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SteMaGE

(HOW) DO WE UNDERSTAND GALAXY STELLAR MASSES?

RESULTS FROM A SPATIALLY RESOLVED SPECTROPHOTOMETRIC ANALYSIS OF THE CALIFA SAMPLE

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the CALIFA Collaboration

Symposium S3
Deconstructing Massive Galaxy Formation
22-24 June 2015

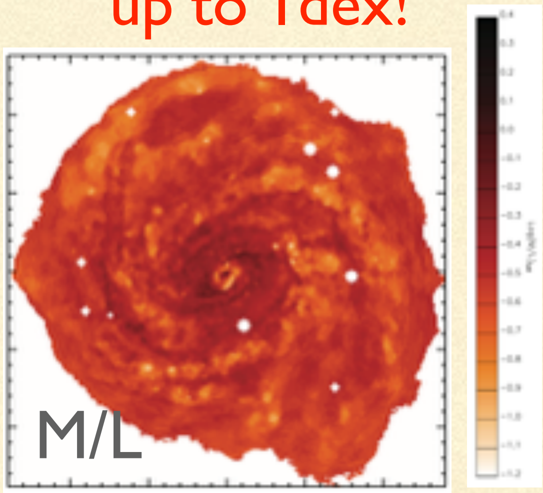
MOTIVATION

- Stellar mass is a key property/driver of galaxy evolution
- Need to measure it as accurately as possible:
  - to measure its build-up, distribution in galaxies and in the intergalactic space, over the cosmic time
  - to understand scaling relations and their evolution
  - to quantify dynamical effects *inside* galaxies
- **Accuracy at 10% level is desirable: is it actually attainable?**

M* FROM STELLAR POPULATION ANALYSIS: FOCUS PROBLEMS (THERE ARE MANY OTHERS!)

- Light is not a linear tracer of stellar mass
- Stellar mass can be reliably obtained from light (VIS-NIR) ***ONLY IF*** we can constrain to some level:
  - the star-formation and chemical enrichment history of a composite stellar population (see e.g. Gallazzi & Bell, 2009)
  - the properties of dust and the relative distribution of dust and stars
- Galaxies are (often) very inhomogeneous: need to properly weigh different regions (see e.g. Zibetti, Charlot & Rix, 2009 ZCR09)

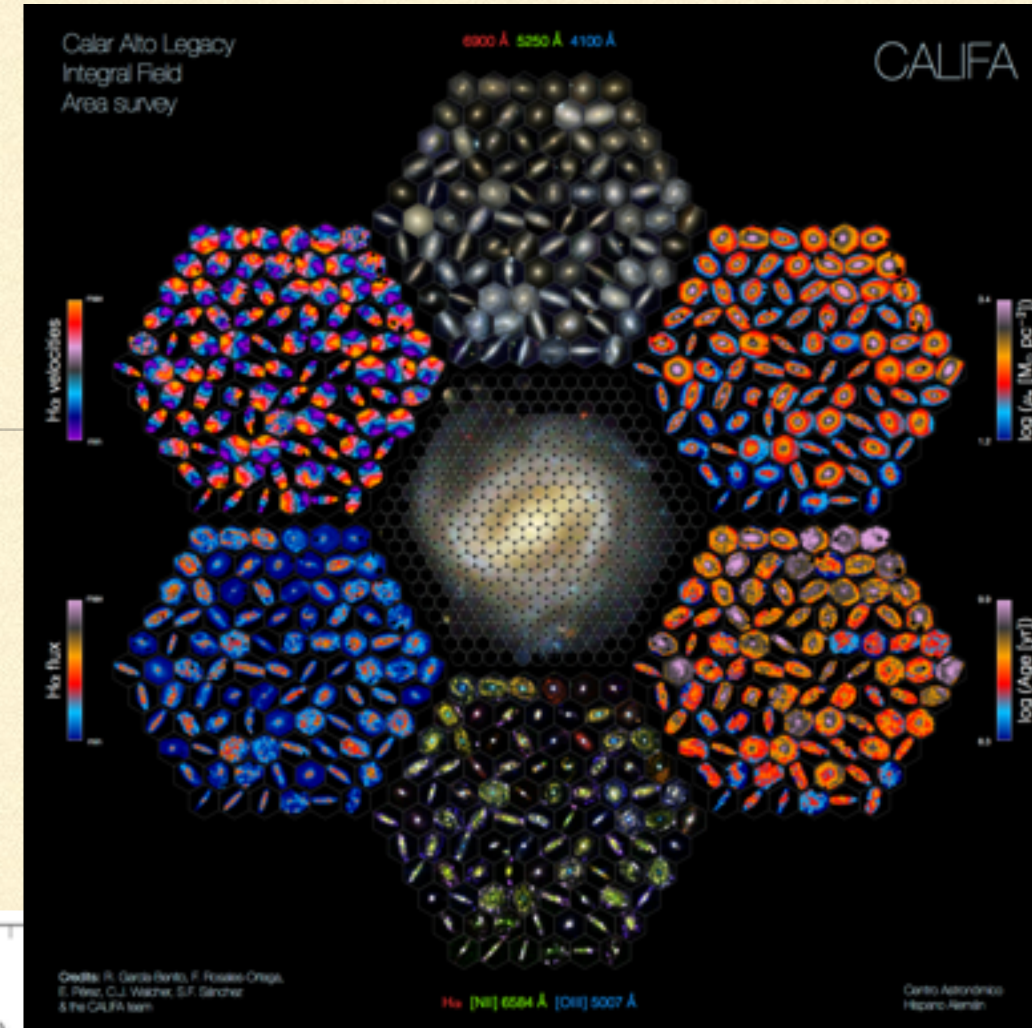
M/L variations up to 1dex!



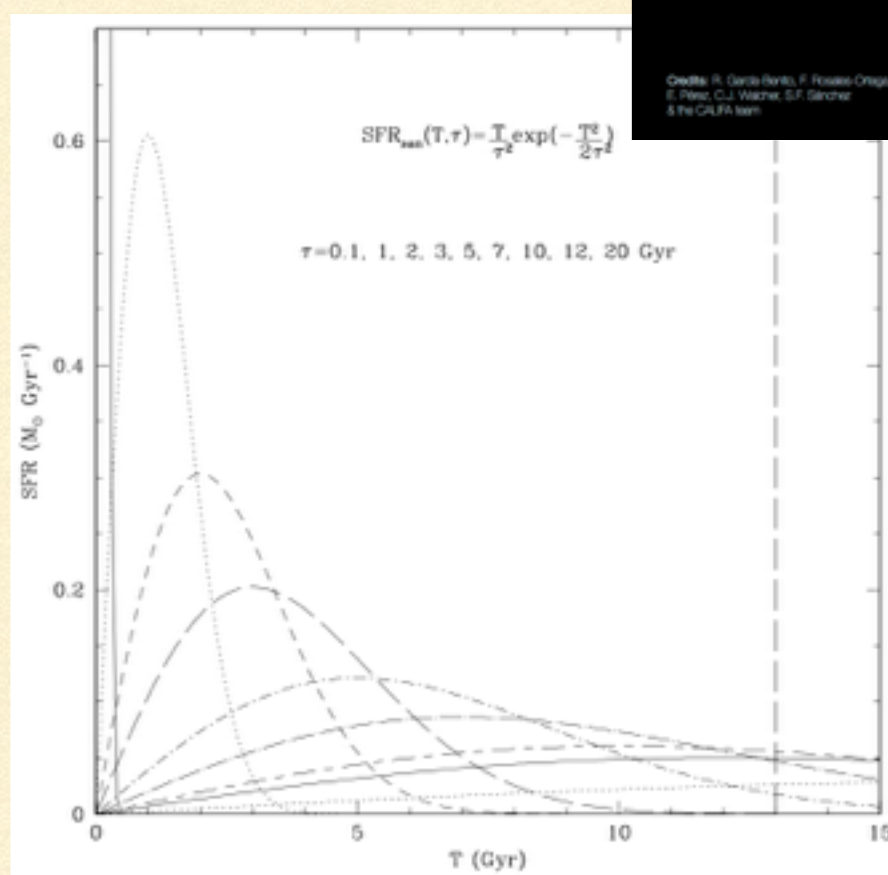
OBJECTIVES

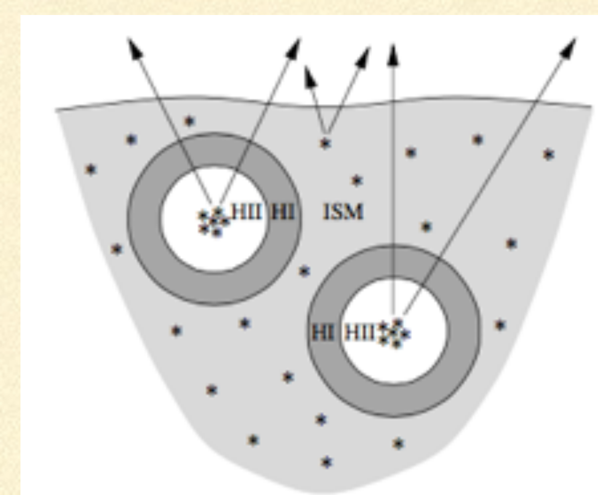
- Create a *benchmark* of **optimally measured stellar masses** on a sample of galaxies that offers:
  - good quality optical spectroscopy to nail down SFH and metallicity
  - multi-band imaging, to constrain dust attenuation
  - spatial resolution (scales ~1 kpc) not to miss dim components
- I. Calibrate "cheaper" estimators (e.g. color-M/L relations)
- II. **Quantify biases** arising from:
  - lack of complete information (e.g. no spectroscopy available)
  - lack of spatial resolution (check results from ZCR09)/ limited spatial sampling
  - assumptions in the models (chiefly SF and ChEn Histories, dust)
- Note: Use of resolved regions allows us to test more "extreme" conditions than galaxies overall

