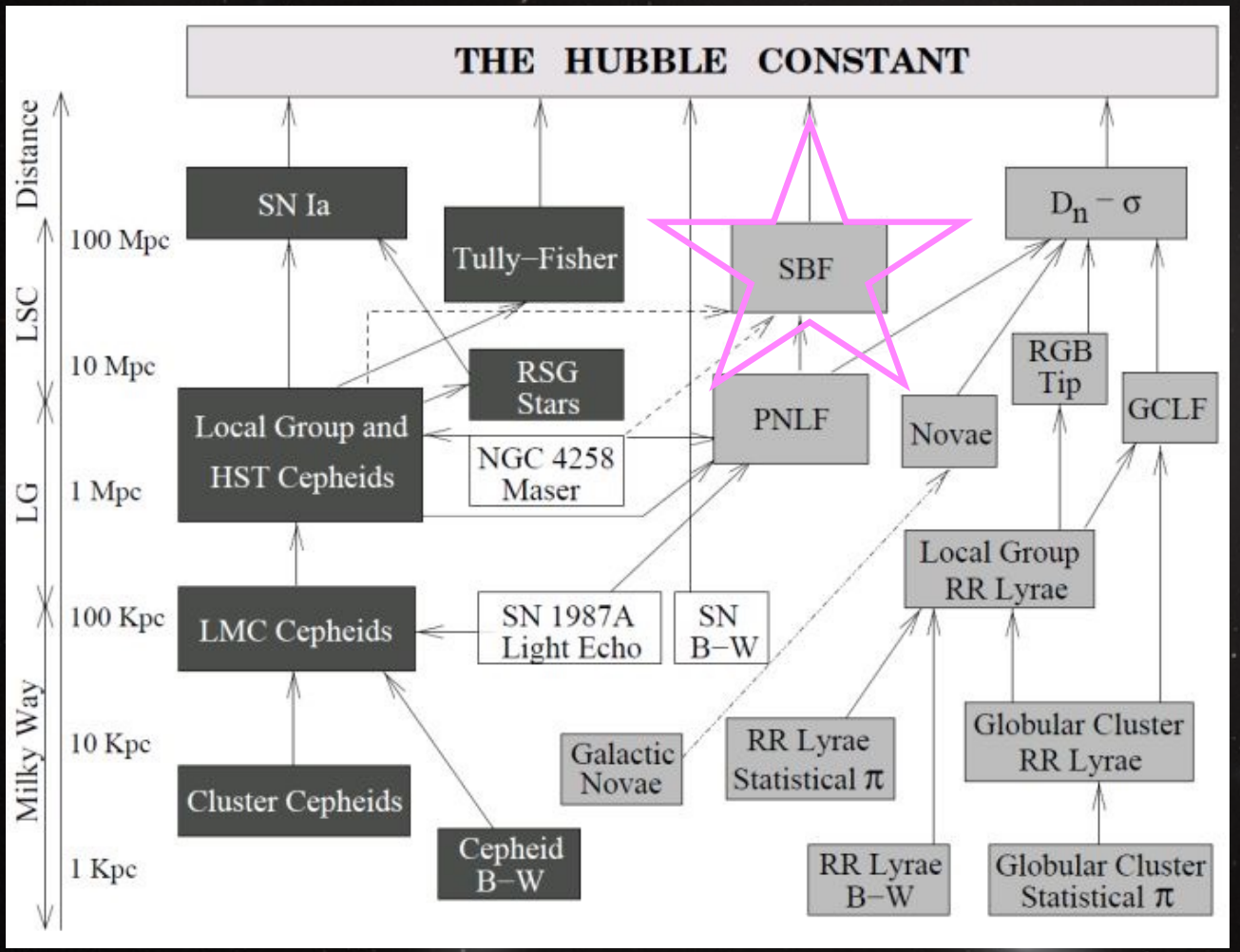
Surface Brightness Fluctuations as a Distance Method

By Ella Roselli

How far along are we?

- Ground: ~40 Mpc
- Space: ~100 Mpc
- JWST: ~300+ Mpc

Credit: Caltech lecture notes



Basic Concept

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A NEW TECHNIQUE FOR MEASURING EXTRAGALACTIC DISTANCES[a)]

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Received 26 April 1988

$$\sigma = \sqrt{n}$$

Advantages!

