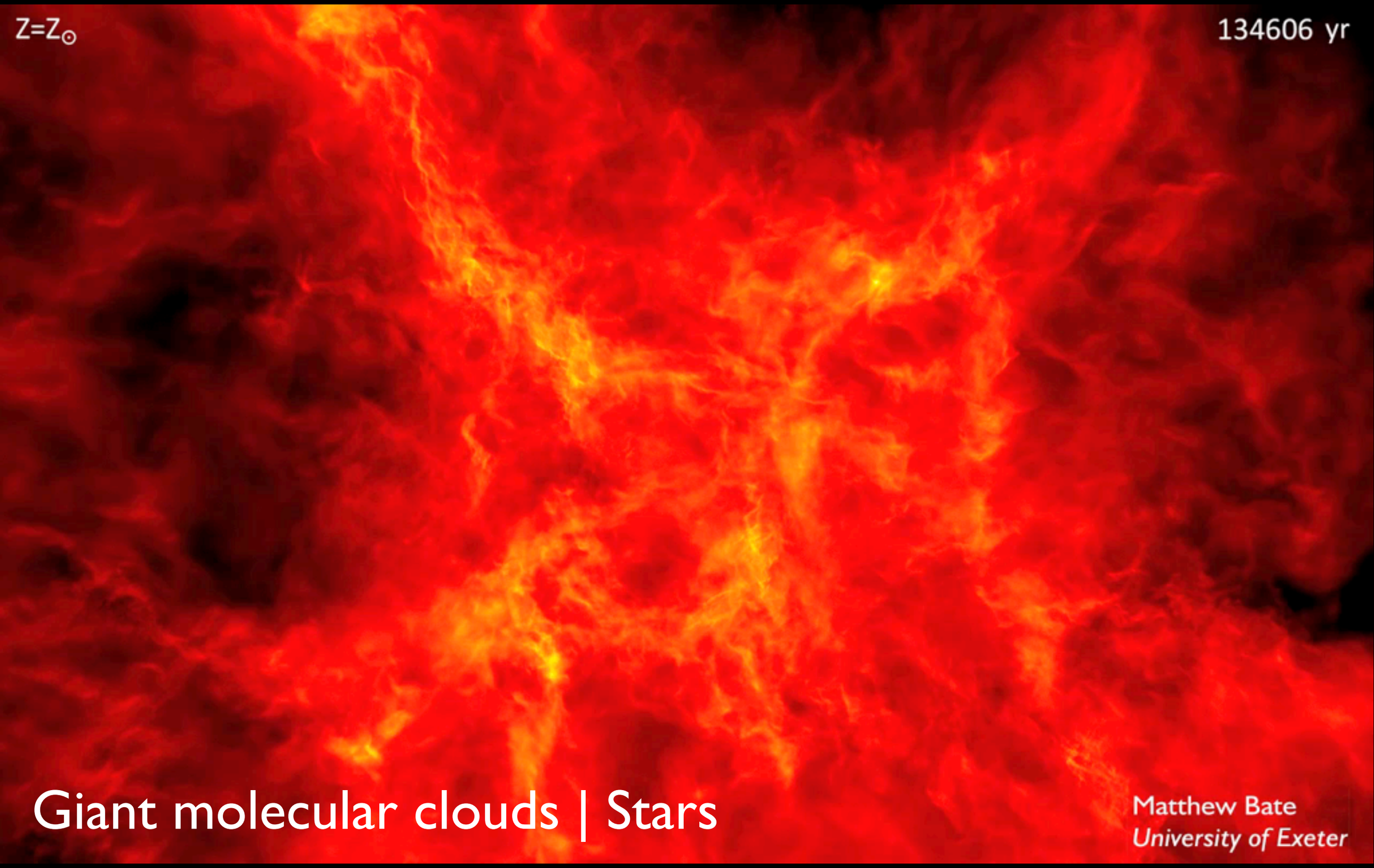
Chemical tagging with Open Clusters

S. Blanco-Cuaresma
C. Soubiran, U. Heiter



Giant molecular clouds | Stars

Matthew Bate
University of Exeter

Chemical enrichment | Metallicity

F.I. Pelupessy

Stellar clusters | Disruption

Chemical Tagging

Do stars born together have a unique chemical signature?

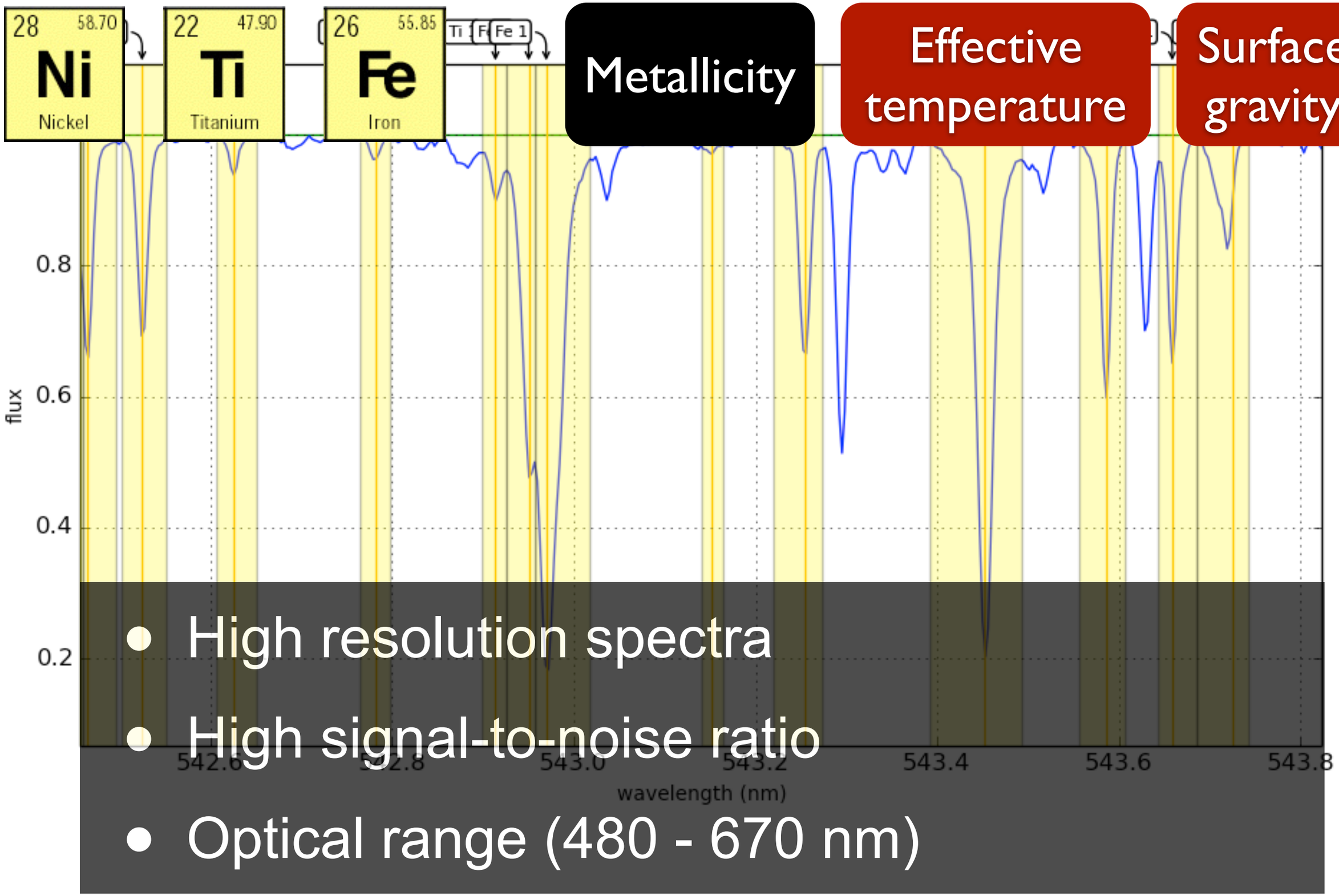
Are the chemical signatures different enough to distinguish stars formed from different molecular clouds?

OC

The experiment

Abundances

Atmospheric parameters



- High resolution spectra
- High signal-to-noise ratio
- Optical range (480 - 670 nm)

OC

The experiment

- High resolution spectra: R > 47,000 || SNR >= 40
  - NARVAL @ TBL (Pic du Midi, France)
  - HARPS @ ESO's 3.6m telescope (La Silla, Chile)
  - UVES @ VLT (Cerro Paranal, Chile)

