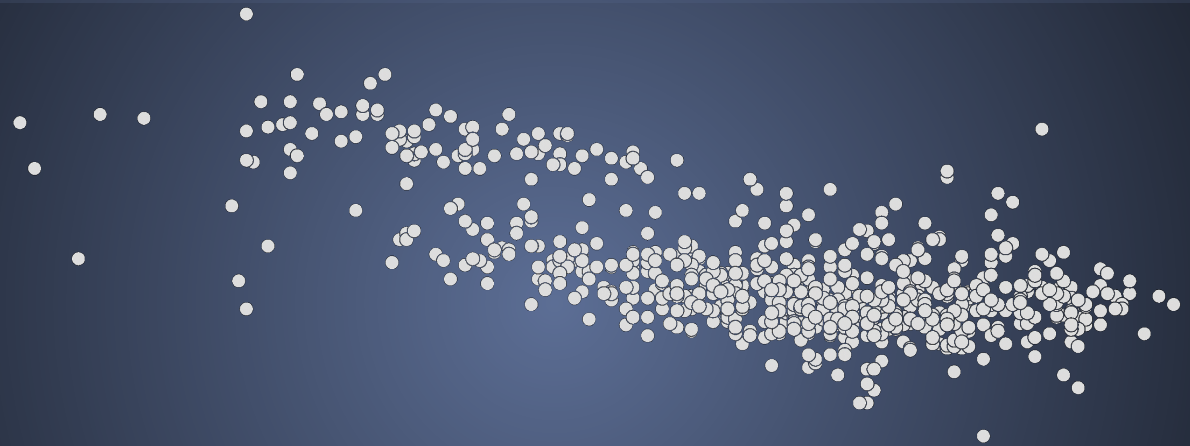
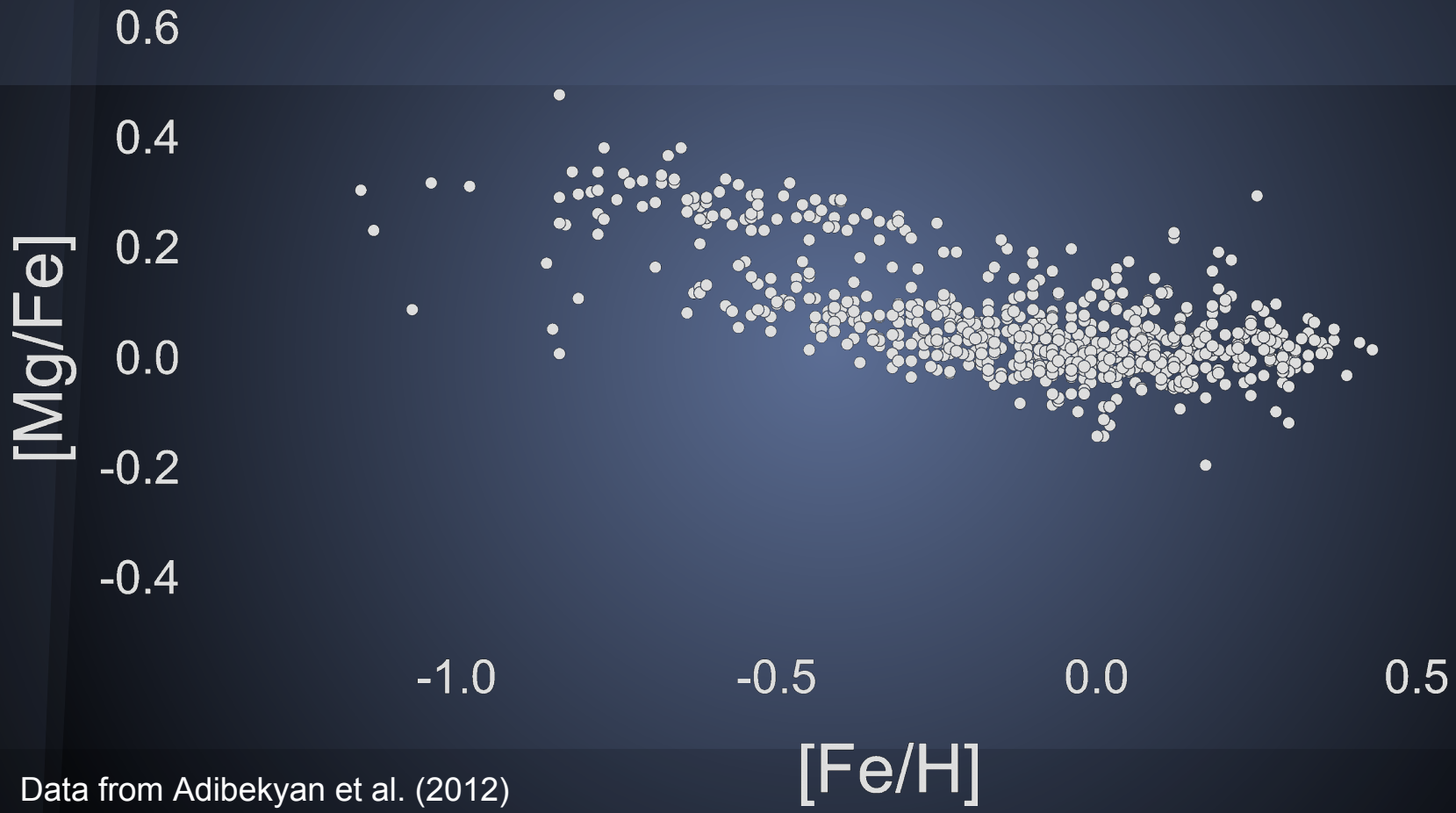
Chemical structure of Galactic discs

The power of GIRAFFE spectroscopy

PORTO, 10/11/2014

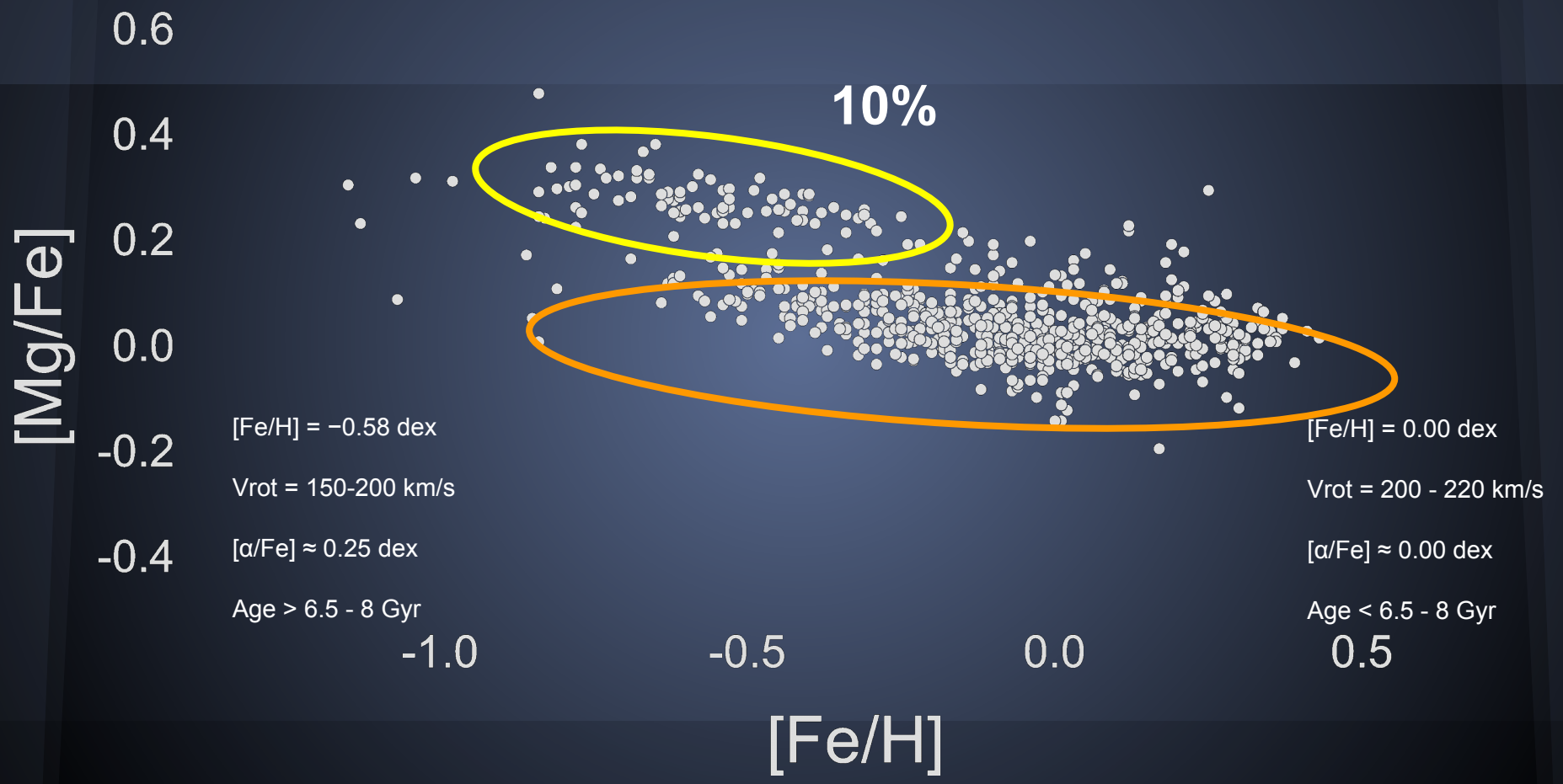


The trademark (HR)



Data from Adibekyan et al. (2012)

We know very well the chemical fingerprint of our neighbourhood



HR studies

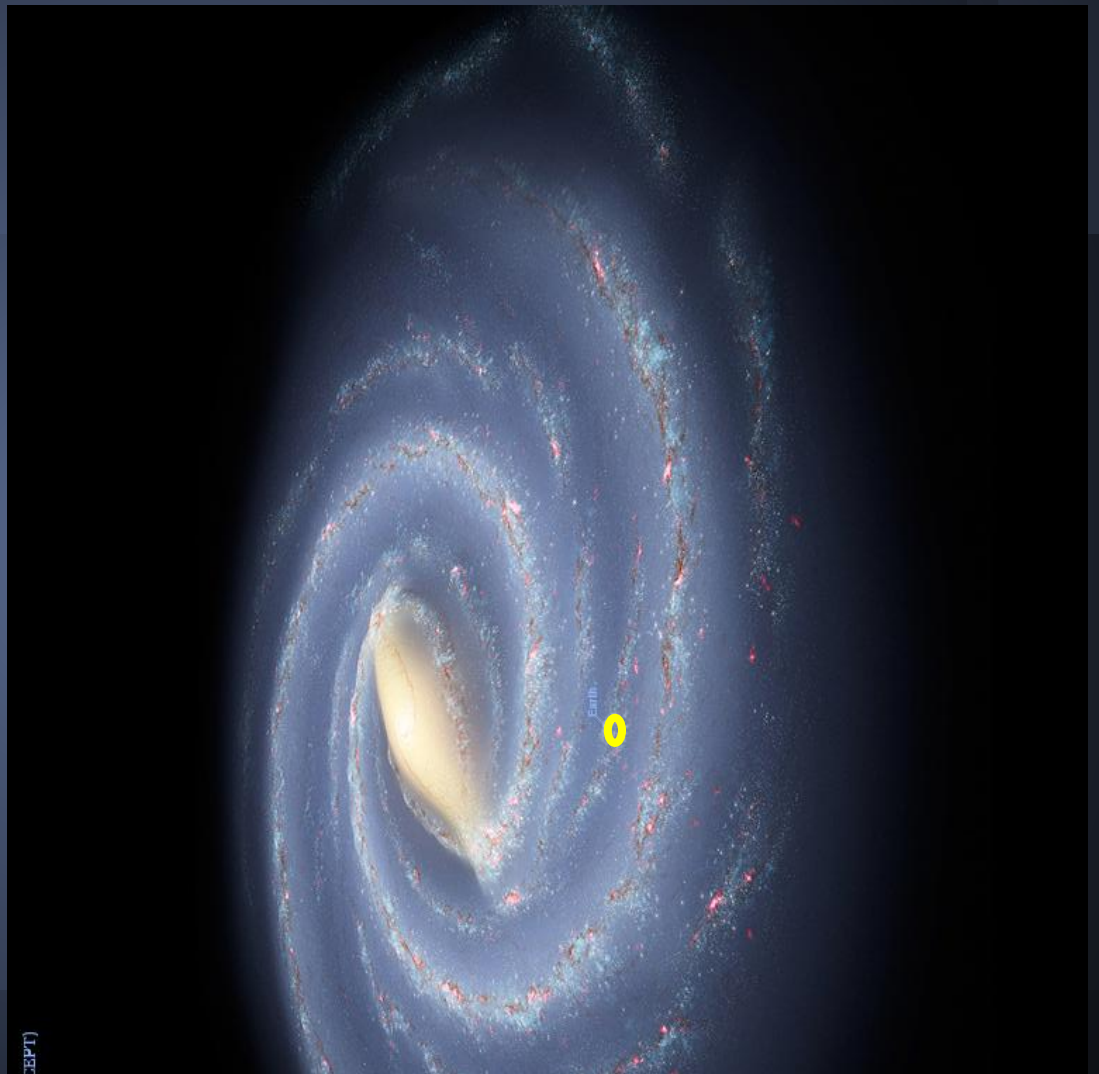
Good quality spectra

Exquisite precision

Solar vicinity

Up to 1111 stars per study

e.g. Fuhrmann (2011),
Adibekyan et al. (2012), Bensby et al. (2014)



