaxy morphology.** *Subtract light model and normalize*

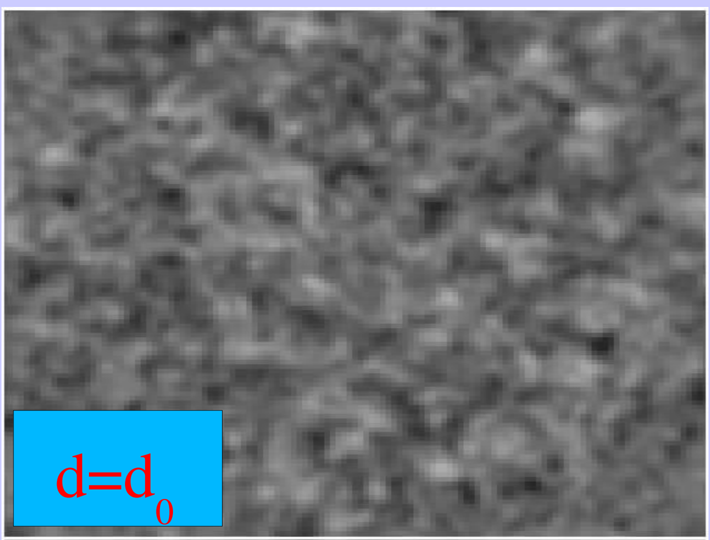


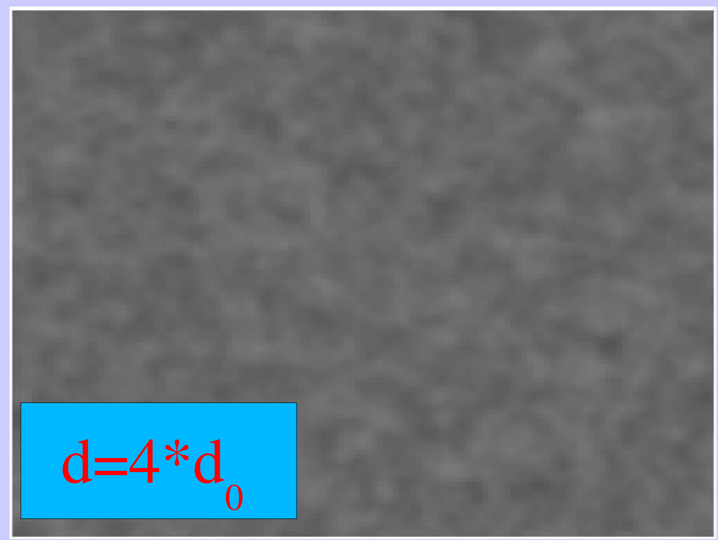


2. Principle of SBF

SBF issues in practise:

1. Atmosphere. ***Fluctuations are convolved with PSF***
2. Galaxy morphology. ***Subtract light model and normalize***

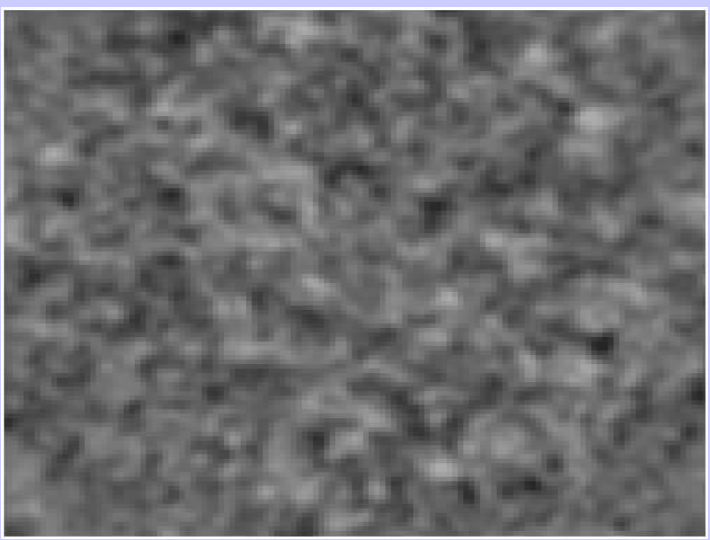




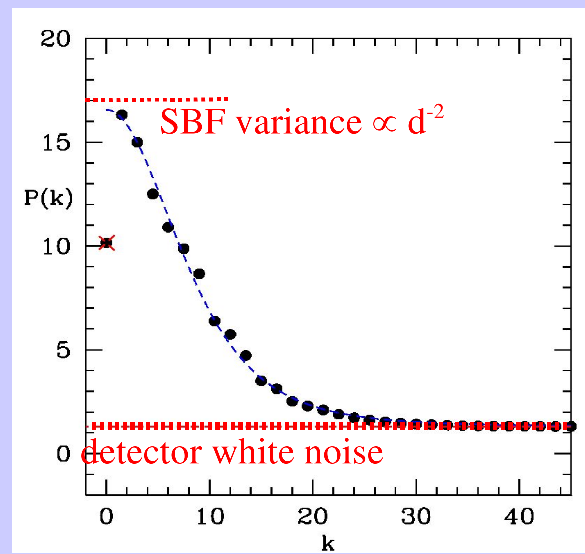
2. Principle of SBF

SBF issues in practise:

1. **Atmosphere.** ***Fluctuations are convolved with PSF***
2. **Galaxy morphology.** ***Subtract light model and normalize***
3. **Detector.** ***Poisson noise on top of SBF***



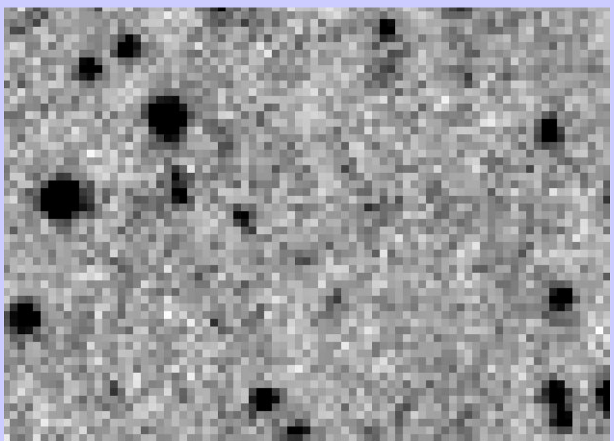
power spectrum



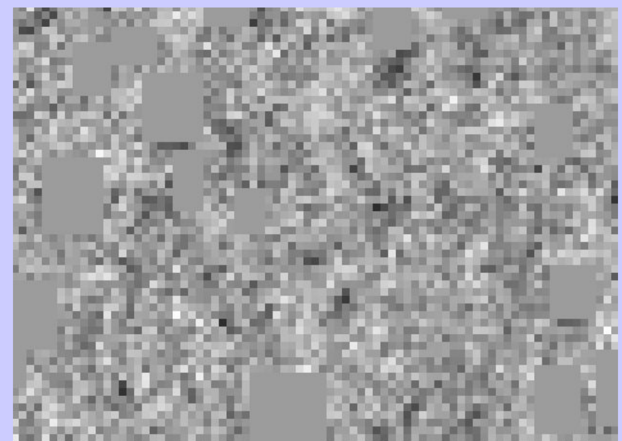
2. Principle of SBF

SBF issues in practise:

1. **Atmosphere.** ***Fluctuations are convolved with PSF***
2. **Galaxy morphology.** ***Subtract light model and normalize***
3. **Detector.** ***Poisson noise on top of SBF***
4. **Globular clusters.** ***Contaminate the signal if undetected***



