Surface Brightness Fluctuations

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Distance Ladder Presentations

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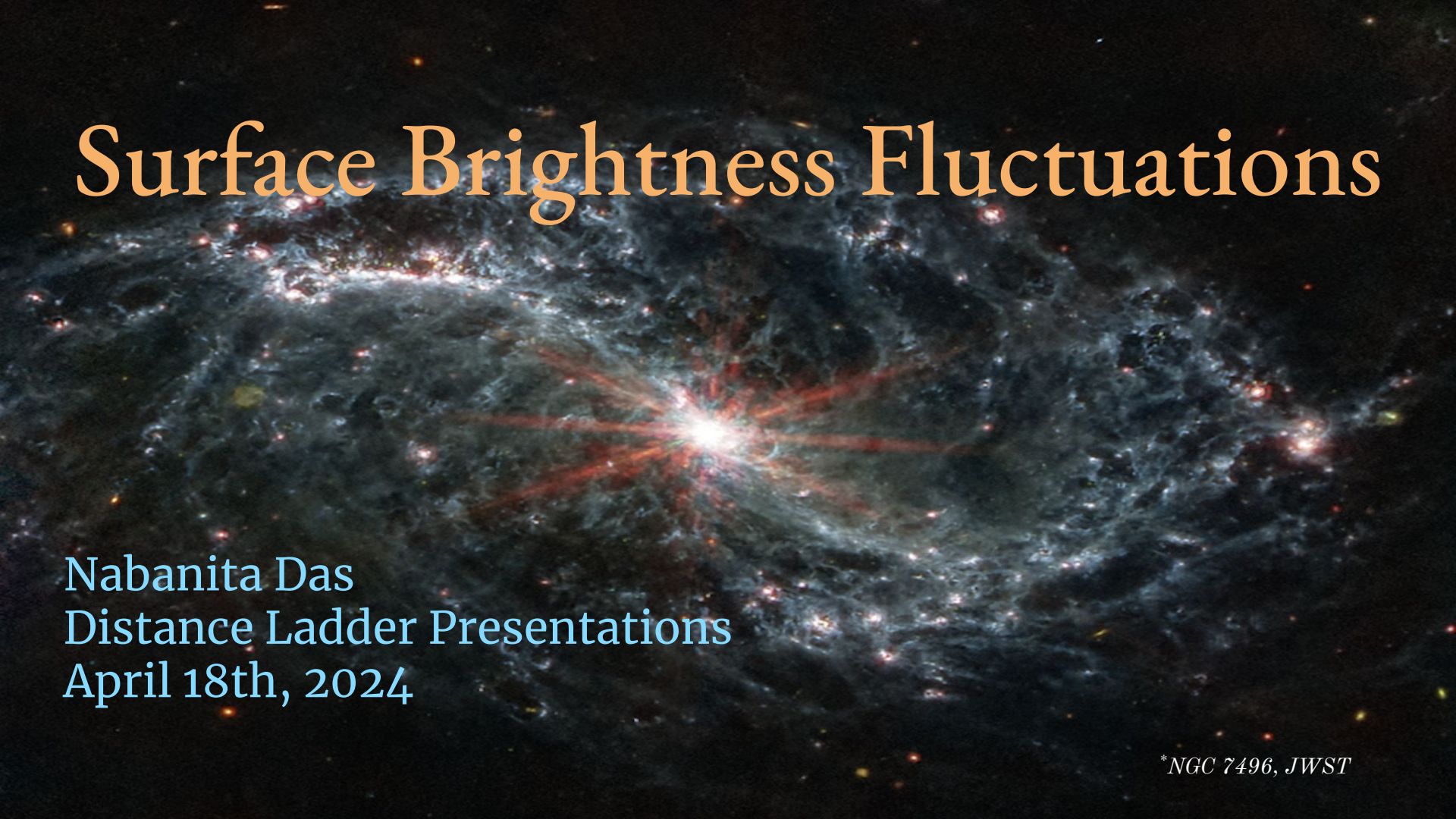
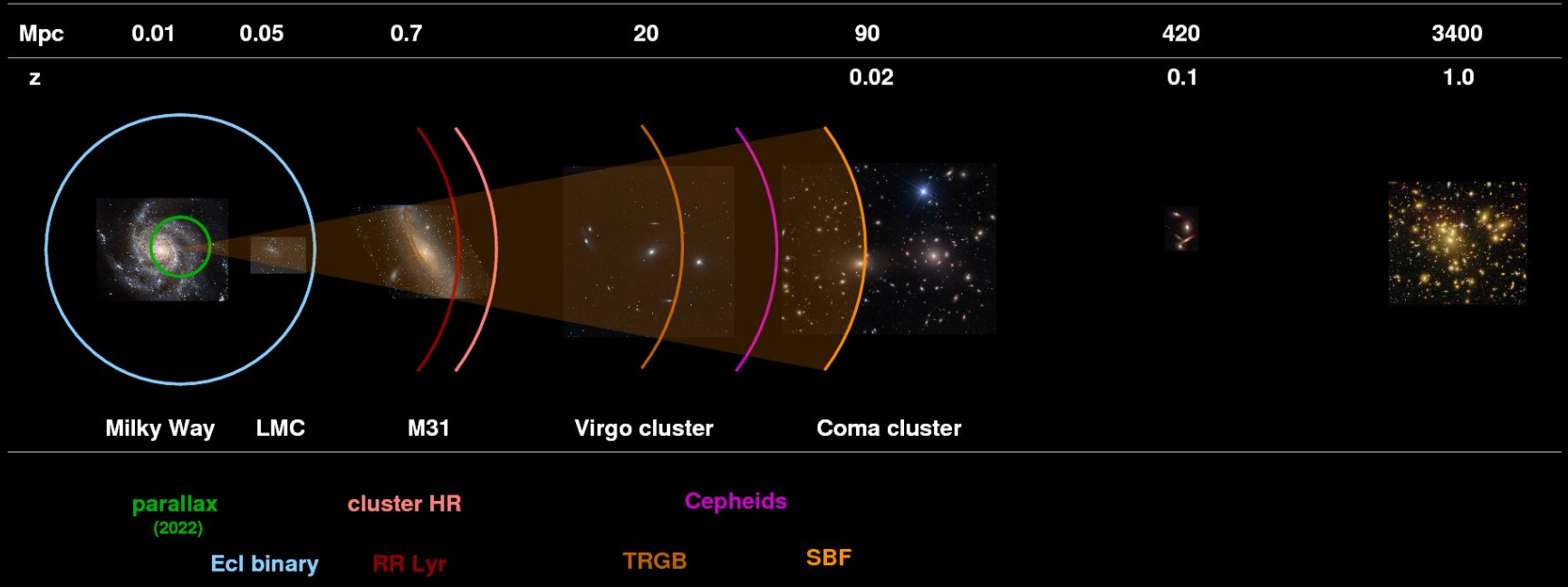


