Spectroscopic Bulge-Disc Decomposition:

a new method to study the evolution of S0s

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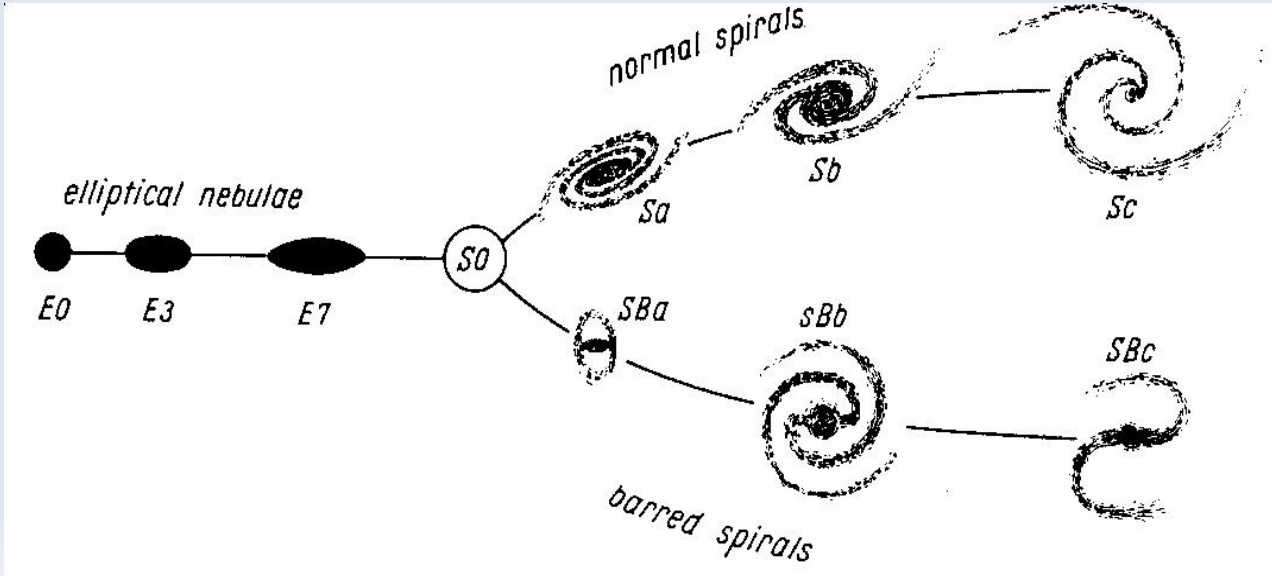
Outline

- S0s in galaxy evolution
- Summary of the method
- Examples of applications
  - Measurement of relative global ages and metallicities
  - Measurement of colour gradients
  - Measurement of line index gradients
- Summary
- Next steps

S0s in Galaxy Evolution

- **1926- Hubble**
- 1959- de Voucouleurs
- 1976- van den Bergh
- 2011- Cappellari et al
- 2012- Kormendy and Bender



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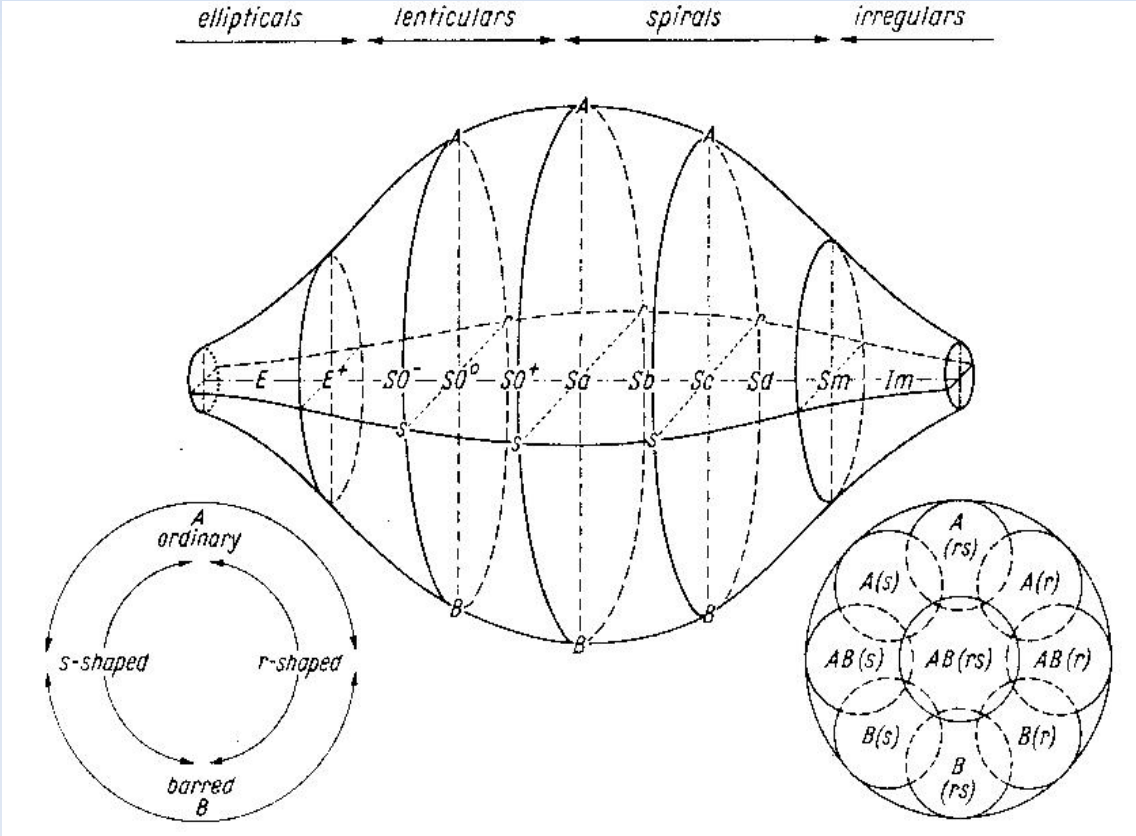