EXPERIMENTAL SETUP



- Dataset: *CALIFA* (DR2, Garcia Benito, SZ, Sanchez +2015) + SDSS:
  200 galaxies, all morphologies, ~500,000 spaxels
- Models: ***new*** Stellar Popopulation Synthesis libraries
  - BC03 SSPs, Chabrier IMF
  - SFH: á la Sandage (1986, Gavazzi et al. 2002), variable age, variable tau, bursts
  - Generalised leaking box model for metal enrichment history (adapted from Erb 2006)
  - 2-component dust á la Charlot & Fall (2000)
  - library #500,000



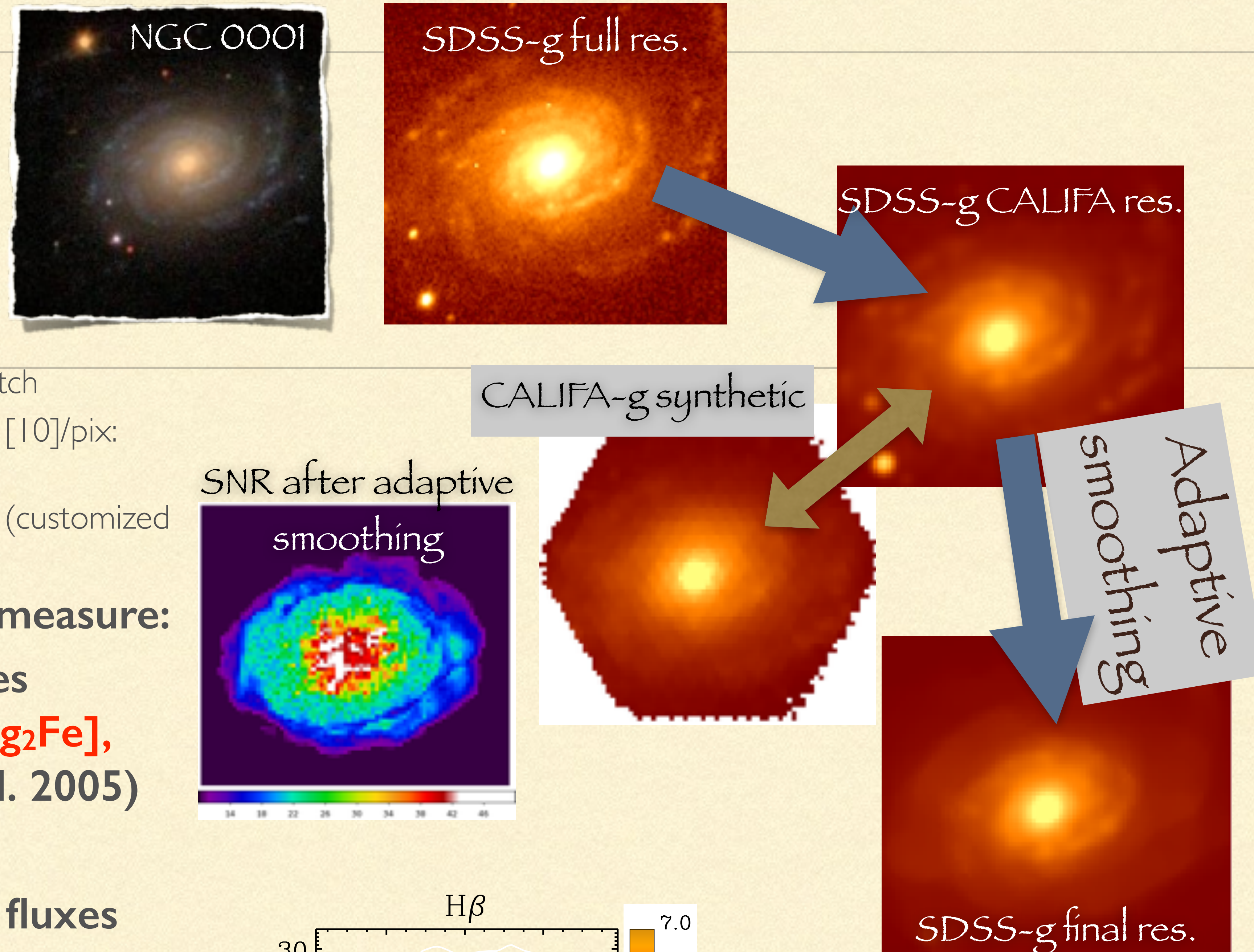


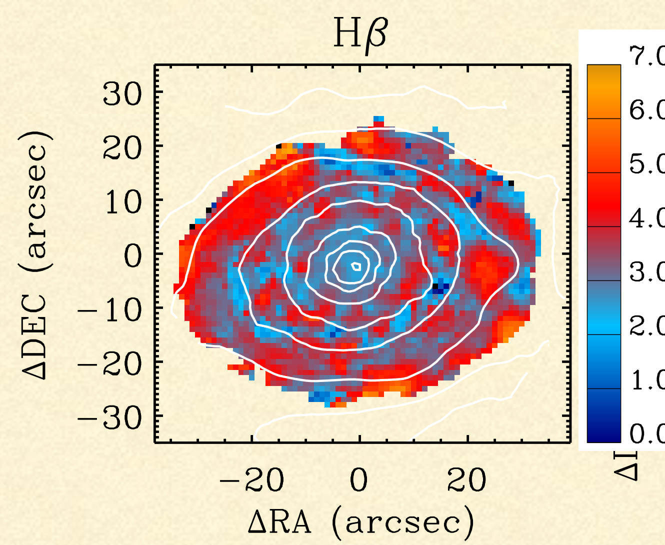
METHOD

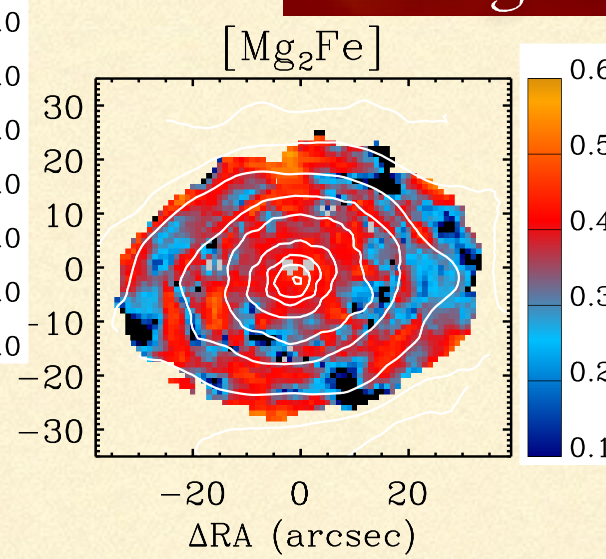
- CALIFA-SDSS match: resample & PSF match
- Adaptive smoothing for optimal SNR>20 [10]/pix: azmooth3C
- Stellar continuum-nebular line decoupling (customized GANDALF+pPXF) spaxel by spaxel
- **Spaxel-by-spaxel *consistently* measure:**
  - **5 stellar absorption indices (D4000n, Hβ, Hγ+Hδ, [Mg_2Fe], [MgFe]’ as in Gallazzi et al. 2005)**

AND

  - **5 broadband photometric fluxes (SDSS ugriz)**
- ***Bayesian* parameter estimation: compare observables with each model**
  ⟹ likelihood function
  ⟹ posterior Probability Distribution Function
  ⟹ marginalisation
  ⟹ Median-likelihood M*

