Questions 8/19

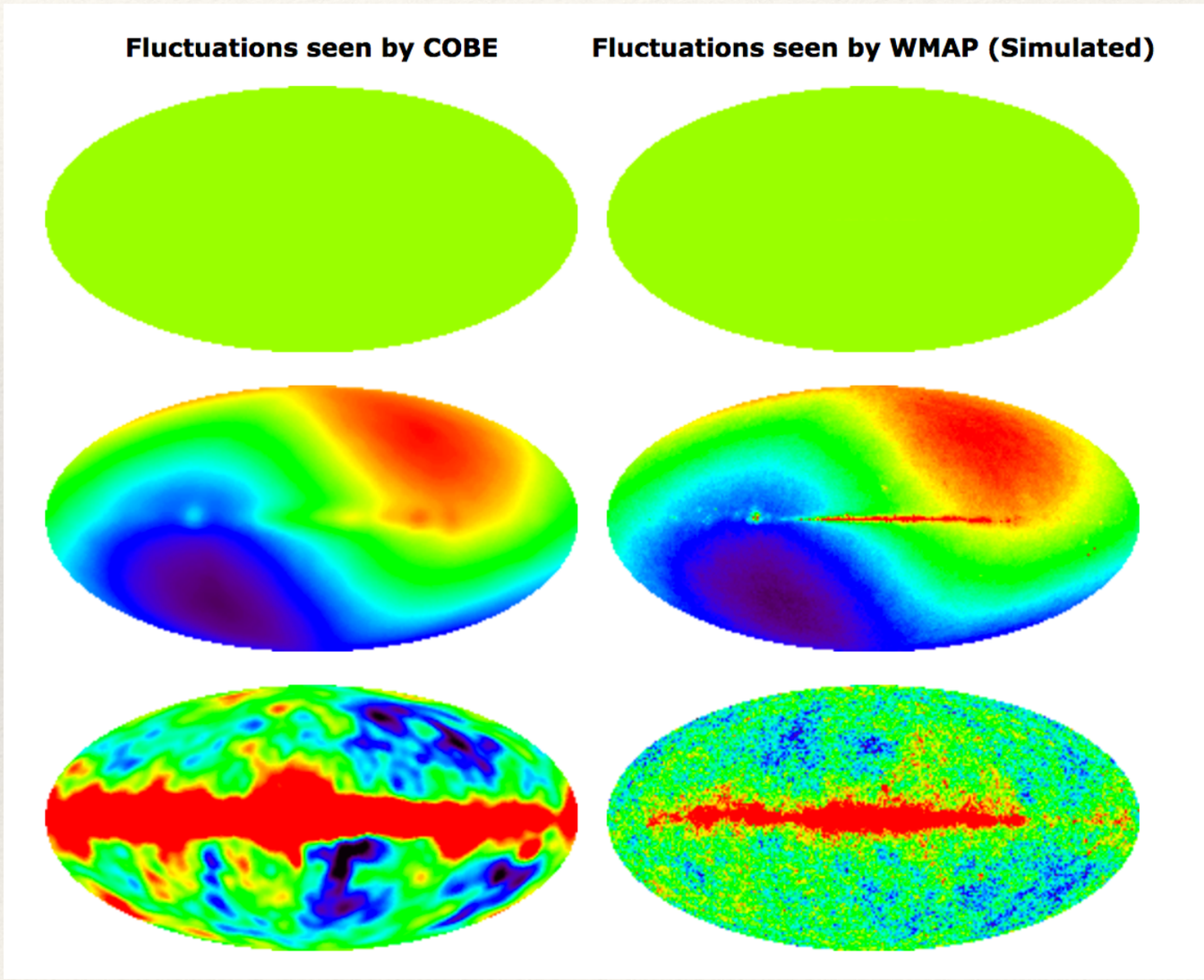
- How did we determine the contribution of dark energy, dark matter, and baryonic matter within our Universe?
- What was the source of van Manner's (van Maanen) error, was it a physical observation plate error or calculations, how do you detect galactic rotation?
- Vera Rubin used a spectrometer as a way to measure galaxy rotation curves, but how exactly did she do this? Did you look at individual stars? Whole clusters?
- Did early Astronomers apply Kepler's Laws to stellar motion?
    - Kepler was from the late 1500s through the early 1600s...Were there attempts to apply these laws to nebulae before it was realized many of them were made up of stars?

- How much do globular clusters vary by size, is this a flawed assumption?
- What portion of the Messier and NGC catalogs were not galaxies?
- Star counting is difficult. How accurate was the Herschels' method?

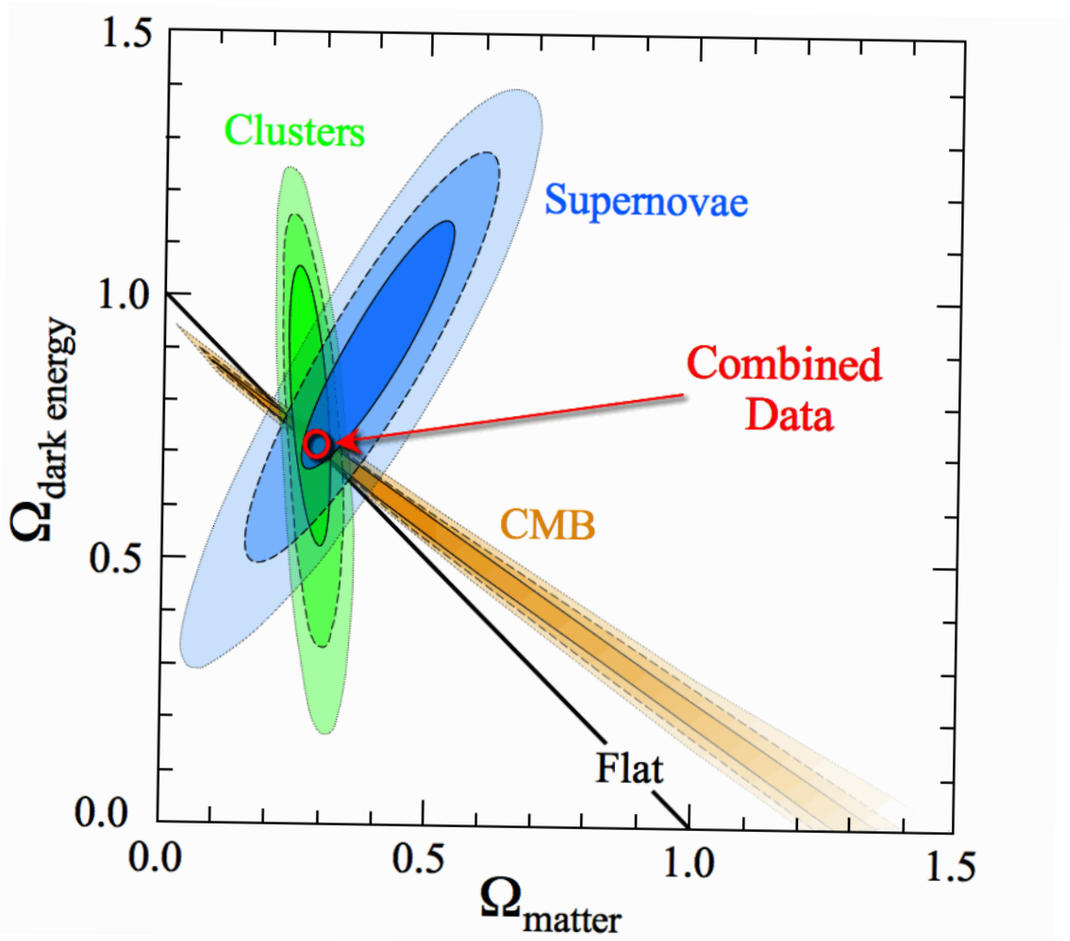
- Our knowledge of galaxies is founded on the basis of the cosmological principle, is there any evidence against it?
- With the heat death of the universe theory, where space itself has expanded so much that individual galaxies are so far apart that they can't interact with each other anymore.... will the Island Universe hypothesis be technically correct for galaxies
    - What would extraterrestrial life experience in one of these old, red galaxies?
    - Would their astronomers see the universe as only their own galaxy?

