The Future of Infrared Surface Brightness Fluctuation Distance Measurements

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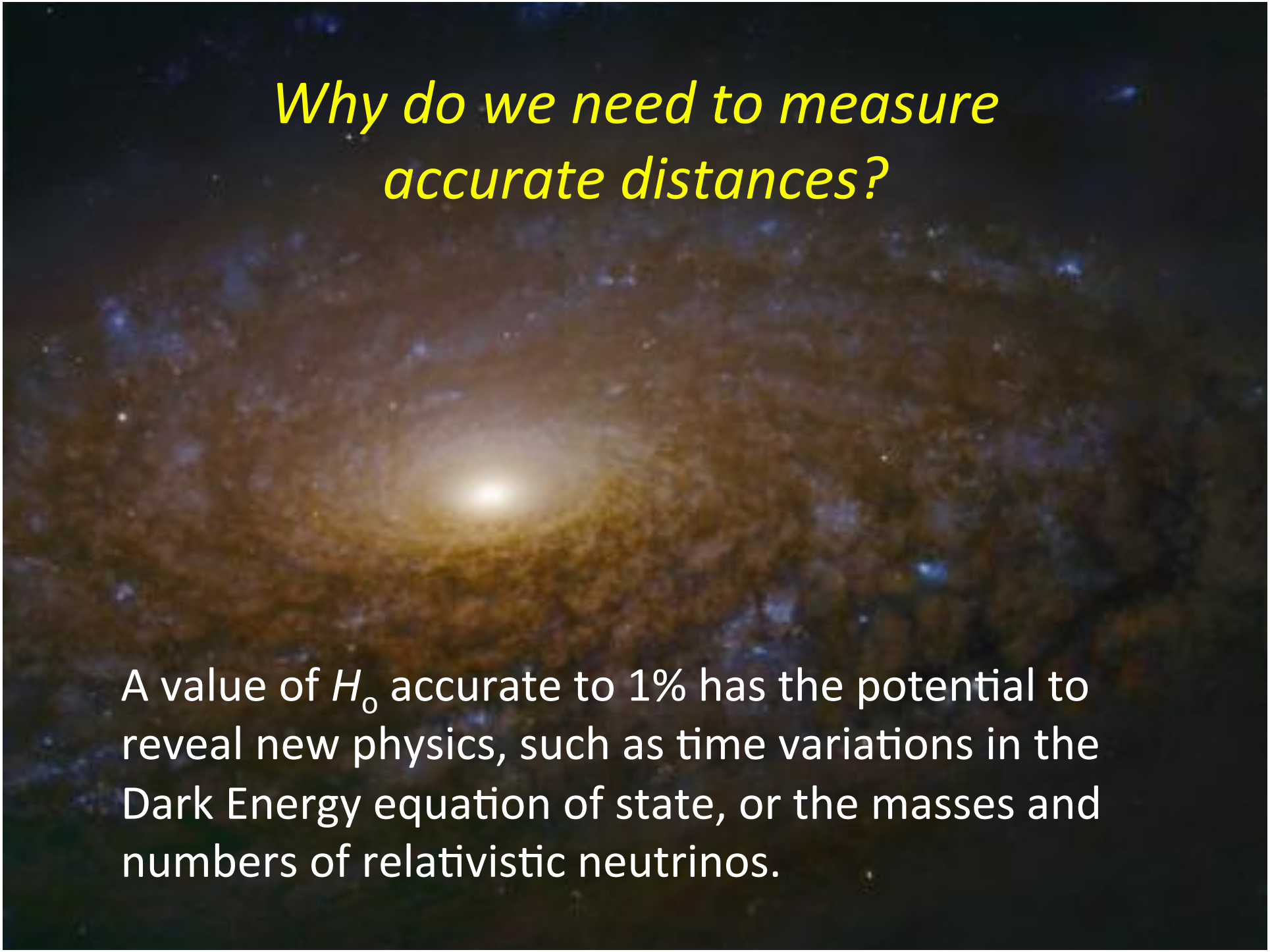
The Future of Infrared Surface Brightness Fluctuation Distance Measurements

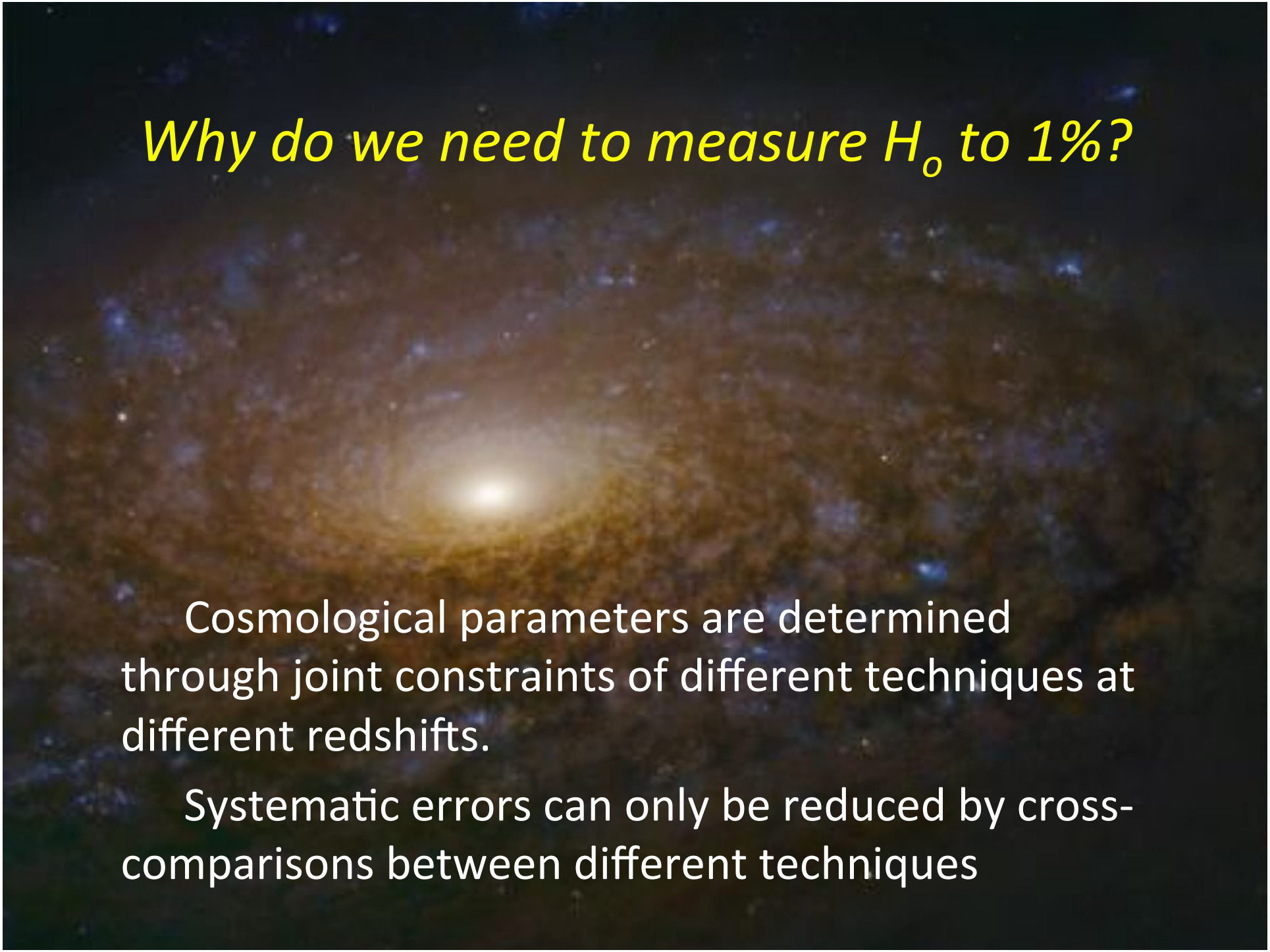
Key Points:

- *Not all distance techniques are "time domain"!*
- *IR SBF will be part of a 1% precision H_o effort.*
- *MCAO requires additional calibrations to overcome field distortions and to constrain the photometry.*



Why do we need to measure accurate distances?

A value of H_0 accurate to 1% has the potential to reveal new physics, such as time variations in the Dark Energy equation of state, or the masses and numbers of relativistic neutrinos.



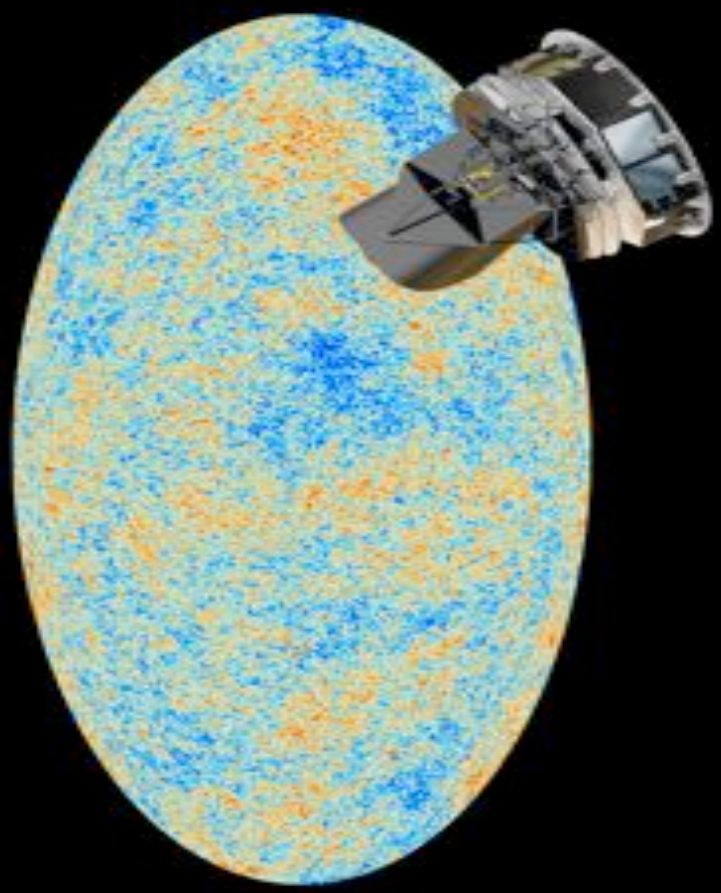
Why do we need to measure H_o to 1%?