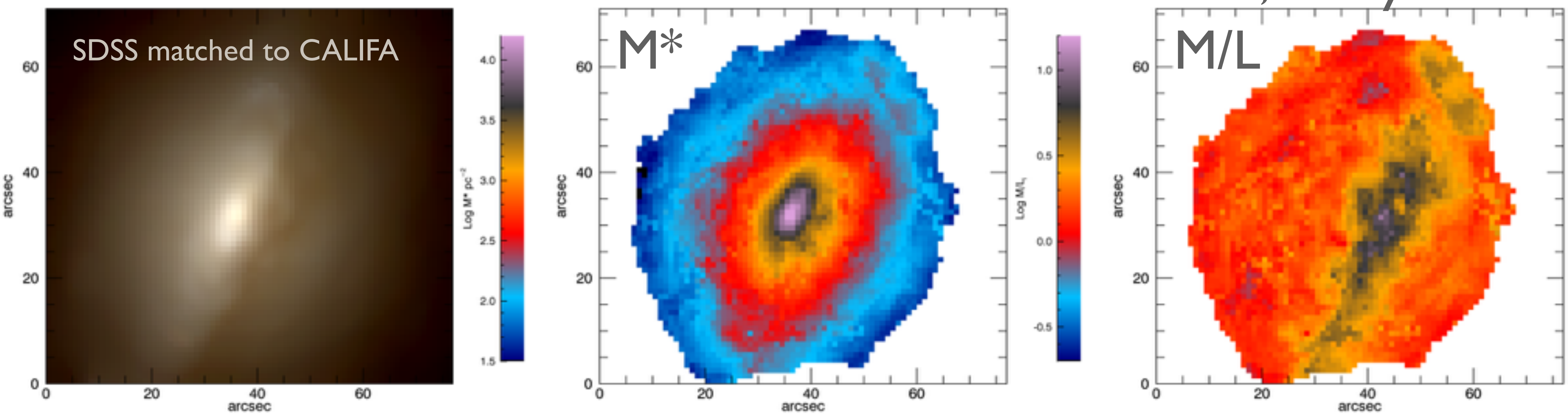


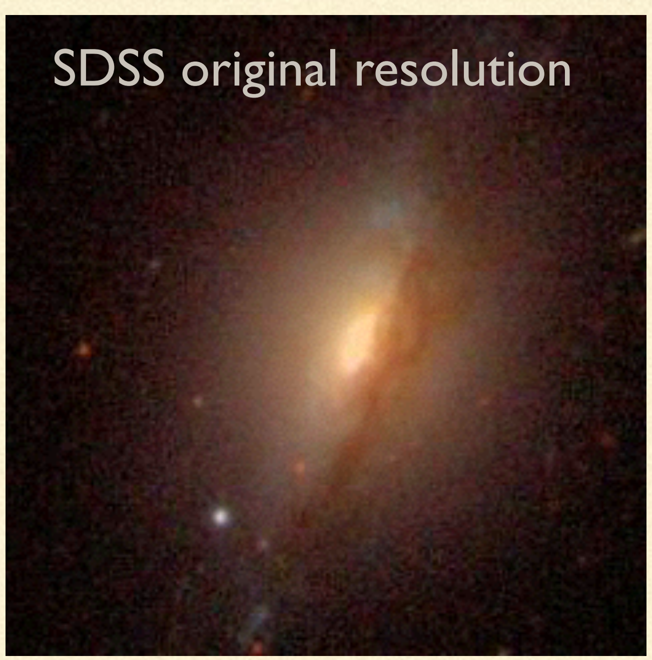




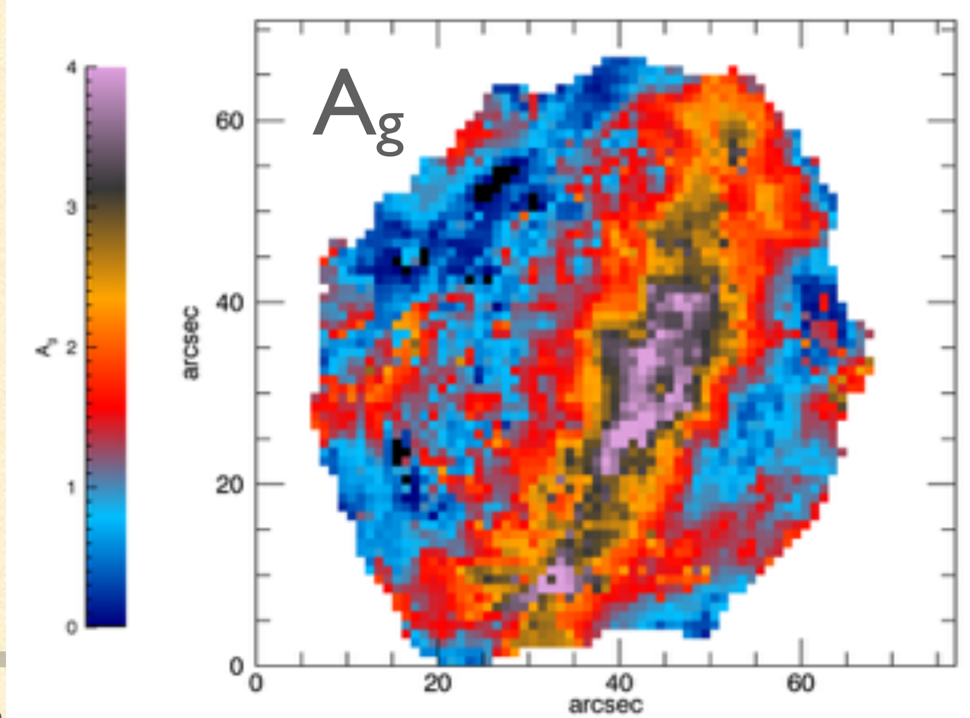
DOES IT WORK WELL?

NGC1056: one of the most difficult cases: distinct SPs, heavy dust





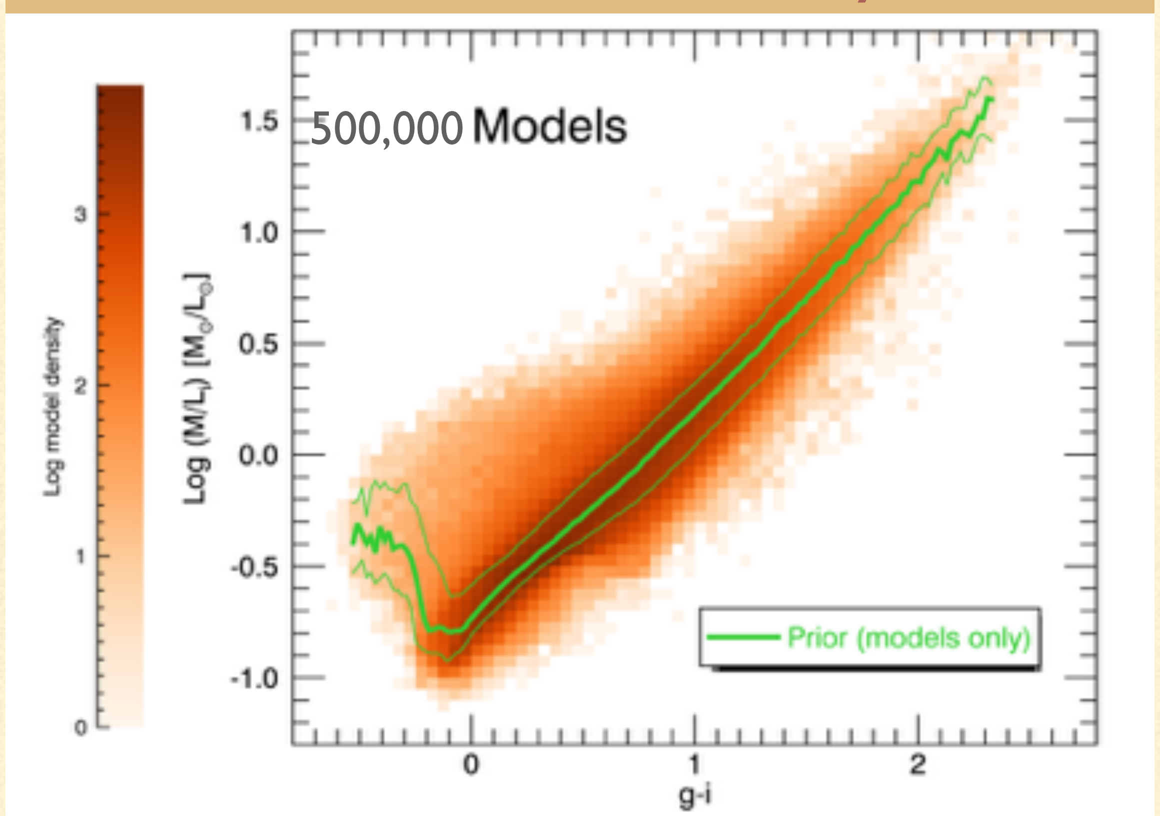
More than words, one example:
dust lanes properly "corrected", smooth mass distribution



COLOR-M/L RELATIONS

- Cheapest M* estimator
- Origin: at fixed mass, what makes the stellar light dimmer, it makes it redder as well (age, Z, dust, nearly degenerate)