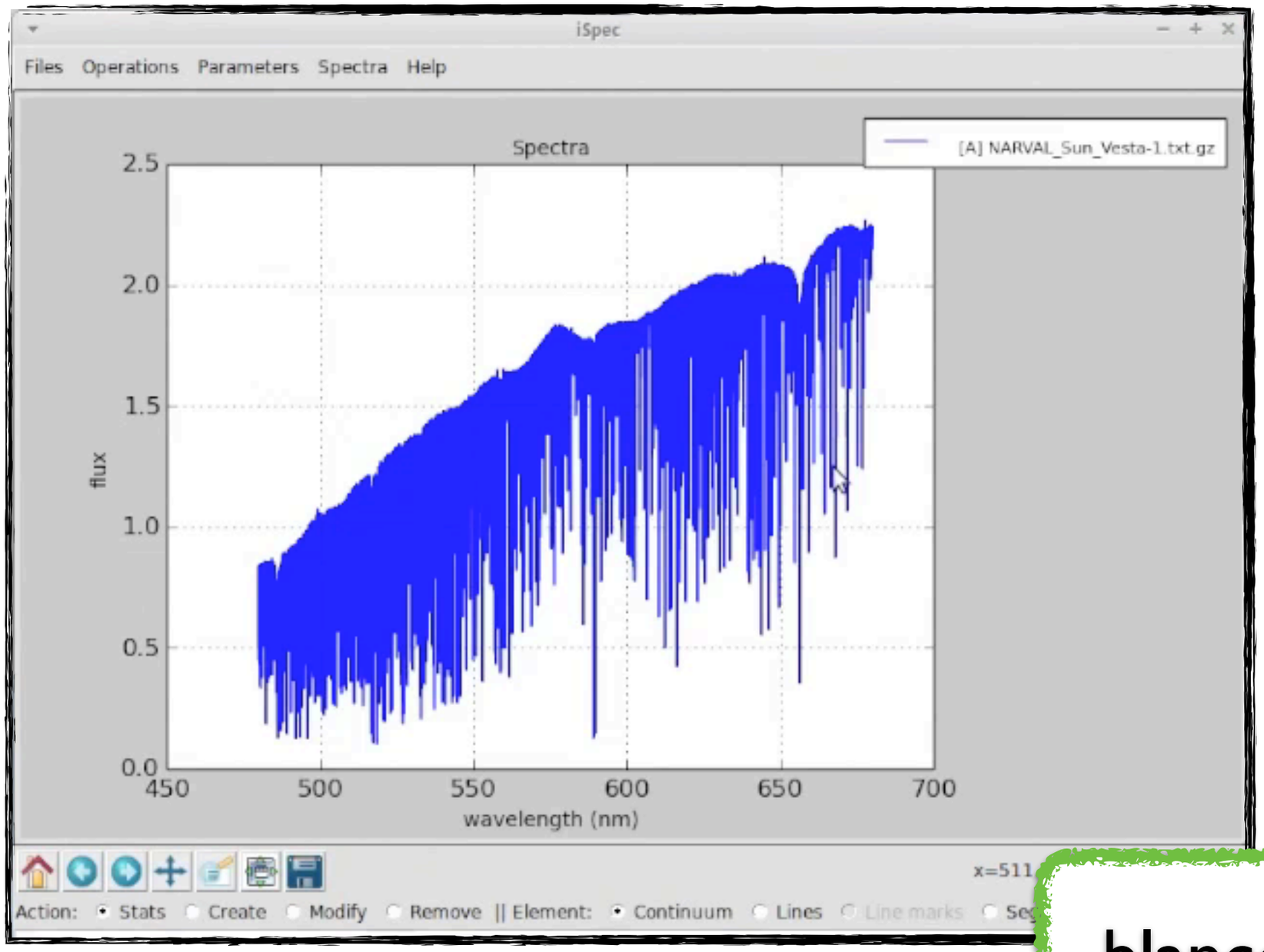
32

clusters

189 stars

iSpec

Visual interface + Python

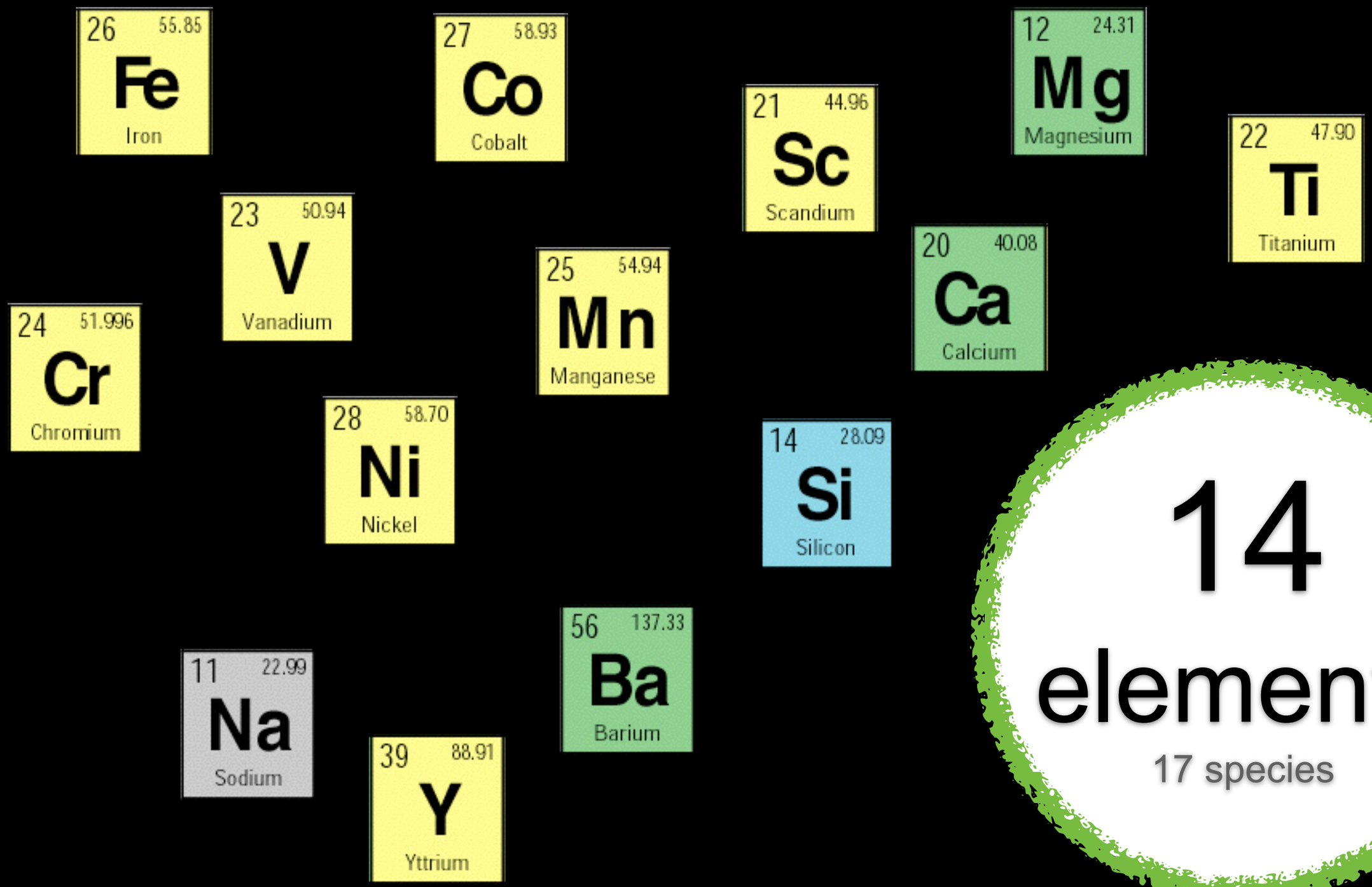


Determining stellar atmospheric parameters and chemical abundances of FGK stars with iSpec (Blanco-Cuaresma et al. 2014a)