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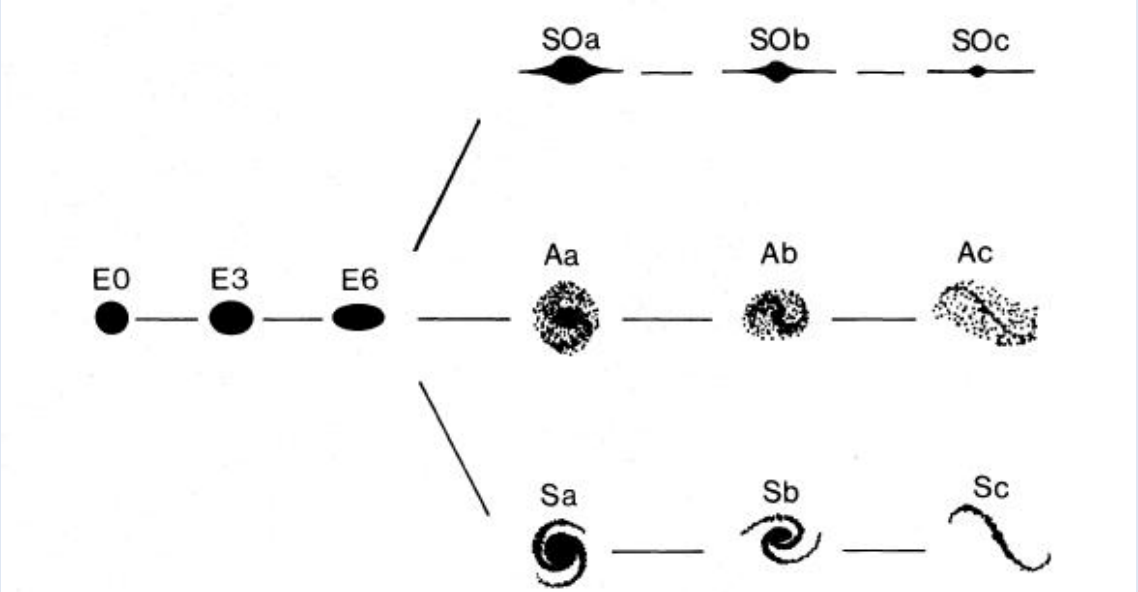

FIG. 2.—Schematic representation of the proposed new galaxy classification system

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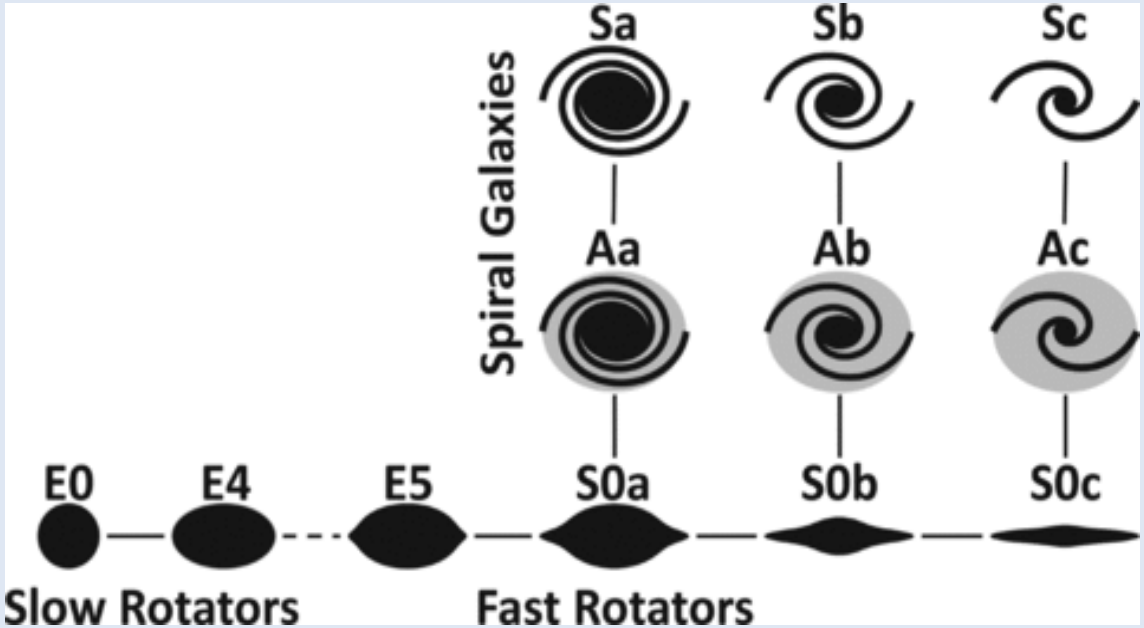

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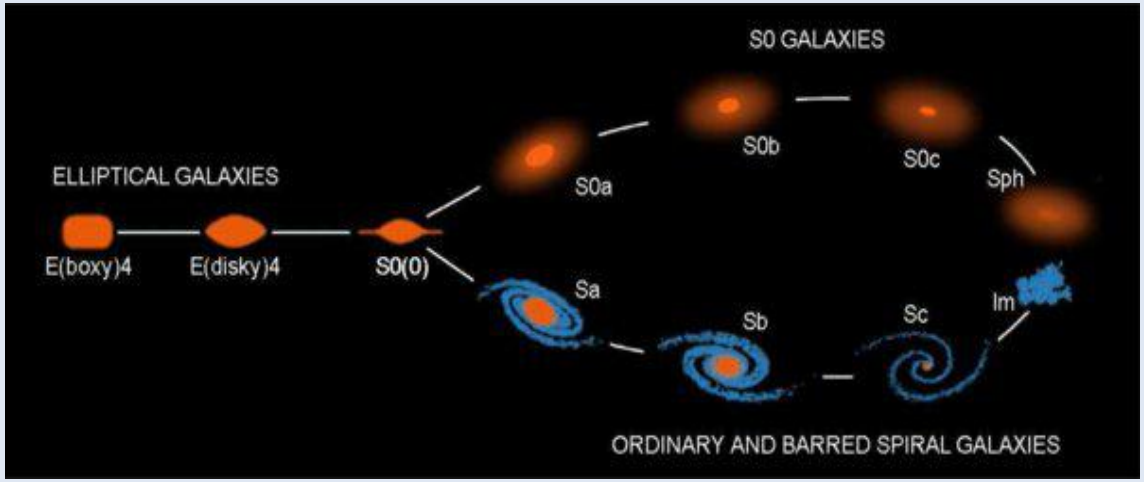