At any given color, a range of <~1dex in M/L is allowed by models



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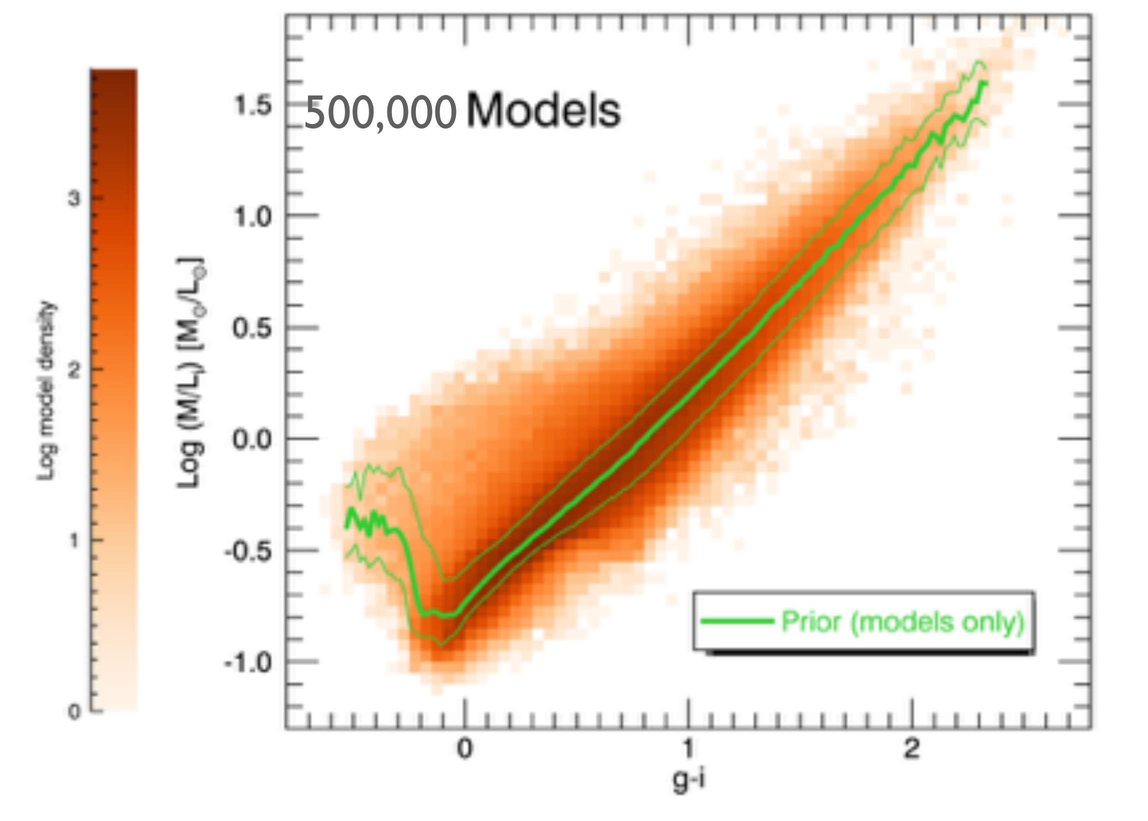
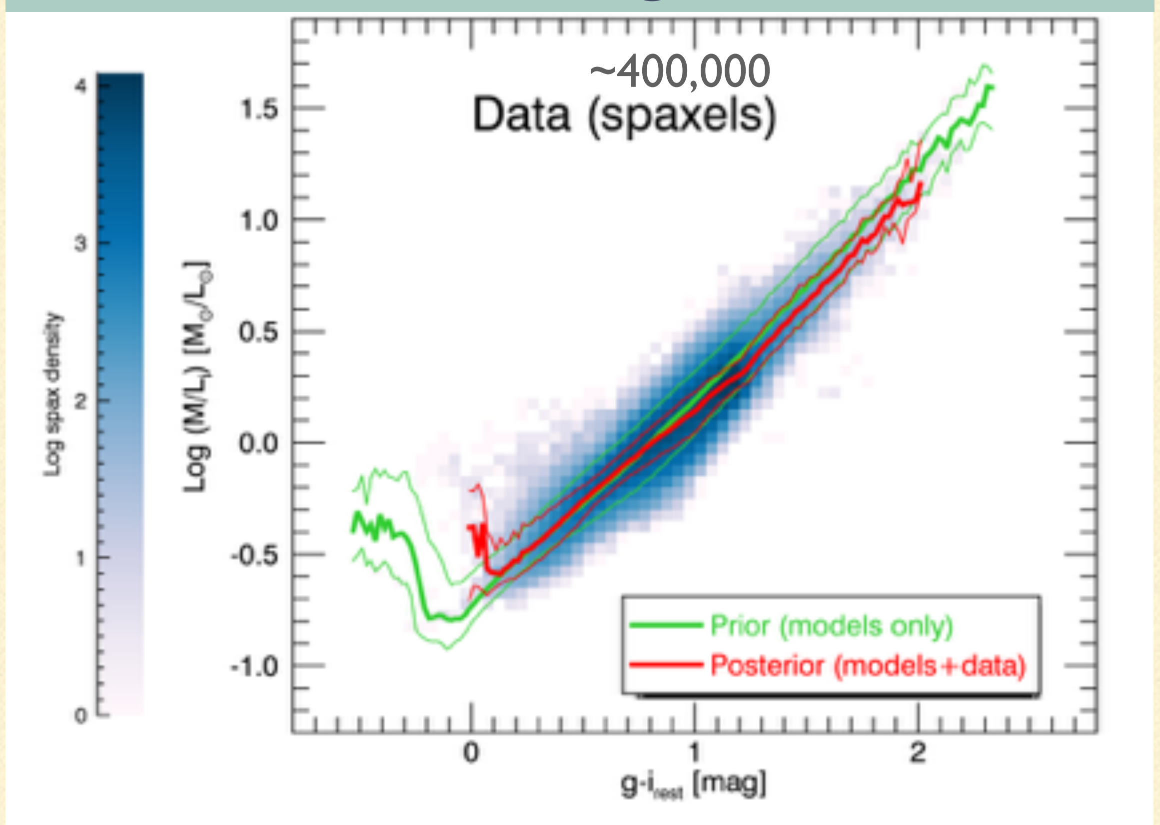
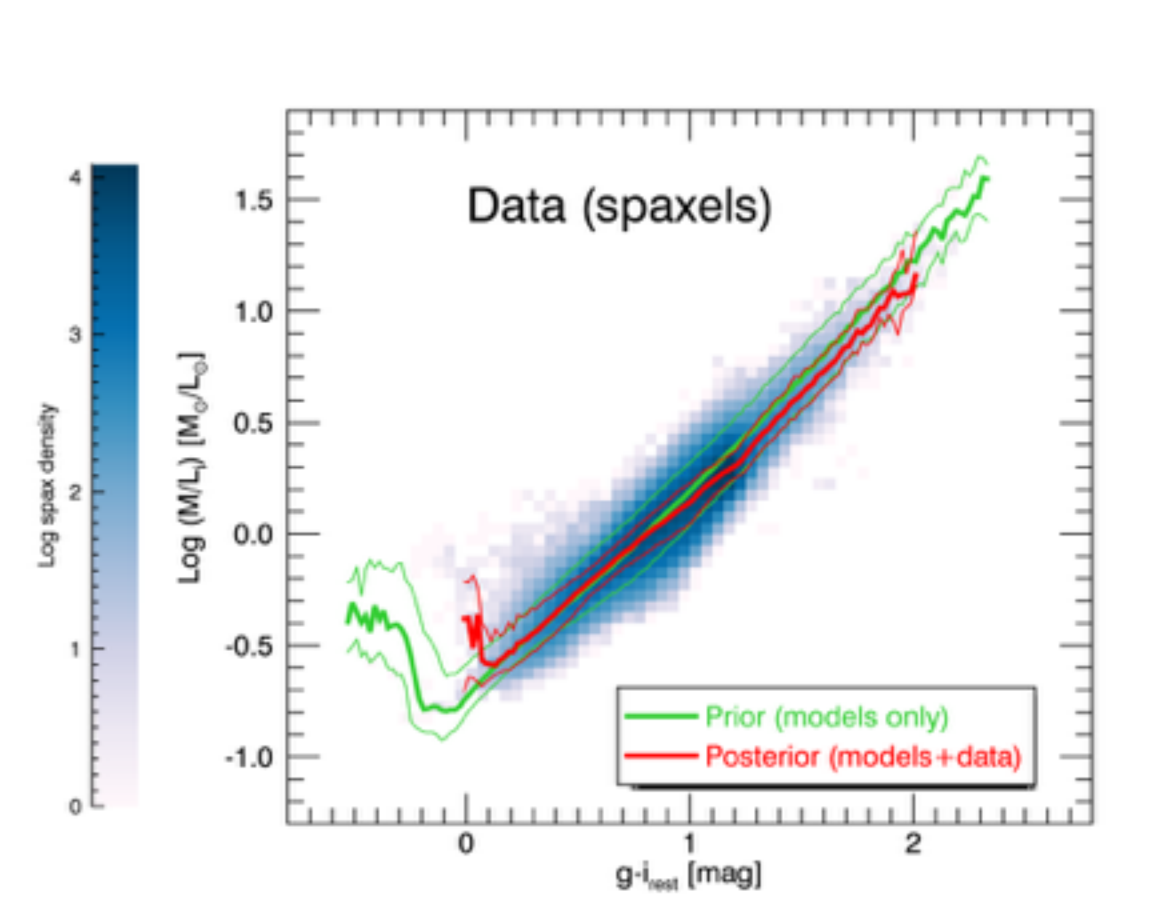


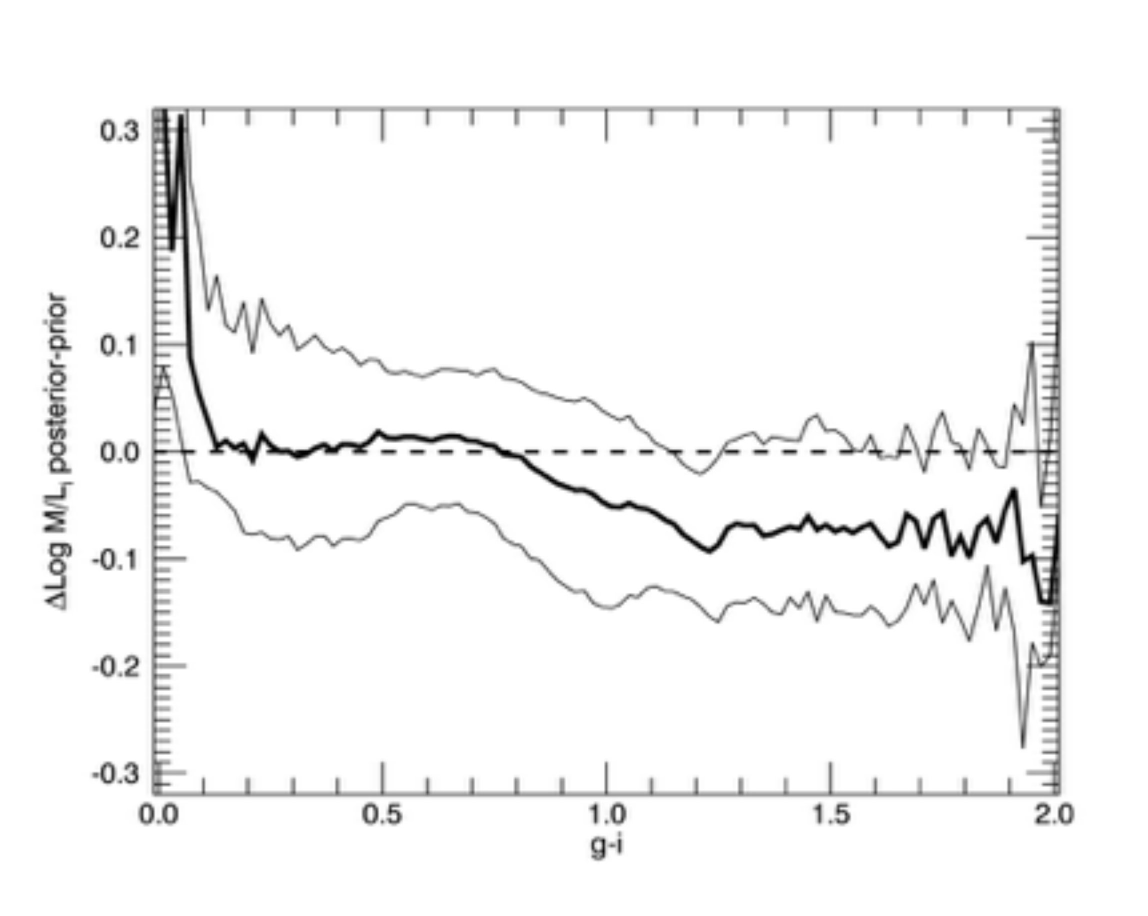
Real regions span marginally narrower ranges in M/L