Fluctuations + globulars

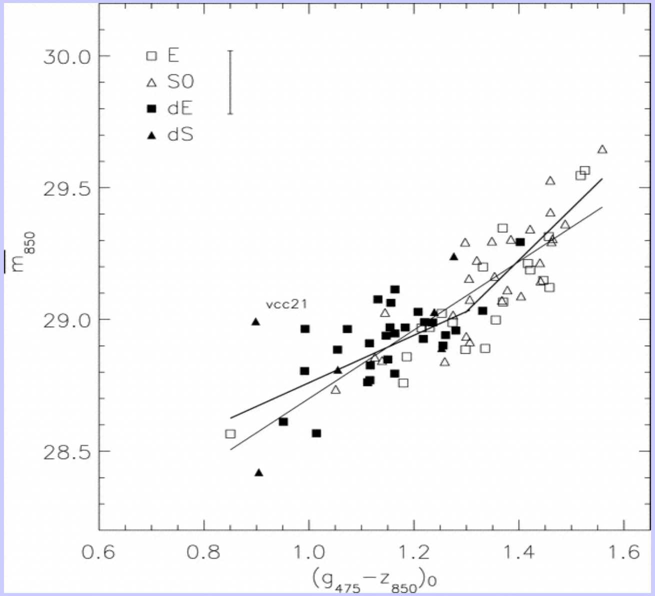


Fluctuations with masked globulars

2. Principle of SBF

SBF issues in practise:

1. **Atmosphere.** ***Fluctuations are convolved with PSF***
2. **Galaxy morphology.** ***Subtract light model and normalize***
3. **Detector.** ***Poisson noise on top of SBF***
4. **Globular clusters.** ***Contaminate the signal if undetected***
5. **Calibration based on colour.** ***≥ 0.10 mag uncertainty***



Mei et al. 2005
(ACS Virgo cluster survey)

2. Principle of SBF

Boundary conditions for reliable SBF distances:

1. SBF variance 2-3 times higher than photon noise
2. Undetected GCs contribute $\leq$ 0.4 mag to SBF signal

Then: SBF signal can be measured to $\leq$ 0.2 mag precision.

Inevitable: calibration uncertainty 0.1-0.2 mag

<u>Distance accuracy ~ 0.25 mag.</u>

3. Limiting SBF distances with ELT

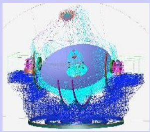
Simulate SBF in a giant elliptical galaxy (Fe/H=0) in a few (kpc)^2 region with $\mu_{eff,I}$ (~ 20 mag/”^{2}).

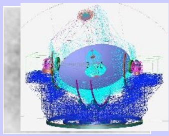
Aim: Investigate S/N of SBF signal and GC crowding

3 distances:	**36, 37, 38 mag (160 to 400 Mpc)**
Observing Mode:	**42m ELT. GLAO/LTAO in I/K**
Integration time:	**1 hour. Survey, not single objects.**
SBF calibration:	**Tonry et al. 2001, Liu et al. 2003**

Do without GLAO simulations for 37 and 38 mag because GC contribution to the fluctuations too high (>0.7 mag). For LTAO, GC contributions <0.4 mag for all distances.