- No time series data necessary
  - Single epoch imaging
- Can measure distances without resolving single stars
  - Doubles the range of TRGB
  - Can probe the Hubble tension
- Effective in early-type galaxies without young stars (no Cepheids)

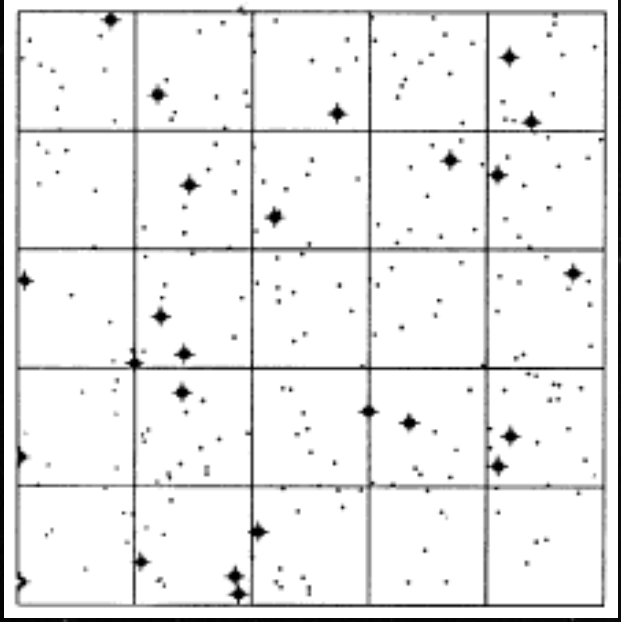
Problems with the technique

- Assumptions:
  - Homogenous stellar populations within galaxies
    - Fluctuation magnitude varies with age and metallicity of stellar population
    - Globular clusters
    - Background galaxies
- Observational constraints:
  - Requires high SNR
  - Requires stable PSF

Credit: Caltech lecture notes

D~1 Mpc

- Average 1 star per pixel

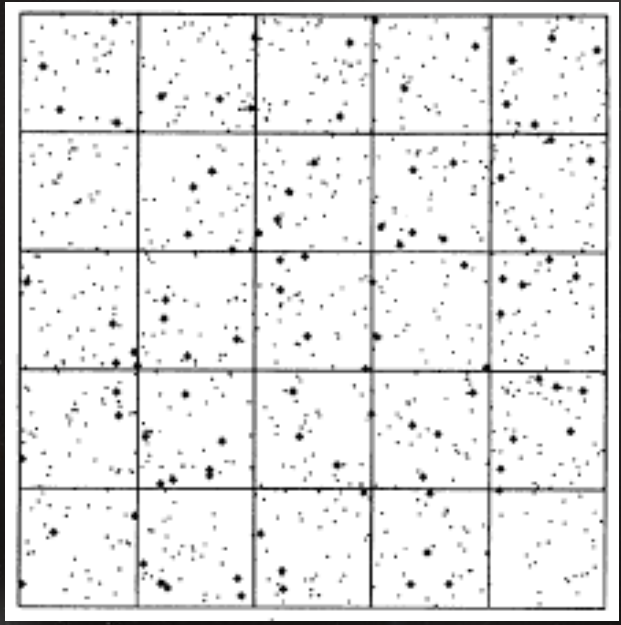


$$n \propto d^2$$

$$f \propto d^{-2}$$

D~10 Mpc

- Average 10 stars per pixel



Credit: RIT lecture notes

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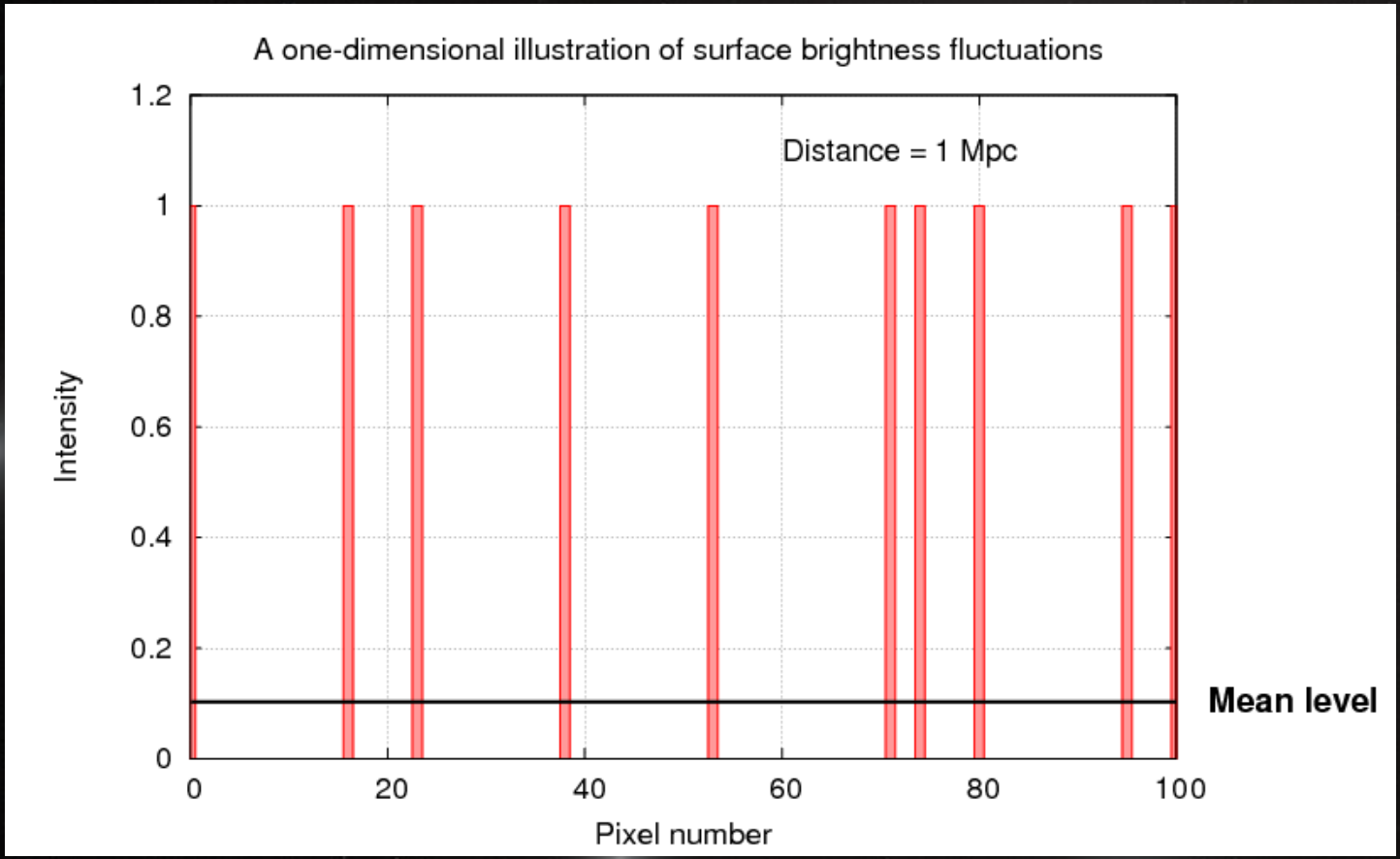