*NGC 7496, JWST

Overview

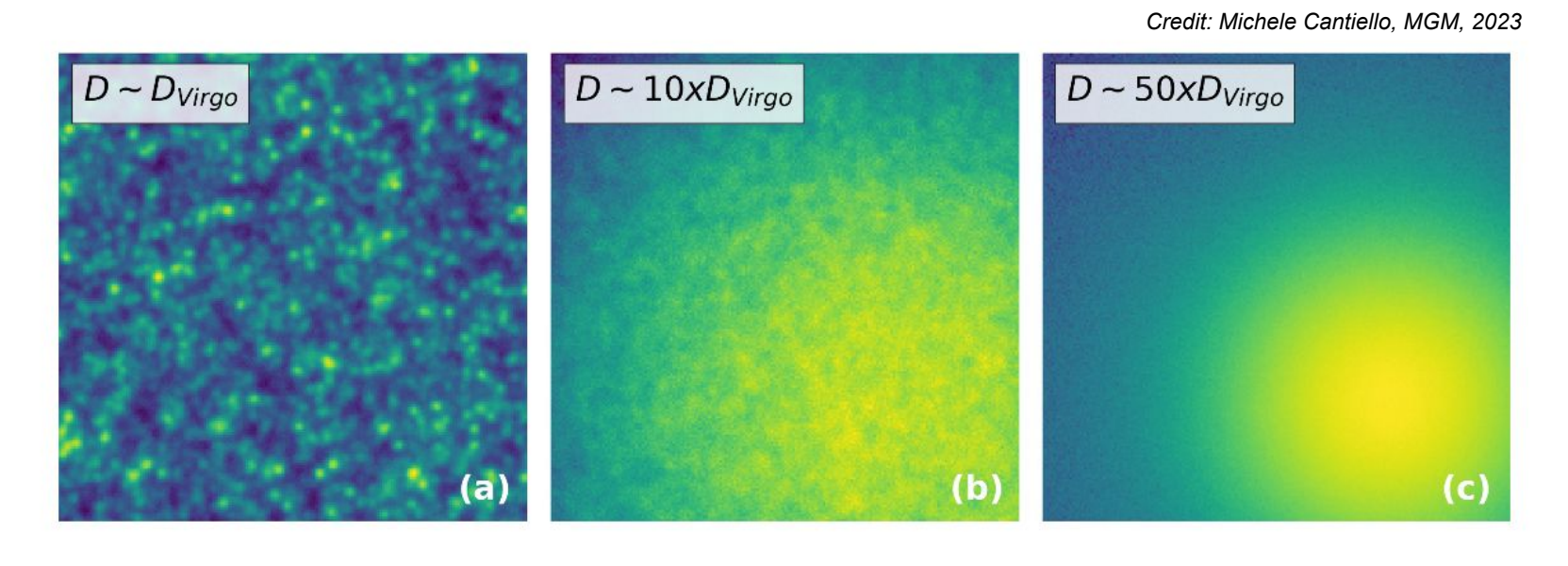
1. Distance limit
2. Basic technique
3. Errors
4. Recent results

How Far Can We Go?



Most reliable extragalactic distance measured is upto about 150 Mpc (HST).

How Far Can We Go?



Qualitative example of SBF. Resolved stars at relatively small distances, gradually blend in a smooth brightness profile with increased distances.

Basic Technique

Where do we start?

m M

$$m - M = 5\log(d/10pc)$$

Basic Technique

Where do we start?