Large spectroscopic surveys

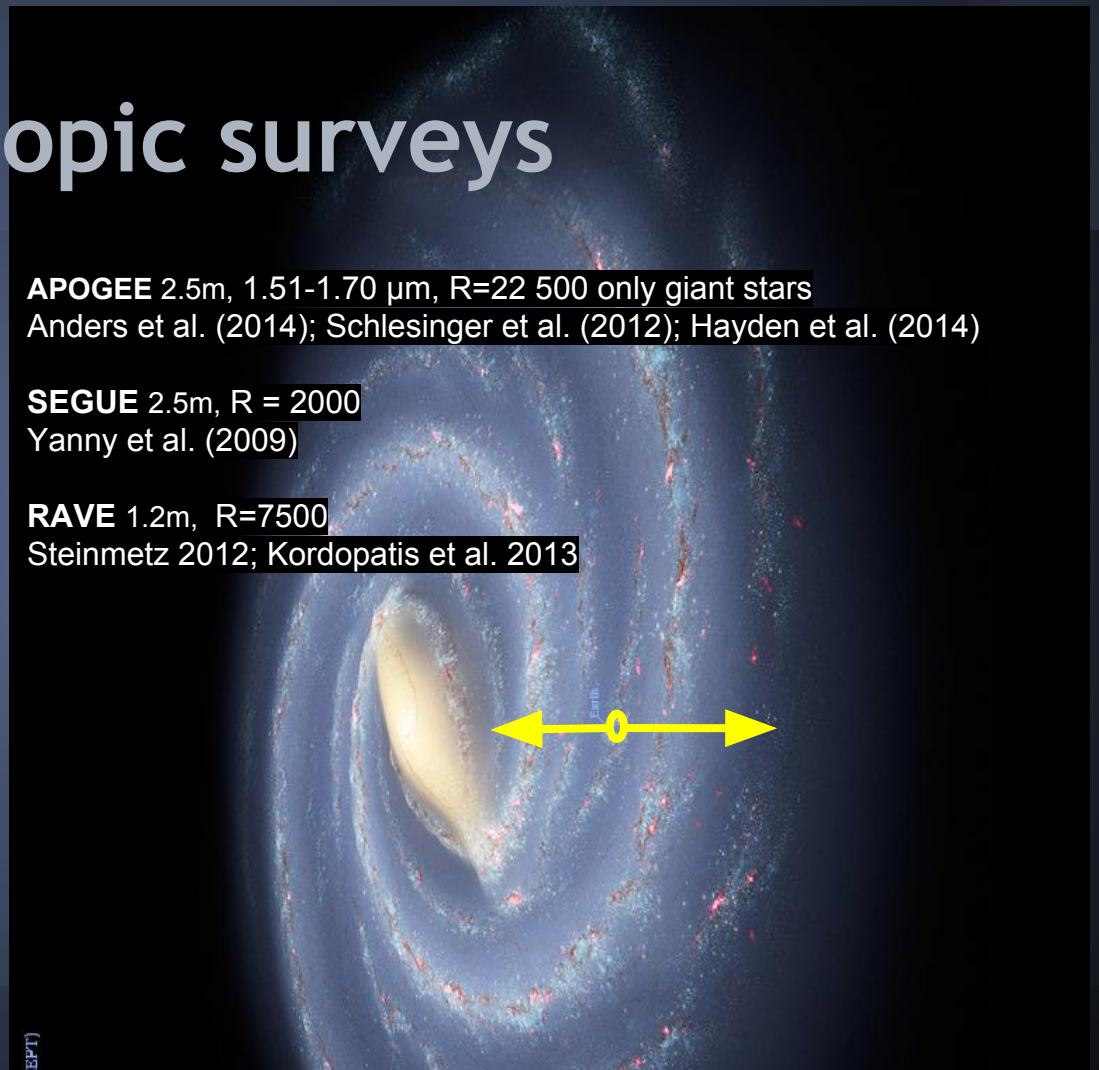
Large data
Large radius

Smaller telescopes
Lower resolution
Lower magnitudes

APOGEE 2.5m, 1.51-1.70 μm, R=22 500 only giant stars
Anders et al. (2014); Schlesinger et al. (2012); Hayden et al. (2014)

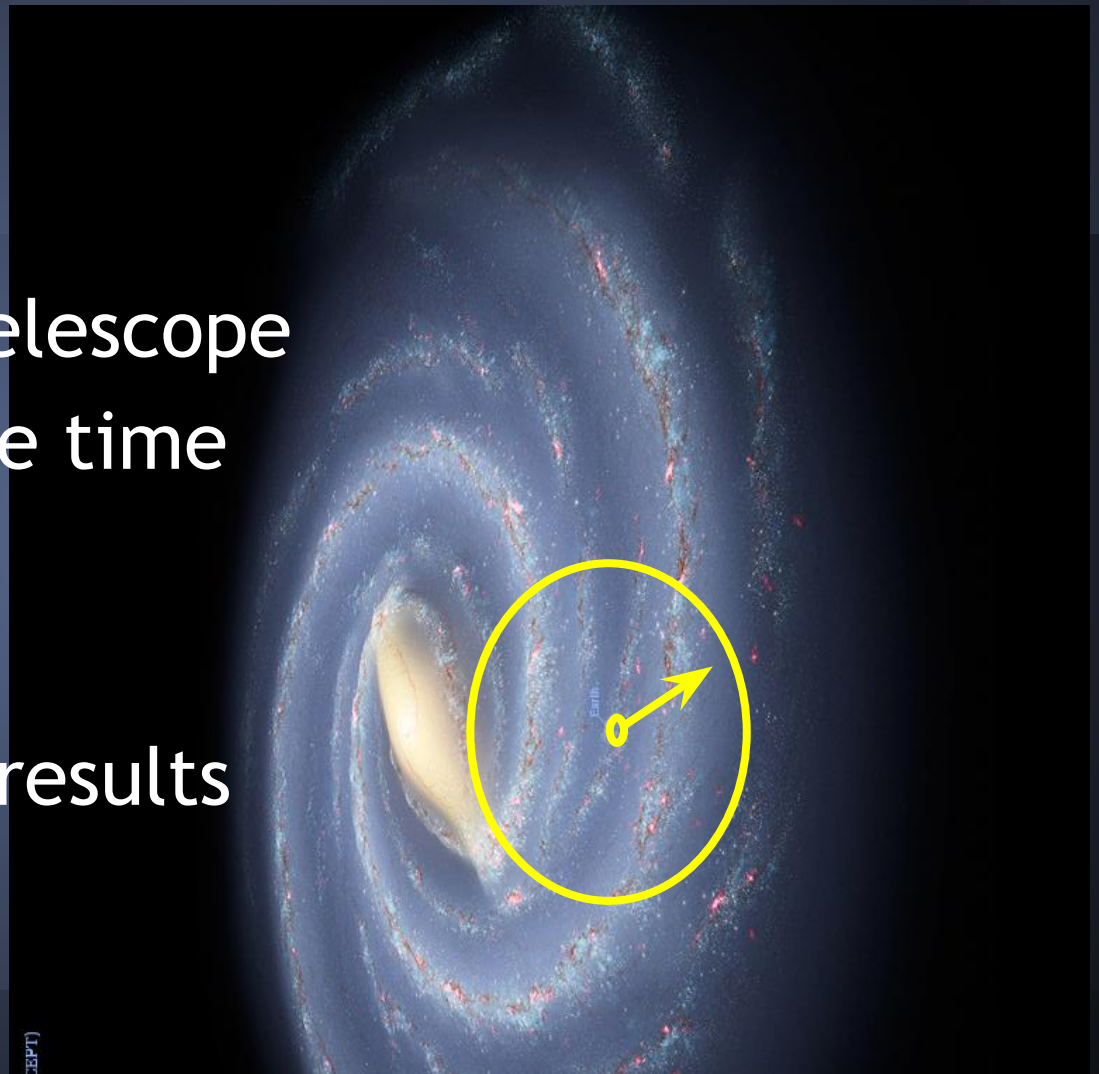
SEGUE 2.5m, R = 2000
Yanny et al. (2009)

RAVE 1.2m, R=7500
Steinmetz 2012; Kordopatis et al. 2013



GES - next step

We have the best telescope
All year of telescope time
High resolution
Large distances
We will have great results



What we did with iDR1?

We used atm par. recommended by GES.

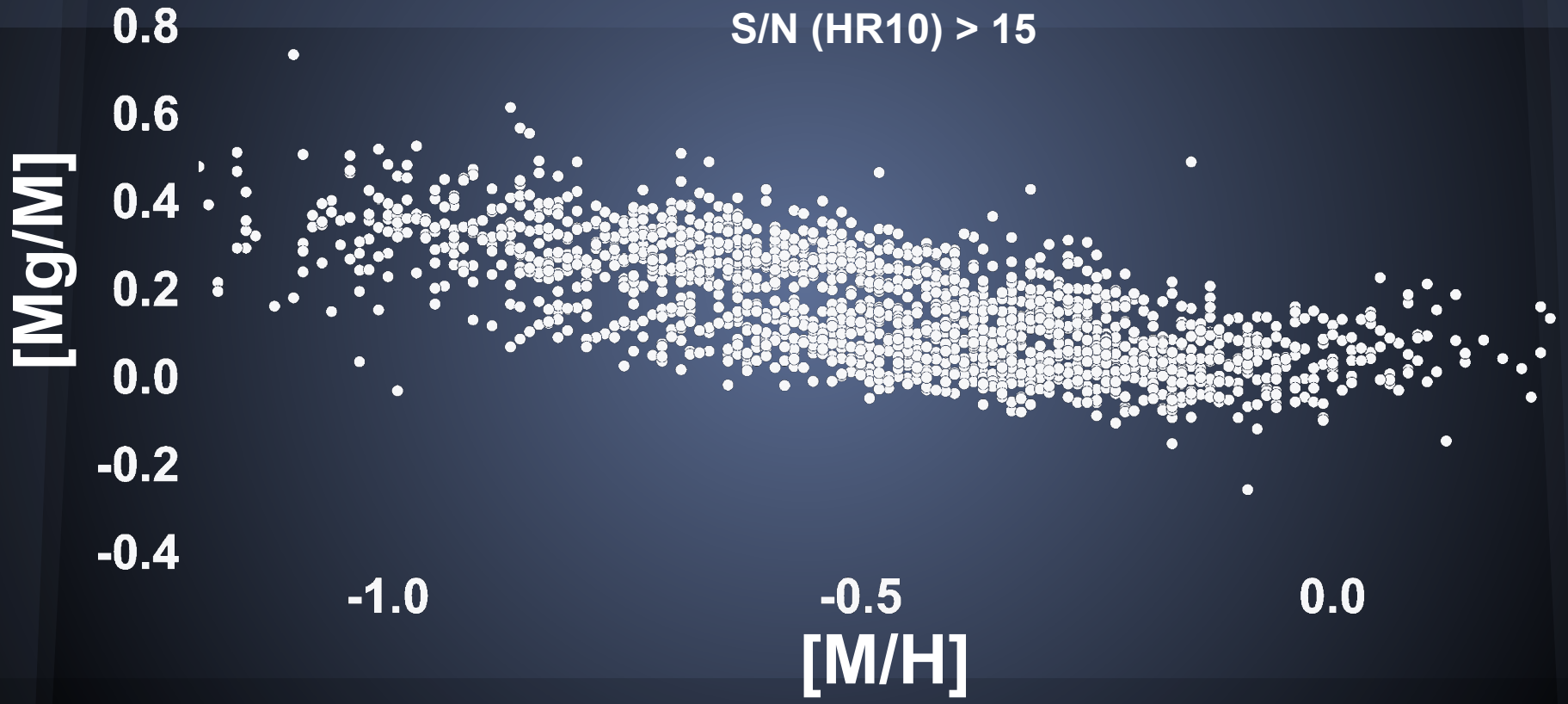
We derived abundances of Mg, Si, Ca, Ti, Cr, Ni, Y

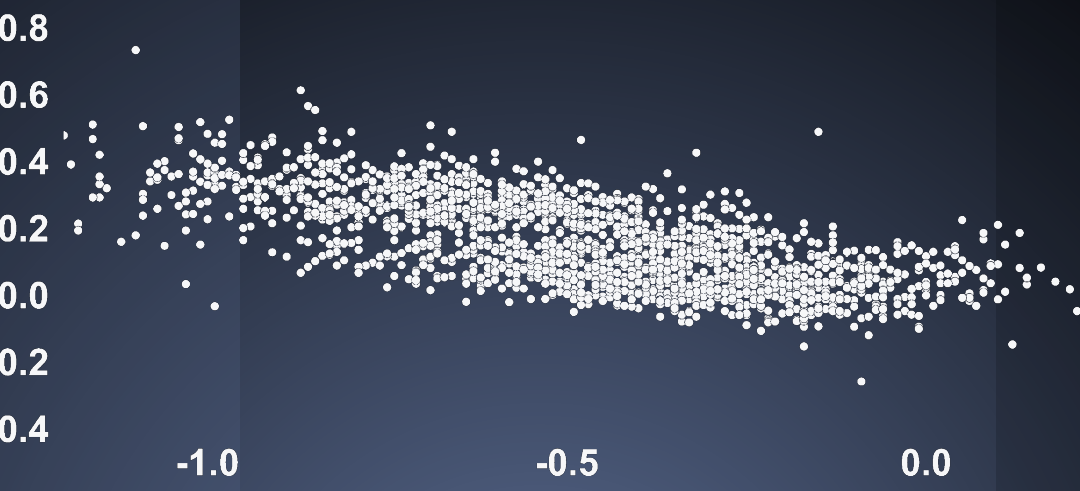
We studied the thin and thick disk chemistry.

The trademark

iDR1 1916 stars @ Mikolaitis et al. (2014)

