Galaxy Parameters Extraction from Simulated PFS Spectra

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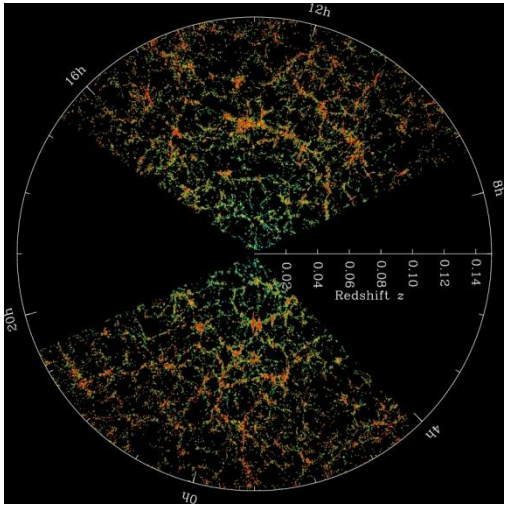
JHU

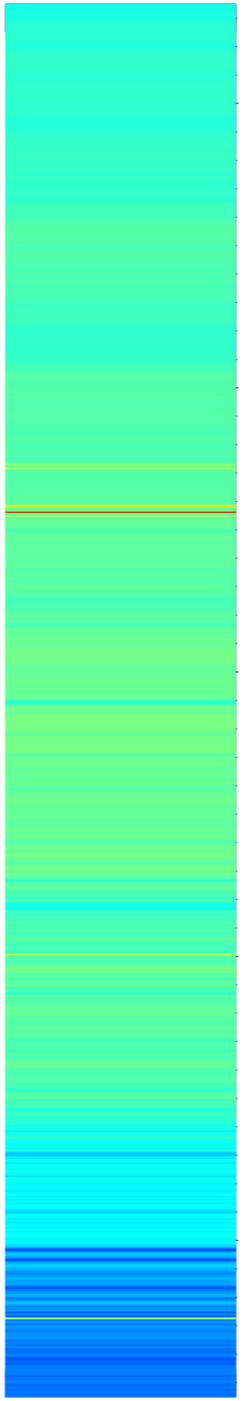
Physical Parameter Estimation:

- Stellar Age
- Stellar Metallicity
- Star Formation Rate
- Dust Extinction
- etc.

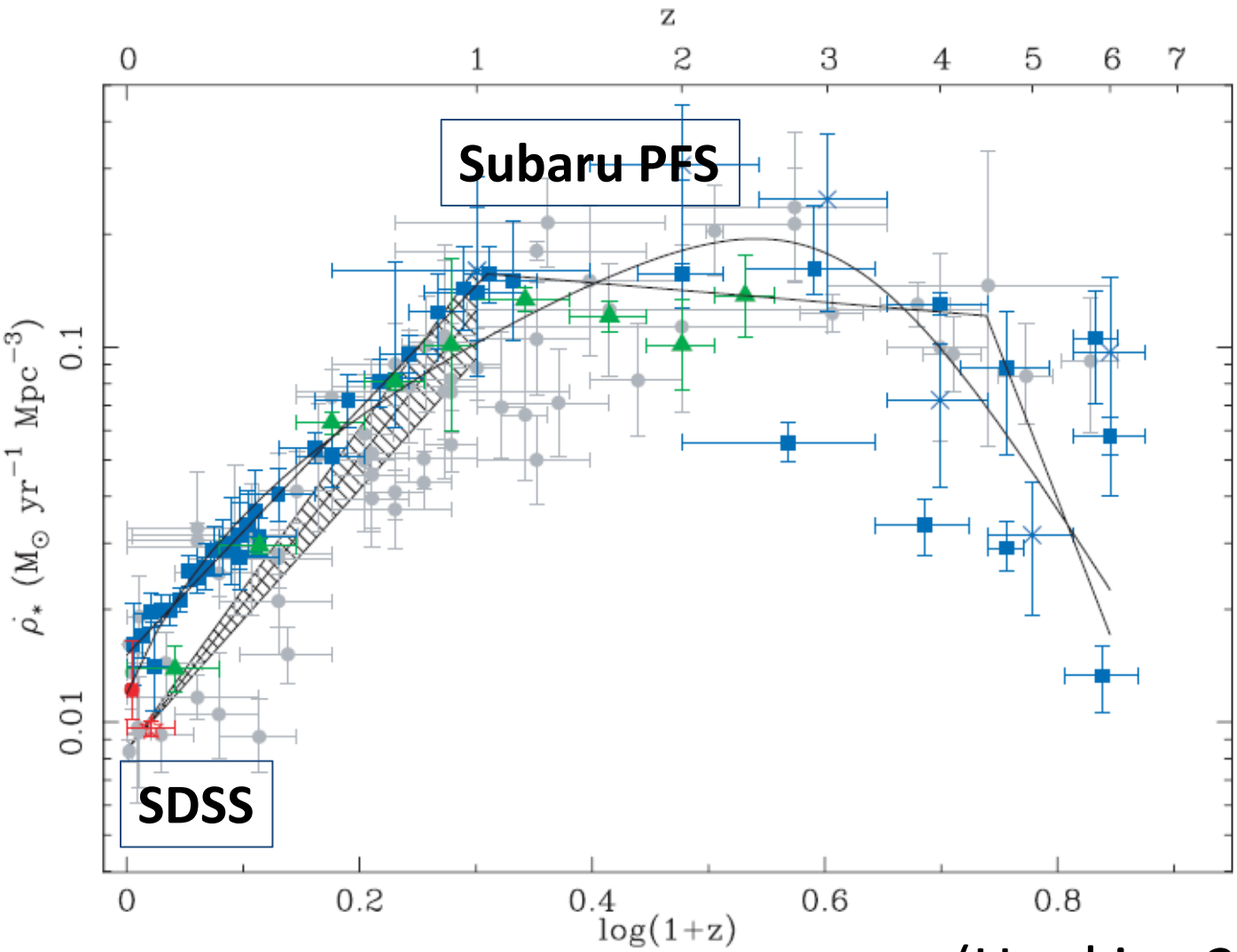


Brute force Bayesian approach:

