The stellar initial mass function: radial variations in early-type galaxies?

Padraig Alton

With thanks to Russell Smith, John Lucey, and Ray Sharples

Outline

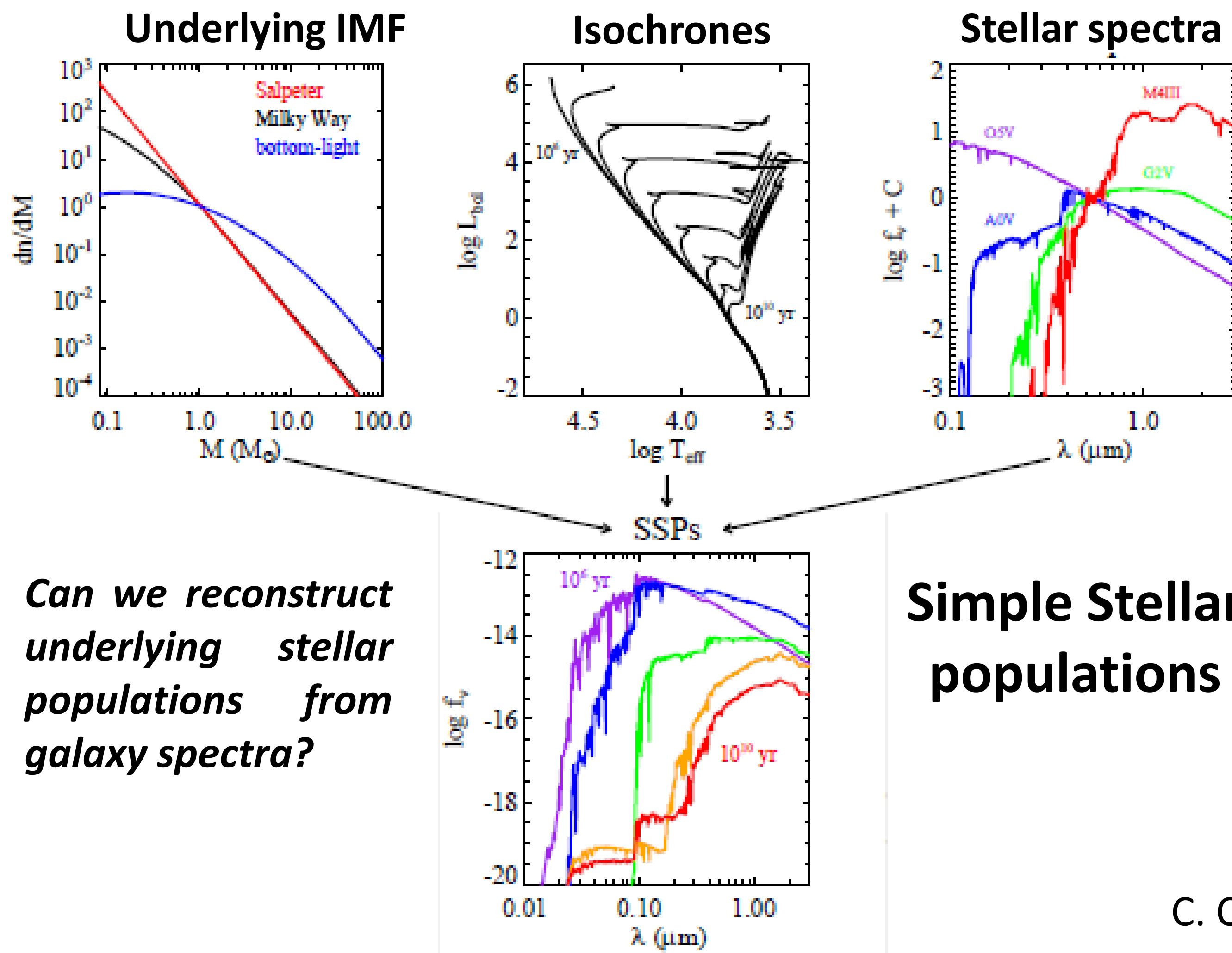
Introduction to SSP modelling: how spectra can be used to infer the IMF of an unresolved stellar population

Review of evidence and theoretical support for radial dependence of the IMF in ETGs