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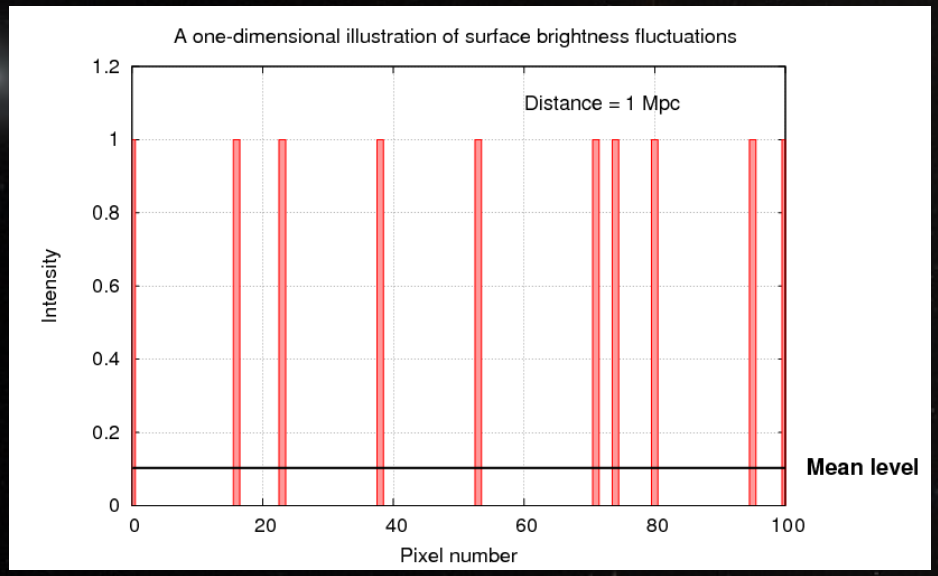