0.35

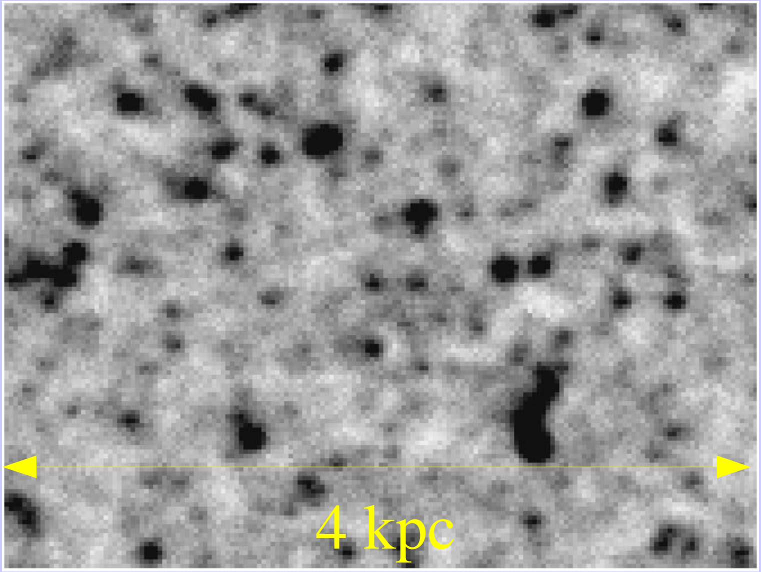




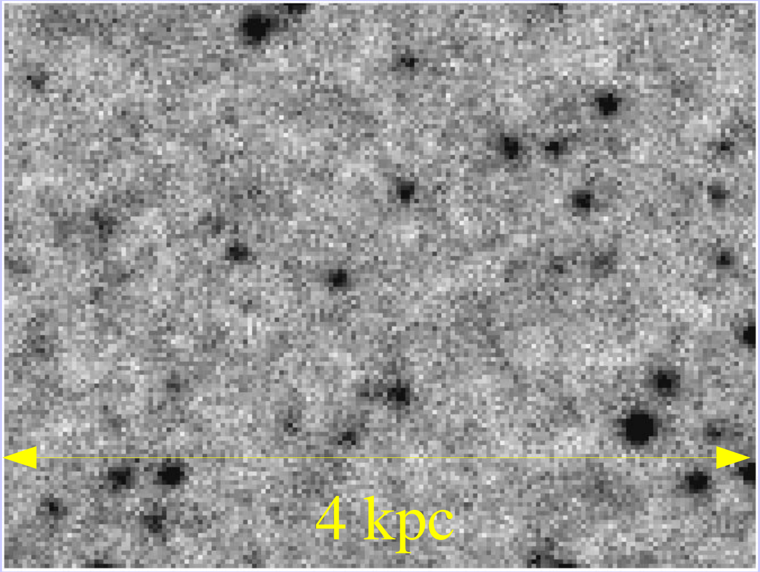
3. Limiting SBF distances with ELT

I-GLAO, (m-M)=36 mag (100 mas pixel):

@ $_{eff}$: S/N=7



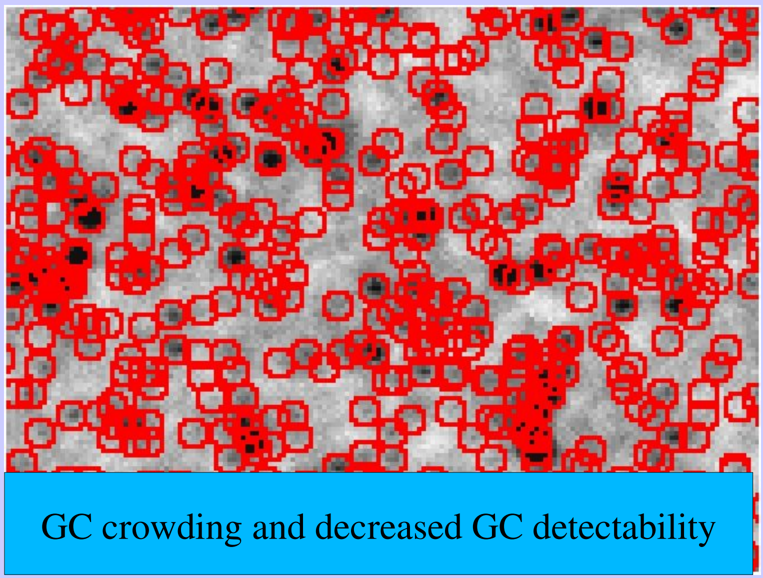
@($_{eff}$+2 mag): S/N=2.5

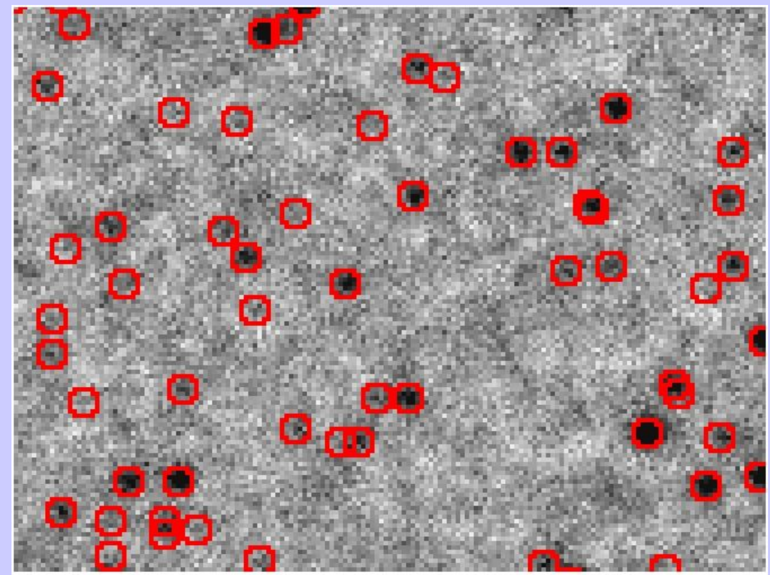


3. Limiting SBF distances with ELT

I-GLAO, (m-M)=36 mag (100 mas pixel):