N = 1 Million	galaxies
M = 4,000	pixels
P = 4	parameters
T = 20 years	CPU time



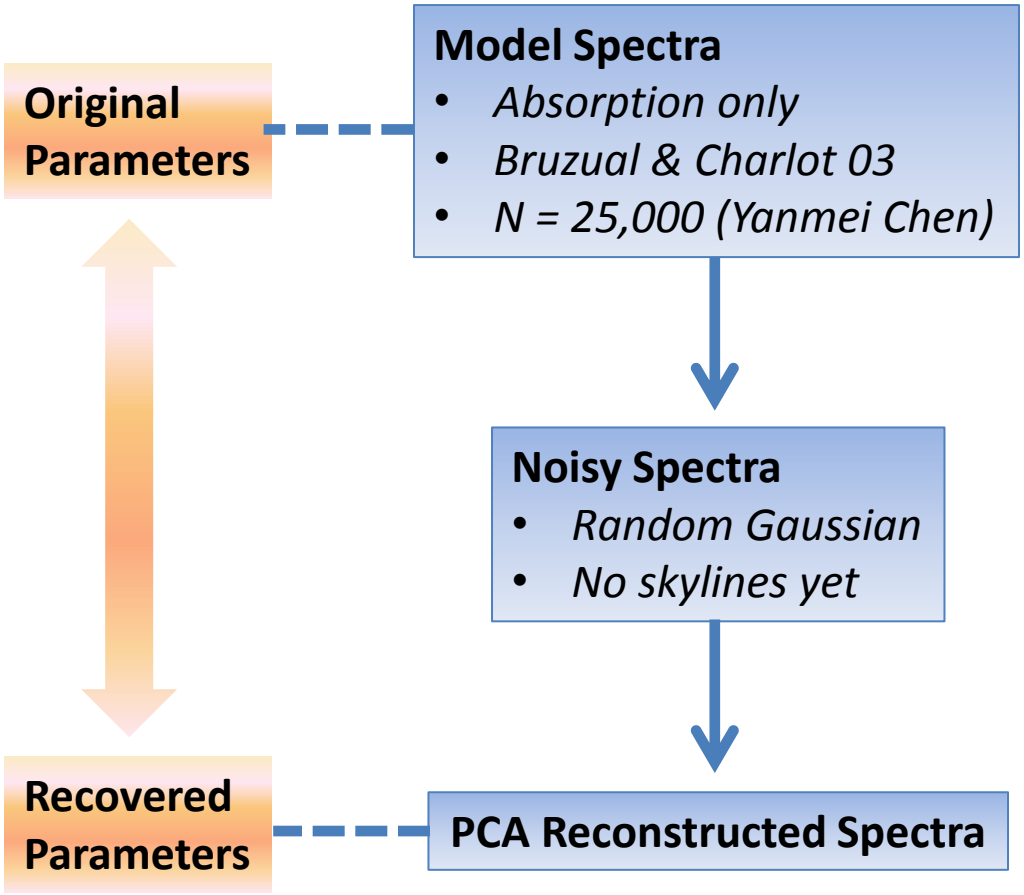
Cosmic Evolution of Galaxy Properties



(Hopkins 2006)

Galaxy Parameters Extraction from Simulated PFS Spectra

- 25,000 model spectra
- Realistic star formation history
- Focus on Dn4000



(Yip & Heckman, et al.)

Galaxy Parameters Extraction from Simulated PFS Spectra

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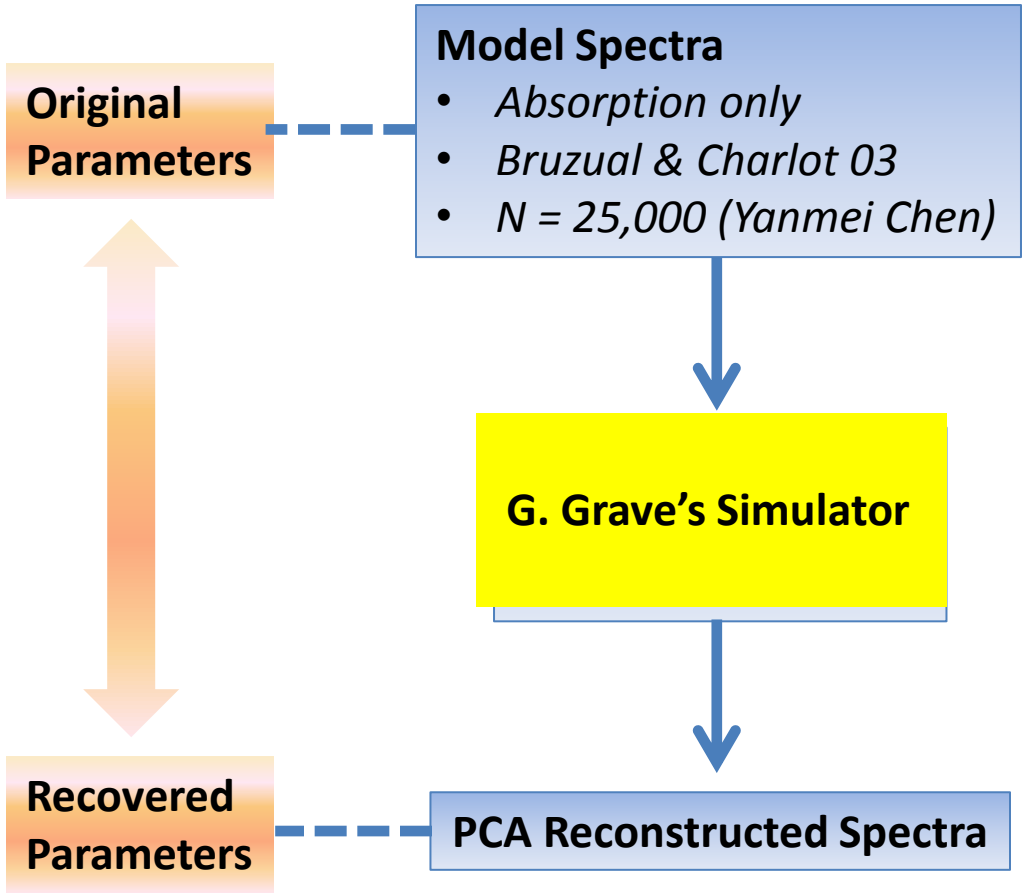


(Yip & Heckman, et al.)

25K Model Spectra 91-16,000 Å

Yanmei Chen, Tim Heckman, et al. (2012).
Bruzual & Charlot 2003 Model.
Kroupa IMF.
Continuous & Exponentially Decreasing Star Formation + Stochastic Bursts.

- **5 Model Parameters**

  τ
  Age_Galaxy
  Z/Z_Sun
  τ_V
  μ

- **18 Derived Parameters**

  Mass-Weighted Age
  r-band Weighted Age
  D4000
  HδA
  Fraction of stars formed at X years (x 5)
  Fraction of stars (in bursty mode only) at X years (x5),
  Total mass (stars + gas) of galaxy
  Stellar mass of galaxy
  Total mass of galaxy (different method)
  SFR truncation flag