VLT-KMOS observations of 8 nearby ETGs and our results

Questions

Simple Stellar Population Models

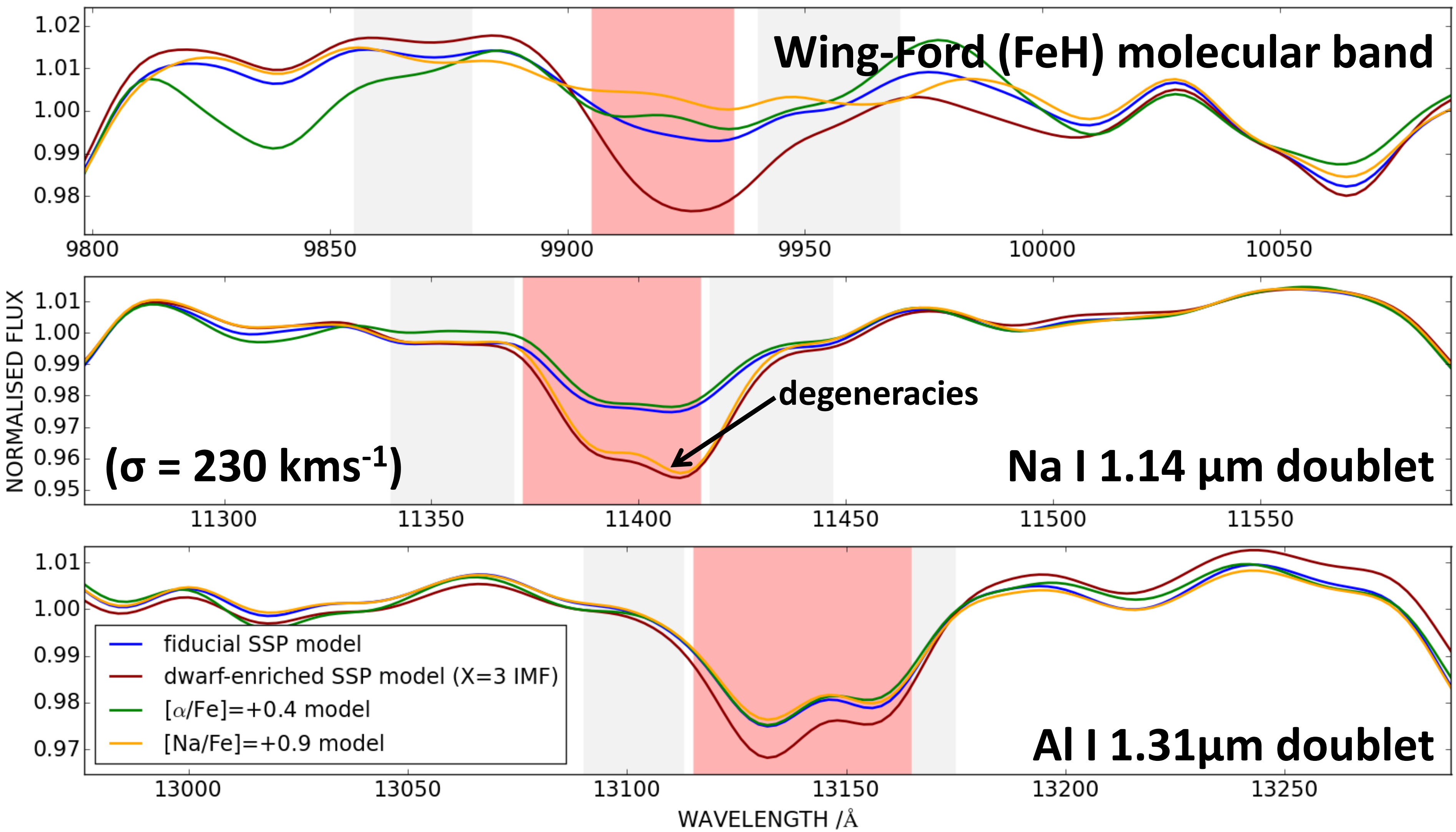


Can we reconstruct underlying stellar populations from galaxy spectra?