Questions

- **COBE map of the Cosmic Microwave Background:**
  - Tiny temperature fluctuations believed to trace fluctuations in the density of matter in the early universe, related to the origin of galaxies.
  - What leads to the middle panel?
  - What about the bottom panel?



https://wmap.gsfc.nasa.gov/universe/bb_cosmo_fluct.html


Clusters
Supernovae
Combined
Data
CMB
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Ω_{matter}
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1.0
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0.0
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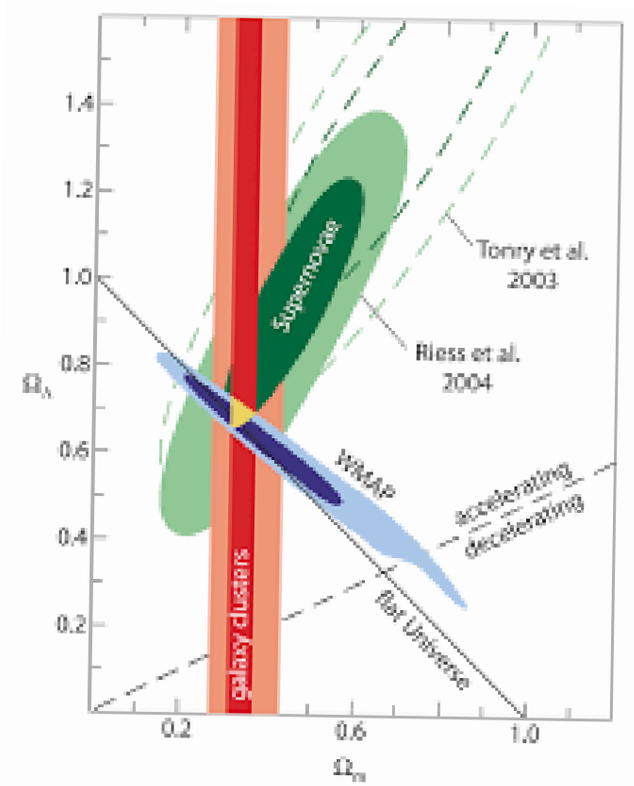
1.0
1.5


Supernovae
Tonry et al. 2003
Riess et al. 2004
WMAP
galaxy clusters
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decelerating
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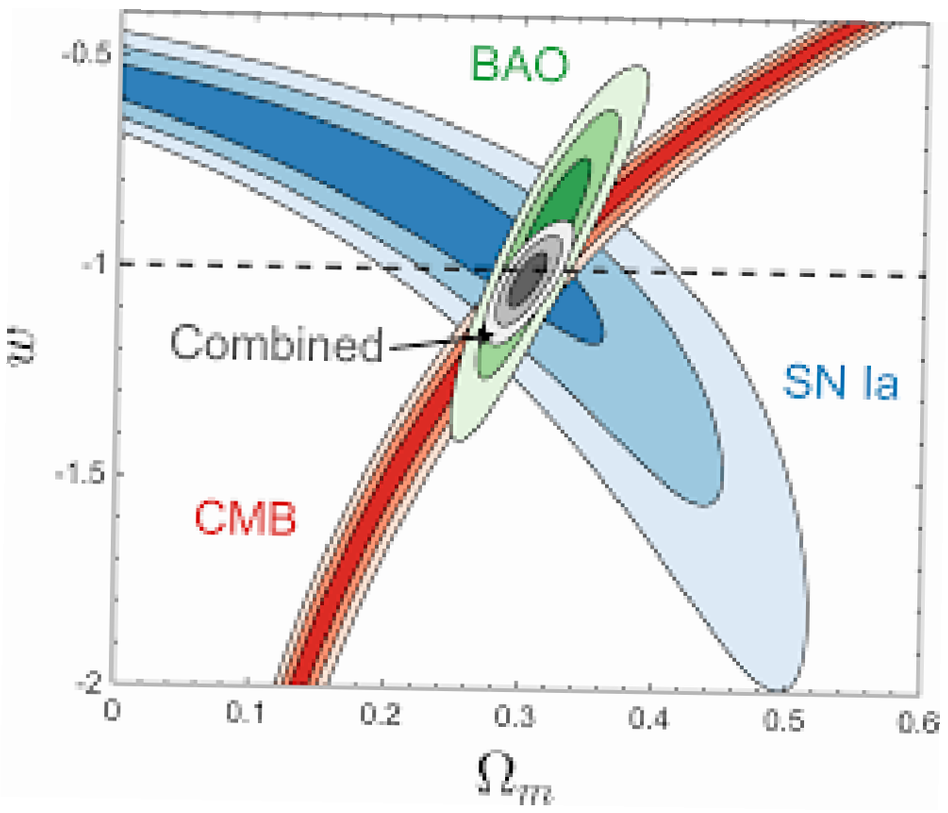
BAO
Combined
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CMB
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-1
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0.3
0.4
0.5
0.6

Questions 8/26

SSurface brightness

- Did not understand the surface brightness and profile plots, the discussion in class over the plot when asked which profile is more concentrated (red)?
- How much do foreground stars either masked or unmasked impact a brightness measurement for a galaxy? Is it significant?
- How do the methods of calculating surface brightness change for galaxies that are mid-interaction, like M51 (the Whirlpool Galaxy), or for unusual shapes like ring galaxies (the Cartwheel Galaxy)? Perhaps using 2 separate profiles like you can for the galactic disk and bulge?
- We talked a lot about n=1 (spirals) and n=4 (ellipticals), but what about irregulars? What is up with those? How much more complicated is it to measure their properties?

MMagnitudes

- If we were to do away with the current magnitude system, what would be a better system in its place? (for example, should the scale remain non-linear or become linear? should we keep it like a ranking system or should we do away with negative values?)
- Don t know how to calculate the surface brightness of the 21mag/ galaxy with 21 mag/ galaxy also in the back of the box

TTotal (intergted) brightness

- IIs there a preference for a specific total brightness magnitud model?