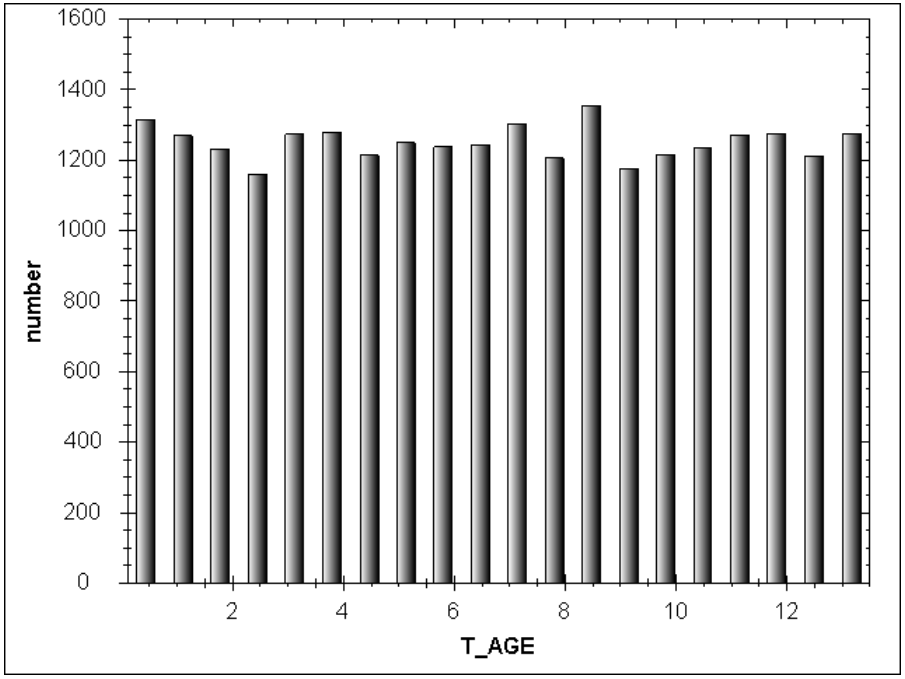
Model Spectra Management & Spectral Analysis Tools

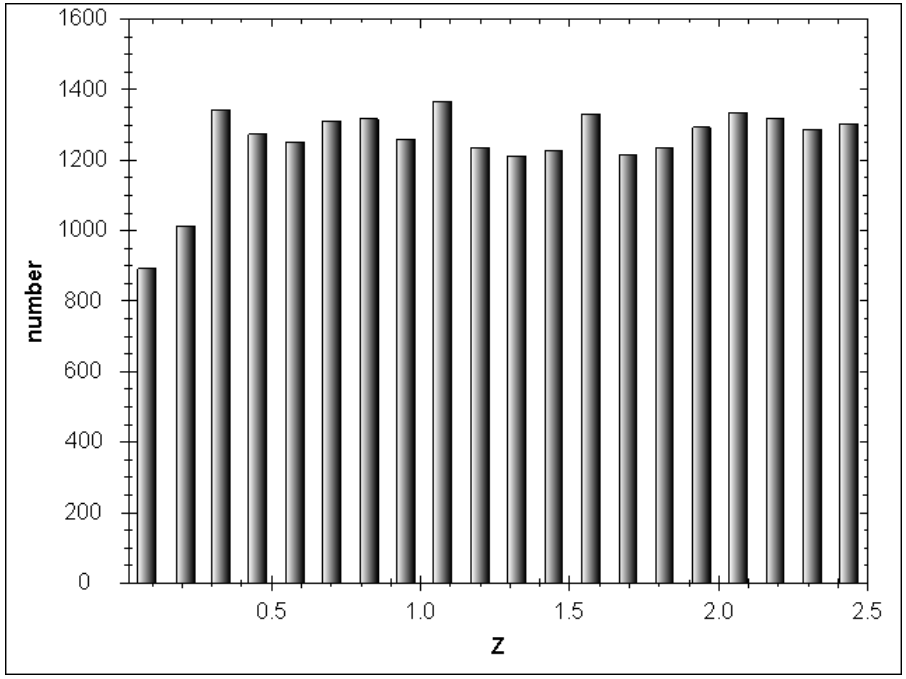
```
set tagised = mymodel_I
set fileised = $dirout/$tagised\.ised

### save parameters to file (overwrite)
set fileparm = $fileised\.par
echo $ssp > $fileparm
echo $flagdust >> $fileparm
if ( $flagdust == "Y" ) then
    echo $tau_nu >> $fileparm
    echo $mu >> $fileparm
endif
echo $sfr >> $fileparm
echo $fileised >> $fileparm

### construct models
echo "$dirbc03src/csp_galaxev < $fileparm"
$dirbc03src/csp_galaxev < $fileparm
echo "done. gal spec output to $fileised"

### save galaxevpl parameters
set fileparm2 = $fileised\.spec.par
echo $fileised > $fileparm2
echo "0.0,2000000.0" >> $fileparm2
echo $age >> $fileparm2
echo $fileised\.spec >> $fileparm2
### extract spectra
$dirbc03src/galaxevpl < $fileparm2
### delete hdr from spec file
set filespec = $tagised\.spec
sed '1,7d' < $fileised\.spec > $filespec

### loop through E(B-V)
set e_bvindex = 1
while ( $e_bvindex <= $#e_bv )
set E_BV = $e_bv[$e_bvindex]

### create idl batch file
echo ".compile count_columns.pro" > bc03tofits_batch
echo ".compile count_rows.pro" >> bc03tofits_batch
echo ".compile fetchcolfilein.pro" > bc03tofits_batch
echo ".compile mkhdr.pro" >> bc03tofits_batch
echo ".compile sxaddpar.pro" >> bc03tofits_batch
echo ".compile mwrfits.pro" >> bc03tofits_batch
echo ".compile bc03tofits.pro" >> bc03tofits_batch
set specfile = \'$filespec\'
set fitsout = \'$dirOut/spec$id.fits\'
set parm = \[\"AGE_B\",\"METAL_B\",\"TAU\",\"TSFR_CUT\",\"FLAGDUST\",\"TAU_NU\",\"MU\",\"E_BV_B\",\"FRAC_B\"\]
set parmVal = \["$age","$z","$tau","$tsfr_cut","$Keydust","$tau_nu","$mu","$E_BV","$fracb"\]
set comment = \[\""in Gyr"\",\""metallicity in ..."\",\""e-folding time in SFR"\",\""SFR = 0 after this time"\",\""dust accumulation
"\",\""total eff opt depth"\",\""frac of tau_nu from ambient"\",\""Reddening"\",\""burst flux fraction"\"\]
### set history line
set ageindexfix = 1
### do not scale flux by fracB, do this inside the code
echo "bc03tofits, $specfile, $fitsout, $ageindexfix, $parm, $parmVal, $comment, E_BV=$E_BV, /C99" >>  bc03tofits_batch
echo "exit" >> bc03tofits_batch

### exec idl to make fits
setenv IDL_STARTUP bc03tofits_batch
idl
unsetenv IDL_STARTUP
@ id = $id + 1

@ e_bvindex = $e_bvindex + 1
end

### delete result files
foreach fileresult ($tagised*color $tagised*ABmag $tagised*sindx* *ised $tagised*spec)
    rm -f $fileresult
end

@ epsilonindex = $epsilonindex + 1
end
@ muindex = $muindex + 1
end
@ taunuindex = $taunuindex + 1
end
@ tauindex = $tauindex + 1
end

@ ageindex = $ageindex + 1
end

@ Zindex = $Zindex + 1
end
```

- Script (csh) to generate BC03
- Save each spectrum to FITS
- Save associated model parameters to FITS hdr
- Pipeline (C#) for spectral analysis
  - Convolution, red/blue shifting, resampling, etc.
  - PCA
  - Objective line indices identification
  - N-D interpolation & parameter estimation
  - Connect SDSS & other SQL databases (Szalay)

(Yip)