Cosmological parameters are determined through joint constraints of different techniques at different redshifts.

Systematic errors can only be reduced by cross-comparisons between different techniques

Precision Cosmology

- $\Omega_\Lambda = 0.692 \pm 0.010$
- $\Omega_{DM} = 0.258 \pm 0.004$
- $\Omega_b = 0.0482 \pm 0.0005$
- $\Omega_k = -0.0005 \pm 0.0065$
- Age = 13.798 ± 0.037 Gyr
- h = 0.678 ± 0.0077
- w = -1.13 ± 0.24
- z(reionization) = 11.3 ± 1.1
- Neutrino mass < 0.23 eV



Joint constraints: Planck XVI (2013)

CMB vs. Locally-calibrated H_o

Planck 2013 results:

H_o = 67.3±0.7 km/s/Mpc

- Based on ΛCDM + Planck CMB

H_o = 69.3±0.7 km/s/Mpc

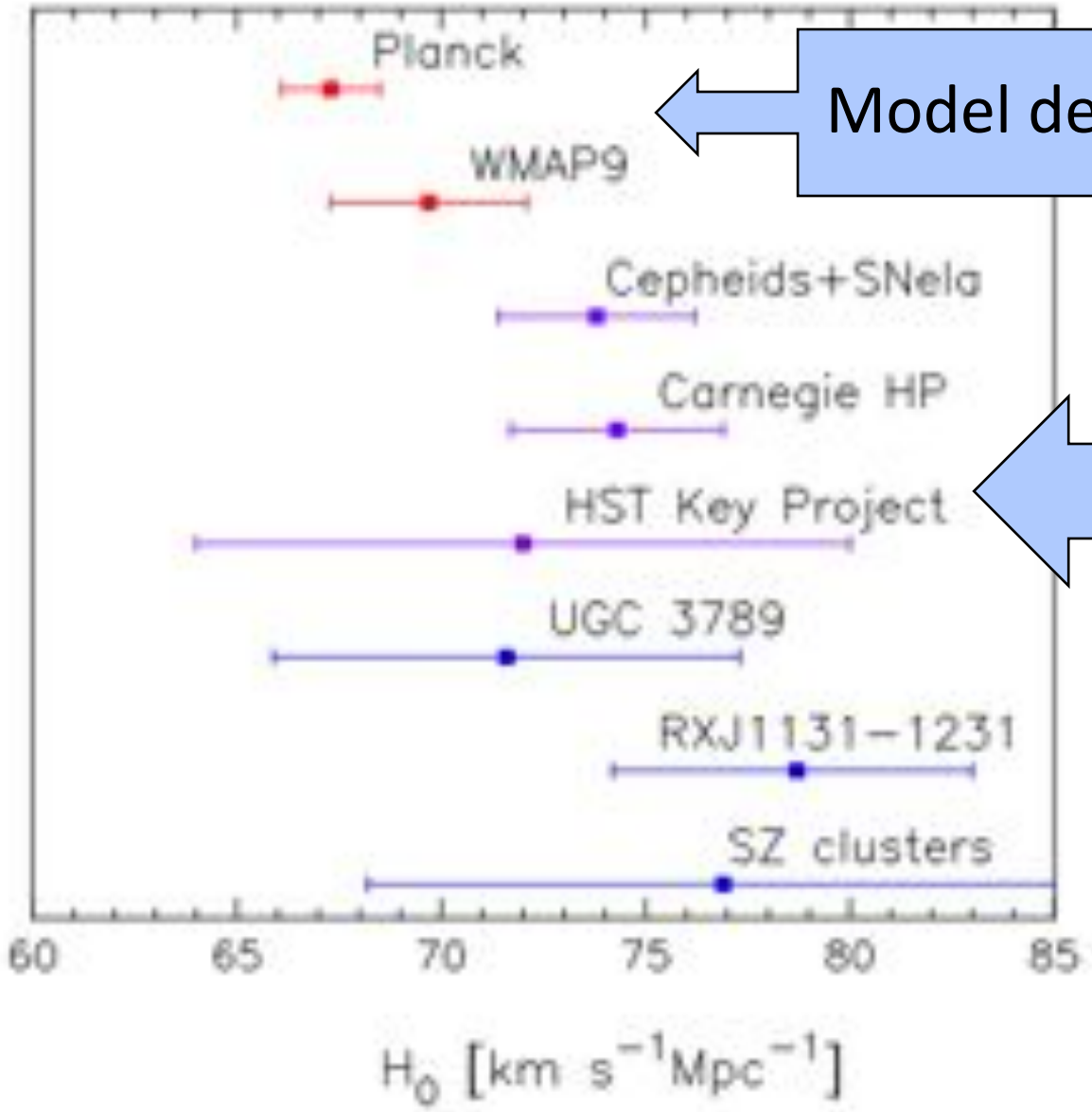
Including all CMB+BAO

Riess et al. 2016

H_o = 73.0±1.8 km/s/Mpc

- SNe Ia distances calibrated using direct Cepheid, NGC 4258 maser, and DEB geometrical distances

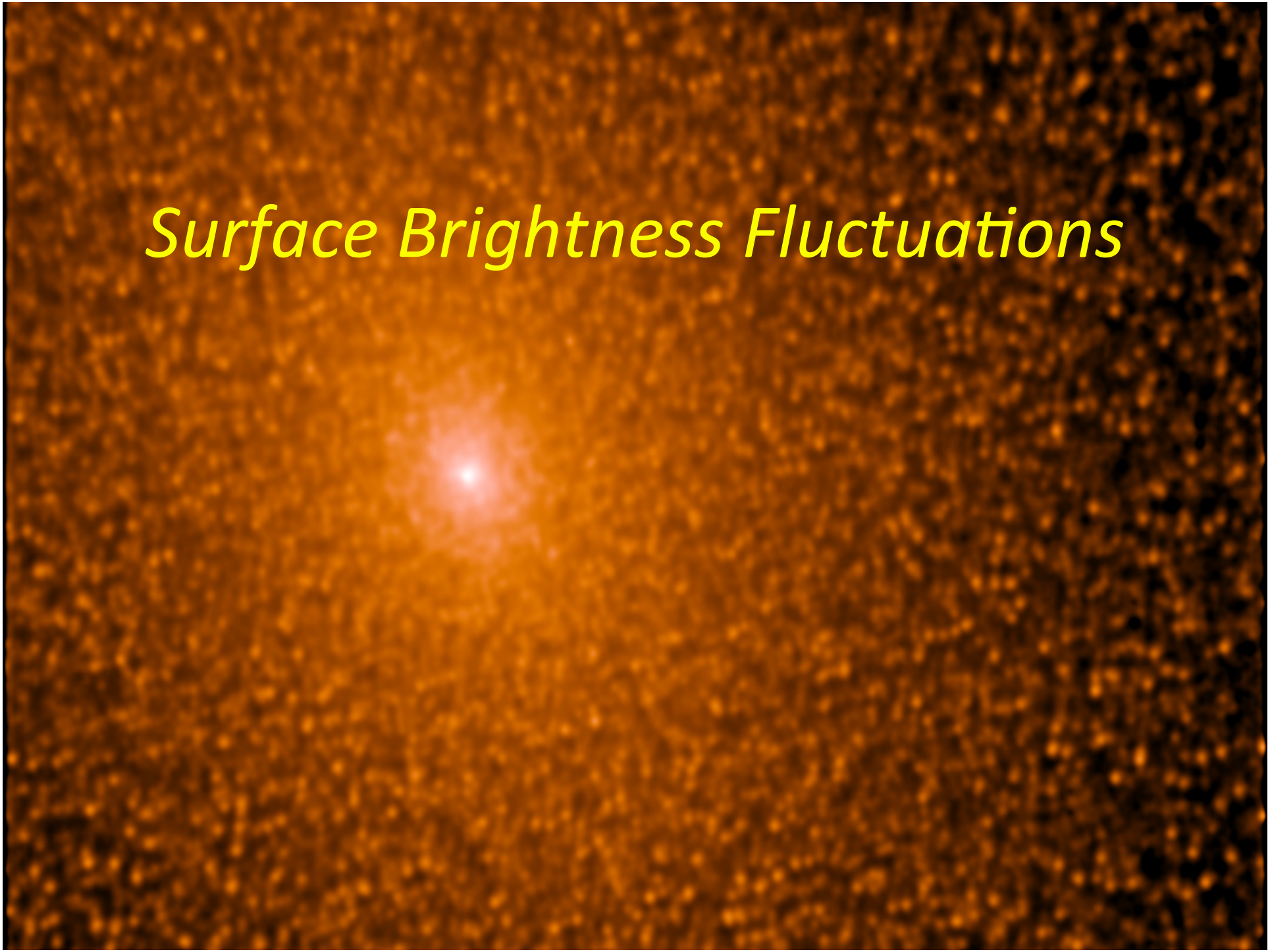
This represents an uncomfortable 2- to 3-σ discrepancy.