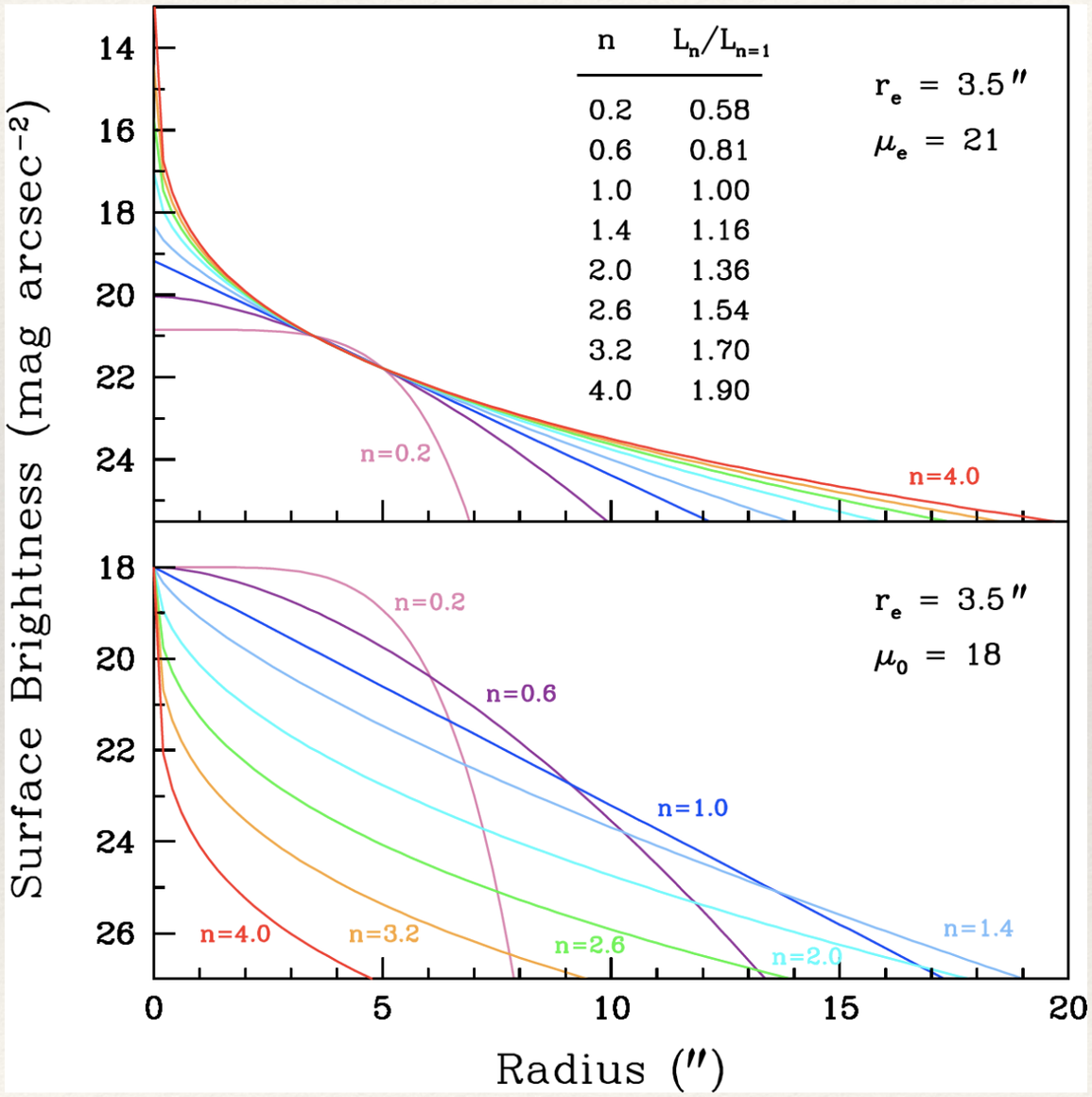
KK corrections

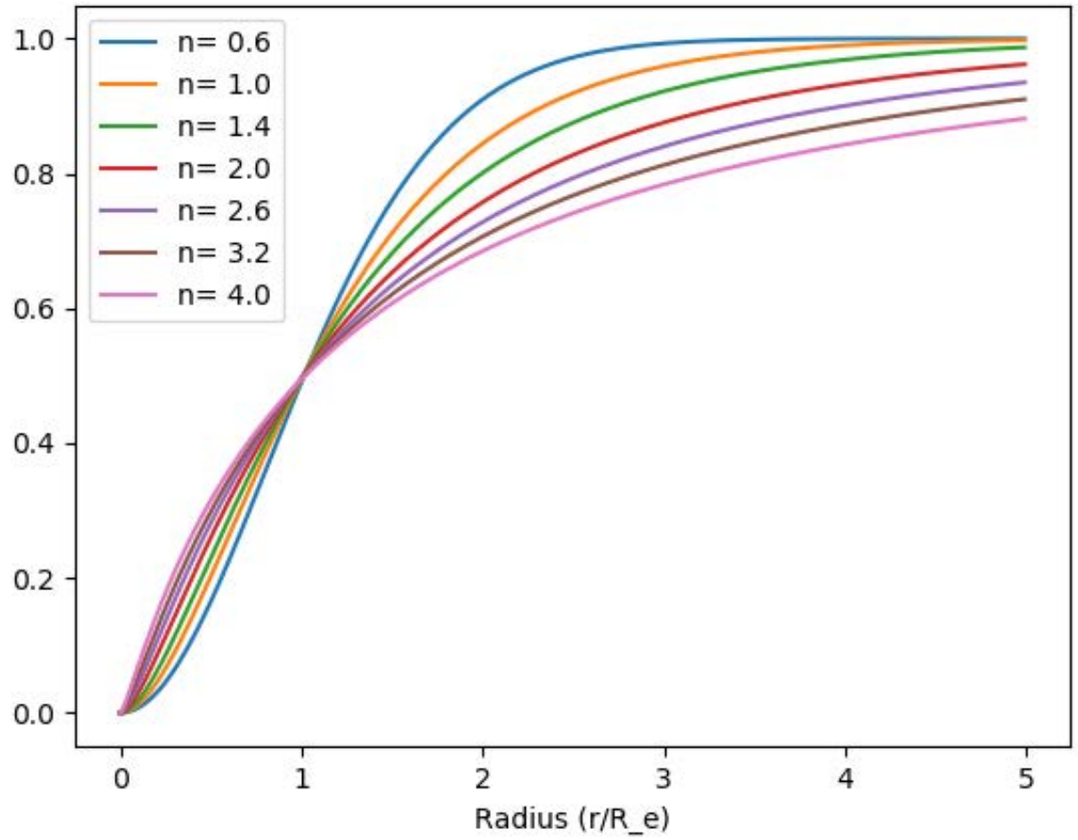
- In practice what are the limitations/uncertainties when calculating K-corrections?
- In theory are there ways to calculate K-corrections, that don't require a spectra?

DDust

- We are amazed and confused by the potential complexity of dust and high redshift and disentangling that from an observation.
- How are we able to tell dust mass from observations of galaxies? What are some of the assumptions made to calculate or estimate dust mass?
- How is dust content related to redshift/galactic evolution?
- How does cluster environment affect observations in relation to dust?

Questions


n
$L_n/L_{n=1}$
0.2 0.58
0.6 0.81
1.0 1.00
1.4 1.16
2.0 1.36
2.6 1.54
3.2 1.70
4.0 1.90
r_e = 3.5″
μ_e = 21
n=0.2
n=4.0
r_e = 3.5″
μ_0 = 18
n=0.2
n=0.6
n=1.0
n=1.4
n=2.0
n=2.6
n=3.2
n=4.0
Surface Brightness (mag arcsec^{-2})
Radius (″)


n= 0.6
n= 1.0
n= 1.4
n= 2.0
n= 2.6
n= 3.2
n= 4.0
Radius (r/R_e)

Questions 9/2

- How are we able to differentiate the emission/absorption lines coming from dust/gas and those from our target that we're observing? Is it just from knowing which emission/absorption lines are more common in dust/gas clouds or is there a more refined method?
- Jason mentioned (in astrophysics class) a debate about dust attenuation; the astronomical community is not in an agreed upon method, what is the issue?

- How does doppler broadening change estimates of column density and vice versa?
- How would I start to consider the velocity dispersion I could measure with a given instrument in nominal conditions?

- How do we actually calibrate the distance ladder? We said that we use objects we know the intrinsic brightness of, but how do we actually know for sure what their intrinsic brightness is?
- How did we initially calibrate the distance modulus for type 1A supernova brightness?

- What fraction of our solar system is dark matter, and why is this not taken into account when calculating the gravitational interactions of the planets and sun?
- Is there a Hill Sphere equivalent to galaxies and or clusters? What does that look like since they can't really be approximated by point masses?
- At what mass regime can we no longer ignore general relativity corrections (or special relativity for that matter)? How would this affect the spectra aside from the Doppler Effect? Gravitational lensing?

Questions 9/9

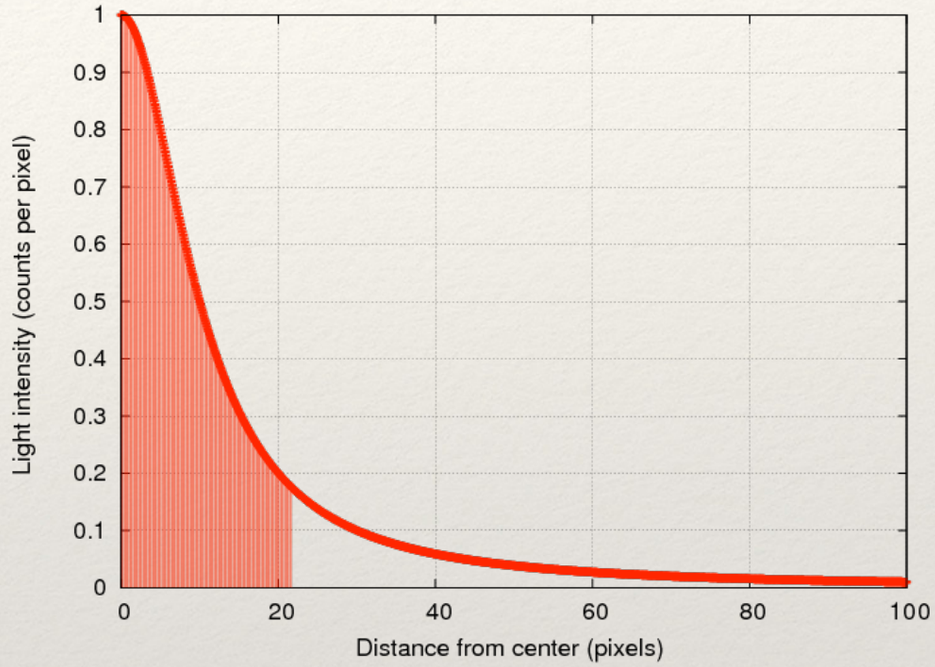
- Confusion on how to actually calculate part F from Problems 1.
- More elaboration on K-corrections pretty please.
- When does redshift become important when calculating distances?

- In quantitative morphology schemes using non-parametric methods, we were wondering how the justification for determining the concentration of light, where r90/r50 came from and why not other forms such as r95 / r10 or r70/r5?
- There is inconsistency between the quantitative classification criteria. Do they correlate somehow? For example, how would we best communicate asymmetry data to someone working with Gini coefficients?
- Does the clumpiness of a galaxy depend on inclination angle?
- Is there a consensus growing towards preferring qualitative vs quantitative ways classifying galaxy morphology?
- Are the machine learning morphology classifications used in published papers yet? Or is the method still being worked on?

- Is there a correlation between spiral arms of a galaxy and the gravitational environment surrounding it? For example, how far away could we resolve a dwarf galaxy orbiting a larger galaxy and would an unresolved dwarf misinform our perception of the morphology of the larger galaxy?

