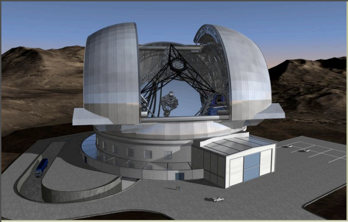
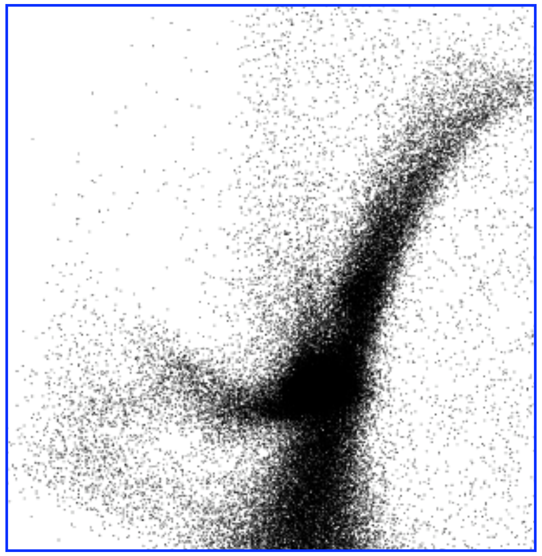
Unresolved and Nearly-Resolved Spectroscopy

Russell Smith
(Durham)

1. Unresolved spectroscopy
2. Some recent results
3. E-ELT ideas
4. Nearly-resolved spectroscopy



Integrated stellar populations

$\int$  $=$

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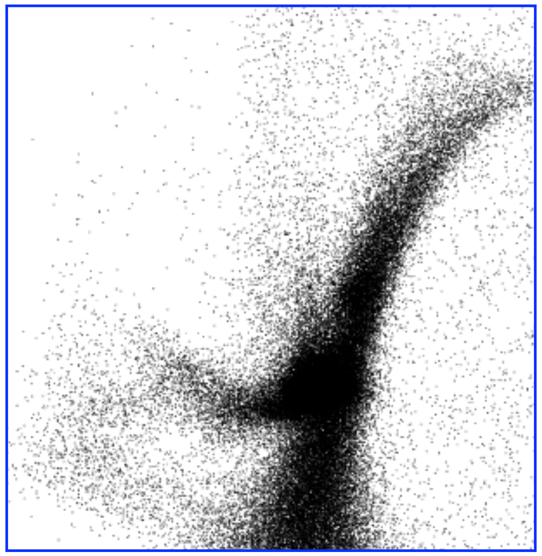
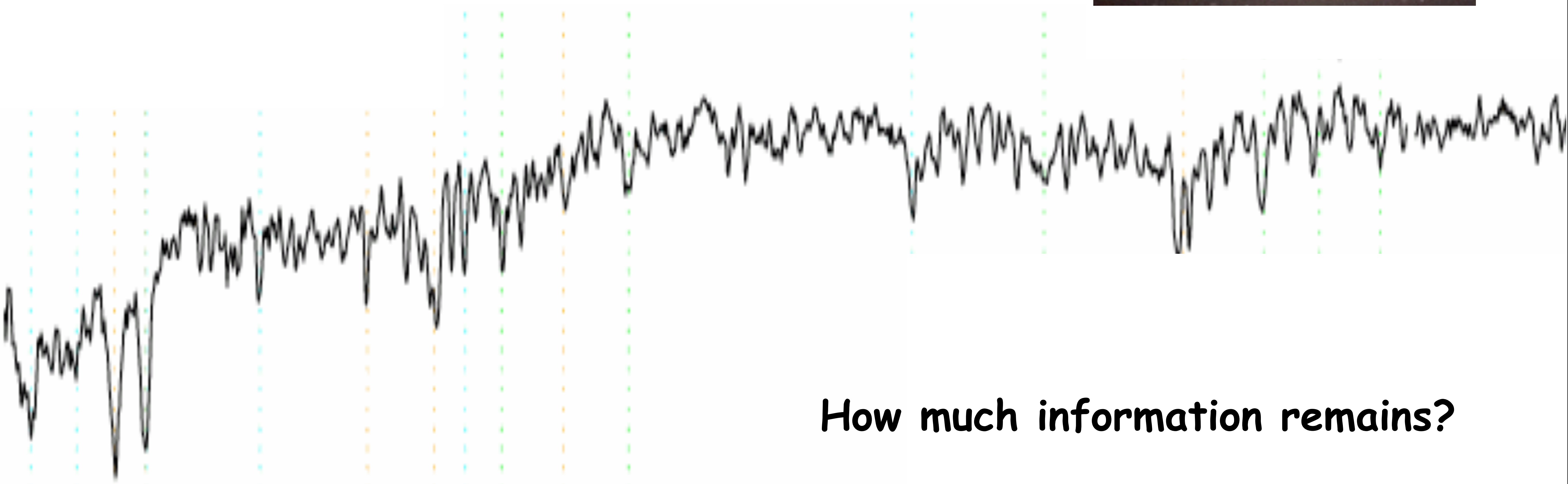
$$\int$$  $=$ 



How much information remains?

Integrated stellar populations

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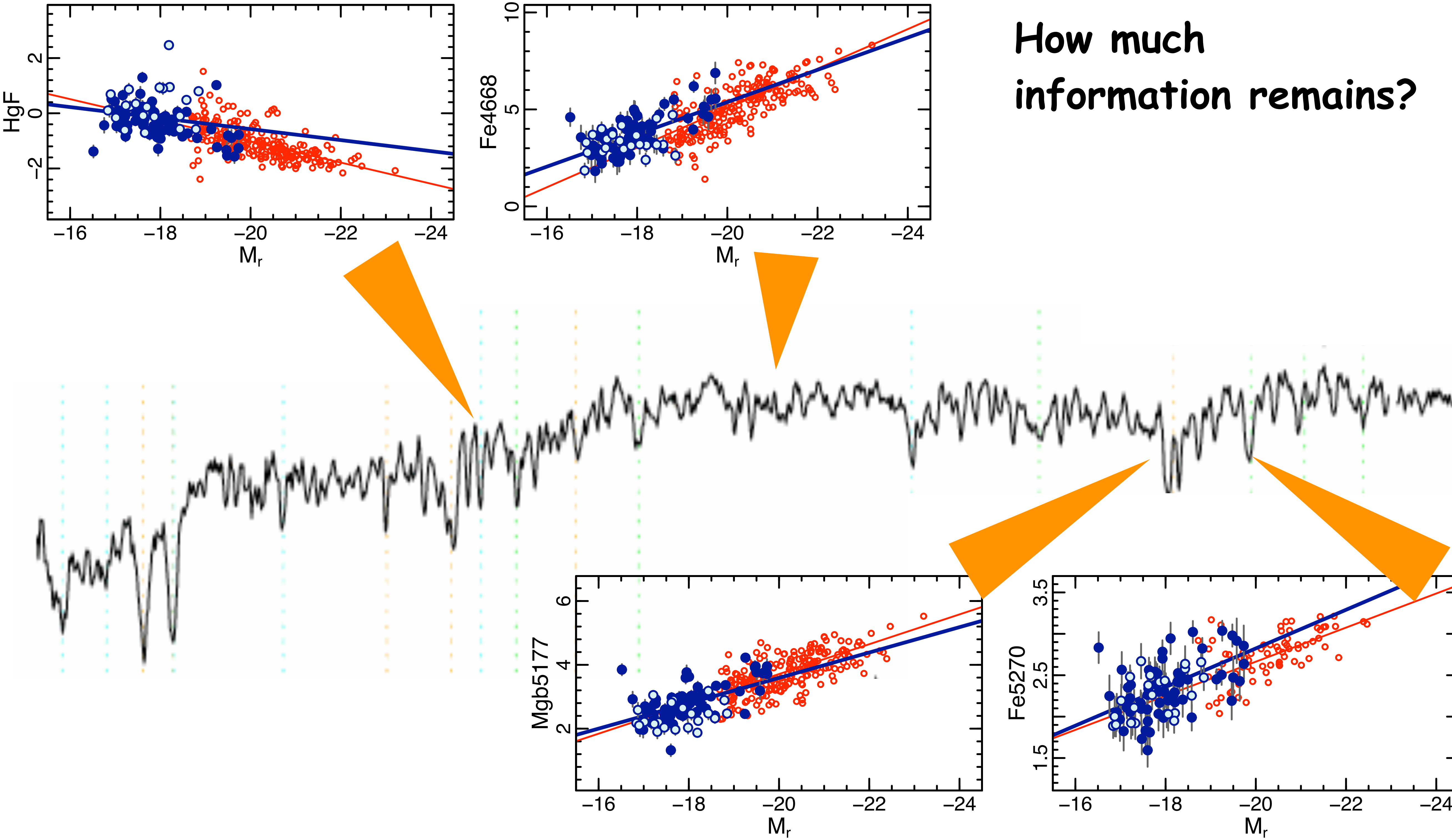
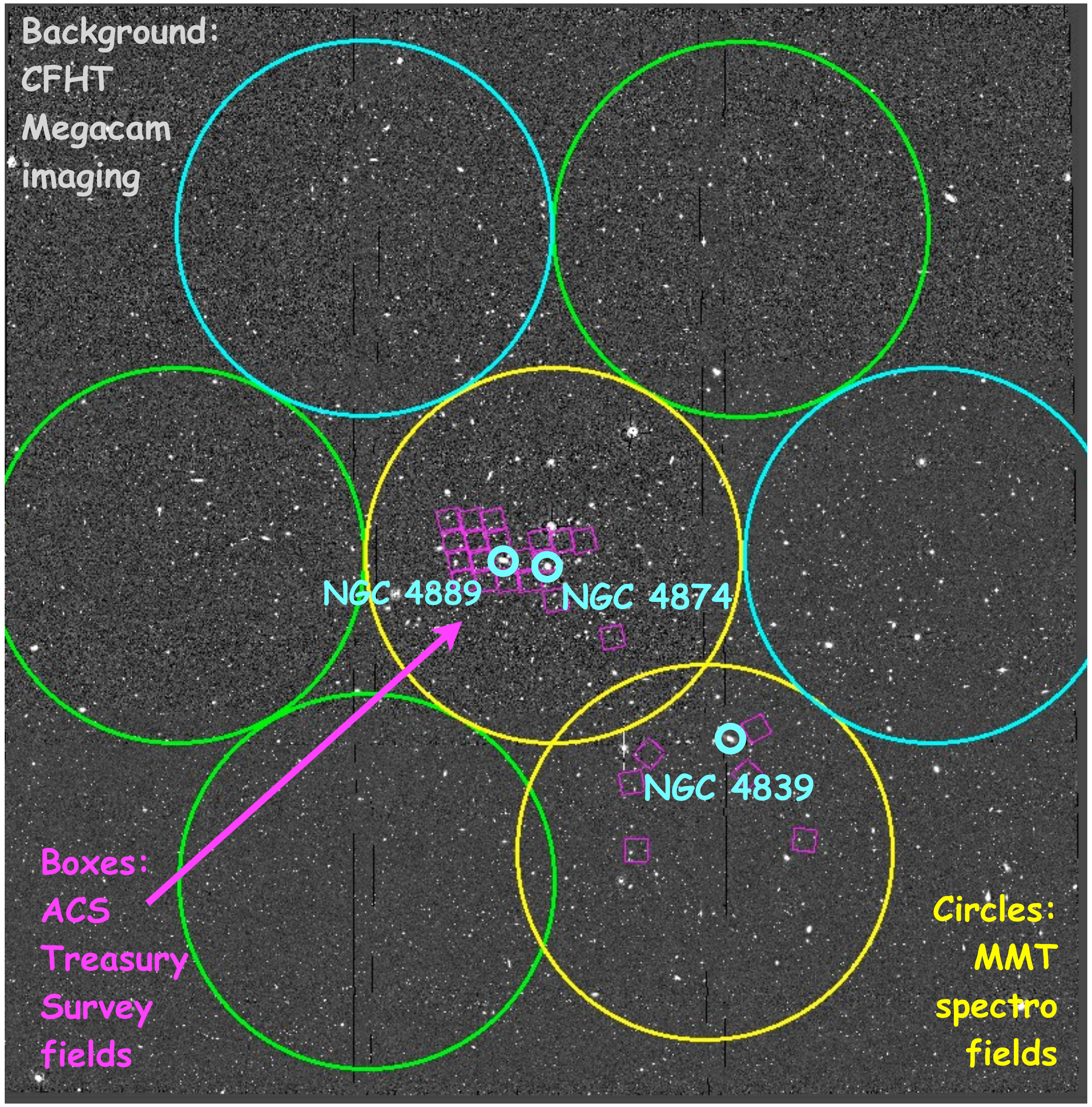
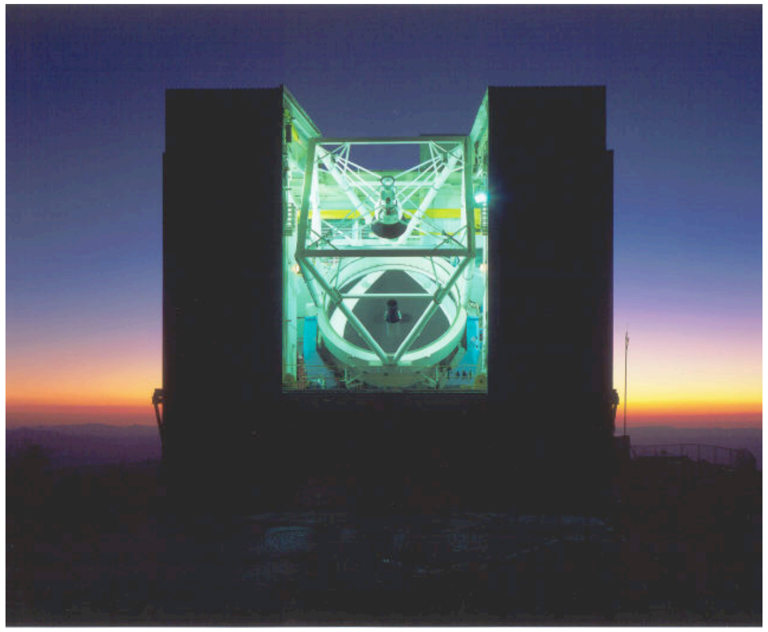


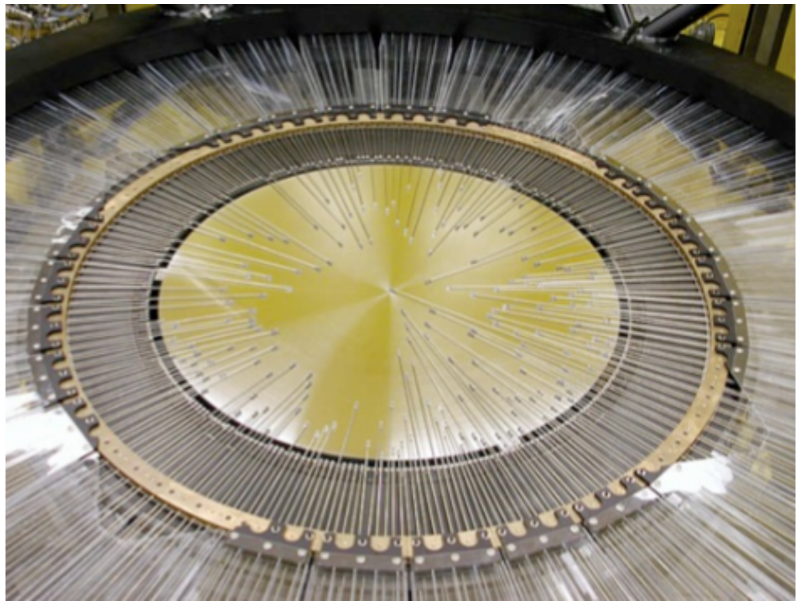
The Coma 3-degree Survey



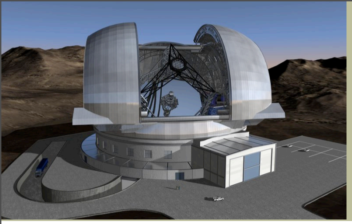
3 deg = 5 Mpc @ Coma



A mere 6.5m telescope...