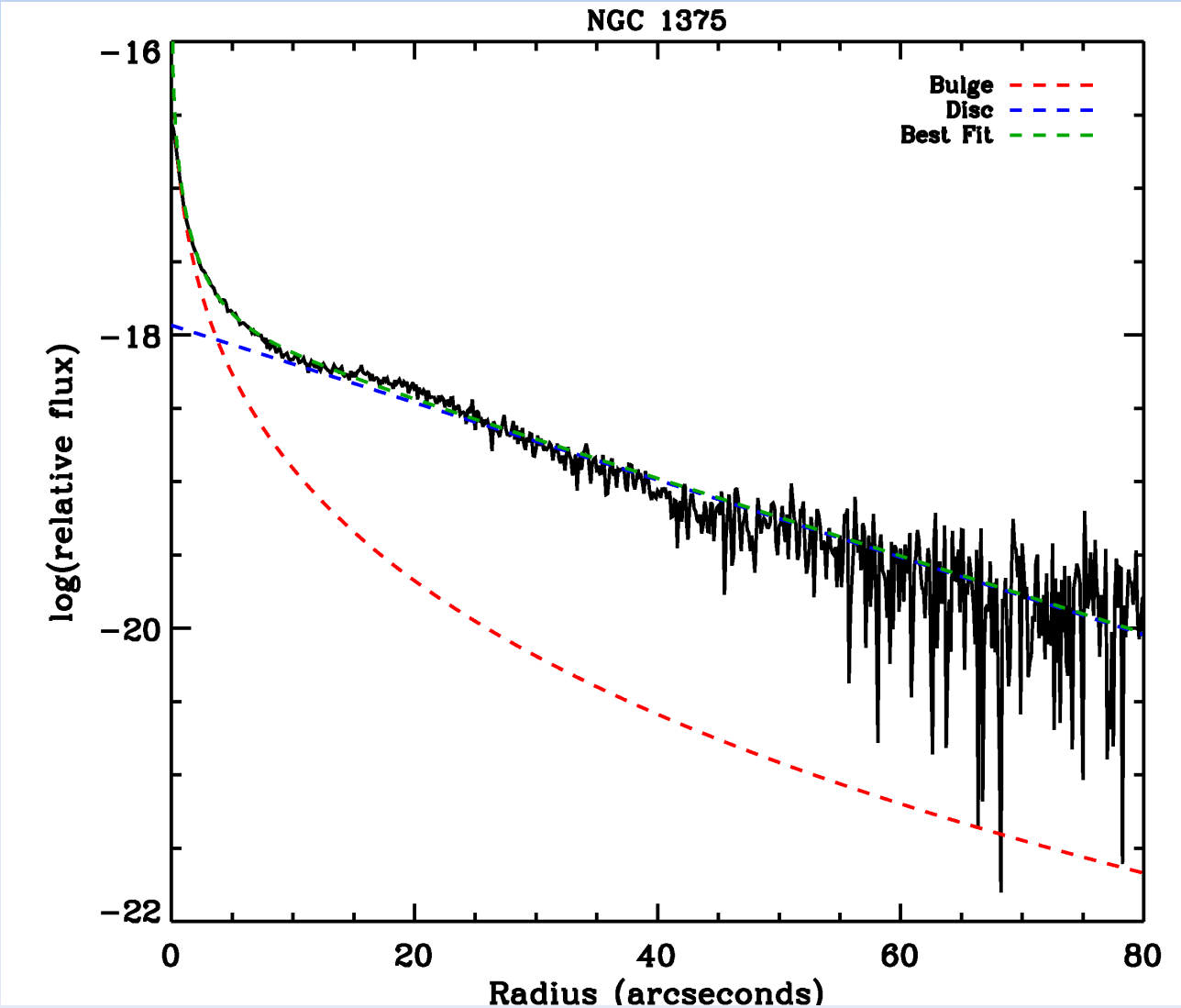
Evolution of S0s in Clusters

- Fraction of S0s in clusters increases to lower redshift, while that of spirals decreases (Dressler 1980)
- Theories for transformation of spirals to S0s tend to focus on disappearance of gas and truncation of star formation
  - Ram pressure stripping (Gunn & Gott, 1972)
  - Starvation (Larson, Tinsley & Caldwell, 1980)
  - Galaxy harassment (Moore, Lake & Katz, 1998)
  - Unequal mass galaxy mergers (Mihos & Hernquist 1994
- These processes will affect the bulge and disc in different ways

Spectroscopic Bulge-Disc Decomposition

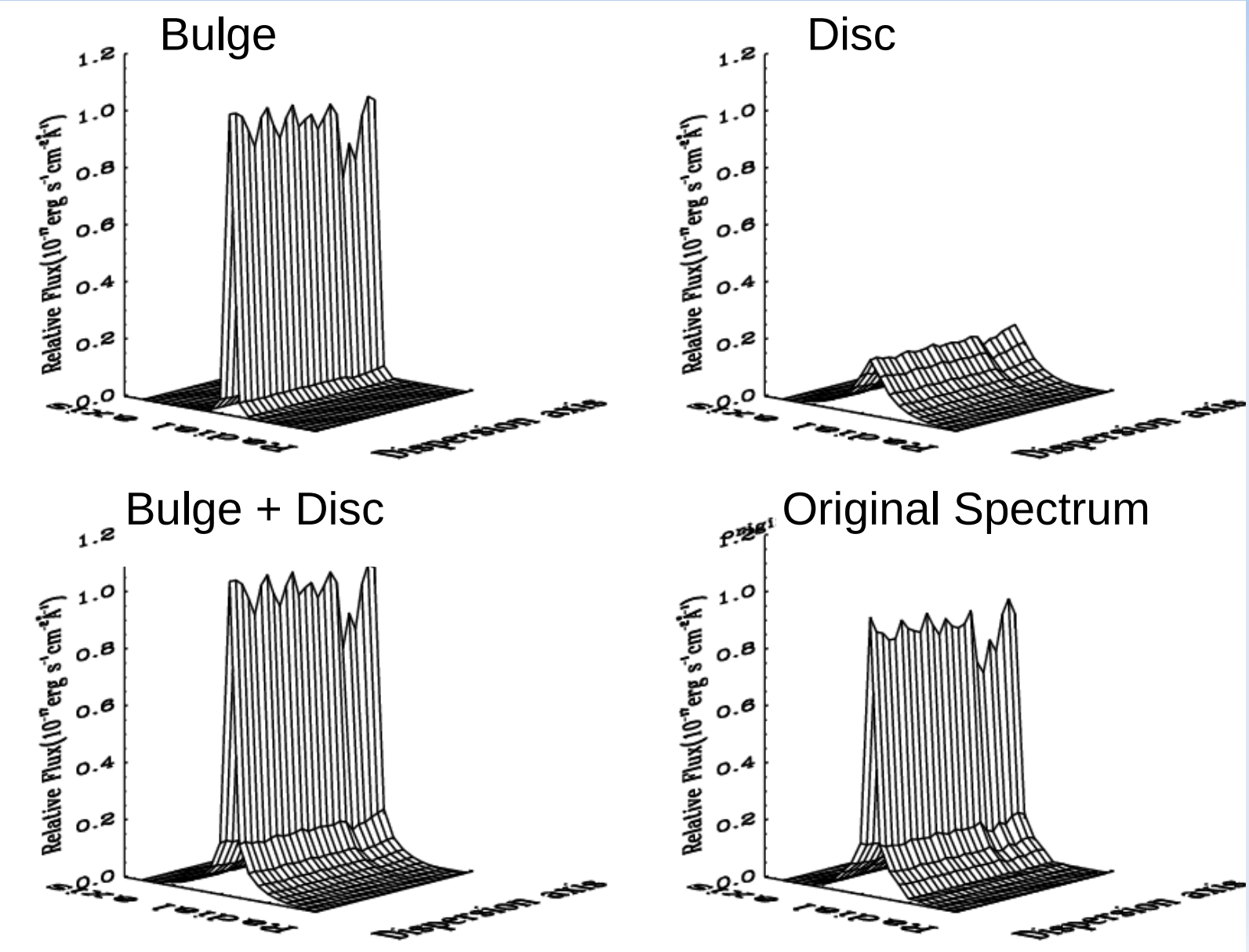
- Similar to multi-waveband photometric bulge-disk decomposition
- Study effects as a function of wavelength, not waveband
- Fit bulge and disc to light profile at each wavelength