Observing Galaxies - Imaging: Sizes

- **Petrosian radius**:
  - radius at which local surface brightness drops to some fraction (e.g., SDSS uses 0.2) of average surface brightness within this radius
- independent of distance!



surface brightness at Rp

e.g., 0.2

average surface brightness within Rp

$$\text{at the Petrosian radius } R_P \qquad I(R_P) \;=\; \eta \left(\frac{\int_0^{R_P} I(r) 2\pi r dr}{\pi R_P^2} \right)$$

http://spiff.rit.edu/classes/phys443/lectures/gal_1/petro/petro.html

Observing Galaxies - Imaging: K-corrections

- m = m - K
  to correct observation in band to one in band

- Plot shows some typical galaxy spectra (as we ll discuss more next time)

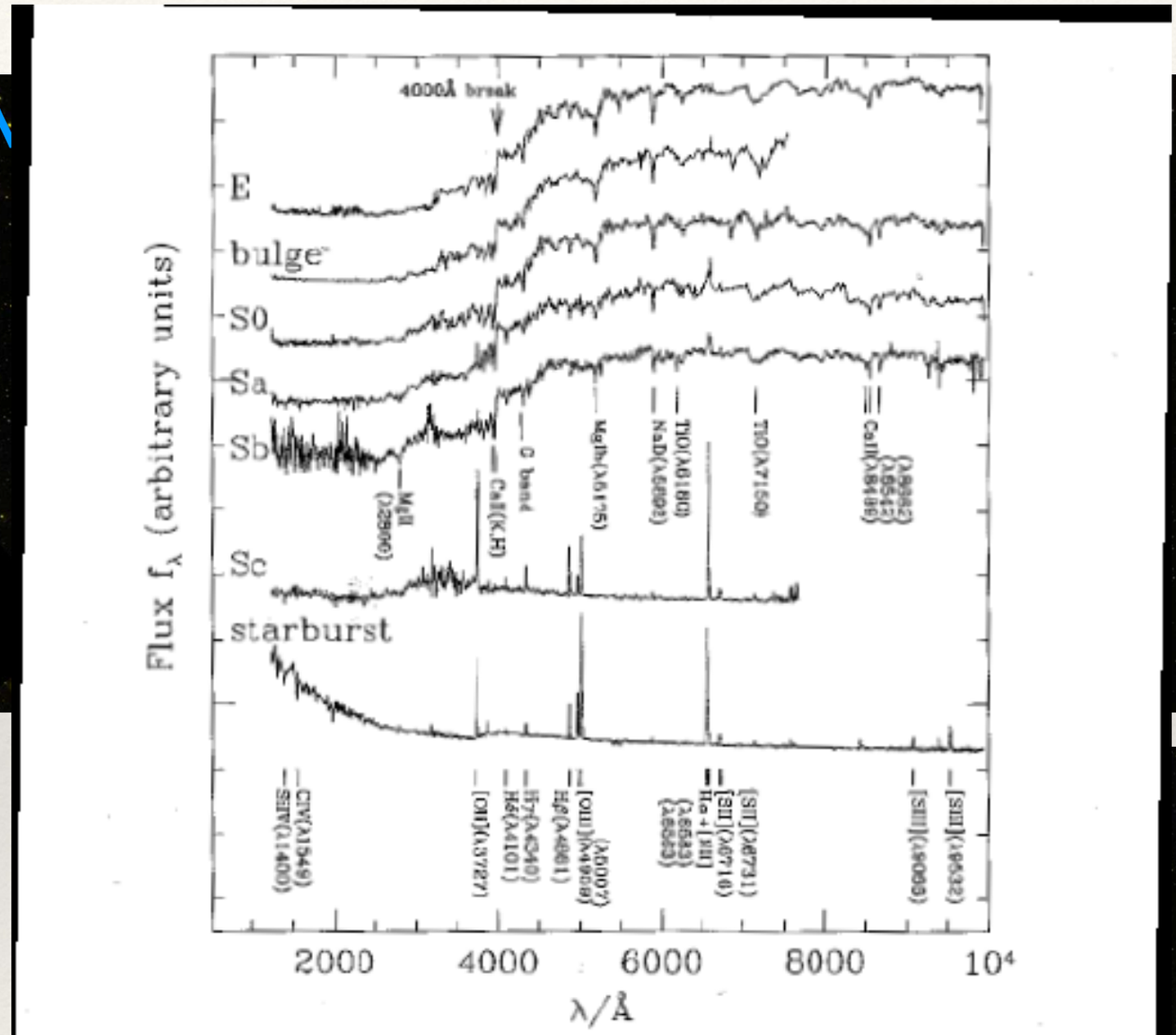


Fig. 2.12. Spectra of different types of galaxies from the ultraviolet to the near-infrared. From ellipticals to late-type spirals, the blue continuum and emission lines become systematically stronger. For early-type galaxies, which lack hot, young stars, most of the light emerges at the longest wavelengths, where one sees absorption lines characteristic of cool K stars. In the blue, the spectrum of early-type galaxies show strong H and K absorption lines of calcium and the G band, characteristic of solar type stars. Such galaxies emit little light at wavelengths shorter than 4000 Å and have no emission lines. In contrast, late-type galaxies and starbursts emit most of their light in the blue and near-ultraviolet. This light is produced by hot young stars, which also heat and ionize the interstellar medium giving rise to strong emission lines. [Based on data kindly provided by S. Charlot]

https://arxiv.org/abs/1807.10406

https://www.aanda.org/articles/aa/full_html/2020/06/aa37697-20/aa37697-20.html

Questions 9/16

- How do we know all Type-Ia supernovae are the same (in terms of the distance ladder)?
- Could you re-explain Eddington Bias and maybe provide some examples of what this looks like? I am having trouble understanding the effects this has on collected data and external sources have provided little clarity.
- Could a pocket of very high star formation rate in an otherwise quiescent galaxy skew the position of the galaxy on the CMD?Why do galaxies transition so quickly through the green valley? What processes allow this to occur on such short timescales?
- Do galaxies undergo several rounds of quenching as O,B stars die and trigger star formation?
- What are the mechanisms that cause a galaxy to transition from blue -> red? Once a late-type spiral runs out of material to drive star formation, does it slowly fade to a red galaxy?
- Is the timescale of transition faster for galaxy mergers than for a galaxy running out star-forming material?
- How are we able to tell that the Milky Way is a green galaxy?
- How far along is the Milky Way in the green valley? Are we closer to red sequence or the blue cloud? How do we know, given the differences in observational data between internal observations of the Milky Way and other galaxies?
- What happens to the red hot dust in galaxies?
- How do we know there are more faint galaxies than bright ones if we cannot see the faint galaxies? Is this based off local observations or extrapolation?

Questions 9/23

- Is the Schechter function the same as the luminosity function?
- What is alpha, and what is phi*?
- How is α determined in the Schechter function? Does it have any physical significance?
- In terms of the luminosity function, how do you correct for the scatter of lower magnitudes entering into higher magnitude bins (Eddington bias)? What is the actual method to correct for this?

- More clarity on the nuker profile?
- Why do we see so much diversity of elliptical galaxies? Is it physical reality, or is this caused by their orientation in our line of sight?
- Can it be hard to tell from observations if/when a galaxy has conclusively undergone a merger event? What is conclusive evidence of a galaxy merger, other than morphology?
- Why can't we assume galaxies in local groups evolved together, and therefore contain similar properties?

A Tip of the Red Giant Branch Distance to the Dark Matter Deficient Galaxy NGC 1052-DF4 from Deep Hubble Space Telescope Data

Shany Danieli[1,2,3], Pieter van Dokkum[3], Roberto Abraham[4,5], Charlie Conroy[6], Andrew E. Dolphin[7,8], and Aaron J. Romanowsky[9,10]

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The Astrophysical Journal Letters, Volume 895, Number 1

Citation Shany Danieli *et al* 2020 *ApJL* 895 L4

Article PDF Article ePub

Figures References

+ Article information

Abstract

Previous studies have shown that the large, diffuse galaxies NGC 1052-DF2 and NGC 1052-DF4 both have populations of unusually luminous globular clusters as well as a very low dark matter content. Here we present newly obtained deep Hubble Space Telescope Advanced Camera for Surveys imaging of one of these galaxies, NGC 1052-DF4. We use these data to measure the distance of the galaxy from the location of the tip of the red giant branch (TRGB). We find a rapid increase in the number of detected stars fainter than $m_{F814W} \sim 27.3$, which we identify as the onset of the red giant branch. Using a forward modeling approach that takes the photometric uncertainties into account, we find a TRGB magnitude of $m_{F814W,TRGB} = 27.47 \pm 0.16$. The inferred distance, including the uncertainty in the absolute calibration, is $D_{TRGB} = 20.0 \pm 1.6$ Mpc. The TRGB distance of NGC 1052-DF4 is consistent with the previously determined surface brightness fluctuation distance of $D_{SBF} = 18.7 \pm 1.7$ Mpc to NGC 1052–DF2 and is consistent with the distance of the bright elliptical galaxy NGC 1052. We conclude that the unusual properties of these galaxies cannot be explained by distance errors.