S/N (HR10) > 15

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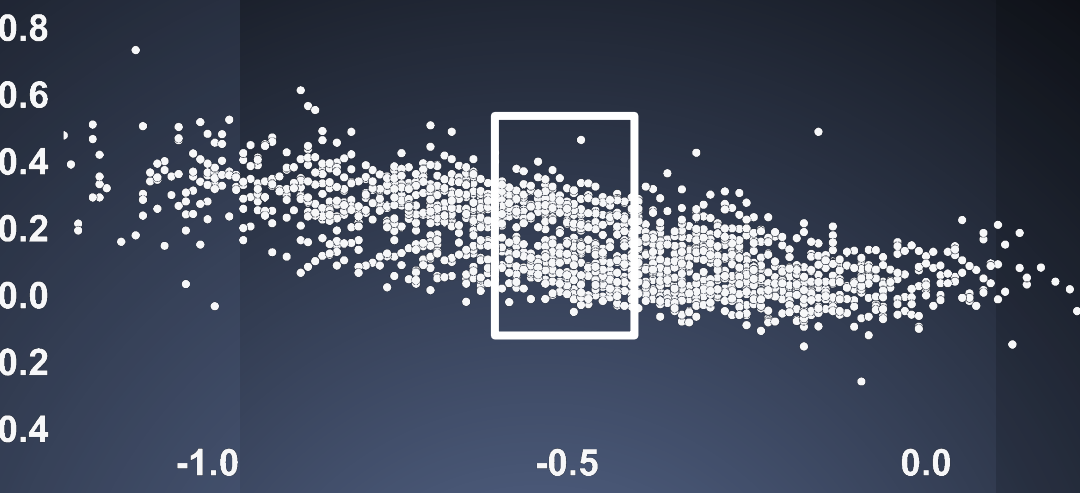
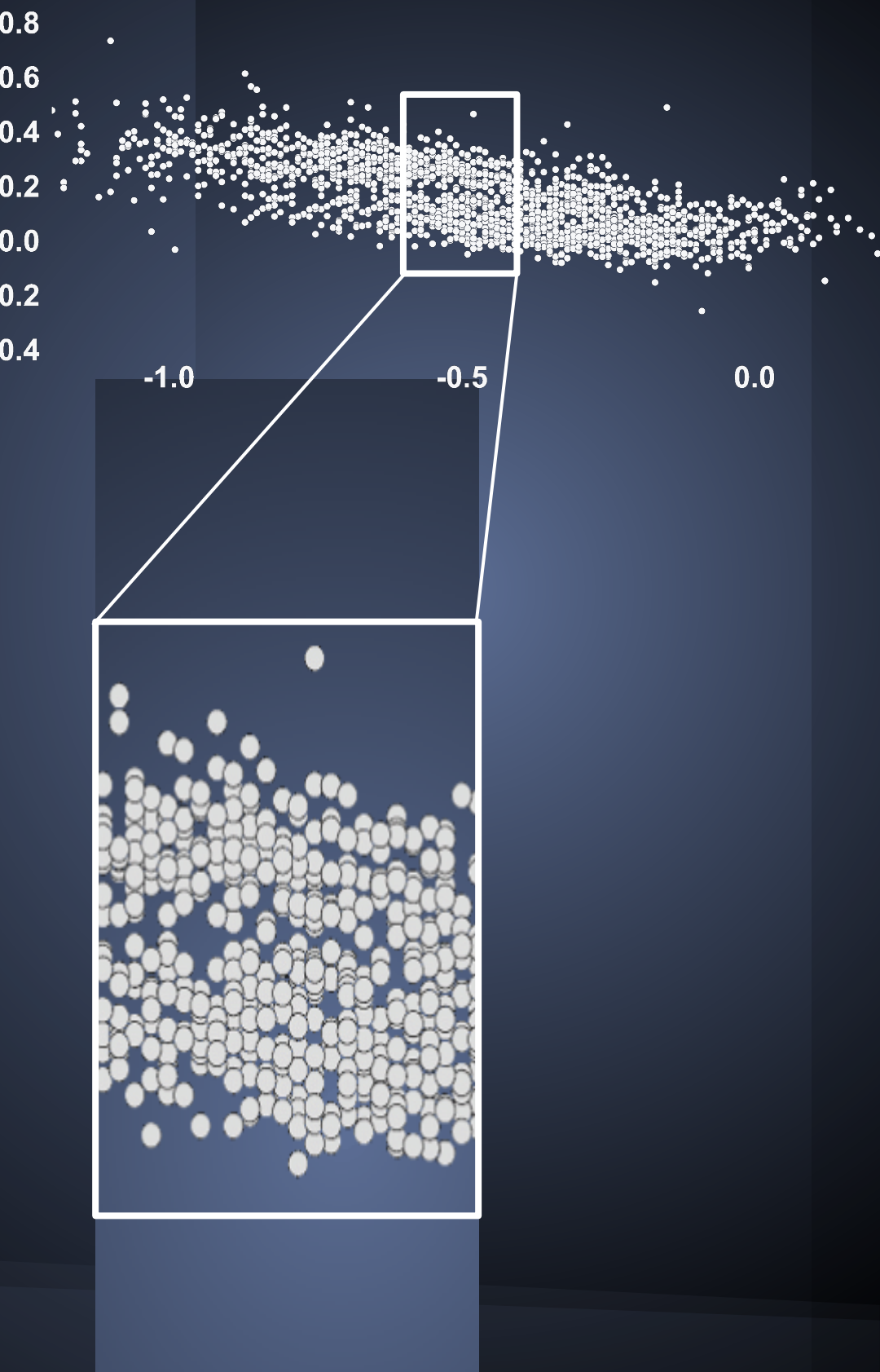
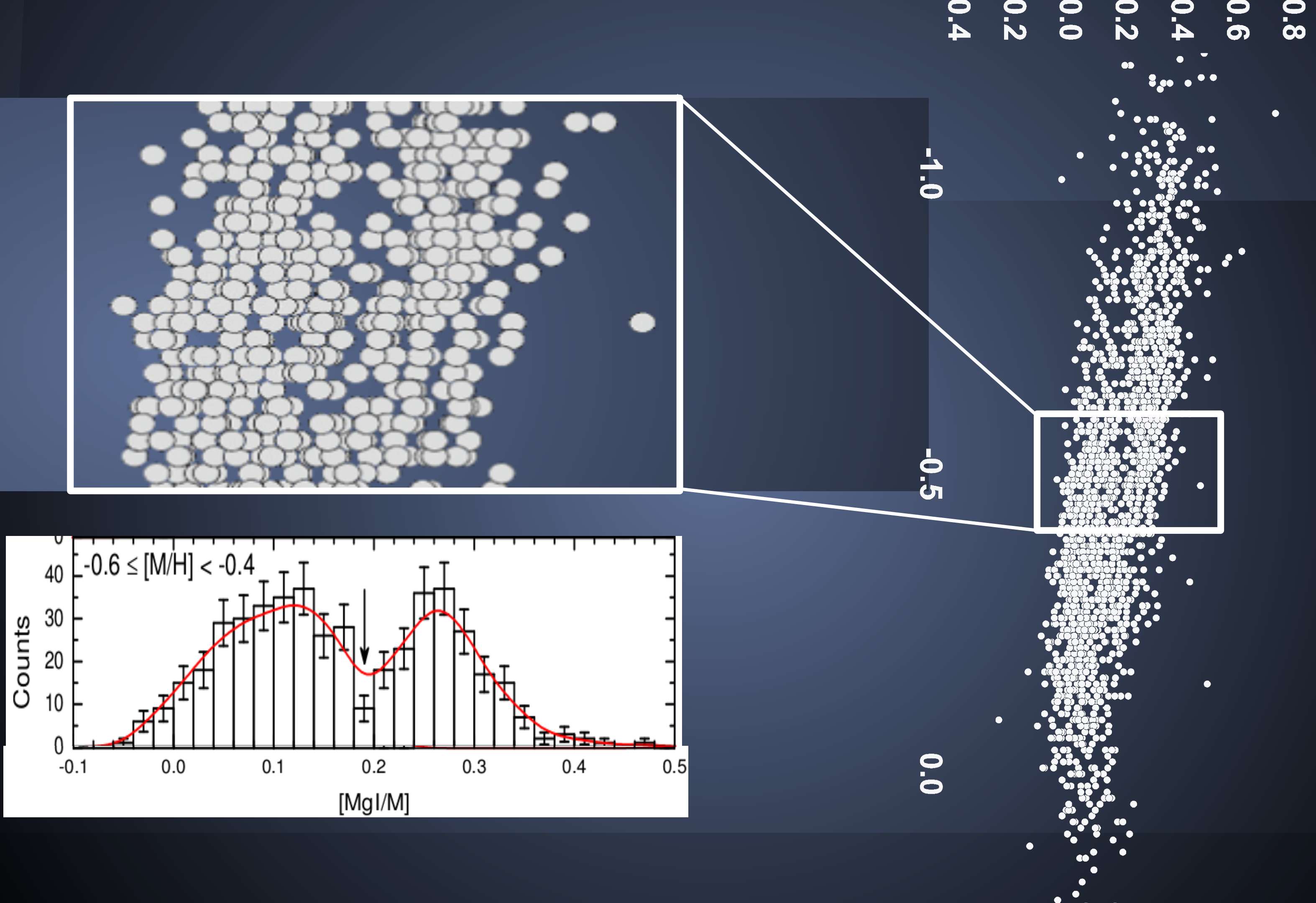
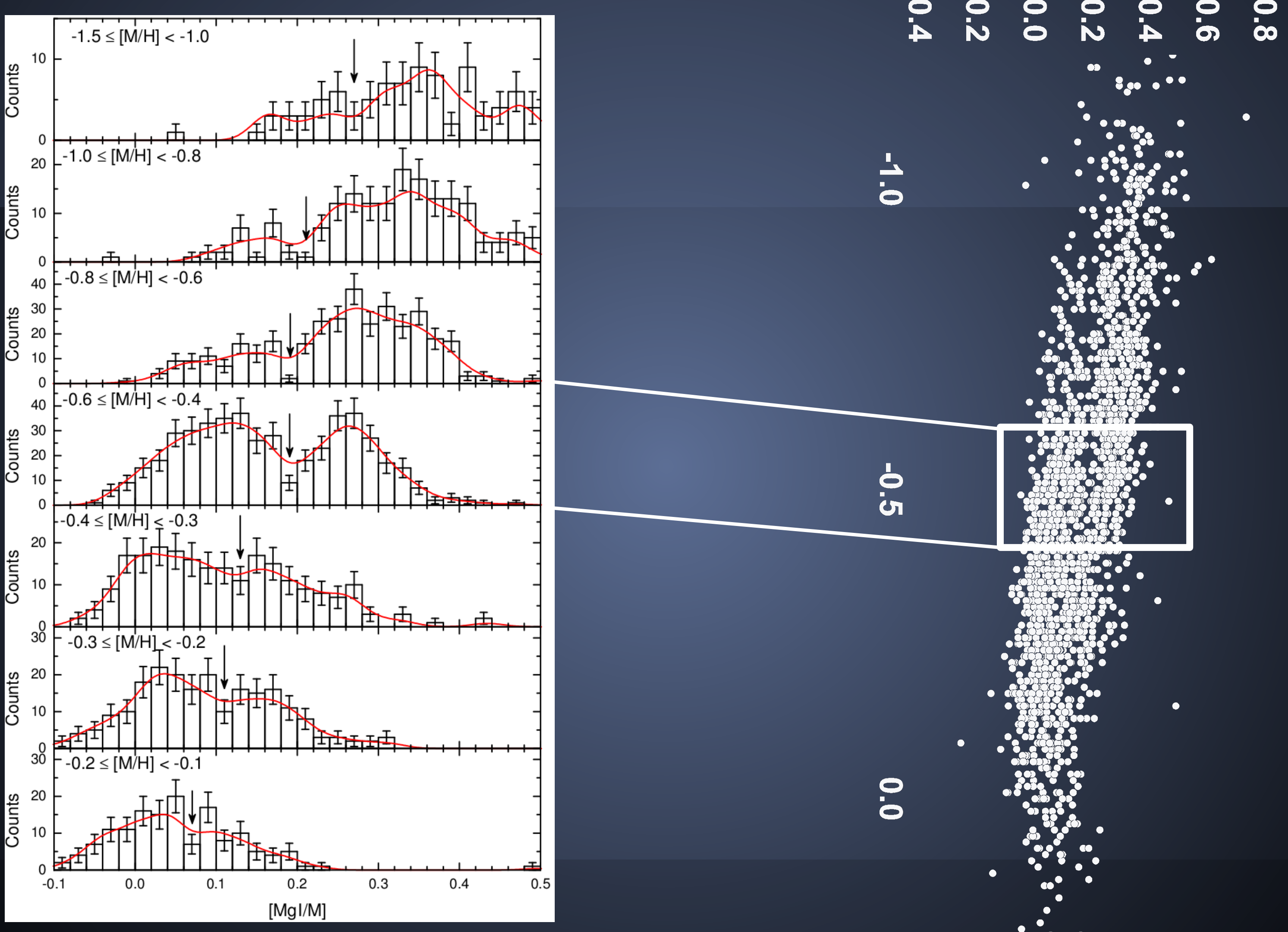
0.6
0.4
0.2
0.0
0.2
0.4
-1.0
-0.5
0.0


0.8
0.6
0.4
0.2
0.0
0.2
0.4
-1.0
-0.5
0.0

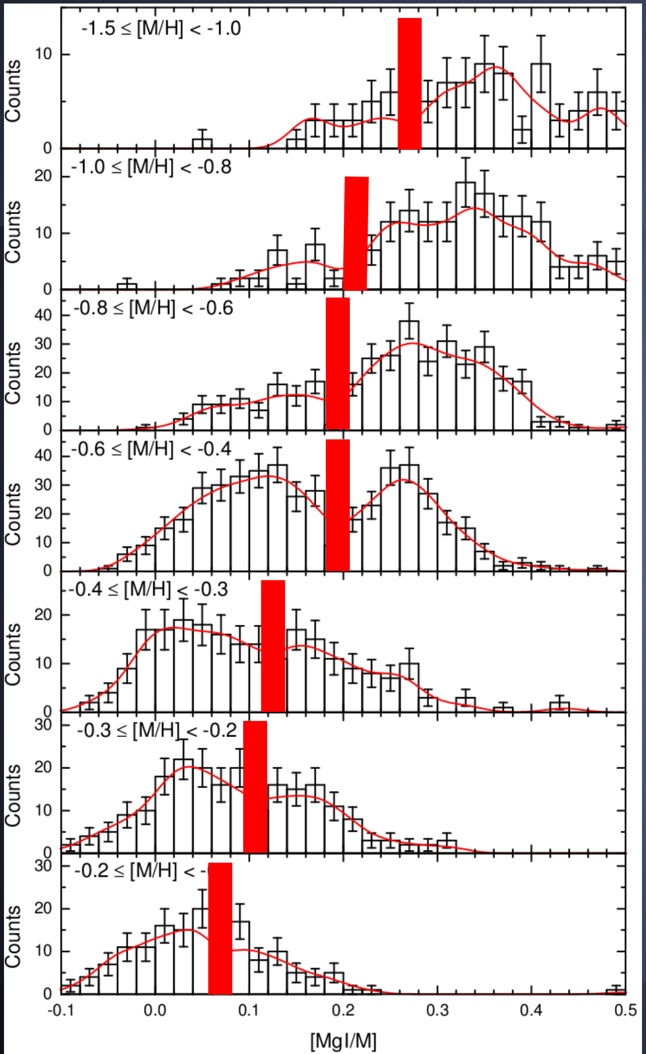

0.8
0.6
0.4
0.2
0.0
0.2
0.4
-1.0
-0.5
0.0

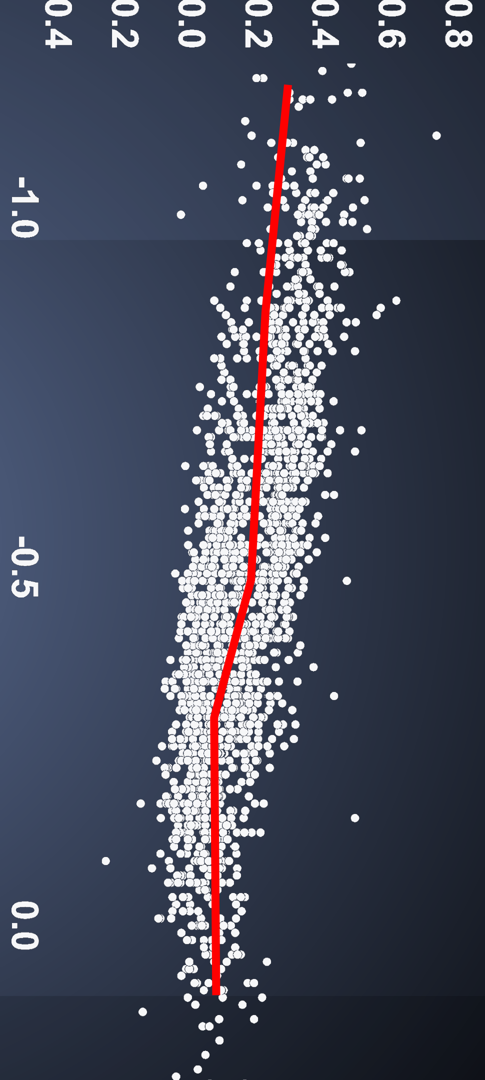


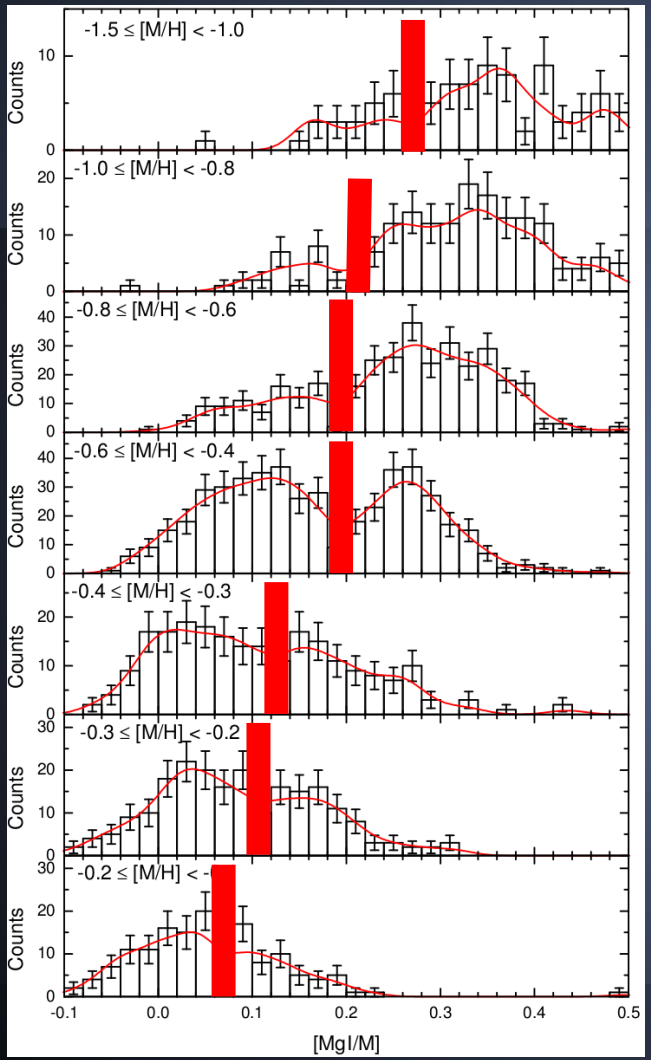
-0.6 ≤ [M/H] < -0.4
Counts
0
10
20
30
40
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
[MgI/M]
-1.0
-0.5
0.0
0.4
0.2
0.0
0.2
0.4
0.6
0.8