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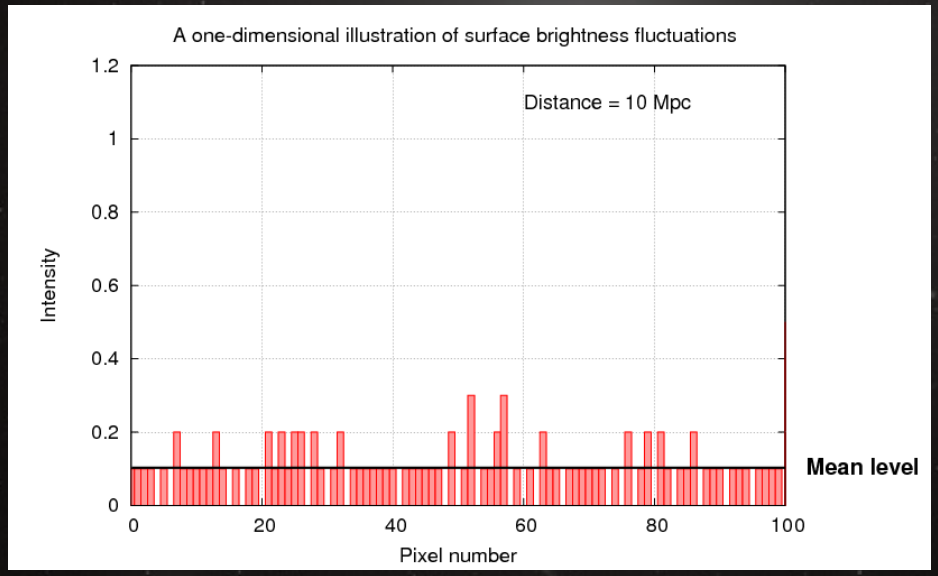