blancocuaresma.com/s/

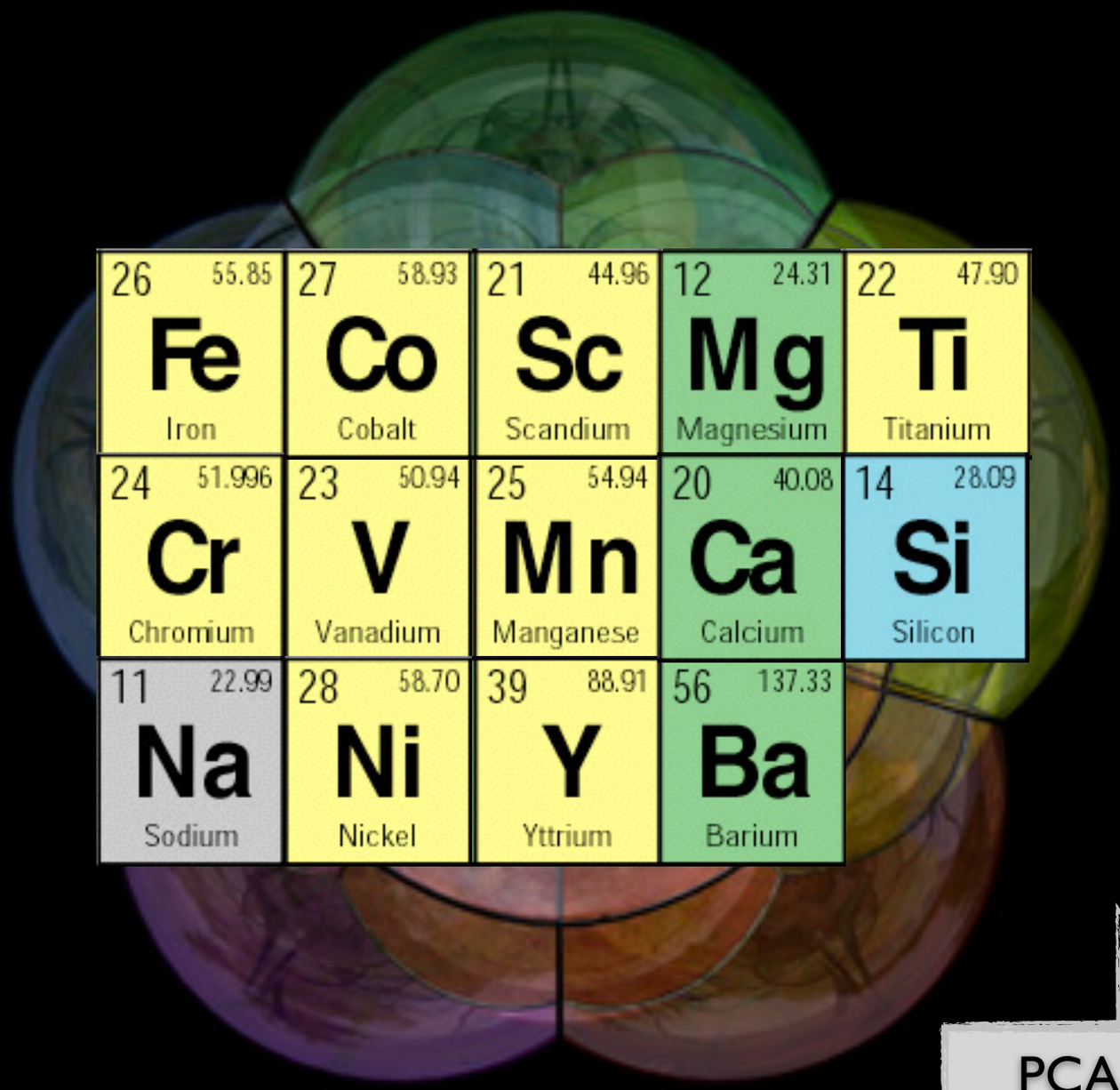
OC

The experiment



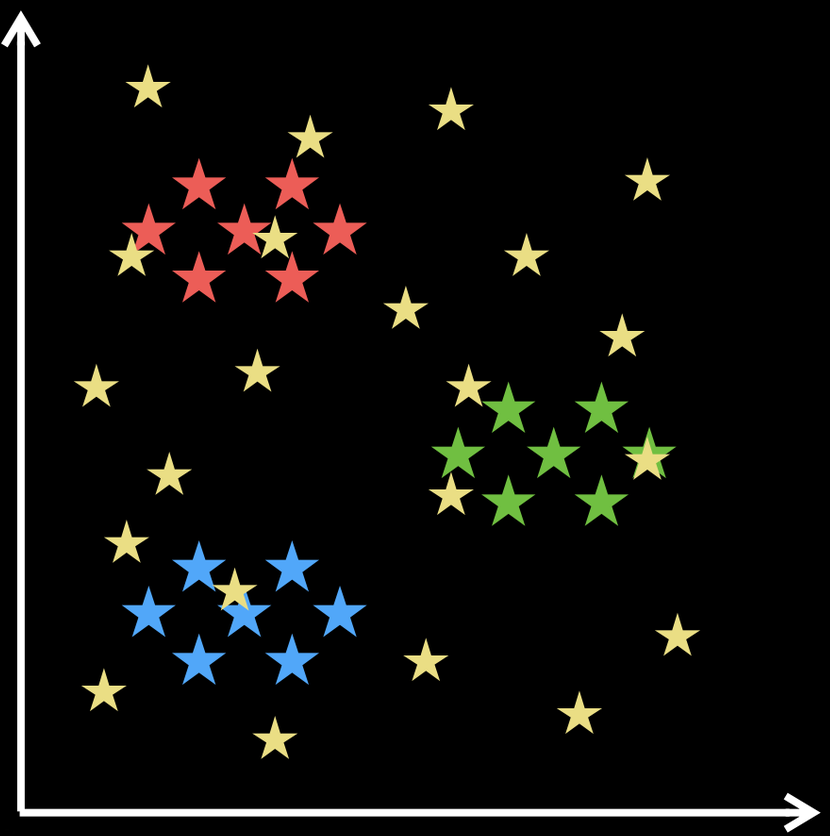
OC

Principal Component Analysis



17 dimensions

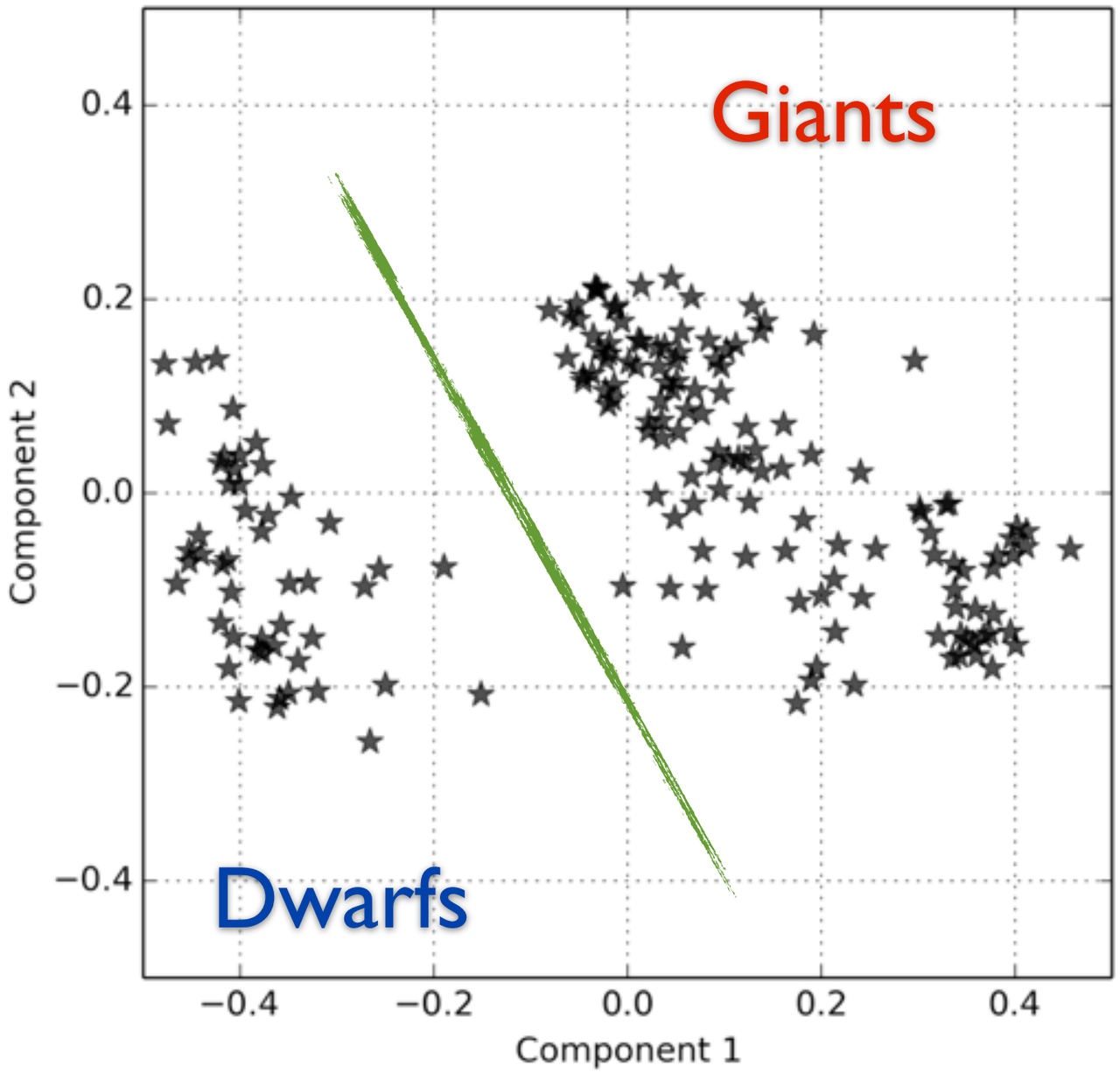
PCA



2 dimensions

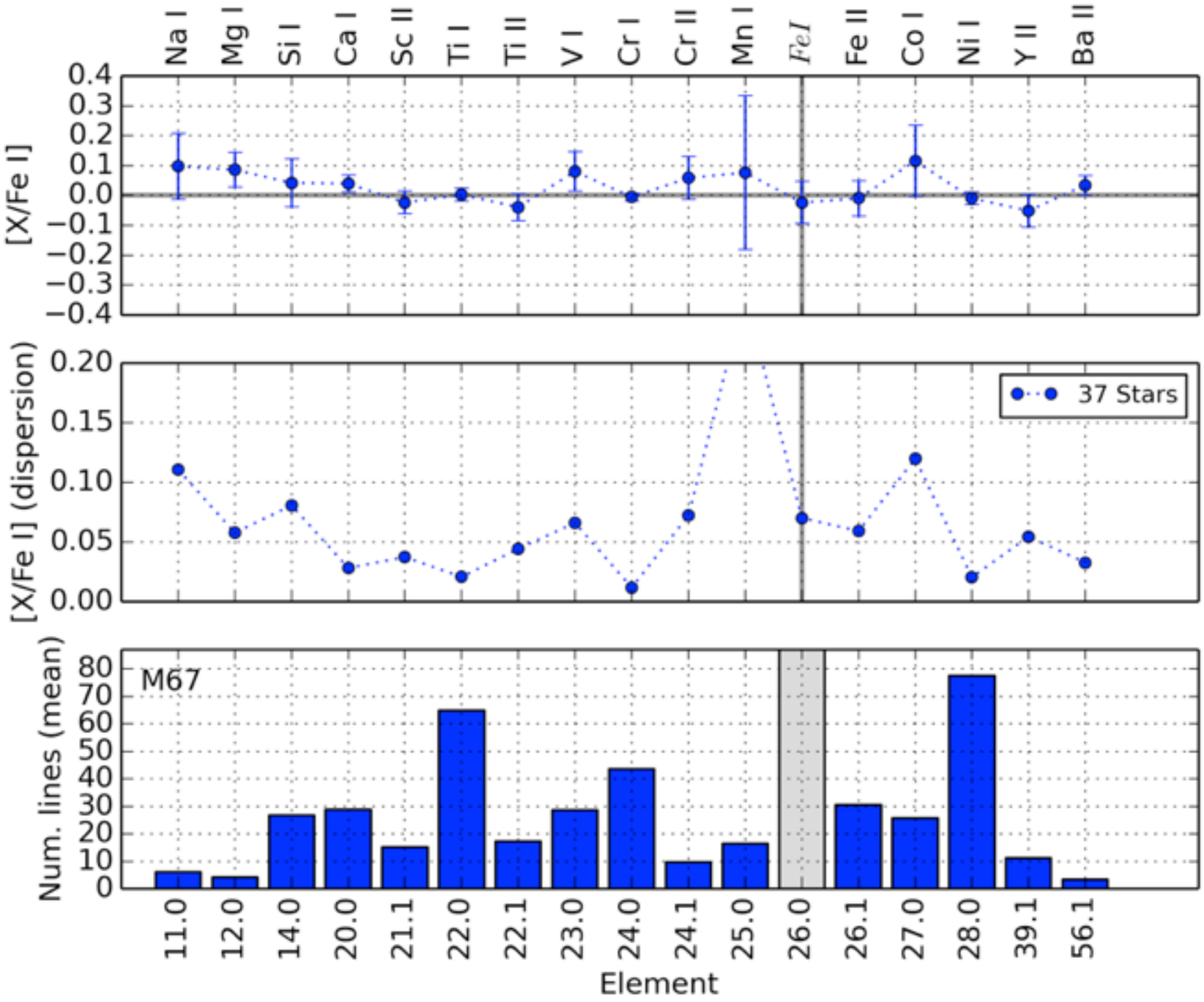
OC

Principal Component Analysis



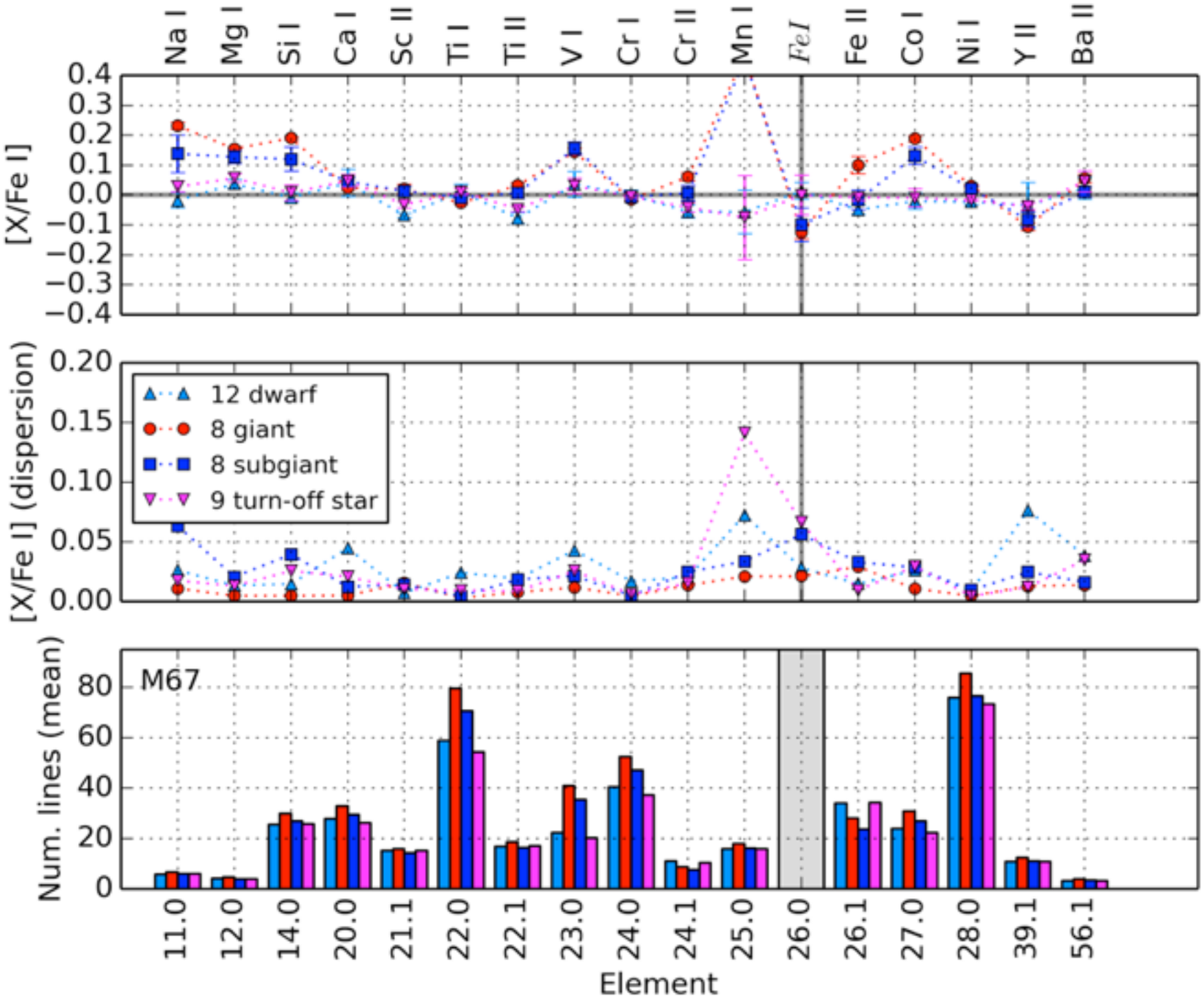
OC

M67


Na I
Mg I
Si I
Ca I
Sc II
Ti I
Ti II
V I
Cr I
Cr II
Mn I
FeI
Fe II
Co I
Ni I
Y II
Ba II
[X/Fe I]
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
[X/Fe I] (dispersion)
0.20
0.15
0.10
0.05
0.00
37 Stars
Num. lines (mean)
M67
80
70
60
50
