Disentangling the Stellar Populations in the Counter-Rotating Disc Galaxy NGC 4550

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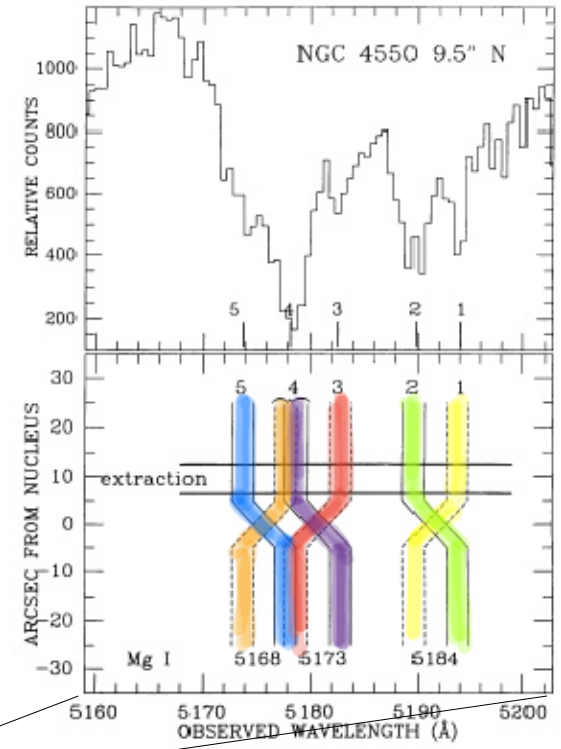
Why Study NGC 4550?

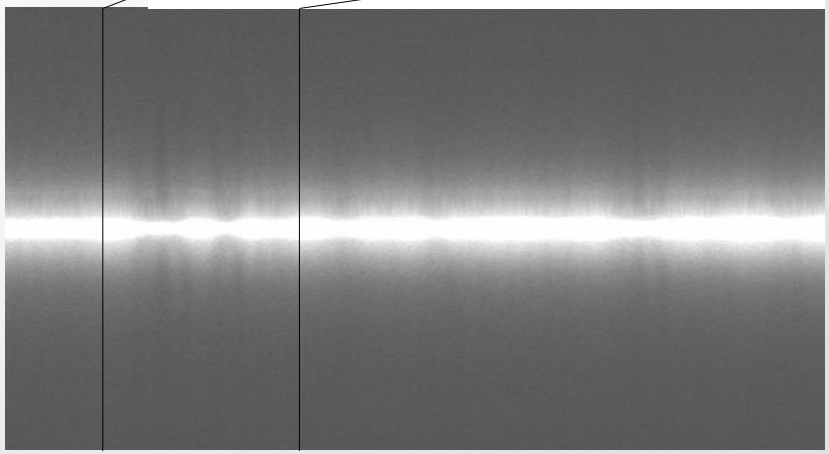
- Understanding the formation of lenticular galaxies is key to understanding the evolution of galaxies
- Any theory needs to be able to explain the presence of the more unusual features that we detect within galaxies
- < 10% of S0 galaxies are thought to contain counter-rotating stellar discs *(Kuijken, Fisher & Merrifield, 1996)*
- In most cases the counter-rotating disc is significantly less massive than the main disc *(Cappellari et al 2011)*
- One example of a counter- rotating disc galaxy is NGC 4550

Why Study NGC 4550?

- Images show a normal looking edge-on S0.
- Spectra show X-shaped absorption features, first noted by Rubin, Graham & Kenney (1992)
- These features represent two counter-rotating stellar discs.
- The two stellar discs have comparable masses, sizes and kinematics (Rix et al, 1992), making the formation of NGC 4550 a challenge to understand



Rubin, Graham & Kenney (1992)



How Did NGC 4550 Form?