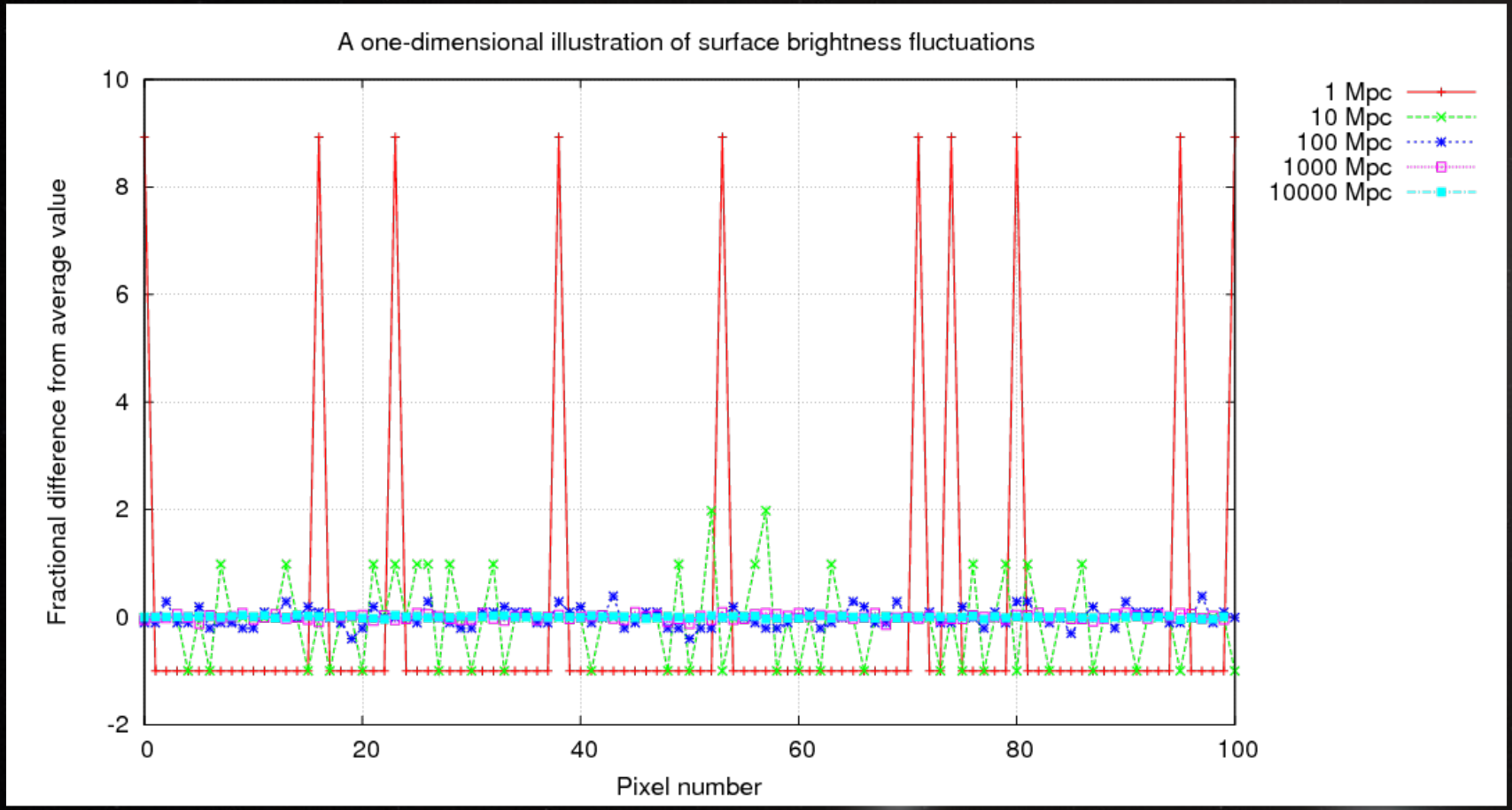
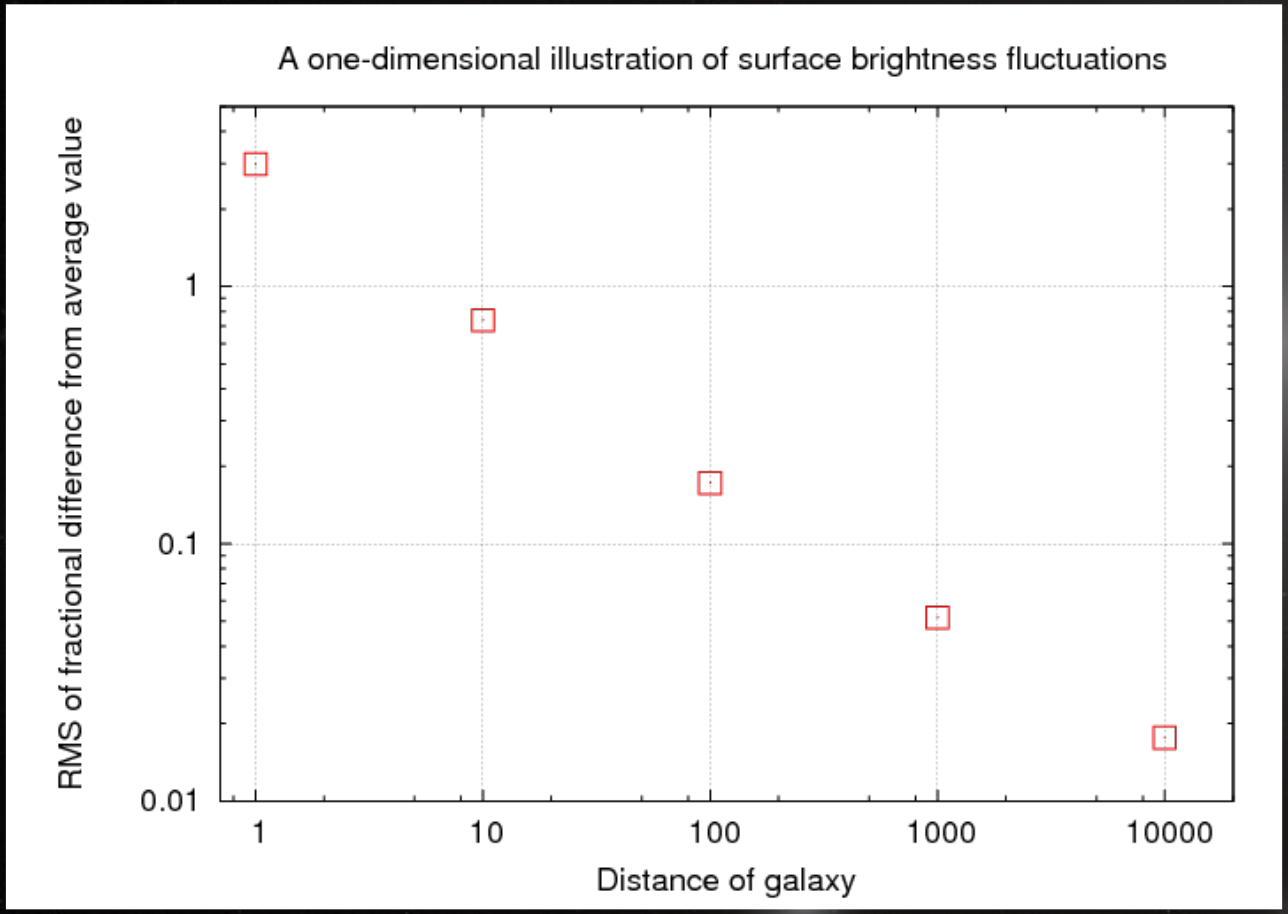