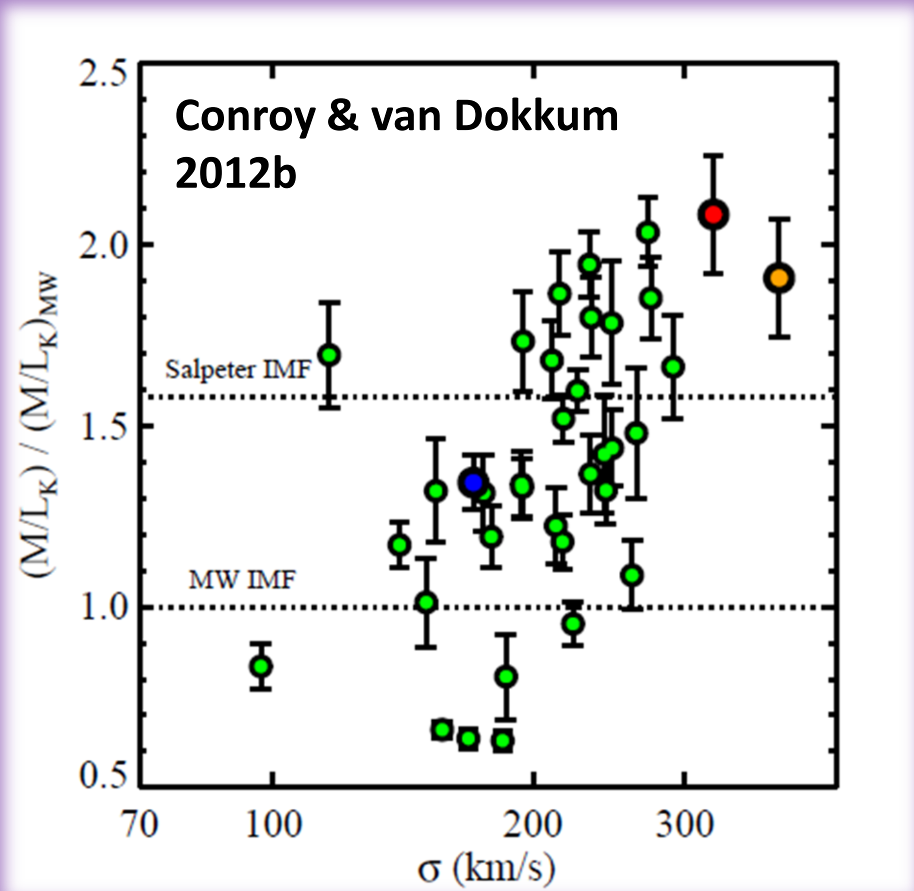
Simple Stellar populations

C. Conroy

Simple Stellar Population Models



Bottom heavy IMFs



Correlation in ETGs between steeper (more bottom-heavy) IMFs and increasing galaxy mass.

See also:
Spiniello et al. 2012;
Smith, Lucey, and Carter 2012;
La Barbera et al. 2013

But galaxy-by-galaxy mismatch with M/L methods (Smith et al. 2014)!

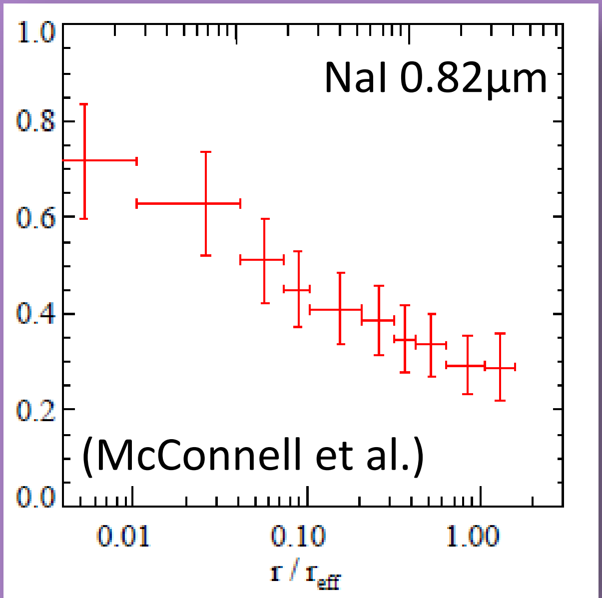
Method works best on high S/N data … so spectra taken from cores.