...but with 300 fibres and a one degree field



Unresolved stellar populations

Stellar population parameters

* Extract by comparison to **single-burst** models e.g. from Schiavon (2007)

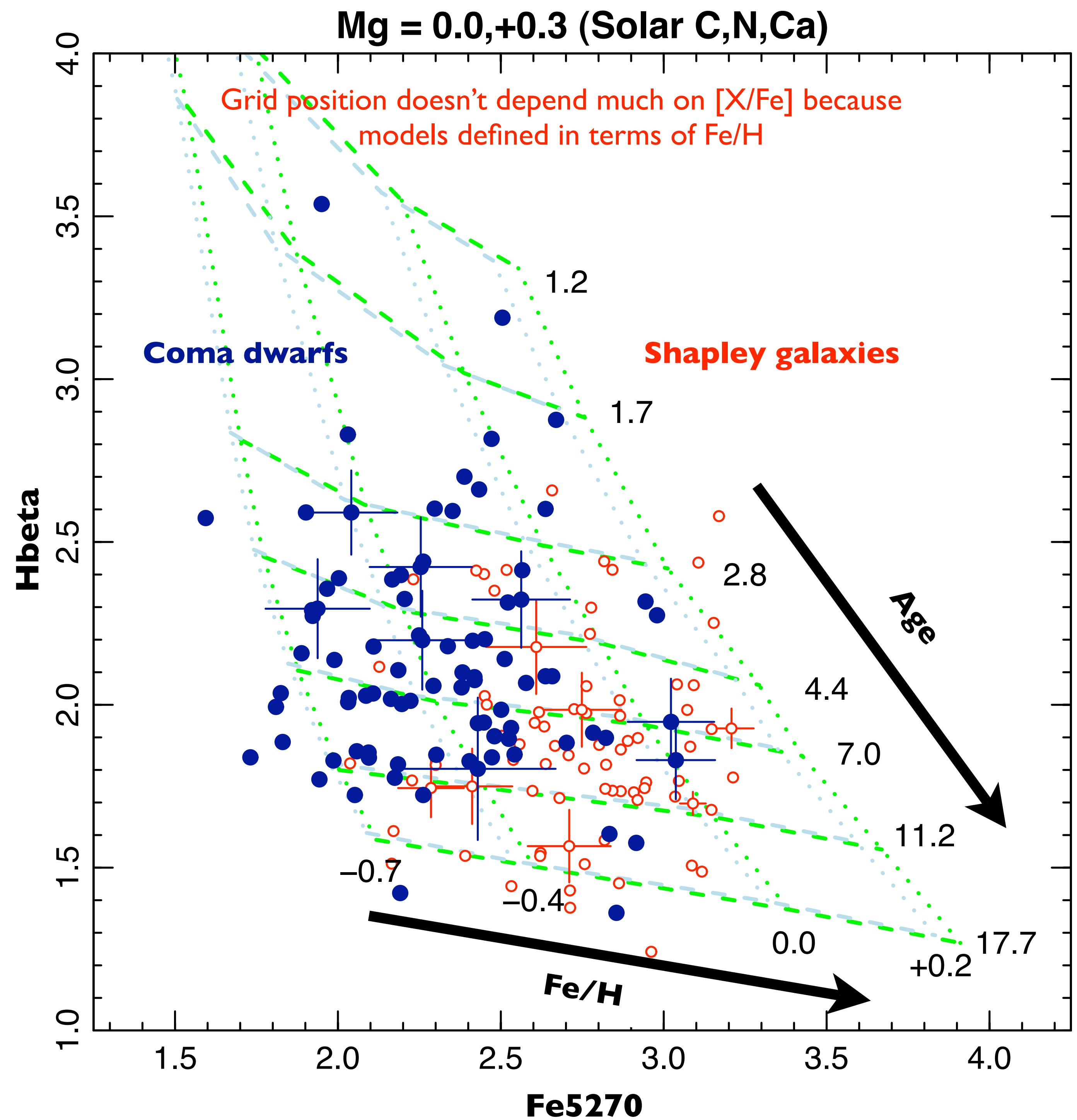
* Age, Fe/H from Balmer vs metal-line grids.

* Abundances of Mg, C, N, Ca from Mgb5177, C4668, CN_2, Ca4227

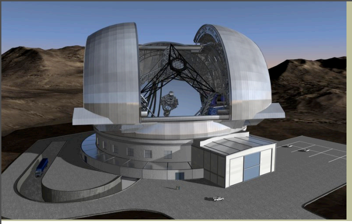
For Coma dwarfs:

*Wide range of SSP-equivalent ages, 1.5 Gyr up to >10 Gyr.

*Typical Fe abundances 0.2-0.5x solar.



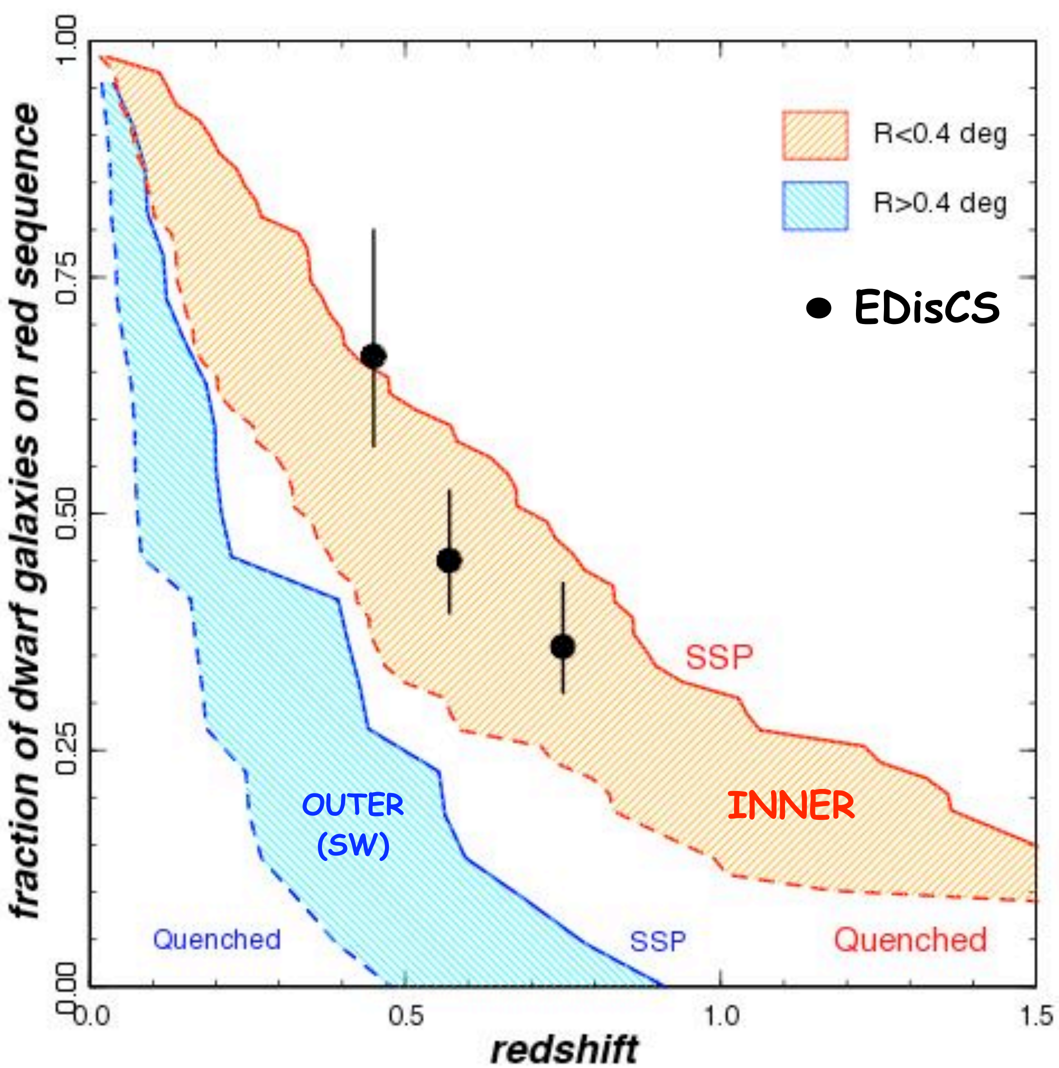
RJS et al. 2009a, MNRAS, 392, 1265



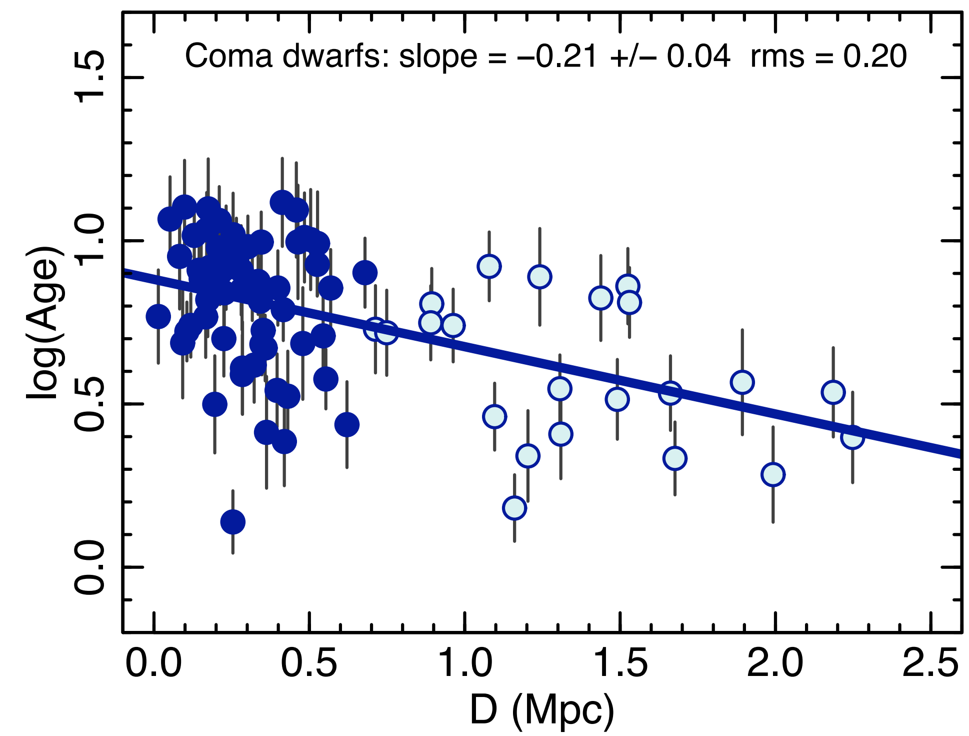
Selection of recent results

(aka shameless plugging of my recent papers)

Coma dwarfs (~M*+3) from first phase of the MMT/Hectospec programme



Ages in cluster core imply faint red-sequence galaxies have doubled in number since z~0.6: Consistent with red-sequence LF in EDisCS clusters

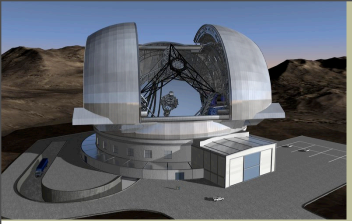


Beyond cluster core most dwarfs ~3 Gyr SSP-equivalent ages

Implies quenching at z<0.2

(But this is in the south-west where a subcluster merger is occuring)

RJS et al. 2009a, MNRAS, 392, 1265



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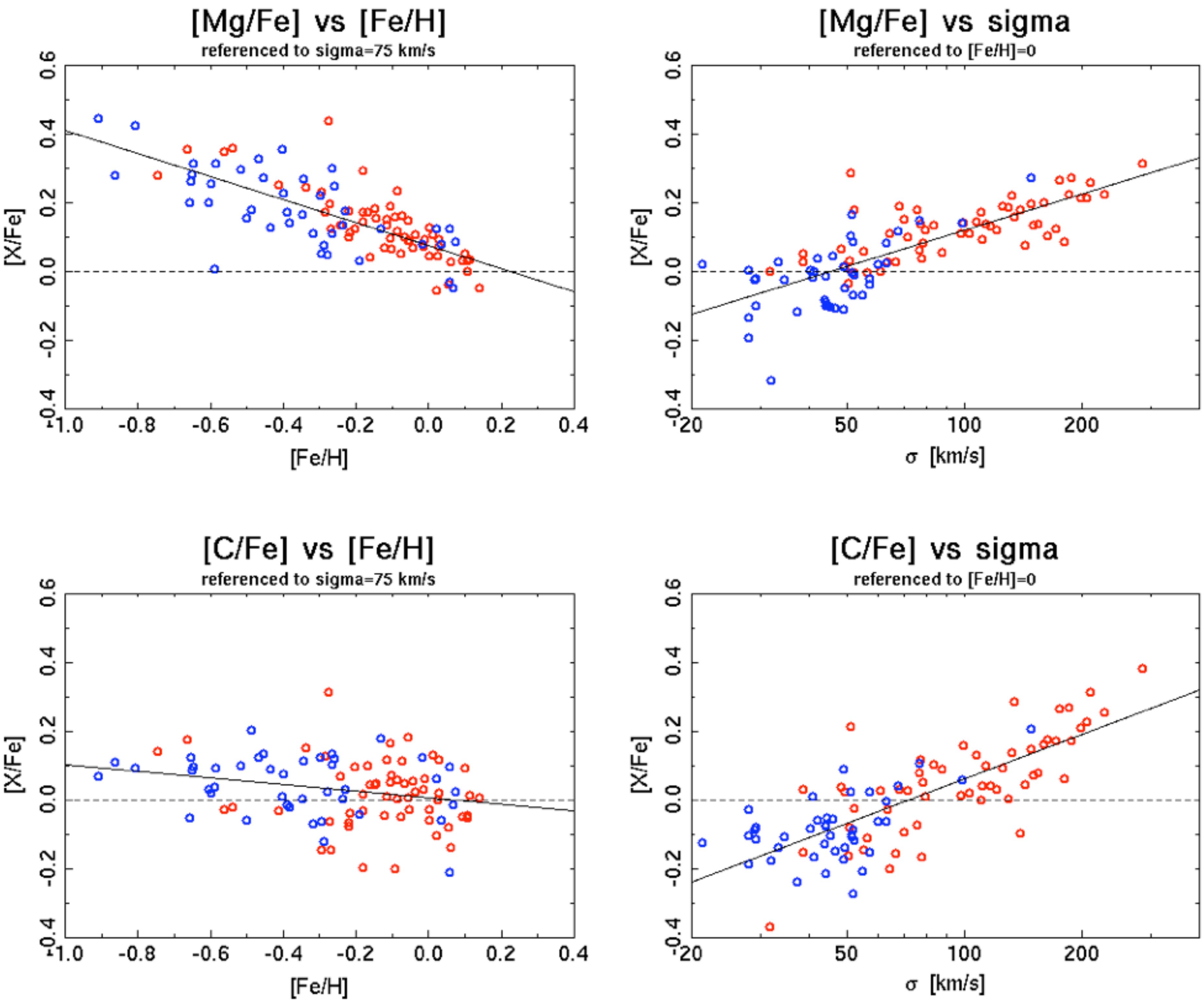
New abundance ratio correlations for Mg,Ca,C,N

Puzzling results suggest:

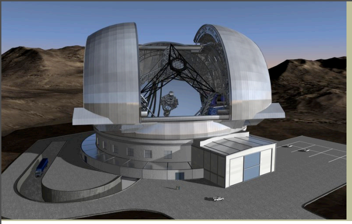
* C,N enrichment dominated by low/ intermediate-mass stars (same range as for Fe)

* Mg/Fe - sigma relation is **not** a reflection of SF time-scale vs sigma.