Spectroscopic Bulge-Disc Decomposition



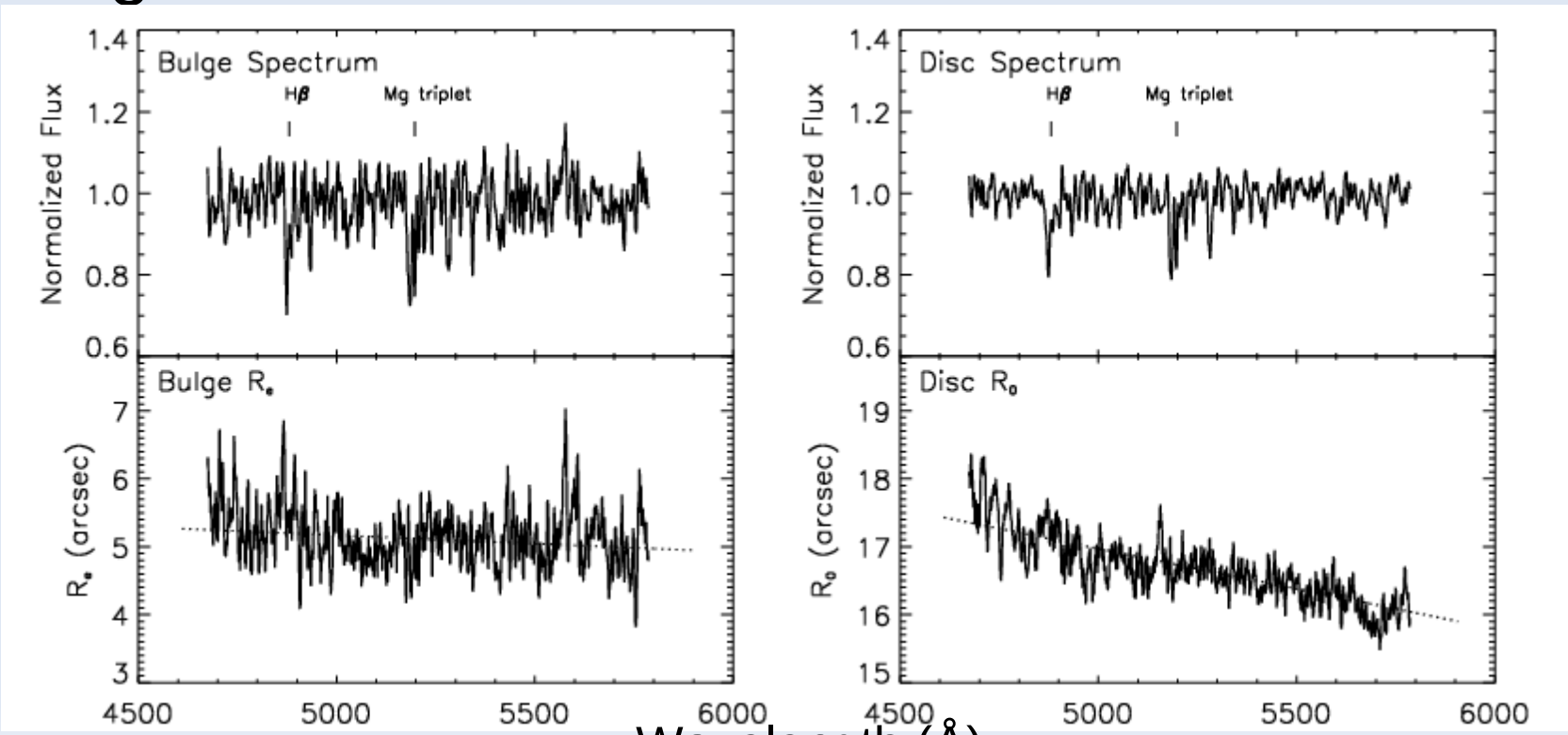
- de Voucouleurs bulge and exponential disc
- Success rate for this model ~1/3
- Repeat at each wavelength
- Correct for velocity dispersion and rotational velocity

Spectroscopic Bulge-Disc Decomposition



Spectroscopic Bulge-Disc Decomposition

- Integrate to get bulge and disc spectra
- Results also show variation in bulge and disc scale lengths