Problems 2

- What is the form of a Schechter function? What does it represent?
- Does the normalization matter when calculating the normalized cumulative function?
- What is the form of the luminosity contribution as a function of luminosity look like, if the luminosity function takes the form of a Schechter function?
- if alpha=-1, what does this function look like? Can you integrate it?
- What's a natural unit to use for the luminosity?

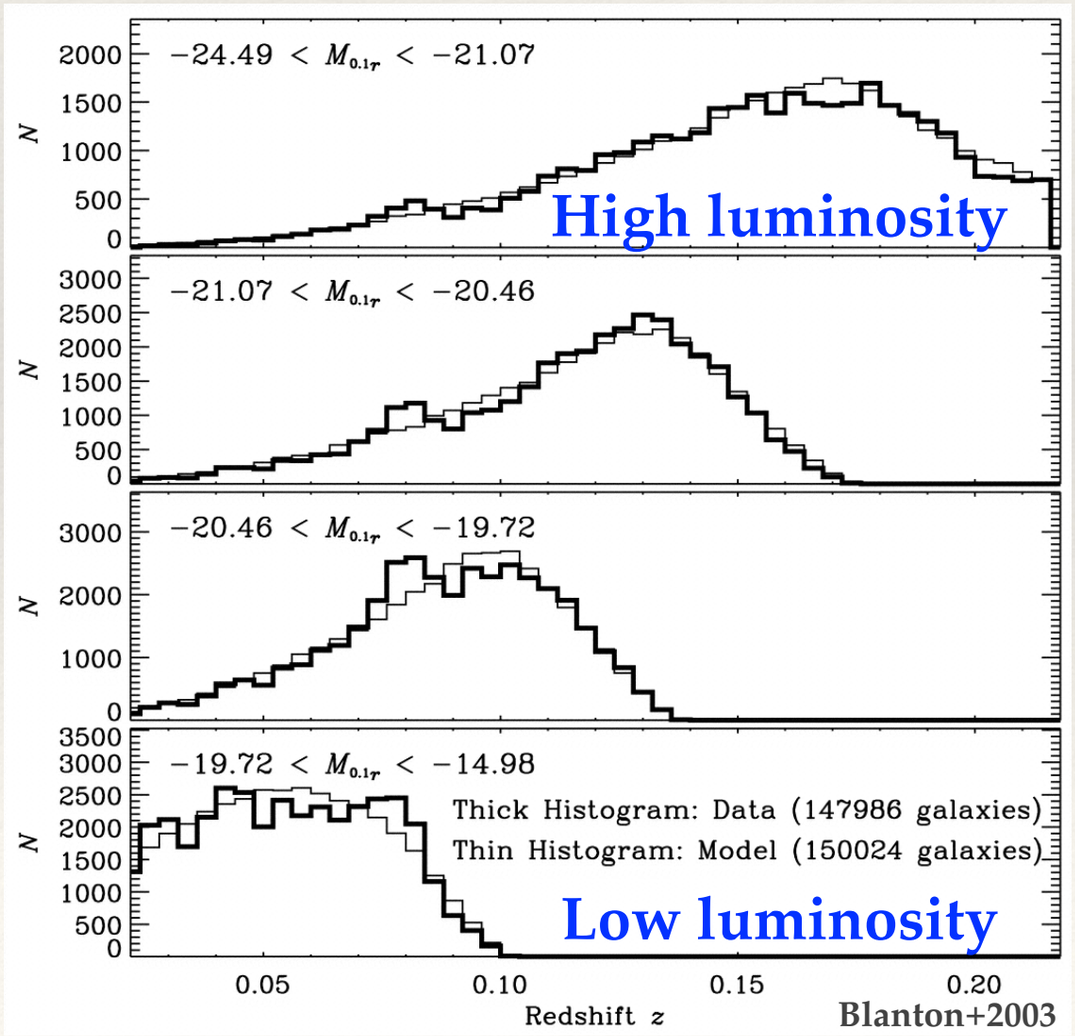
- What do you expect a plot of color vs absolute magnitude will look like?
- What does g-r=0 mean? What does B-V=0. mean?
- What does galaxy color bimodality mean?

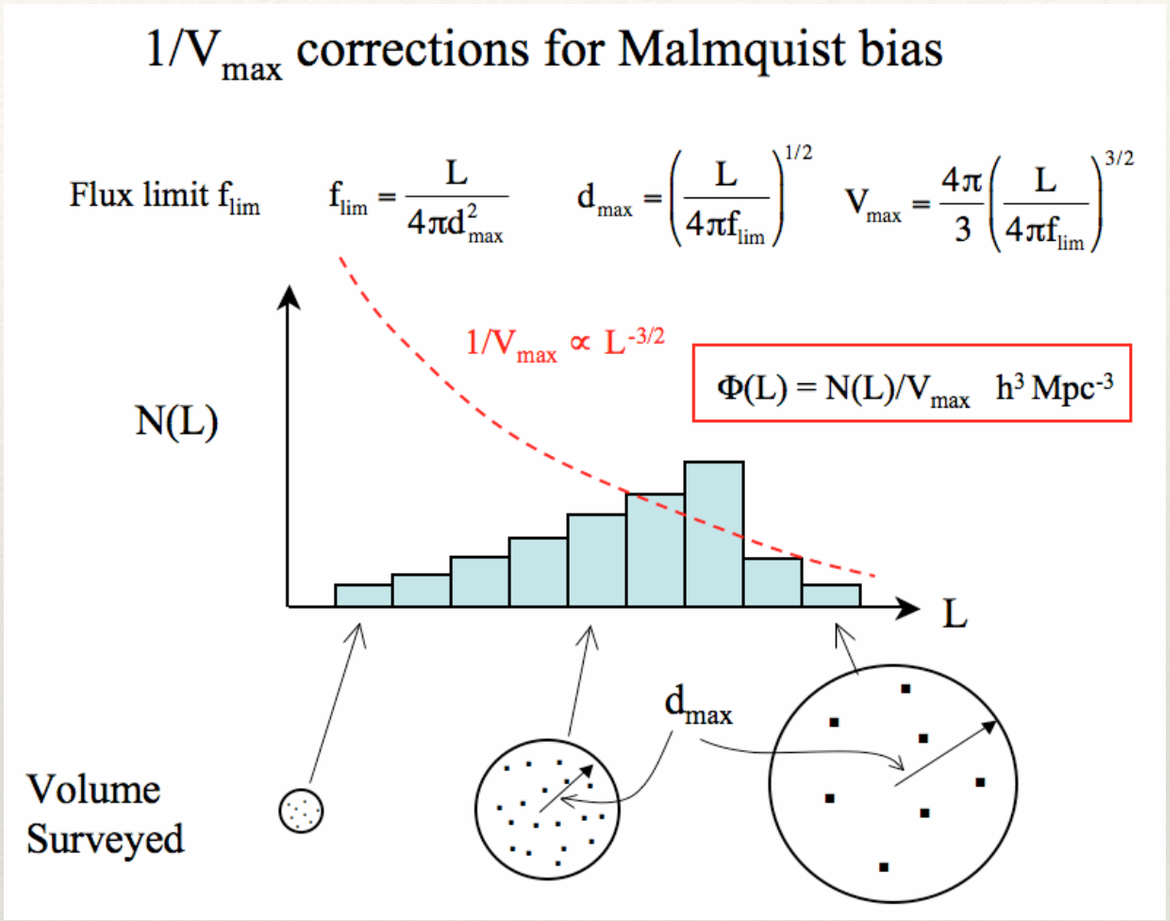
- How do you correct a raw luminosity function for survey selection for an apparent magnitude limited survey?
- What does Vmax mean? How is it determined for your sample?

- What does V/Vmax mean?
- What range of values do you expect?

Statistical Properties: Luminosity Function

- See luminous galaxies from a larger volume (Malmquist Bias)





http://people.virginia.edu/~dmw8f/astr5630/Topic04/t4_malmquist.gif

- Number density at each L has to be computed using the appropriate volume
- Divide N(L) by $V_{max}(L)$ to get $\Phi(L)$

Questions 9/30

- There was a question that was like "suppose ellipticals were all thin prolate ellipsoids...roughly what sort of axis ratio distribution would we expect if galaxies are randomly oriented to our L.O.S.?" – I don't think I parsed the answer when it was given in class, I'm just not entirely sure what this means :(
- How do you apply forward modelling to the shape distribution of ellipticals?
- Why wouldn't triaxial-shaped ellipticals smooth out over time due to gravity?