Model Parameter Space

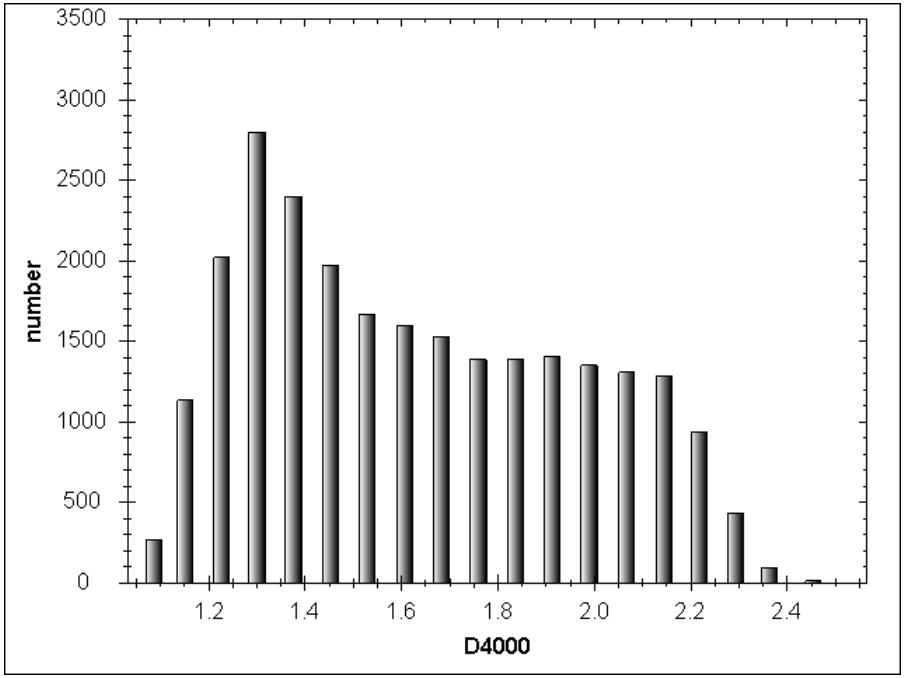


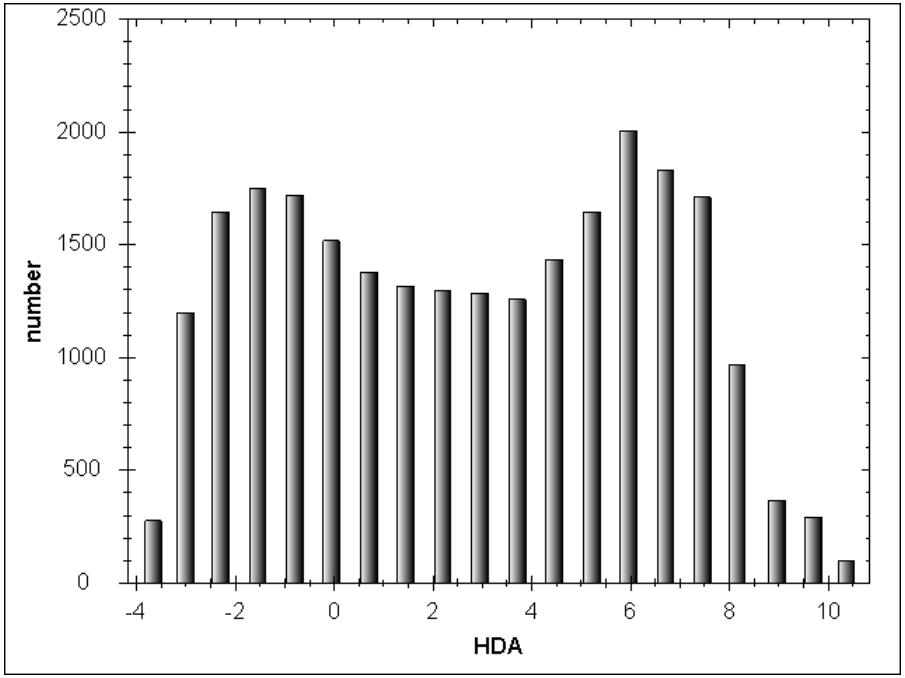


Age of Oldest Stars

Stellar Metallicity

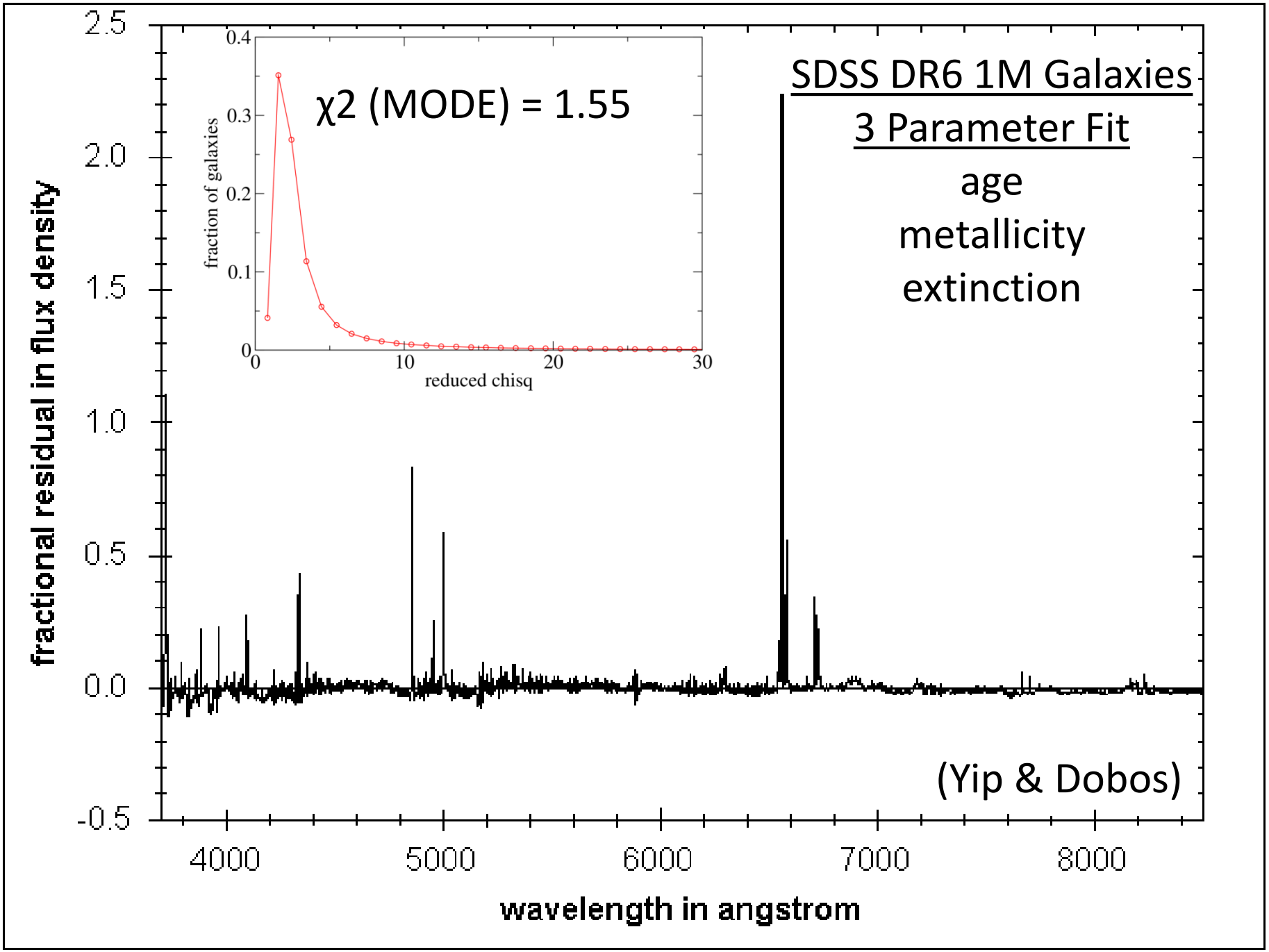
Derived Parameter Space





Dn4000

$H\delta_A$


SDSS DR6 1M Galaxies
3 Parameter Fit
age
metallicity
extinction
χ2 (MODE) = 1.55
fraction of galaxies
reduced chisq
fractional residual in flux density
wavelength in angstrom
(Yip & Dobos)

PCA Eigenspectra Representation of Galaxy Spectra