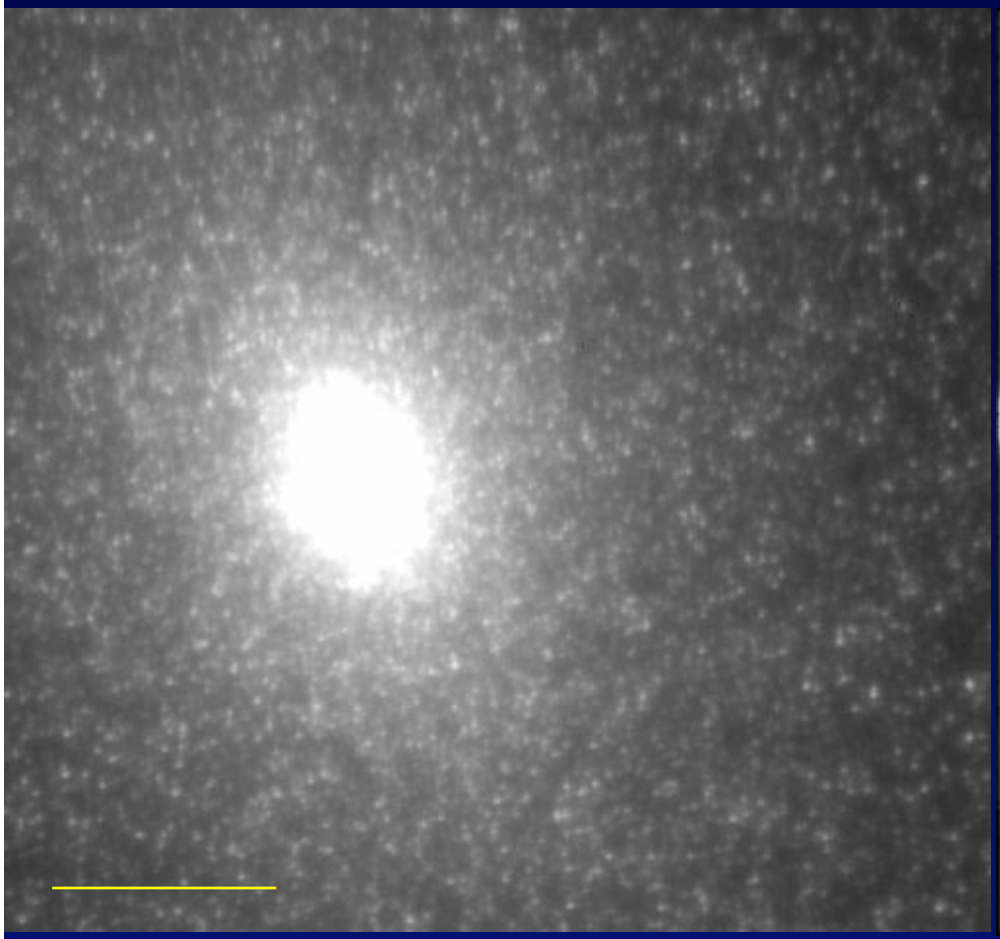
Model dependencies

"First rung" systematic uncertainties

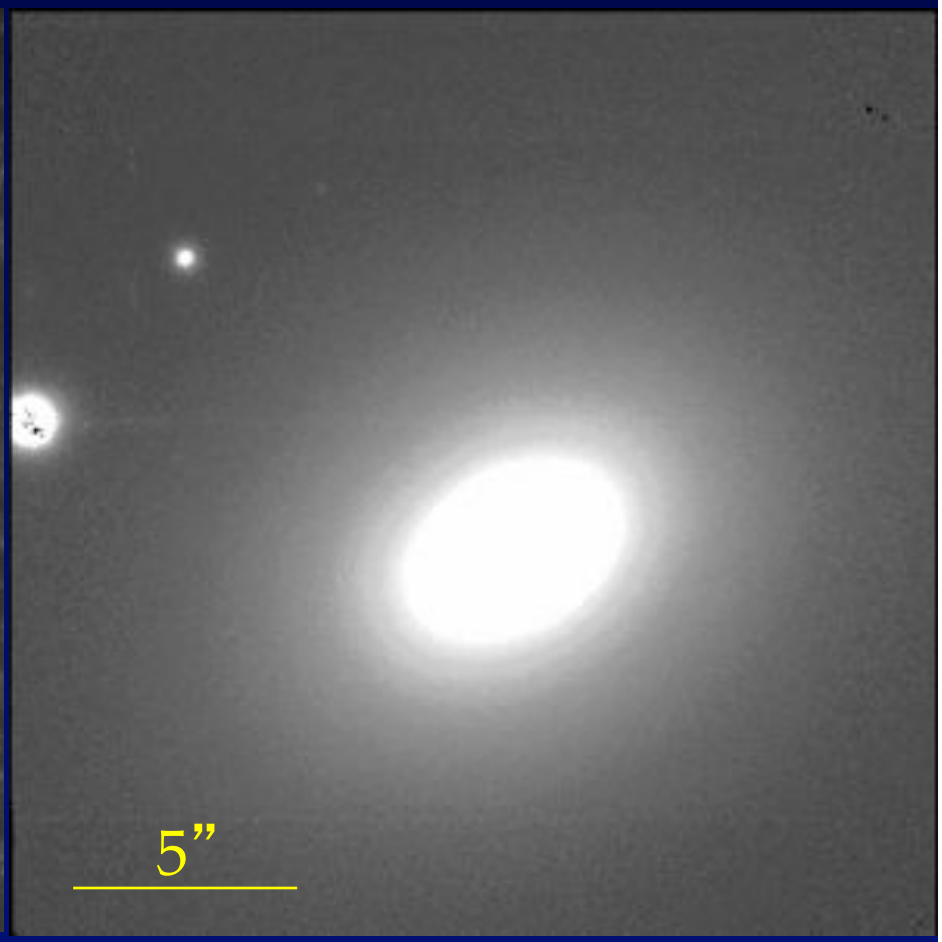
Planck collaboration (2013)


Surface Brightness Fluctuations

Distant galaxies appear smooth compared to nearby ones.



M 32 (0.77 Mpc)



NGC 7768 (120 Mpc)

SBFs: a Complementary Technique

SBF can't reach z>1 like supernovae, but…

- SBF provides a luminosity distance indicator independent of Ia supernovae
  - Different types of galaxies
  - Different types of stars
  - Different age stars
  - Different stellar environment

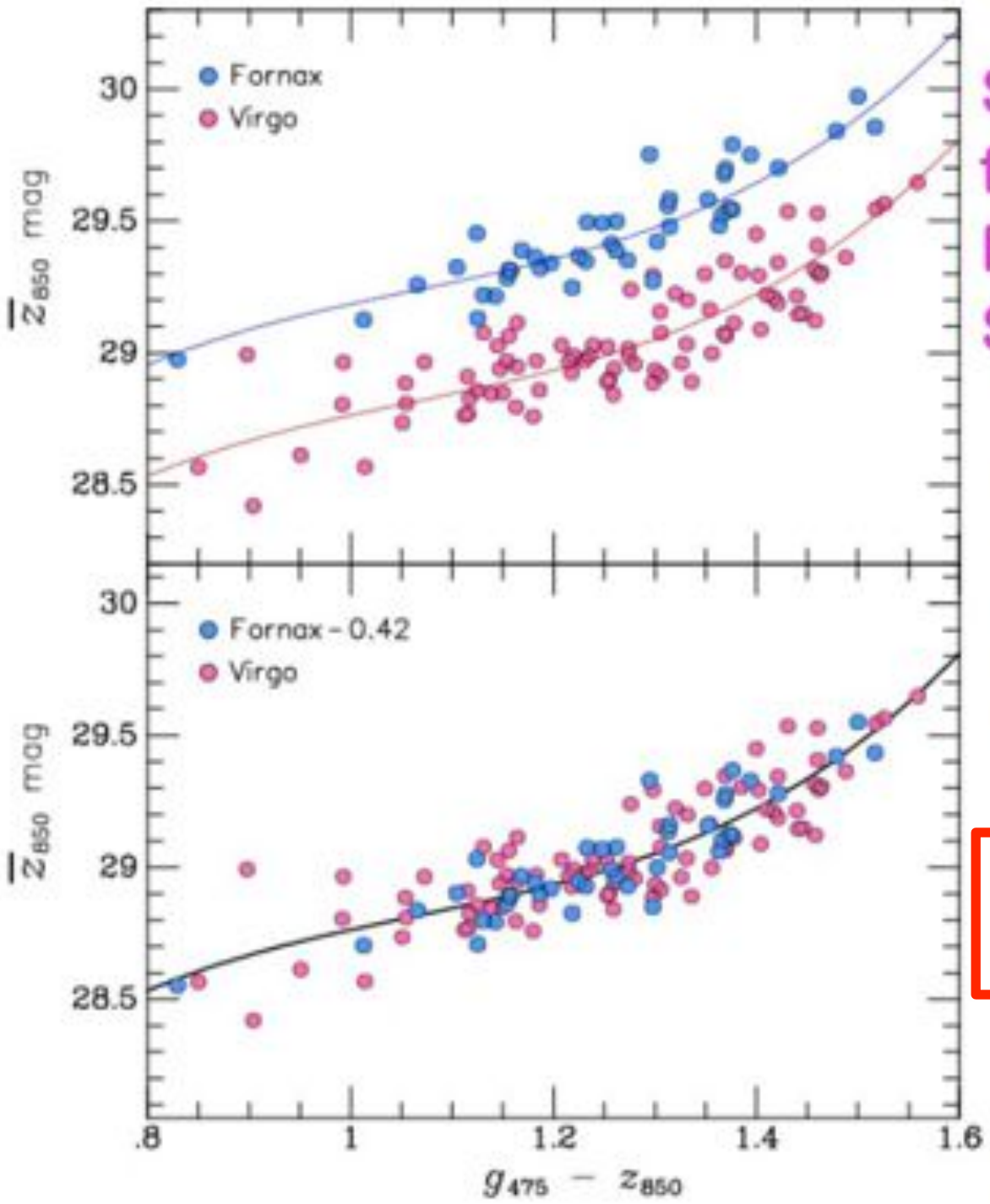
- SBF allow targeted surveys of the nearby universe