- What are the physics that lead to the fundamental plane? Or is it just empirical and we don't know?
- What are systematic M/L variations?
- How do the different ellipsoid shapes (oblate, triaxial, prolate) affect the fundamental plane?
- Would globular clusters also fall onto the fundamental plane?

- When we talk about galaxy spectra we never mention a black hole? Do we see these in elliptical galaxies or emission from their disks if there is no dust?

Questions 10/7

- I am not entirely clear why we should expect a higher H-alpha/Fe ratio in redder, elliptical galaxies.

- Do all disk galaxies have both a thick & thin disk? If not, what are some ways (besides the disk) that those galaxies differ from galaxies that do have both a thin & thick disk?
    - If there are galaxies without both, what are the typical characteristics/traits of their disk (i.e. does it look more like the thin or thick portion of the disk of galaxies with both)?

- Why do some galaxies have bars and others don't?

- Simulations that incorporate the Lambda Cold Dark Matter theory of the universe are able to reproduce the relative number of spirals and ellipticals as they exist today; what is it about dark matter haloes that influence galaxy morphology and evolution?

Questions 10/14

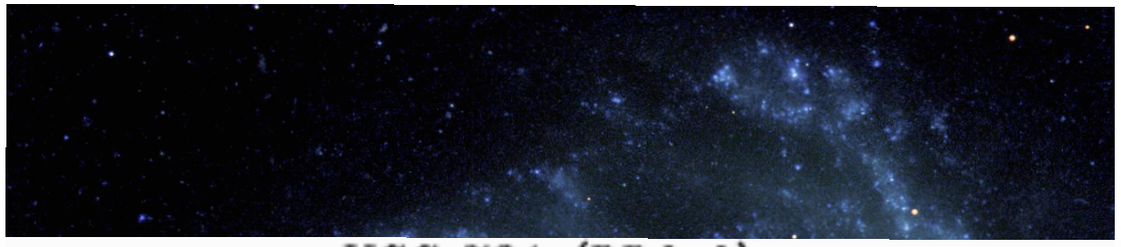
- What is phi in Vr(R,i) = Vsys+V(R) sin(i) cos(ϕ)
- Better way to think of a PV diagram or see PV diagram next to galaxy
- Review the warm-up question: "consider the Position Velocity diagram for NGC 4666"? I wasn't totally clear on the explanation.

- Is the disk influenced by the pseudobulge or vice versa?

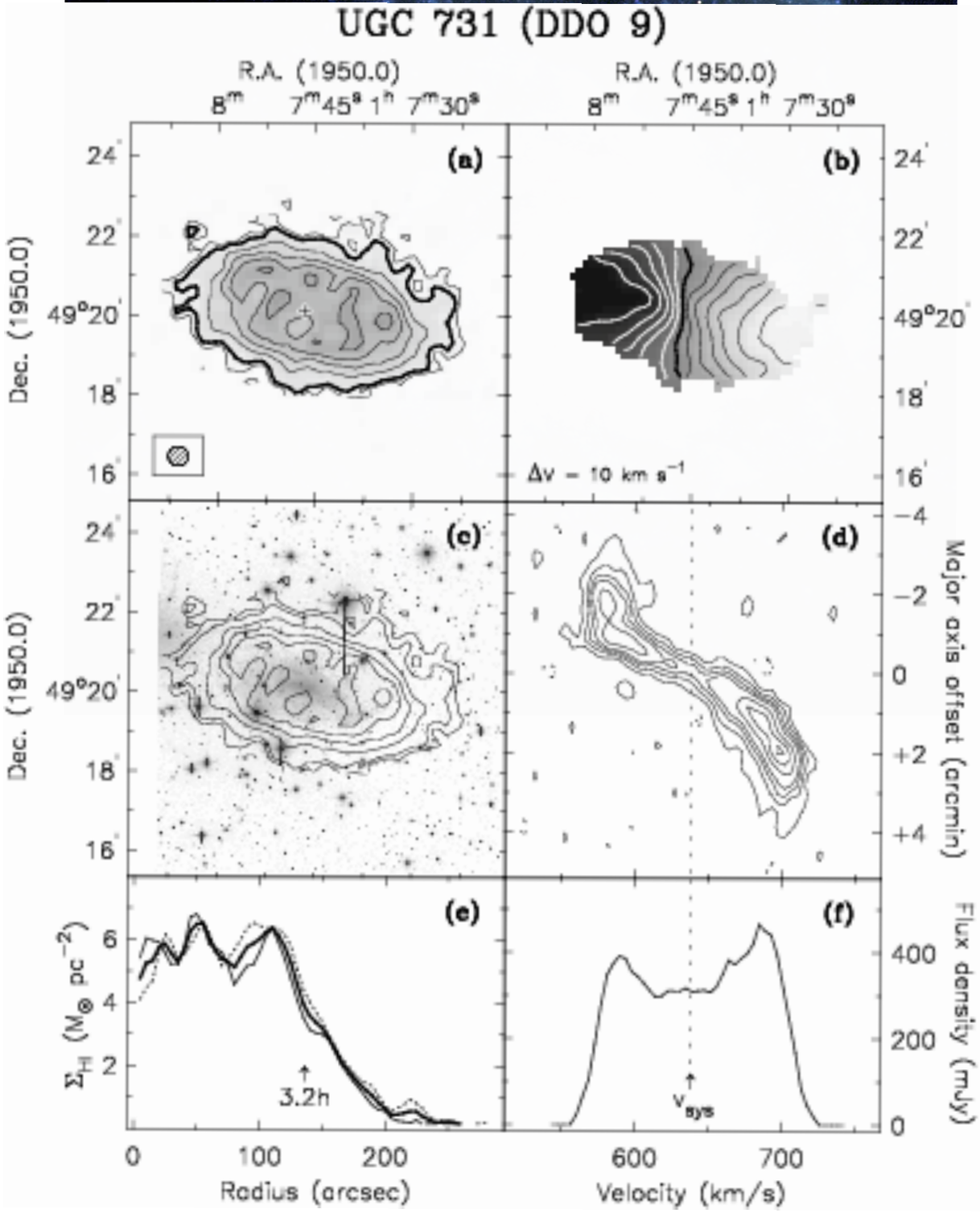
- Learning that there were less barred galaxies in the early universe inspires two questions—do we have observations of galactic rotation rates as a function of redshift and are there any observational signatures of the dynamical instabilities proposed to form bars?
- How do we know the Milky Way is a barred spiral?

- Still don't understand density wave pattern & how it forms—can we go over it a little more?
- What are density waves in a physical context? Show me what they are
- Do flocculent spirals not have a density wave pattern?

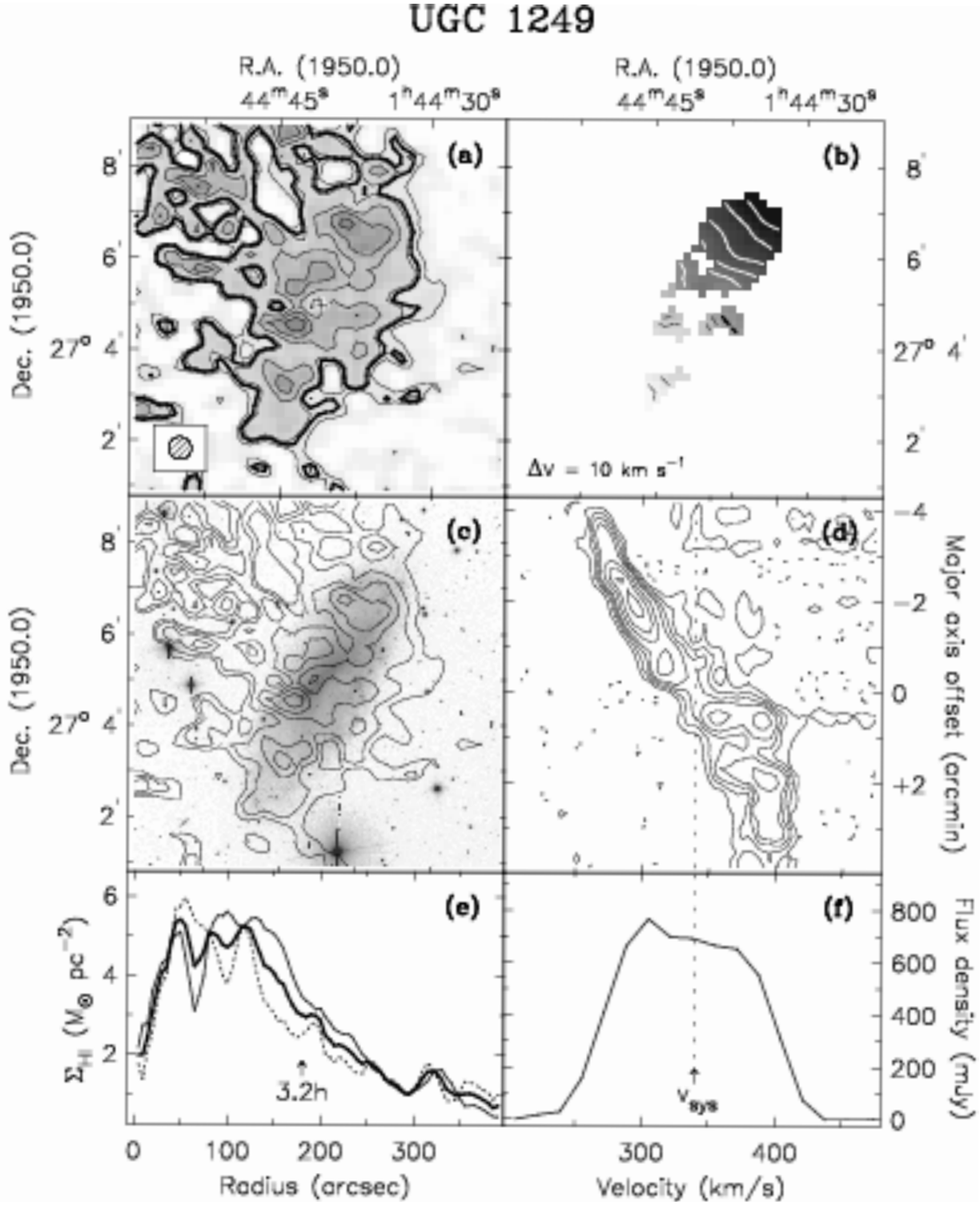
- What is the actual physical relationship between absolute magnitude and rotational velocity? Why do they scale with one another?
- Do we expect OII and OIII lines in spiral SEDs because they're young and therefore more chemically enriched from previous generations of stars?