m

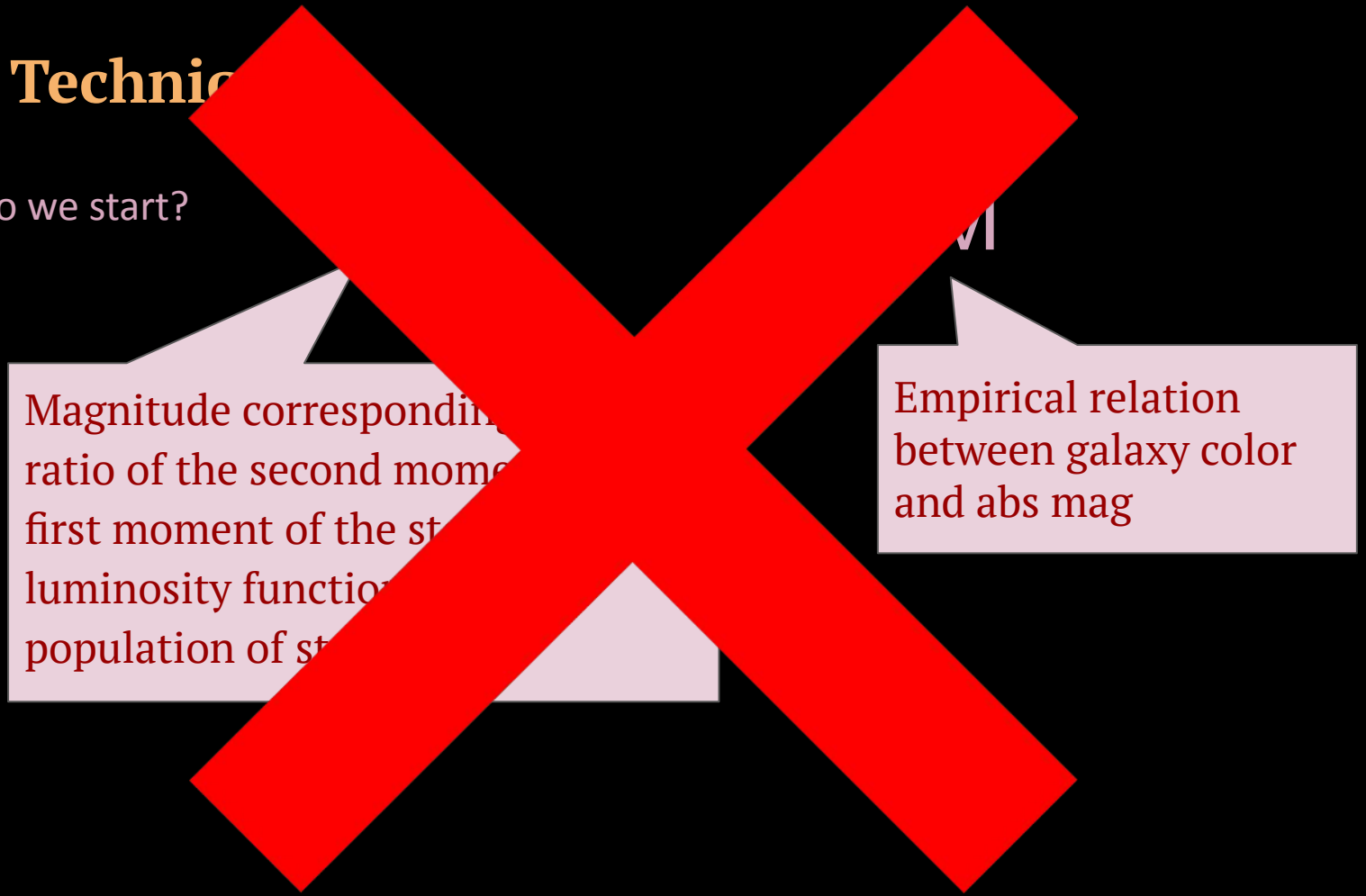
Magnitude corresponding to the ratio of the second moment to the first moment of the stellar luminosity function in a population of stars

M

Empirical relation between galaxy color and abs mag

Basic Techni

Where do we start?



Basic Technique (m)

Flux from a star, $f_* = L / 4\pi d^2$

Flux from a pixel, $F = N \times f_*$

Poisson scatter,

$\sigma / F = 1 / \sqrt{N}$

Hence, $\sigma^2 = F^2 \times N$

SBF flux,

$f_{mean} = \sigma^2 / F = NF^2 / NF = F$

But all stars don't have the same luminosity!

Basic Technique (m)