40
30
20
10
0
11.0
12.0
14.0
20.0
21.1
22.0
22.1
23.0
24.0
24.1
25.0
26.0
26.1
27.0
28.0
39.1
56.1
Element

OC

M67


Na I
Mg I
Si I
Ca I
Sc II
Ti I
Ti II
V I
Cr I
Cr II
Mn I
FeI
Fe II
Co I
Ni I
Y II
Ba II
[X/Fe I]
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
[X/Fe I] (dispersion)
0.20
0.15
0.10
0.05
0.00
12 dwarf
8 giant
8 subgiant
9 turn-off star
Num. lines (mean)
M67
80
60
40
20
0
11.0
12.0
14.0
20.0
21.1
22.0
22.1
23.0
24.0
24.1
25.0
26.0
26.1
27.0
28.0
39.1
56.1
Element

Chemical Tagging

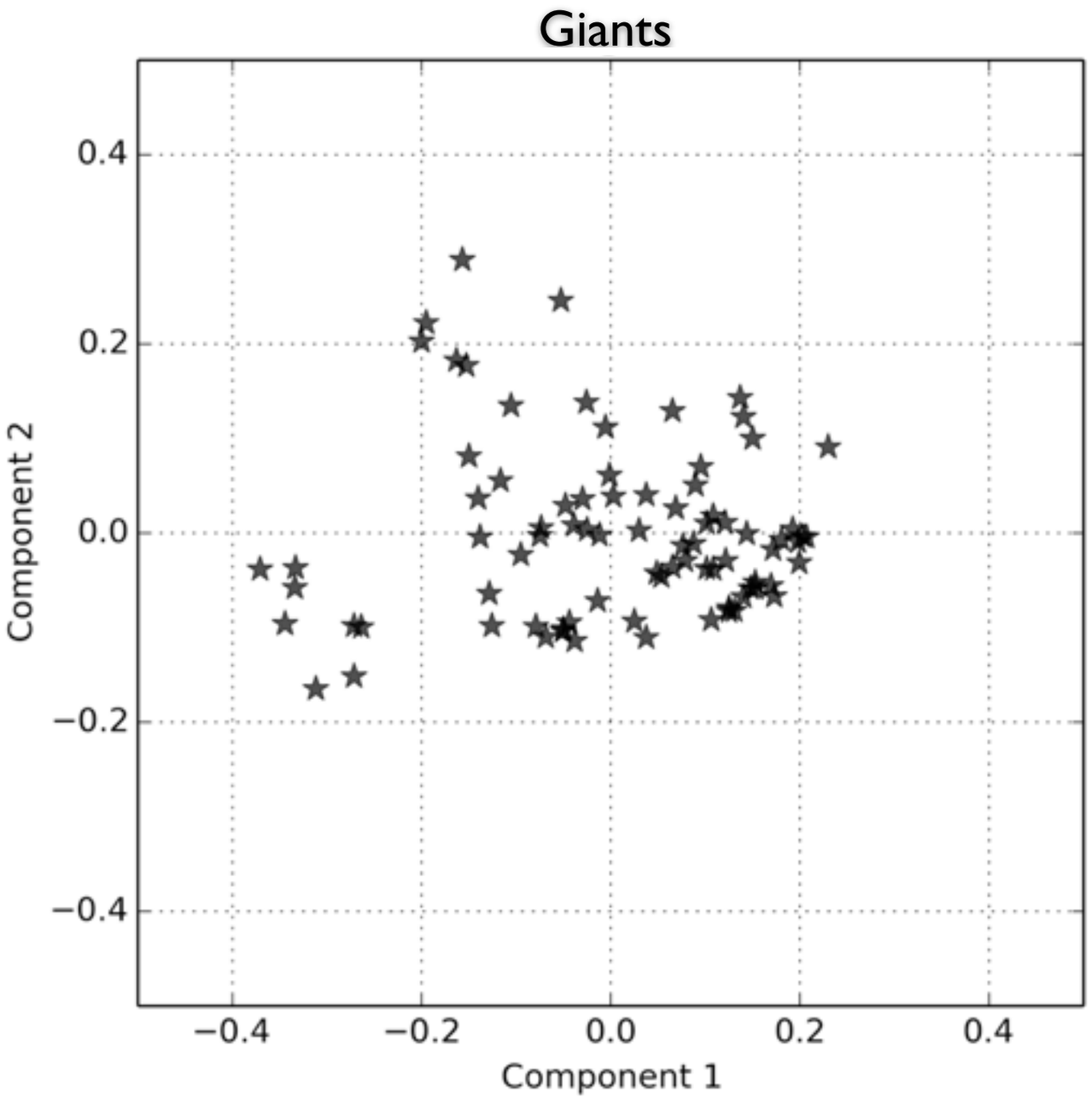
Do stars born together have a unique chemical signature?