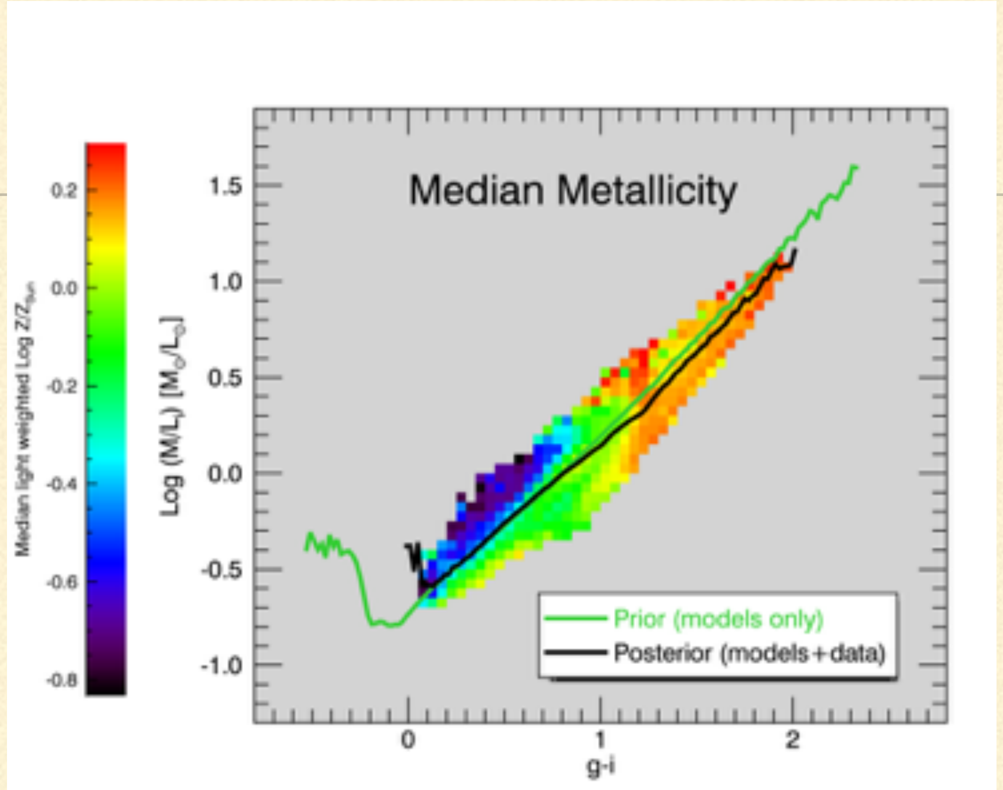
COLOR-M/L: CALIBRATION

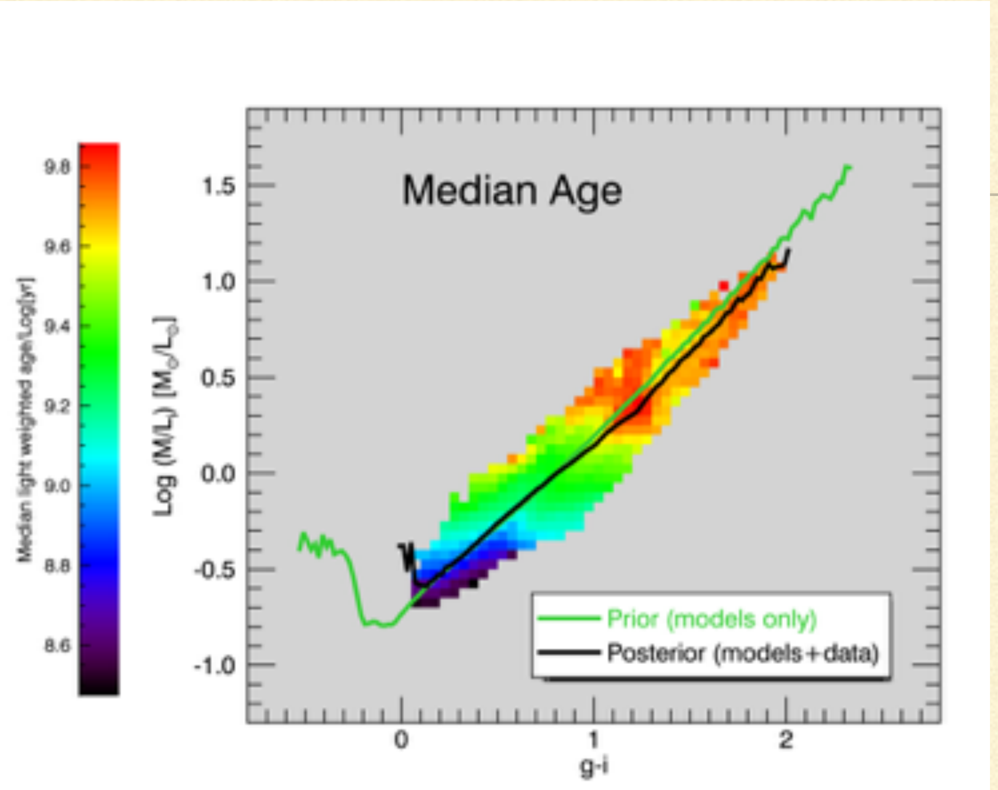
- Importance of calibrating model libraries against data (see also Taylor+11)