Instead we have,

Total flux, $f_{tot} = \sum_i N_i \, x \, f_i$

Hence, SBF flux,

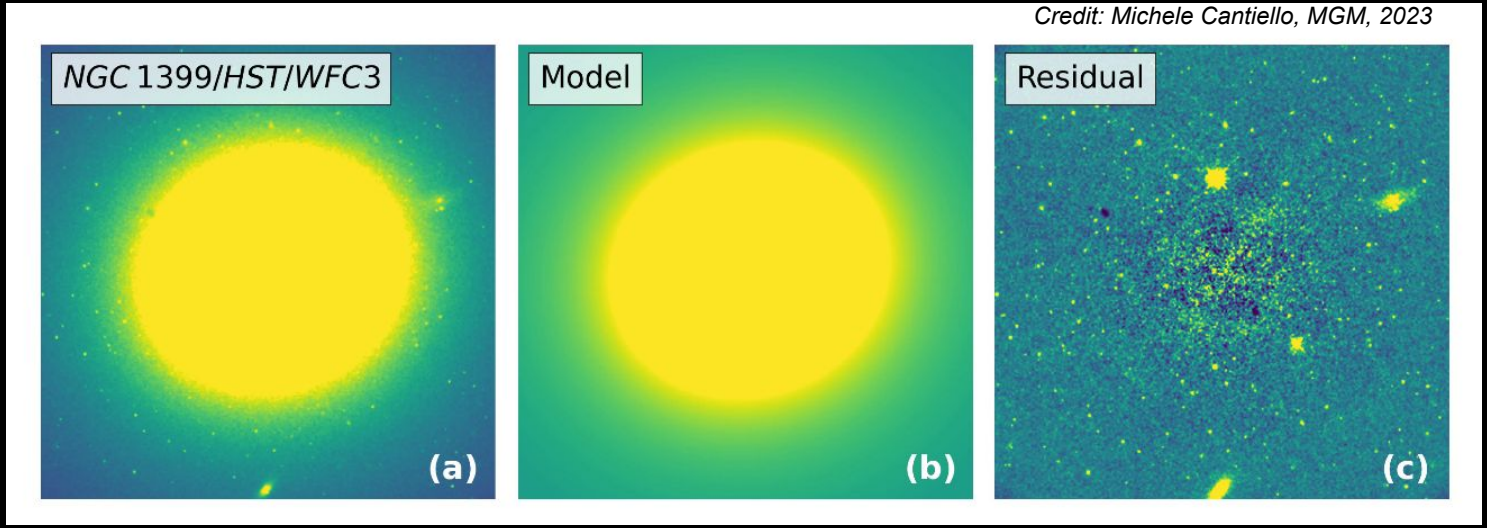
$$f_{mean} = \sum_i N_i f^2_i \, / \, \sum_i N_i \, f_i$$

Correspondingly,

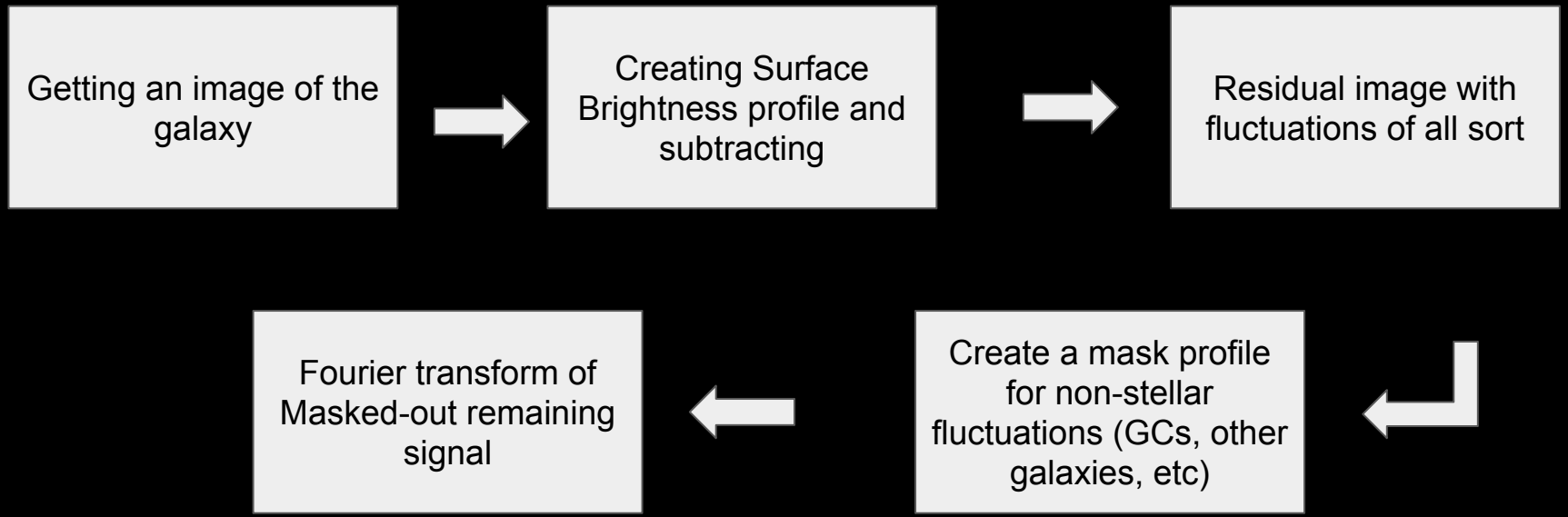
$$m_{mean} = -2.5 log \, (f_{mean}) + C$$