"Counter-rotation is a general signature of material acquired from outside the main confines of the galaxy"

(Bertola & Corsini, 1999)

- Three possible mechanisms could explain NGC 4550
  - A carefully controlled merger between two disc galaxies *(Kenney, Faundez & Murphy 2000; Puerari & Pfenniger 2001)*
  - Accretion of gas from an external source into a gaseous disc that later underwent star formation *(Rubin, Graham & Kenney 1992; Thakar & Ryden 1996,1998)*
  - Separatrix-crossing scenario, where a single, initially-triaxial elliptical galaxy evolved slowly into counter-rotating disc system *(Evans & Collett 1994)*

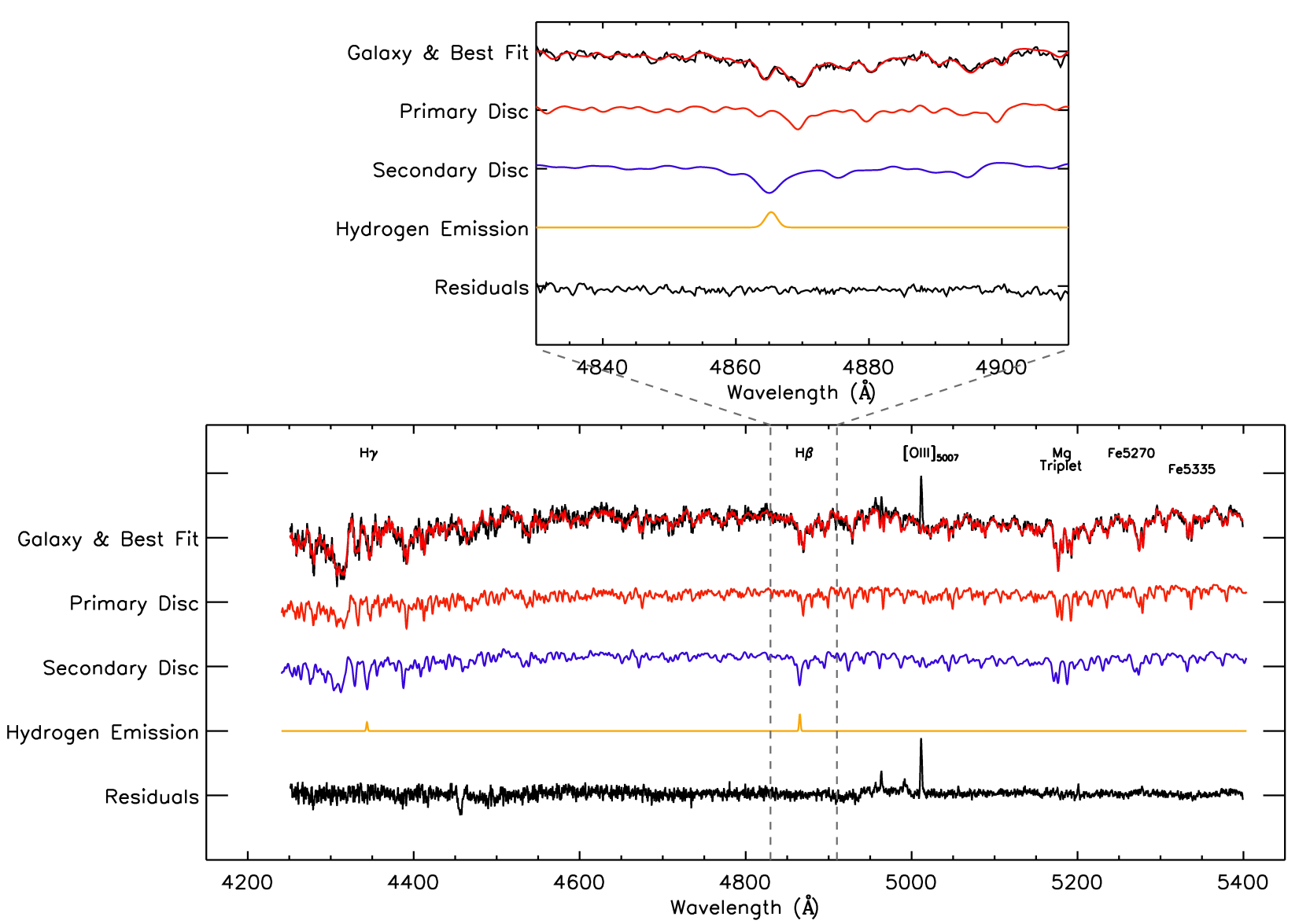
Observations and Data

- Long-slit spectroscopy from Gemini/GMOS
- 3600s exposure time in total
- 4100 Å < λ < 5450 Å
- Spectral resolution ~ 1.13 Å FWHM
- S/N ratio of the central 2 arcsec of the galaxy is in excess of 100
- Spectrum was binned to maintain a S/N > 20 throughout the galaxy.

