Measuring absorption indices with SHARDS data

The Balmer break (exploratory work in progress!)

Nicolás Cardiel[1], Pablo G. Pérez González[1], + SHARDS volunteers

[1] Departamento de Astrofísica y Ciencias de la Atmósfera

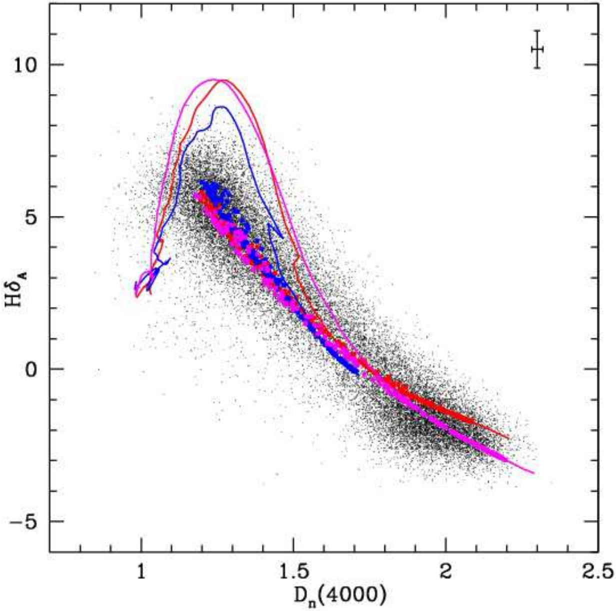
Facultad de Ciencias Físicas

Universidad Complutense de Madrid

Outline

Outline

Kauffmann et al. (2003, MNRAS, 341, 33)



Data

$\sim$ 25000 SDSS galaxies
$\Delta\, H\delta_A < 0.8$ Å
$\Delta\, D_n(4000) < 0.03$

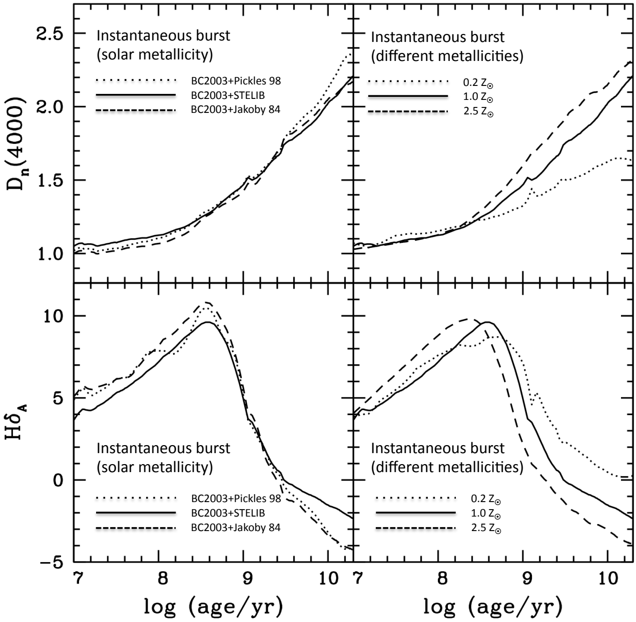
Model predictions

$0.2\times$ solar metallicity
$1.0\times$ solar metallicity
$2.5\times$ solar metallicity

lines $\rightarrow$ **burst**

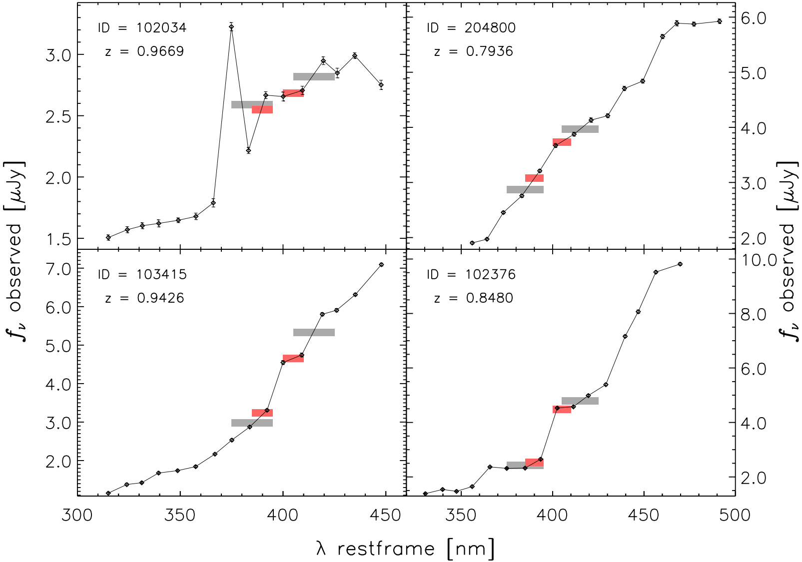
symbols $\rightarrow$ **continuous SF**

Kauffmann et al. (2003, MNRAS, 341, 33)



Hernán-Caballero et al. (2013, in press)

The 4000 Å break can be measured in SHARDS spectra!



$H\delta_A$ is defined with three bandpasses of 38.15, 38.75 and 32.50 Å. Thus, it cannot be properly measured in SHARDS spectra.

Is there an alternative to $H\delta_A$ that we can define with bandpasses of ~ 100 Å?

$\longrightarrow$ The Balmer break

Kriek et al. (2006, ApJ, 645, 44)

THE ASTROPHYSICAL JOURNAL, 645:44–54, 2006 July 1

DIRECT MEASUREMENTS OF THE STELLAR CONTINUA AND BALMER/4000 Å BREAKS OF RED $z > 2$ GALAXIES: REDSHIFTS AND IMPROVED CONSTRAINTS ON STELLAR POPULATIONS[1,2,3]

MARISKA KRIEK,[4] PIETER G. VAN DOKKUM,[5] MARIJN FRANX,[4] NATASCHA M. FÖRSTER SCHREIBER,[6] ERIC GAWISER,[5]
GARTH D. ILLINGWORTH,[7] IVO LABBÉ,[8,9] DANILO MARCHESINI,[5] RYAN QUADRI,[5] HANS-WALTER RIX,[10]
GREGORY RUDNICK,[11,12] SUNE TOFT,[5] PAUL VAN DER WERF,[4] AND STIJN WUYTS[4]
Received 2005 November 20; accepted 2006 March 1

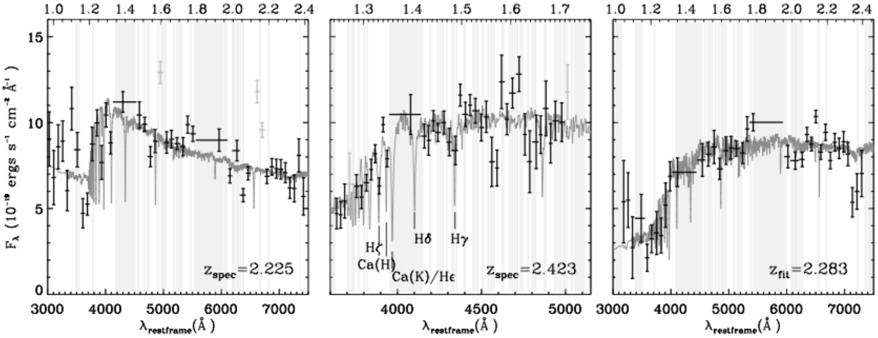
ABSTRACT

We use near-infrared (NIR) spectroscopy obtained with the GNIRS on Gemini, NIRSPEC on the Keck, and ISAAC on the VLT to study the rest-frame optical continua of three "distant red galaxies" (with $J_s - K_s > 2.3$) at $z > 2$. All three galaxy spectra show the Balmer/4000 Å break in the rest-frame optical. The spectra allow us to determine spectroscopic redshifts from the continuum with an estimated accuracy of $\Delta z/(1+z) \sim 0.001$–0.04. These redshifts agree well with the emission-line redshifts for the two galaxies with Hα emission. This technique is particularly important for galaxies that are faint in the rest-frame UV, as they are underrepresented in high-redshift samples selected in optical surveys and are too faint for optical spectroscopy. Furthermore, we use the break, continuum shape, and equivalent width of Hα, together with evolutionary synthesis models, to constrain the age, star formation timescale, dust content, stellar mass, and star formation rate of the galaxies. Inclusion of the NIR spectra in the stellar population fits greatly reduces the range of possible solutions for stellar population properties. We find that the stellar populations differ greatly among the three galaxies, ranging from a young dusty starburst with a small break and strong emission lines to an evolved galaxy with a strong break and no detected line emission. The dusty starburst galaxy has an age of 0.3 Gyr and a stellar mass of $1 \times 10^{11}\ M_\odot$. The spectra of the two most evolved galaxies imply ages of 1.3–1.4 Gyr and stellar masses of $4 \times 10^{11}\ M_\odot$. This large range of properties strengthens our previous, more uncertain results from broadband photometry. Larger samples are required to determine the relative frequency of dusty starbursts and (nearly) passively evolving galaxies at $z \sim 2.5$.