(Alternatively need fine tuning to explain flat C/Fe vs Fe/H?)



see RJS et al. 2009b, MNRAS, 398, 119



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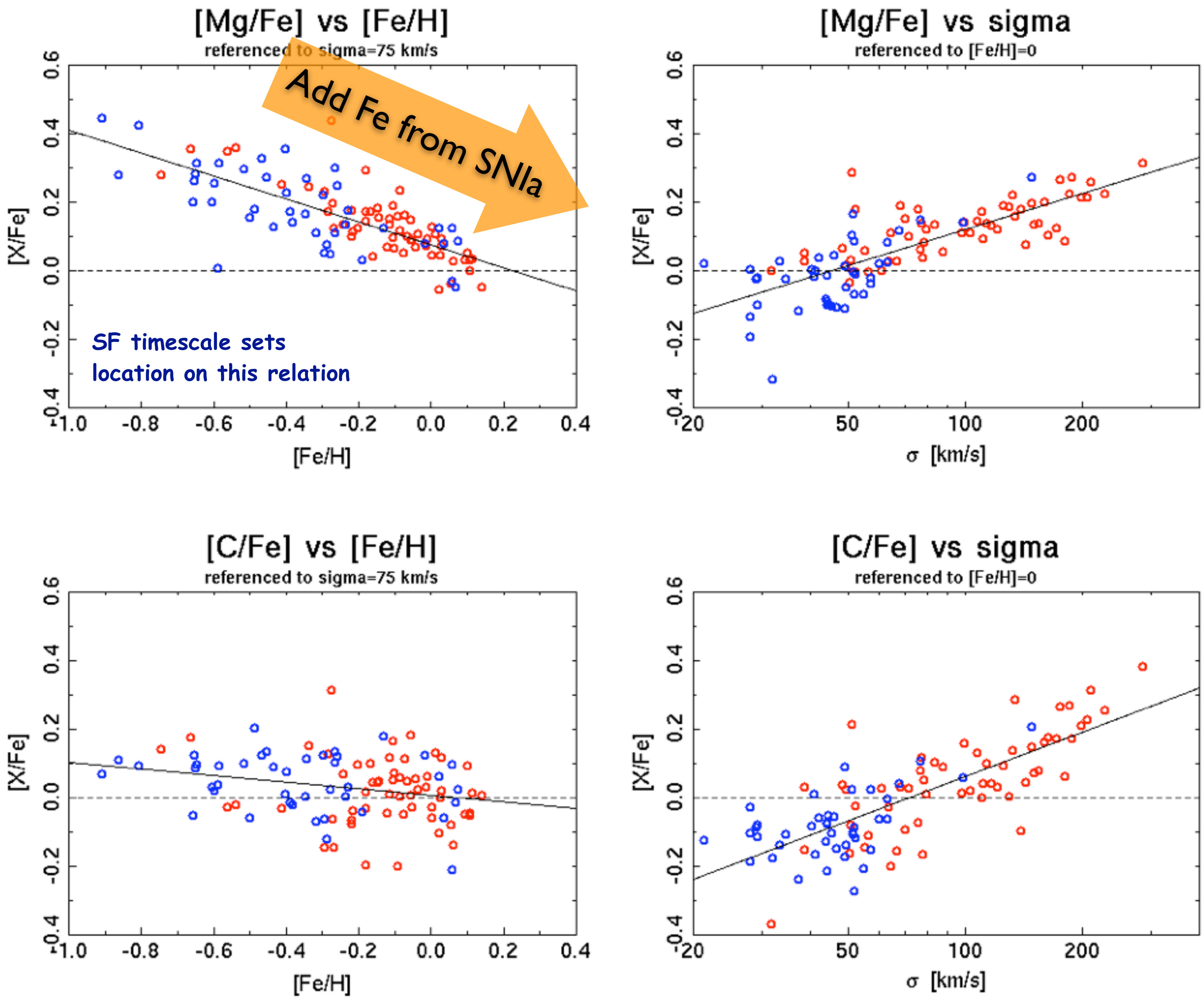

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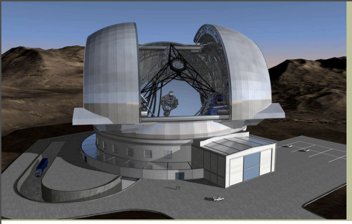

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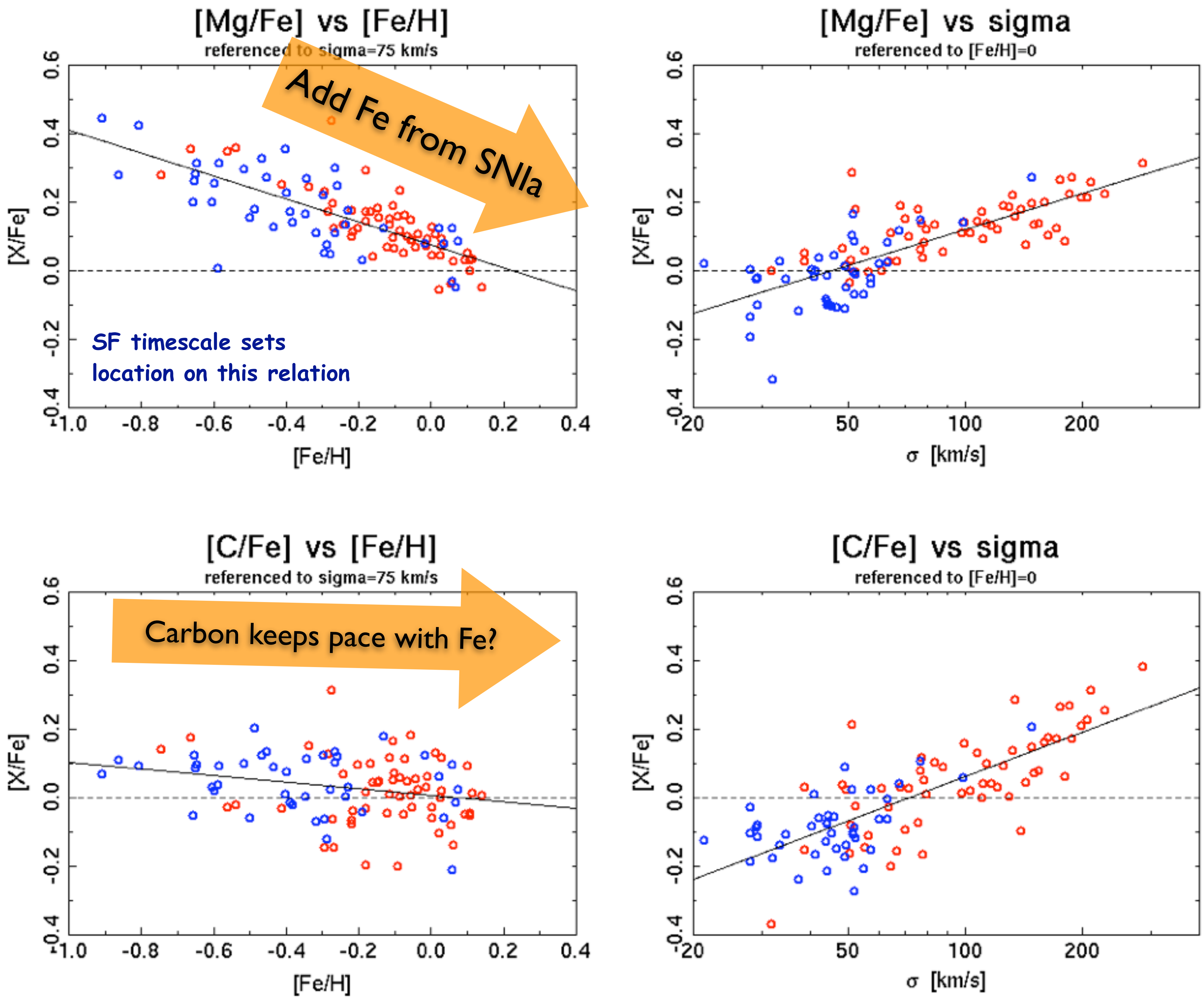

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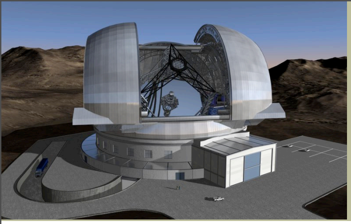

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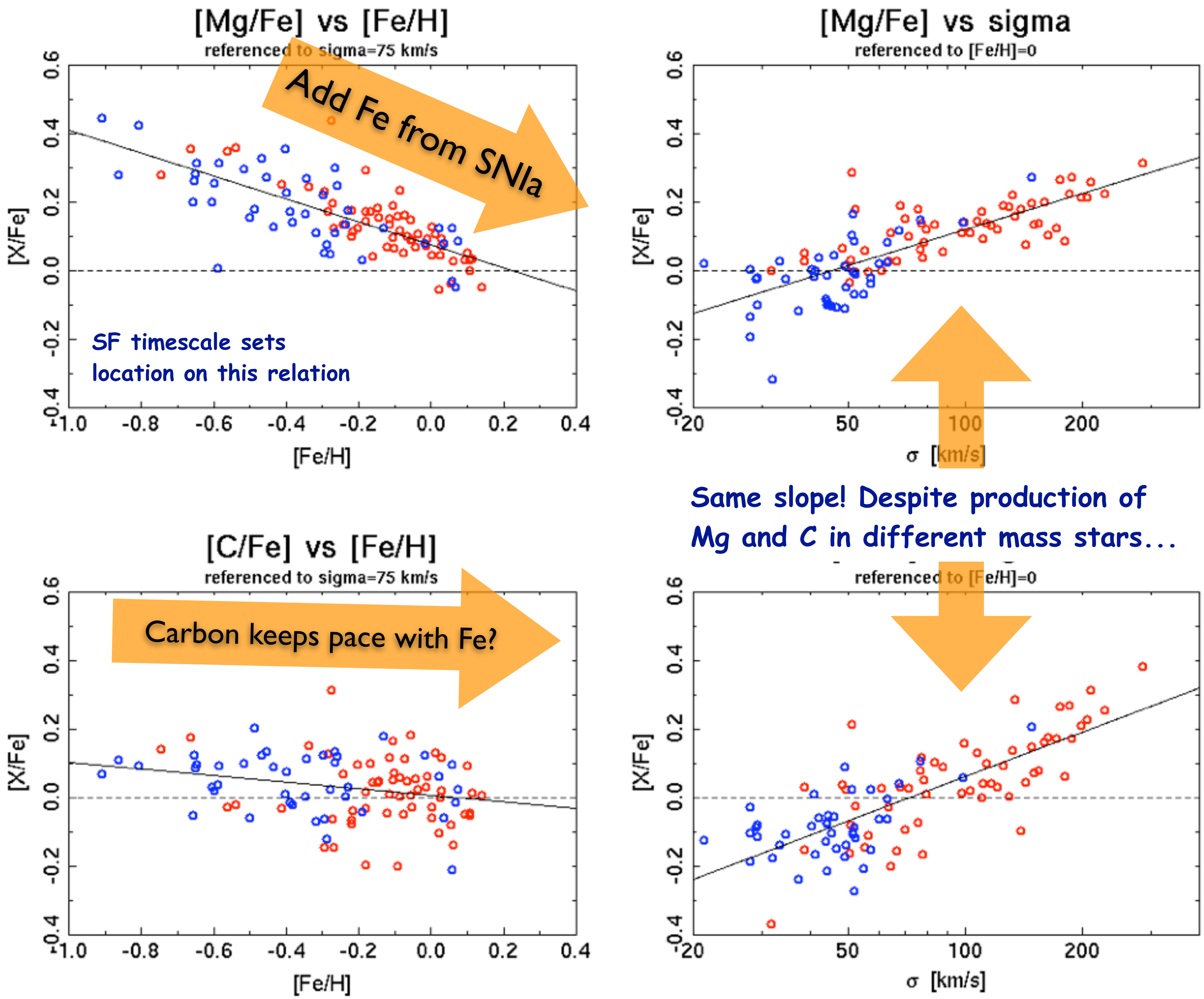

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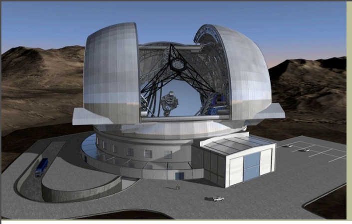


Where to go with E-ELT?

Repeat all the usual analyses at z~1?

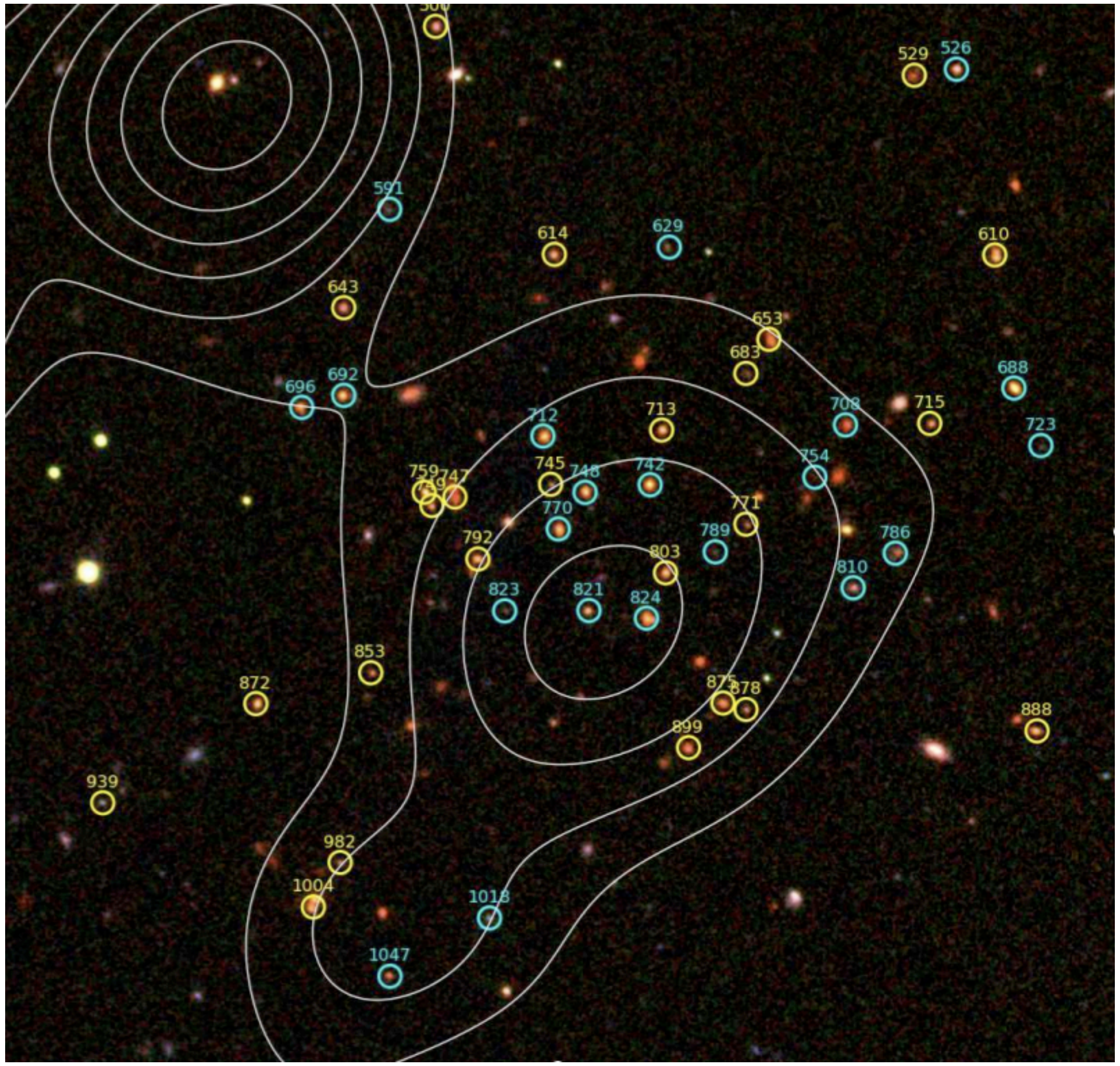
* Probe formation epoch of the giant ellipticals (z~2-3) using the red galaxies in place at z~1.