Kinematic Decomposition

- Similar method used by Coccato et al (2010) to analyse NGC 5719
- Modified the Penalized Pixel Fitting code (pPXF) of Cappellari & Emsellem (2004) to fit two stellar components and a gas disc
- Template spectra were used to create model spectra for each disc, which when co-added would best fit the galaxy spectrum
- Repeated for every binned spectrum
- Plotted kinematics of the three components
- Gas disc kinematics measured from Hydrogen and [OIII] emission lines

Kinematic Decomposition



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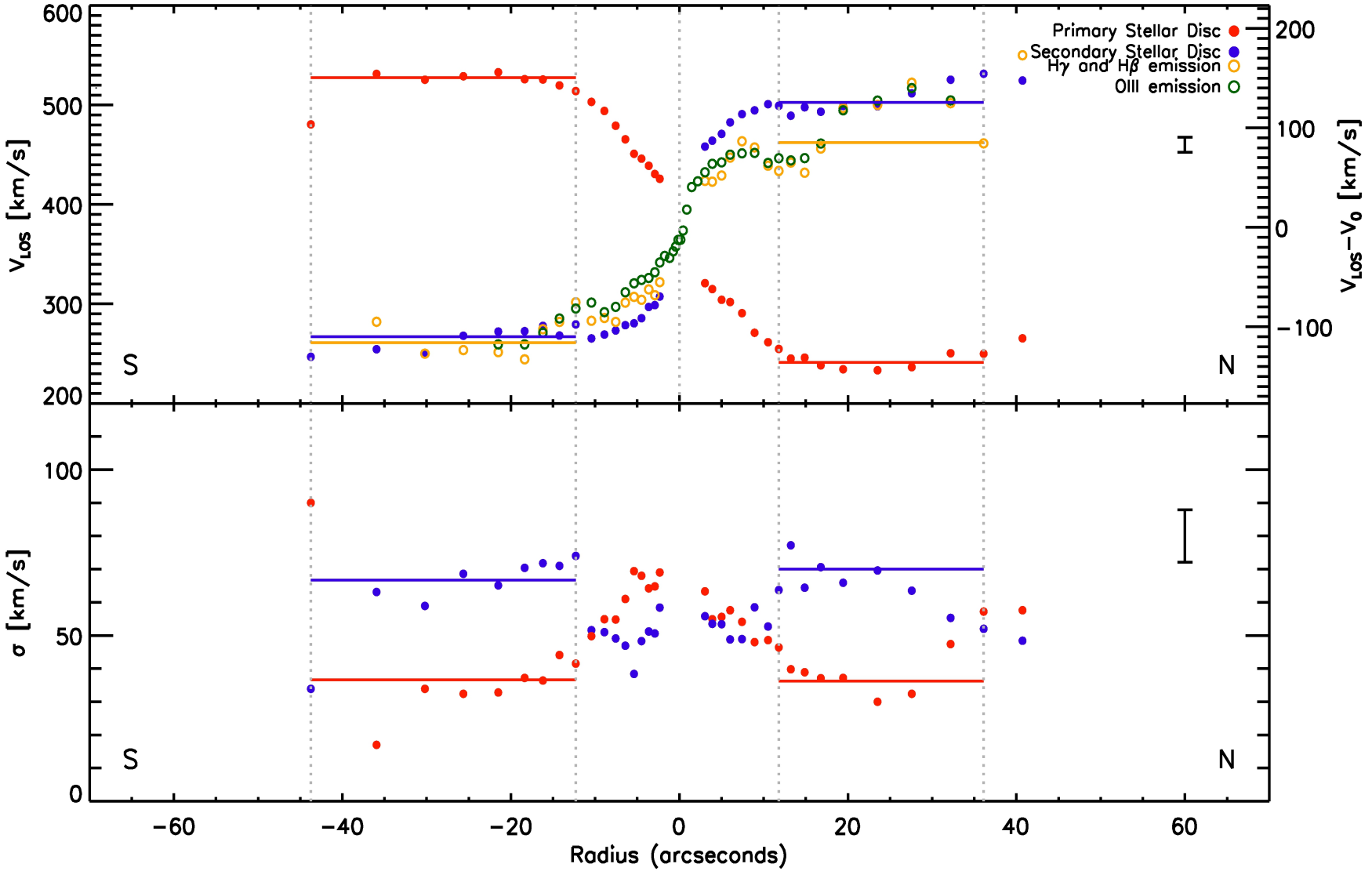
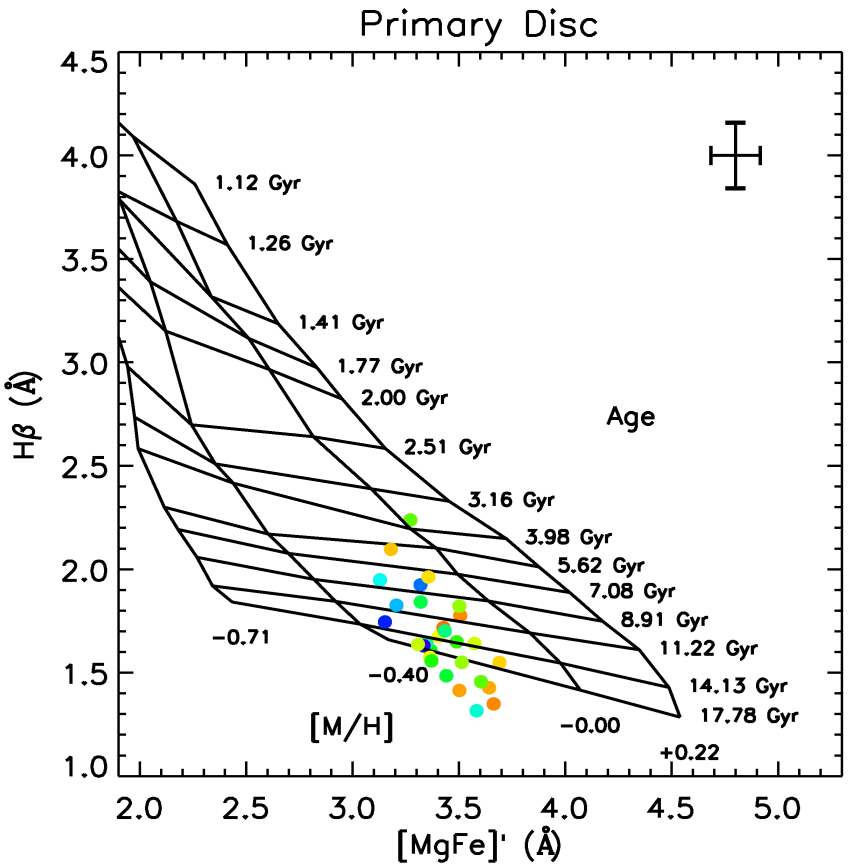
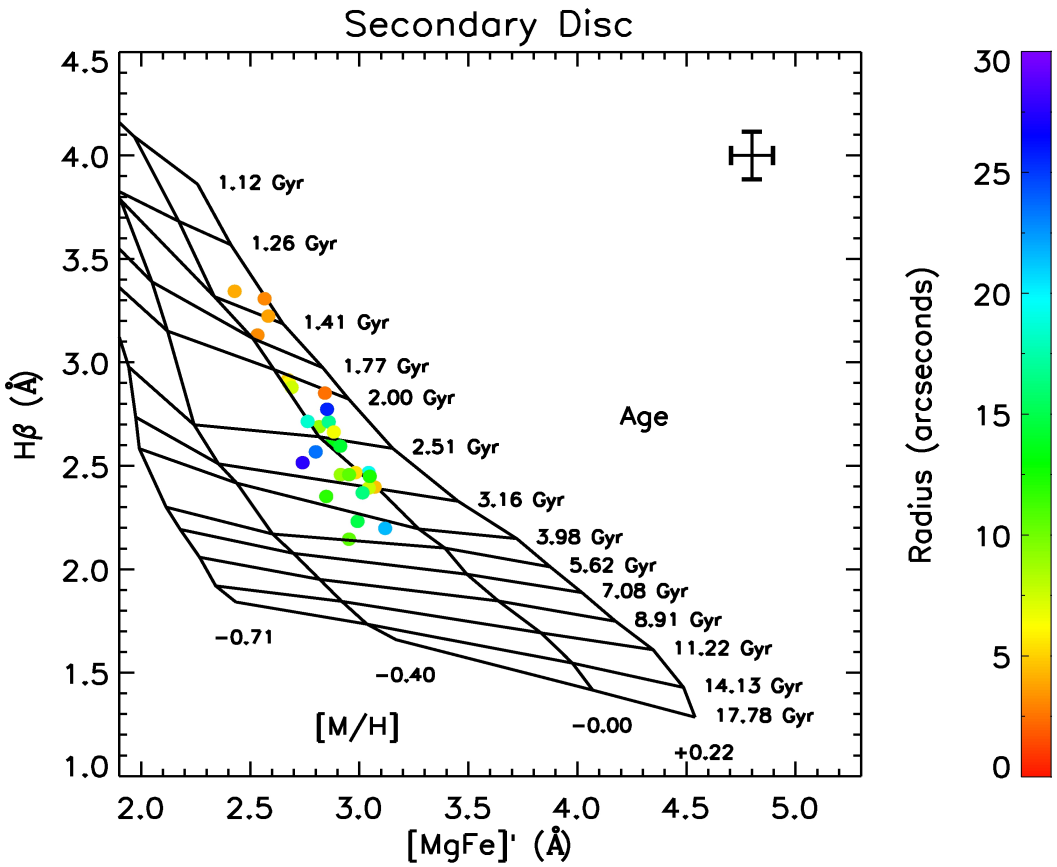