Advantages of IR SBF Distances

- SBFs are much more luminous in the NIR
  - Dominated by luminous RGB stars
- Increased contrast with contaminating globular clusters and background galaxies
- Image quality is better in the near-IR
- Dust extinction is much lower than in the optical
- Crowding/blending are not an issue
- Comparable accuracy to SNe

BUT…

- IR SBF are sensitive to young populations and AGB stars, so we avoid the bluest ones
- Also depends on the Cepheid calibration

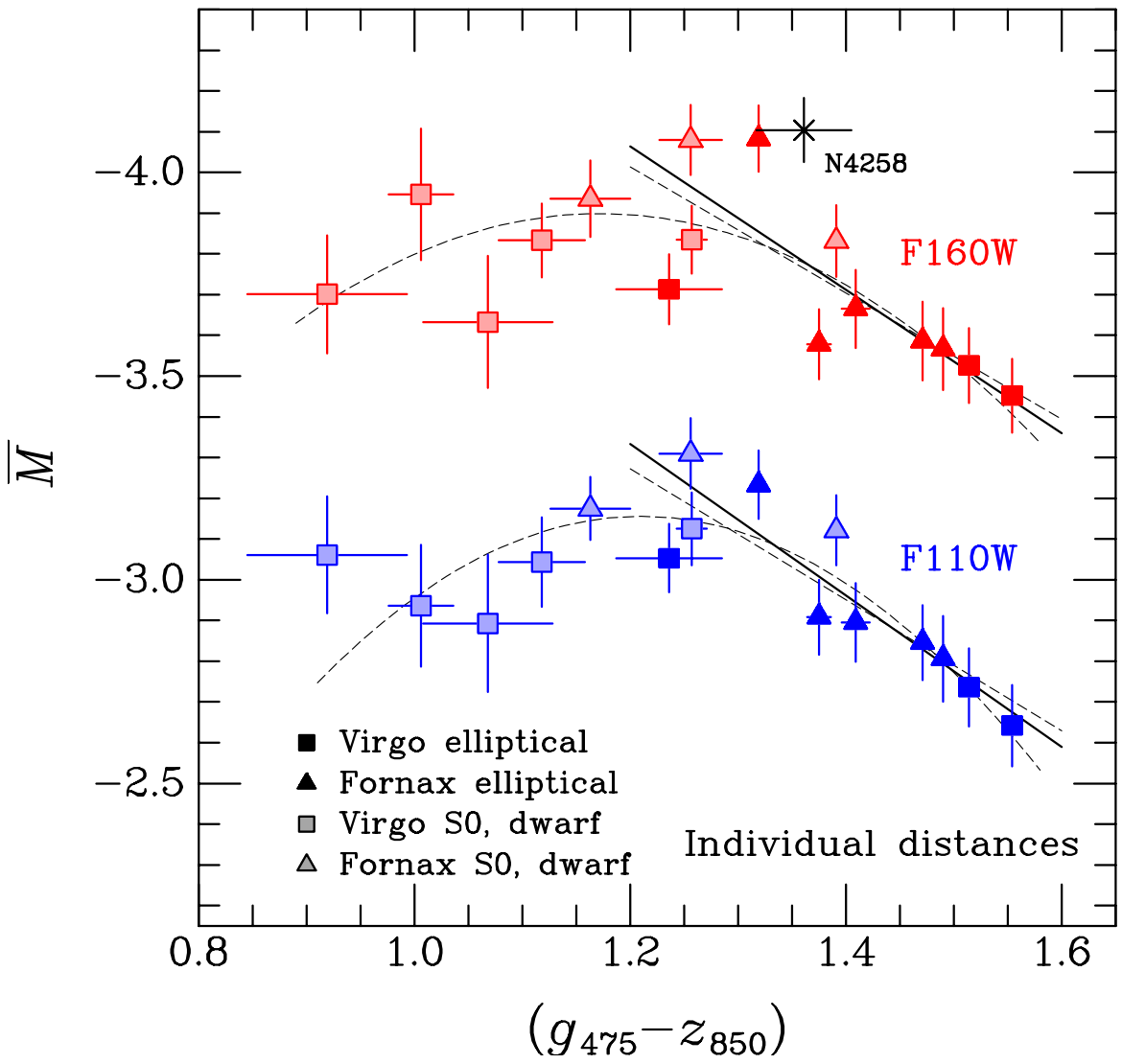


SBF Results from ACS Fornax + Virgo Surveys

Fornax cluster 21±1% more distant than Virgo cluster.