IMF radial variations

Radial variations of the IMF motivated by 'inside-out' ETG formation (e.g. Oser et al. 2010). Rapid starburst builds up the galaxy core, outer regions assembled later, primarily via accretion of smaller systems.

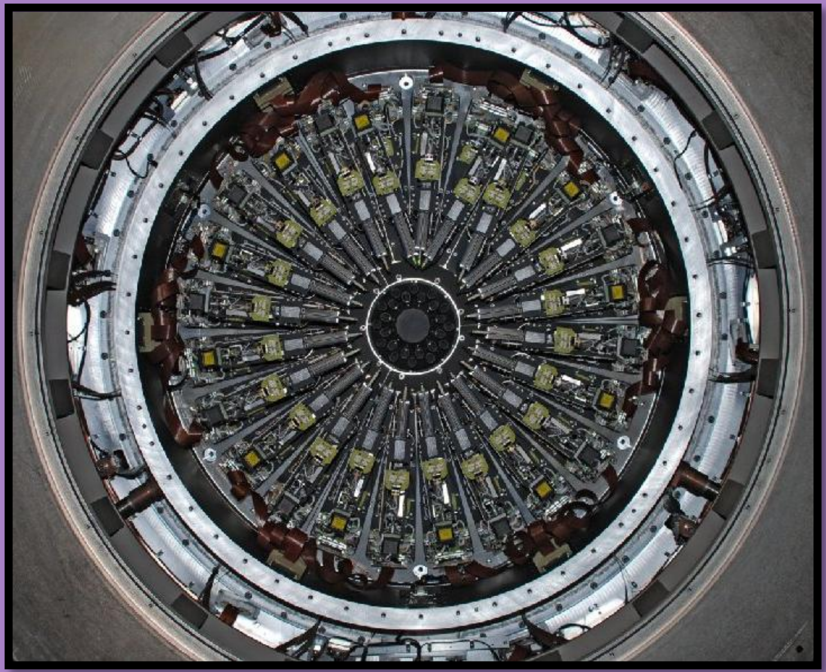
Attempts to constrain: Martin-Navarro et al. 2015, McConnell et al. 2015, La Barbera et al. 2015...

... but small samples (1-2 galaxies) and conflicting conclusions.



Our work

Advances in instrumentation and development of SSP models in the IR allow us to move out of the optical and into the infrared: spectra dominated by cool stars and contain many IMF-sensitive features - essential for breaking degeneracies.

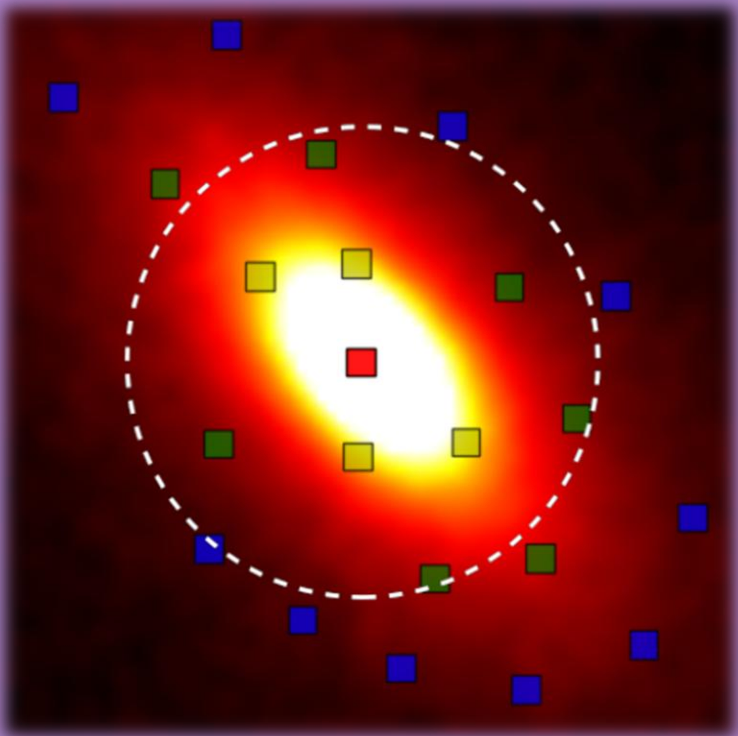


KMOS (Sharples et al. 2003): able to observe multiple targets simultaneously using 24 arms.