* Exploit best-calibrated low-resolution spectral features (Hbeta, Mgb, Fe5270, etc) at z ~ 1.

* Lick-type analysis has good sensitivity in relavant age range (1-4 Gyr).

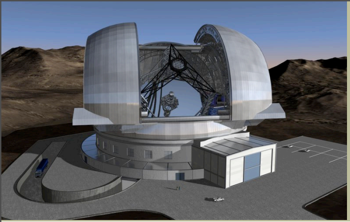
* IR MOS on large telescopes

* May be do-able, at a push, with KMOS, certainly feasible with E-ELT/ EAGLE



XCS2215 @ z = 1.46

Hilton et al. 2007



Where to go with E-ELT?

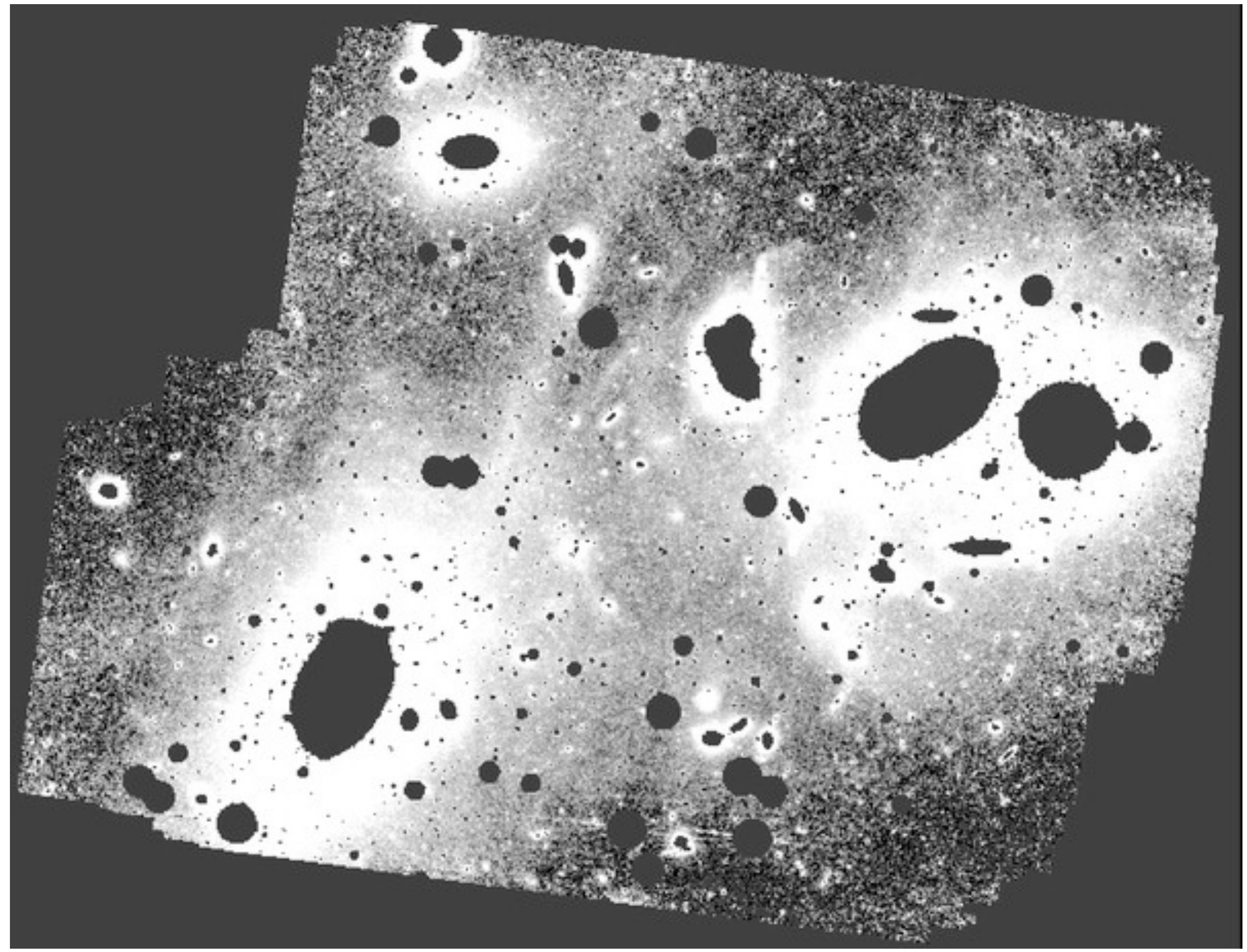
Repeat all the usual analyses for even fainter, lower SB objects?

* faint dwarf galaxies

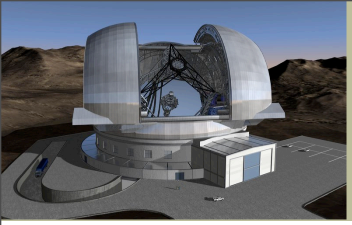
* outermost parts of galaxies

* cD halos

* Intra-cluster streams/ debris?

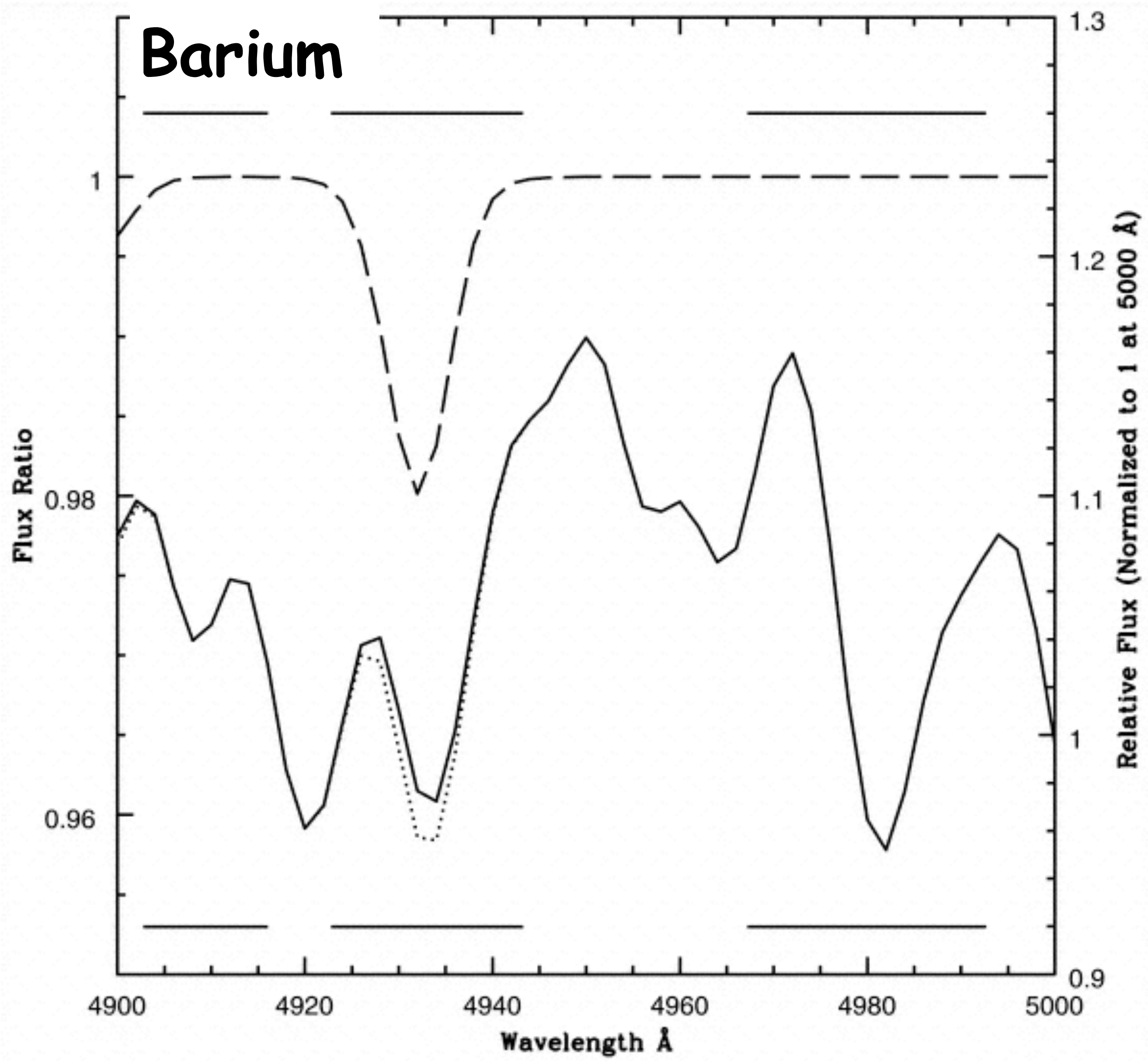


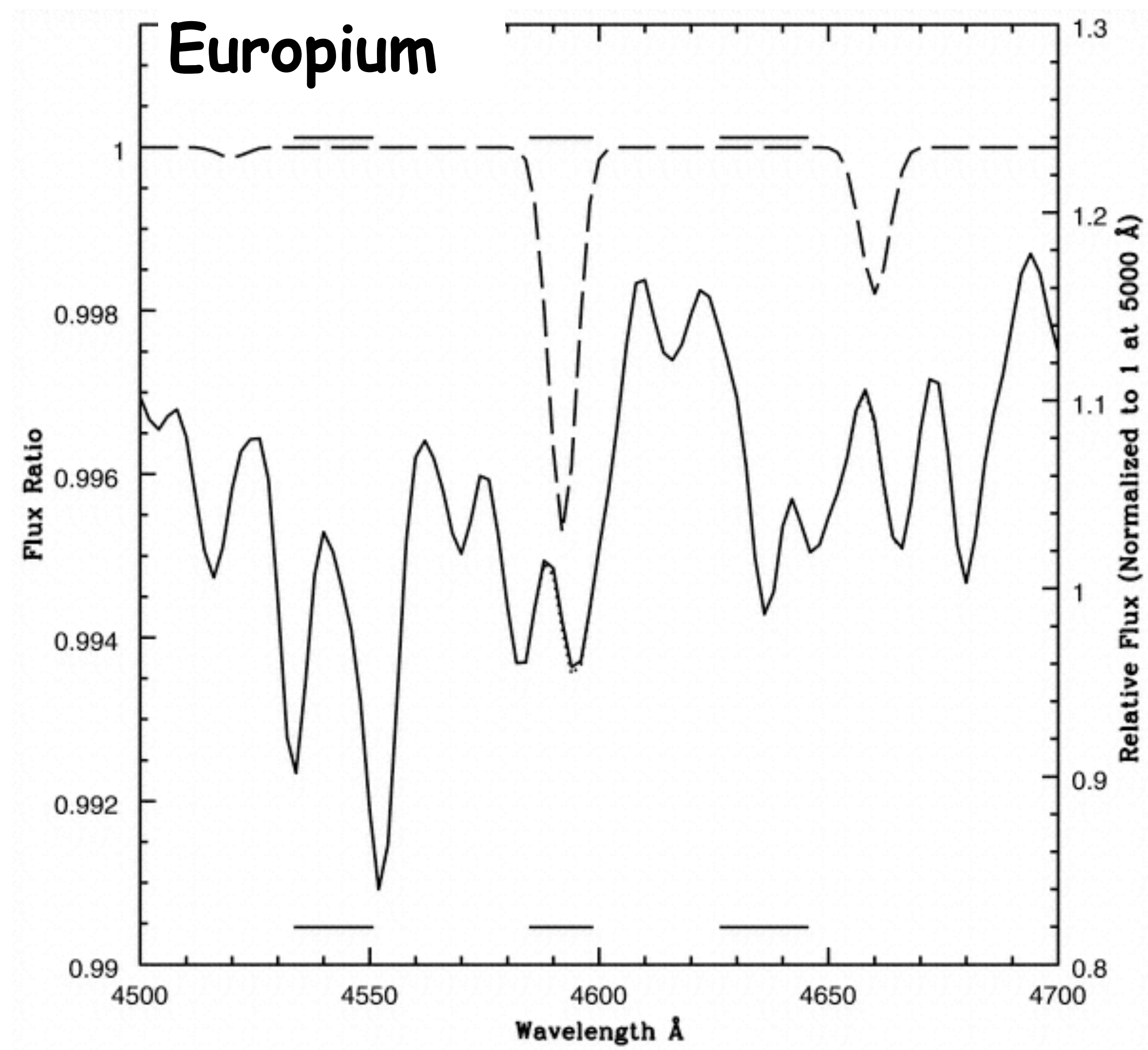
Virgo intra-cluster light: Mihos et al. 2005



Where to go with E-ELT?

Go to extremely high S/N, to extract detailed abundance patterns?

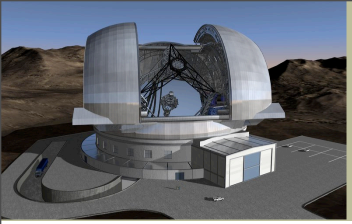




Serven & Worthey 2005

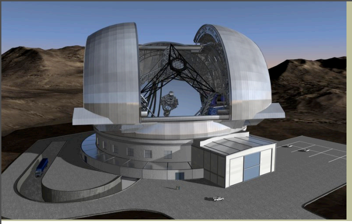
What are the most promising low-res indicators in NIR?
(cores of ellipticals limit us to R~500-1000!)

Where to go with E-ELT?



$$42^2 \gg 8^2$$

Worth considering some more radical ideas!



Warnings

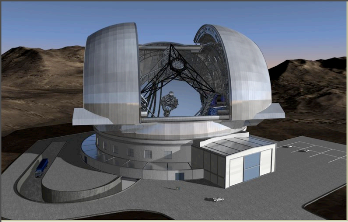
* What I'm about to show you is only a half-baked idea...