$$\boxed{f_\lambda = \sum_i a_i e_{i_\lambda}}$$

Minimize reconstruction error with respect to a_i's:

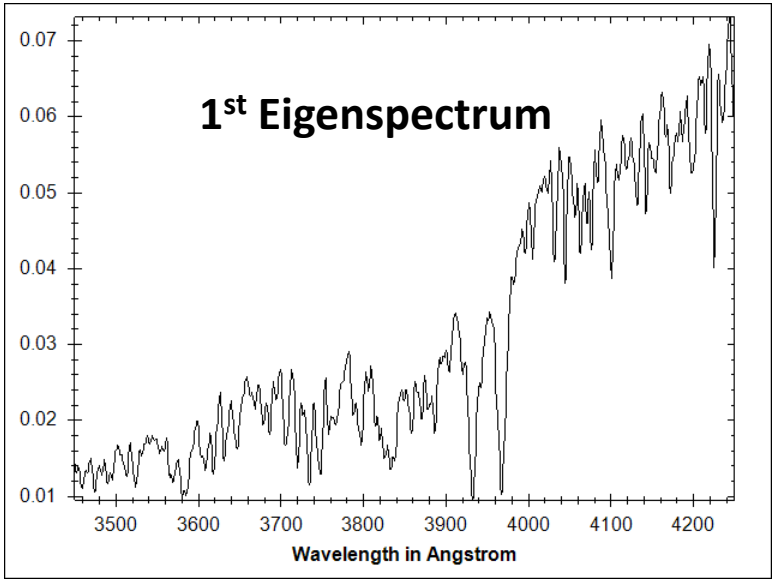
$$x^2 = \sum_\lambda w_\lambda \left(f_\lambda - \sum_i a_i e_{i_\lambda}\right)^2$$

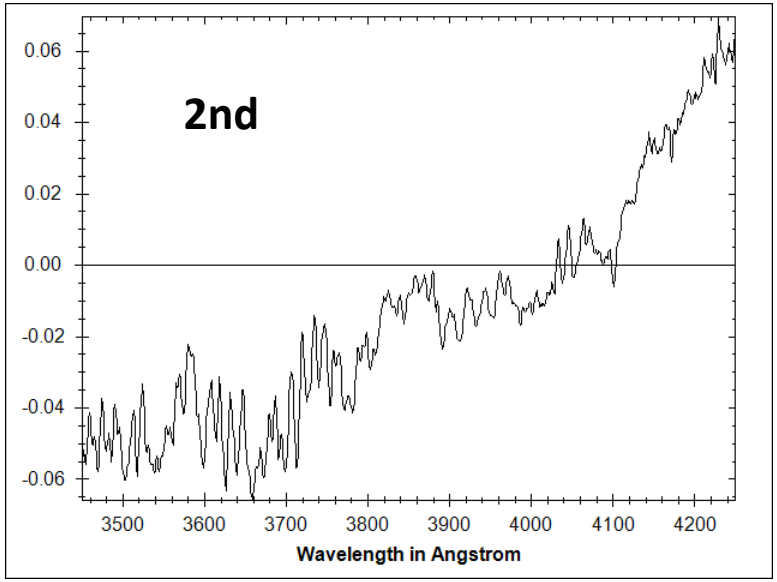
Get:

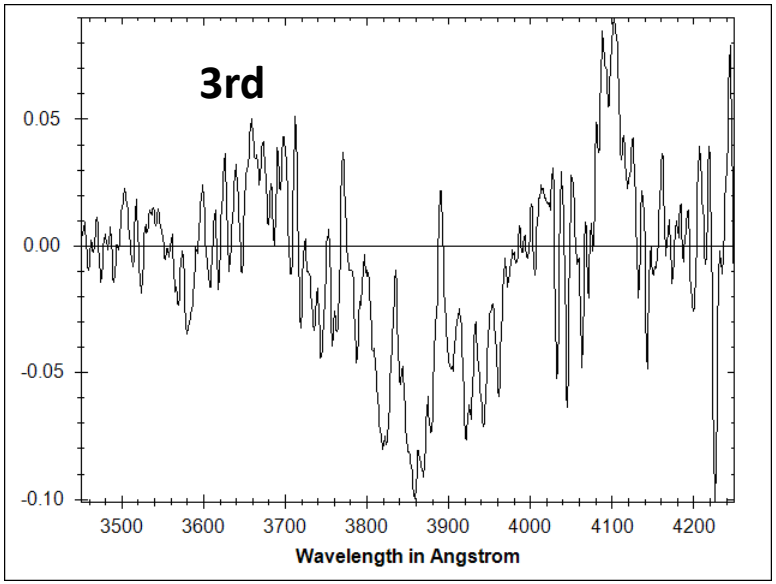
$$a_i = a_i(w_\lambda, e_{i_\lambda}, f_\lambda)$$

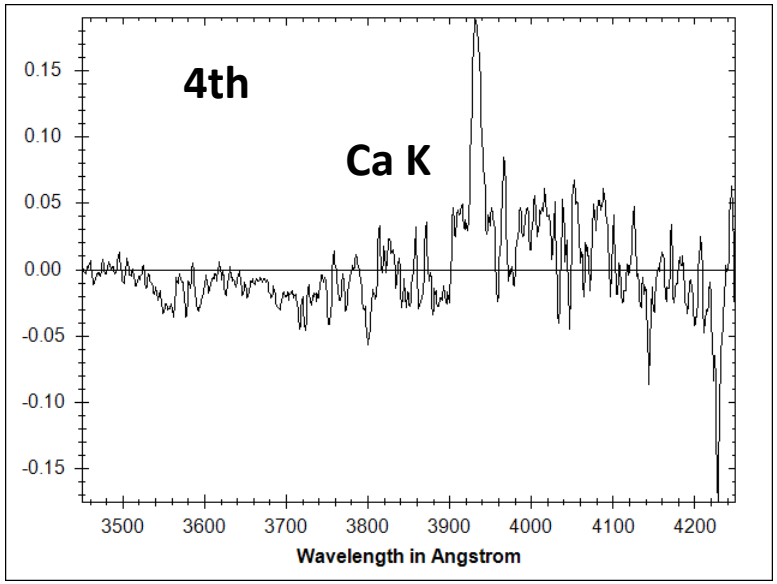
(Connolly & Szalay 99)