Stellar Populations Analysis

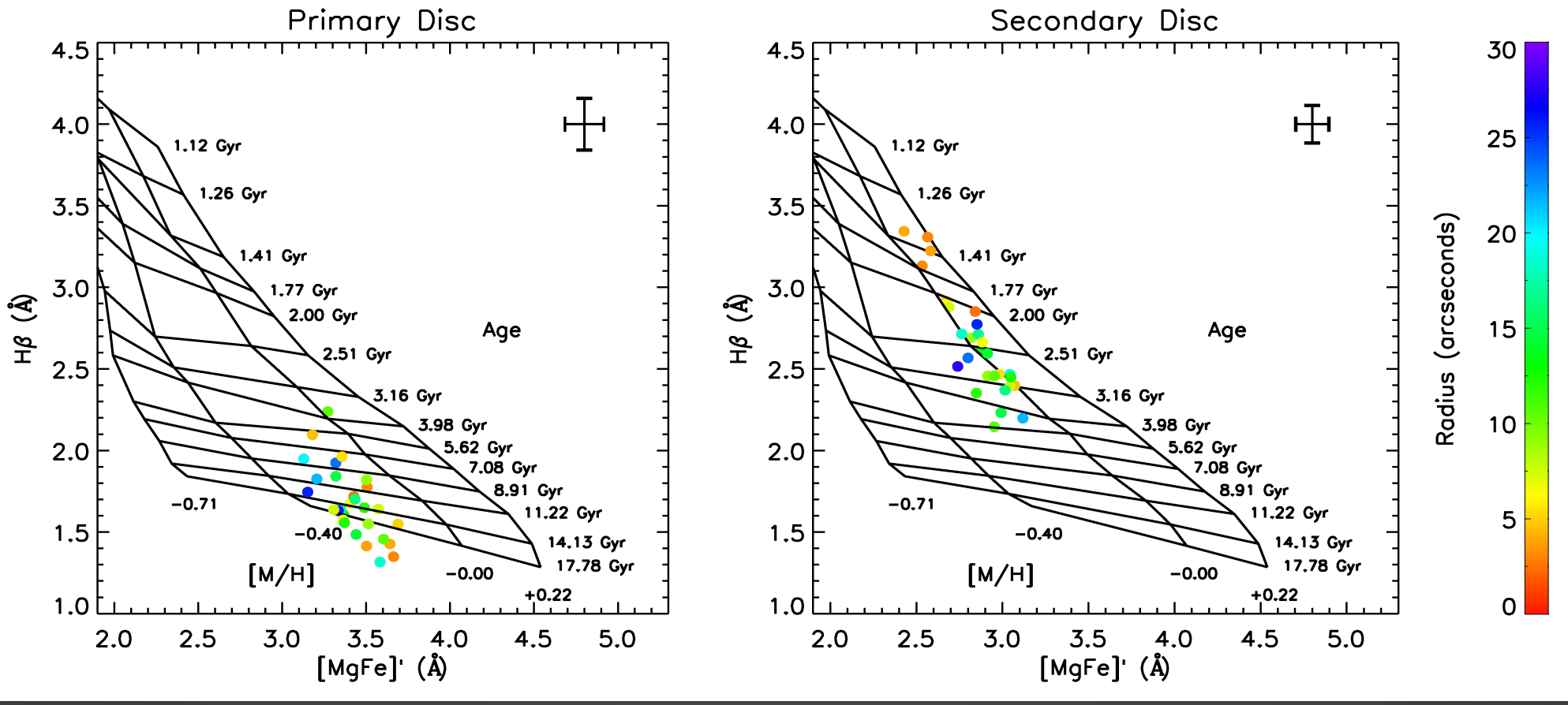
- Measured line indices from model spectra for each disc
- Plotted line indices onto SSP models of Vazdekis et al (2010)