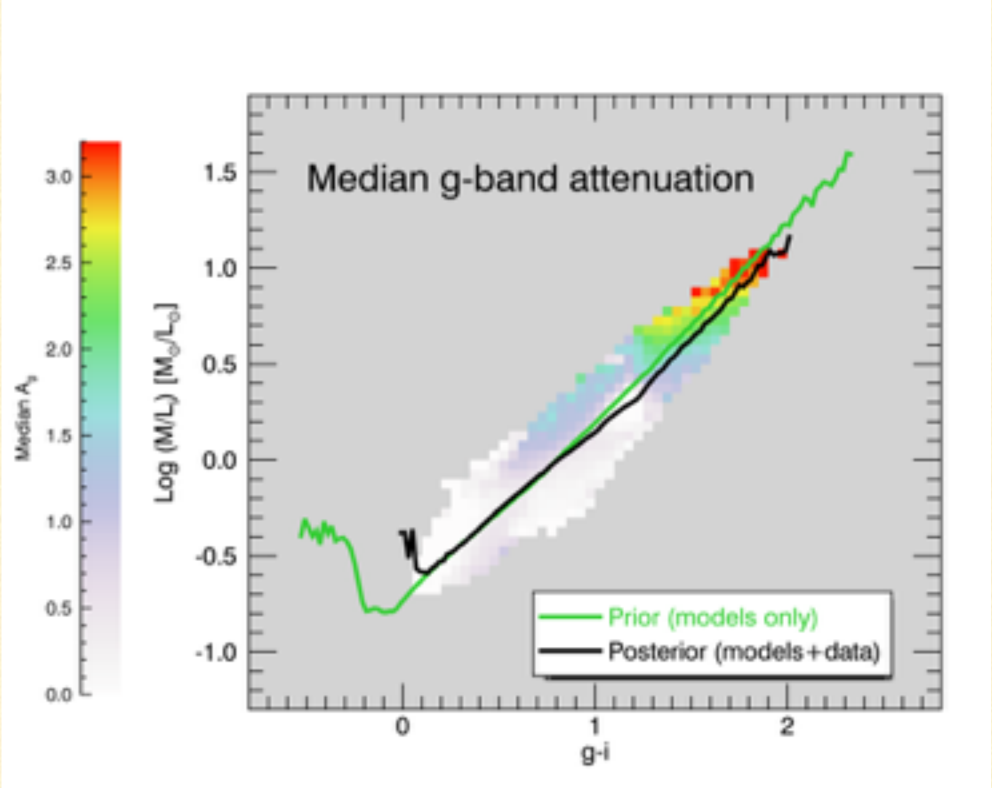




CMLR: ORIGIN OF SCATTER AND BIAS

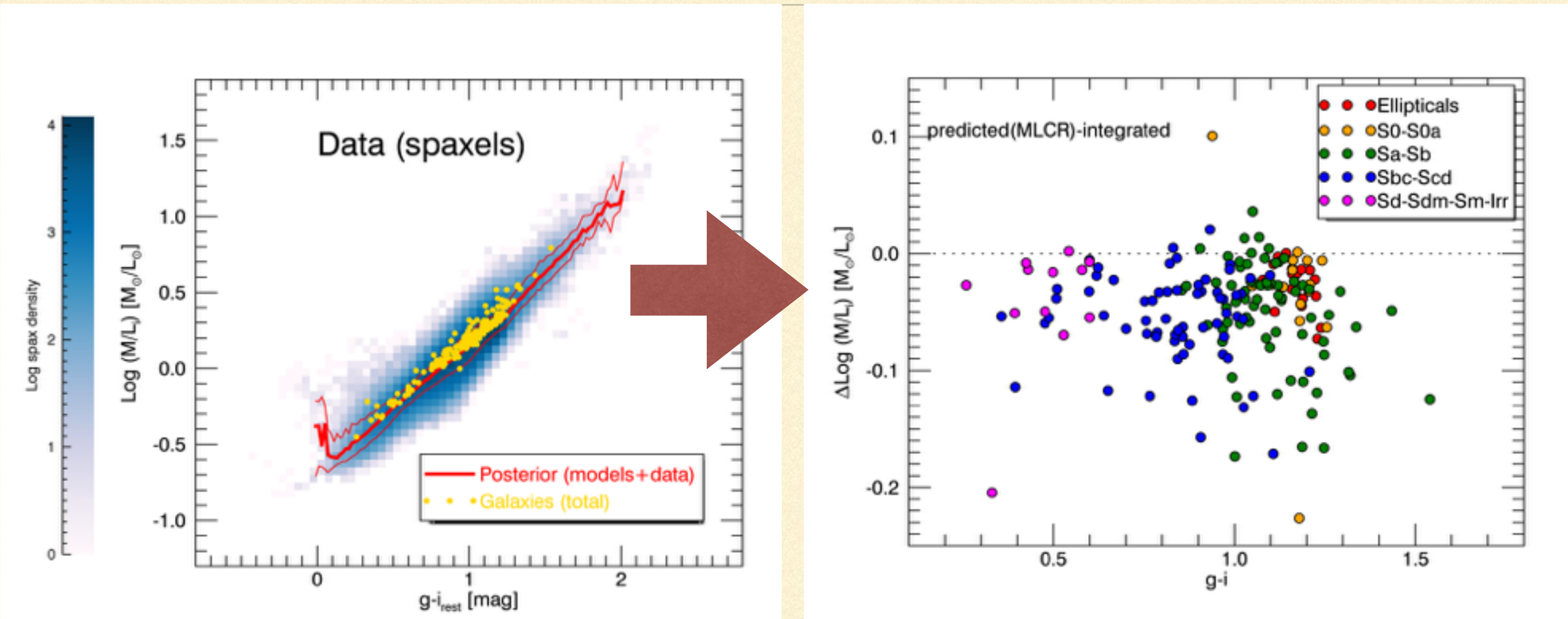






- Age, Z and dust are not perfectly degenerate!
- Blue colors: mainly metallicity
- Red colors: mainly dust
- Age contributes at blue and intermediate colors

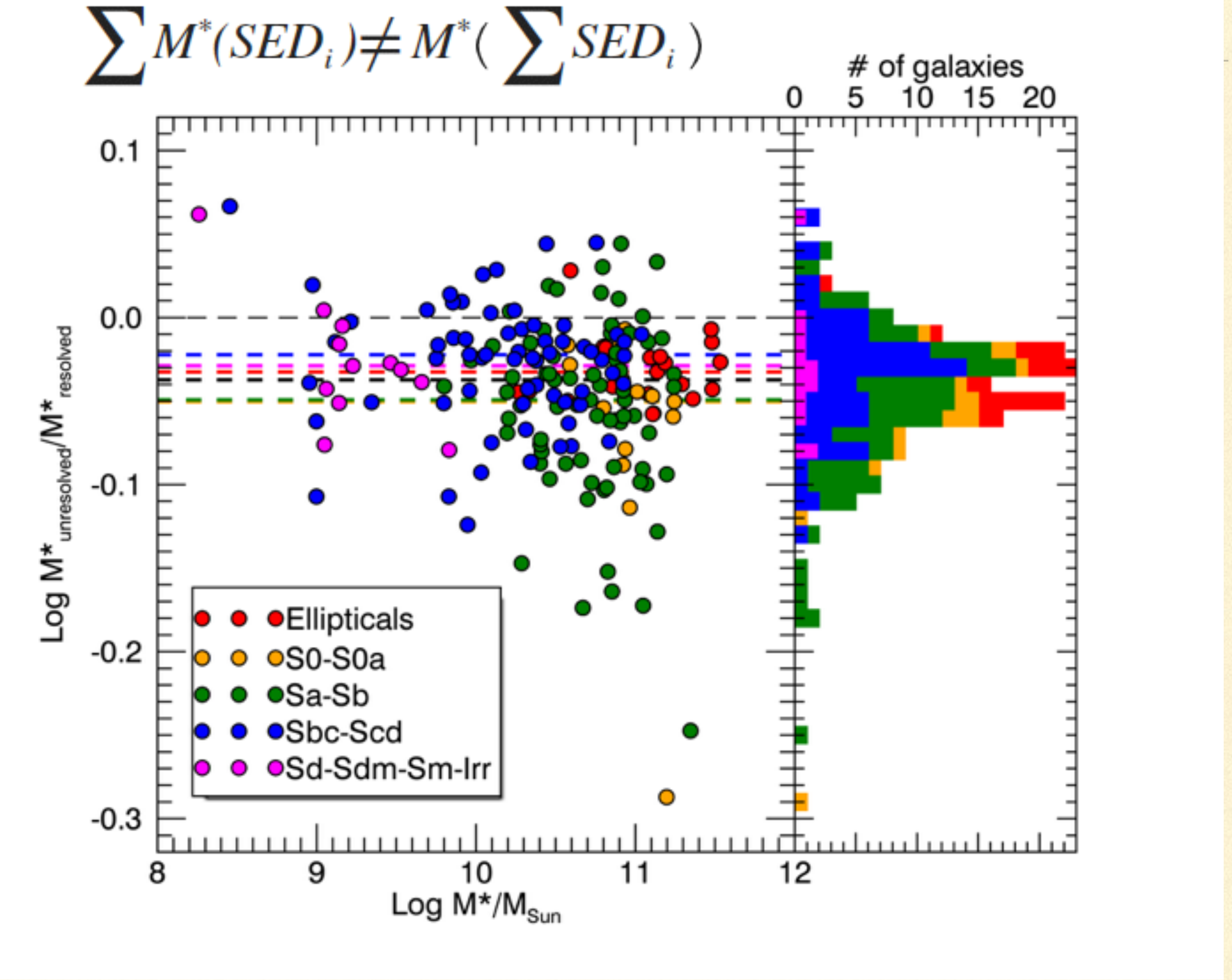
RESOLUTION EFFECTS



Is this due to different CMLR for regions and galaxies or to resolution effects?

RESOLUTION EFFECTS

Same method (full spec-photo) for spaxels and integrated light: bias still there! Stronger for less homogeneous galaxies