* The experiments I'll show are
  - simplistic and probably unreasonable
  - not well tuned to the E-ELT spectral range / resolution

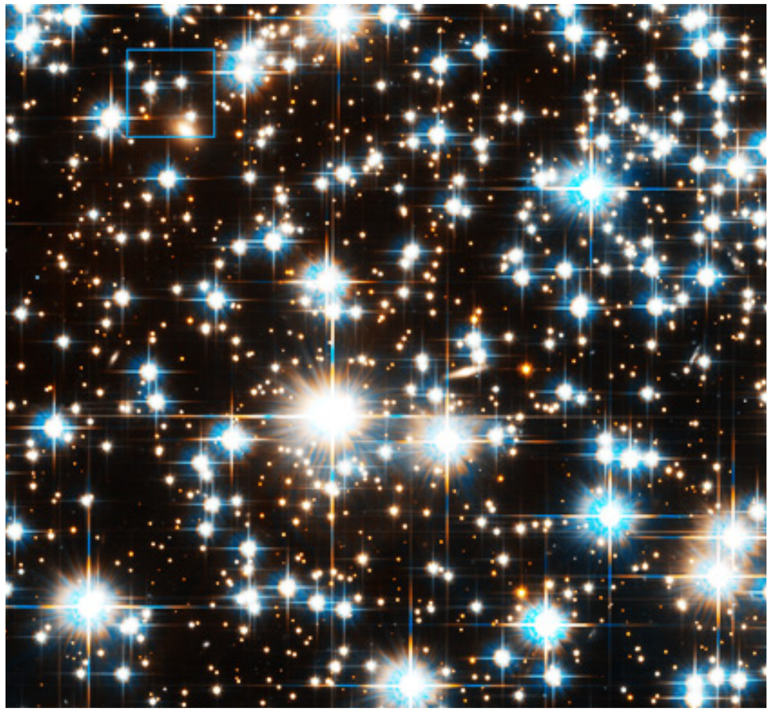
* The whole thing might not work.

* Or it might not tell us anything new.

* Intention is simply to get you thinking...



An intermediate regime?



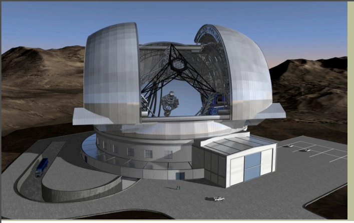
?

Resolved case:

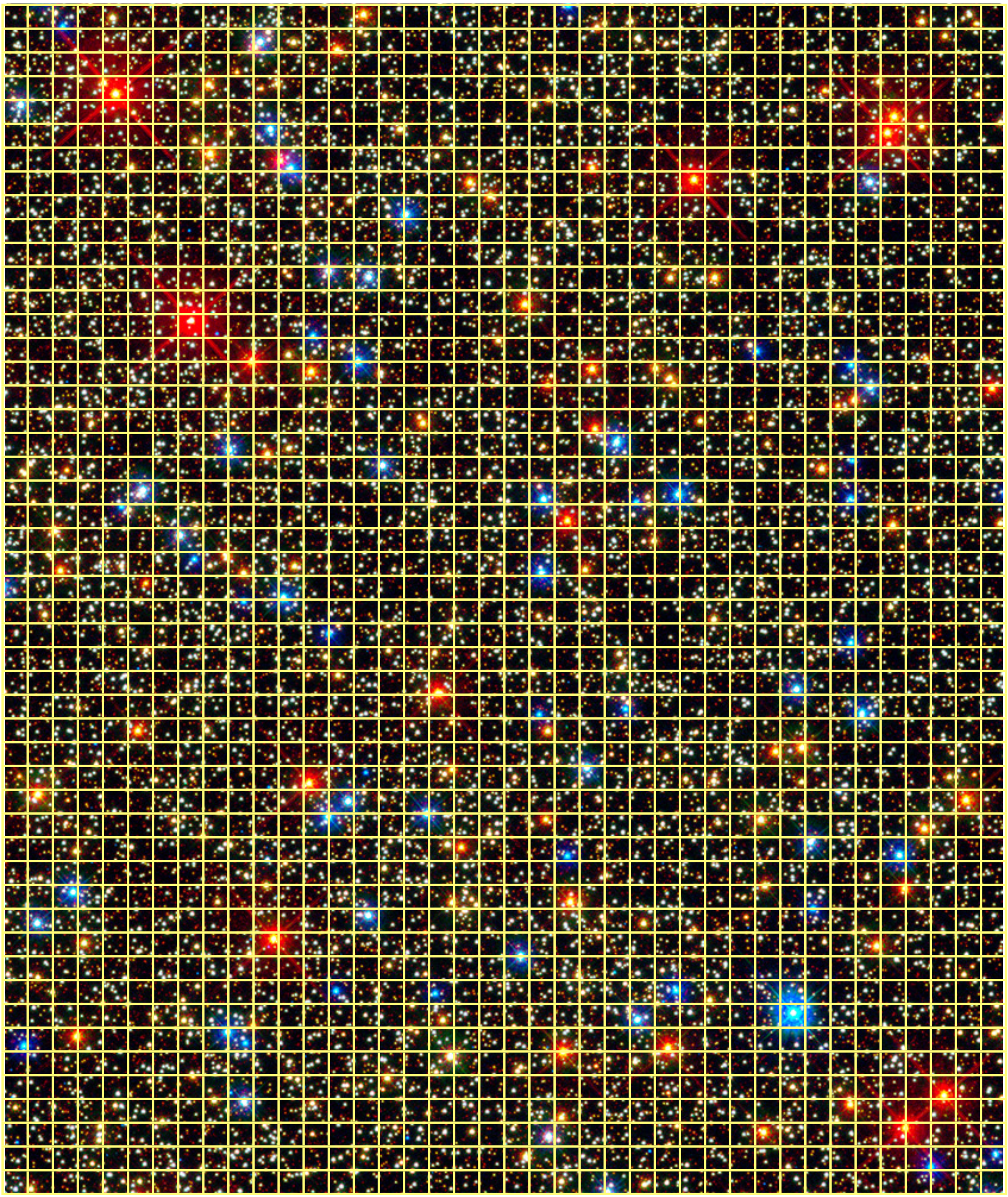
Individual stars - Metallicity distribution - Chemical tagging - Applicable to few galaxies (even with ELT) - Limited to outer regions

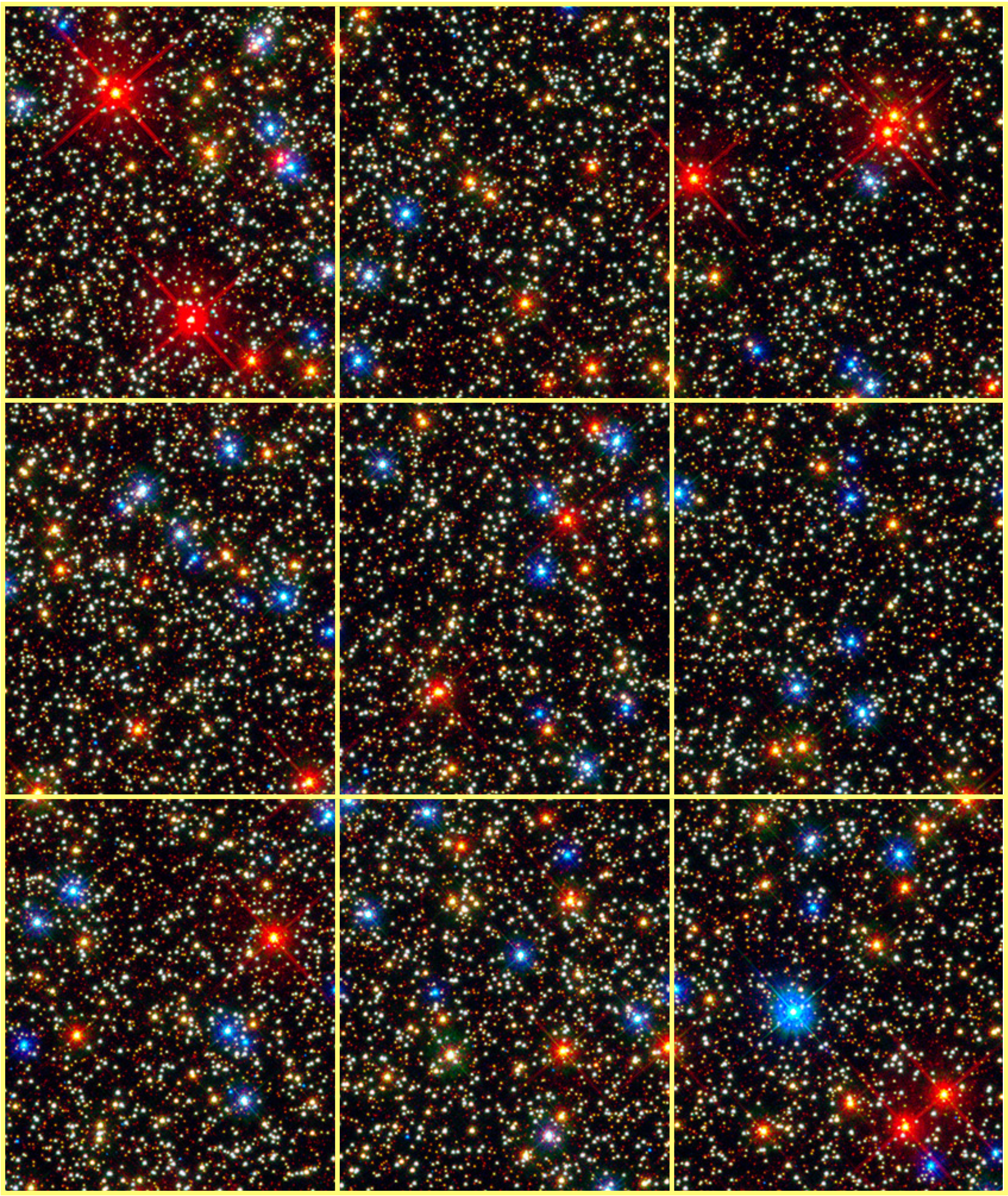
Unresolved case:

Many galaxies within range, even to cosmological distances - only average properties over all stellar generations



Nearly-resolved spectroscopy





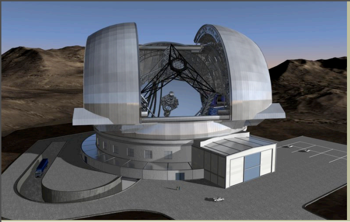
Resolved spectroscopy:

Each bright star dominates its spatial element

Nearly-resolved spectroscopy:

Single stars don't dominate any element

Large poisson fluctuations in bright stars per element



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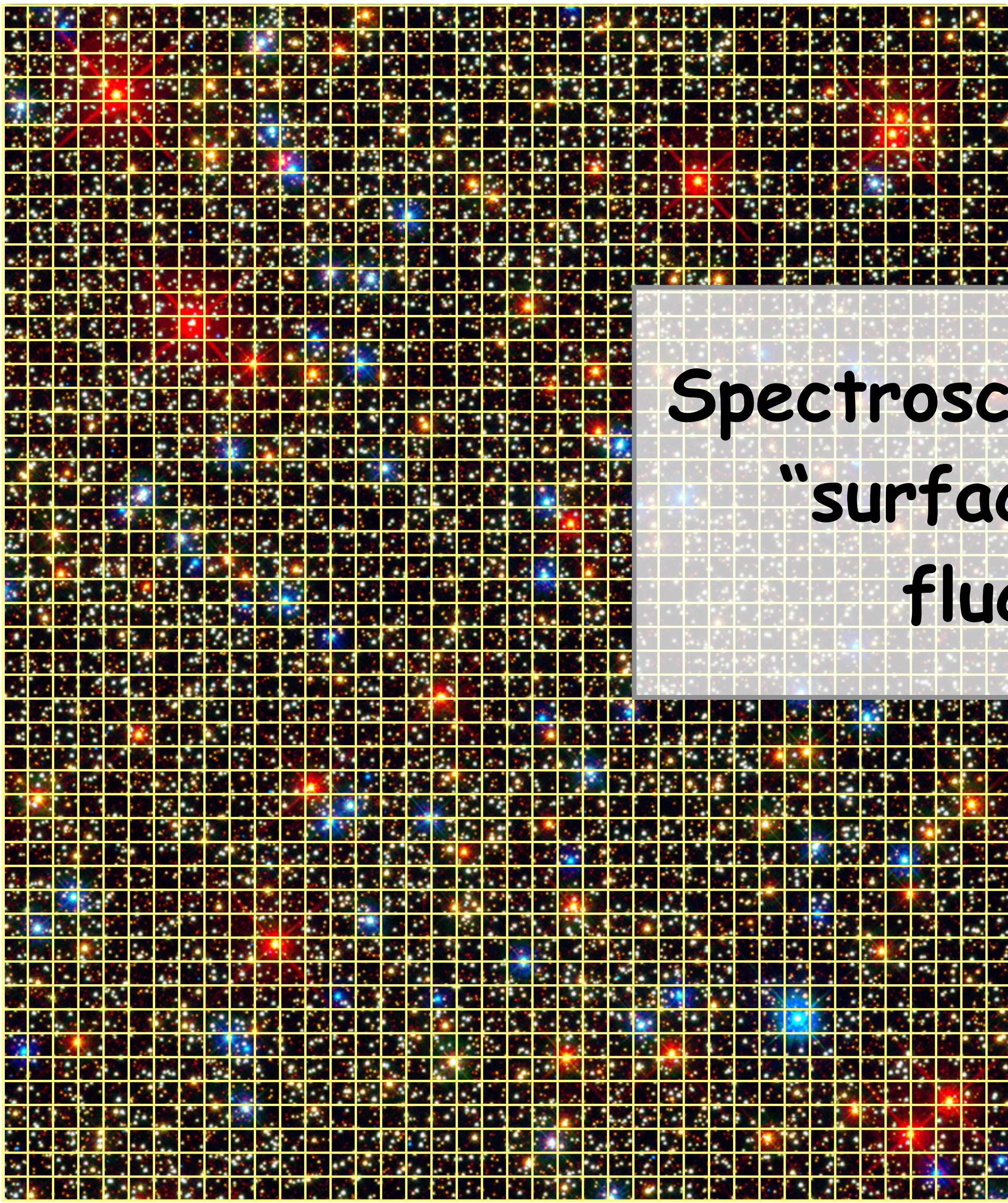
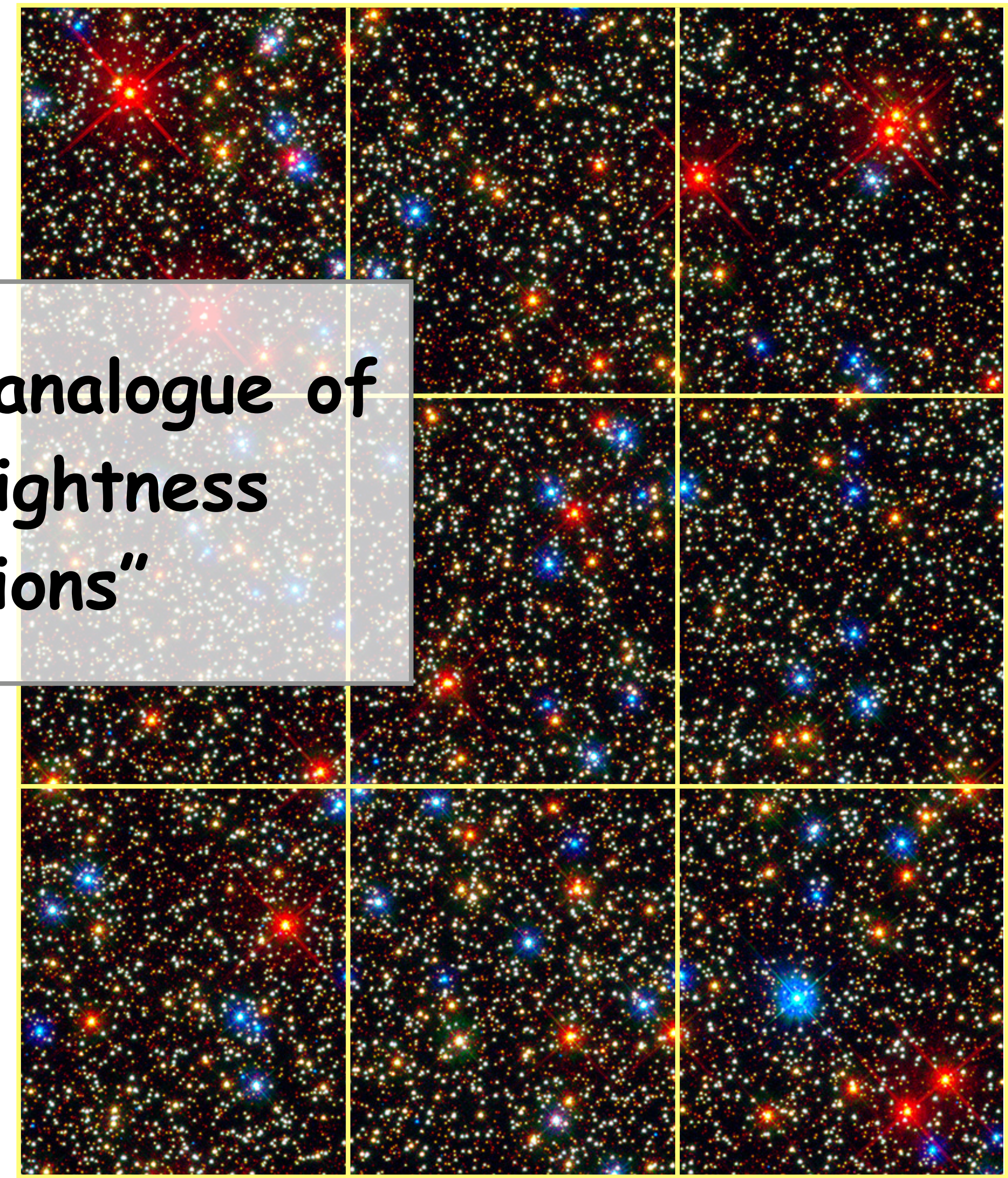