Subject headings: galaxies: evolution — galaxies: formation — galaxies: high-redshift — infrared: galaxies

→

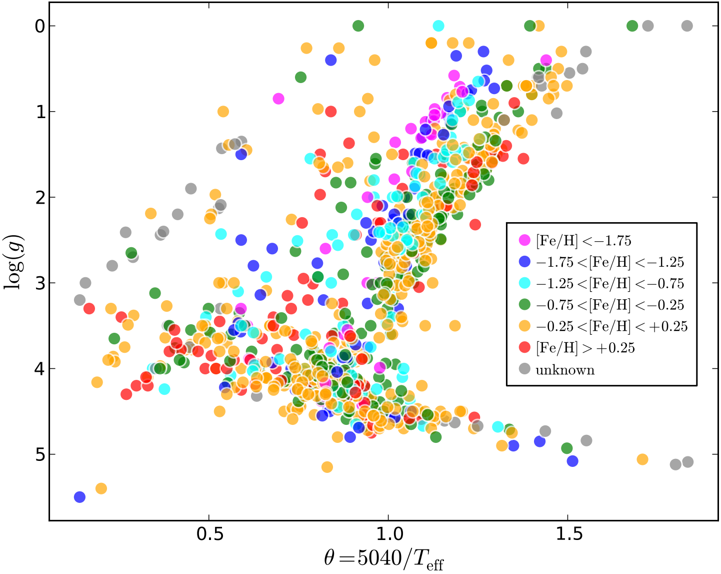
The Balmer break at 3646 Å marks the termination of the hydrogen Balmer series and is strongest in A-type stars. Therefore, the break strength does not monotonically increase with age, but reaches a maximum in stellar populations of intermediate ages (0.3–1 Gyr). The strength of the Balmer sequence can be best measured from the individual Balmer lines, such as Hδ. However, as our spectra do not allow the measurement of this feature, we use the strength of the Balmer break (D_B), which we define as the ratio of the average flux density F_ν in the bands 3500–3650 and 3800–3950 Å around the break. The large regions are not optimal, but they are a trade-off between dust dependence and having sufficient S/N using the spectra of high-redshift galaxies. This index is also partially influenced by the 4000 Å break. Nevertheless, the age dependence of D_B is very similar to that of Hδ.

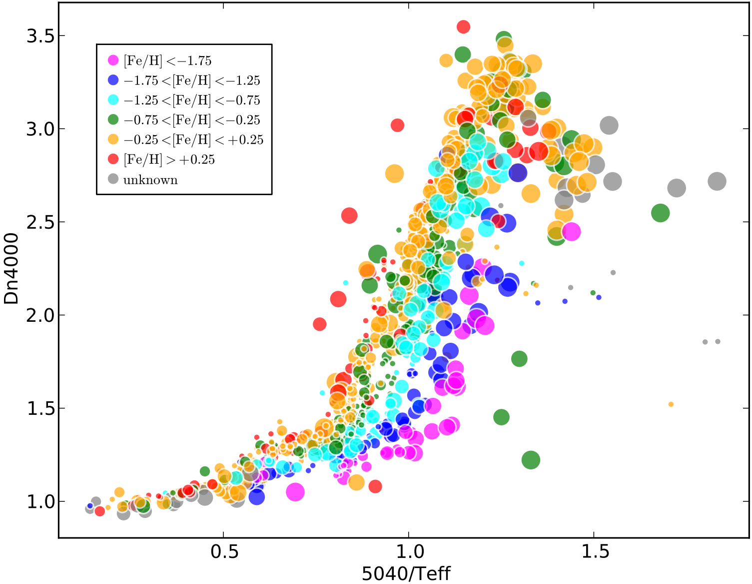


Outline

Stellar library: MILES

Sánchez-Blázquez et al. (2006), Cenarro et al. (2007); Falcón-Barroso et al. (2011)