Data Set

Already Analysed

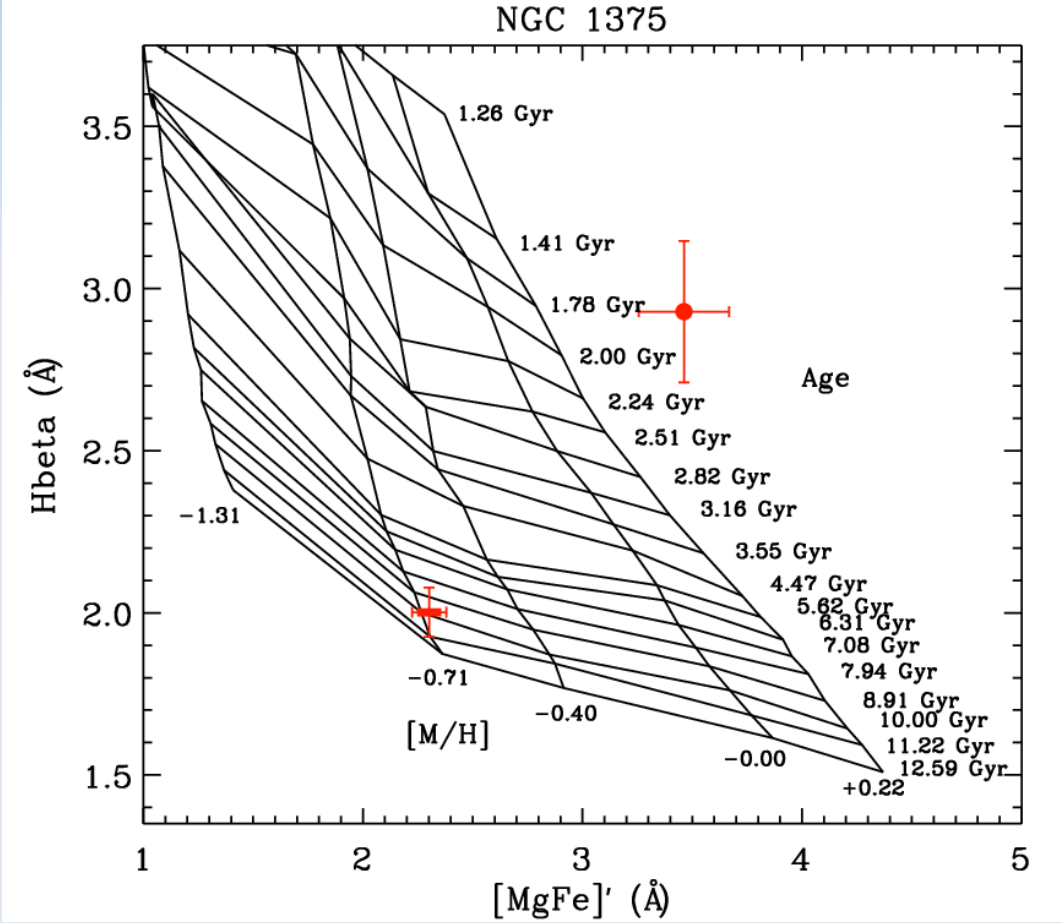
- 9 S0s from Fornax Cluster
- Long slit spectroscopy from VLT/FORS2
- $-22.3 < M_B < -17.3$
- Reduced and analysed by Alejandro Bedregal (Bedregal et al 2006a, 2006b, 2008, 2010)

Analysis In Progress

- 21 S0s from Virgo Cluster
- Long slit spectroscopy from Gemini/GMOS
- $-20.6 < M_B < -17.5$

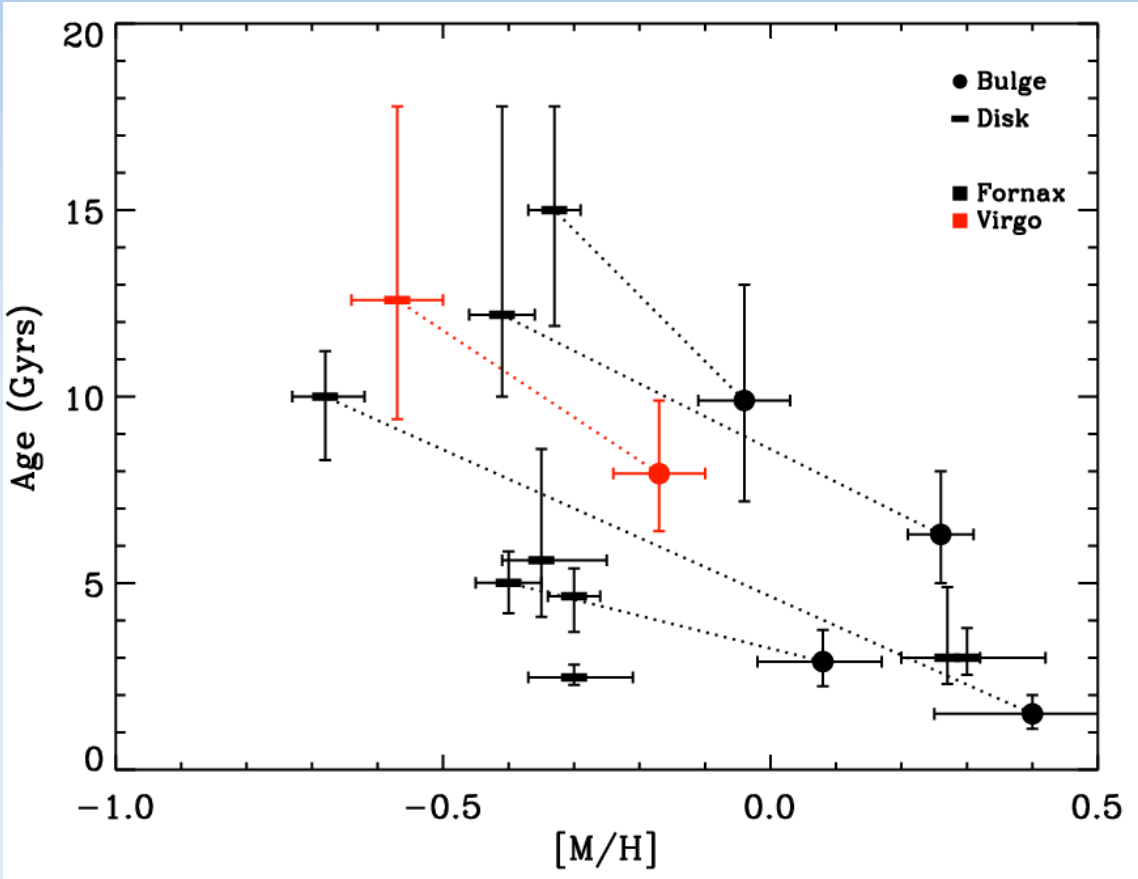
Relative Ages and Metallicities

- Measured the strengths of the Lick indices, and plotted onto SSP models from Vazdekis et al (2010)
- Estimated relative global ages and metallicities from these models for bulge and disc
- Results are light weighted, thus represent the youngest, brightest stellar populations