Yes, but...

Are the chemical signatures different enough to distinguish stars formed from different molecular clouds?

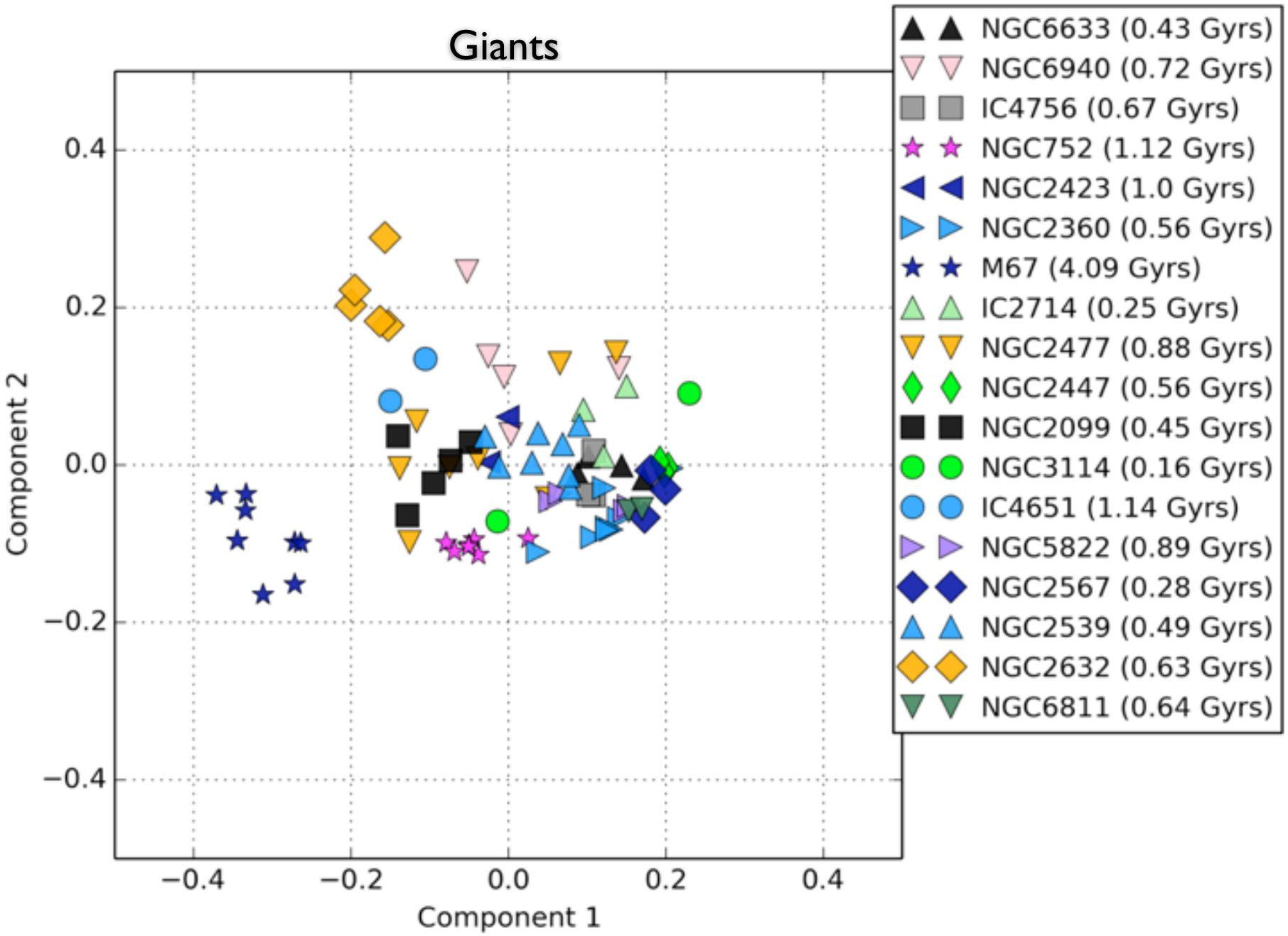
OC

Principal Component Analysis



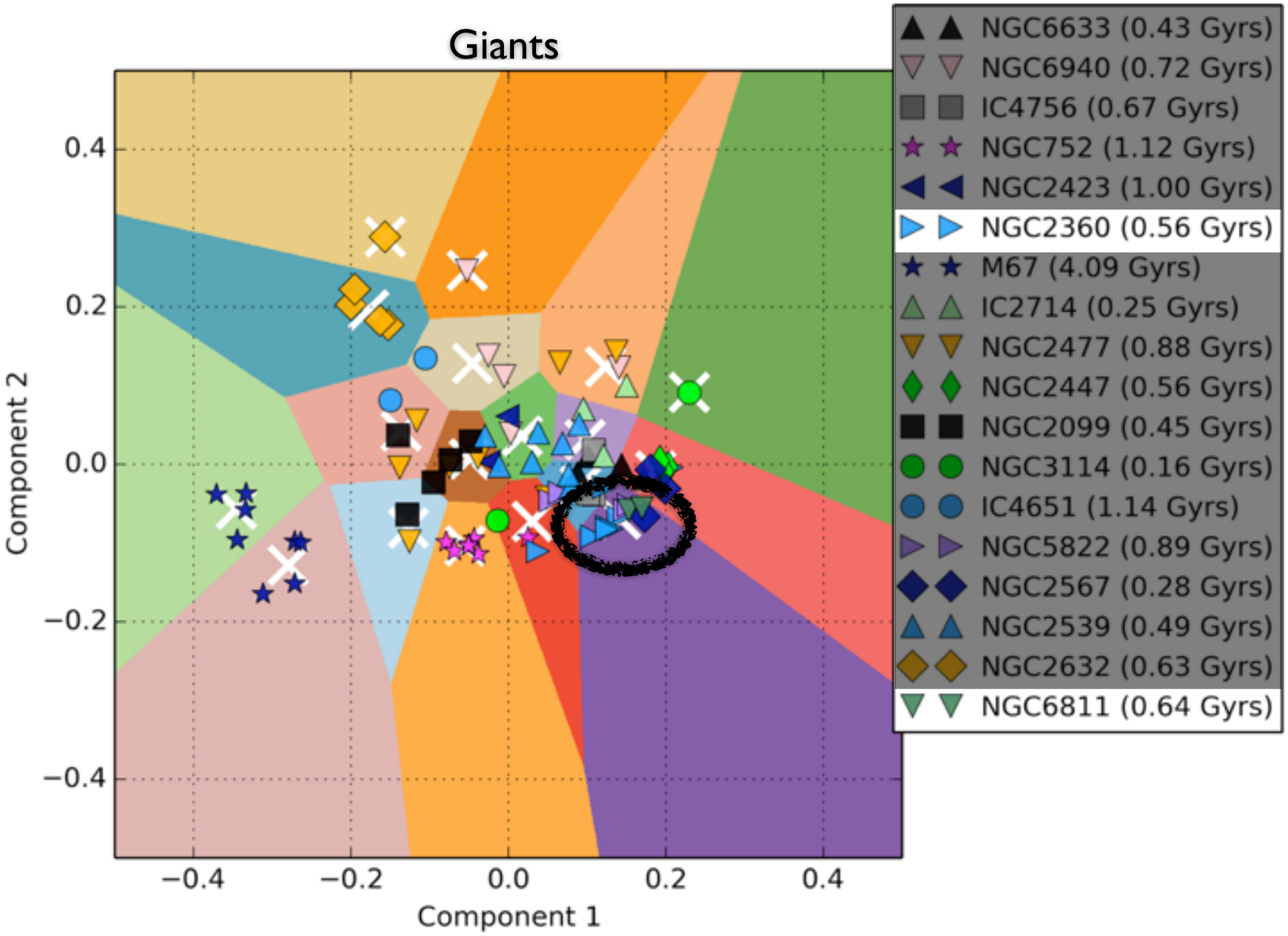
OC

Principal Component Analysis



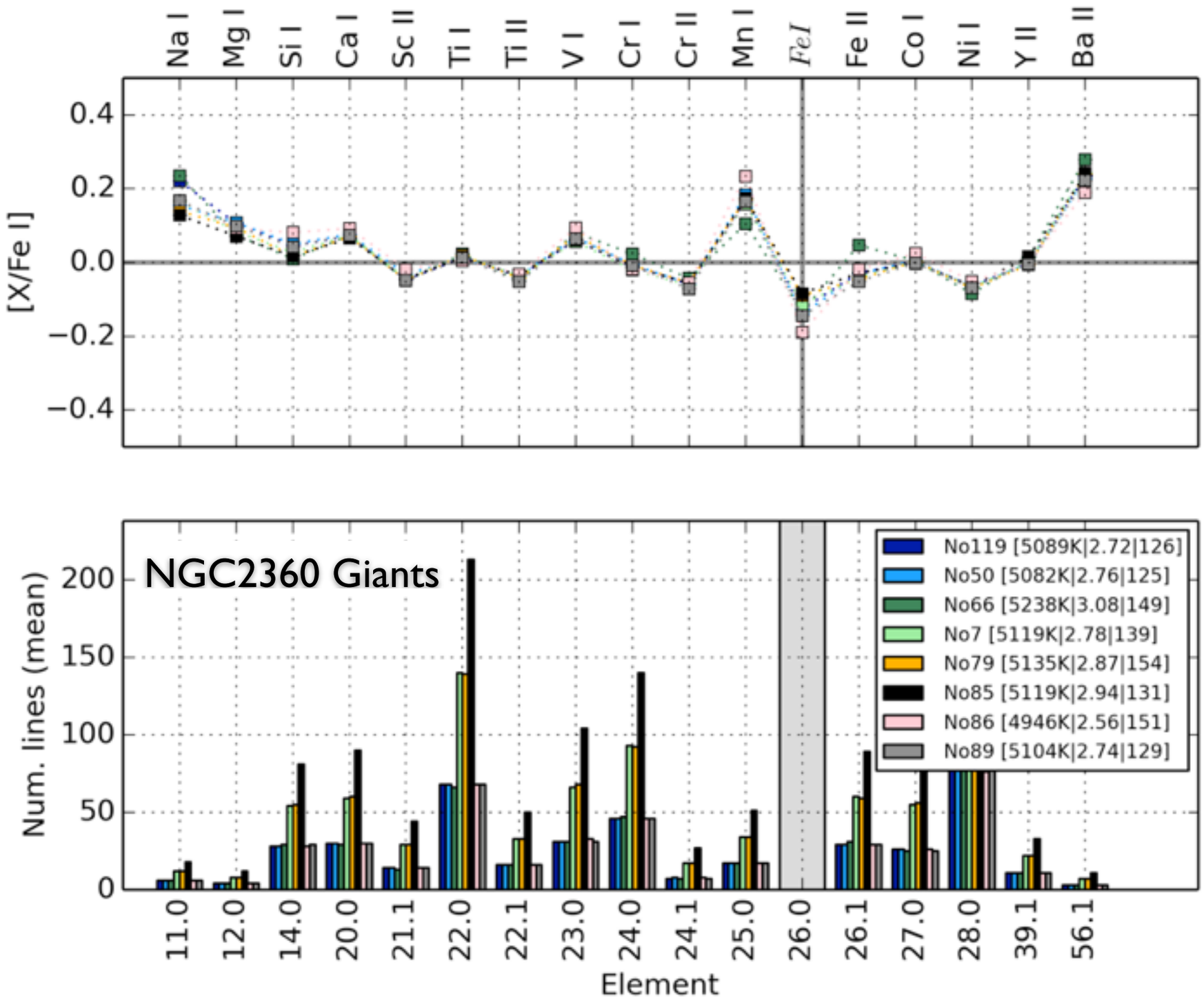
OC

K-Means++


Giants
Component 2
Component 1
0.4
0.2
0.0
−0.2
−0.4
−0.4
−0.2
0.0
0.2
0.4
NGC6633 (0.43 Gyrs)
NGC6940 (0.72 Gyrs)
IC4756 (0.67 Gyrs)
NGC752 (1.12 Gyrs)
NGC2423 (1.00 Gyrs)
NGC2360 (0.56 Gyrs)
M67 (4.09 Gyrs)
IC2714 (0.25 Gyrs)
NGC2477 (0.88 Gyrs)
NGC2447 (0.56 Gyrs)
NGC2099 (0.45 Gyrs)