The Real deal though…

Getting an image of the galaxy → Creating Surface Brightness profile and subtracting → Residual image with fluctuations of all sort

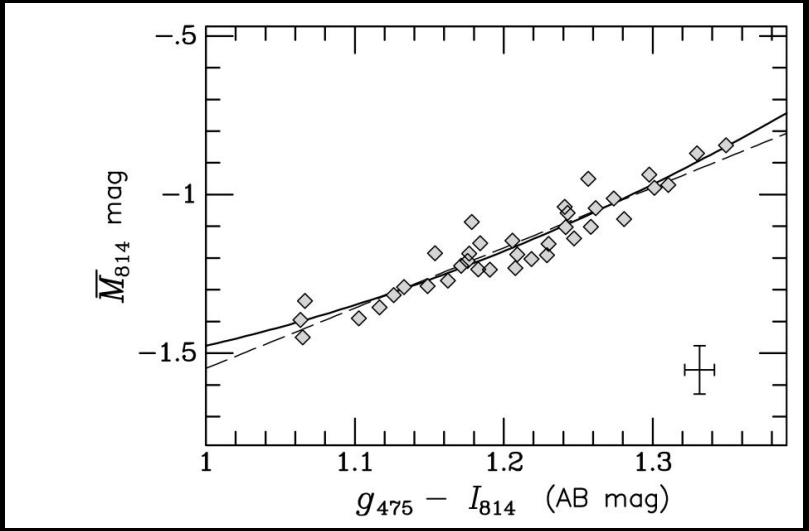


The Real deal though…



Basic Technique (M)

- Tonry et al. (1997) noted that *M* in the *I* band is a universal function of *(V-I)* color.
- Follow up studies also found a linear relationship for other optical/ IR pass bands.



Blakeslee et al, ApJ, 2010

Possible Sources of Error

- Dust and extinction affects SBF and distance
- Contamination from GCs
- Multiple stellar population

Ideal for red and dead massive elliptical galaxies

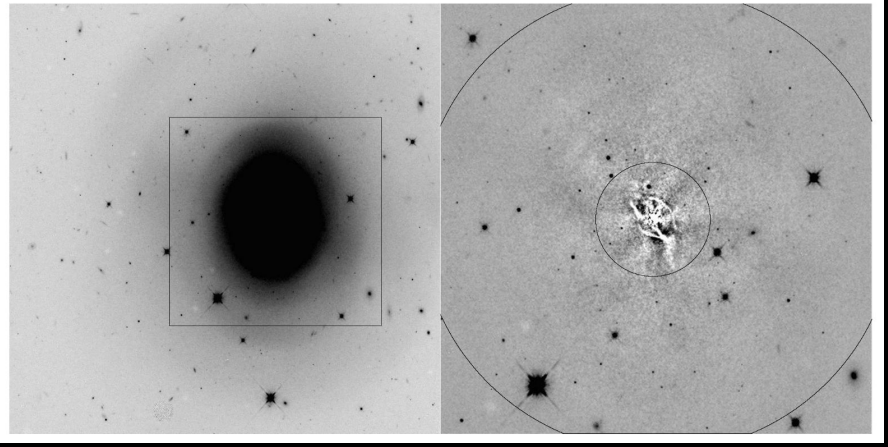
- No young stars → can't use Cepheids
- Too distant for TRGB
- No star formation → no SNe