Relative Ages and Metallicities

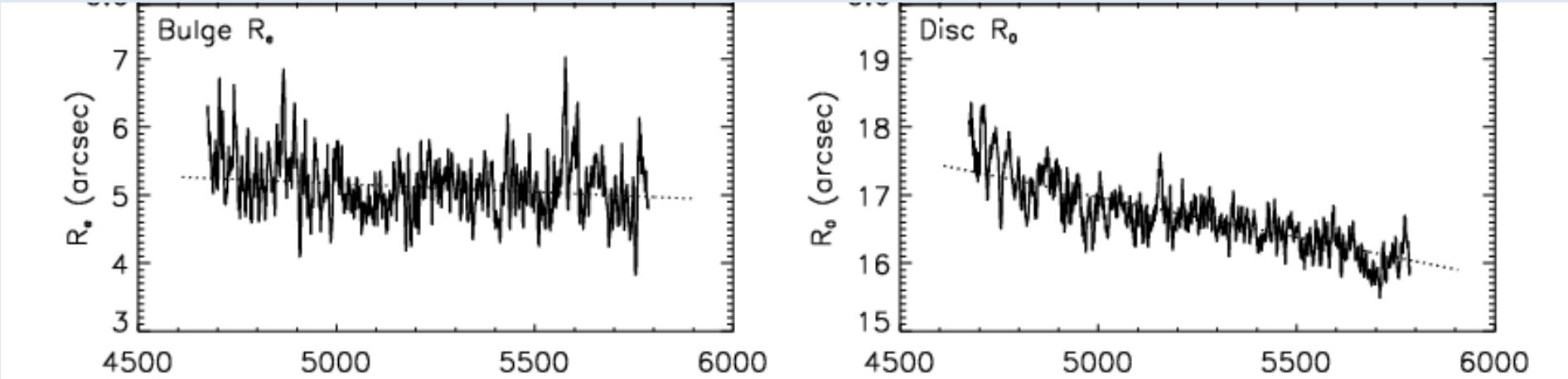
- Galaxies with younger stellar populations appear to have higher metallicities
- Bulges appear to have younger stellar populations and higher metallicities than discs
- Trend confirmed in Fornax data set by Bedregal et al (2011)



- Also seen in other S0s by Fisher, Franx & Illingworth (1996), Bell and de Jong (2000), Kuntschner (2000), MacArthur et al. (2004) and Prochaska Chamberlain et al. (2011)

Colour Gradients

- Variation in the bulge and disc scale length with wavelength provides information on colour gradients
  - Shorter scale lengths at longer wavelengths
  - Negative colour gradients
  - Red light more centrally concentrated than blue light



Colour Gradients

- Take the ratio of the B-band to V-band luminosity

$$\frac{I_B}{I_V}=\left(\frac{I_{0B}}{I_{0V}}\right)\exp\left[-\left(\frac{1}{R_{0B}}-\frac{1}{R_{0V}}\right)R\right]$$

- Convert to magnitudes

$$B-V=const-2.5\log\left(\frac{I_{0B}}{I_{0V}}\right)+2.5\left(\frac{1}{R_{0B}}-\frac{1}{R_{0V}}\right)R\log_{10}e$$