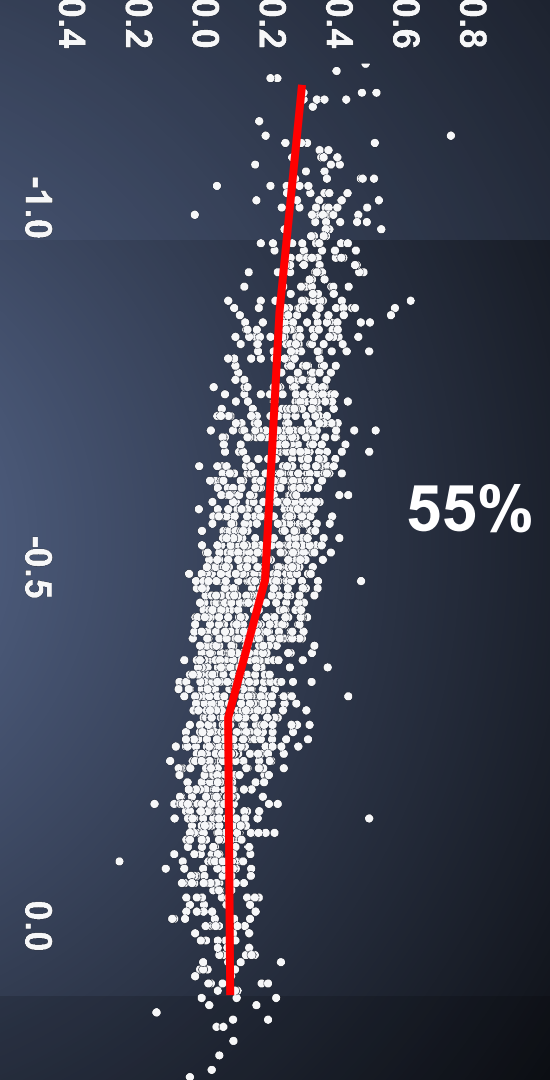


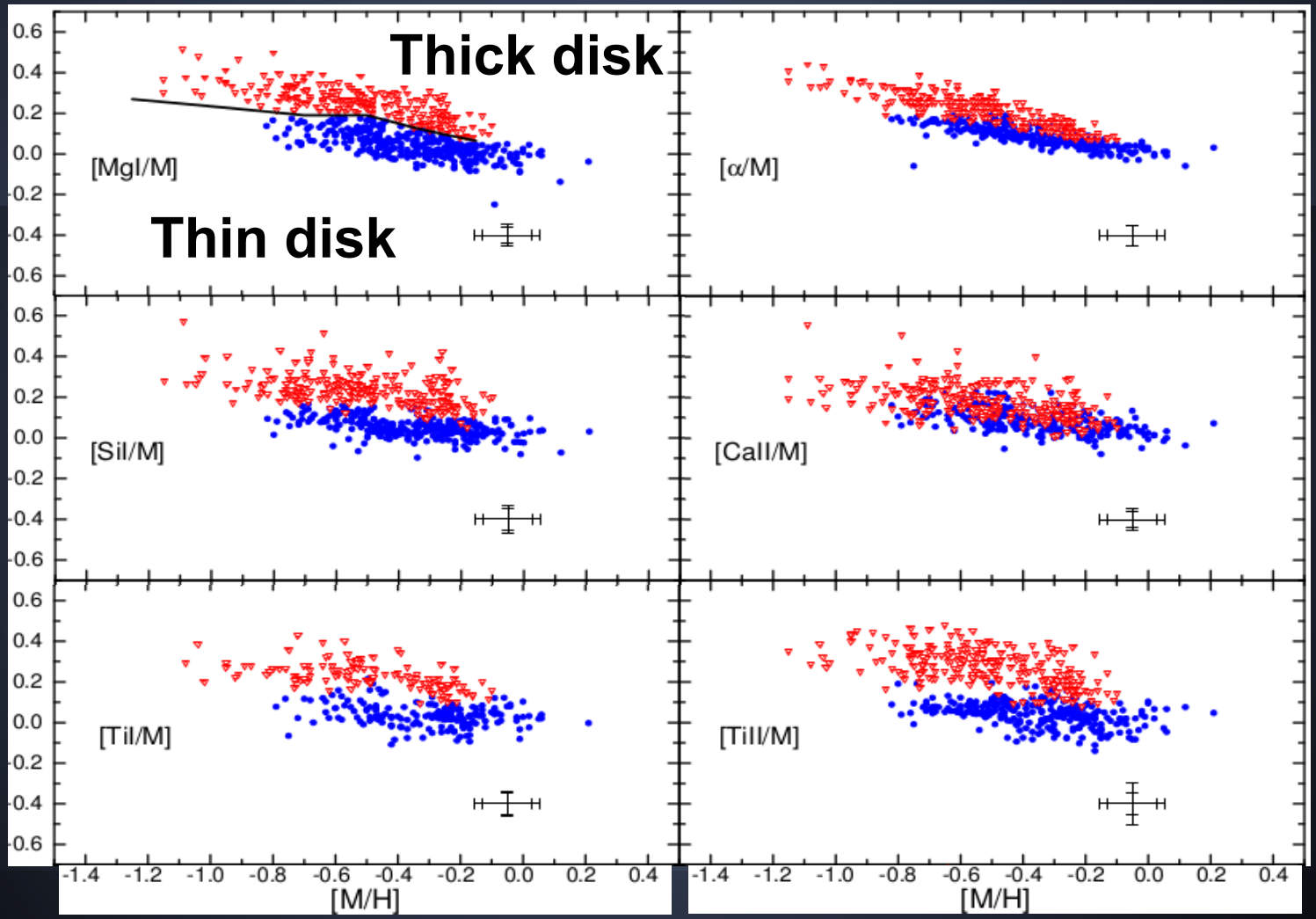
-1.5 ≤ [M/H] < -1.0
-1.0 ≤ [M/H] < -0.8
-0.8 ≤ [M/H] < -0.6
-0.6 ≤ [M/H] < -0.4
-0.4 ≤ [M/H] < -0.3
-0.3 ≤ [M/H] < -0.2
-0.2 ≤ [M/H] < -0.1
Counts
[MgI/M]
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
-1.0
-0.5
0.0


-1.5 ≤ [M/H] < -1.0
-1.0 ≤ [M/H] < -0.8
-0.8 ≤ [M/H] < -0.6
-0.6 ≤ [M/H] < -0.4
-0.4 ≤ [M/H] < -0.3
-0.3 ≤ [M/H] < -0.2
-0.2 ≤ [M/H] <
Counts
[MgI/M]

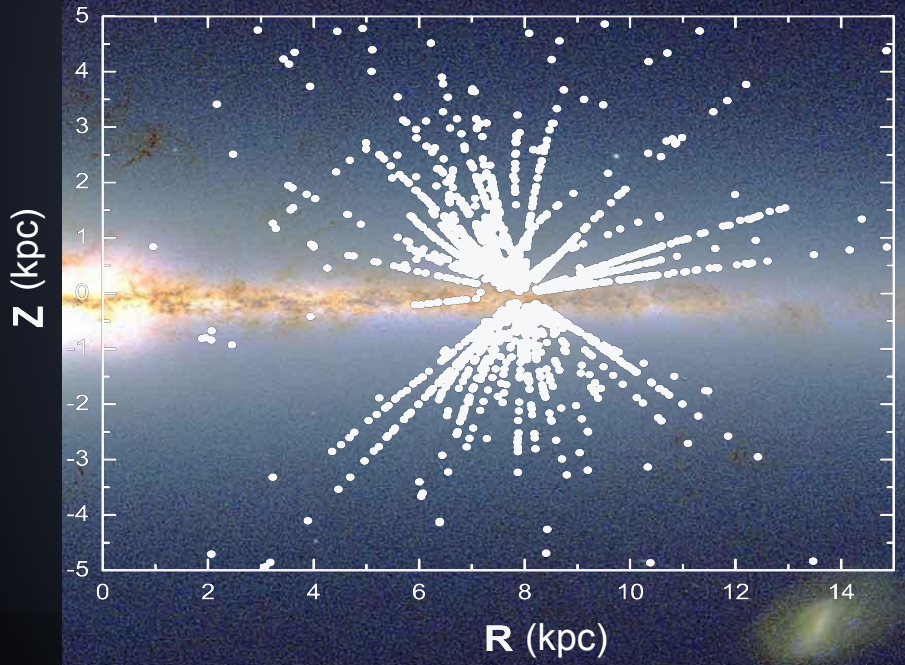



-1.5 ≤ [M/H] < -1.0
-1.0 ≤ [M/H] < -0.8
-0.8 ≤ [M/H] < -0.6
-0.6 ≤ [M/H] < -0.4
-0.4 ≤ [M/H] < -0.3
-0.3 ≤ [M/H] < -0.2
-0.2 ≤ [M/H] < -
Counts
[MgI/M]


-1.0
-0.5
0.0
55%


Thick disk
Thin disk
[MgI/M]
[α/M]
[SiI/M]
[CaII/M]
[TiI/M]
[TiII/M]
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
[M/H]

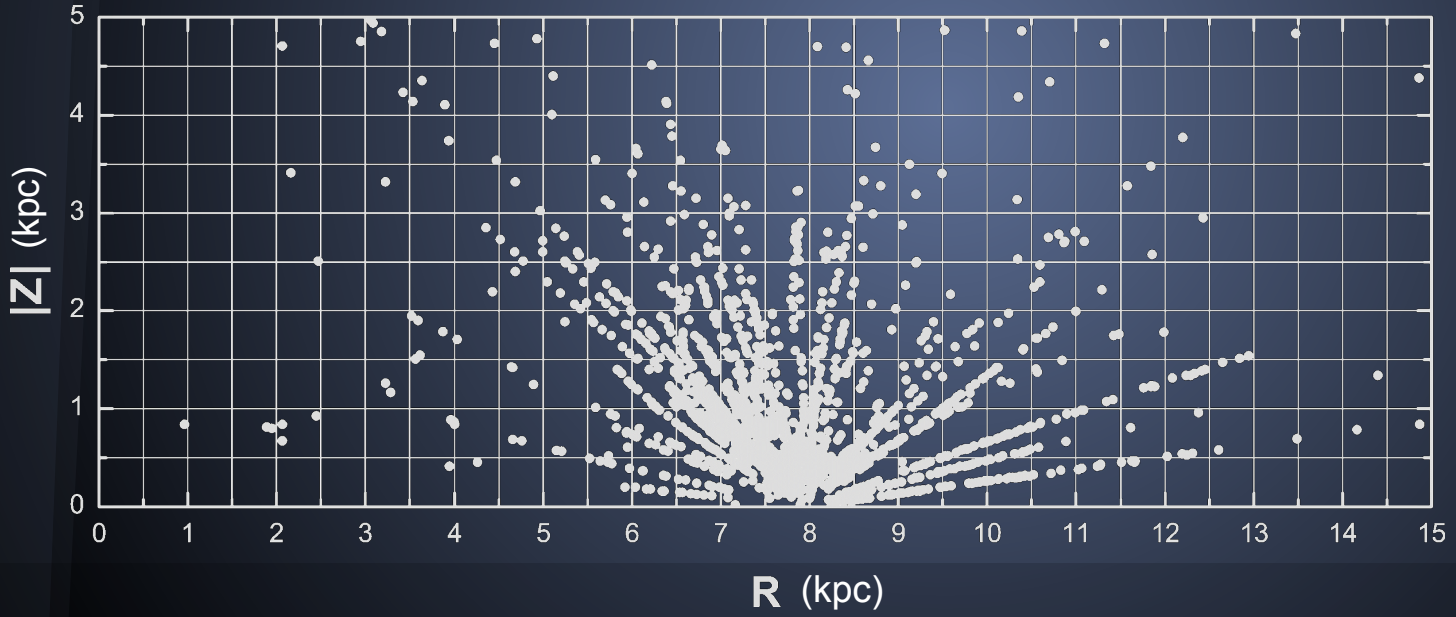
Abundances + distances



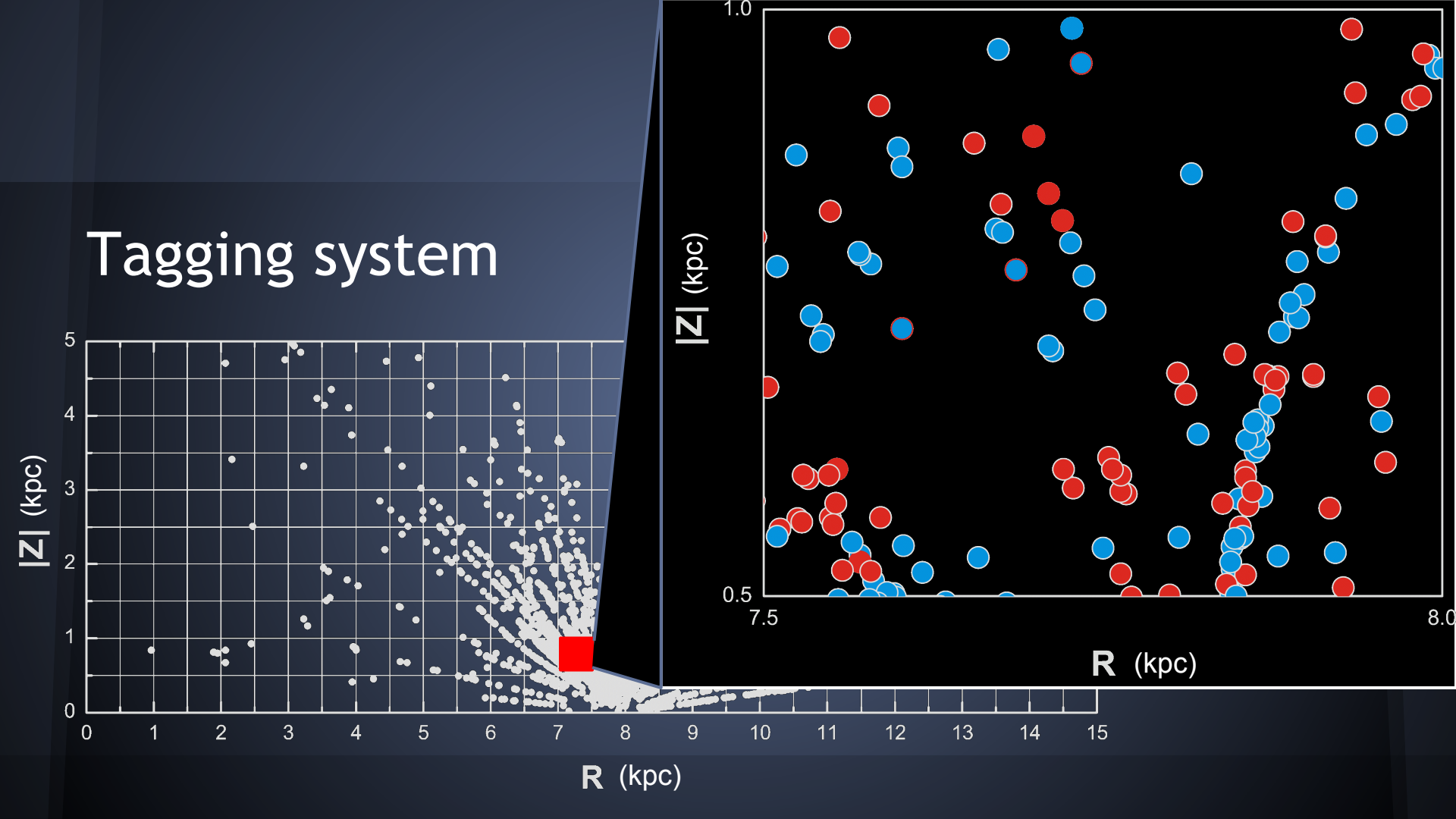
Distances from Recio-Blanco et al. (2014)