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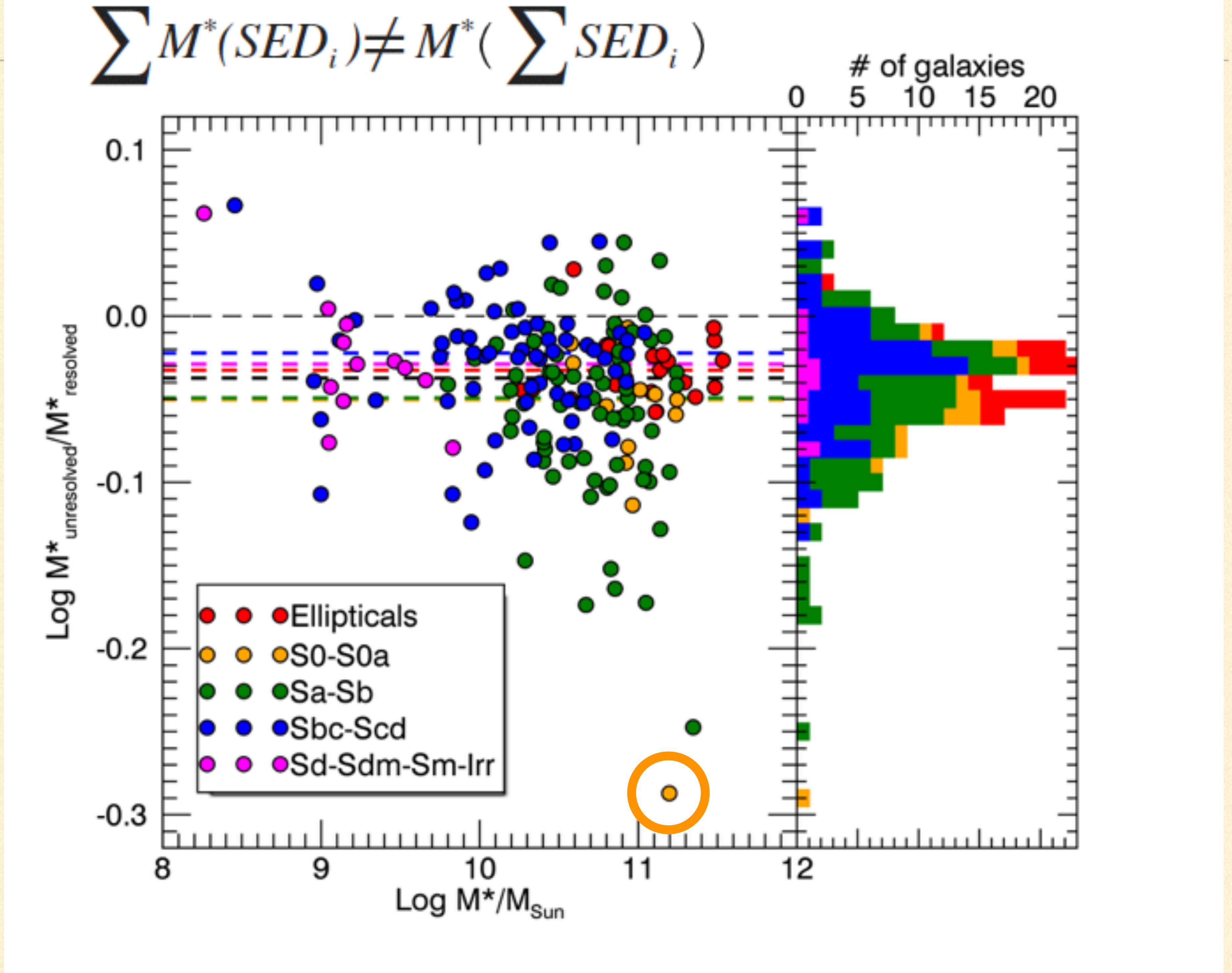
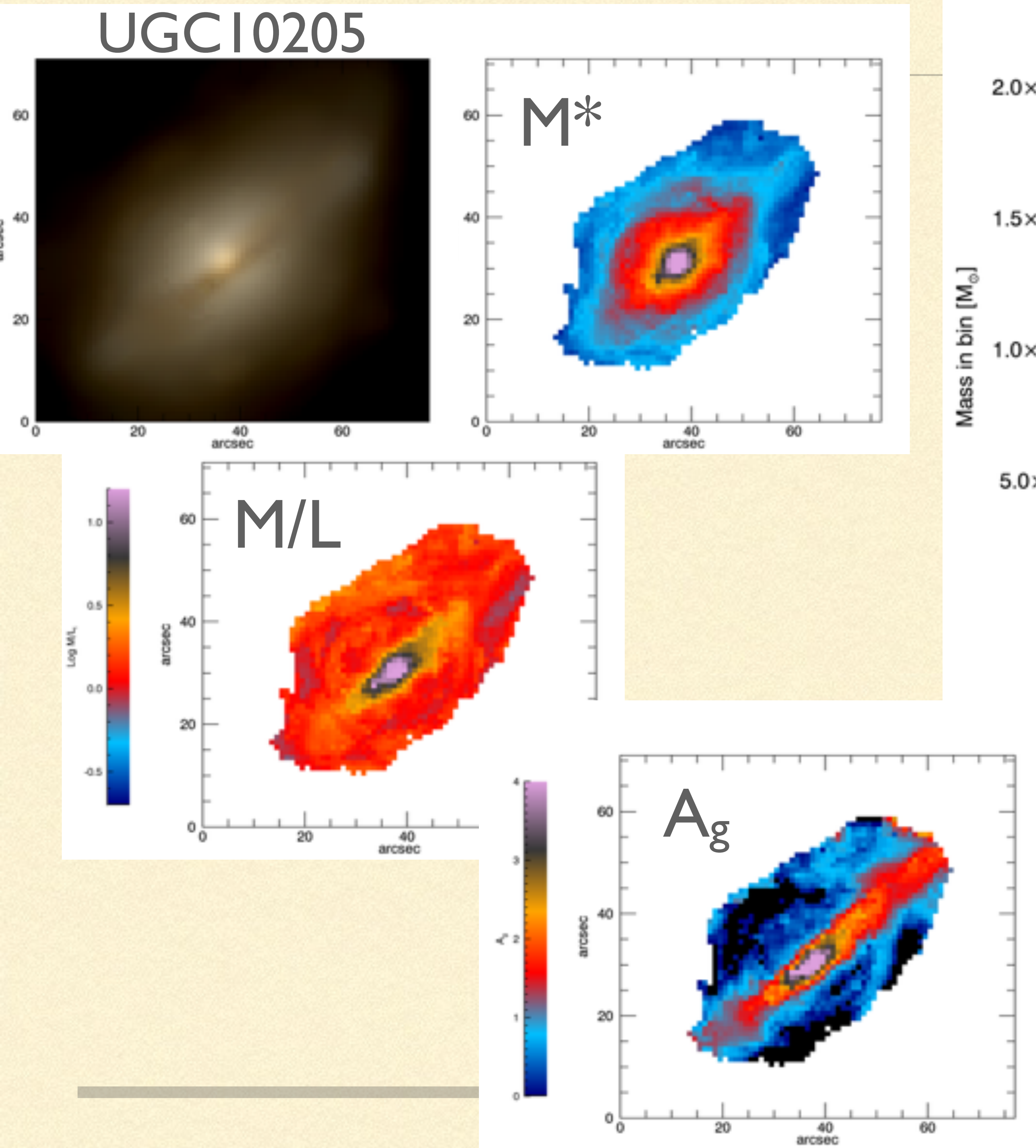
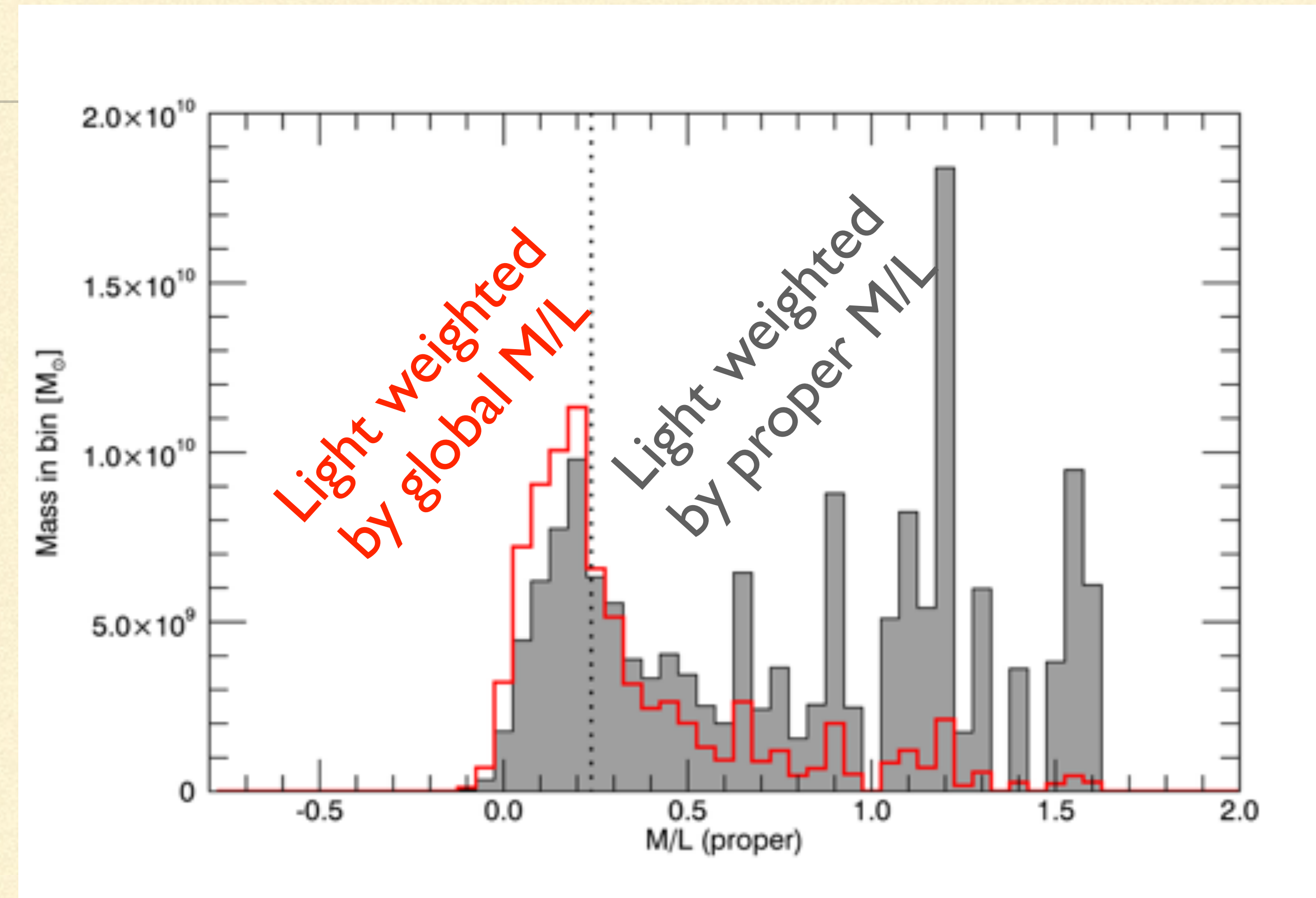


WHY RESOLUTION EFFECTS?

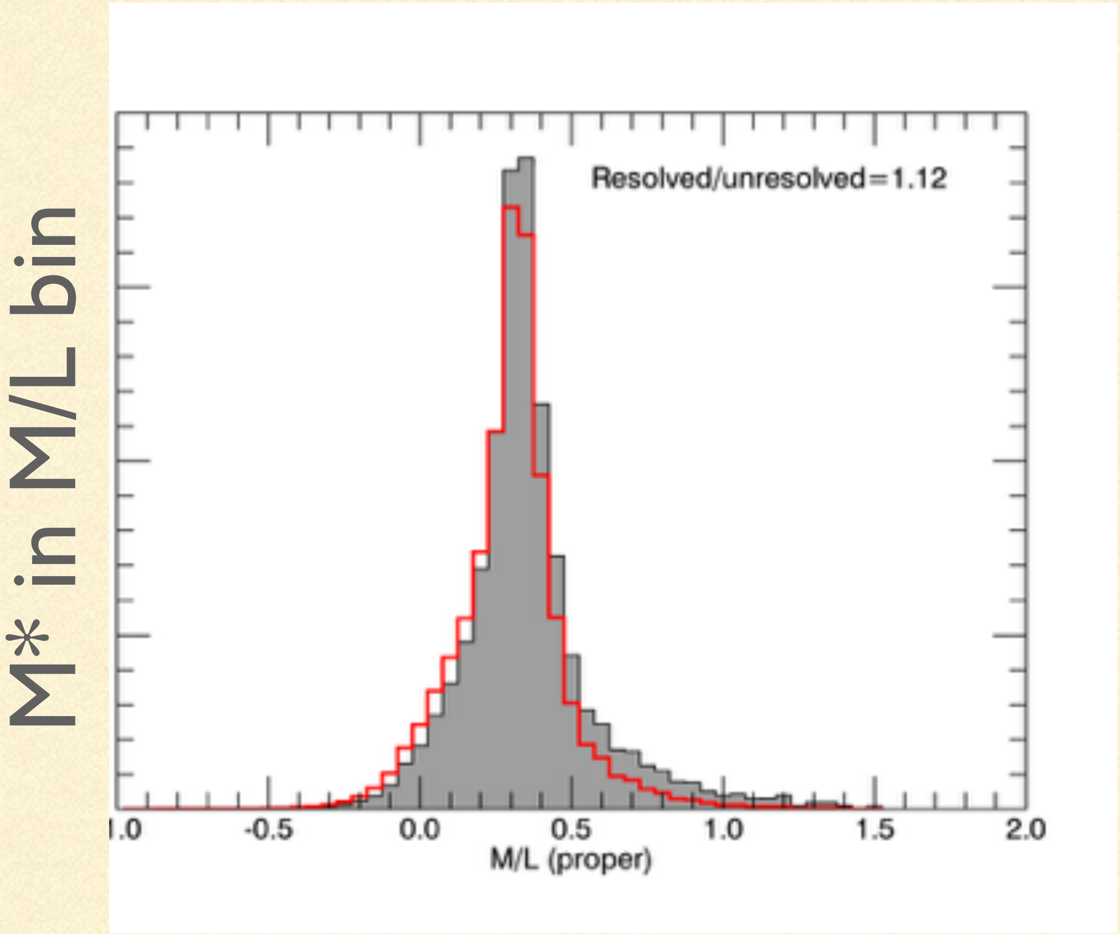




- Low-M/L regions outshine the high-M/L regions and pull down the global M/L estimate

DO WE CARE ABOUT RESOLUTION EFFECTS?