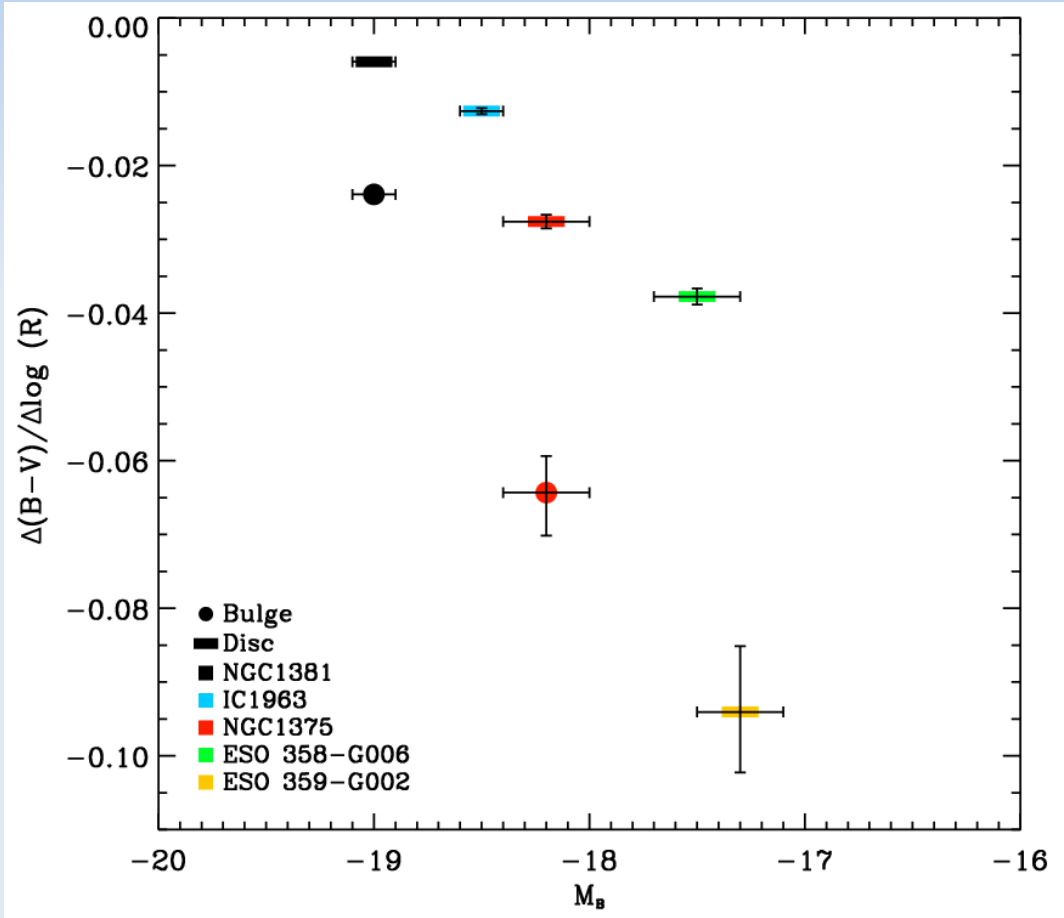
- Differentiate with respect to *R*

$$\frac{d(B-V)}{d(R)}=1.09\left(\frac{1}{R_{0B}}-\frac{1}{R_{0V}}\right)$$

- Integrate between $0 \le R \le R_{0V}$

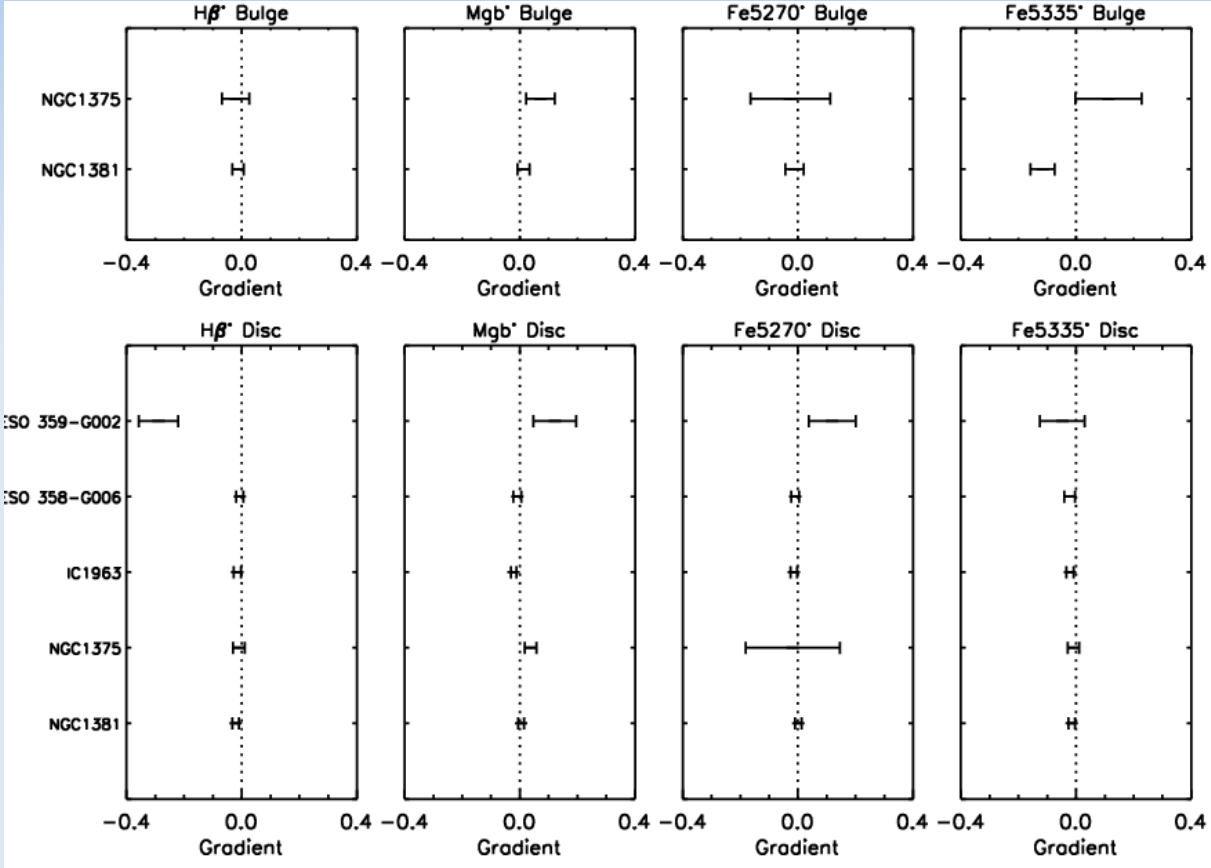
$$(B-V)_{R_{0V}}-(B-V)_0=1.09\left(\frac{R_{0V}}{R_{0B}}-1\right)$$

- Divide by $\log(R_{0V})$



Line Index Gradients

- Measured Lick indices as a function of radius
- Used scale length plots to measure uncertainties



- In most cases, no significant gradient has been detected

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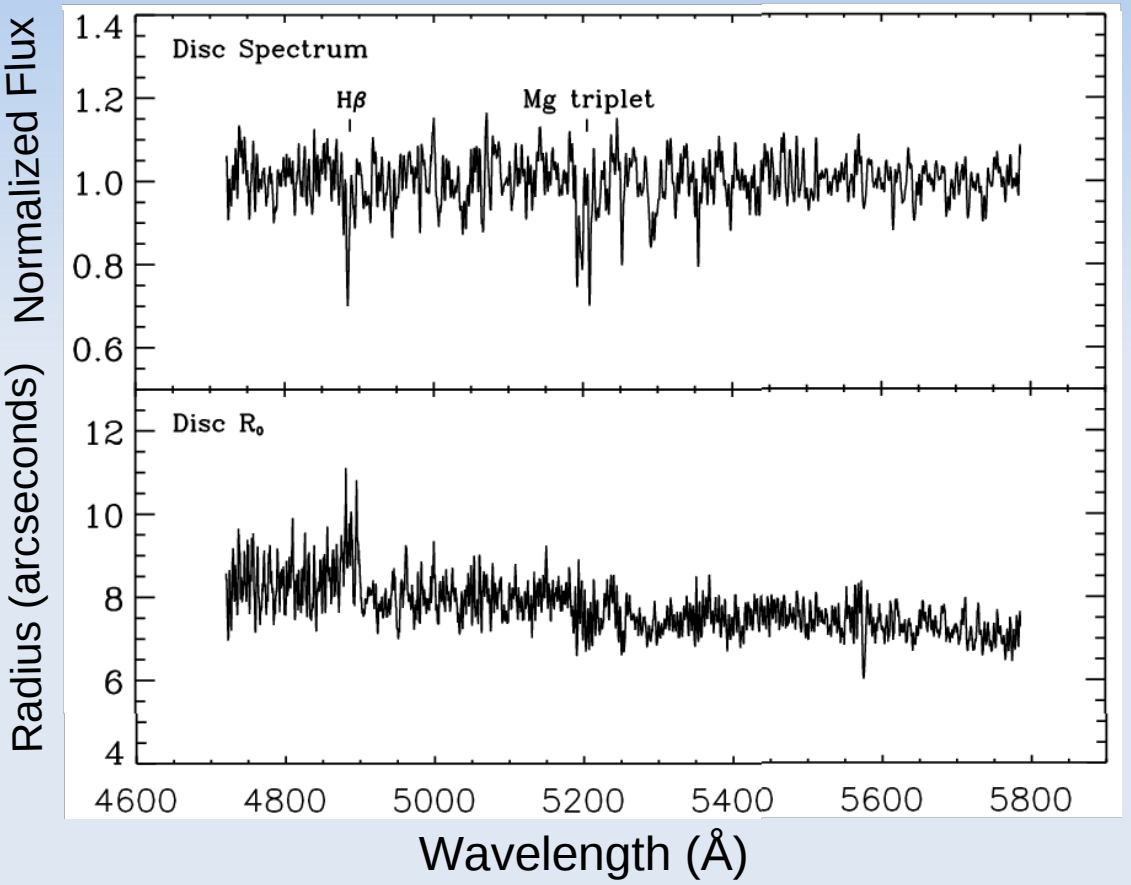