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−1.75 < [Fe/H] < −1.25
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−0.25 < [Fe/H] < +0.25
[Fe/H] > +0.25
unknown
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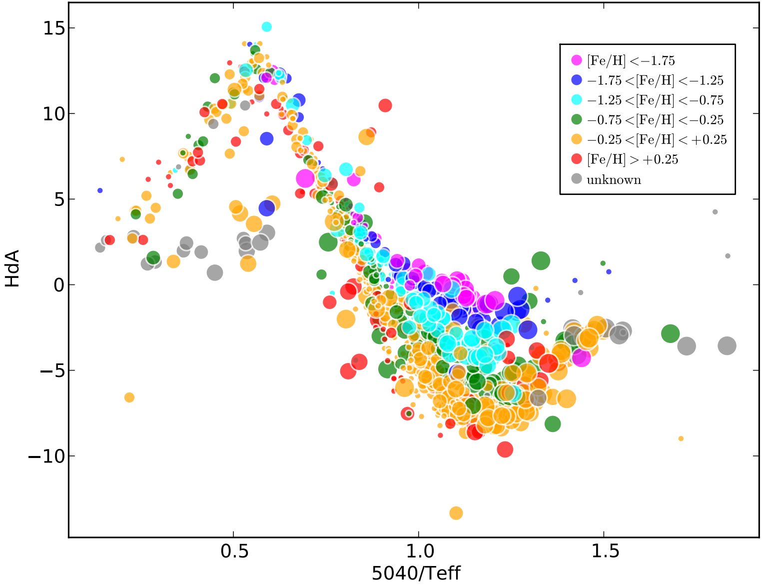
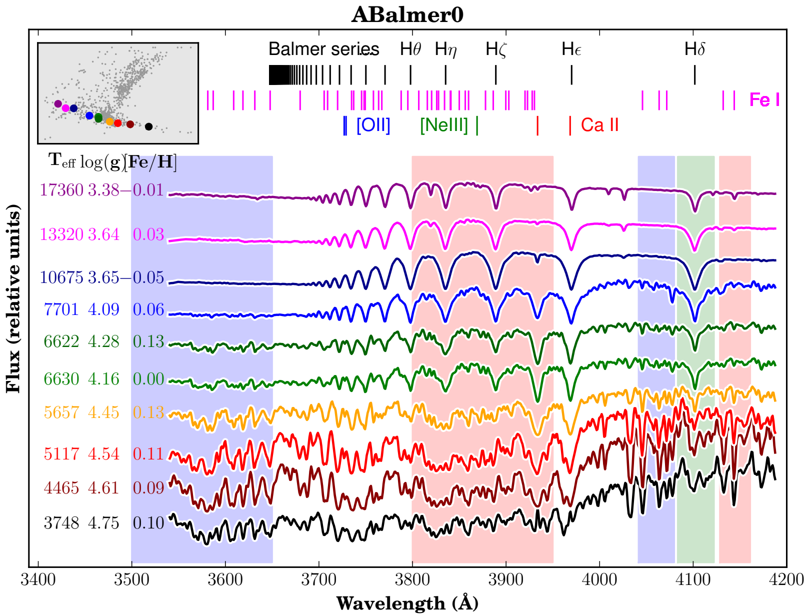
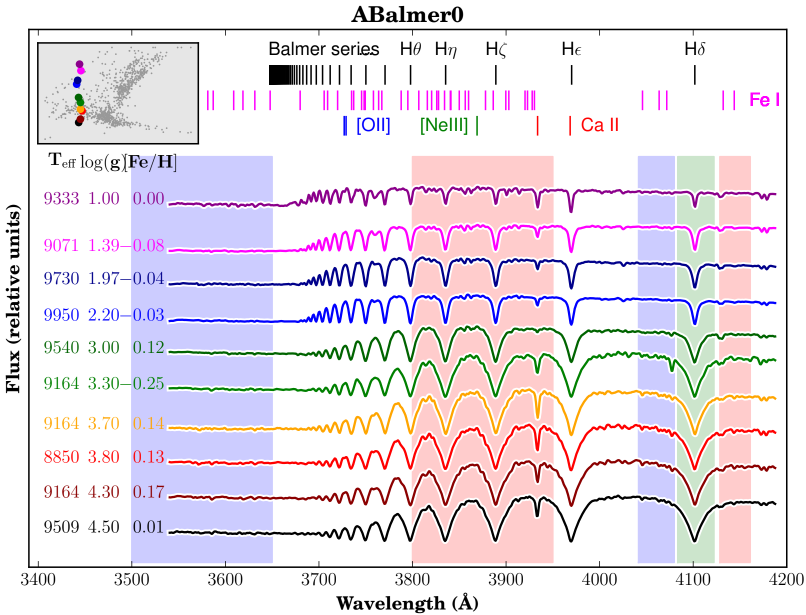
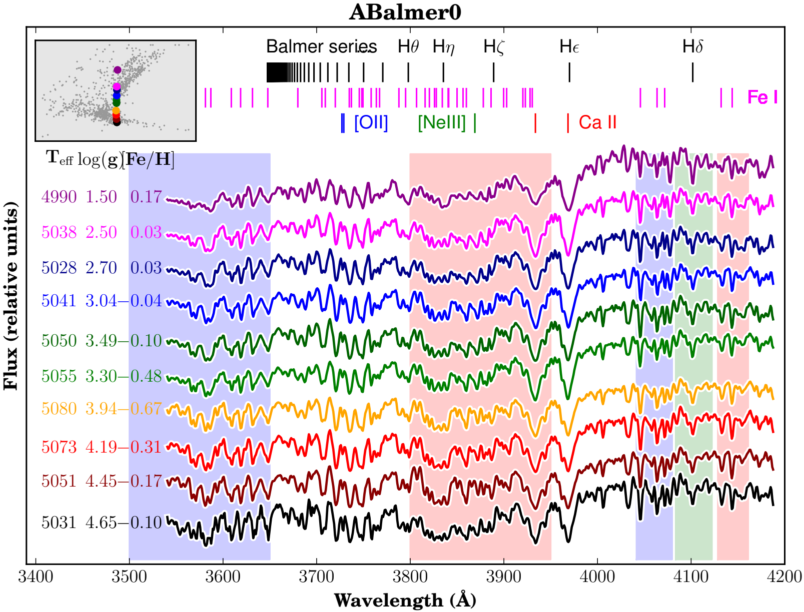
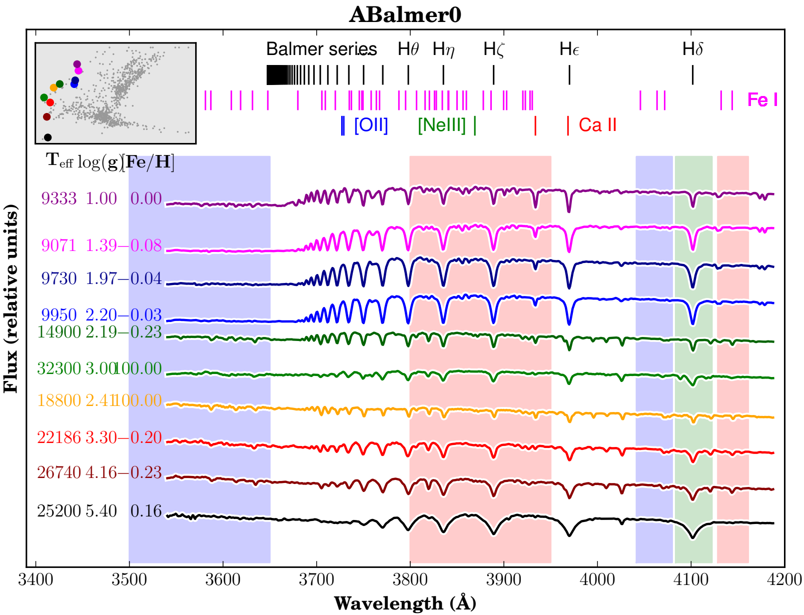
3.0
2.5
2.0
1.5
1.0
Dn4000
0.5
1.0
1.5
5040/Teff

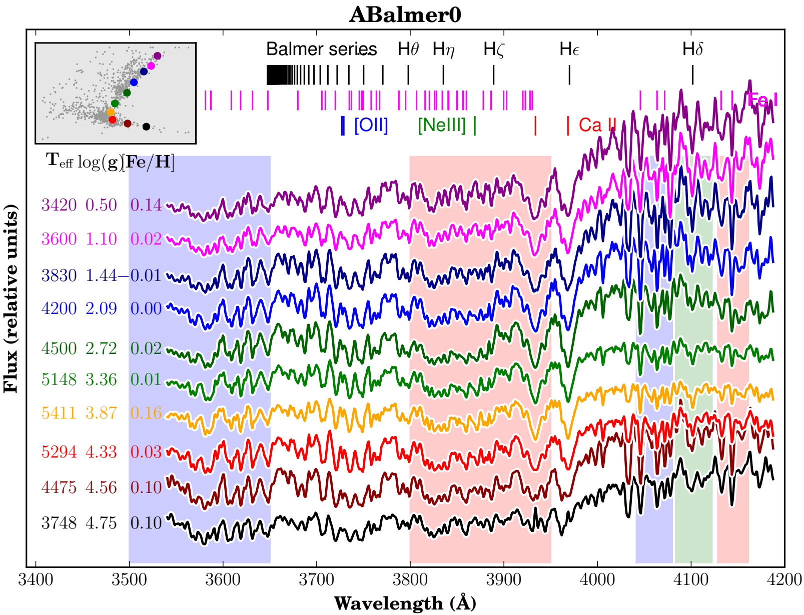

[Fe/H] < −1.75
−1.75 < [Fe/H] < −1.25
−1.25 < [Fe/H] < −0.75
−0.75 < [Fe/H] < −0.25
−0.25 < [Fe/H] < +0.25
[Fe/H] > +0.25
unknown
HdA
5040/Teff
15
10
5
0
−5
−10
0.5
1.0
1.5

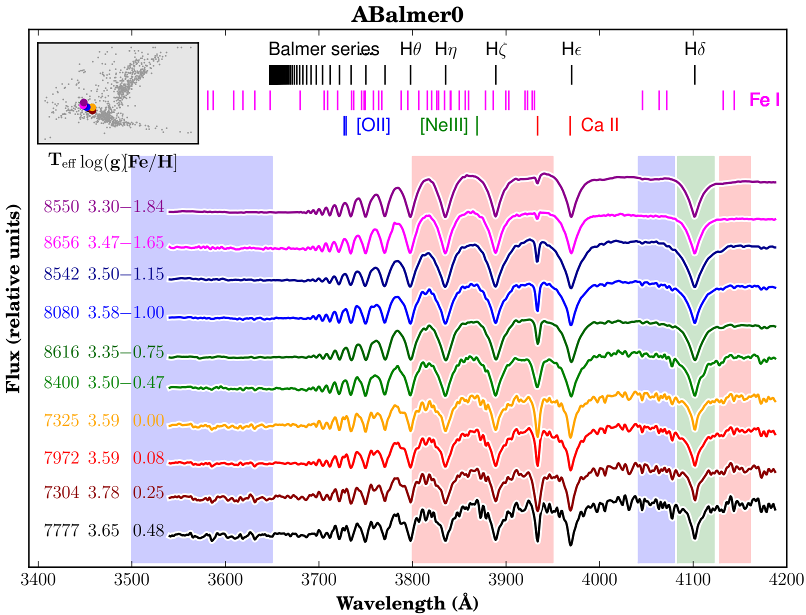

ABalmer0
Balmer series
Hθ
Hη
Hζ
Hϵ
Hδ
Fe I
[OII]
[NeIII]
Ca II
Teff log(g)[Fe/H]
17360 3.38 −0.01
13320 3.64 0.03
10675 3.65 −0.05
7701 4.09 0.06
6622 4.28 0.13
6630 4.16 0.00
5657 4.45 0.13
5117 4.54 0.11
4465 4.61 0.09
3748 4.75 0.10
Flux (relative units)
3400
3500
3600
3700
3800
3900
4000
4100
4200
Wavelength (Å)