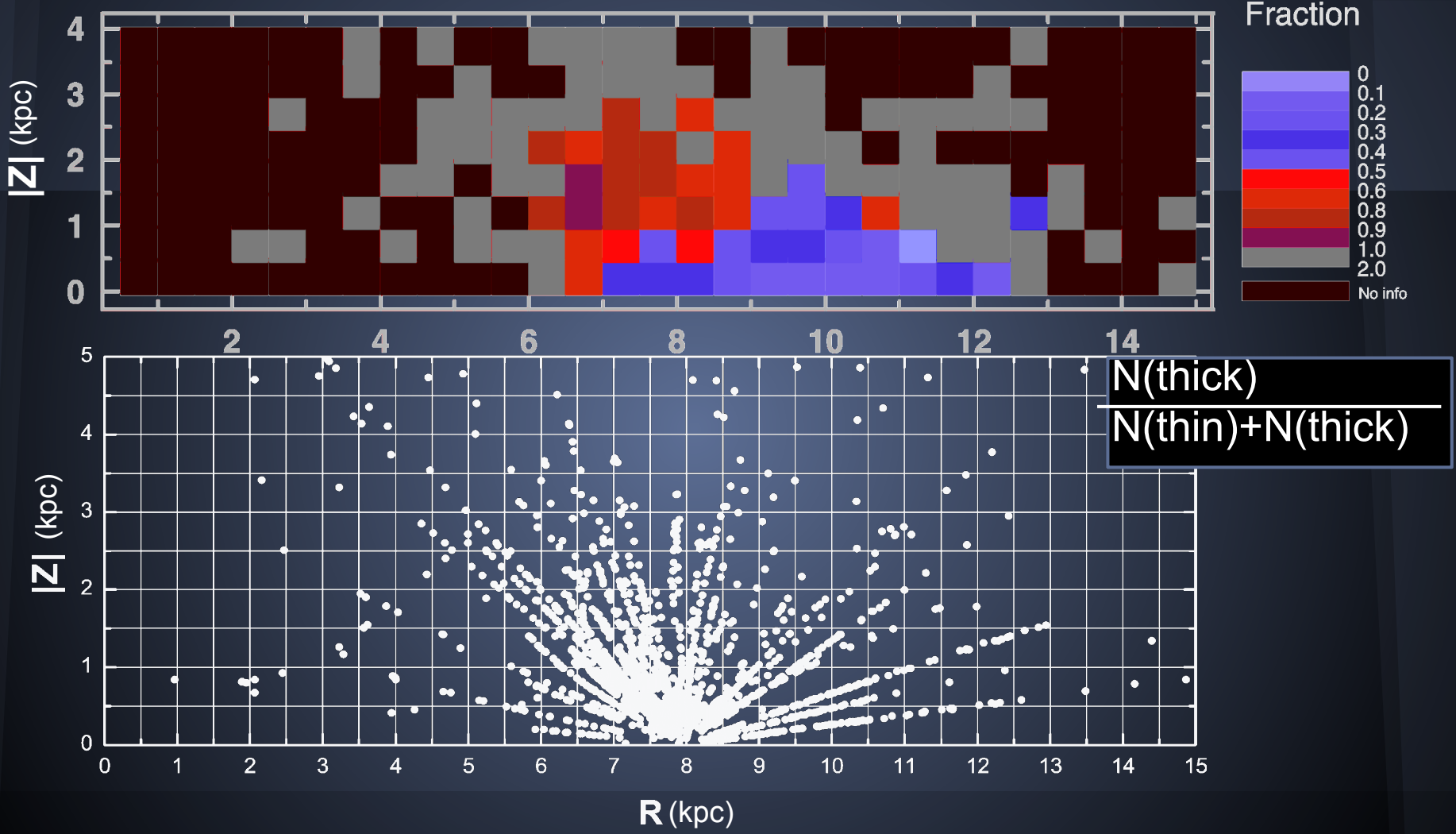
Abundances + distances

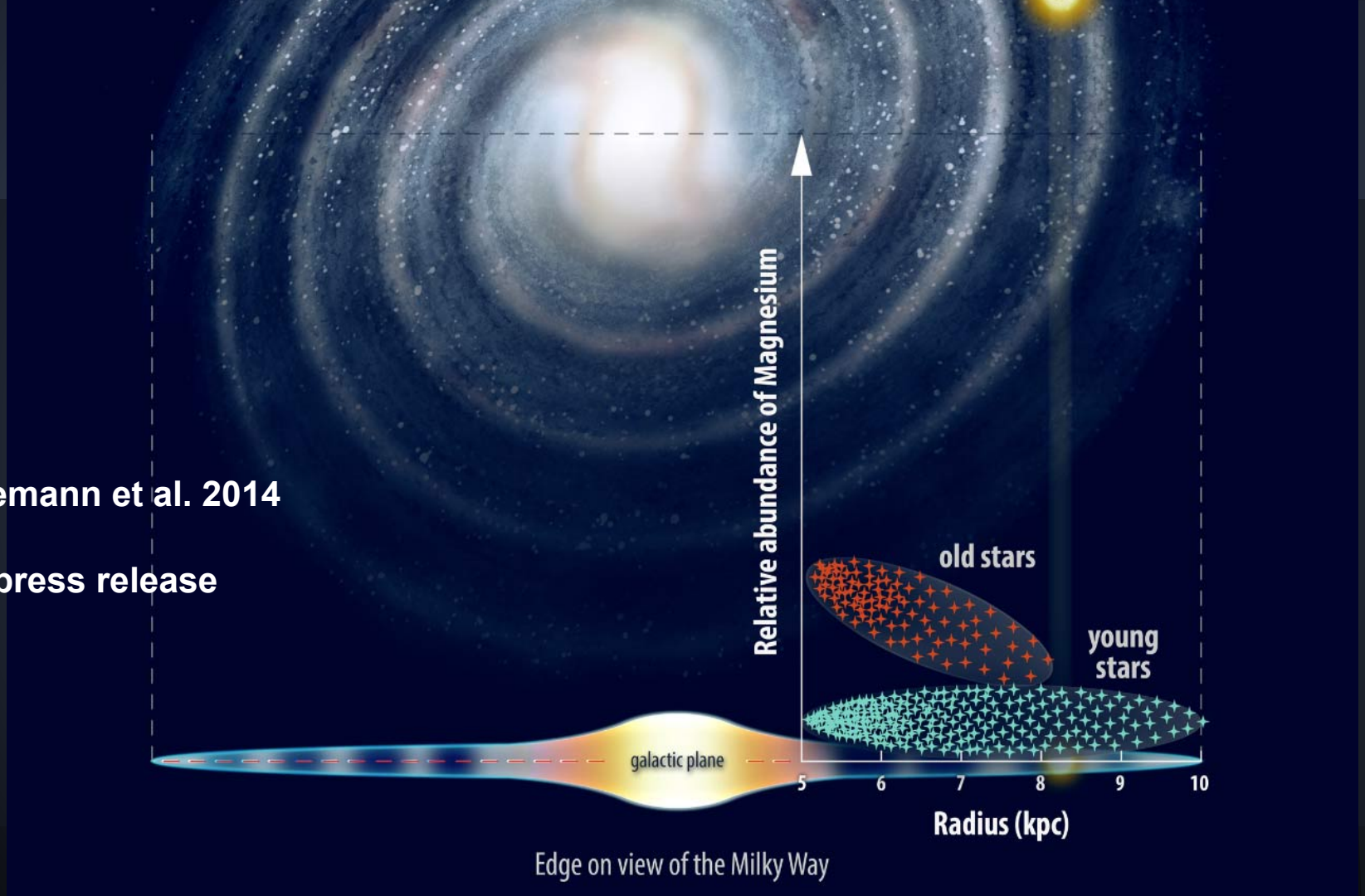
Use tagging



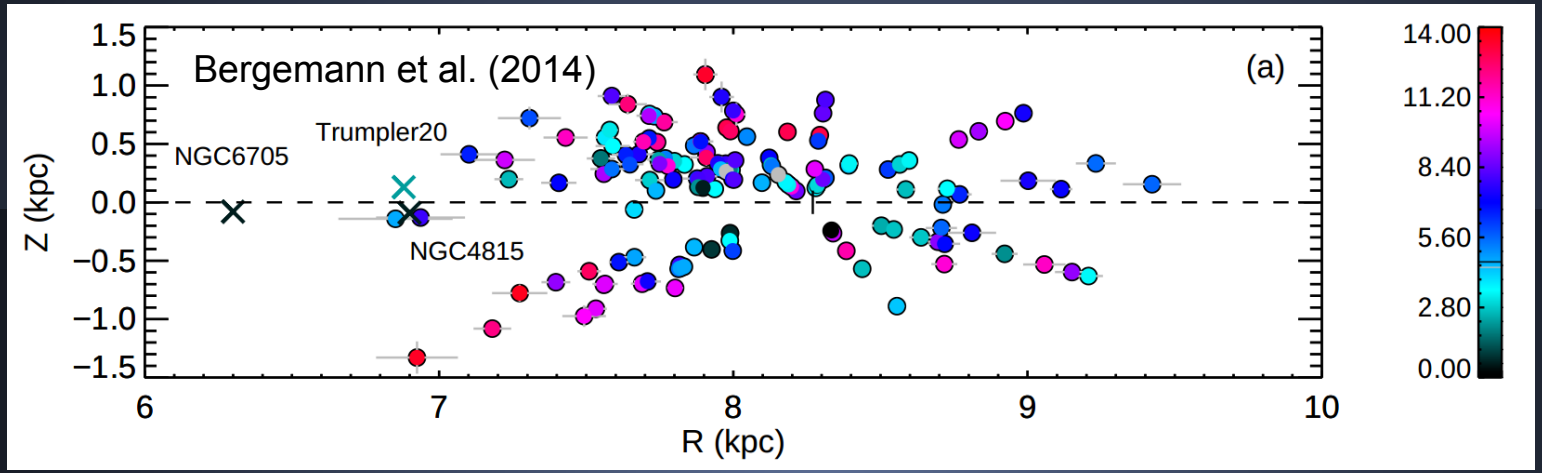
Tagging system

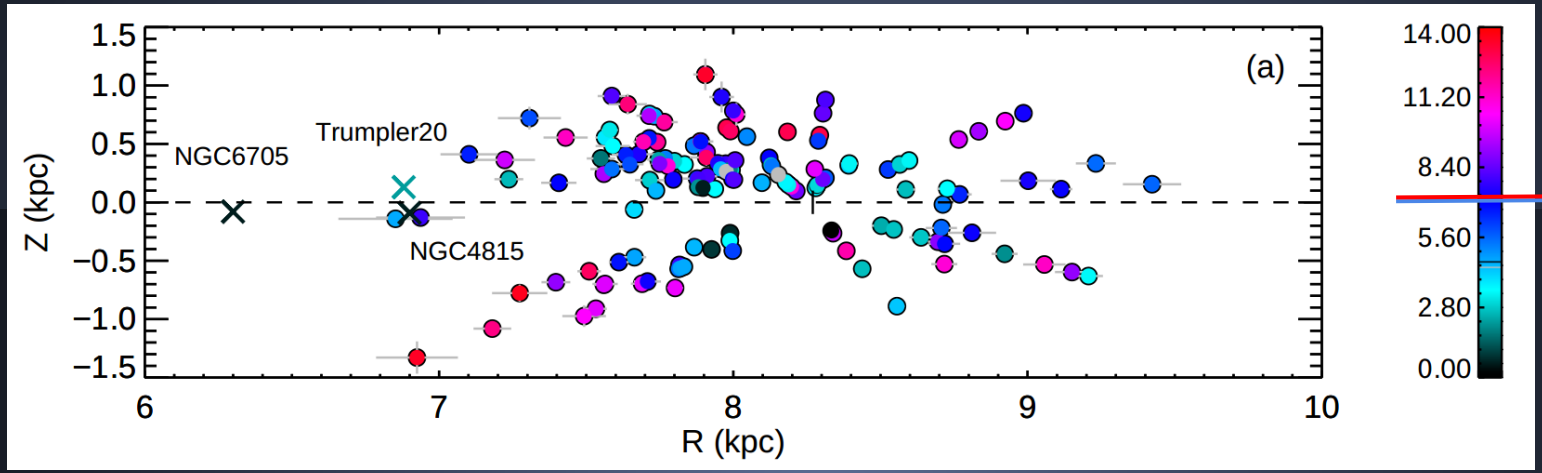


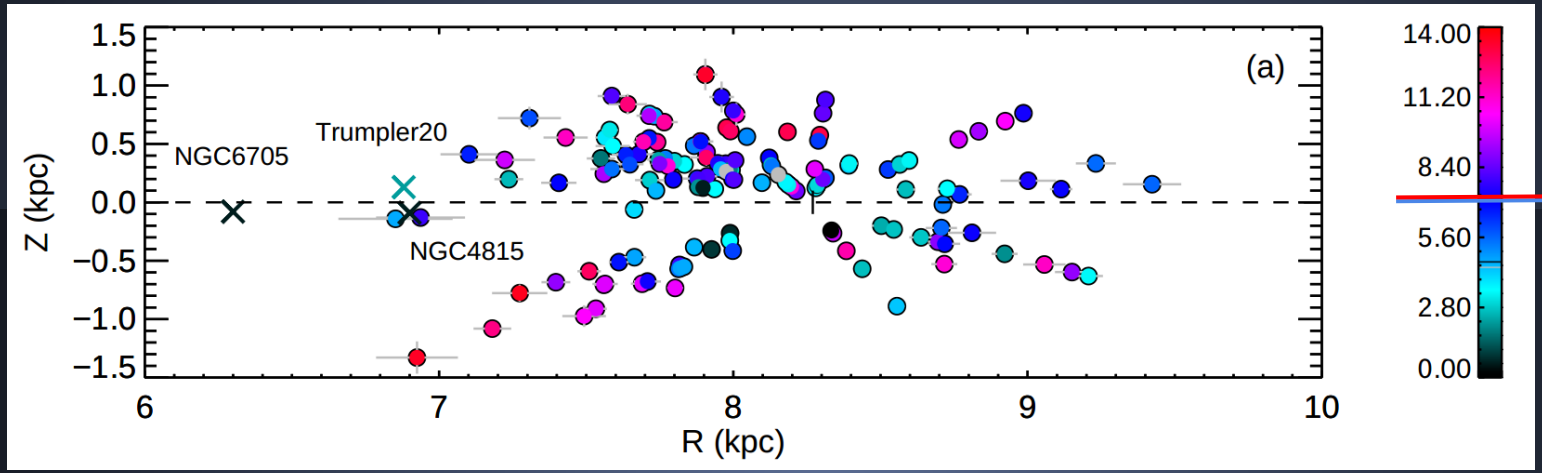

Fraction
0
0.1
0.2
0.3
0.4
0.5
0.6
0.8
0.9
1.0
2.0
No info
|Z| (kpc)
R (kpc)
N(thick)
N(thin)+N(thick)