- Roughly 10-15% of the Universe's stellar mass budget (based on uncorrected CALIFA DR2 sample) is LOST due to resolution effects



REALITY IS TOUGH…

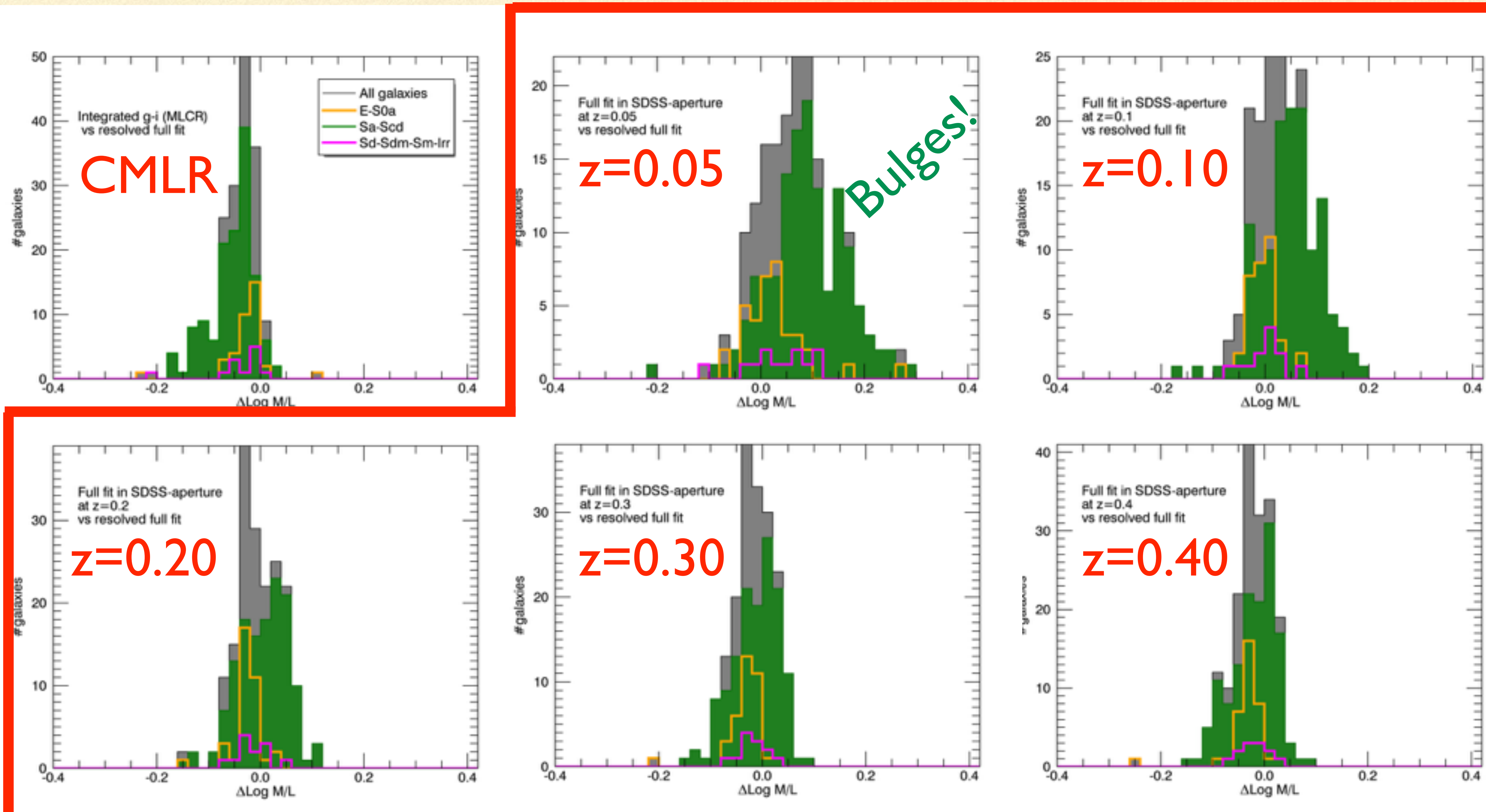
- Large surveys (e.g. SDSS) provide complete (possibly resolved) information only in broadbands
- Spectroscopy is available only as as fibre-aperture integrated spectra, with significant light-loss
- Better to use
  - Colors (or broadband SED fitting) w/out light-loss

    OR

  - spectrophotometry w/ light-loss?

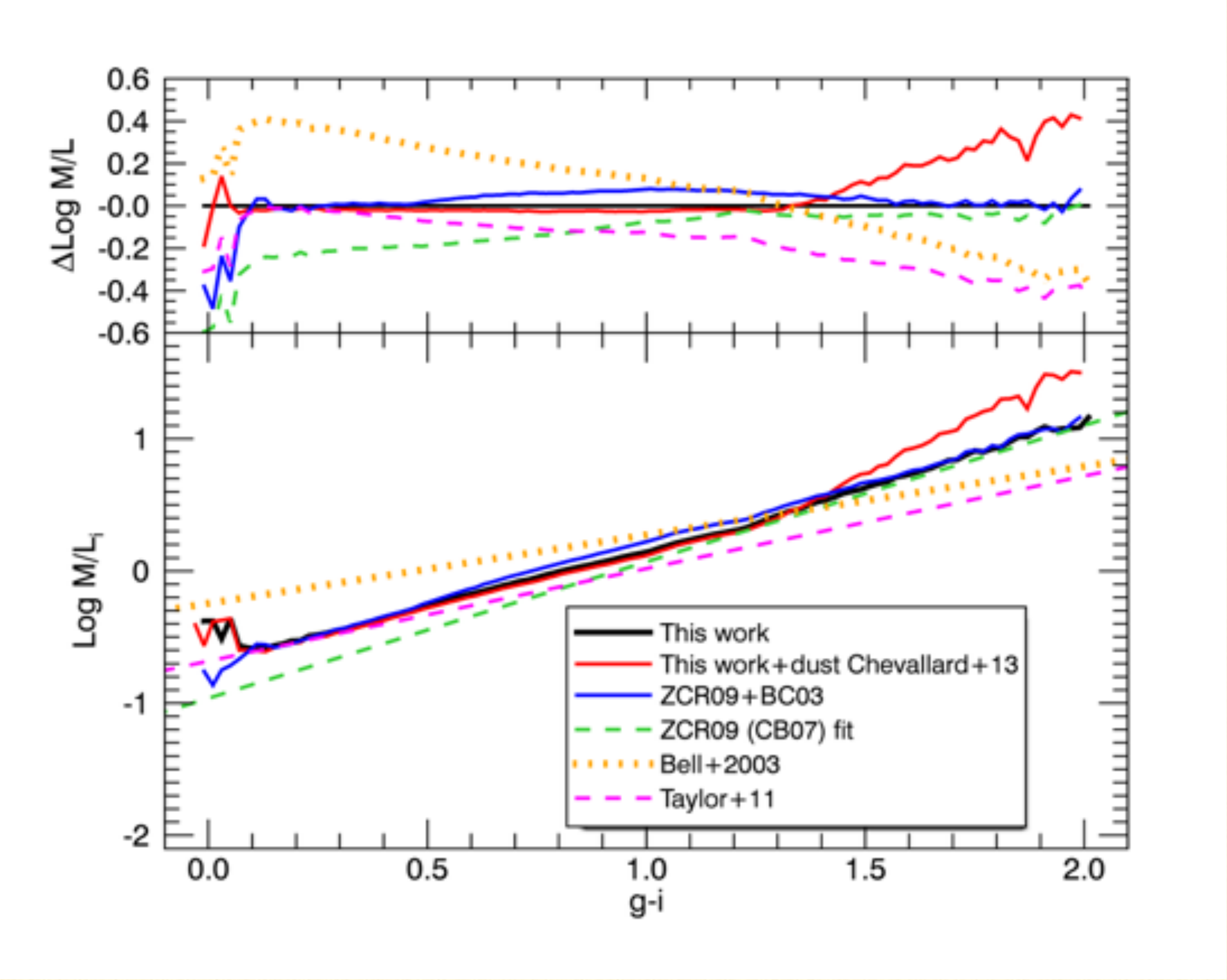
CMLR VS APERTURE EFFECTS

Spectrophotometry in simulated SDSS-like apertures (including seeing) at different z based on low-z CALIFA observations



BUT… IF WE CHANGE OUR ASSUMPTIONS??

- SFH:
  - exponential vs delayed (Sandage)?
  - importance/distribution of bursts
- Chemical enrichment history
- Treatment of dust (multi-components, effective attenuation curves as a function of optical depth [Chevallard+13])
- Calibrators
- **Systematics >>10% to be understood!**



"Accuracy at 10% level is desirable:
is it actually attainable?"

Very tough!

Stay tuned for further results from the SteMaGE project!