@ $_{eff}$: S/N=7 **@(μ_{eff}+2 mag): S/N=2.5**



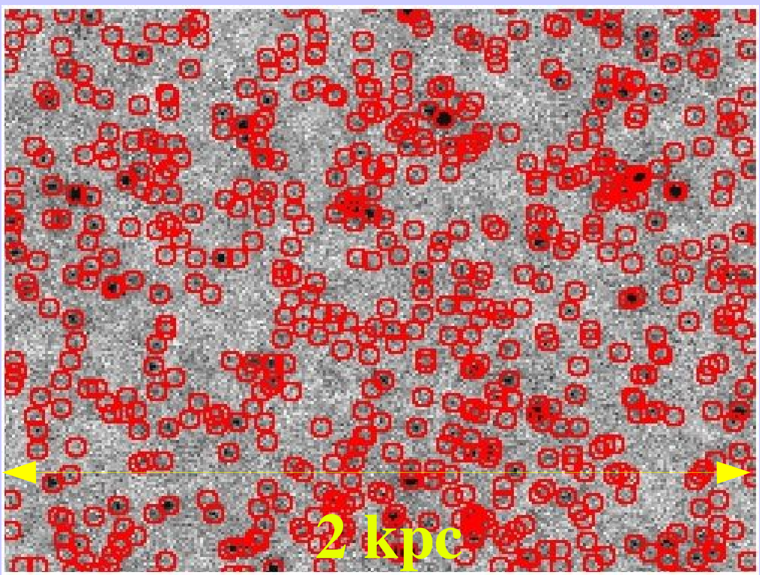


I-GLAO @ (m-M)=36 mag just about possible when measuring in outer regions of the galaxy

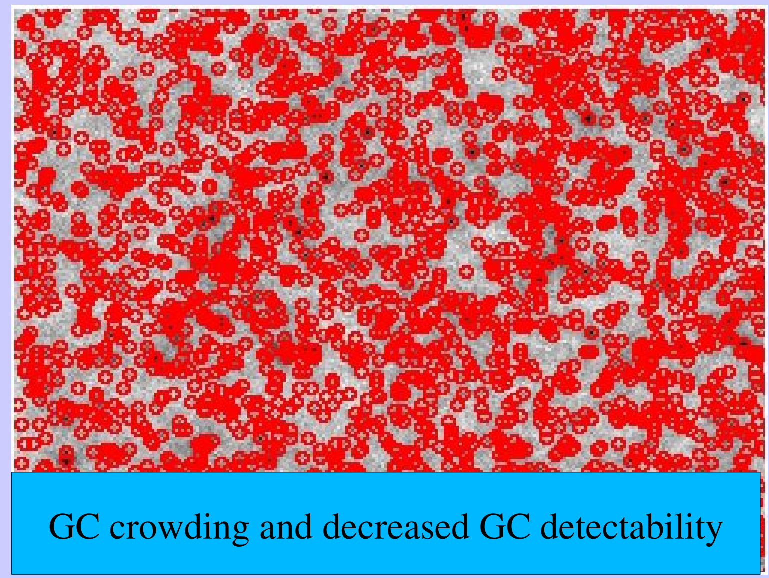
3. Limiting SBF distances with ELT

K-GLAO, (m-M)=36 mag (50 mas pixel):