NGC3114 (0.16 Gyrs)
IC4651 (1.14 Gyrs)
NGC5822 (0.89 Gyrs)
NGC2567 (0.28 Gyrs)
NGC2539 (0.49 Gyrs)
NGC2632 (0.63 Gyrs)
NGC6811 (0.64 Gyrs)

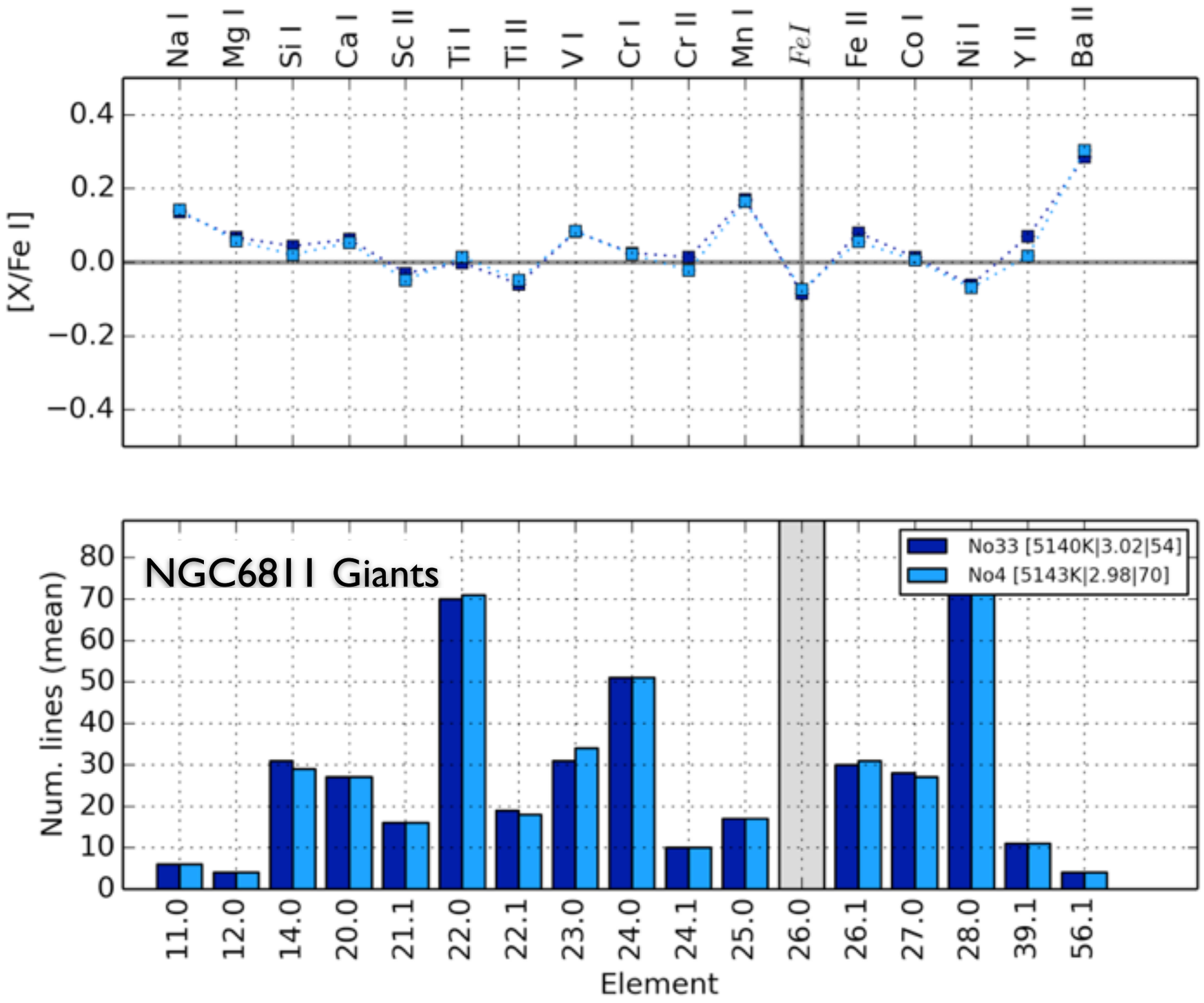
OC

K-Means++


Na I
Mg I
Si I
Ca I
Sc II
Ti I
Ti II
V I
Cr I
Cr II
Mn I
FeI
Fe II
Co I
Ni I
Y II
Ba II
[X/Fe I]
0.4
0.2
0.0
−0.2
−0.4
NGC2360 Giants
No119 [5089K|2.72|126]
No50 [5082K|2.76|125]
No66 [5238K|3.08|149]
No7 [5119K|2.78|139]
No79 [5135K|2.87|154]
No85 [5119K|2.94|131]
No86 [4946K|2.56|151]
No89 [5104K|2.74|129]
Num. lines (mean)
200
150
100
50
0
11.0
12.0
14.0
20.0
21.1
22.0
22.1
23.0
24.0
24.1
25.0
26.0
26.1
27.0
28.0
39.1
56.1
Element