Eigenspectra 3450-4250 Å @ 1 Å/pixel





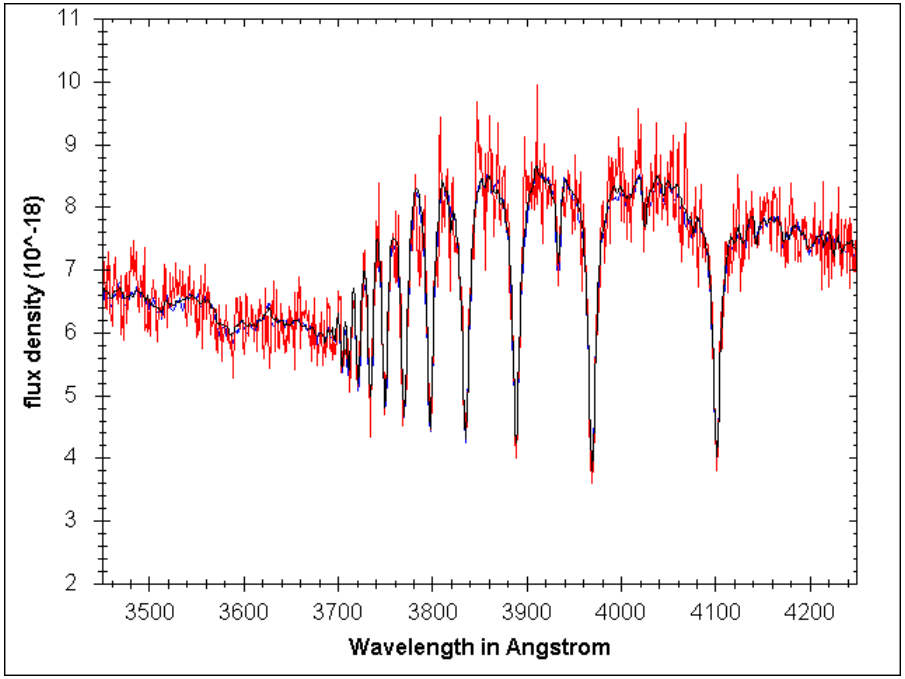




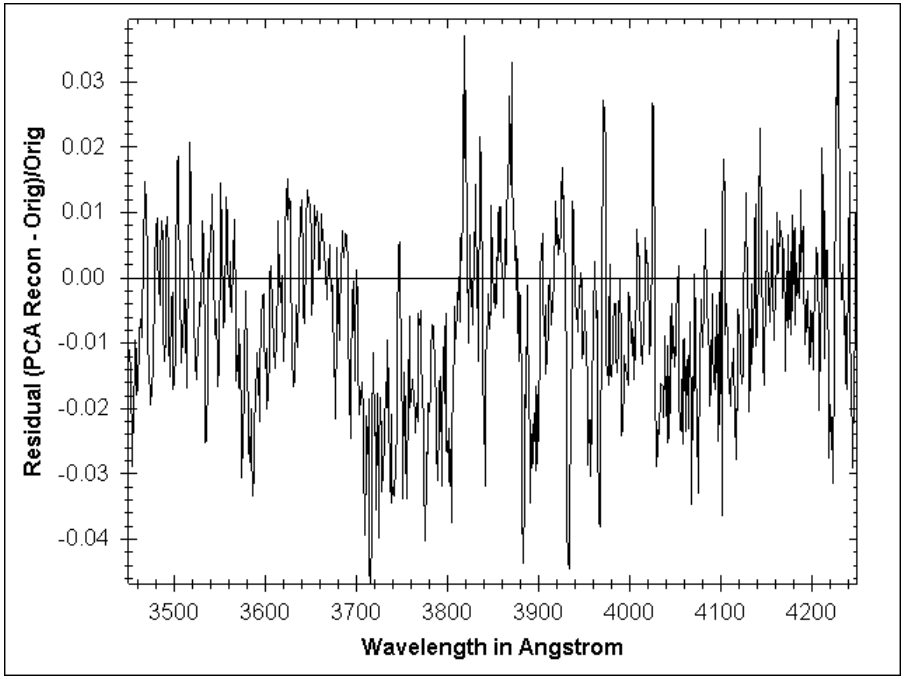
20-Mode PCA Reconstruction
S/N per Å = 10