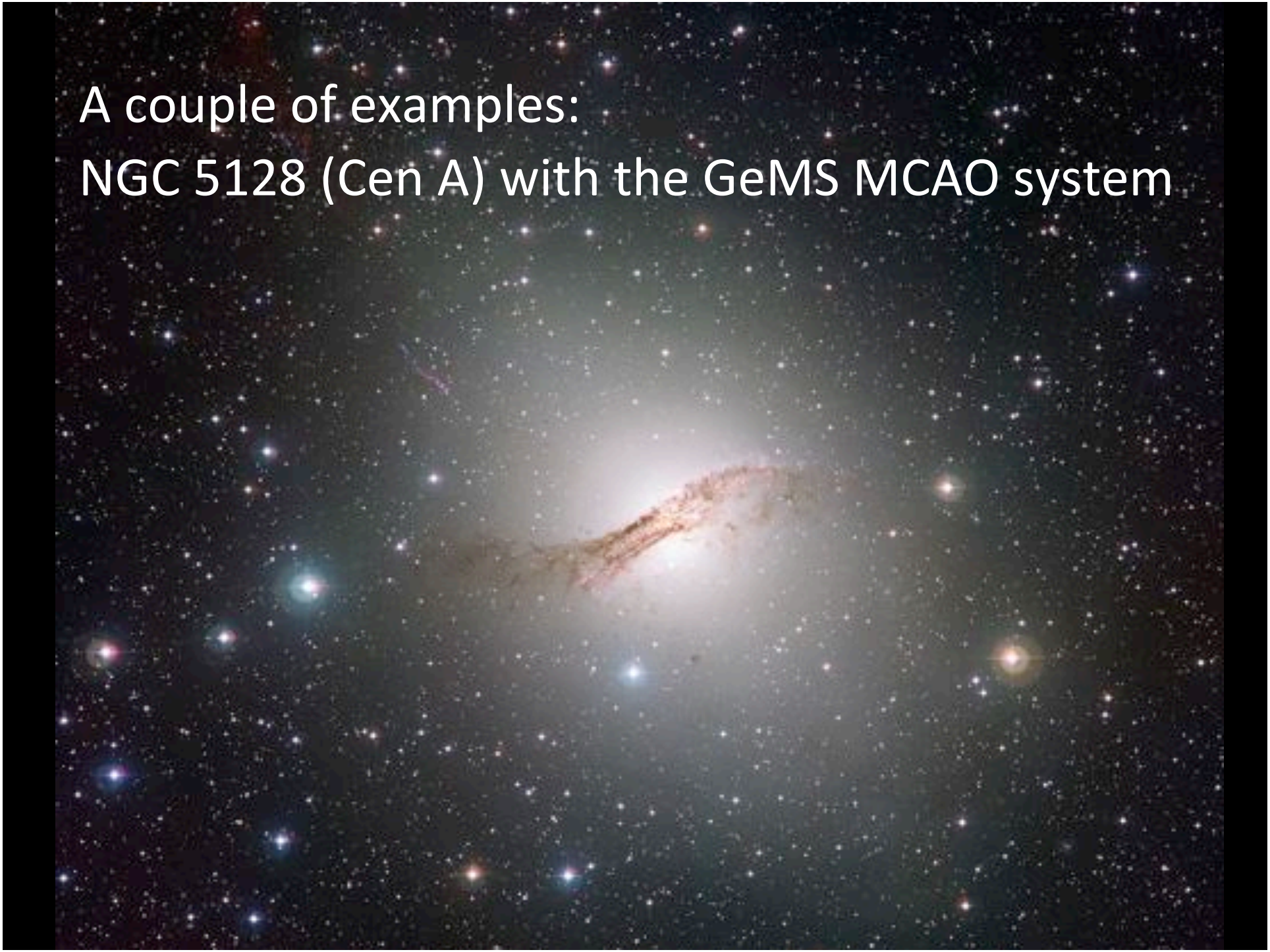
intrinsic scatter
σ = 0.06 mag

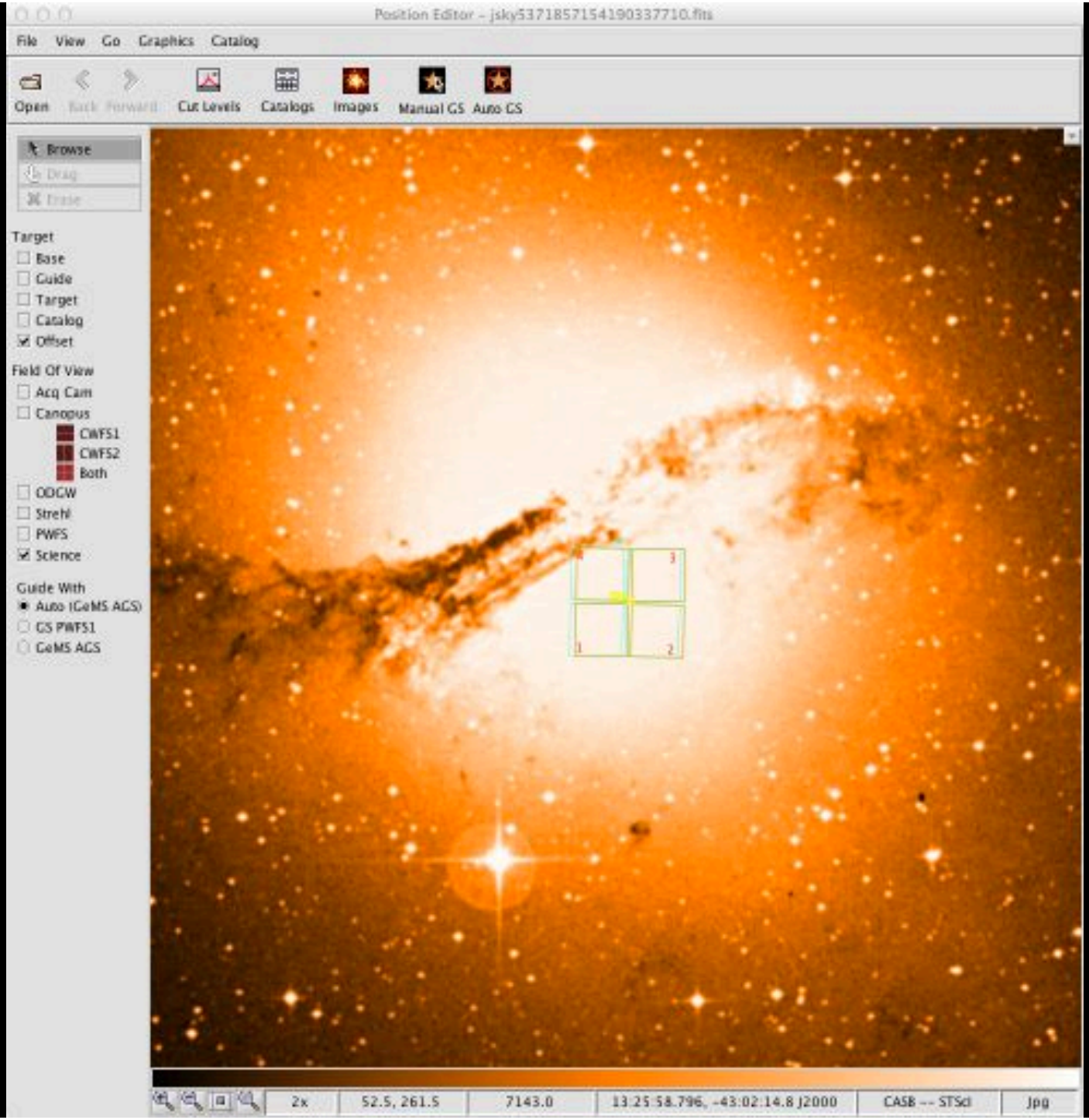
Blakeslee, Jordan, Mei+ 2009



The IR SBF calibration (based on fewer points) has intrinsic scatter of 0.08 and 0.11 mag at *J* and *H*