ABalmer0
Balmer series
Hθ Hη Hζ Hϵ Hδ
Fe I
[OII]
[NeIII]
Ca II
Teff log(g) [Fe/H]
9333 1.00 0.00
9071 1.39 −0.08
9730 1.97 −0.04
9950 2.20 −0.03
9540 3.00 0.12
9164 3.30 −0.25
9164 3.70 0.14
8850 3.80 0.13
9164 4.30 0.17
9509 4.50 0.01
Flux (relative units)
3400 3500 3600 3700 3800 3900 4000 4100 4200
Wavelength (Å)

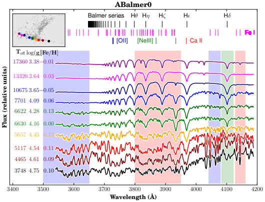

ABalmer0
Balmer series
Hθ
Hη
Hζ
Hϵ
Hδ
Fe I
[OII]
[NeIII]
Ca II
Teff log(g)[Fe/H]
4990 1.50 0.17
5038 2.50 0.03
5028 2.70 0.03
5041 3.04 −0.04
5050 3.49 −0.10
5055 3.30 −0.48
5080 3.94 −0.67
5073 4.19 −0.31
5051 4.45 −0.17
5031 4.65 −0.10
Flux (relative units)
3400
3500
3600
3700
3800
3900
4000
4100
4200
Wavelength (Å)

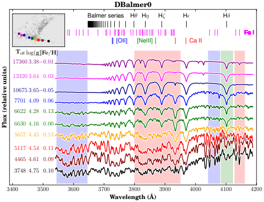

ABalmer0
Balmer series
Hθ
Hη
Hζ
Hϵ
Hδ
Fe I
[OII]
[NeIII]
Ca II
Teff log(g)[Fe/H]
9333 1.00 0.00
9071 1.39−0.08
9730 1.97−0.04
9950 2.20−0.03
14900 2.19−0.23
32300 3.00100.00
18800 2.41100.00
22186 3.30−0.20
26740 4.16−0.23
25200 5.40 0.16
Flux (relative units)
3400 3500 3600 3700 3800 3900 4000 4100 4200
Wavelength (Å)

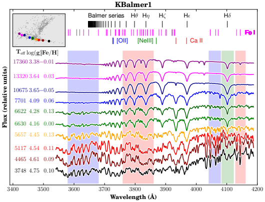

ABalmer0
Balmer series
Hθ
Hη
Hζ
Hϵ
Hδ
Fe I
[OII]
[NeIII]
Ca II
Teff log(g)[Fe/H]
3420 0.50 0.14
3600 1.10 0.02
3830 1.44 −0.01
4200 2.09 0.00
4500 2.72 0.02
5148 3.36 0.01
5411 3.87 0.16
5294 4.33 0.03
4475 4.56 0.10
3748 4.75 0.10
Flux (relative units)
3400
3500
3600
3700
3800
3900
4000
4100
4200
Wavelength (Å)

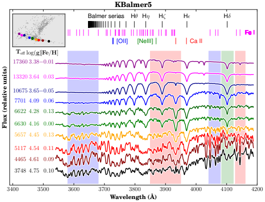

ABalmer0
Balmer series
Hθ Hη Hζ Hϵ Hδ
Fe I
[OII]
[NeIII]
Ca II
Teff log(g)[Fe/H]
8550 3.30 −1.84
8656 3.47 −1.65
8542 3.50 −1.15
8080 3.58 −1.00
8616 3.35 −0.75
8400 3.50 −0.47
7325 3.59 0.00
7972 3.59 0.08
7304 3.78 0.25
7777 3.65 0.48
Flux (relative units)
3400 3500 3600 3700 3800 3900 4000 4100 4200
Wavelength (Å)

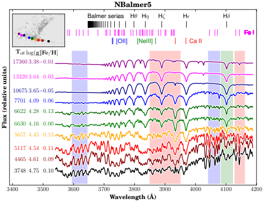
Time to play with the bandpass limits. . .