We observe 8 ETGs in the IZ band (0.78-1.08μm) and 6 of these in the YJ band (1.03-1.34μm) also.

Our work

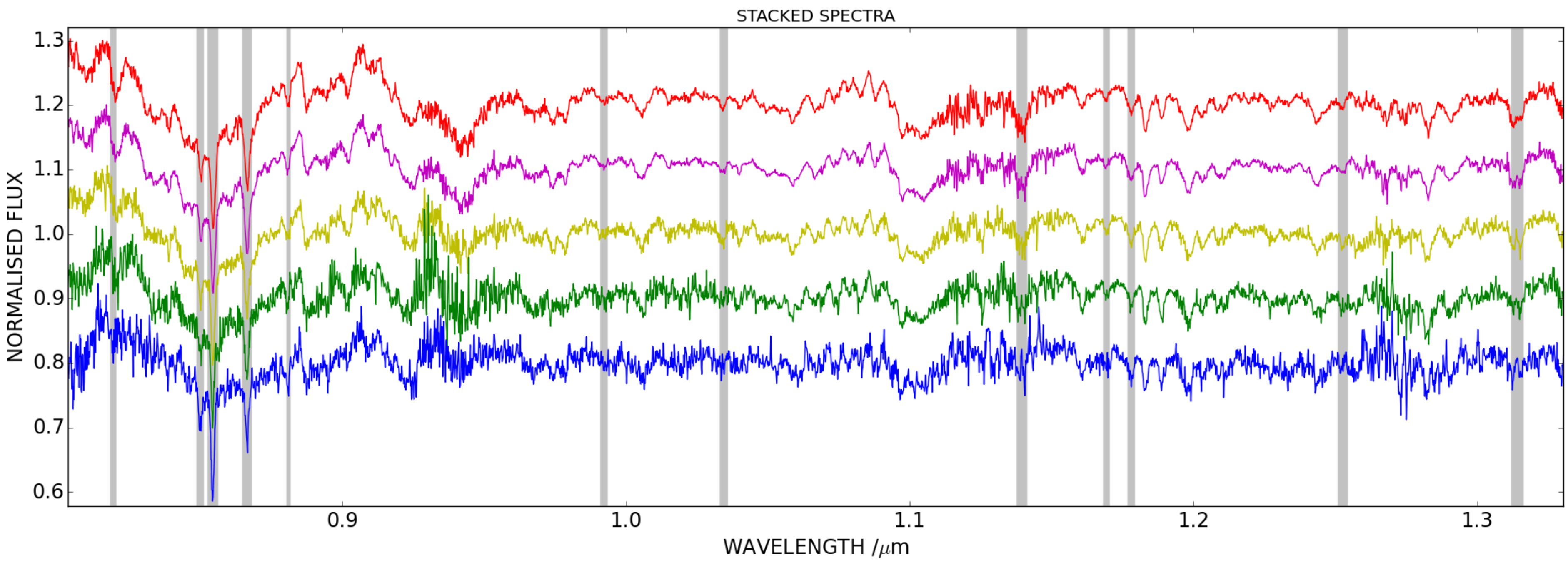
Observing strategy: arms arranged on isophotal lines out to the effective radius – create composite spectra at a range of different radii.