@ $_{eff}$: S/N=1.5



@($_{eff}$-1.5 mag): S/N=2.9

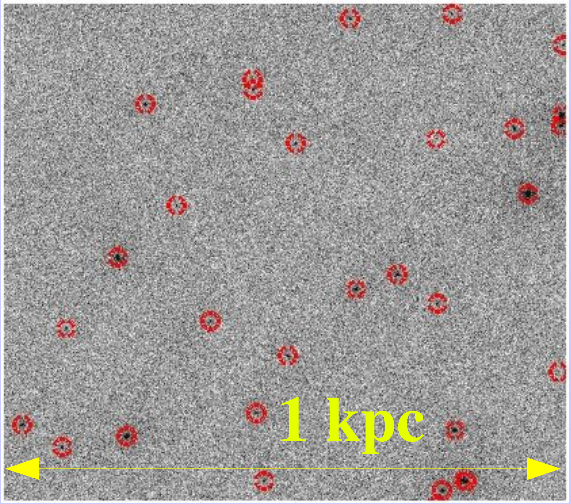


K-GLAO @ (m-M)=36 mag very difficult because of low S/N and GC crowding.

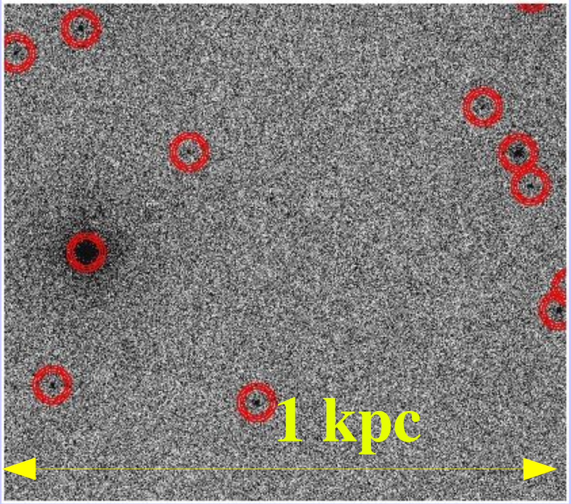
3. Limiting SBF distances with ELT

I-LTAO, (m-M)=36, 37, 38 mag (5 mas pixel), @ $_{eff}$:

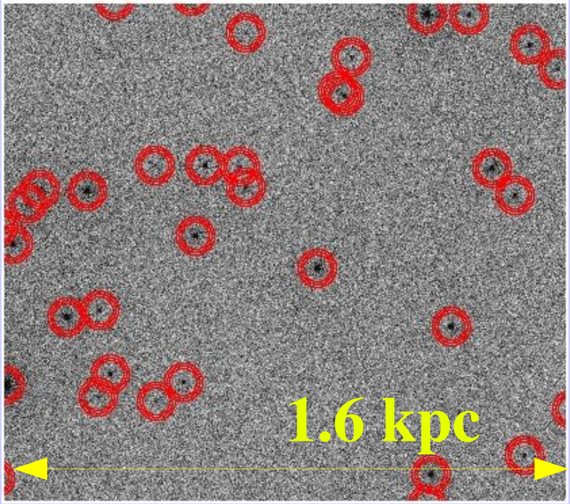
36 mag: S/N=5.7



37mag: S/N=3.6



38 mag: S/N=2.3

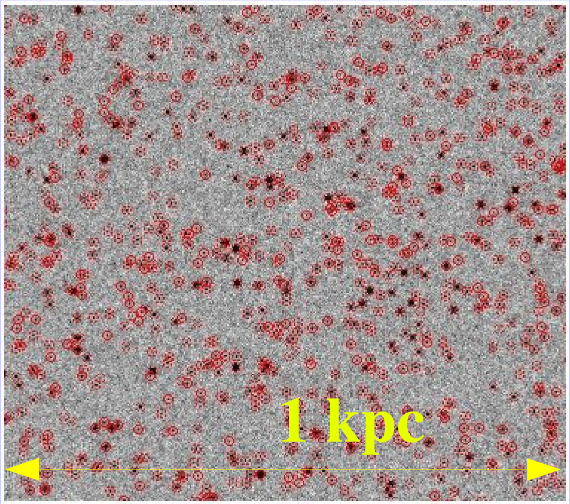


I-LTAO feasible at (m-M)=36 and 37. At 38 mag, about S/N limit reached (integration time >1h needed).