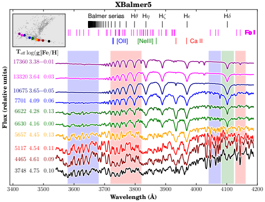


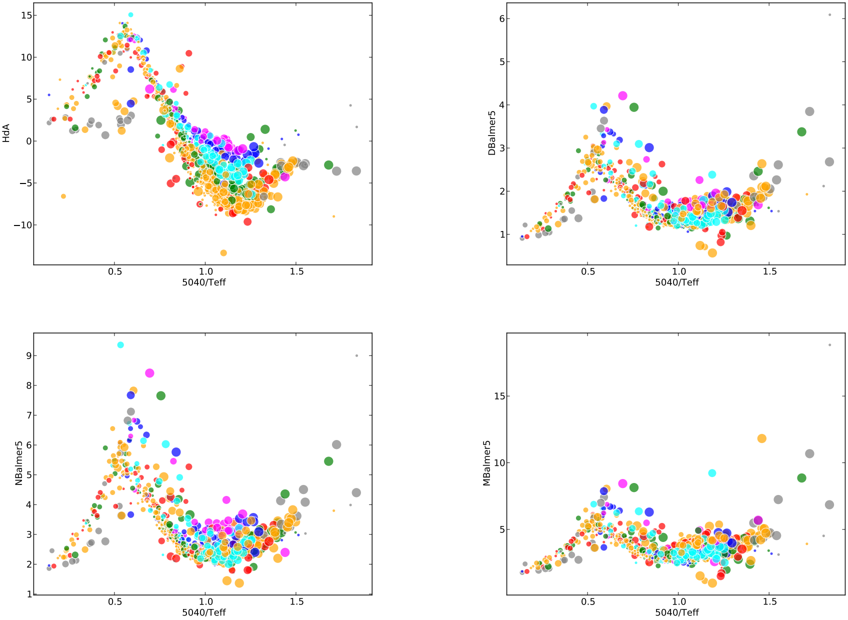


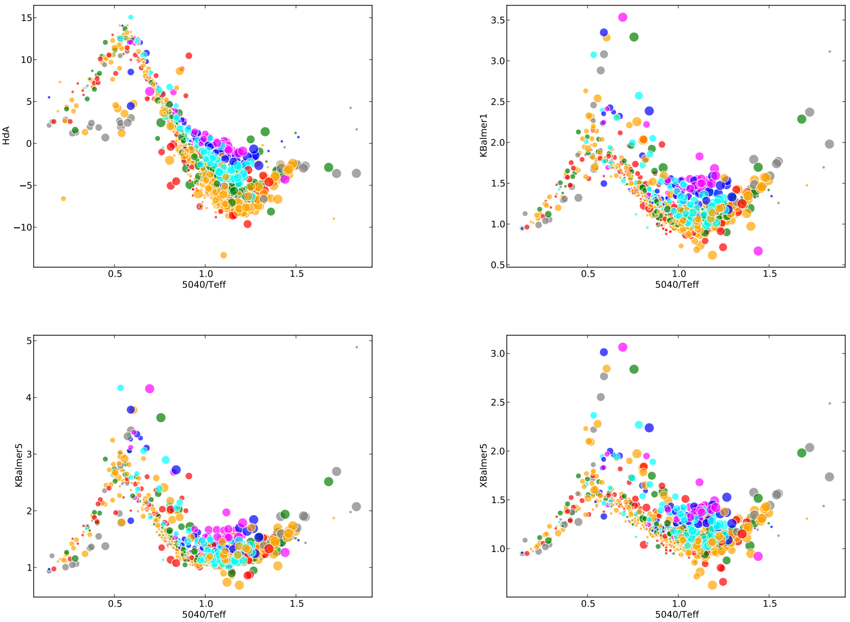




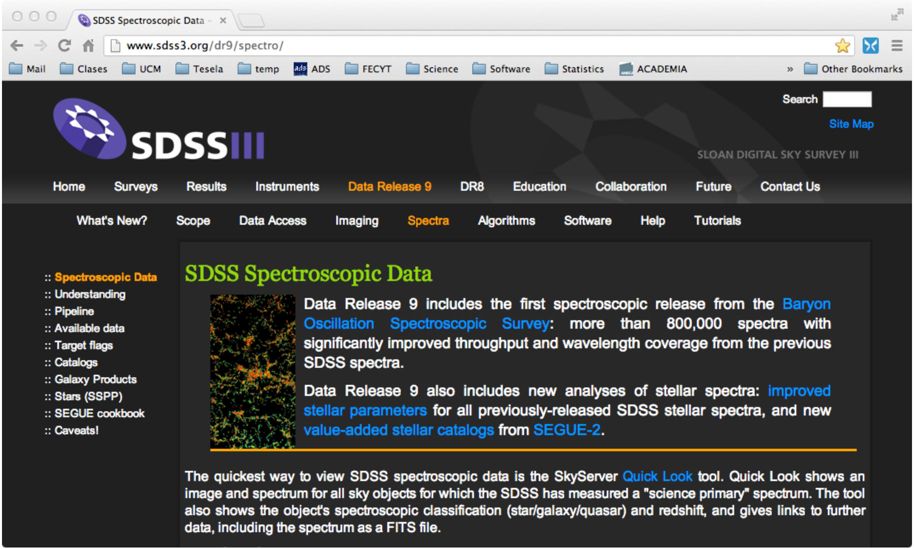





HdA
15
10
5
0
−5
−10
0.5
1.0
1.5
5040/Teff
DBalmer5
6
5
4
3
2
1
0.5
1.0
1.5
5040/Teff
NBalmer5
9
8
7
6
5
4
3
2
1
0.5
1.0
1.5
5040/Teff
MBalmer5
15
10
5
0.5
1.0
1.5
5040/Teff

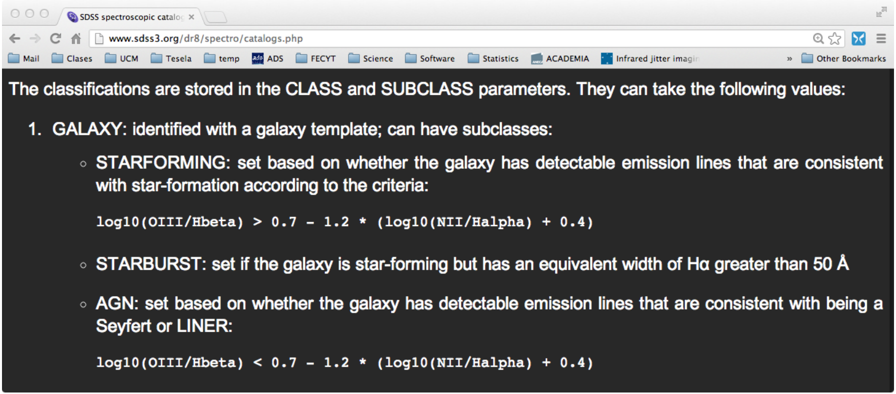

HdA
5040/Teff
KBalmer1
5040/Teff
KBalmer5
5040/Teff
XBalmer5
5040/Teff

Outline


SDSS Spectroscopic Data
www.sdss3.org/dr9/spectro/
Mail
Clases
UCM
Tesela
temp
ADS
FECYT
Science
Software
Statistics
ACADEMIA
Other Bookmarks
Search
Site Map
SDSS III
SLOAN DIGITAL SKY SURVEY III
Home
Surveys
Results
Instruments
Data Release 9
DR8
Education
Collaboration
Future
Contact Us
What's New?
Scope
Data Access
Imaging
Spectra
Algorithms
Software
Help
Tutorials
:: Spectroscopic Data
:: Understanding
:: Pipeline
:: Available data
:: Target flags
:: Catalogs
:: Galaxy Products
:: Stars (SSPP)
:: SEGUE cookbook
:: Caveats!
SDSS Spectroscopic Data
Data Release 9 includes the first spectroscopic release from the Baryon Oscillation Spectroscopic Survey: more than 800,000 spectra with significantly improved throughput and wavelength coverage from the previous SDSS spectra.
Data Release 9 also includes new analyses of stellar spectra: improved stellar parameters for all previously-released SDSS stellar spectra, and new value-added stellar catalogs from SEGUE-2.
The quickest way to view SDSS spectroscopic data is the SkyServer Quick Look tool. Quick Look shows an image and spectrum for all sky objects for which the SDSS has measured a "science primary" spectrum. The tool also shows the object's spectroscopic classification (star/galaxy/quasar) and redshift, and gives links to further data, including the spectrum as a FITS file.

SELECT s.plate, s.mjd, s.fiberid
FROM BESTDR9..SpecObj as s
WHERE s.zWarning=0 AND (s.class='GALAXY')

$\longrightarrow \quad > 1.3 \times 10^6$ galaxies!



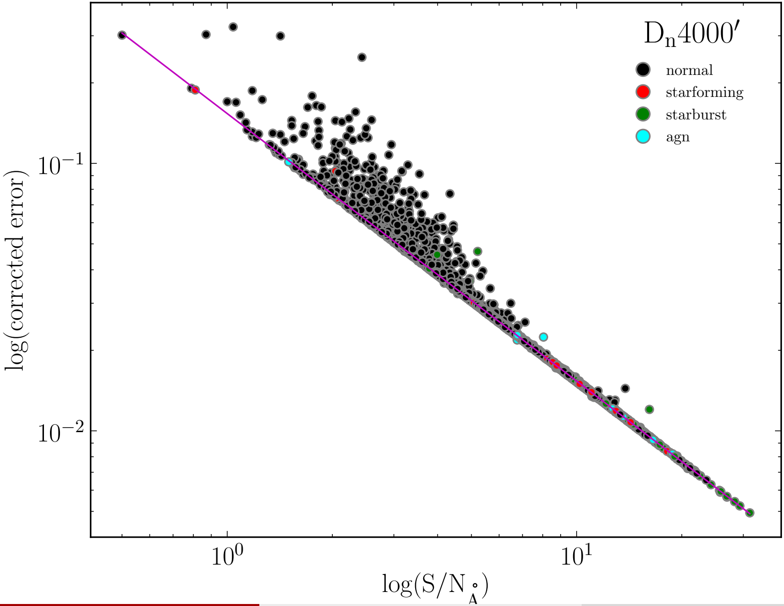
The classifications are stored in the CLASS and SUBCLASS parameters. They can take the following values:

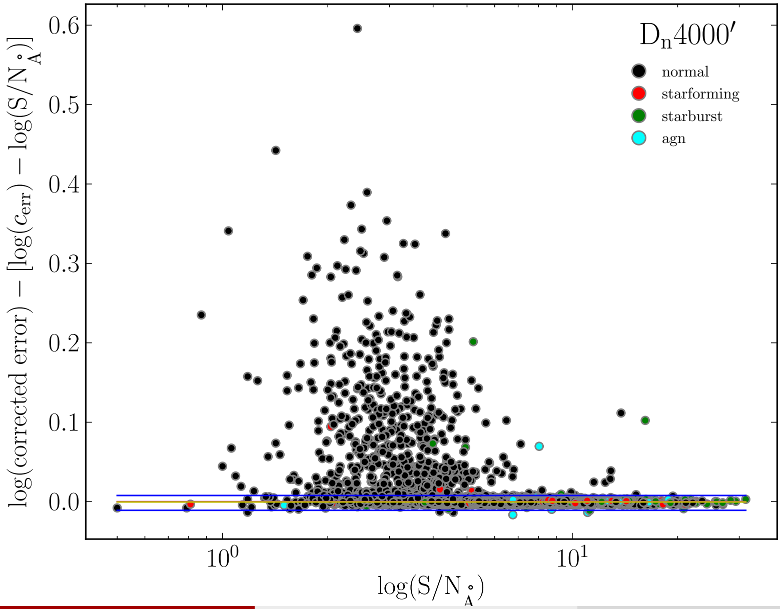
1. GALAXY: identified with a galaxy template; can have subclasses:
   - STARFORMING: set based on whether the galaxy has detectable emission lines that are consistent with star-formation according to the criteria:

     ```
     log10(OIII/Hbeta) > 0.7 - 1.2 * (log10(NII/Halpha) + 0.4)
     ```

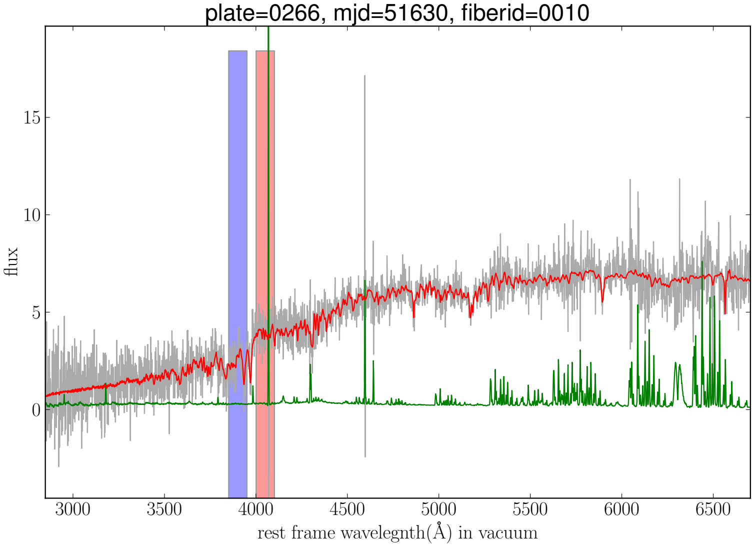
   - STARBURST: set if the galaxy is star-forming but has an equivalent width of Hα greater than 50 Å
   - AGN: set based on whether the galaxy has detectable emission lines that are consistent with being a Seyfert or LINER:

     ```
     log10(OIII/Hbeta) < 0.7 - 1.2 * (log10(NII/Halpha) + 0.4)
     ```


D_n4000'
normal
starforming
starburst
agn
10^{-1}
10^{-2}
log(corrected error)
10^{0}
10^{1}
log(S/N Å)



D_n4000'
normal
starforming
starburst
agn
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10^0
10^1
$\log(\text{corrected error}) - [\log(c_{err}) - \log(S/N_{\AA})]$
$\log(S/N_{\AA})$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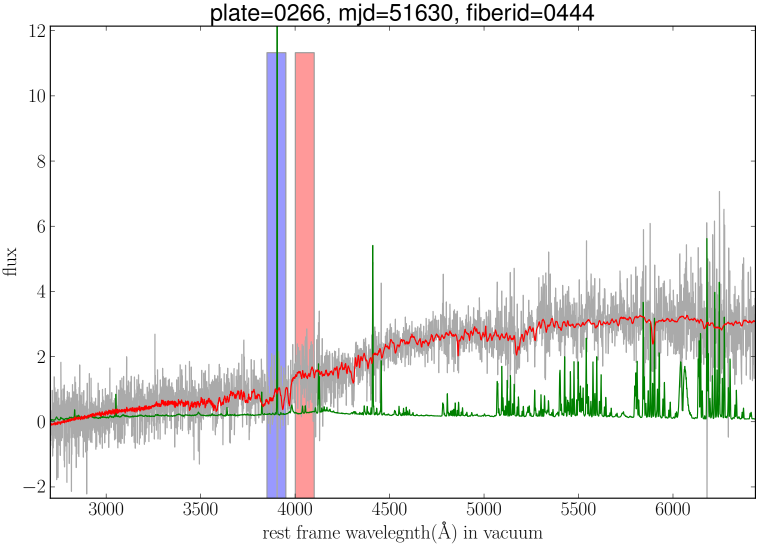
flux
15
10
5
0
3000
3500
4000
4500
5000
5500
6000
6500
rest frame wavelegnth(Å) in vacuum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12
10
8
6
4
2
0
−2
flux
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3500
4000
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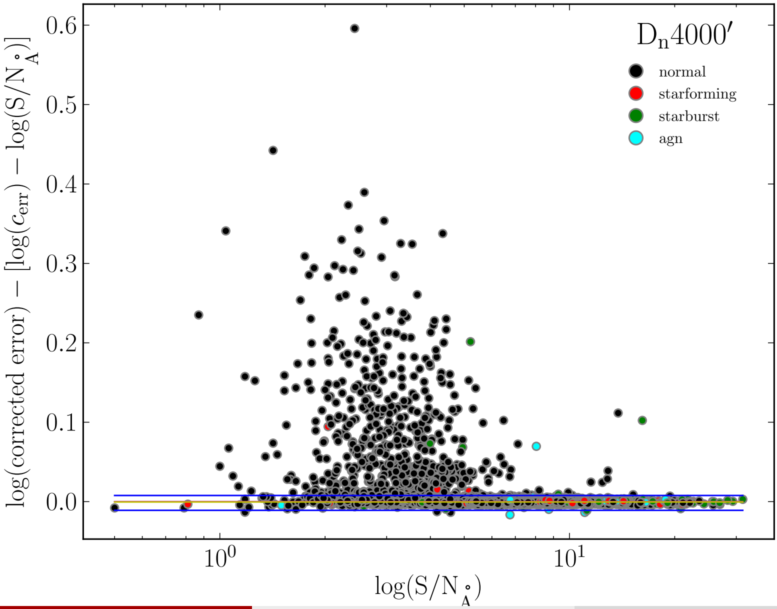
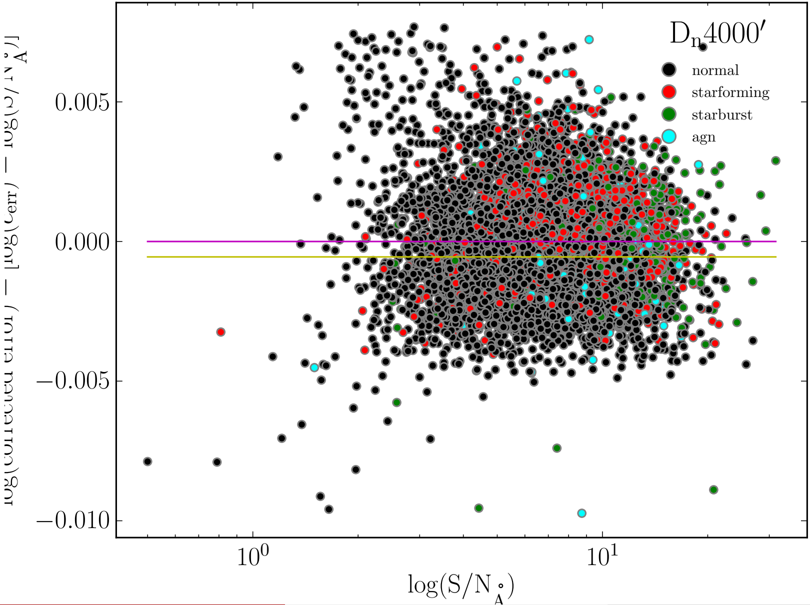
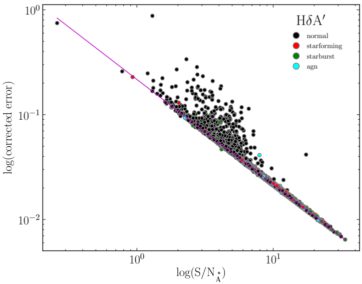
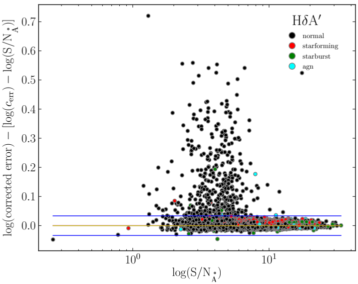
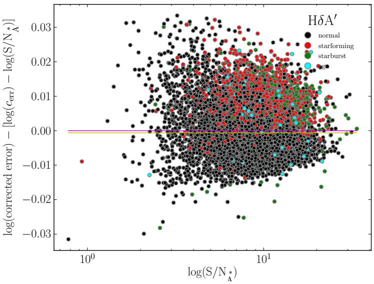
5000
5500
6000
rest frame wavelegnth(Å) in vacuum