Spectroscopic analogue of "surface brightness fluctuations"

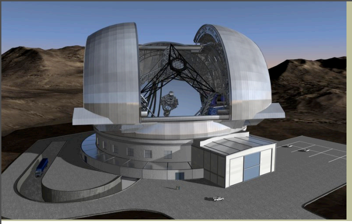
Resolved spectroscopy:

Each bright star dominates its spatial element

Nearly-resolved spectroscopy:

Single stars don't dominate any element

Large poisson fluctuations in bright stars per element

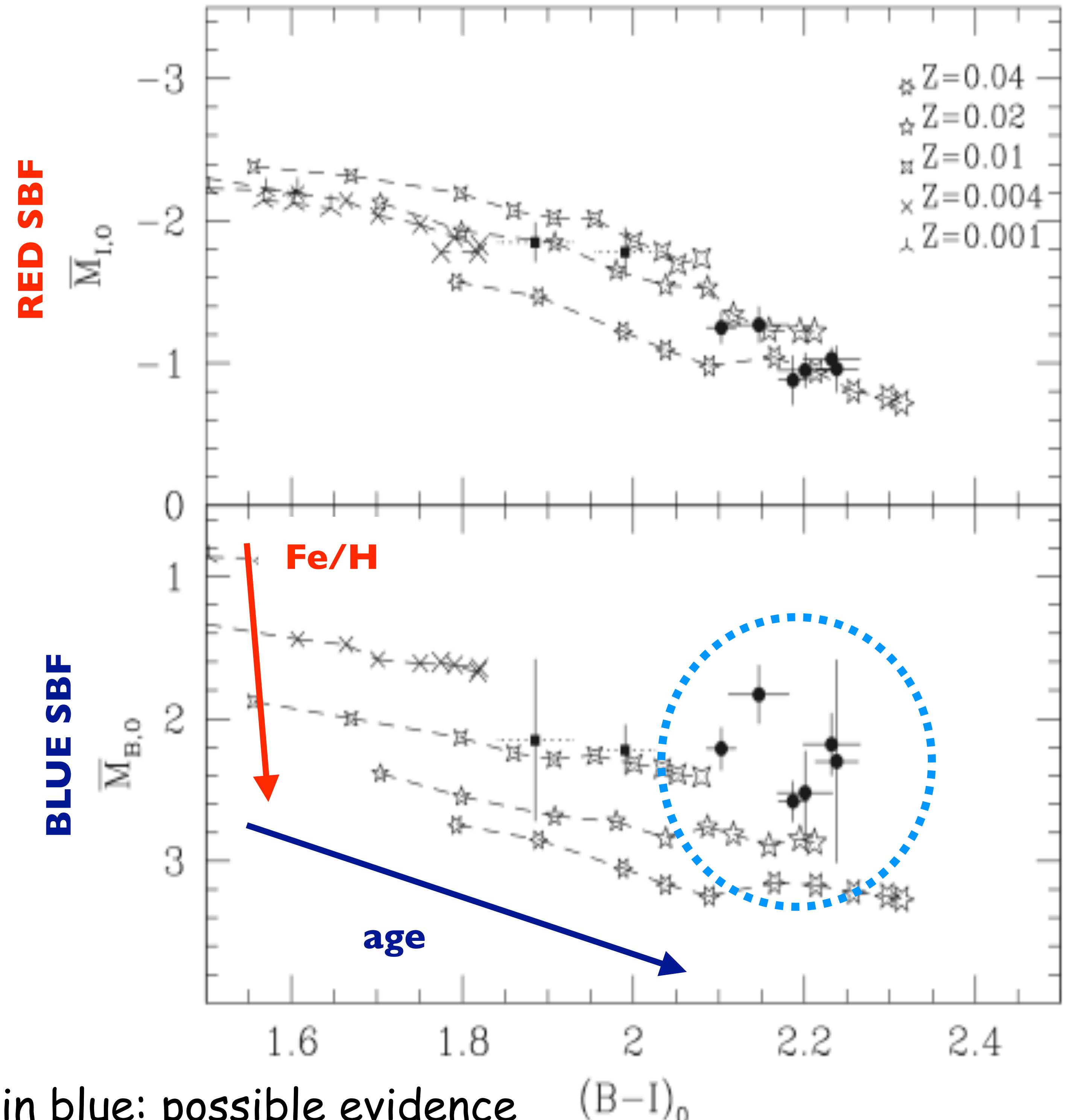


Why?

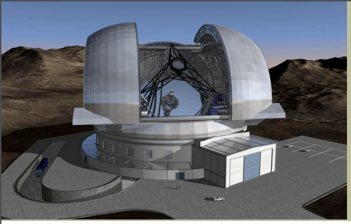
Extra information not recoverable from "normal" integrated spectroscopy.

Constrain **luminosity** of brightest stars in unresolved population: e.g. distinguish Blue HB stars vs MSTO.

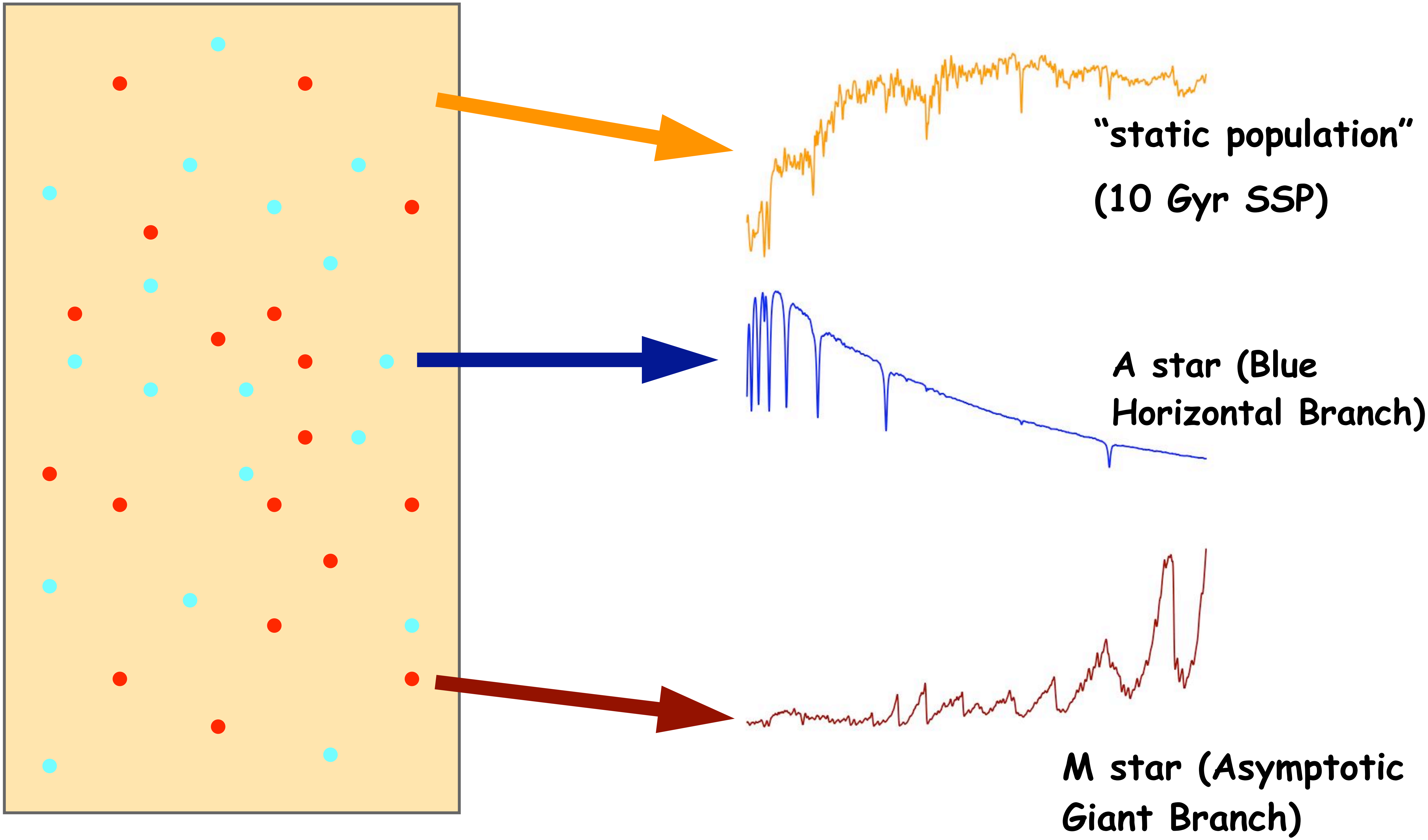
(or multiple MSTO -> age distribution?)

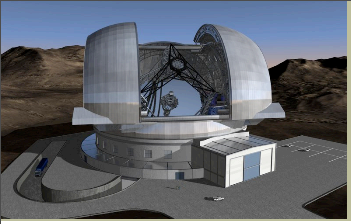


Excess SBF signal in blue: possible evidence for BHB stars. (Cantiello et al. 2007)



A toy galaxy


“static population”
(10 Gyr SSP)
A star (Blue Horizontal Branch)
M star (Asymptotic Giant Branch)



Nearly-resolved spectroscopy

BHB fluctuations example

Base galaxy is 10 Gyr solar-metallicity SSP from Vazdekis et al. 2009 (from MILES library)

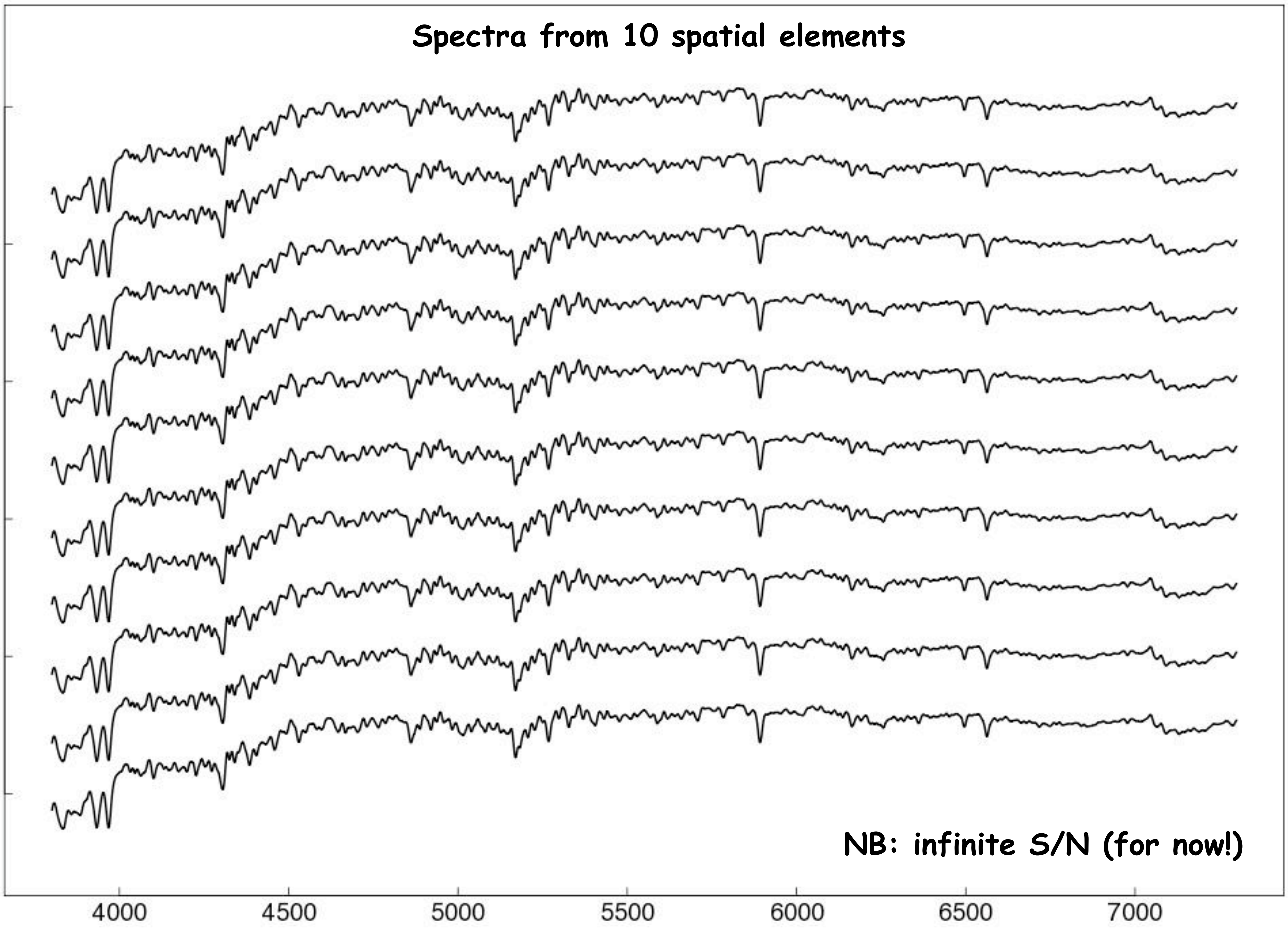
Add 5% of flux in Blue HB stars.

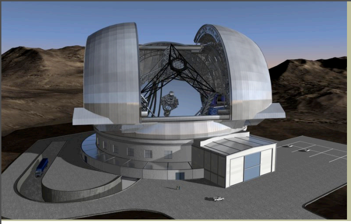
Average of 10 BHBs per spatial resolution element (arbitrary for now)

-> poisson fluctuations of 30%

Simulate spectra for each spatial element of the IFU...