~5% distances to early-type galaxies


A couple of examples:
NGC 5128 (Cen A) with the GeMS MCAO system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Open Back Forward Cut Levels Catalogs Images Manual GS Auto GS
Browse
Drag
Erase
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Base
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Target
Catalog
Offset
Field Of View
Acq Cam
Canopus
CWFS1
CWFS2
Both
ODGW
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Science
Guide With
Auto (GeMS AGS)
GS PWFS1
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2x
52.5, 261.5
7143.0
13:25:58.796, -43:02:14.8 J2000
CASB -- STScI
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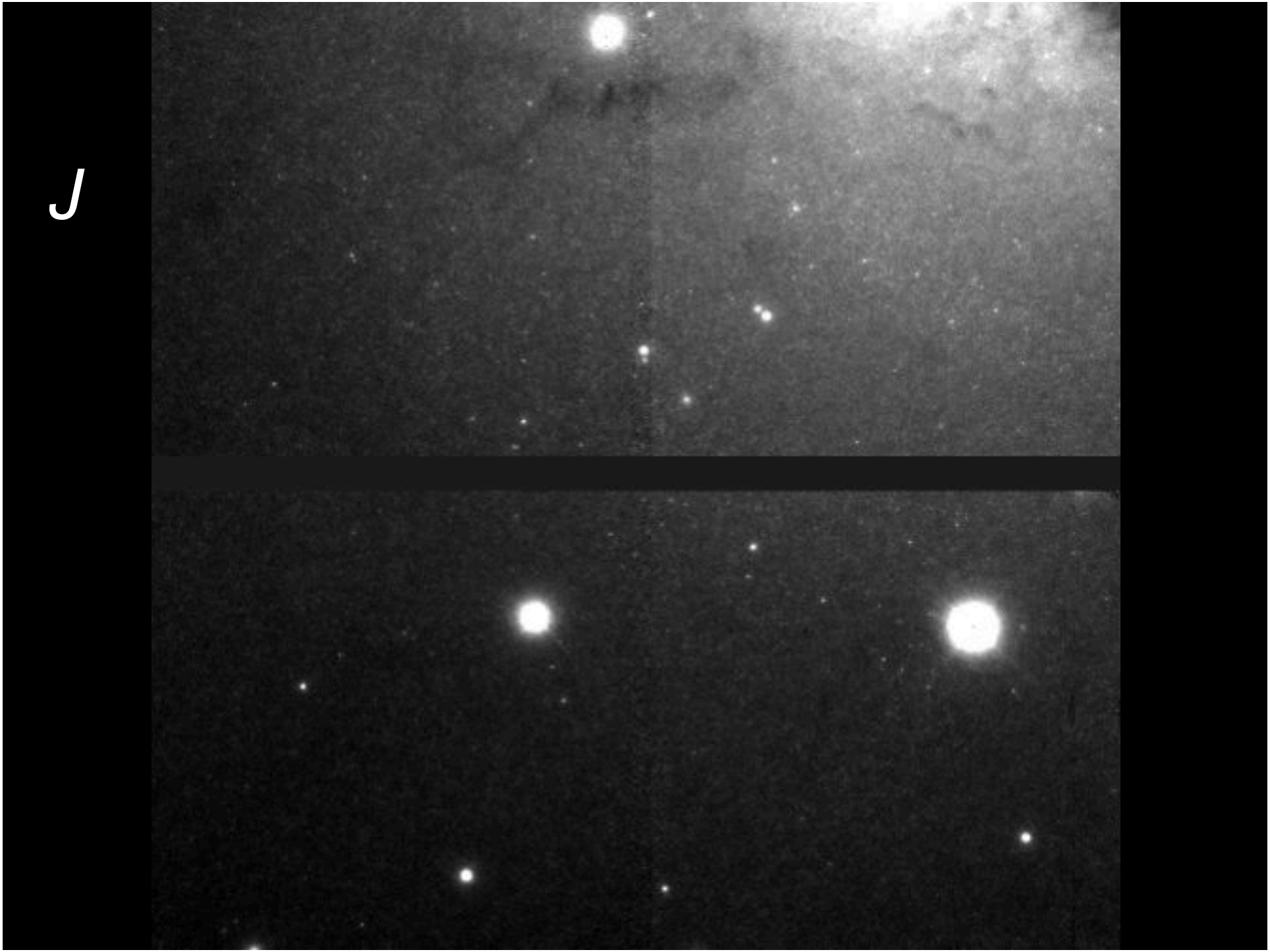
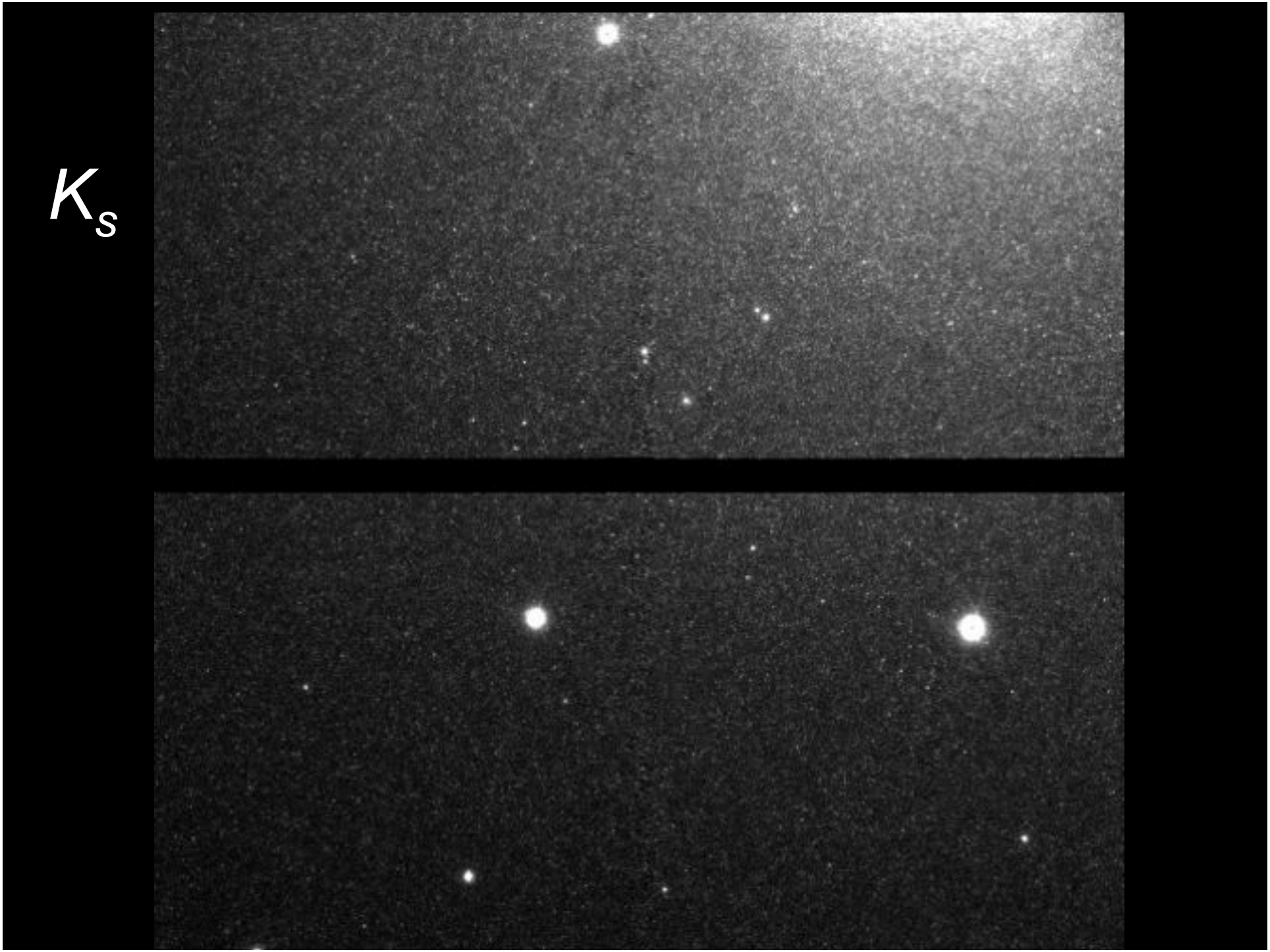
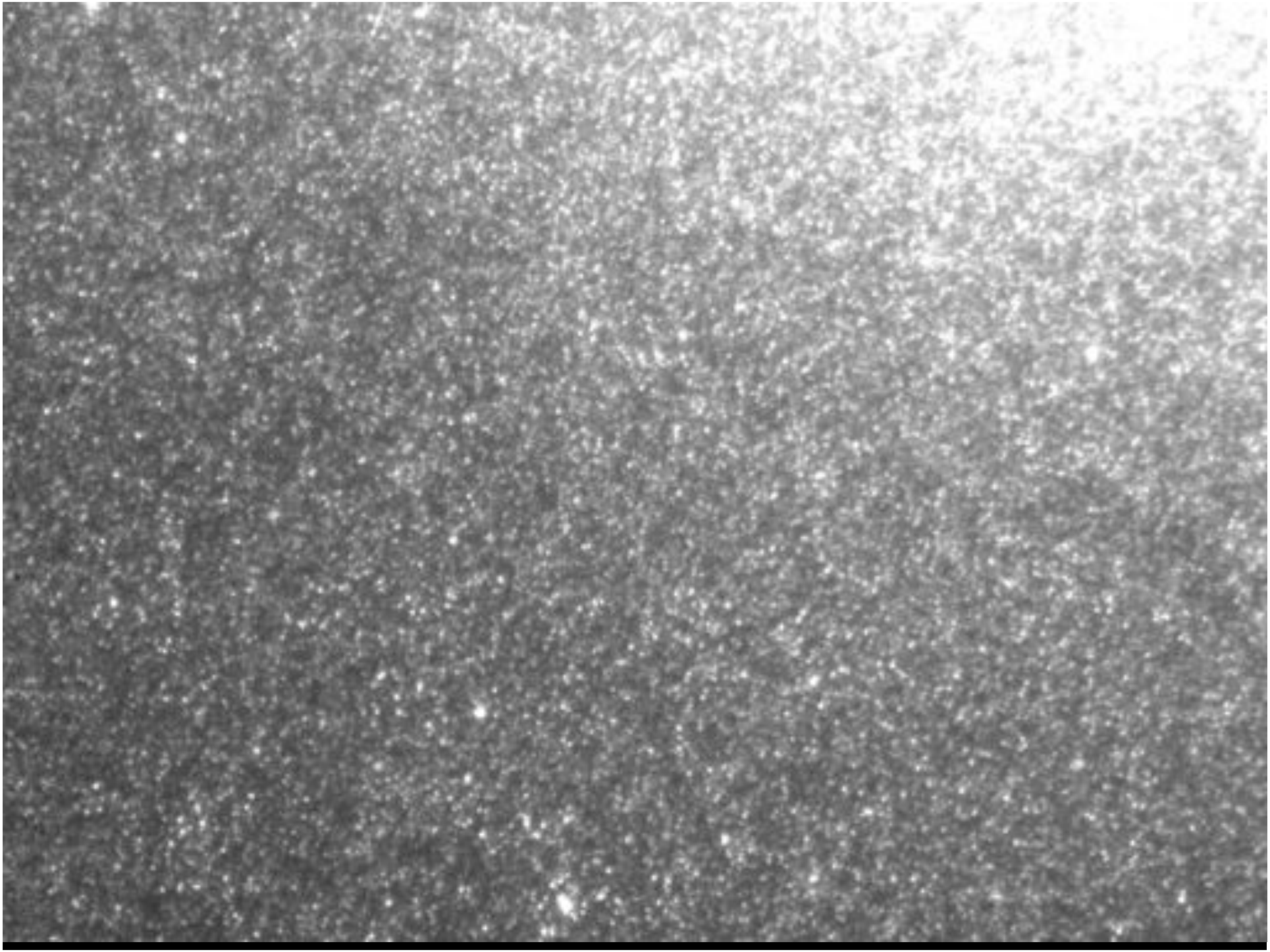
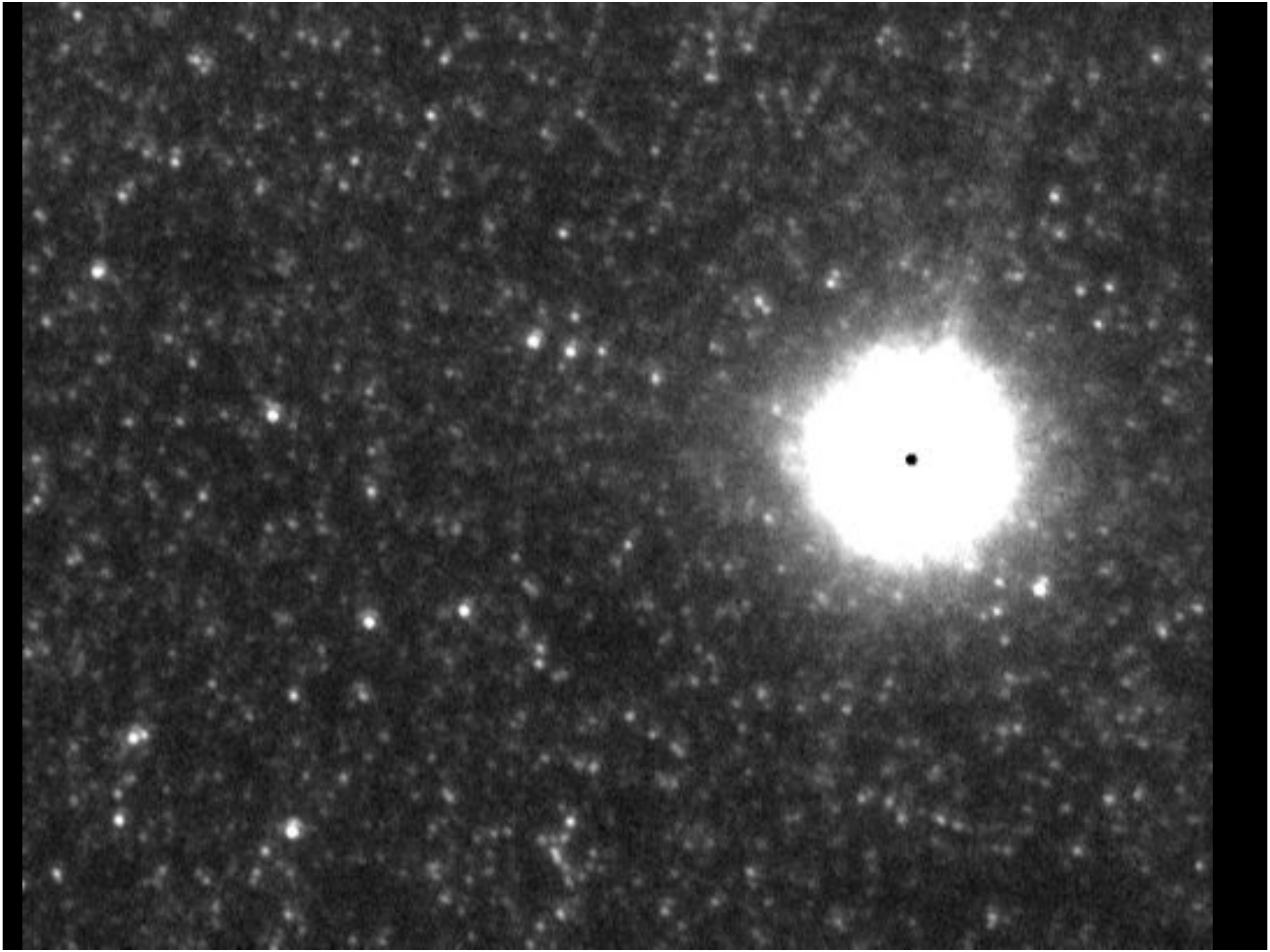
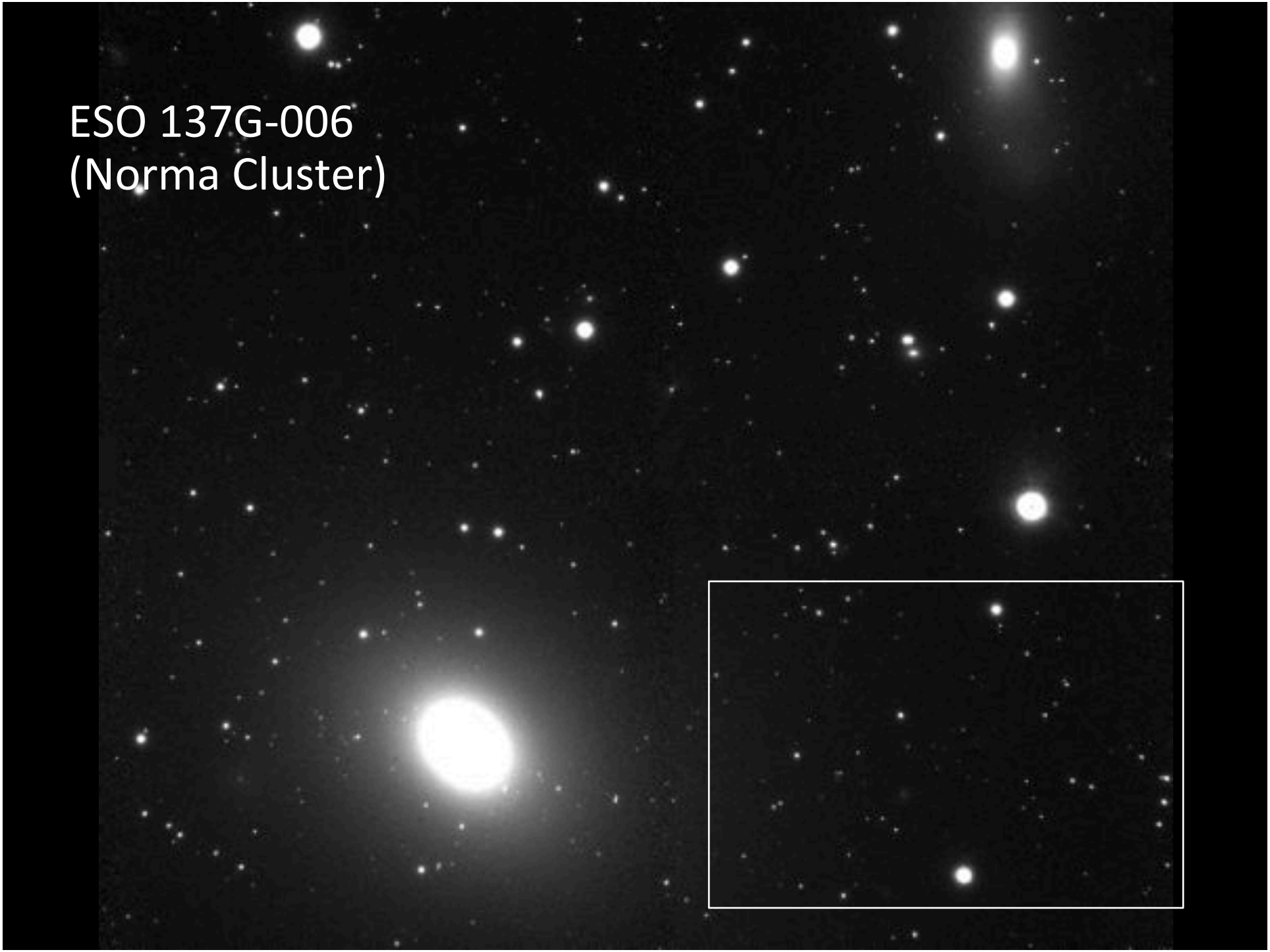
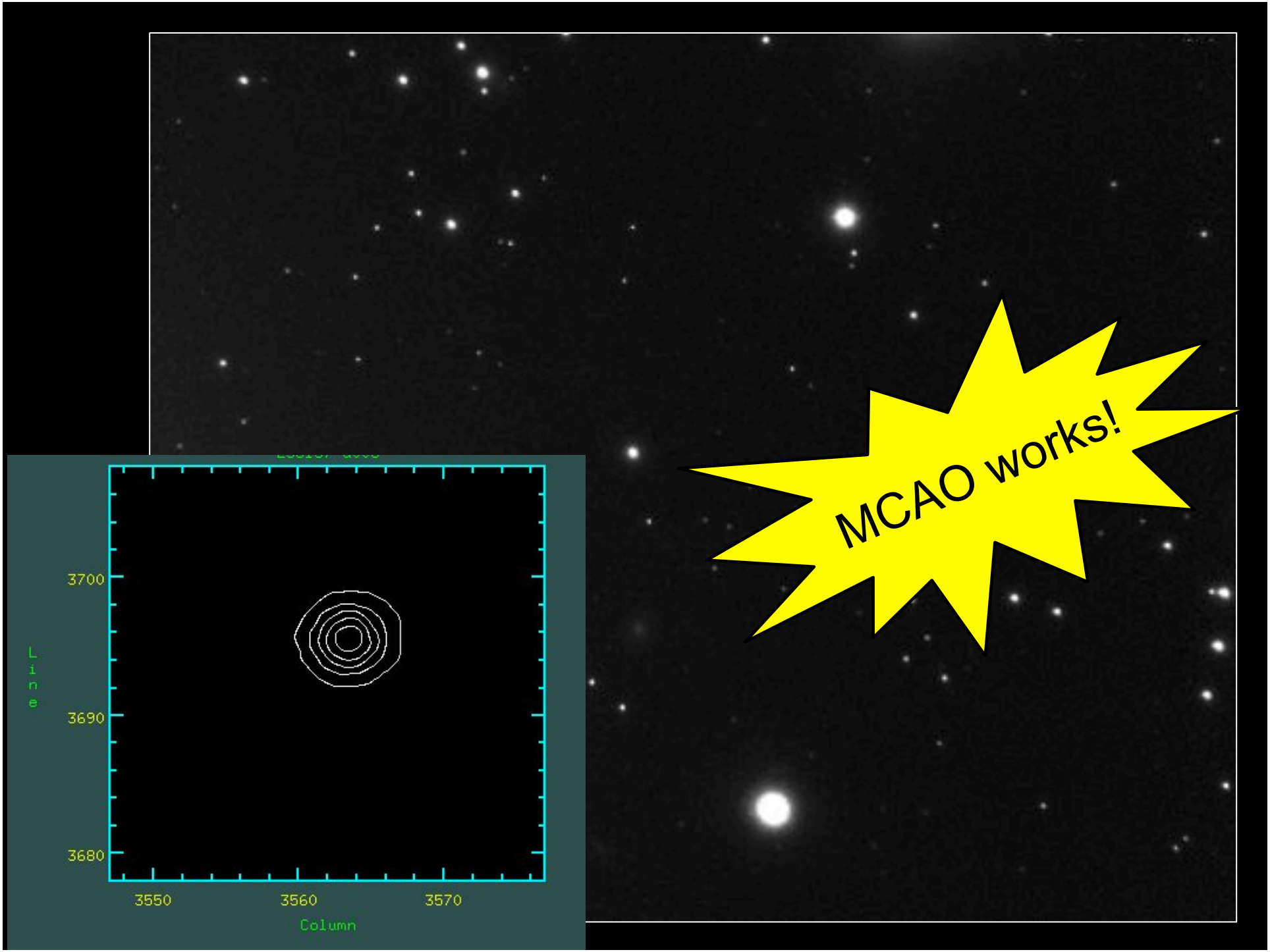