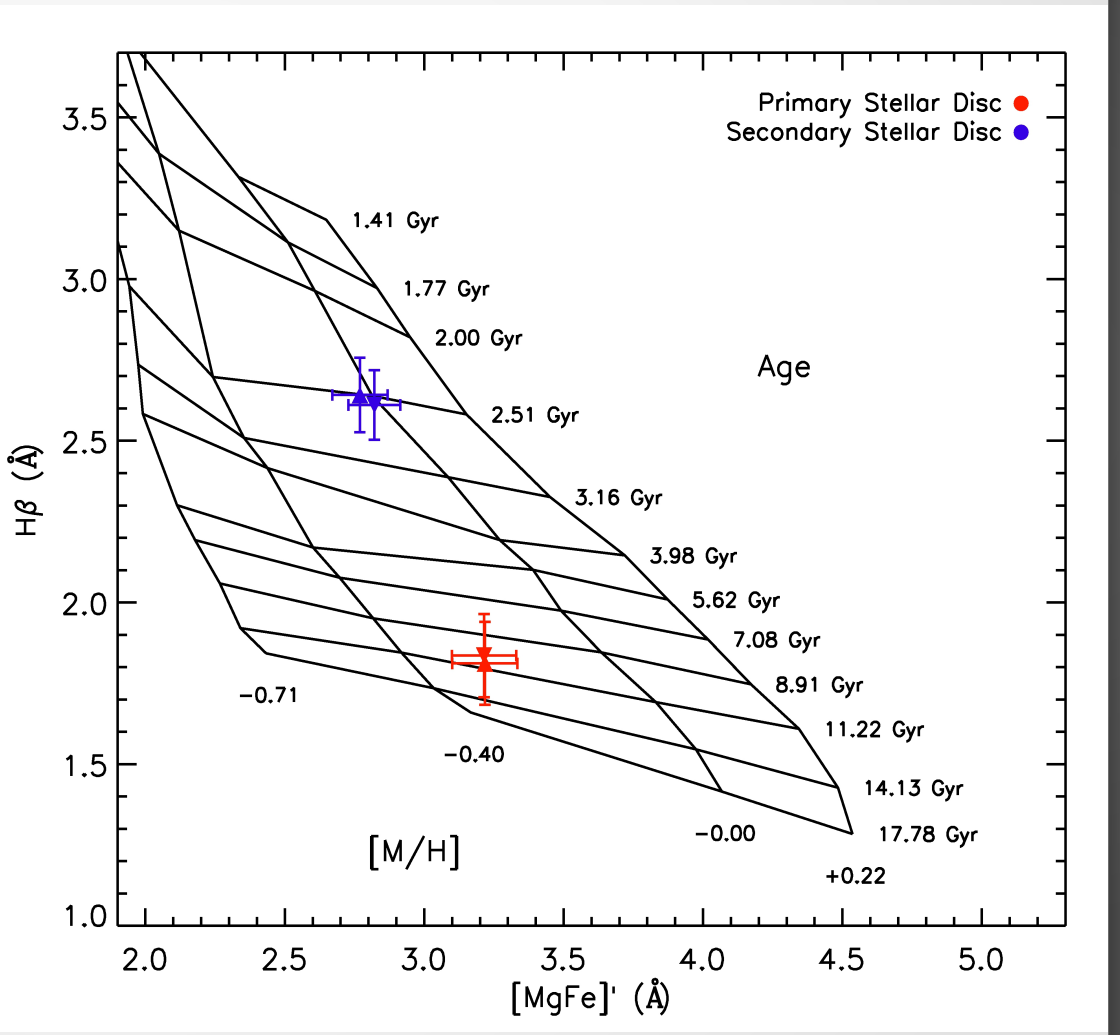
Stellar Populations Analysis

- Lower luminosity-weighted ages and positive age gradient seen in secondary disc