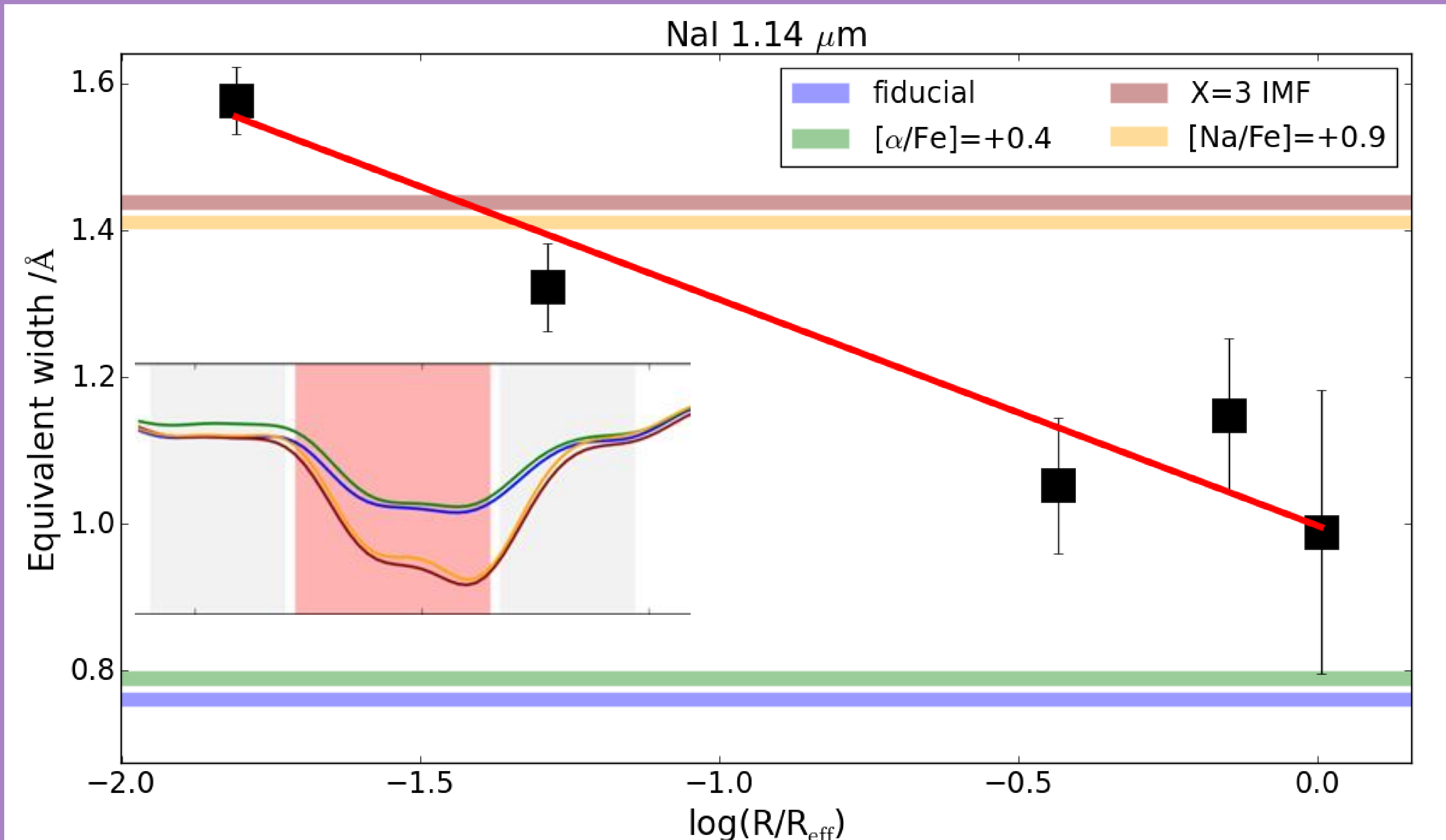
Feature radial trends

Focus on radial trends here: larger sample than all other studies put together & investigate unexplored spectral features.