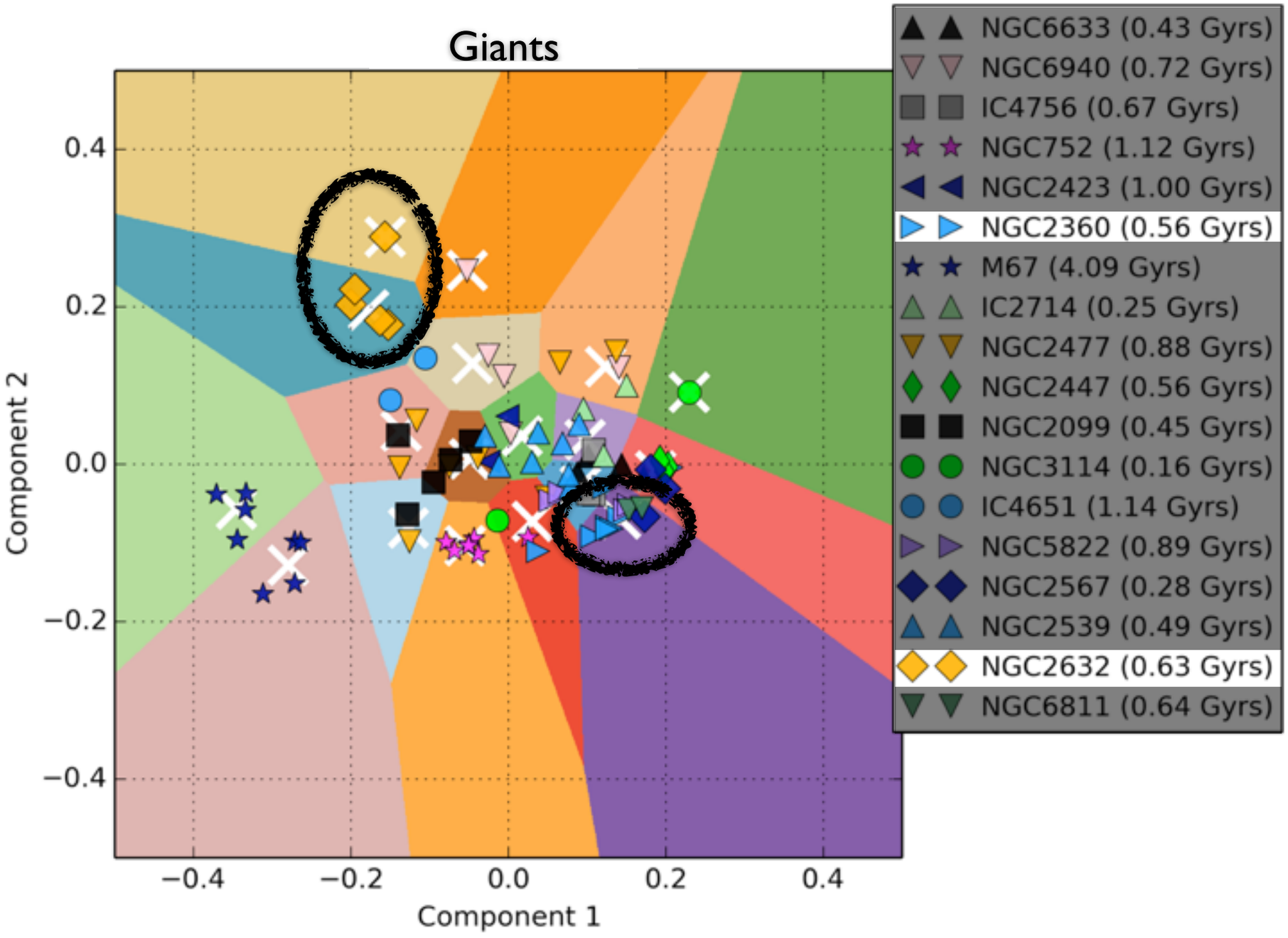
OC

K-Means++


Na I
Mg I
Si I
Ca I
Sc II
Ti I
Ti II
V I
Cr I
Cr II
Mn I
FeI
Fe II
Co I
Ni I
Y II
Ba II
[X/Fe I]
0.4
0.2
0.0
−0.2
−0.4
NGC6811 Giants
No33 [5140K|3.02|54]
No4 [5143K|2.98|70]
Num. lines (mean)
80
70
60
50
40
30
20
10
0
11.0
12.0
14.0
20.0
21.1
22.0
22.1
23.0
24.0
24.1
25.0
26.0
26.1
27.0
28.0
39.1
56.1
Element

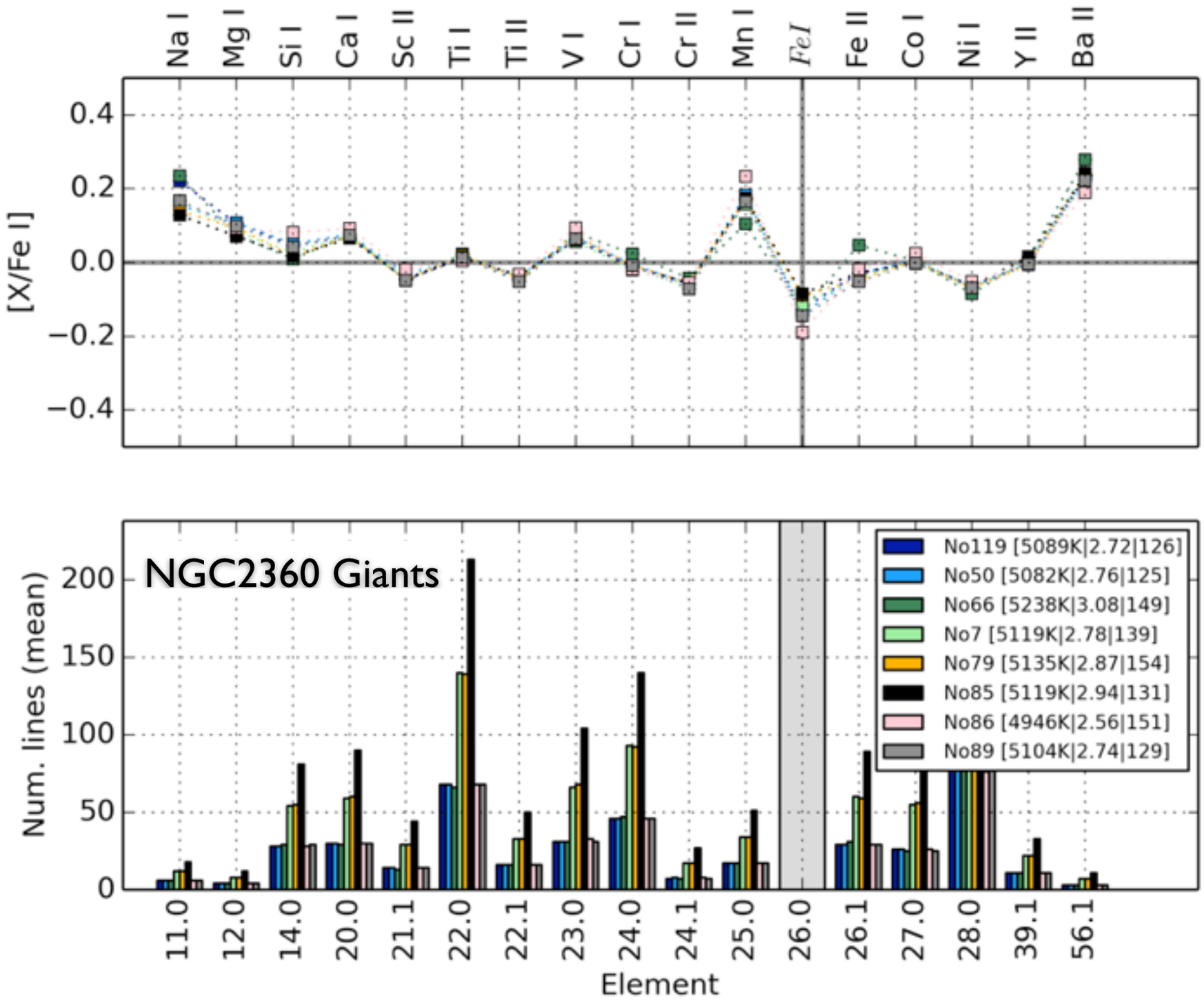
OC

K-Means++


Giants
Component 2
Component 1
0.4
0.2
0.0
−0.2
−0.4
−0.4
−0.2
0.0
0.2
0.4
NGC6633 (0.43 Gyrs)
NGC6940 (0.72 Gyrs)
IC4756 (0.67 Gyrs)
NGC752 (1.12 Gyrs)
NGC2423 (1.00 Gyrs)
NGC2360 (0.56 Gyrs)
M67 (4.09 Gyrs)
IC2714 (0.25 Gyrs)
NGC2477 (0.88 Gyrs)
NGC2447 (0.56 Gyrs)
NGC2099 (0.45 Gyrs)
NGC3114 (0.16 Gyrs)
IC4651 (1.14 Gyrs)
NGC5822 (0.89 Gyrs)
NGC2567 (0.28 Gyrs)
NGC2539 (0.49 Gyrs)
NGC2632 (0.63 Gyrs)
NGC6811 (0.64 Gyrs)