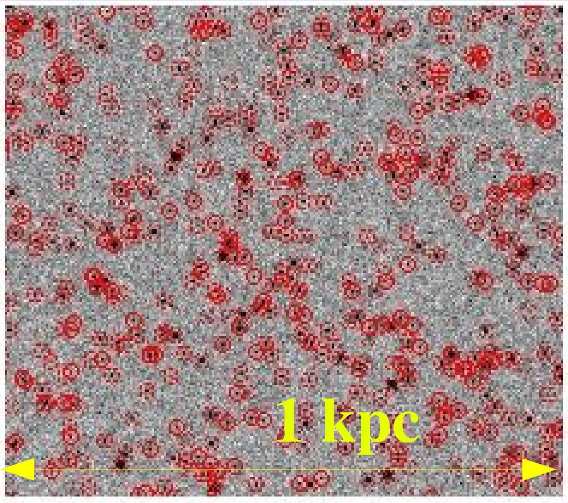
3. Limiting SBF distances with ELT

K-LTAO, 5 mas pixel, <u>but</u> @ ($_{eff}$-2) mag:

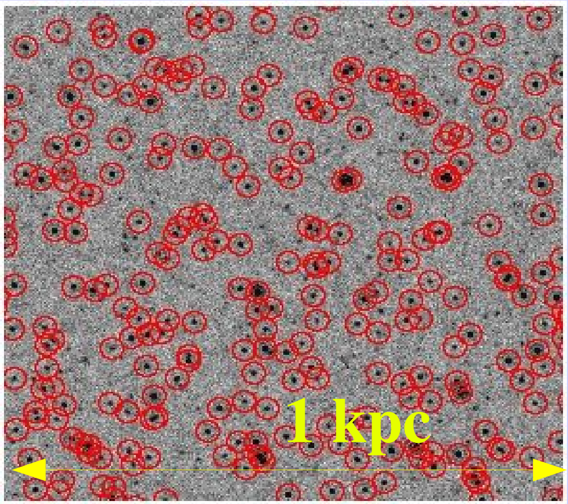
36 mag: S/N=3.6



37mag: S/N=2.3



38 mag: S/N=1.4

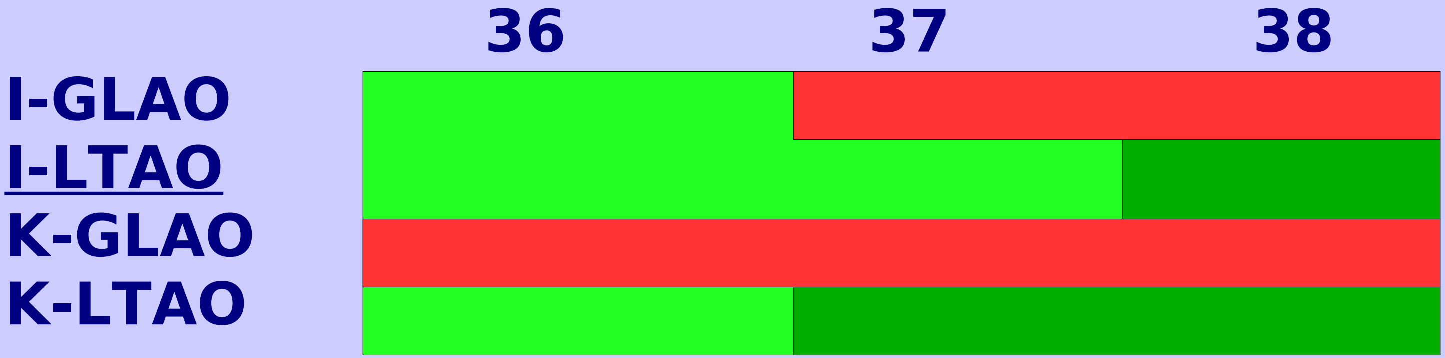


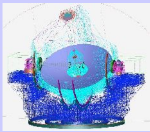
K-LTAO feasible at (m-M)=36 and just so at 37 mag. At (m-M)=38 mag >>1h integration time needed.

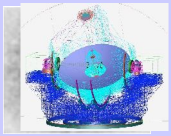
4. Summary and Conclusions

Simulations of SBF measurements in a giant elliptical galaxy using a 42m ELT and 1 hr integration time were presented.
3 assumed distances: (m-M)=36, 37, 38 mag

SBF distances to 0.25 mag accuracy can be achieved for:







4. Summary and Conclusions

SBF vs. TRGB