Nearly-resolved spectroscopy

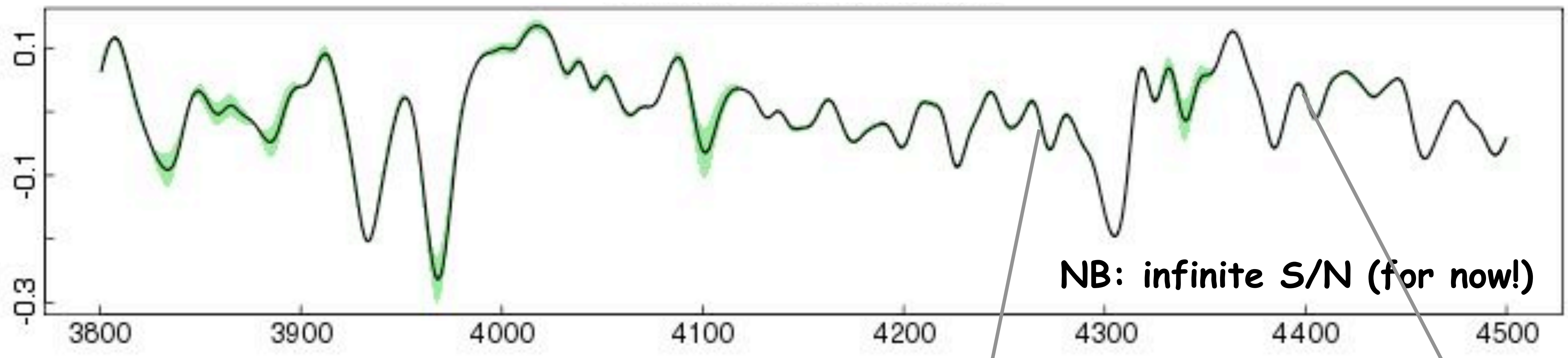




Nearly-resolved spectroscopy

Black line: mean spectrum

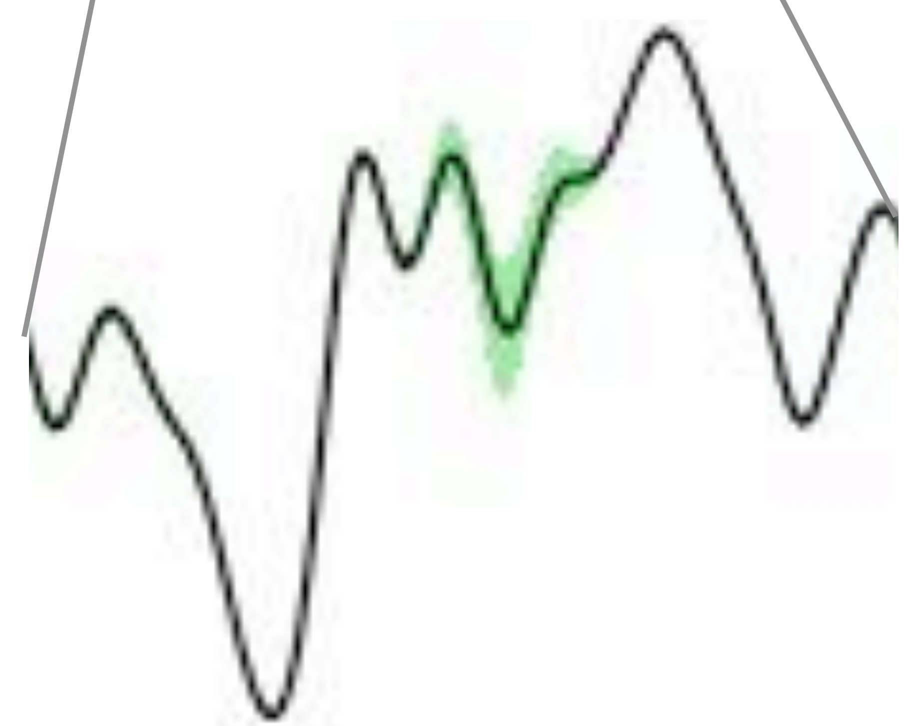
Green range: 3σ range among spatial elements



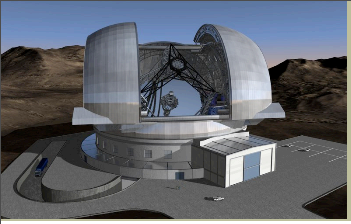
If fluctuations are from a single type of star, trivial correlation structure:

Spatial resolution elements with more than average BHB have stronger than average Hβ **and** stronger than average Hγ **and** Hδ **and** ...

Given a set of continuum-subtracted spectra from different elements, can recover this structure with PCA (or similar techniques)...

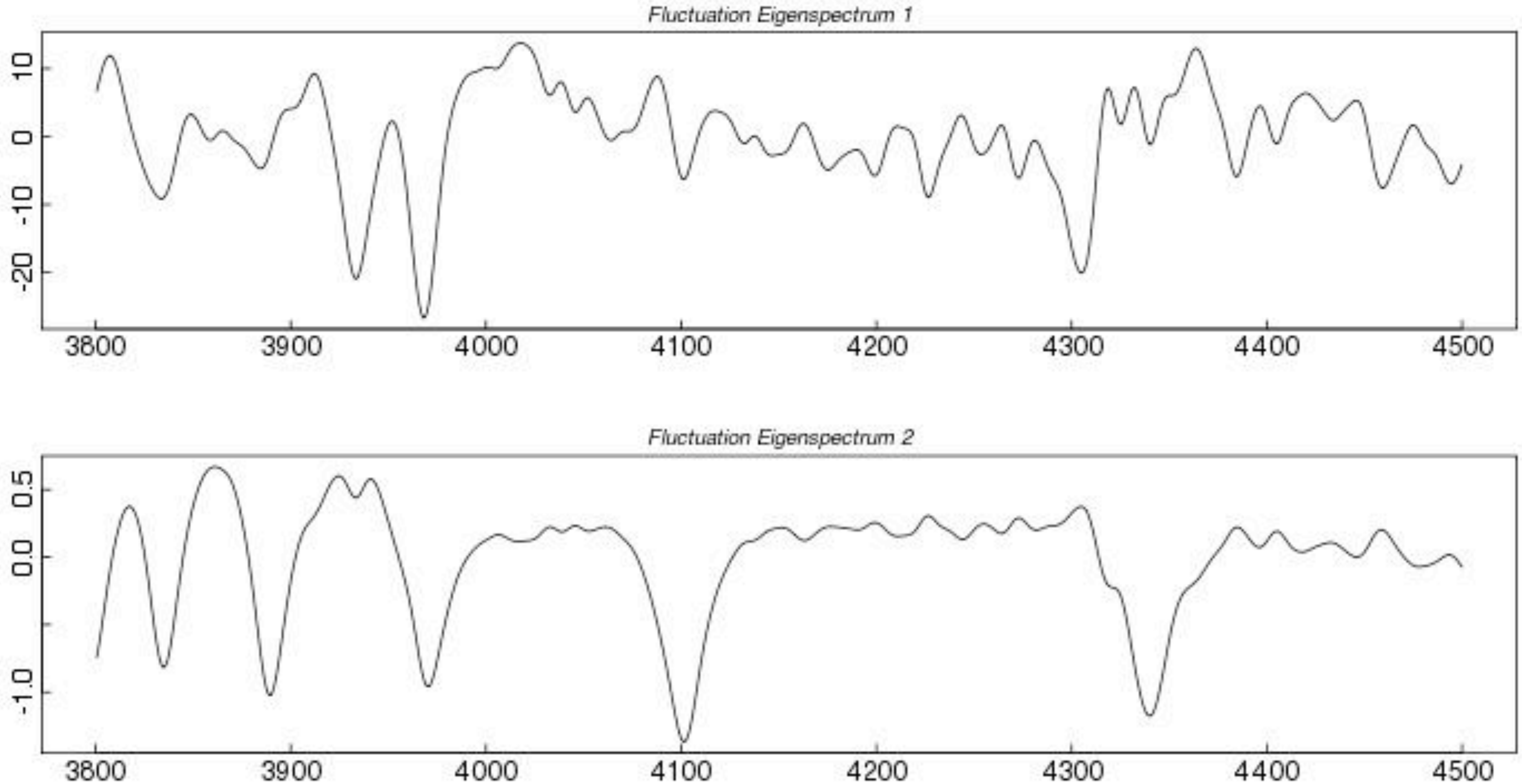


Fluctuations in total spectrum are concentrated at the Balmer lines

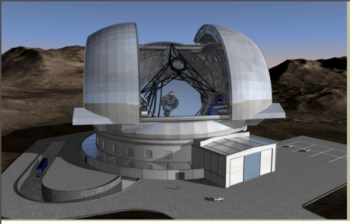


Nearly-resolved spectroscopy

First two fluctuation eigenspectra:



Recovery of BHB signal from fluctuations



Nearly-resolved spectroscopy

Population as before:

Static + 5% flux in BHB (<n>=10 per element)

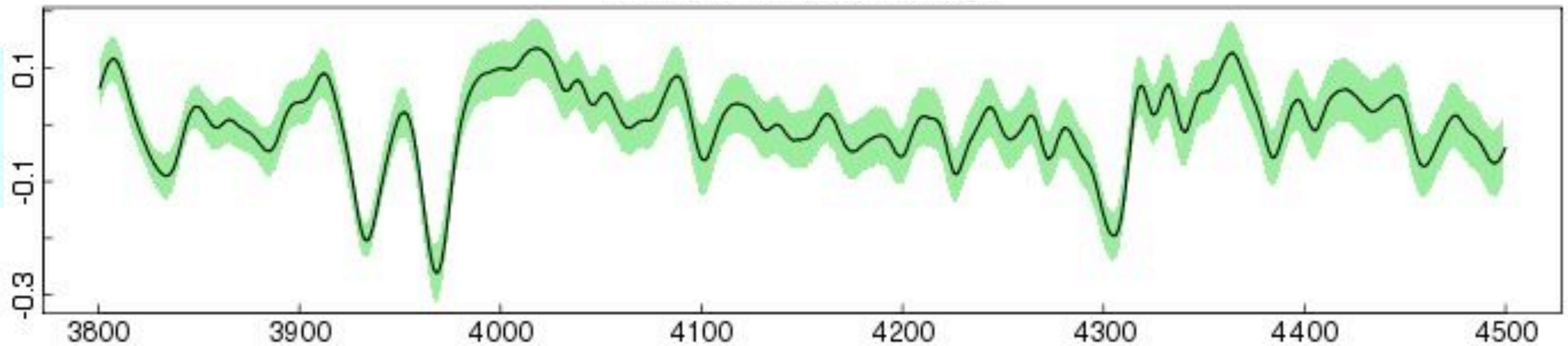
But now add noise:

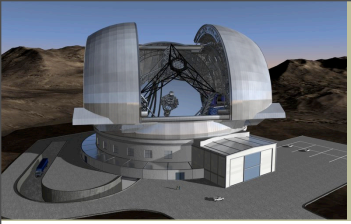
S/N=50 per Ang,

1000 spatial elements

Now **most** of the fluctuations are uncorrelated between spectral pixels.

Mean spectrum and fluctuation range





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Static + 5% flux in BHB (<n>=10 per element)

But now add noise:

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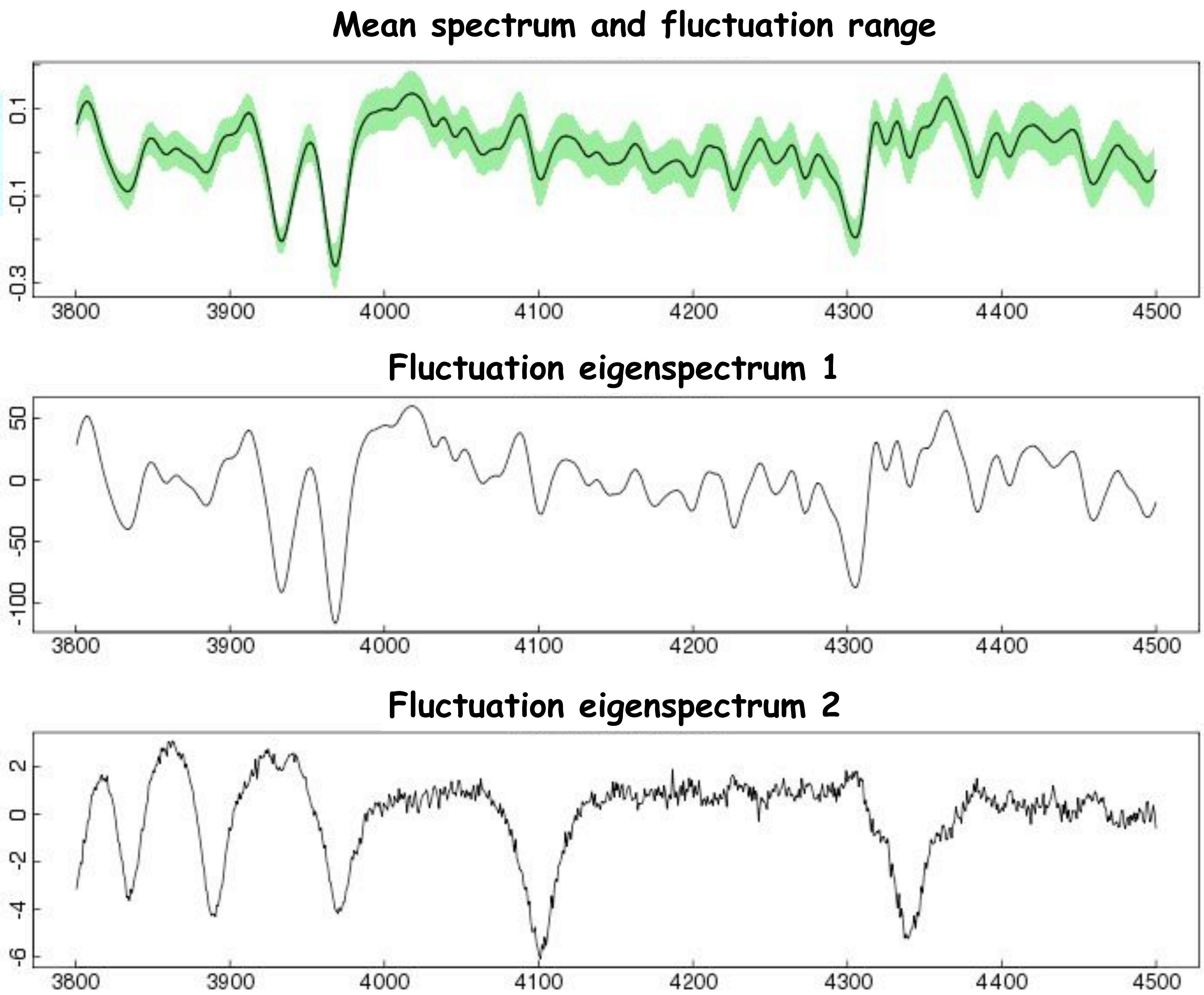
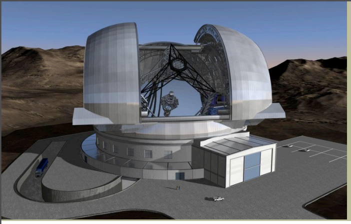
Now **most** of the fluctuations are uncorrelated between spectral pixels.

But still get excellent recovery of the BHB fluctuation signal.