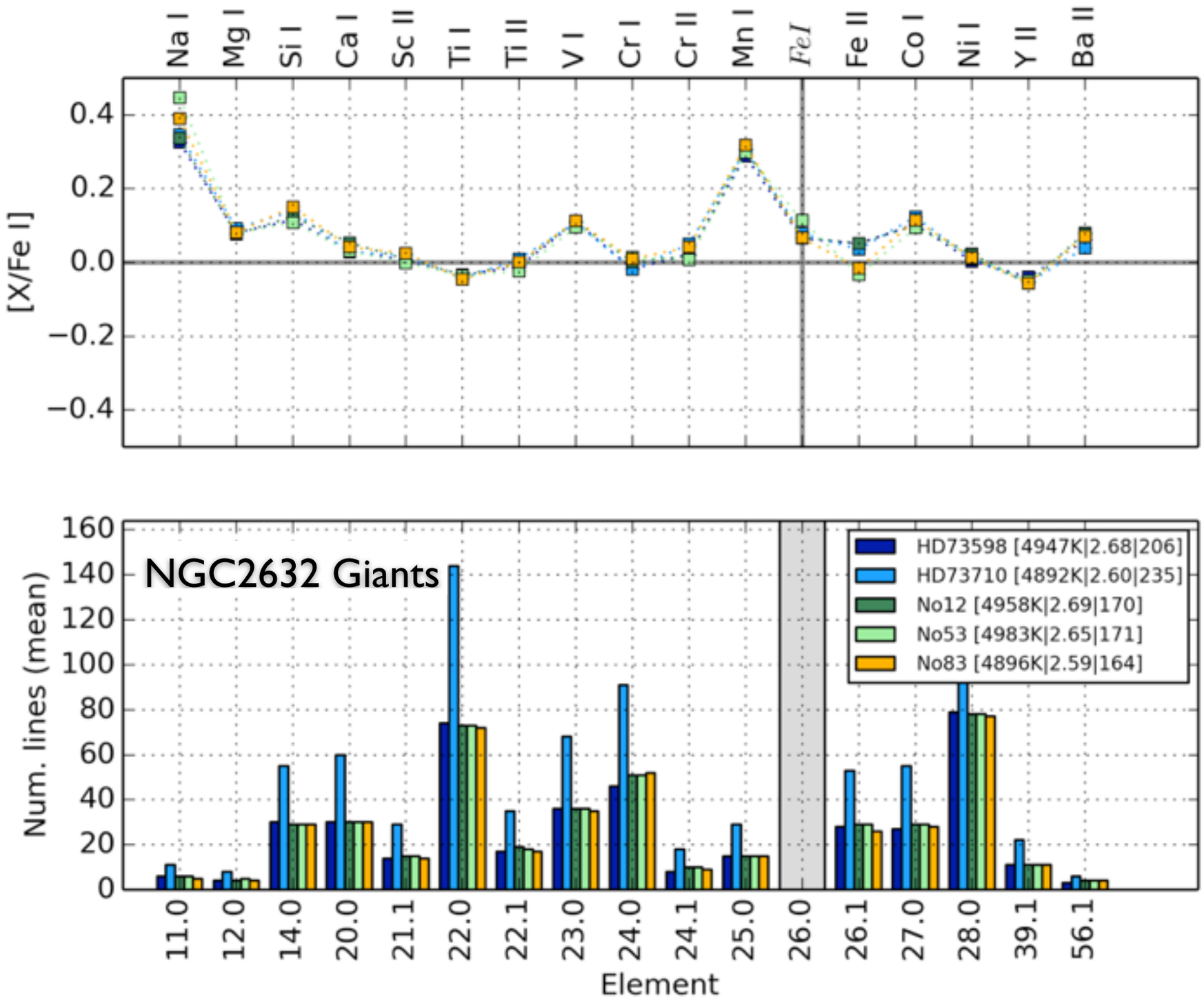
OC

K-Means++


Na I
Mg I
Si I
Ca I
Sc II
Ti I
Ti II
V I
Cr I
Cr II
Mn I
FeI
Fe II
Co I
Ni I
Y II
Ba II
[X/Fe I]
0.4
0.2
0.0
−0.2
−0.4
NGC2360 Giants
No119 [5089K|2.72|126]
No50 [5082K|2.76|125]
No66 [5238K|3.08|149]
No7 [5119K|2.78|139]
No79 [5135K|2.87|154]
No85 [5119K|2.94|131]
No86 [4946K|2.56|151]
No89 [5104K|2.74|129]
Num. lines (mean)
200
150
100
50
0
11.0
12.0
14.0
20.0
21.1
22.0
22.1
23.0
24.0
24.1
25.0
26.0
26.1
27.0
28.0
39.1
56.1
Element

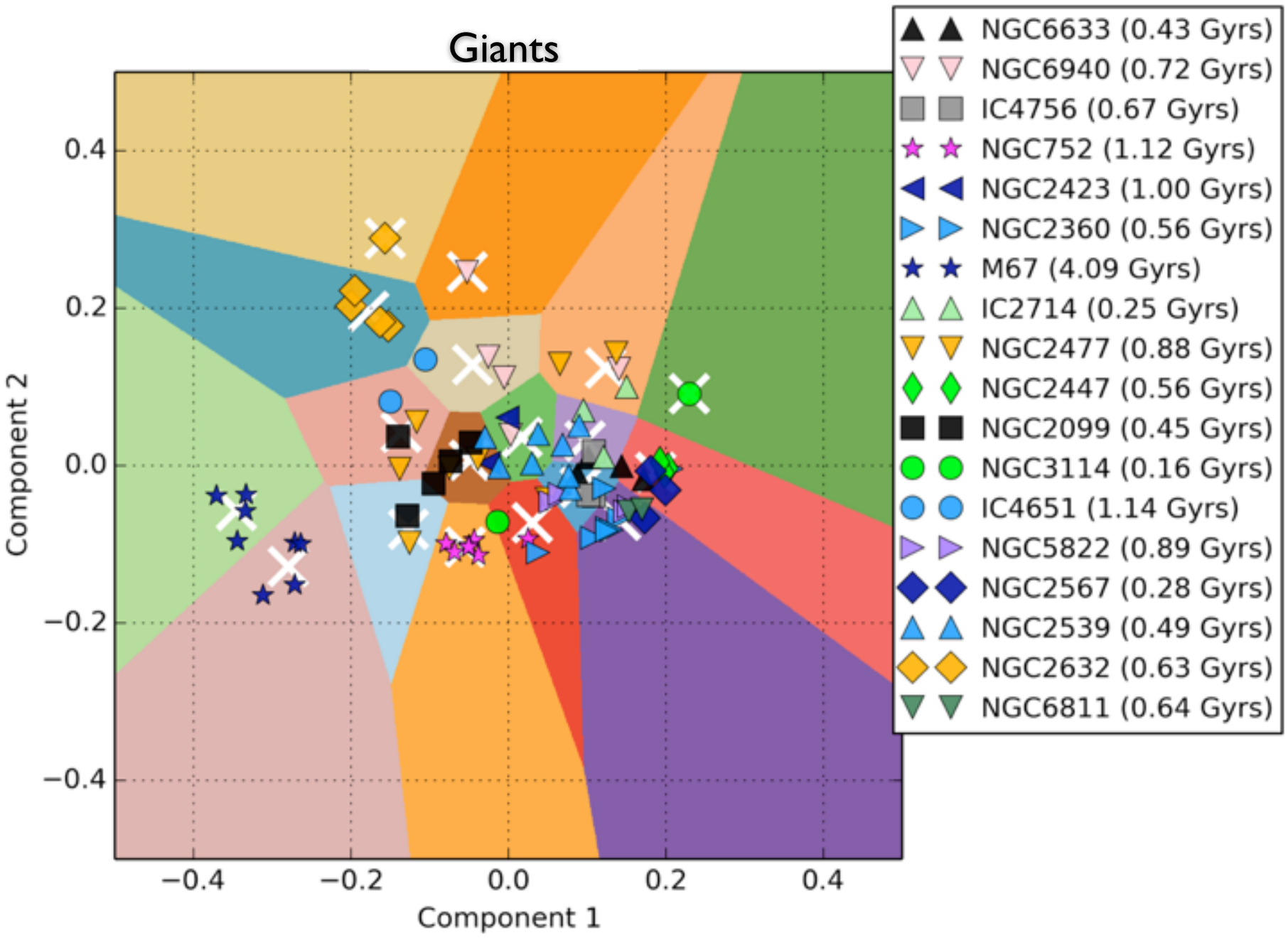
OC

K-Means++


Na I
Mg I
Si I
Ca I
Sc II
Ti I
Ti II
V I
Cr I
Cr II
Mn I
FeI
Fe II
Co I
Ni I
Y II
Ba II
[X/Fe I]
0.4
0.2
0.0
−0.2
−0.4
NGC2632 Giants
HD73598 [4947K|2.68|206]
HD73710 [4892K|2.60|235]
No12 [4958K|2.69|170]
No53 [4983K|2.65|171]
No83 [4896K|2.59|164]
Num. lines (mean)
160
140
120
100
80
60
40
20
0
11.0
12.0
14.0
20.0
21.1
22.0
22.1
23.0
24.0
24.1
25.0
26.0
26.1
27.0
28.0
39.1
56.1
Element

OC

K-Means++


Giants
0.4
0.2
0.0
−0.2
−0.4
Component 2
−0.4
−0.2
0.0
0.2
0.4
Component 1
NGC6633 (0.43 Gyrs)
NGC6940 (0.72 Gyrs)
IC4756 (0.67 Gyrs)
NGC752 (1.12 Gyrs)
NGC2423 (1.00 Gyrs)
NGC2360 (0.56 Gyrs)
M67 (4.09 Gyrs)
IC2714 (0.25 Gyrs)
NGC2477 (0.88 Gyrs)
NGC2447 (0.56 Gyrs)
NGC2099 (0.45 Gyrs)
NGC3114 (0.16 Gyrs)
IC4651 (1.14 Gyrs)
NGC5822 (0.89 Gyrs)
NGC2567 (0.28 Gyrs)
NGC2539 (0.49 Gyrs)
NGC2632 (0.63 Gyrs)
NGC6811 (0.64 Gyrs)

Chemical Tagging

Do stars born together have a unique chemical signature?

Yes, but...

Are the chemical signatures different enough to distinguish stars formed from different molecular clouds?

No, but...

WE ARE
MADE OF
STAR
STUFF

–CARL SAGAN