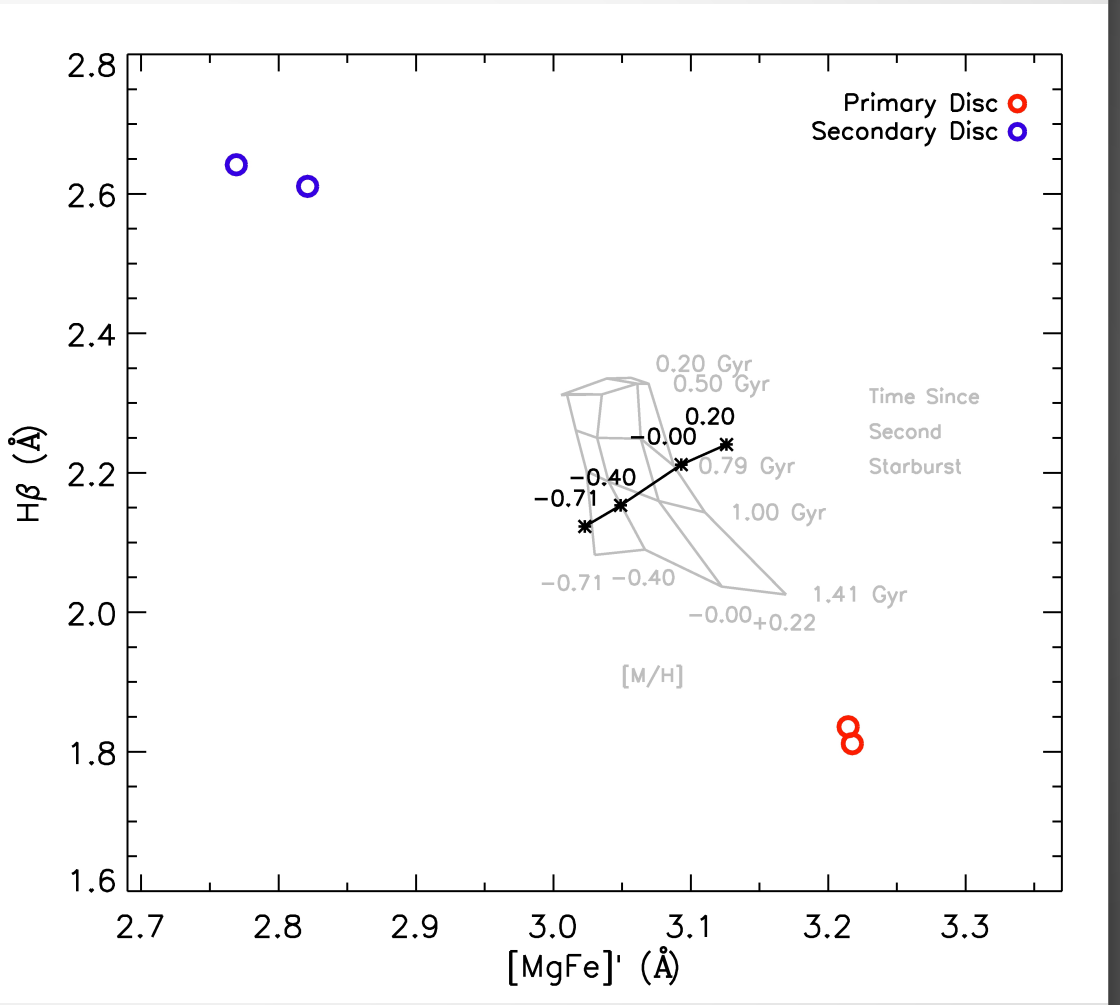
Stellar Populations Analysis

- Rebinned spectra over the regions where kinematics stabilise.
- Refitted spectrum with modified pPXF
- Measured line indices from the model spectra.
- Secondary disc found to be ~20% more luminous than primary disc
- Used luminosity ratio to constrain the effect of later star formation events.



Stellar Populations Analysis

- Looked at two extreme scenarios following the initial formation of the two discs
  - Continuous star formation to the present day (black)
  - Single burst of star formation (grey)
- These cannot reproduce the results measured in the secondary disc



So, How Did NGC 4550 Form?

- We have ruled out the separatrix crossing method
- The presence of the gas disc trailing the secondary disk points towards the gas accretion scenario, where the age of the stellar populations in the secondary disc tells us how long ago this material was accreted.
- A similar study by Coccato et al (2013) using IFU data has also come to this conclusion.
- However we still cannot rule out a carefully controlled merger between two disc galaxies, where the stellar populations of the two discs represent those of the precursor galaxies.