Black: Orignal

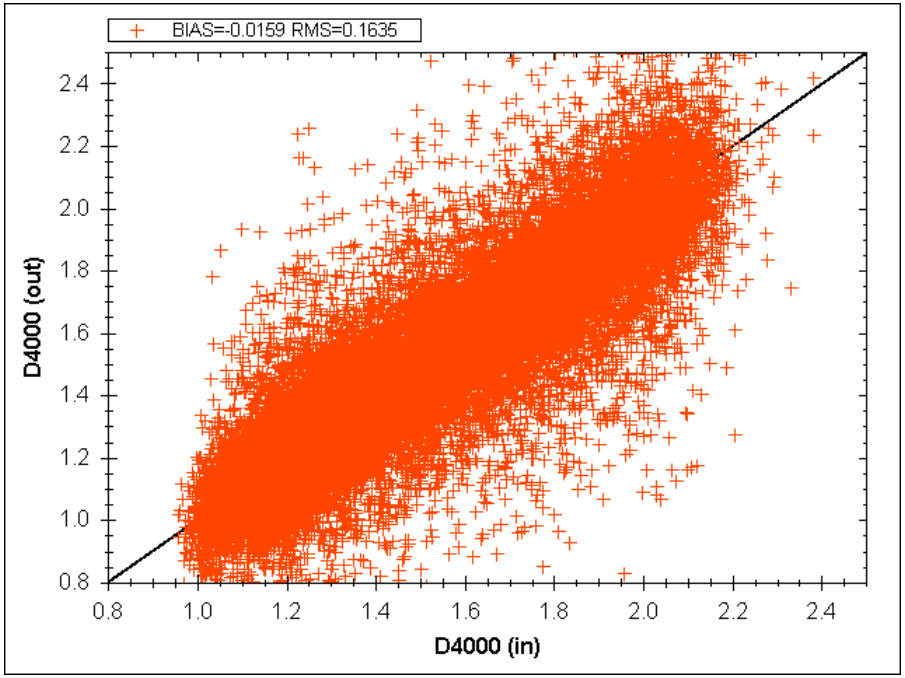
Blue: Reconstruction

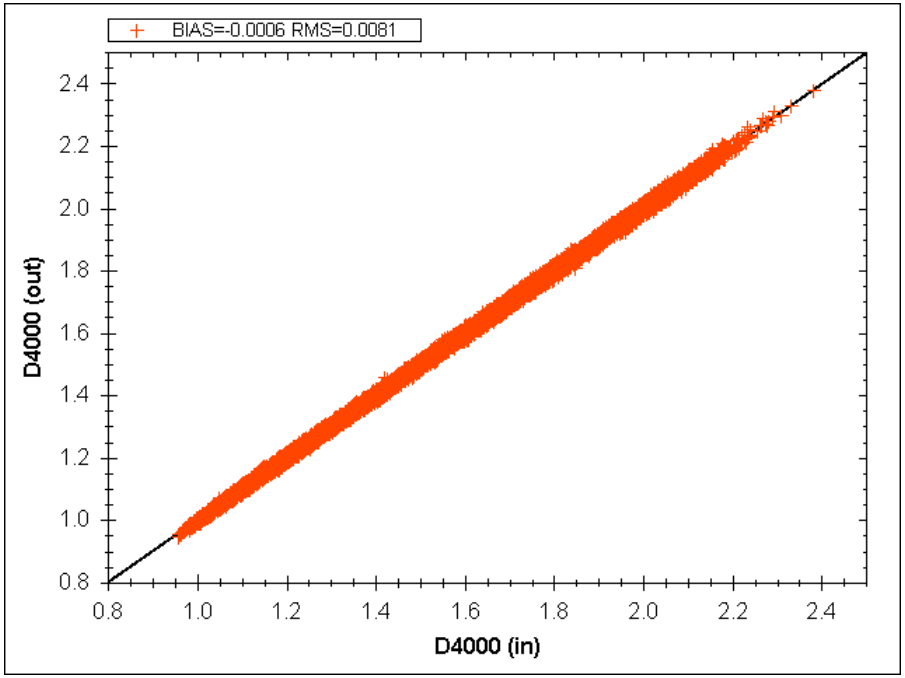


Residual: 2%



Parameter Recovery Dependence on Pixel S/N

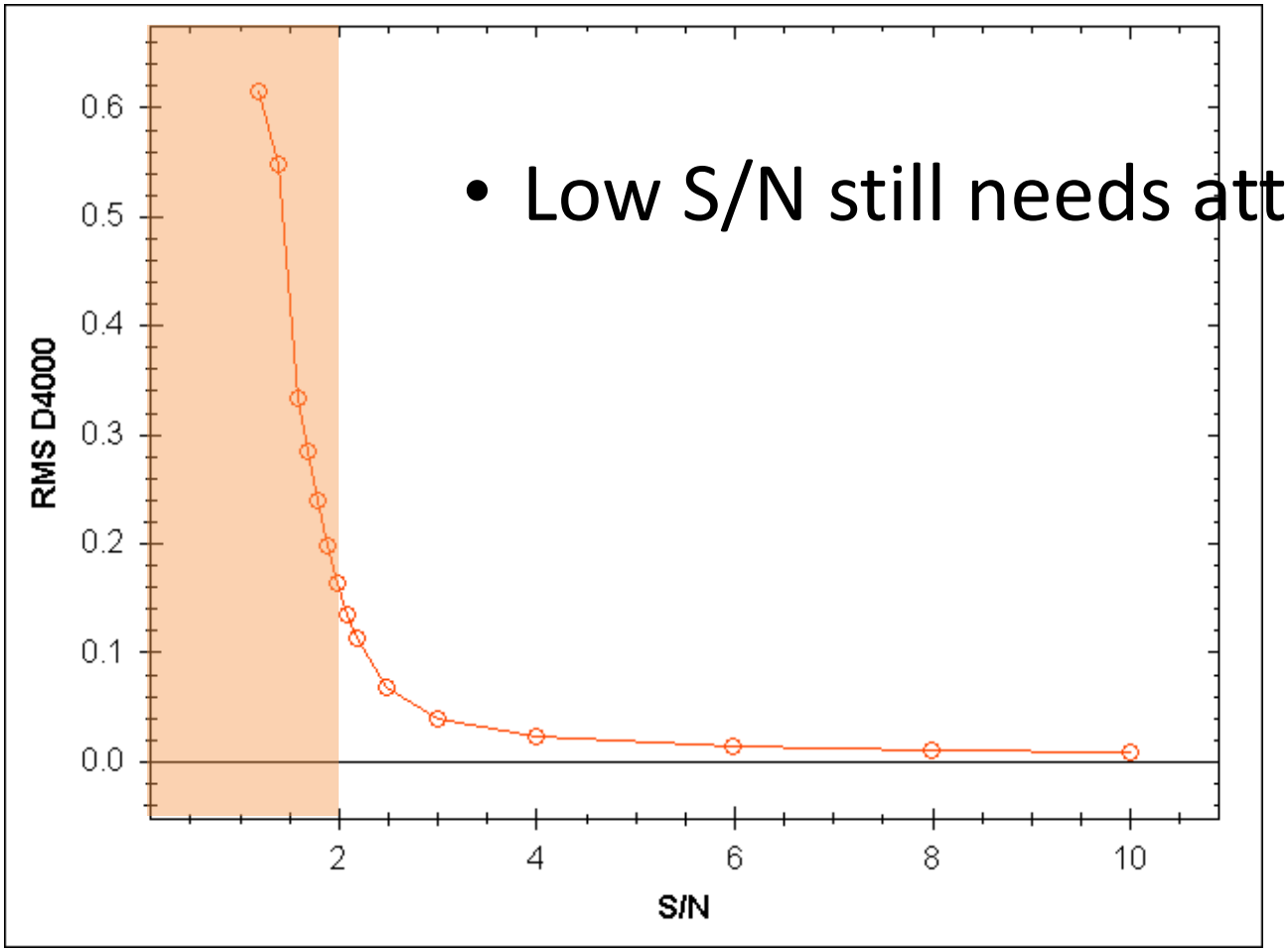




S/N = 2

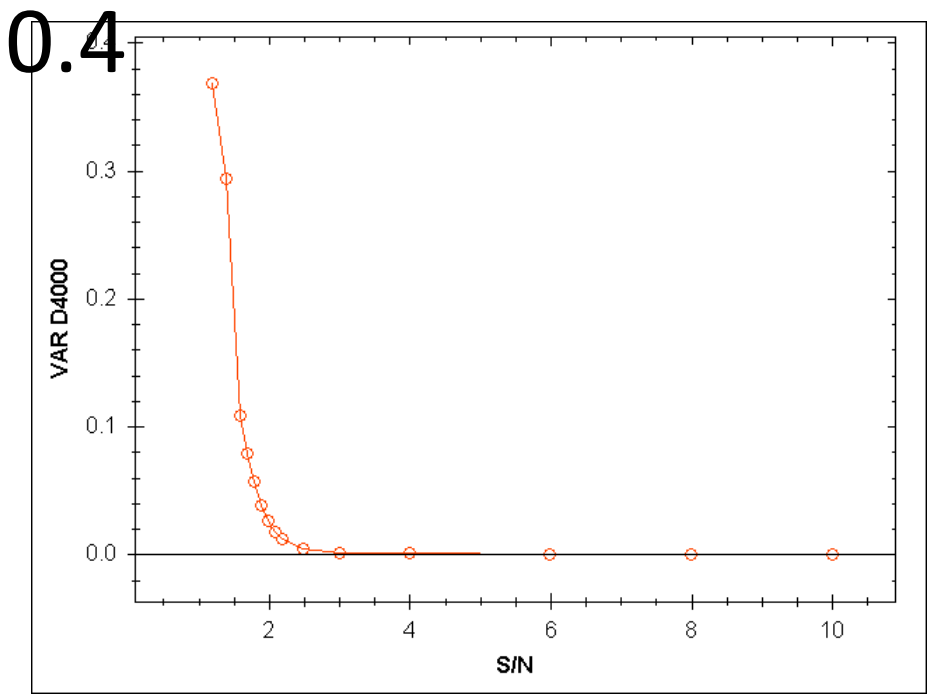
S/N = 10

RMS(Dn4000) vs. S/N per Å

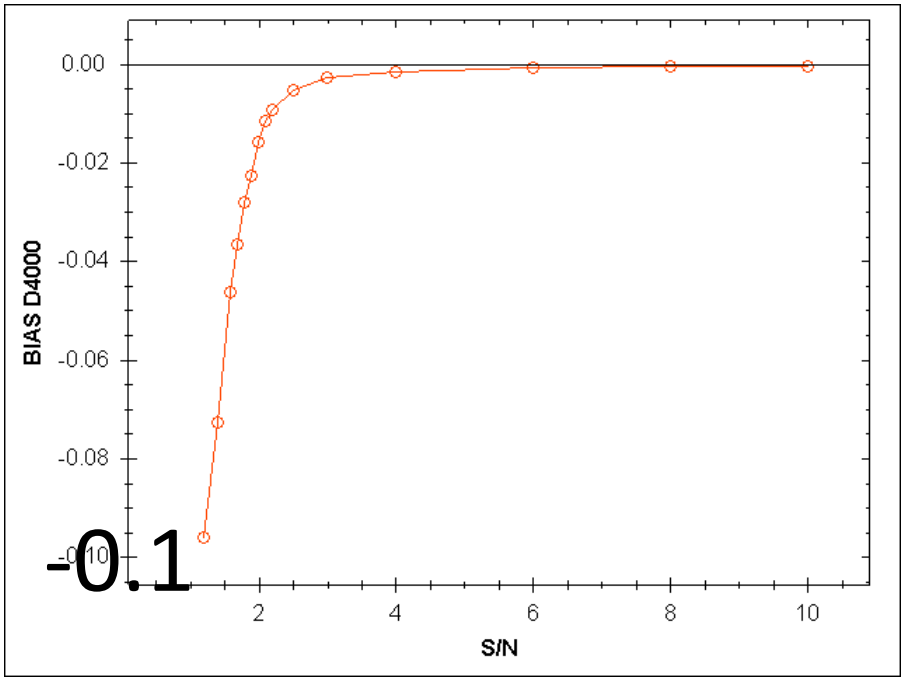


- Low S/N still needs attention

RMS is Variance Dominated (so we have unbiased estimator)



Variance vs. S/N

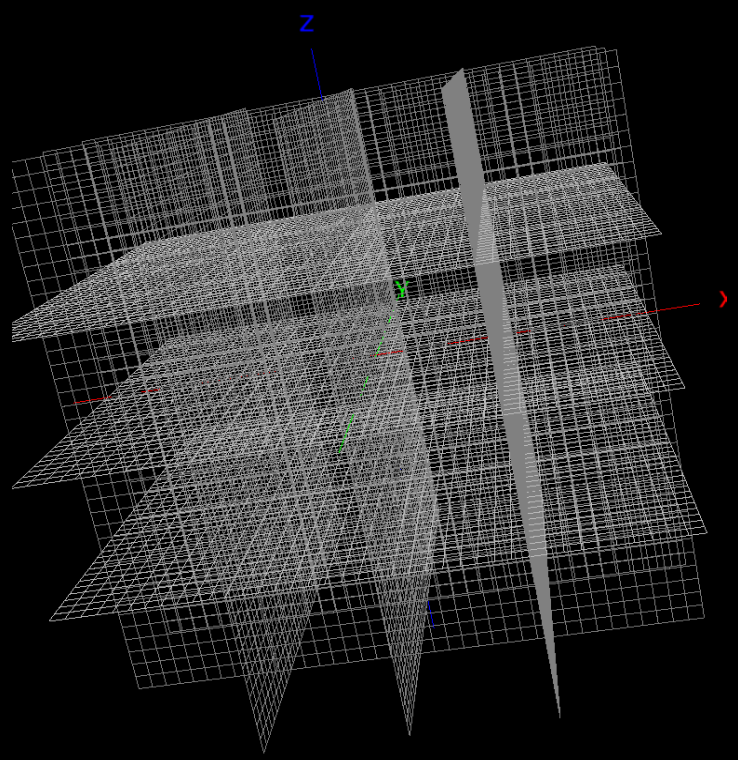


Bias vs. S/N

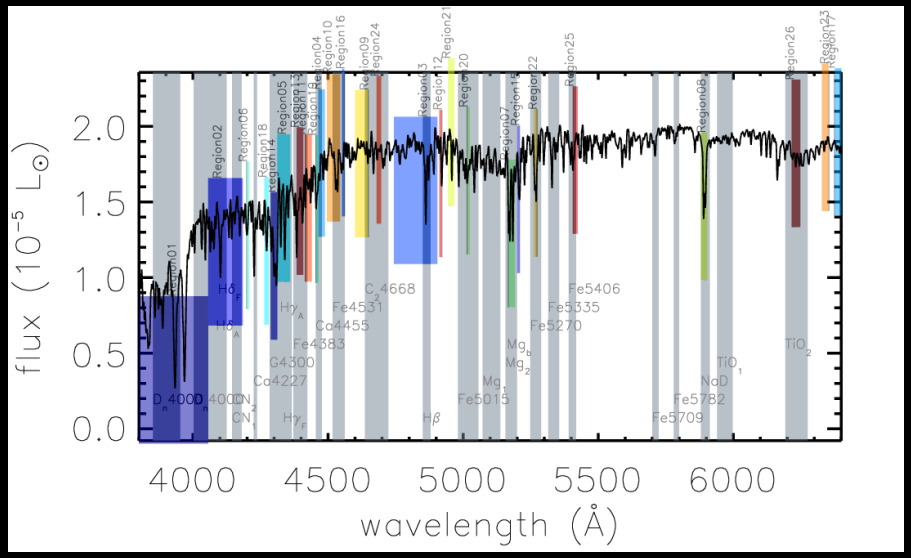
Large Scale Galaxy Parameter Estimation

- Many parameters
- Many objects

N-Dimensional Model Grid (Yip 2010)



Informative Wavelength Regions using CUR
(Yip, Mahoney, Szalay et al. 2013 submitted)



Why N-Dimensional Parameters

- Galaxy formation is complicated: merging, star formation hisotry, gas infall and outflow
- We don’t know how many parameters we need
- Would N-1 to N parameters give new solutions?
- Evidence we need many parameters
  - Stochastic bursts model: exponentially decreasing SFH + bursts during lifetime of galaxies (Kauffmann et al. 2003)
  - 10% Offset between Bruzual & Charlot model and 1 Million SDSS spectra (Yip & Dobos)