Nearly-resolved spectroscopy

Different fluctuations:

Static +2% flux in AGB (<n>=10 per element)

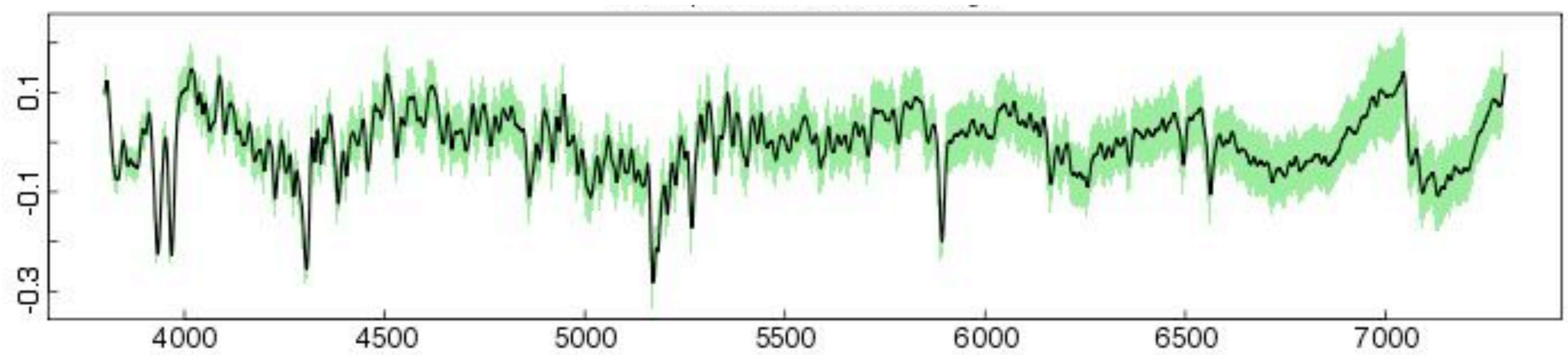
"Observation" as before:

S/N=50 per Ang,

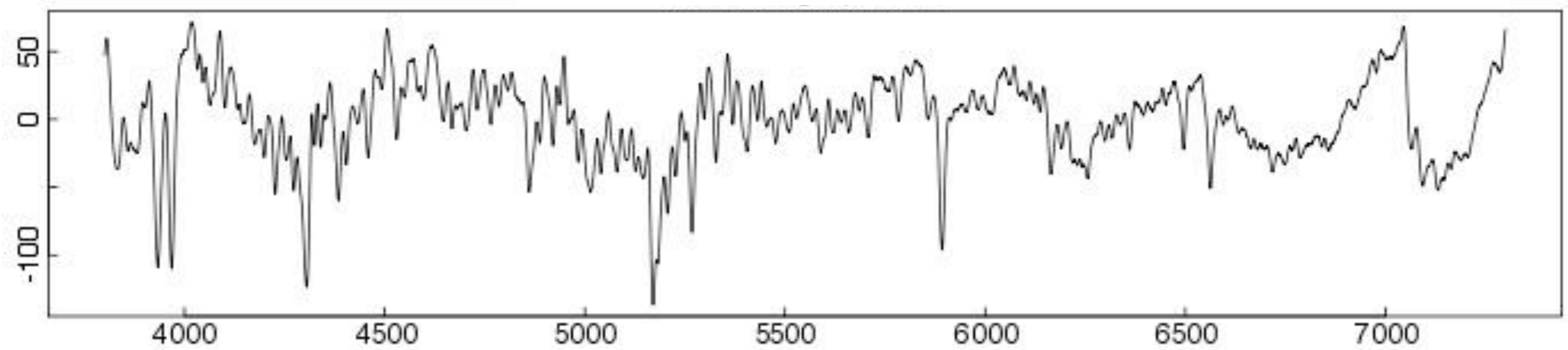
1000 spatial elements

Recover AGB signal in second eigenspectrum (but more "mixing" with static spectrum)

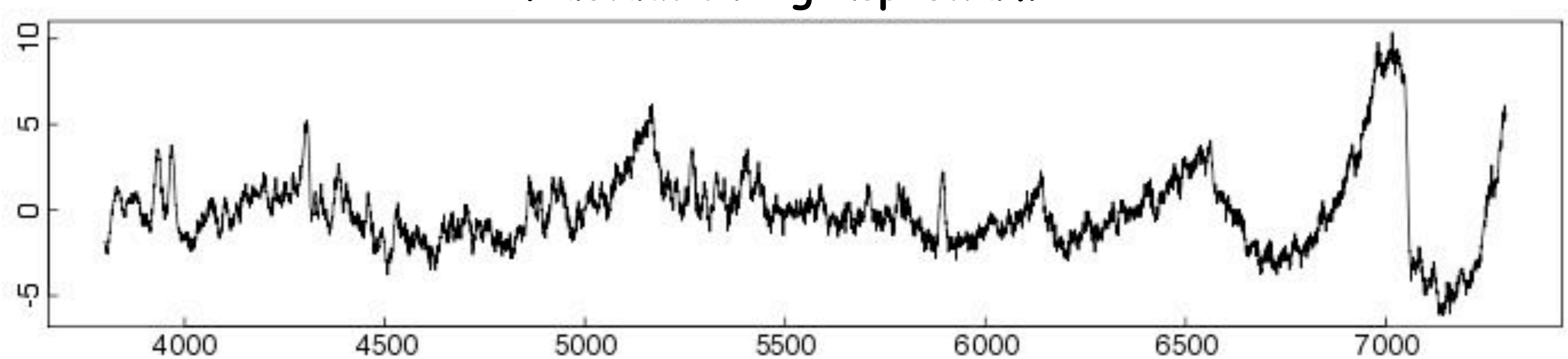
Mean spectrum and fluctuation range

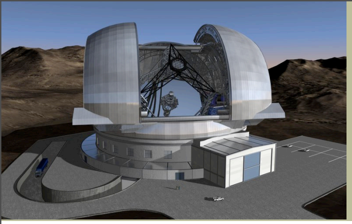


Fluctuation eigenspectrum 1



Fluctuation eigenspectrum 2





Nearly-resolved spectroscopy

Model spectrum with both the BHB and AGB fluctuations:

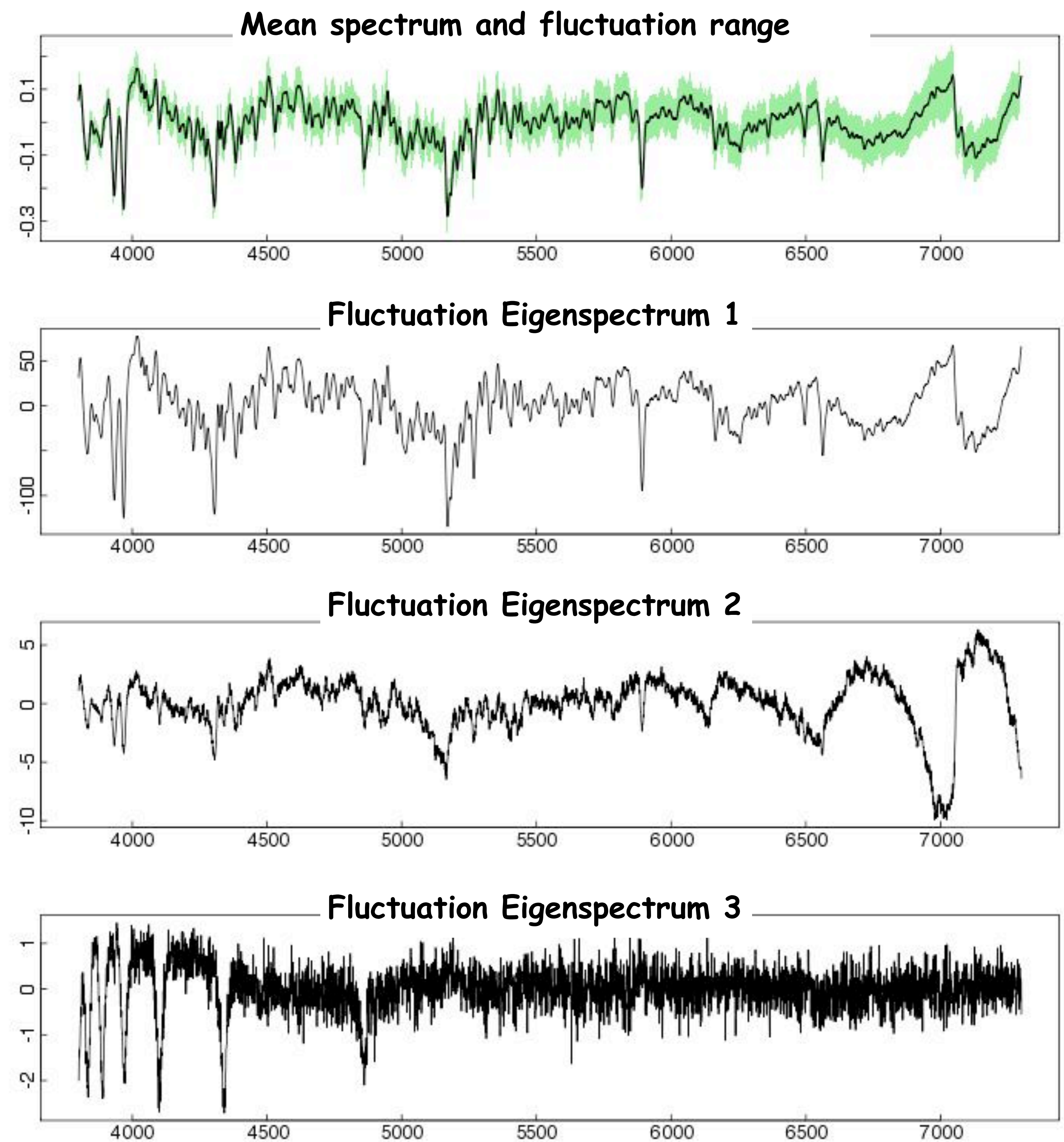
BHB (5% of flux, <n>=50 per element)

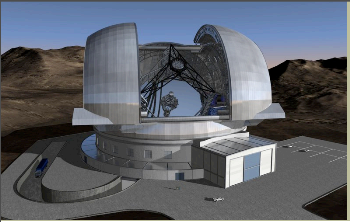
AGB (2% of flux, <n>=10 per element)

S/N=50 per Ang, 1000 element

AGB recovery

BHB recovery





Nearly-resolved spectroscopy

Model spectrum with both the BH
and AGB fluctuations:

BHB (5% of flux, <n>=50 per elemen

AGB (2% of flux, <n>=10 per element

S/N=50 per Ang, 1000 element

Are these inputs reasonable?

$(m-M)_{NGC3379}$ ~ 30

M_g (BHB) ~ 0.5

μ_g = 21.5 @ effective radius

For 5% of flux in BHBs -> (high!)

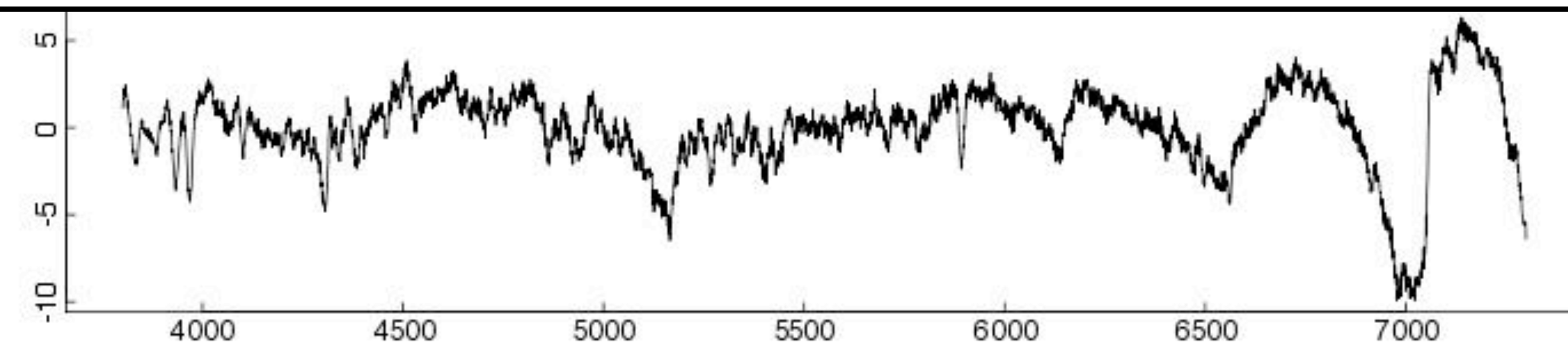
<n> = 8 for 0.2" x 0.2" elements (35% flucts)

<n> = 50 for 0.5" x 0.5" elements (14% flucts)

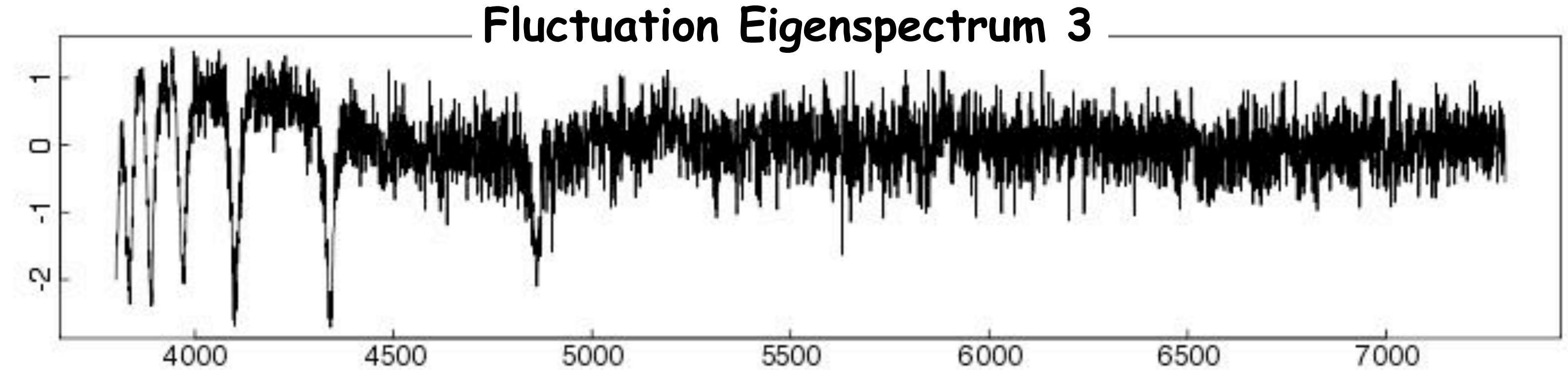
(Same fraction in Blue Stragglers: M ~ 1.5 -> n=50,300)

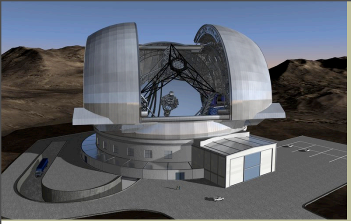
S/N ~ 50 /Å over 0.5"x0.5" @ μ=21.5 in 1ksec with E-ELT

AGB recovery



BHB recovery





Open questions...

Will it work?

* Do "realistic" (continuous) populations yield measurable fluctuations?

* Can we interpret the fluctuations (either through eigenspectra approach or other some method)?

Can it give us new information?

* Probably more than integrated spectra...

* ... but more than SBFs in multiple colours (or colour-fluctuations)?

What can we do now?

* Modellers may be able to extend their existing machinery to make predictions...

* Are there feasible targets for 8m telescopes? (GCs? MUSE...)