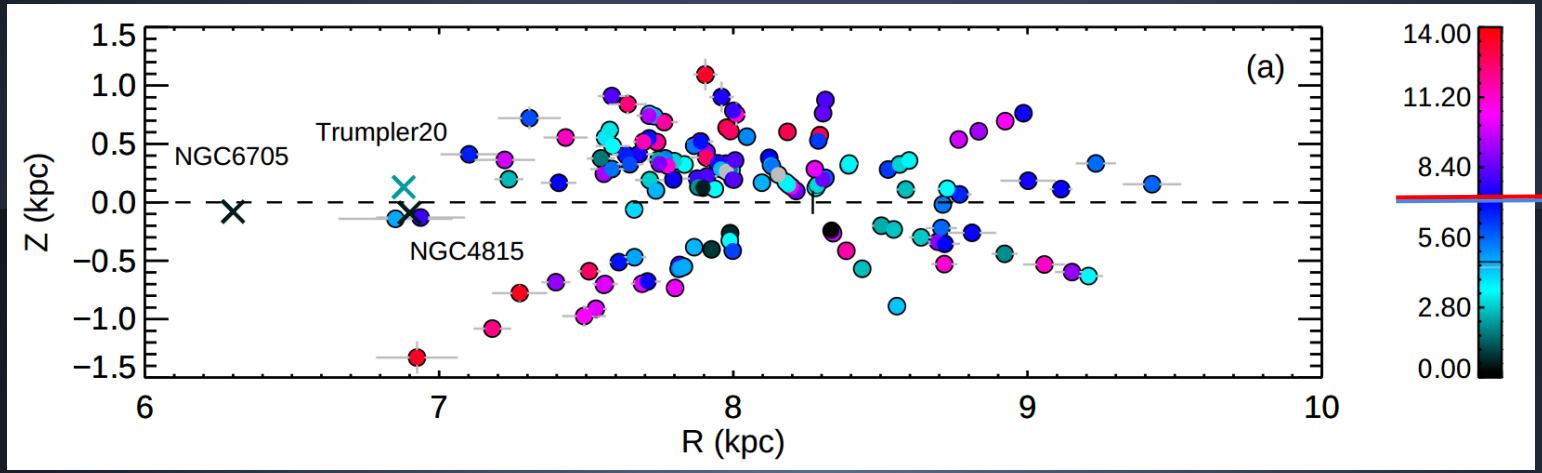


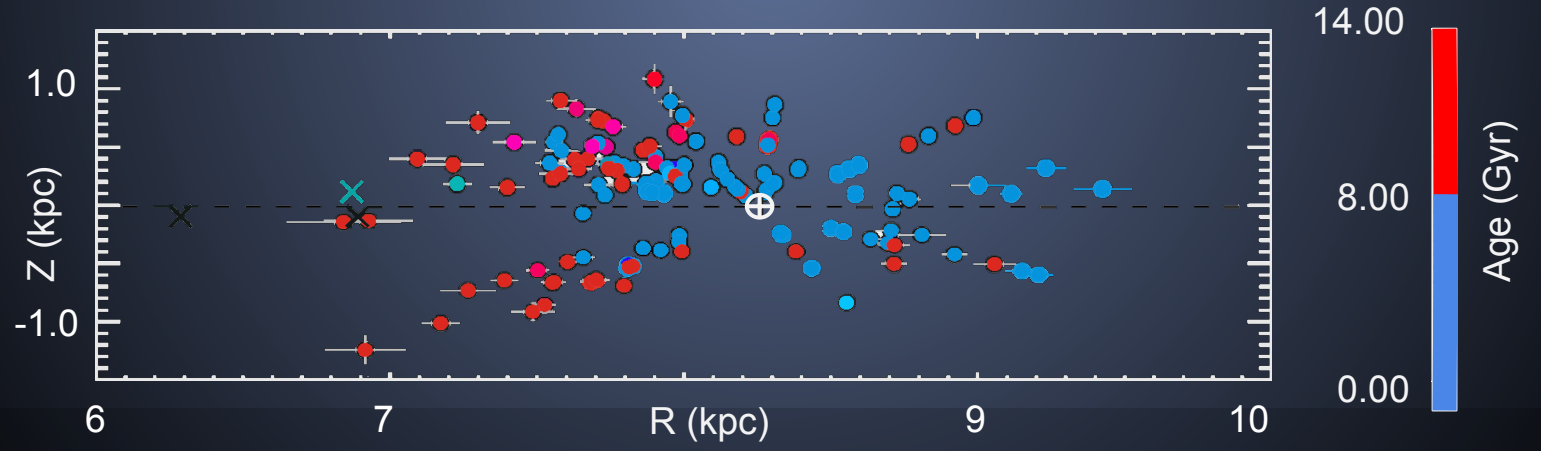
Bergemann et al. 2014
and
GES press release

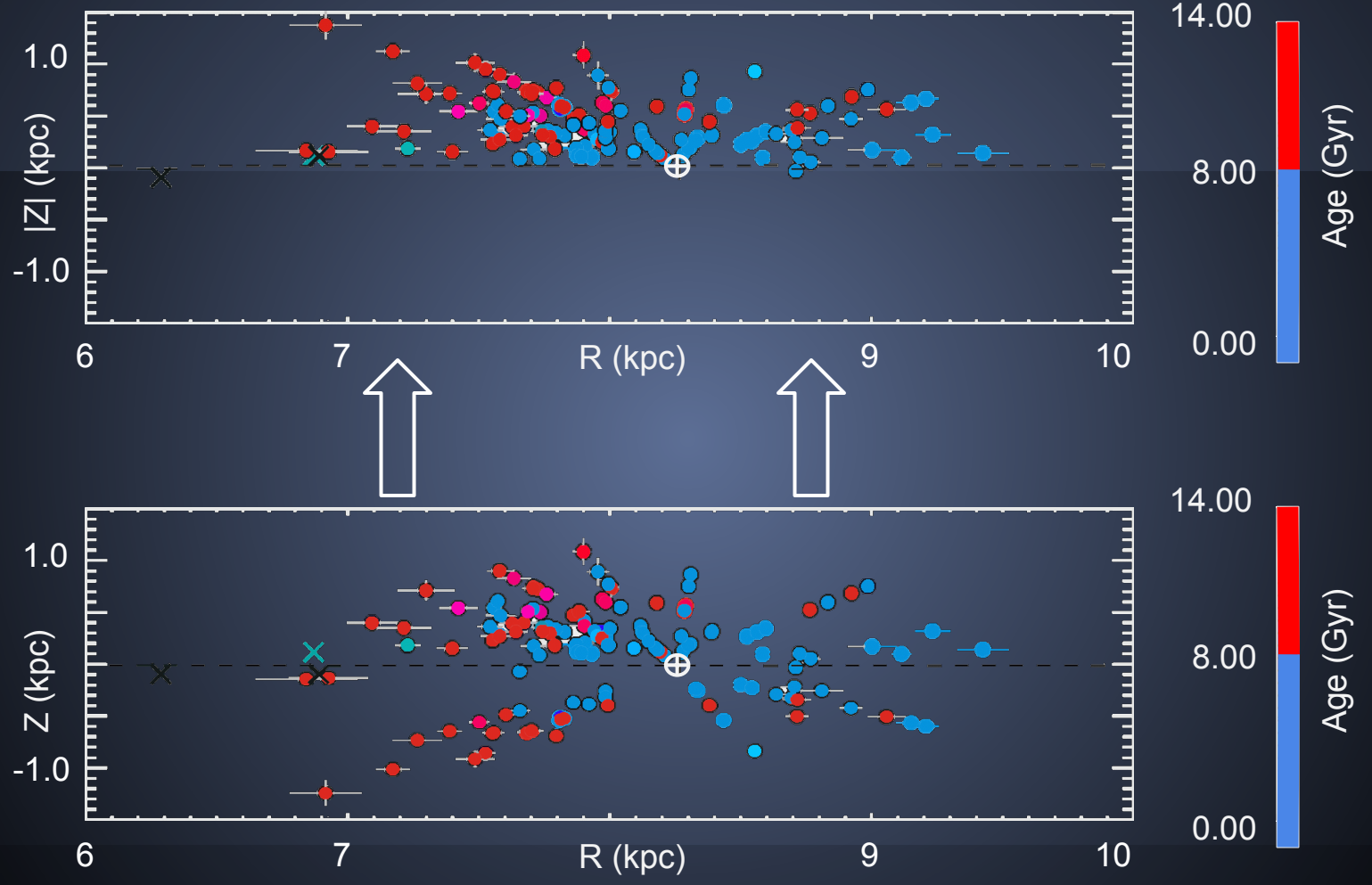

Bergemann et al. (2014)
(a)
Trumpler20
NGC6705
NGC4815
Z (kpc)
R (kpc)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
6
7
8
9
10
14.00
11.20
8.40
5.60
2.80
0.00

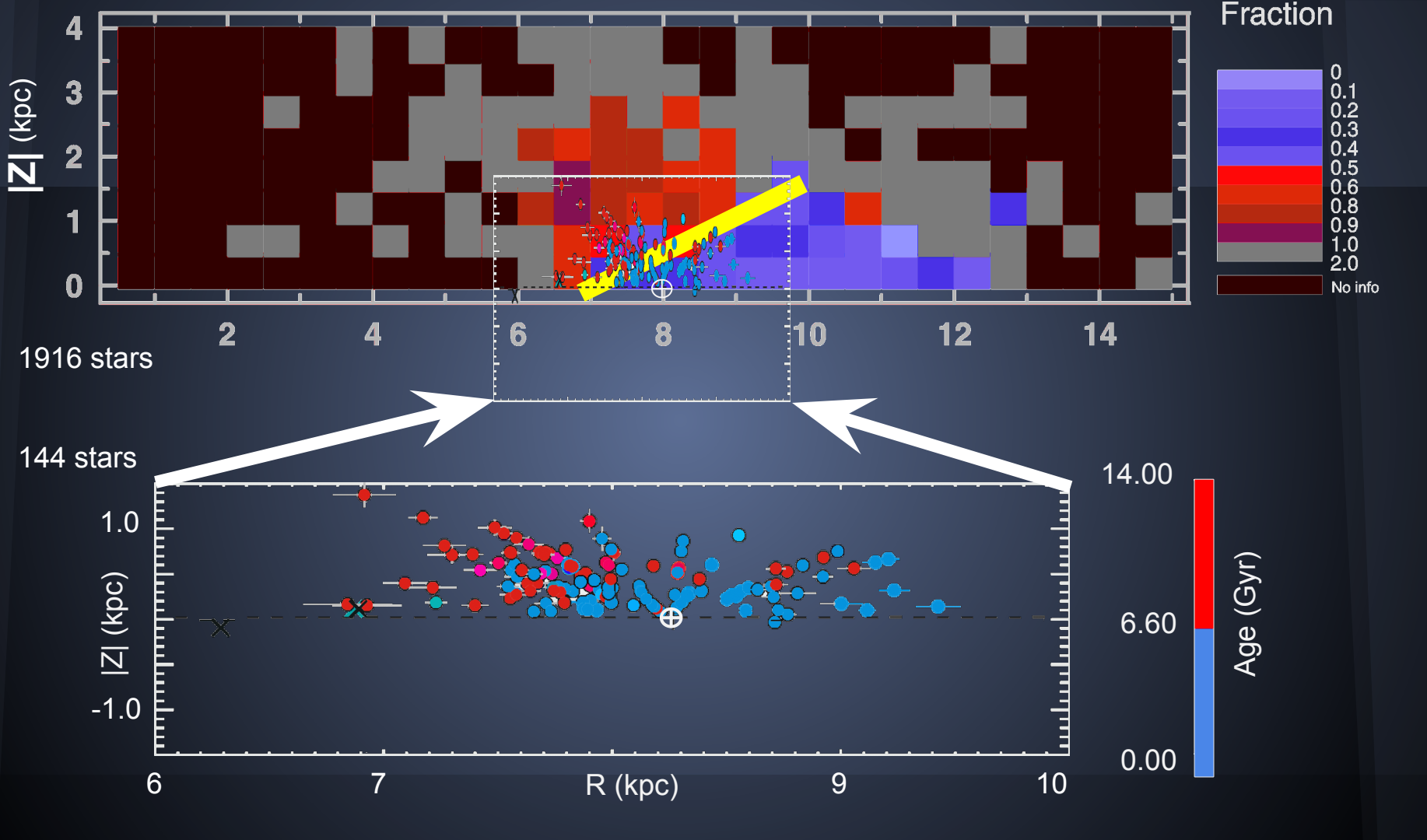

(a)
NGC6705
Trumpler20
NGC4815
Z (kpc)
R (kpc)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
6
7
8
9
10
14.00
11.20
8.40
5.60
2.80
0.00

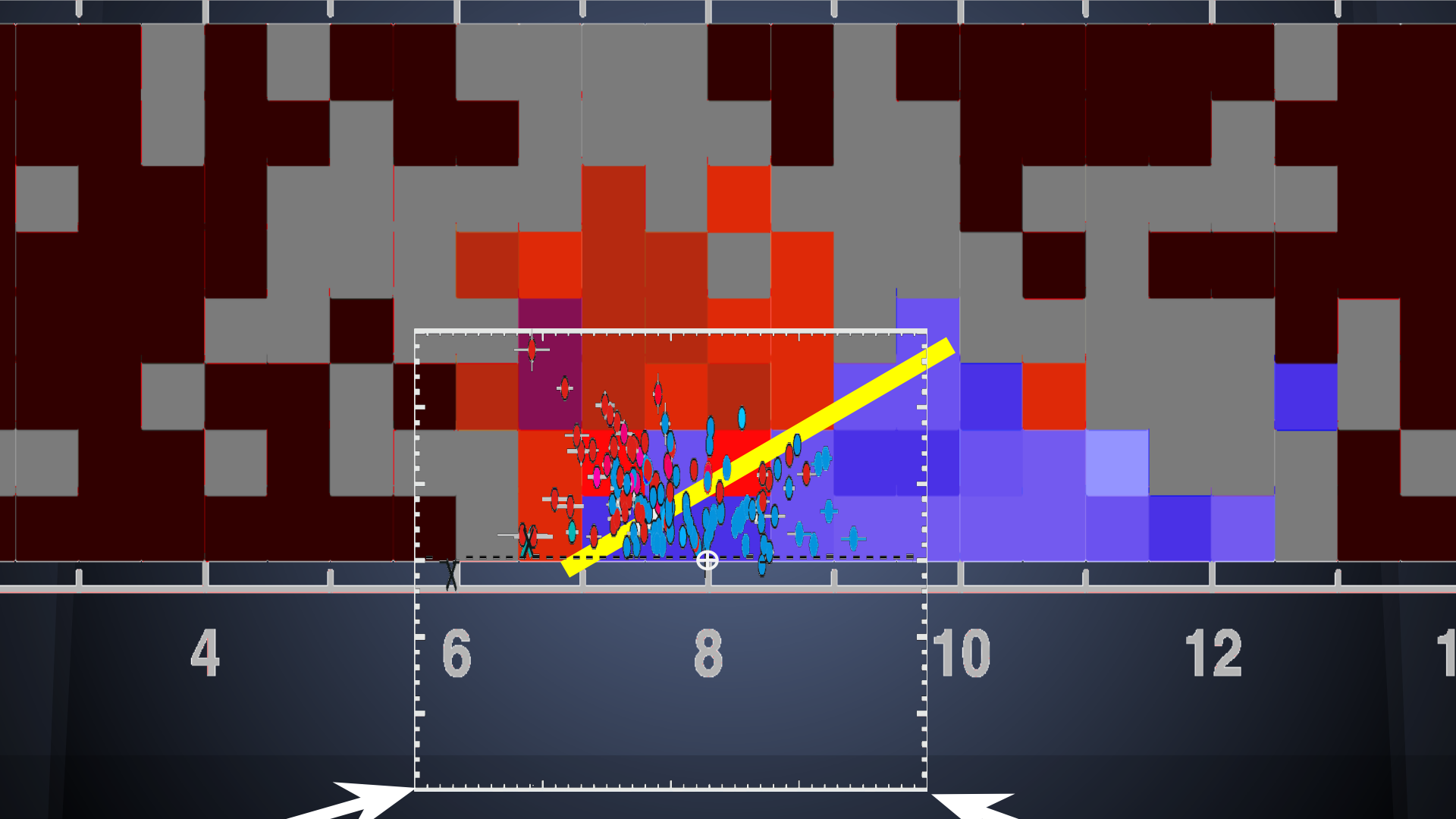

(a)
NGC6705
Trumpler20
NGC4815
Z (kpc)
R (kpc)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
6
7
8
9
10
14.00
11.20
8.40
5.60
2.80
0.00