UGC 731 (DDO 9)



UGC 1249



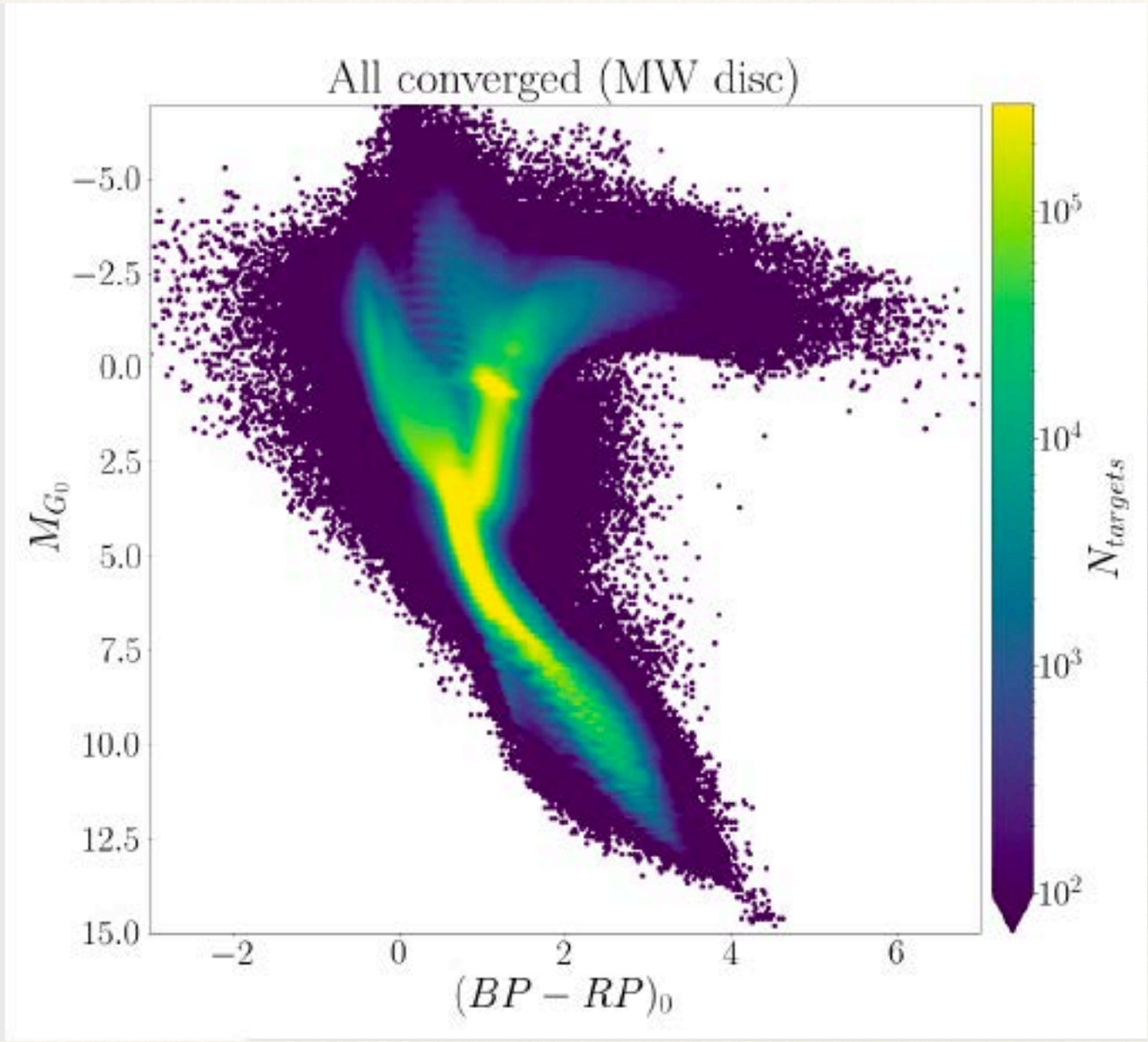
Questions 10/28

- What does convective overshoot mean exactly? How does it relate to the mixing length?

- Why was it a shock that globular clusters aren't really "simple," in that they have multiple ages and different chemical abundances? It seems obvious that they would have different ages and such since stars don't just snap into existence instantaneously, but I think I'm missing something if it really did take some analysis to come to that conclusion.
- In diagram where three burst of star formation were determined, how complicated do binaries make estimates?
- If we had constant star formation, would the HR diagram be a big blobby mess with stars basically at every stage as opposed to one with several discrete epochs and MS turnoffs? In our discussion we decided that this is maybe unrealistic but we are curious.
- Can you really make an HR diagram for an unresolved or poorly resolved galaxy? Seems complicated, especially if the galaxy in question is unusual.
- How do you look at galaxy populations and account for binaries if you can't resolve individual stars?

- Don't understand how IMF can be universal if we see cosmic noon?
- How does the recycling rate influence star formation rates and IMFs?
- What environmental variables are the most important to the IMF if it is not universal?

Questions 10/28



Questions 11.4

- Explain the dependence on bandpass for the M/L ratio again?

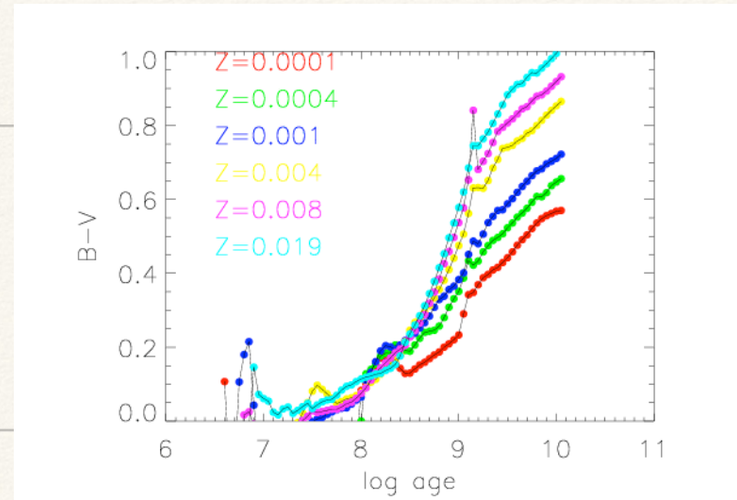
- Unclear on why non-SSPs weighted towards younger populations (point made on lecture 20, slide 3…). Or what this means particularly. Could you provide some clarity on this point from that slide in particular?