- ESO 359-G002 shows a negative Hβ gradient, representing a positive age and colour gradients
  - BUT, a negative colour gradient is detected in this galaxy

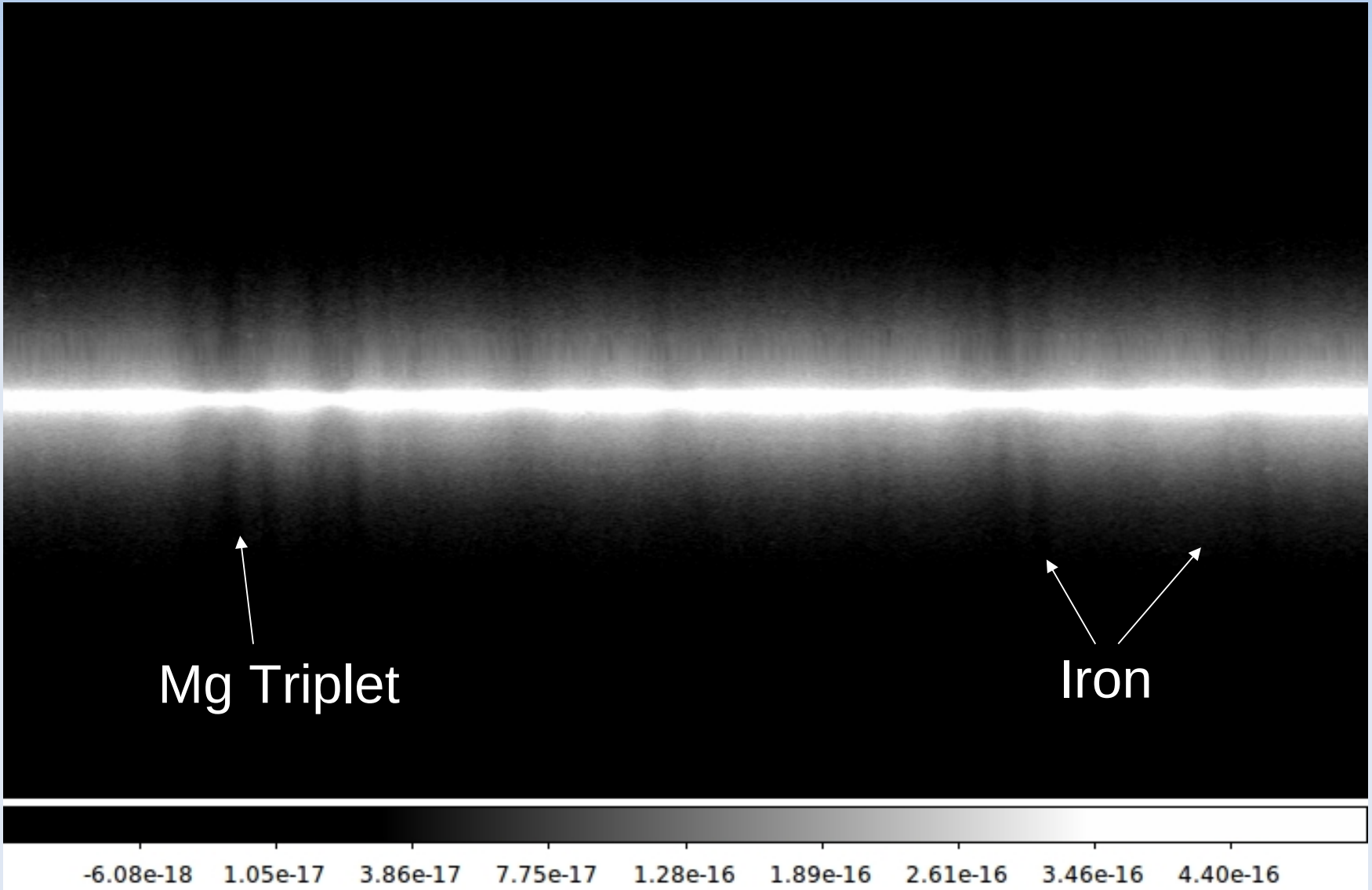
Summary

- Spectroscopic bulge-disc decomposition allows us to:
  - Obtain pure bulge and disc spectra with little contamination
  - Estimate relative ages and metallicities for the bulge and disc
  - Colour gradients within the bulge and disc
  - Age and metallicity gradients within bulge and disc
- Method still limited to de Voucouleurs bulge and exponential disc

Next steps

- Continue analysing Virgo data set with this technique
- Continue working on a new fitting code to fit double discs, sérsic profiles, bars, dust lanes etc
- NGC 4550- an S0 with two counter rotating discs.

NGC 4550


Mg Triplet
Iron
-6.08e-18
1.05e-17
3.86e-17
7.75e-17
1.28e-16
1.89e-16
2.61e-16
3.46e-16
4.40e-16