(a)
NGC6705
Trumpler20
NGC4815
Z (kpc)
R (kpc)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
6
7
8
9
10
14.00
11.20
8.40
5.60
2.80
0.00

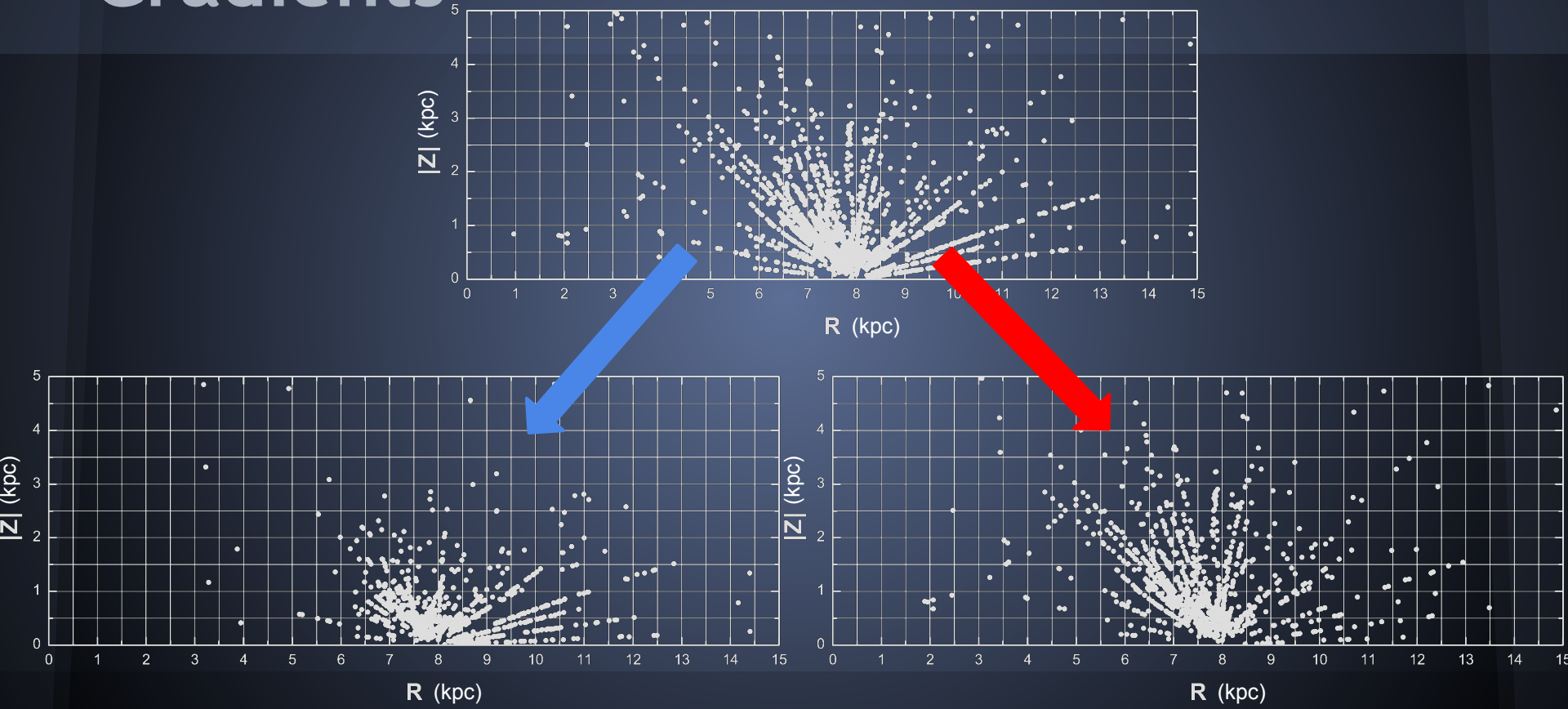

Z (kpc)
R (kpc)
1.0
-1.0
6
7
9
10
14.00
8.00
0.00
Age (Gyr)


1.0
|Z| (kpc)
-1.0
6
7
R (kpc)
9
10
14.00
8.00
0.00
Age (Gyr)
1.0
Z (kpc)
-1.0
6
7
R (kpc)
9
10
14.00
8.00
0.00
Age (Gyr)

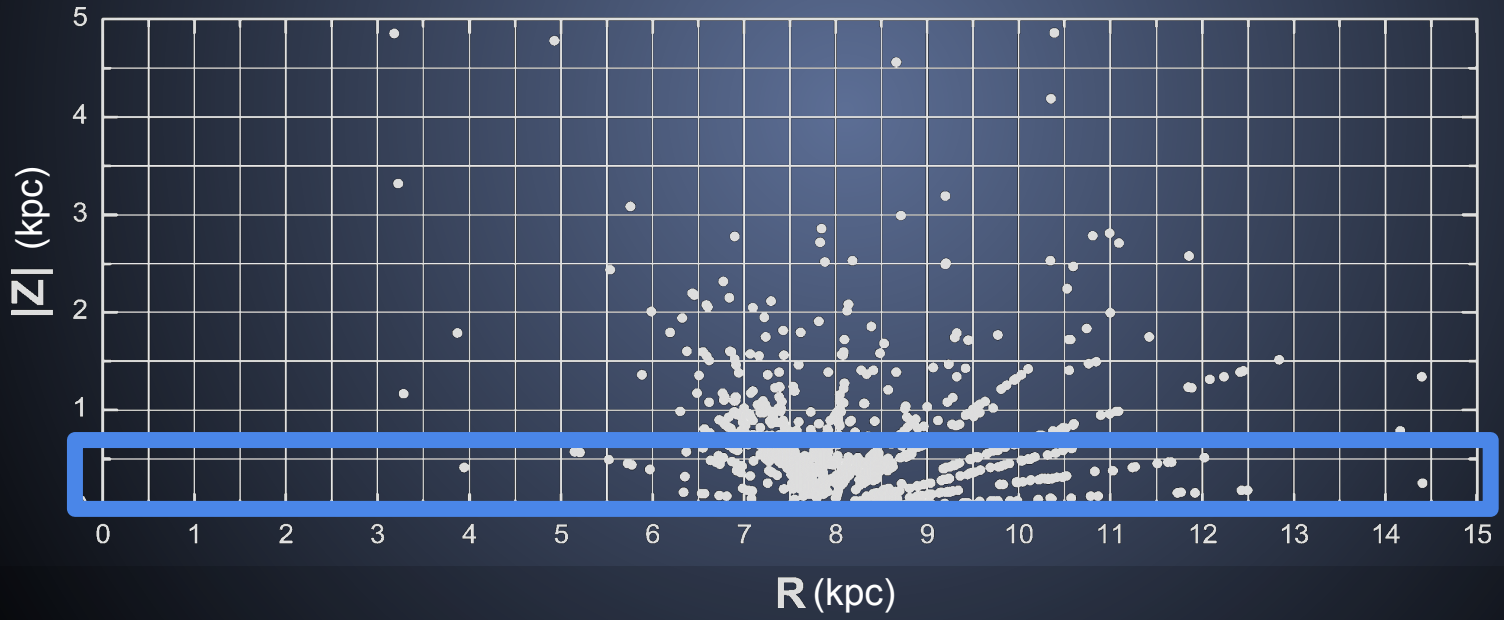

Fraction
0
0.1
0.2
0.3
0.4
0.5
0.6
0.8
0.9
1.0
2.0
No info
|Z| (kpc)
4
3
2
1
0
2
4
6
8
10
12
14
1916 stars
144 stars
1.0
-1.0
|Z| (kpc)
6
7
R (kpc)
9
10
14.00
6.60
0.00
Age (Gyr)