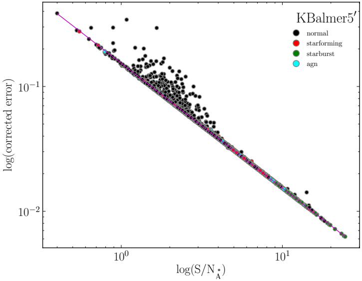

D_n4000'
normal
starforming
starburst
agn
$\log(\text{corrected error}) - [\log(c_{err}) - \log(S/N_{Å})]$
$\log(S/N_{Å})$
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10^0
10^1

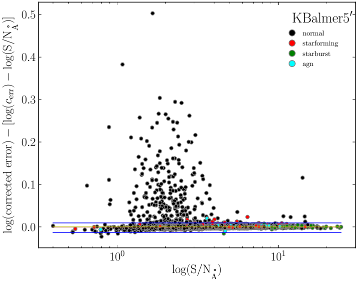

D_n4000'
normal
starforming
starburst
agn
0.005
0.000
−0.005
−0.010
10^0
10^1
$\log(S/N_{\AA})$

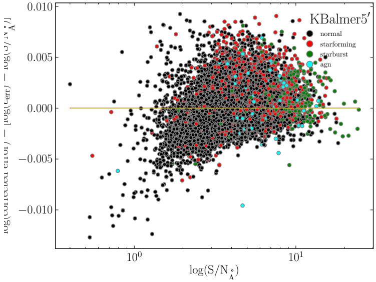

HδA′
normal
starforming
starburst
agn
log(corrected error)
log(S/N)

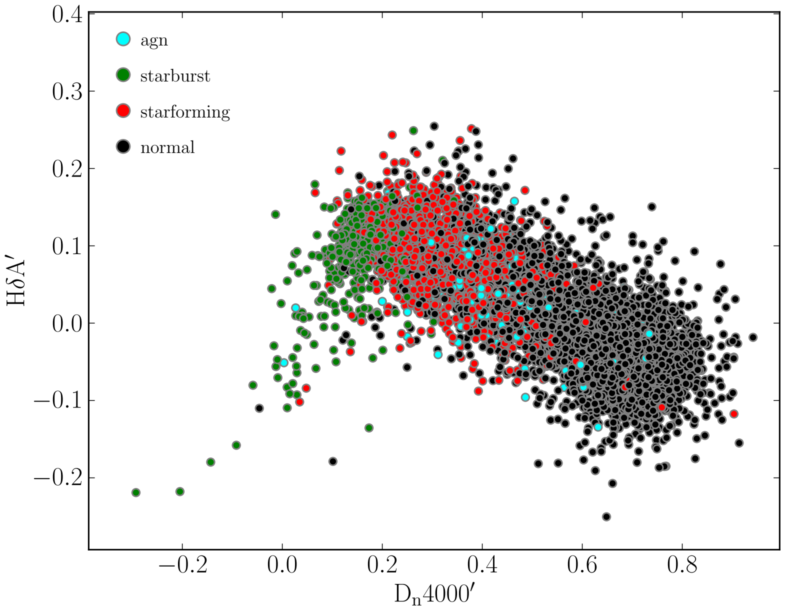

HδA′
normal
starforming
starburst
agn
log(corrected error) − [log(c_err) − log(S/N)]
log(S/N)

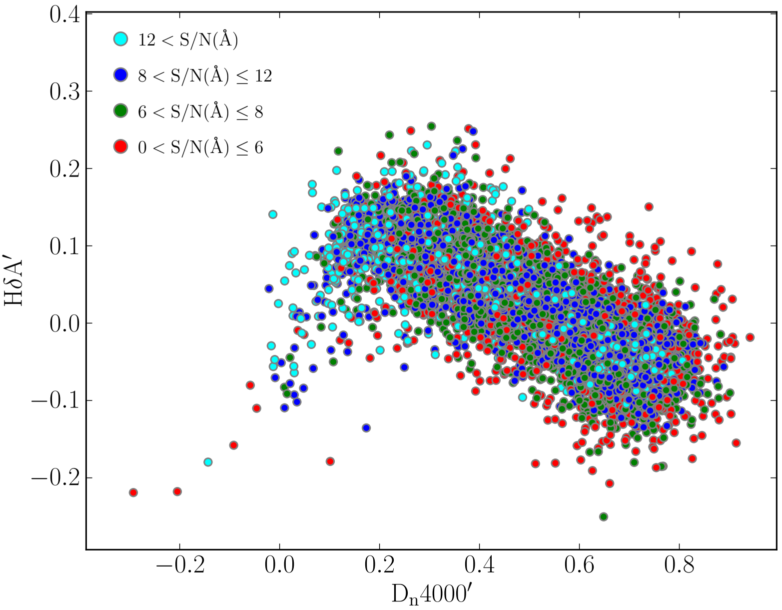

HδA′
normal
starforming
starburst
log(corrected error) − [log(c_err) − log(S/N)]
log(S/N)

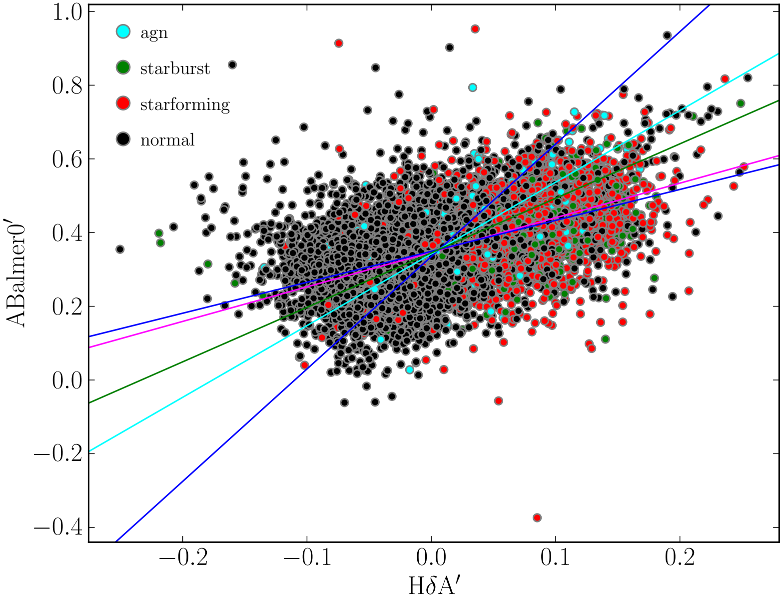

KBalmer5′
normal
starforming
starburst
agn
log(corrected error)
log(S/N$_{Å}$)
10^{-1}
10^{-2}
10^{0}
10^{1}