Credit: RIT lecture notes

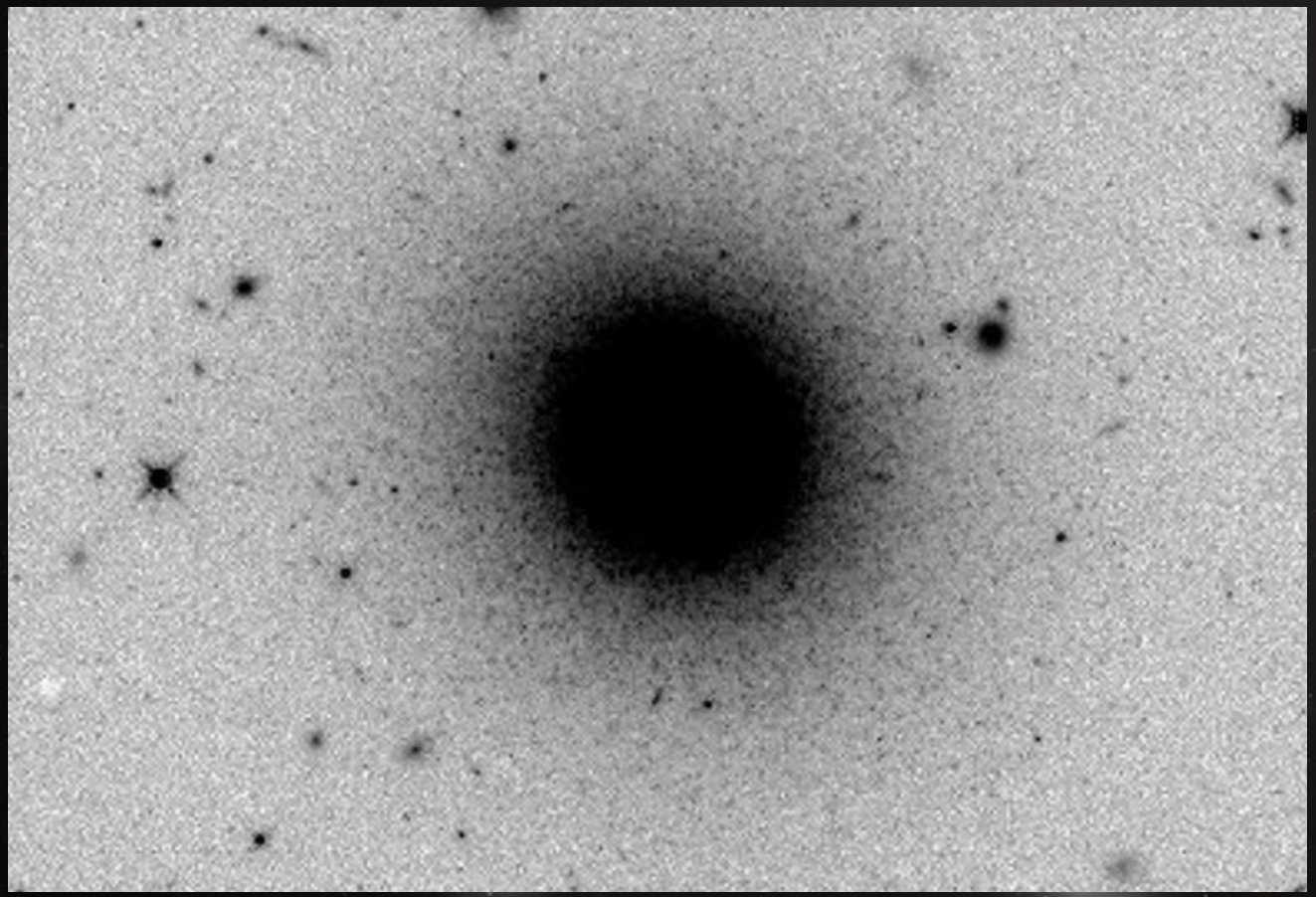


Credit: RIT lecture notes



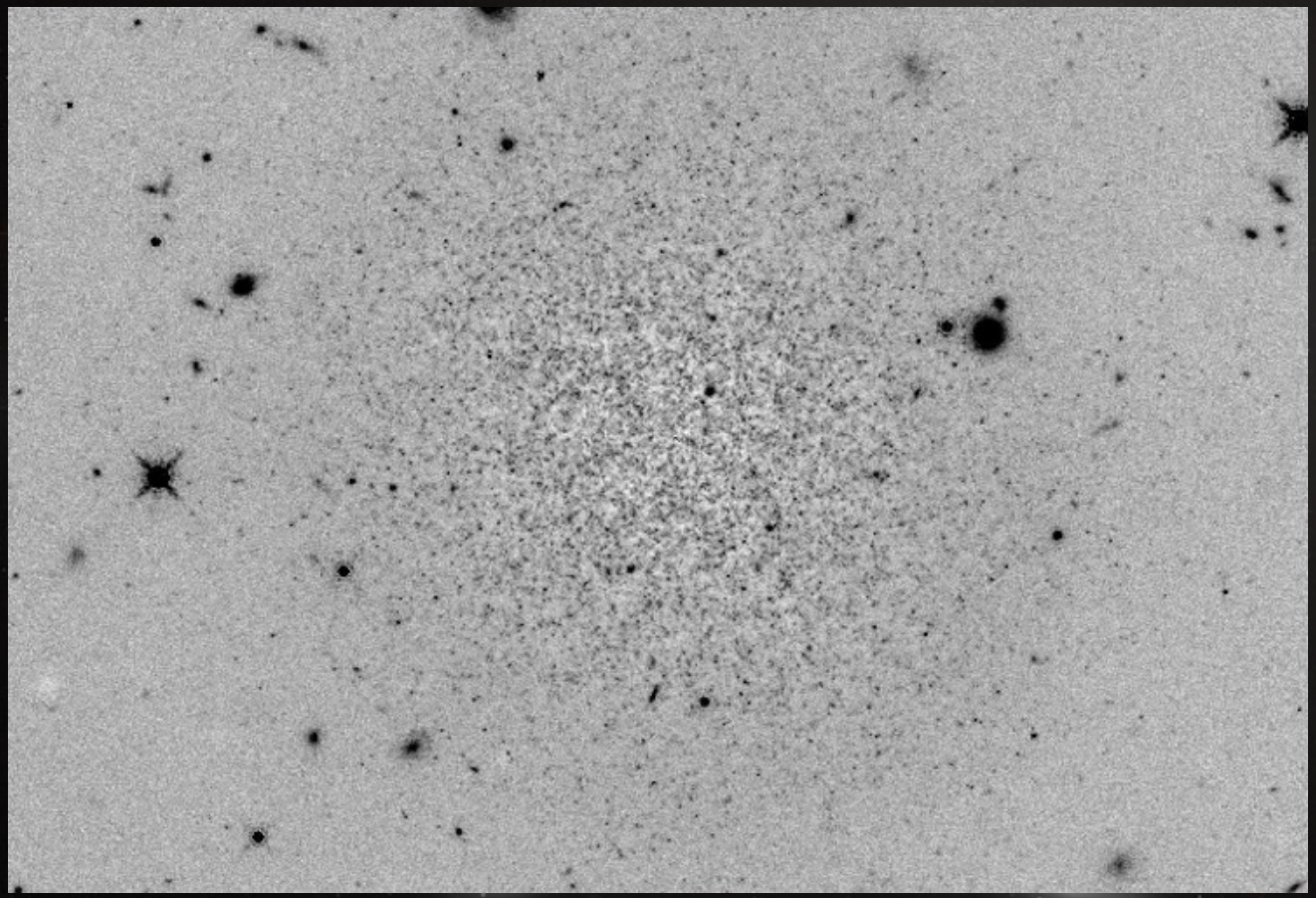
Credit: RIT lecture notes

A bit more complicated in reality…



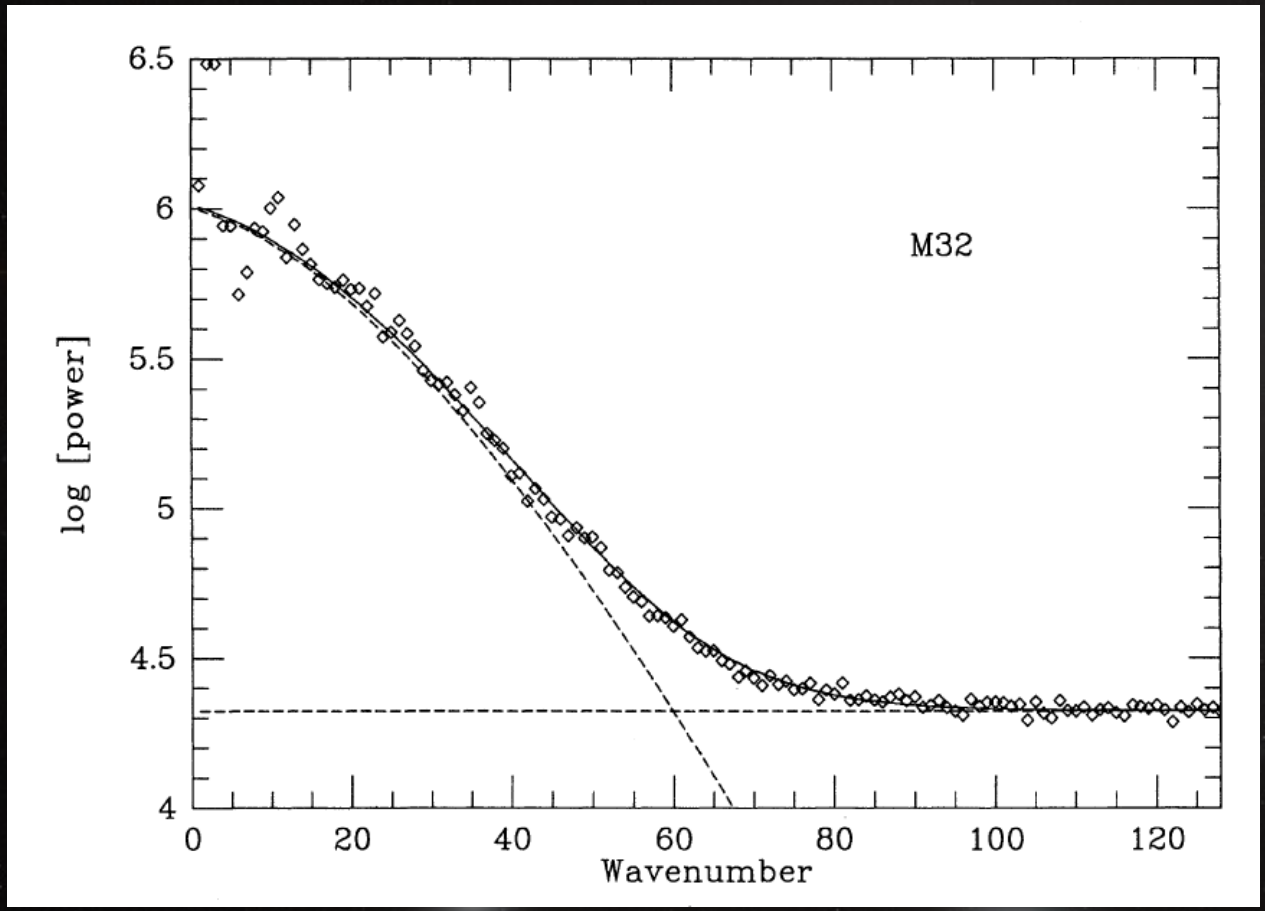
Credit: RIT lecture notes

1) Observe a galaxy
2) Subtract model brightness



Credit: RIT lecture notes

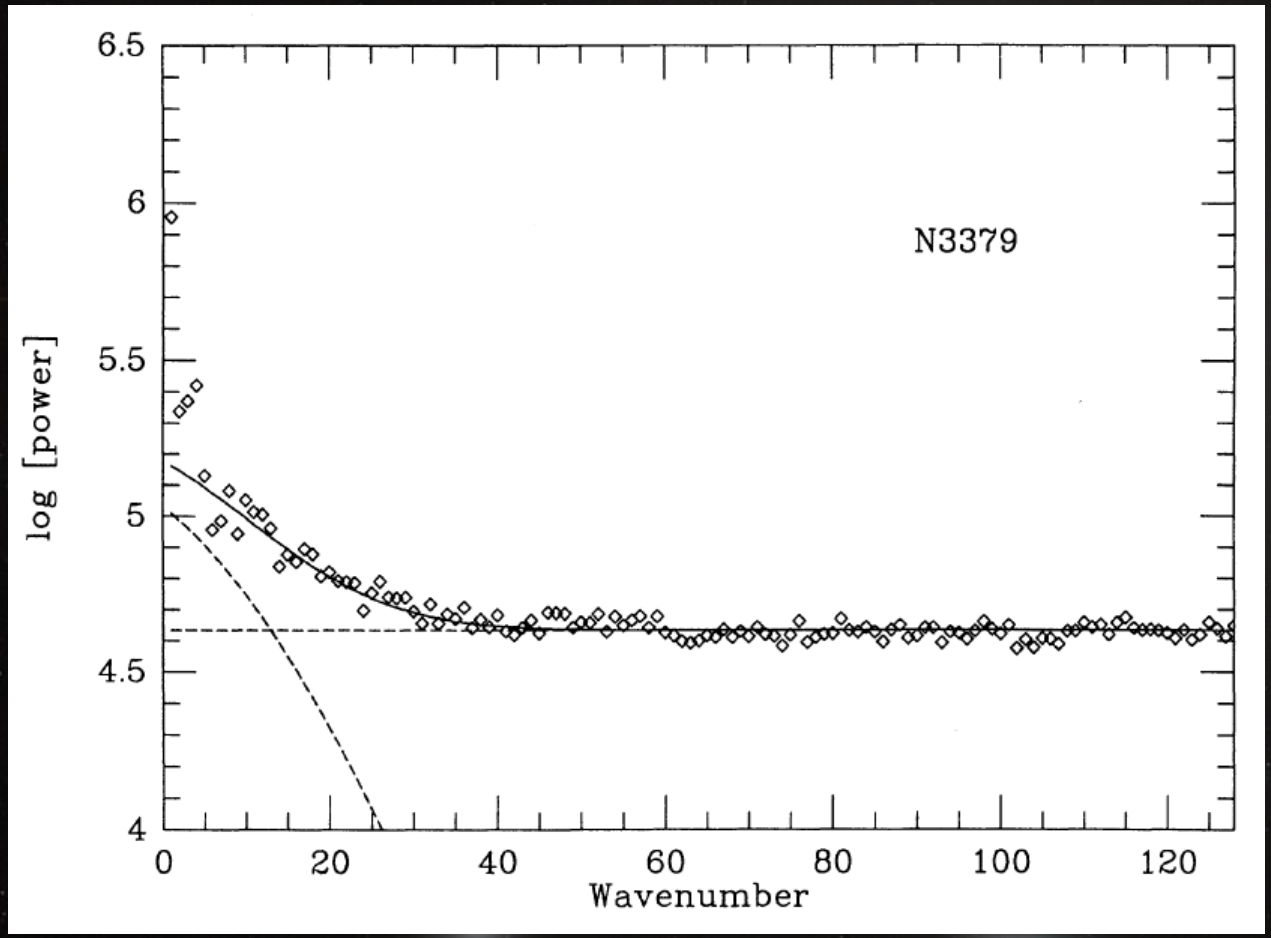
1) Observe a galaxy
2) Subtract model brightness
3) Take a Fourier Transform of the residuals



Tonry and Schneider, AJ 96, 807 (1988).

Credit: RIT lecture notes

1) Observe a galaxy
2) Subtract model brightness