J

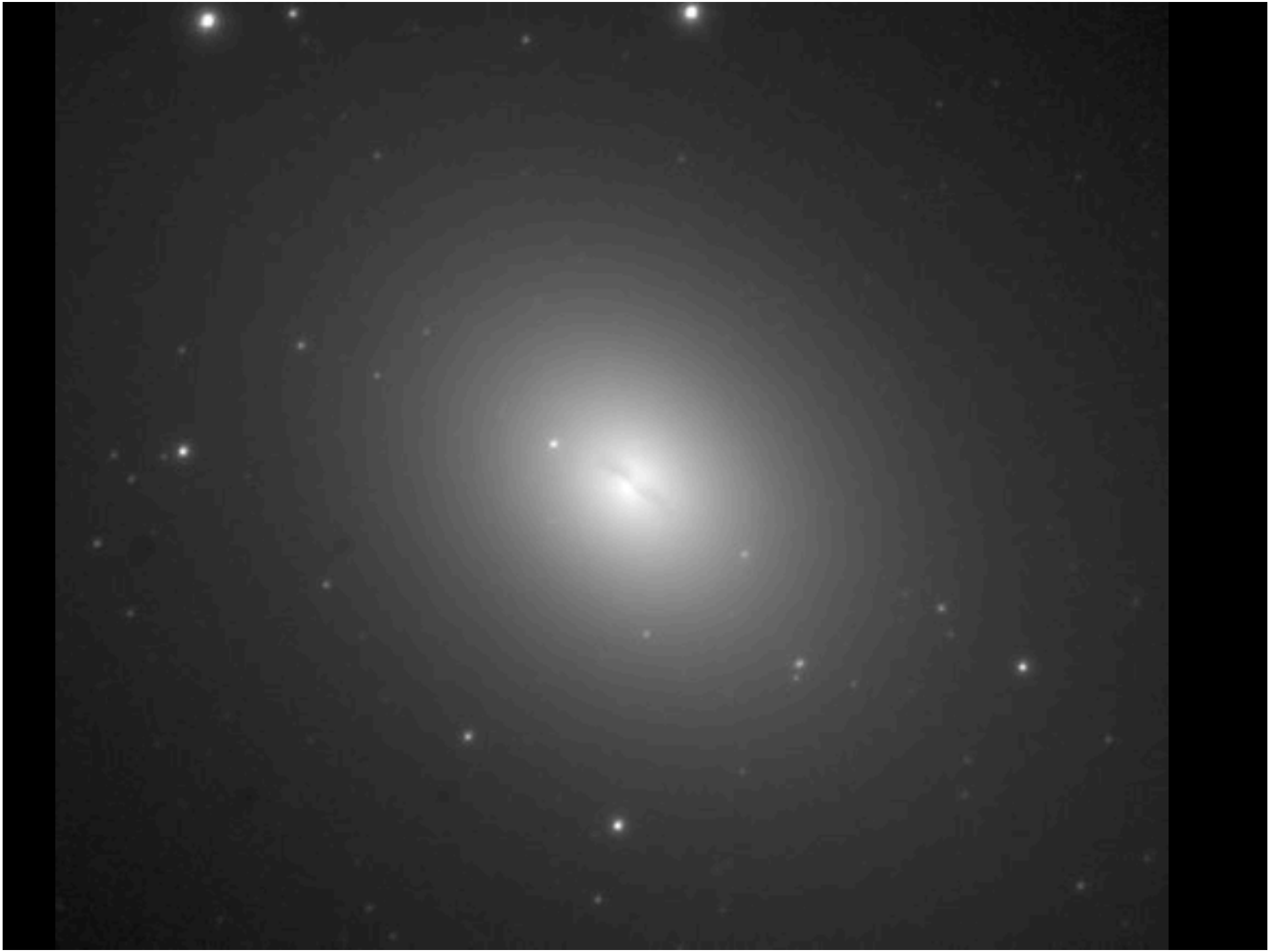

K_s

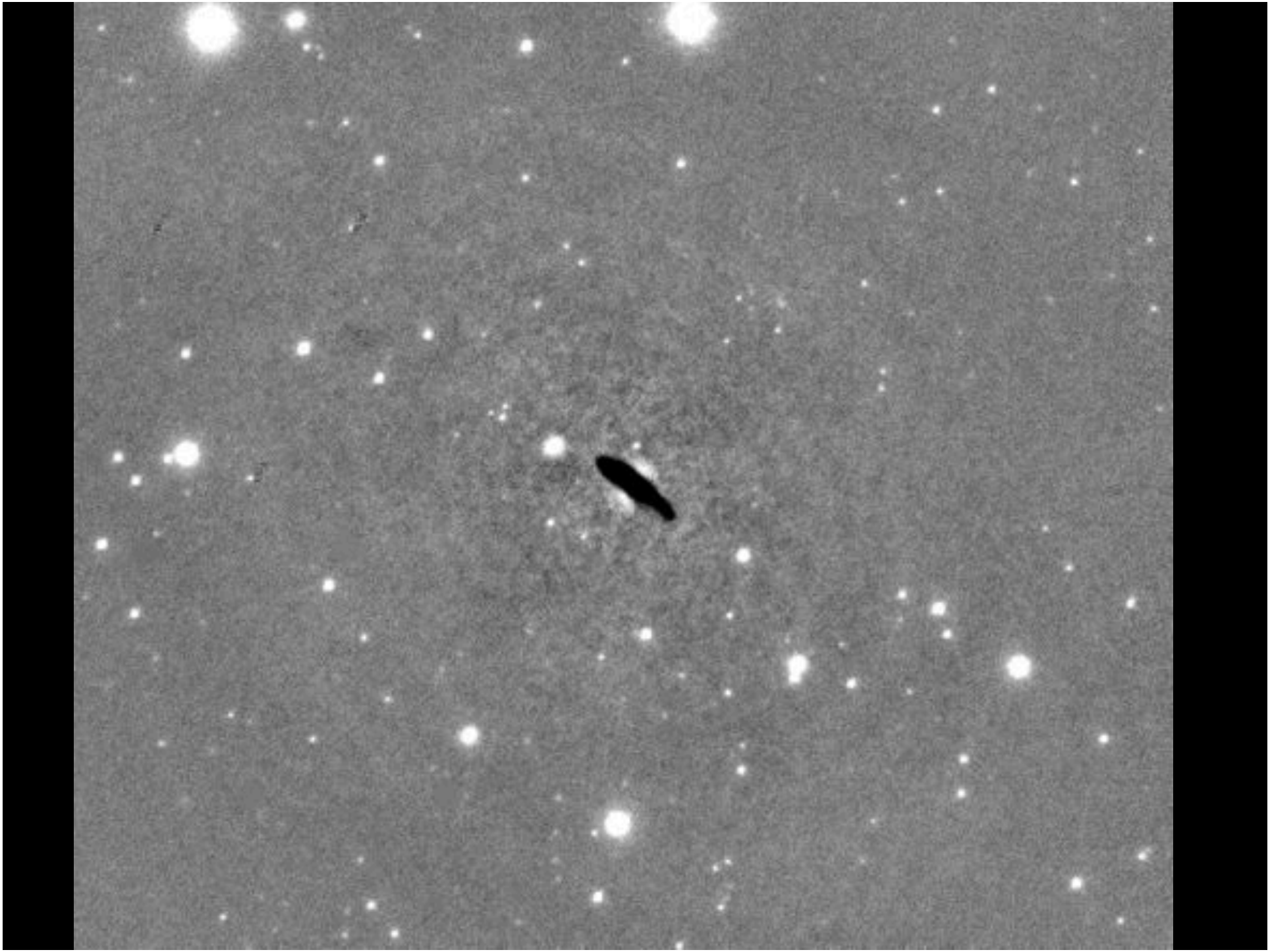




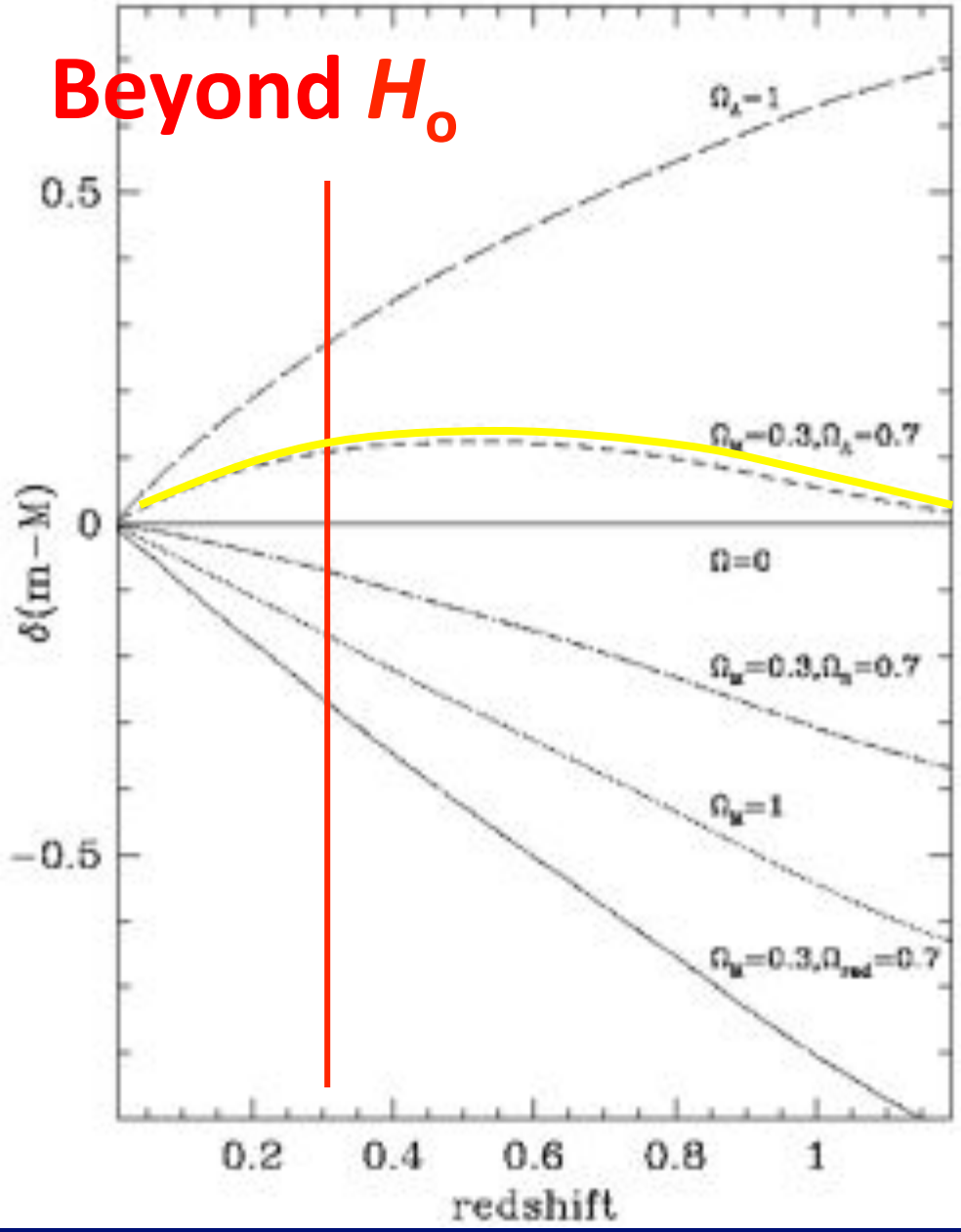

ESO 137G-006
(Norma Cluster)


MCAO works!
3700
3690
3680
Line
3550
3560
3570
Column





Beyond H_o



50× faster than Gemini

5× farther than HST/WFC3

IR SBFs with MCAO: Lessons Learned

- Overheads can really kill you.
  Not every observation is long.

- Astrometric reference is needed to stack images even if astrometry is not critical.

- Photometric reference is also critical.