Recent Work

Cantiello et al., ApJ, 2018

A PRECISE DISTANCE TO THE HOST GALAXY OF THE BINARY NEUTRON STAR MERGER GW170817 USING SURFACE BRIGHTNESS FLUCTUATIONS*

MICHELE CANTIELLO,[1] J. B. JENSEN,[2] J. P. BLAKESLEE,[3,4] E. BERGER
E. BROCATO,[8] K. D. ALEXANDER,[5] P. K. BLANCHARD,[5] M. BRANCHES
P. S. COWPERTHWAITE,[5] P. D'AVANZO,[13] T. EFTEKHARI,[5] W. FONG,[14] A. S.
J. D. LYMAN,[6] I. MANDEL,[19] R. MARGUTTI,[14] M. NICHOLL,[5]



- HST observations to get mean m
- Mean M from galaxy colors *(g-z)*

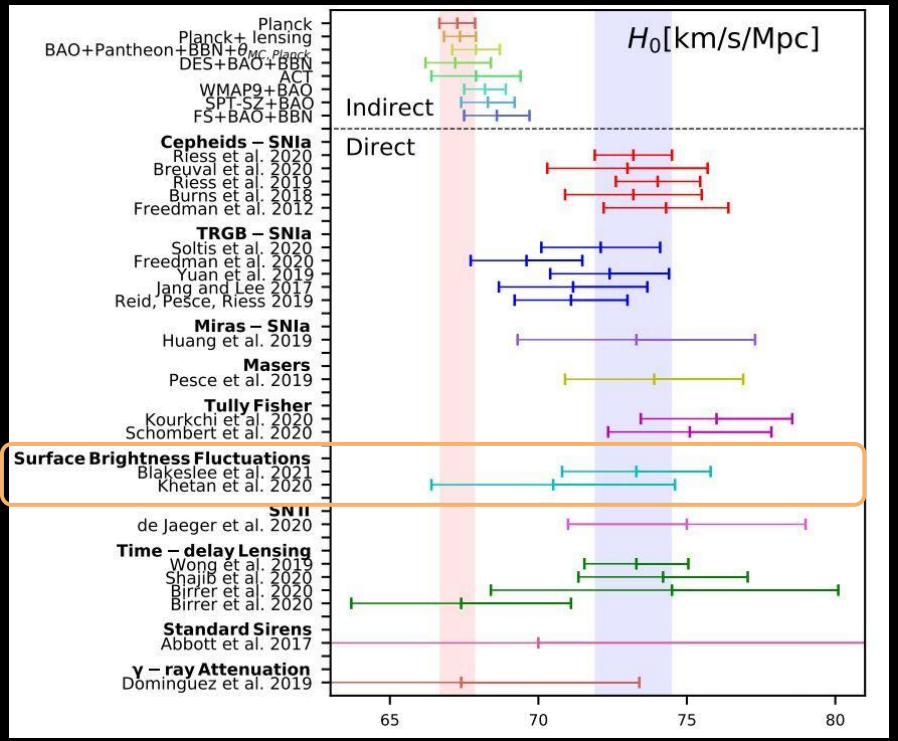
m - M = 5log(d/10pc)

- Distance from SBF consistent with distance from GW

$D_{SBF} = 40.7 \pm 1.4 \pm 1.9$ Mpc $D_{GW} = 43.8\ ^{+2.9}_{-6.9}$ Mpc *(Abbott et al, Nature,551,85)*

Recent Work

*Blakeslee et al, ApJ, 911:65 (12pp), 2021



SBF can also predict a value for H_0

Blakeslee+, (ApJ, 2021*) measured SBF distances to 63 galaxies out to 100 Mpc.

Future scopes

- Better photometry
  - JWST with high-res IR cameras (expected D ~ 300 Mpc)
  - Deep sky survey with LSST
- Well Calibrated M
  - Gaia as a calibrator in local group
  - TRGB/ Cepheid distances to nearby galaxies

Questions?

Basic Technique

SBFs are defined as the ratio of the second to the first moment of the stellar luminosity function in a population of stars.

the distance estimation requires calibrating the absolute SBF magnitude M based on the galaxy stellar population, most commonly parameterized by the integrated galaxy color