3) Take a Fourier Transform of the residuals
4) Compare power of fluctuations



Tonry and Schneider, AJ 96, 807 (1988).

Closest measurements – M31

- K-band observations to measure fluctuations in bulge of M31 (with known distance ~0.77 Mpc) to calibrate absolute fluctuation magnitude to measure the distance to Maffei 1 of ~4.2±0.5 Mpc (Luppino & Tonry 1993).

Furthest confirmed with HST

- HST WFC3/IR camera observations of NGC 4874 in the Coma Cluster to find distance of ~95±6 Mpc (Blakeslee et al. 2021).
- Until recently, represented limit of SBF.

Furthest measurements & future with JWST

- “The TRGB-SBF Project III. Refining the HST Surface Brightness Fluctuation Distance Scale” by Anand et al. 2025 uses JWST observations to calibrate SBF against TRGB distances to nearby galaxies.
- This project is ongoing and will extend to SBF distances ~300+ Mpc away calibrated with Type 1a supernovae.

Summary

- SBF relies on Poisson noise of photometric observations related to star counts
  - Close galaxies look “bumpy” and further galaxies look smoother
- Anchored via TRGB and Cepheids
- Distance range: 0.77 Mpc (M31) to >300 Mpc
- Requires only single epoch observations
- Independent method to probe Hubble tension