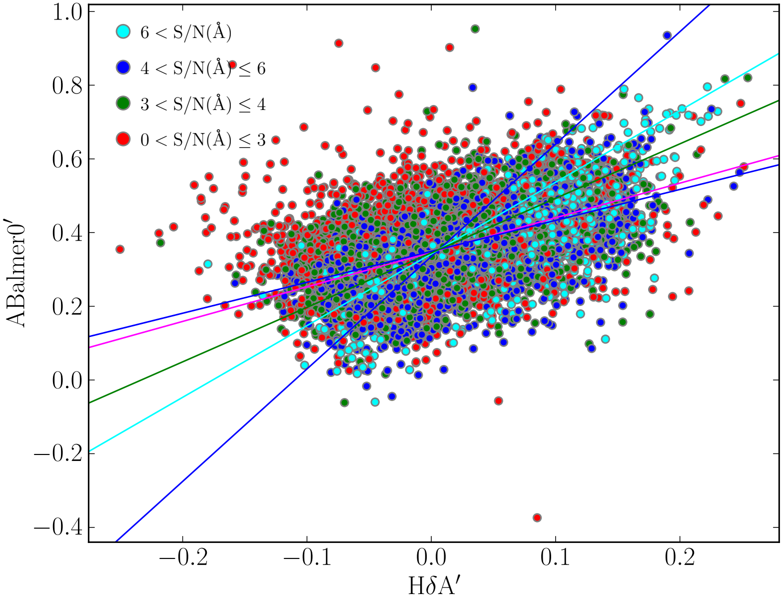

KBalmer5′
normal
starforming
starburst
agn
log(corrected error) − [log(c_{err}) − log(S/N$_{Å}$)]
log(S/N$_{Å}$)
0.5
0.4
0.3
0.2
0.1
0.0
10^{0}
10^{1}

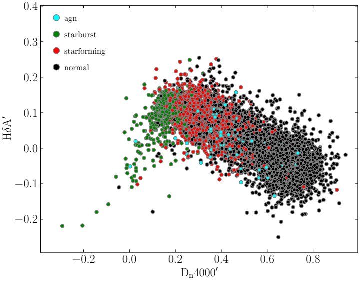

KBalmer5′
normal
starforming
starburst
agn
log(S/N$_{Å}$)
0.010
0.005
0.000
−0.005
−0.010
10^{0}
10^{1}

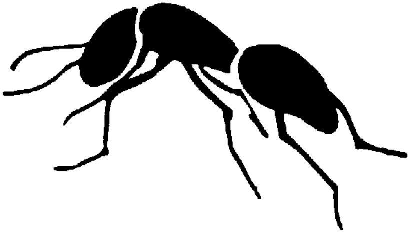

agn
starburst
starforming
normal
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
HδA′
−0.2
0.0
0.2
0.4
0.6
0.8
Dn4000′

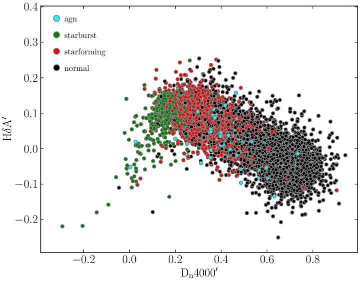

12 < S/N(Å)
8 < S/N(Å) ≤ 12
6 < S/N(Å) ≤ 8
0 < S/N(Å) ≤ 6
HδA′
Dn4000′
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.2
0.0
0.2
0.4
0.6
0.8

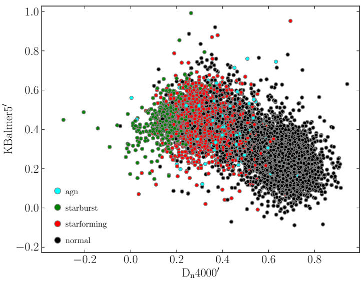

agn
starburst
starforming
normal
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
ABalmer0′
−0.2
−0.1
0.0
0.1
0.2
HδA′

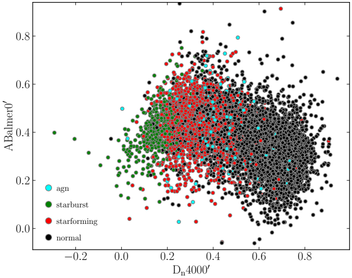

6 < S/N(Å)
4 < S/N(Å) ≤ 6
3 < S/N(Å) ≤ 4
0 < S/N(Å) ≤ 3
ABalmer0′
HδA′
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.2
−0.1
0.0
0.1
0.2

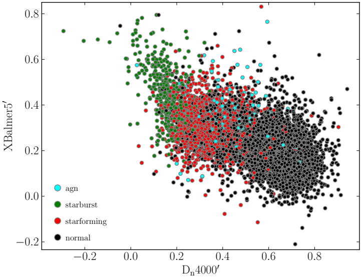

agn
starburst
starforming
normal
HδA′
D_n4000'
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.2
0.0
0.2
0.4
0.6
0.8

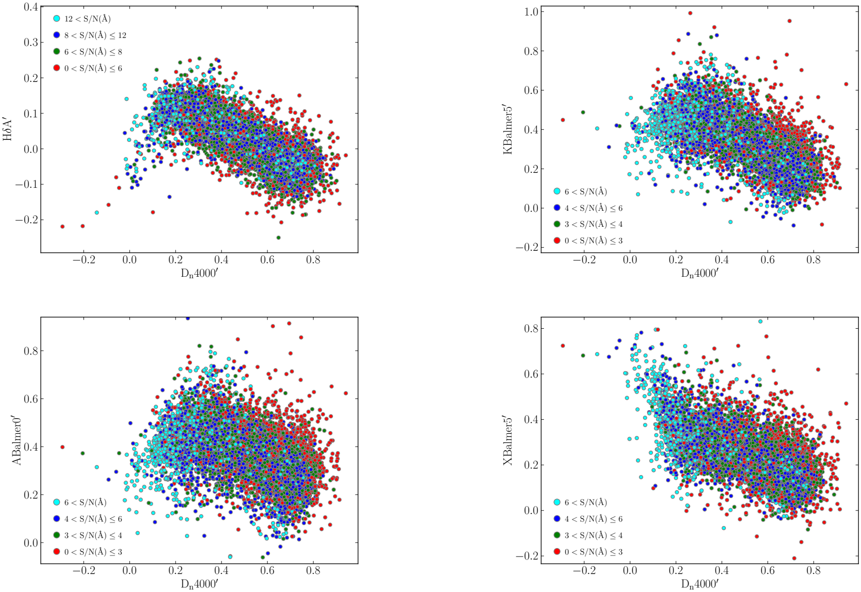


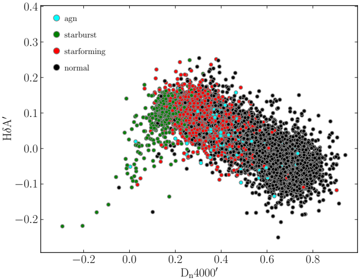

agn
starburst
starforming
normal
$H\delta A'$
D_n4000'

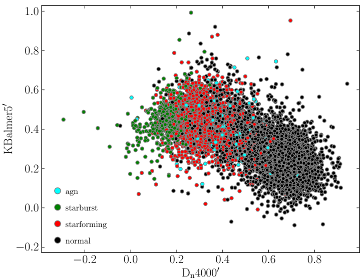

agn
starburst
starforming
normal
KBalmer5′
D_n4000'

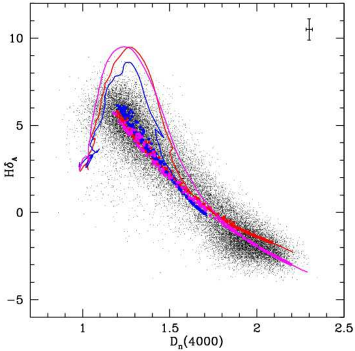

agn
starburst
starforming
normal
ABalmer0′
D_n4000'


agn
starburst
starforming
normal
XBalmer5′
D_n4000'


HδA′
Dn4000′
12 < S/N(Å)
8 < S/N(Å) ≤ 12
6 < S/N(Å) ≤ 8
0 < S/N(Å) ≤ 6
KBalmer5′
ABalmer0′
XBalmer5′
6 < S/N(Å)
4 < S/N(Å) ≤ 6
3 < S/N(Å) ≤ 4
0 < S/N(Å) ≤ 3







$\Rightarrow$ The Balmer break may constitute a good alternative to HδA for spectra with the spectral resolution of SHARDS.