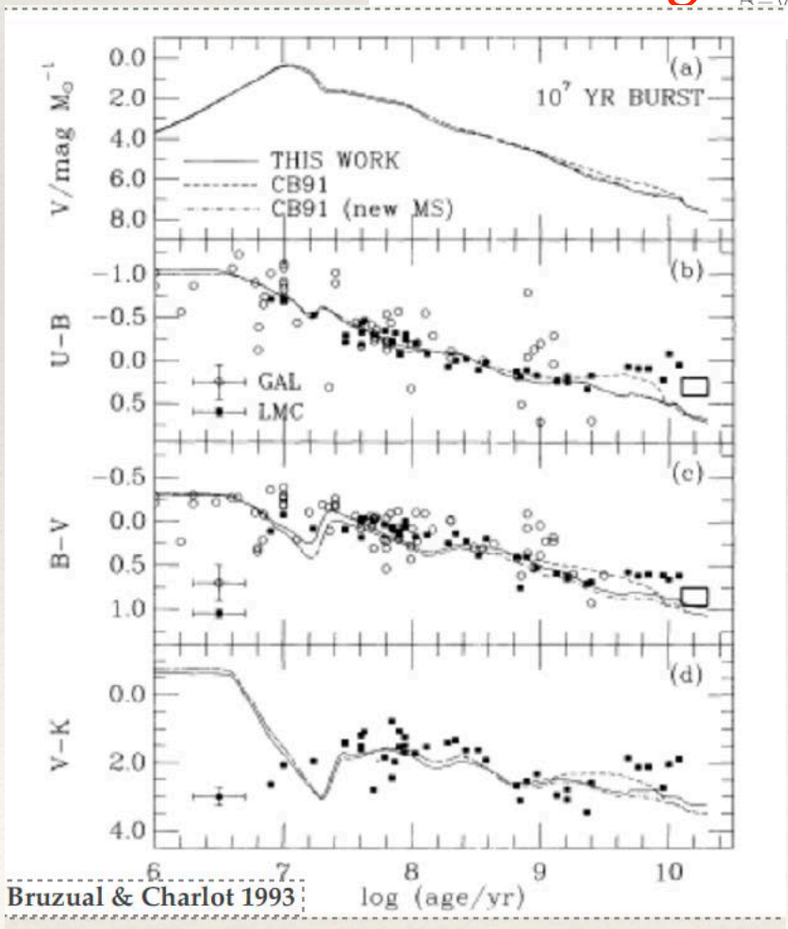
- As you look further away (higher z) or just at old galaxies in general, do galaxies more resemble SSPs as the older populations begin to dominate (lose diversity in population)?

- Do we use longer wavelength observations to get an ISM or dust mass-to-light ratio to ultimately measure the ISM/dust mass (as opposed to a stellar M/L)?

Stars and Stellar Populations

- How can we learn about star formation histories (SFHs) from integrated colors and luminosities?
- Challenges
  - **Age-Metallicity Degeneracy:**
    - both older populations and more metal-rich populations are redder
  - **Luminosity Weighting:**
    - Even if age-metallicity were resolved, non-SSPs are weighted towards younger populations
- Can spectra resolve these?

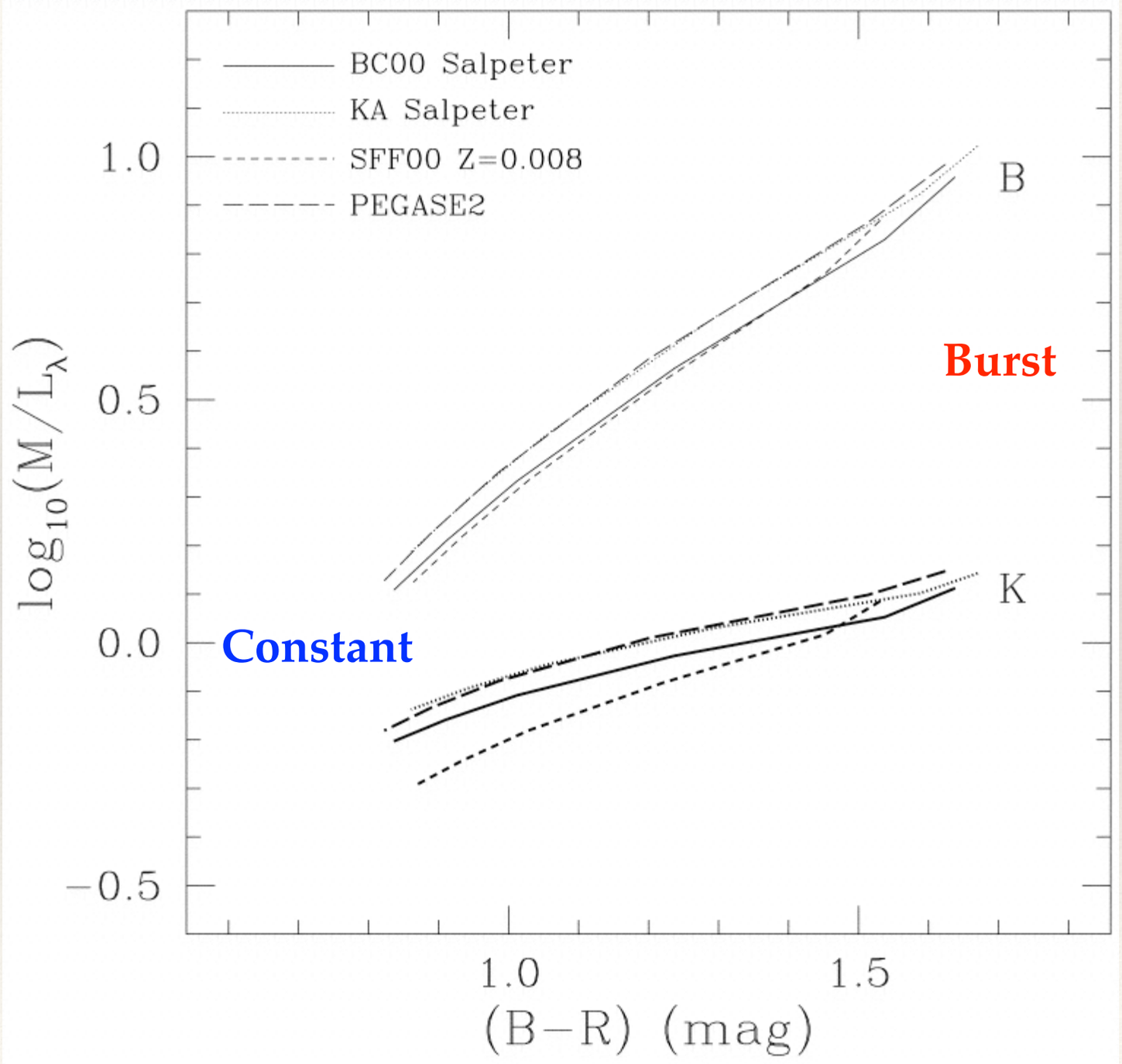




Bruzual & Charlot 1993

Stars and Stellar Populations

- Estimate stellar M/L from broadband color or from spectrum
- Luminosity + stellar M/L gives stellar mass
- Stellar M/L depends on bandpass and SFH
  - Less variation in near-IR (less sensitive to younger stars)
  - K-band luminosity often used as a rough proxy for stellar mass
- Absolute value of M/L of a population depends strongly on IMF. Relative values characterize different stellar pops for fixed IMF.



Bell & de Jong 2001

Questions 11/18

- In lecture 21, slide 18 you write (regarding hot ionized medium) “hard to determine total mass but likely very significant.” Why do we think “likely” if we don’t actually know? What points to its significance?

- Is it difficult to disentangle viewing warm neutral and warm ionised mediums, since they have similar temperatures and densities? Do we see more emission in the ionised medium as opposed to neutral?

- Still unclear about estimating SFR from the HII regions.

- I’m unclear as to why we would see a peak in star formation at z=2/cosmic noon as opposed to another time.

- Review the in class extinction,(flux ratio is close to 3, you observe 4 what is the inferred extinction E(Hbeta-Halpha)) bullet point 3 where you determine the visual extinction and h alpha for your observations?

Thought Questions

- The Halpha/Hbeta flux ratio in the absence of extinction has a value close to 3.
- Imagine you observe a ratio of 4. What is the inferred reddening E(Hbeta - Halpha)?

  E(Hbeta-Halpha) = -2.5 log 0.75 = 0.3

- If $A_{Hbeta}/A_V = 1.2$, and $A_{Halpha}/A_V = 0.8$ (based on extinction law), then what is A_V and A_{Halpha} for your observation??

  E(Hbeta-Halpha) = 0.3

  $(A_{Hbeta}-A_{Halpha}) / A_V = E(Hbeta-Halpha) / A_V = (1.2-0.8) = 0.4$

  $0.3 = 0.4\ A_V$; $A_V = 0.75$, $A_{Halpha} = 0.6$, $A_{Hbeta} = 0.9$

- How much do you have to correct your Halpha flux by?

  10.**(0.4*0.6) = 1.73

Questions 11/18