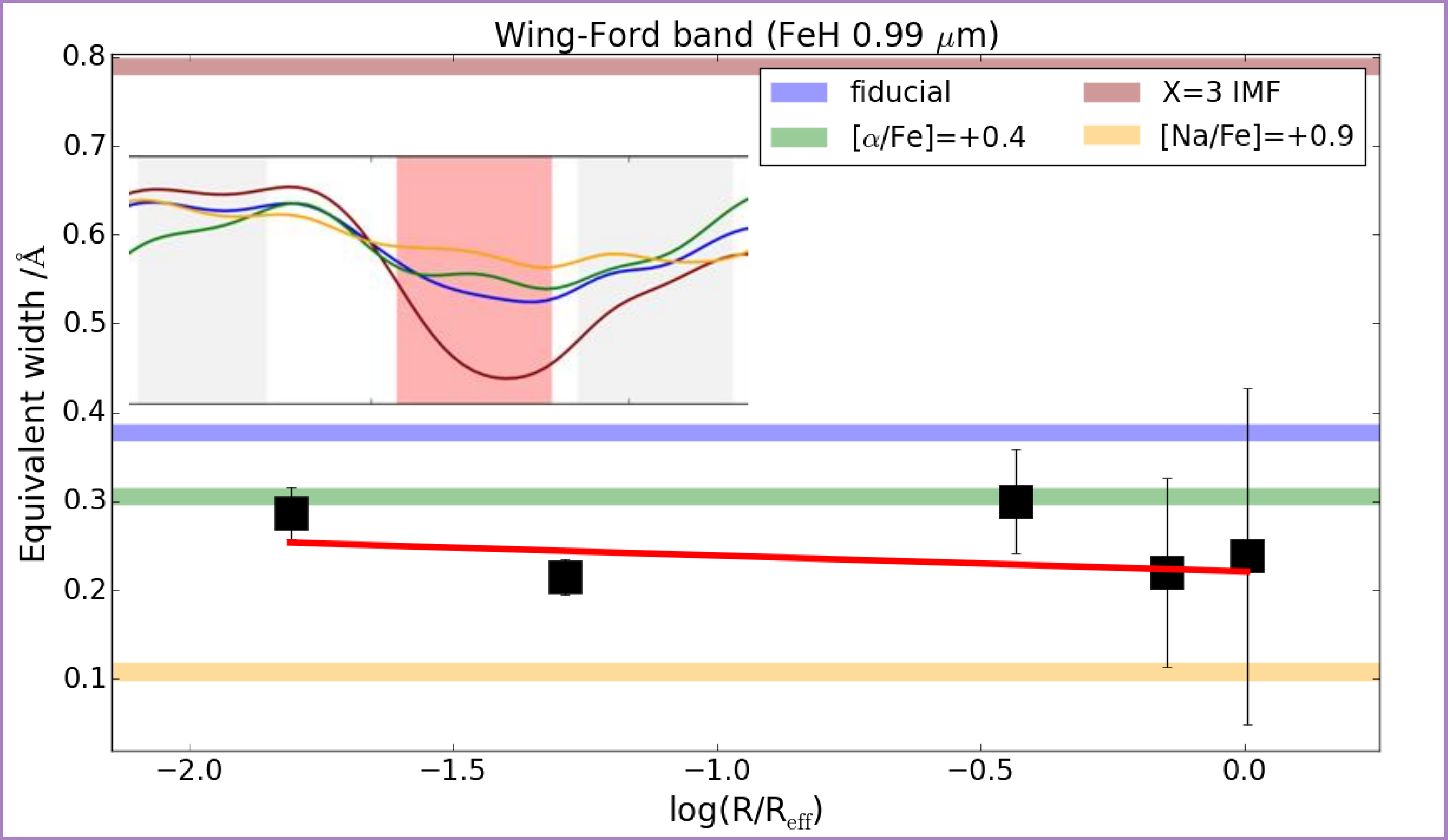
Median stack of spectra in each radial regime: pool information across sample and wash out galaxy-galaxy variations:



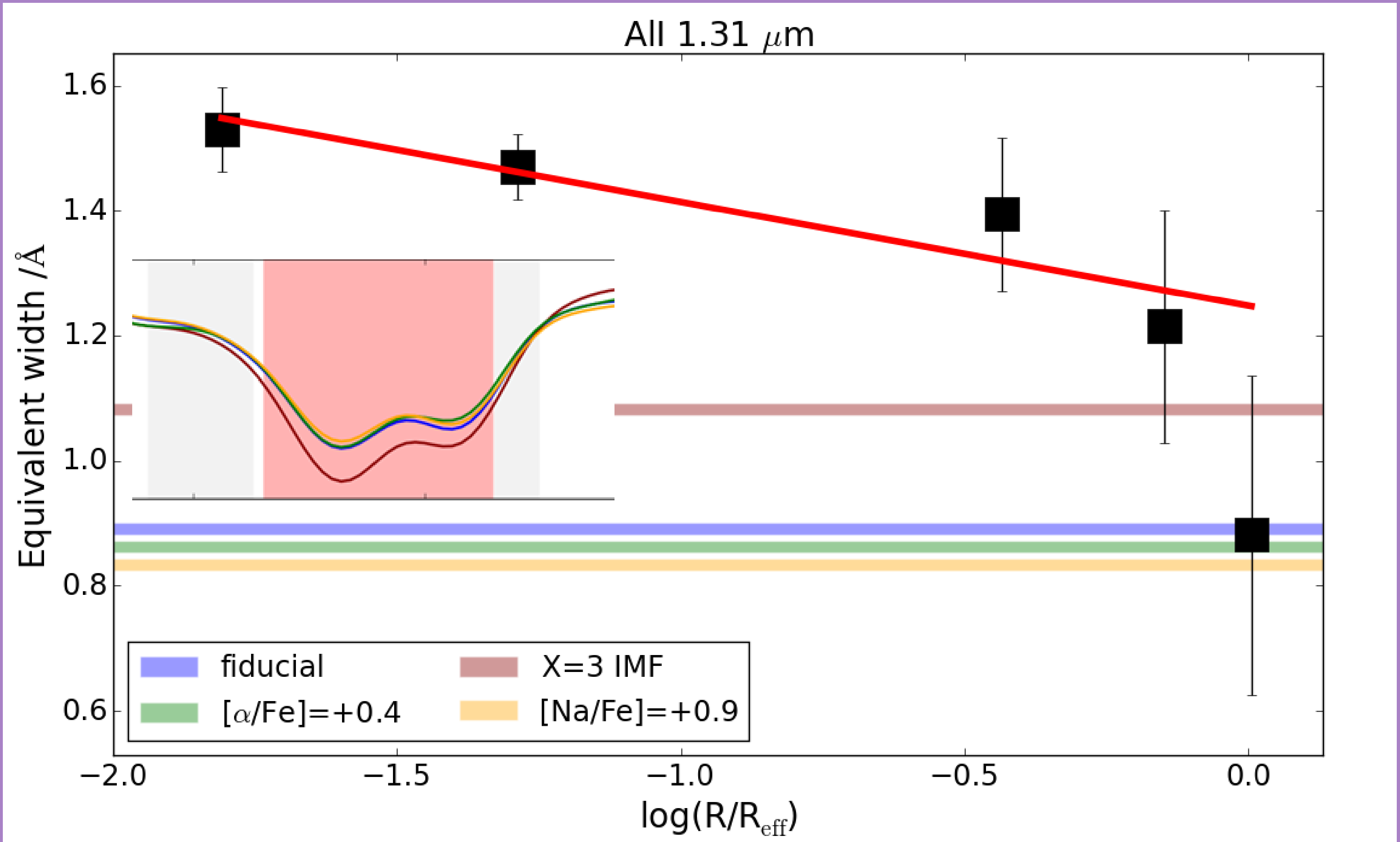
Radial trends



Radial trends



Radial trends



Interpretation of results

What can we do with this data? Goal is to reconstruct trends with radius in properties of underlying stellar population...

$$\frac{dI_i}{dx} = g_i = \frac{\partial I_i}{\partial P_1}\frac{\partial P_1}{\partial x} + \ldots + \frac{\partial I_i}{\partial P_n}\frac{\partial P_n}{\partial x}$$

(where I_i is the equivalent width of index i, x is e.g. $\log(R/R_{eff})$, and the P_j are the parameters of interest, e.g. IMF slope)

$$\underline{g_i} = \frac{\partial I_i}{\underline{\underline{\partial P_j}}} \cdot \frac{\partial P_j}{\underline{\partial x}}$$

... invert to recover ∂P_j terms.

Derived parameters

Some radial abundance trends ([Fe/H], [α/H], [Ca/α]) well constrained from optical spectra of ETGs: makes sense to impose these prior to fitting!

Allows us to constrain unknown parameters more tightly. Of chief interest here are the IMF and [Na/H] (unconstrained parameters which our features have good sensitivity to).

Results:

Change in f_{dwarf} = 0.004 ± 0.014 per dex
Change in [Na/H] = -0.41 ± 0.16 per dex

Summary

We looked for spatial variations in the stellar populations of 8 ETGs using KMOS data.

We recovered radial trends in the strengths of various IMF-sensitive absorption features.

Scenario in which the IMF does *not* vary radially favoured: trends in IMF sensitive feature strengths best explained by abundance gradients (including very steep sodium trend). Can't exclude modest changes in the IMF.

Question: is the IMF bottom-heavy throughout massive ETGs, or is it simply Milky-Way-like after all? Challenges either way!