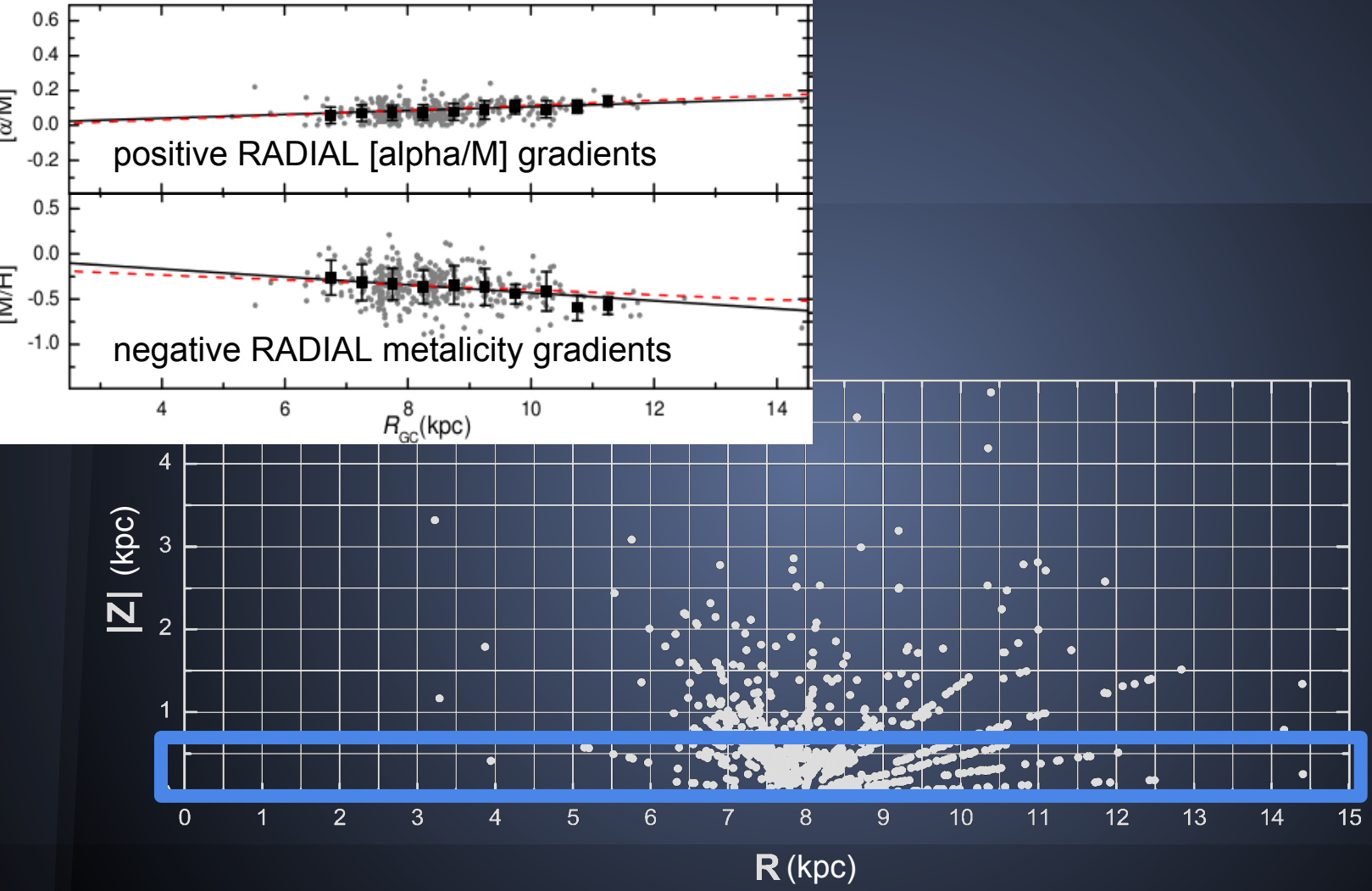

4
6
8
10
12

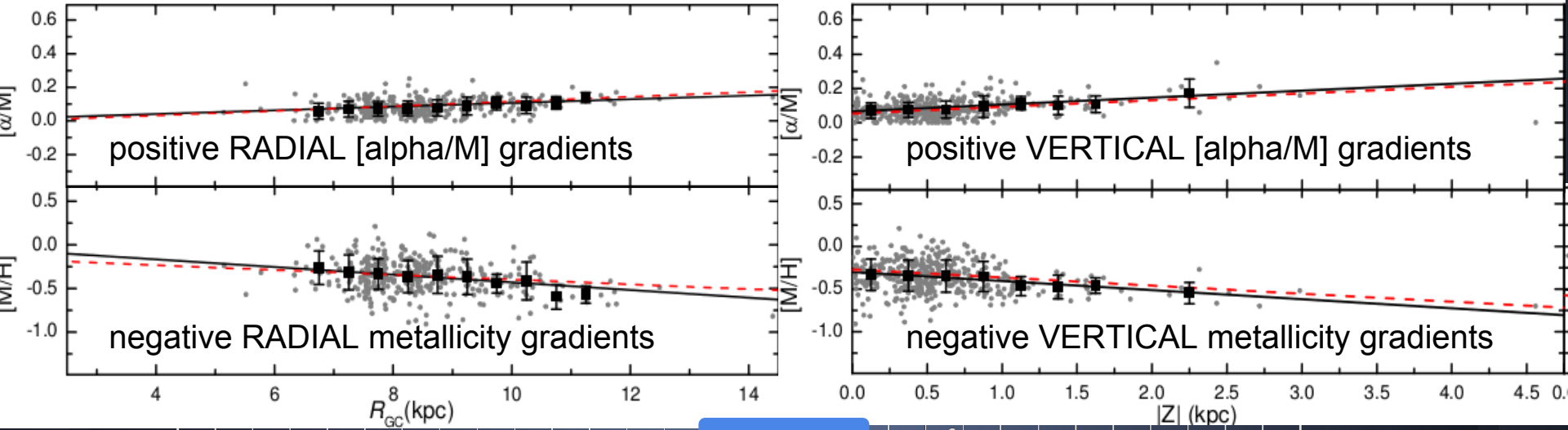
Gradients

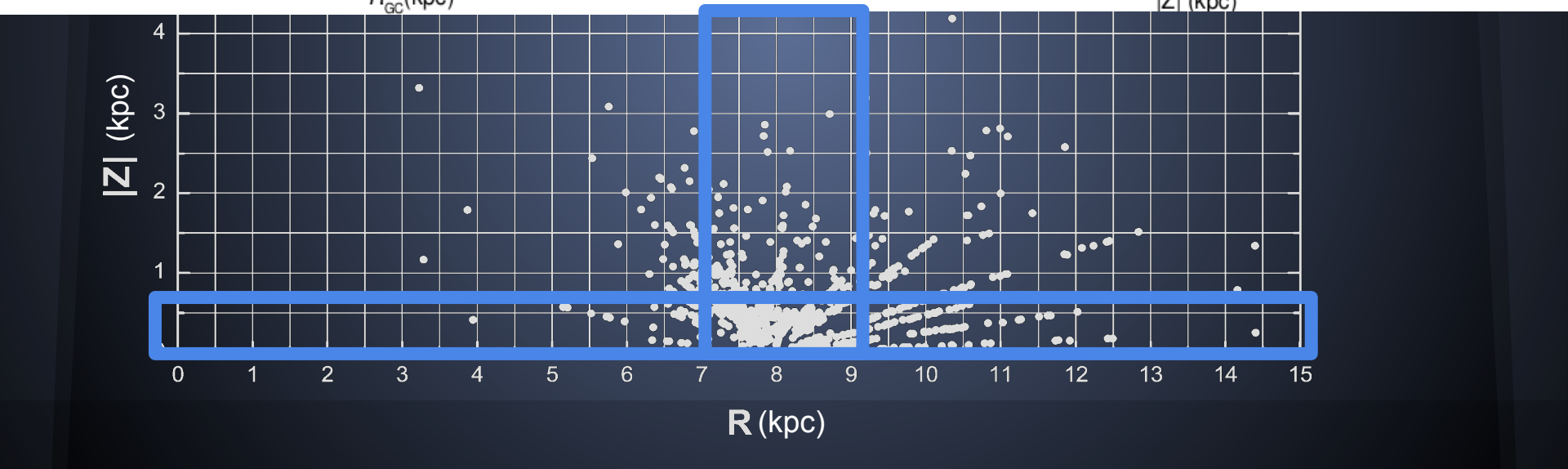


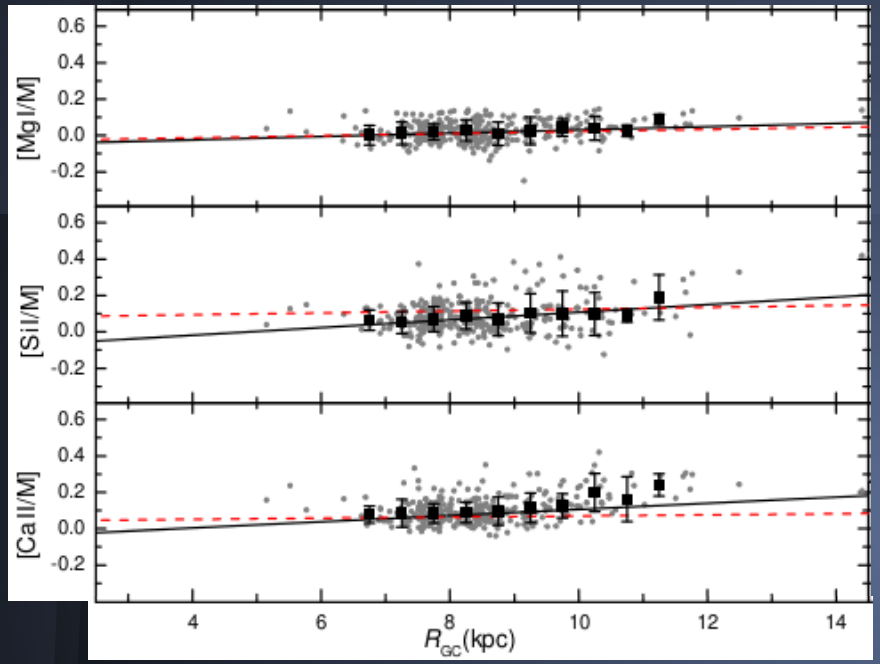
Thin disk abundance gradients

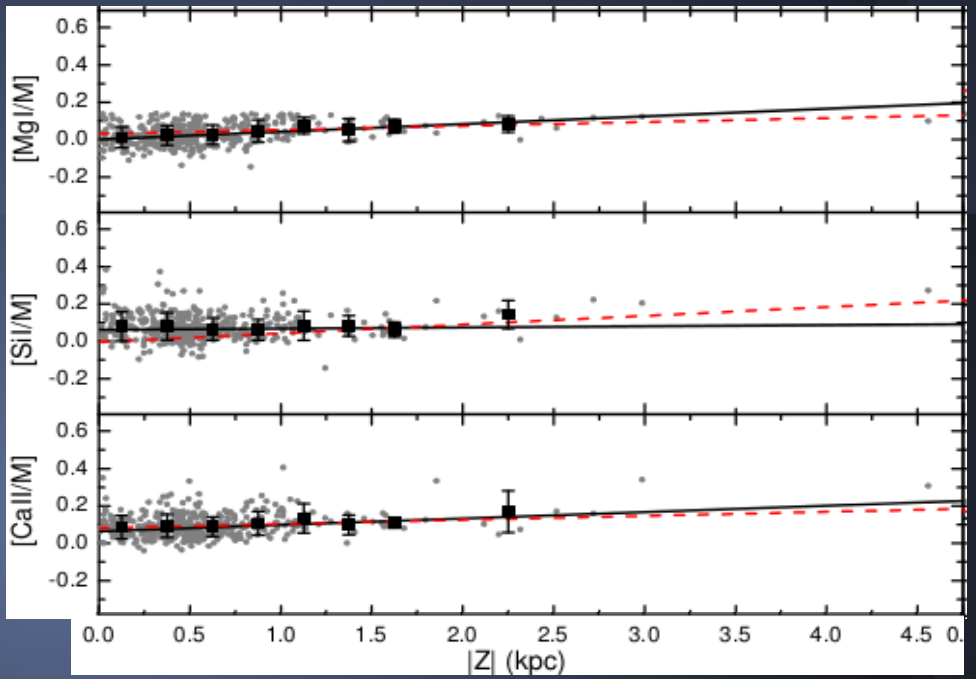


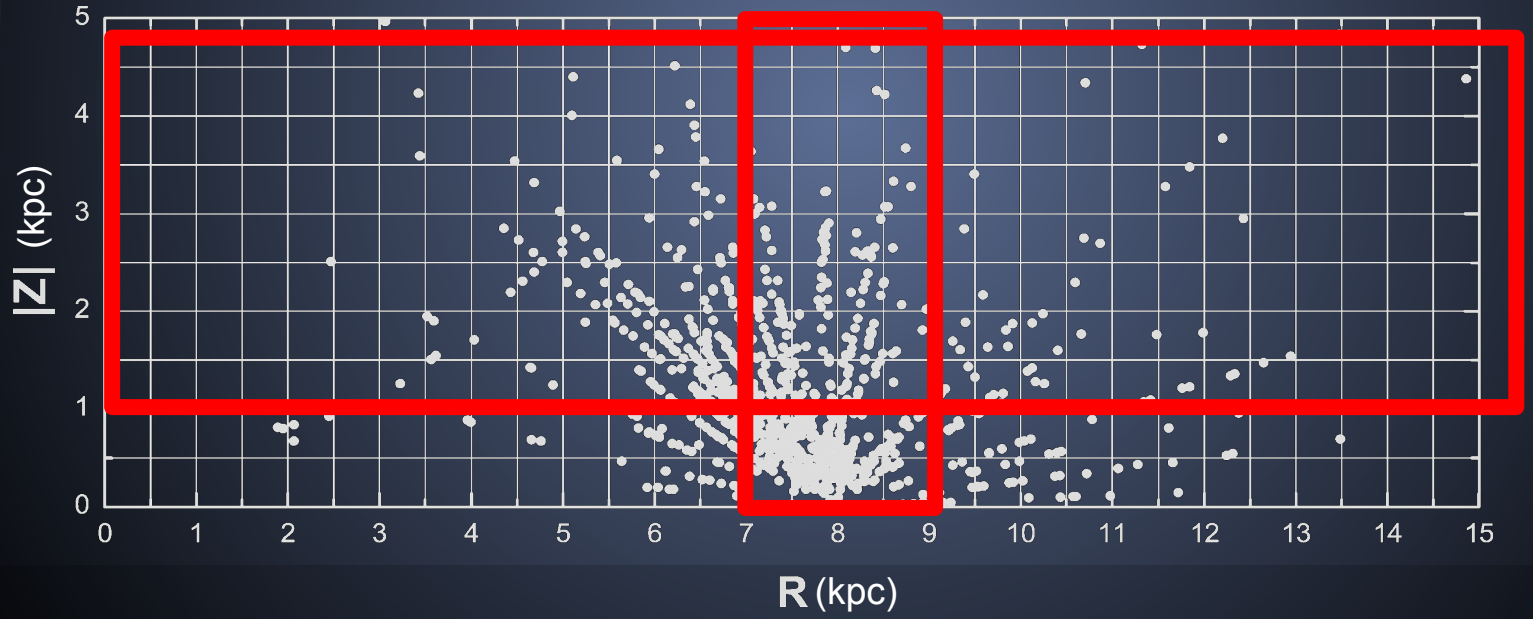

positive RADIAL [alpha/M] gradients
negative RADIAL metalicity gradients
[α/M]
[M/H]
R_{GC}(kpc)
|Z| (kpc)
R (kpc)

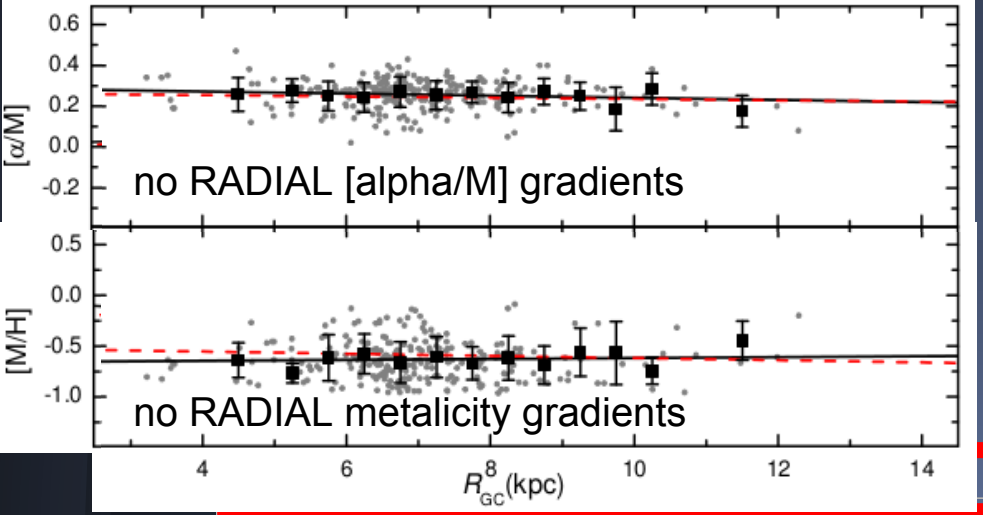

positive RADIAL [alpha/M] gradients
negative RADIAL metallicity gradients
positive VERTICAL [alpha/M] gradients
negative VERTICAL metallicity gradients
[α/M]
[M/H]
R_{GC}(kpc)
|Z| (kpc)

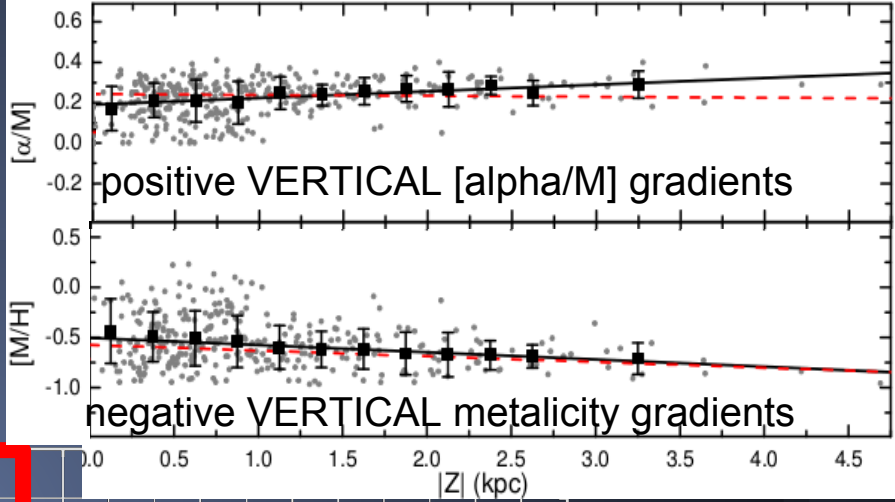

|Z| (kpc)
R (kpc)

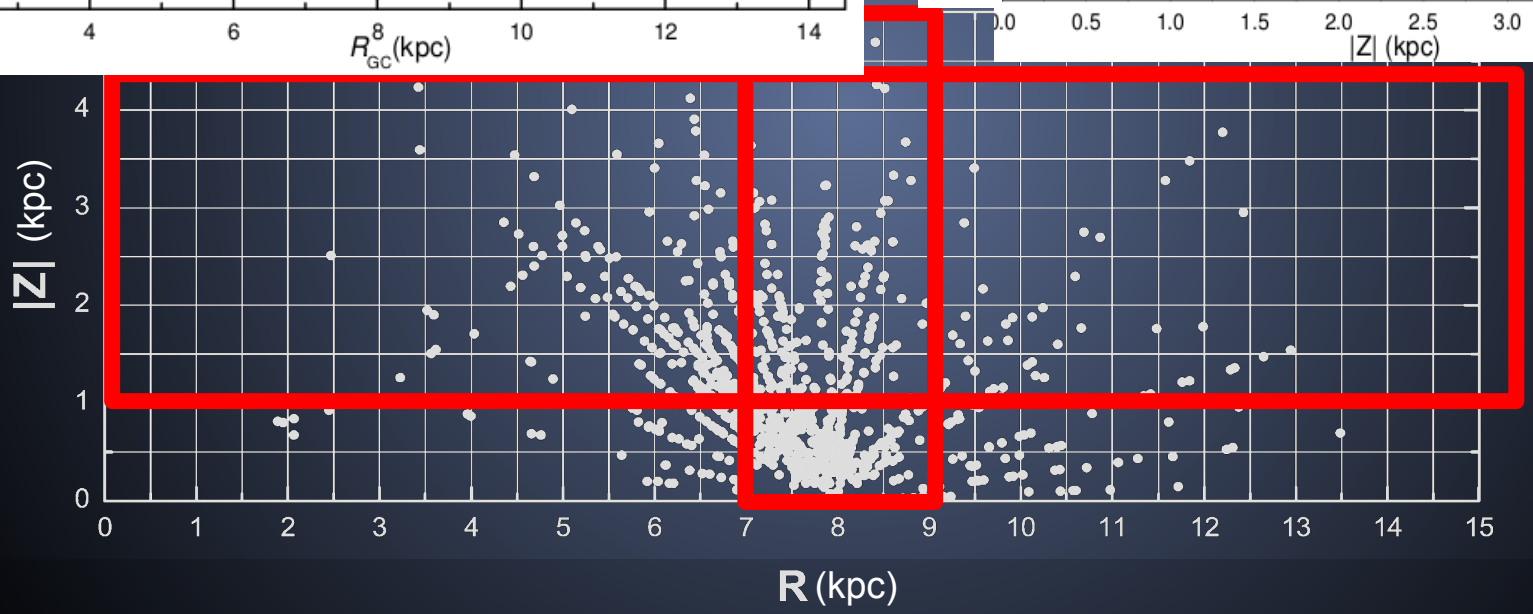

[Mg I/M]
[Si I/M]
[Ca II/M]
0.6
0.4
0.2
0.0
-0.2
4
6
8
10
12
14
R_{GC}(kpc)

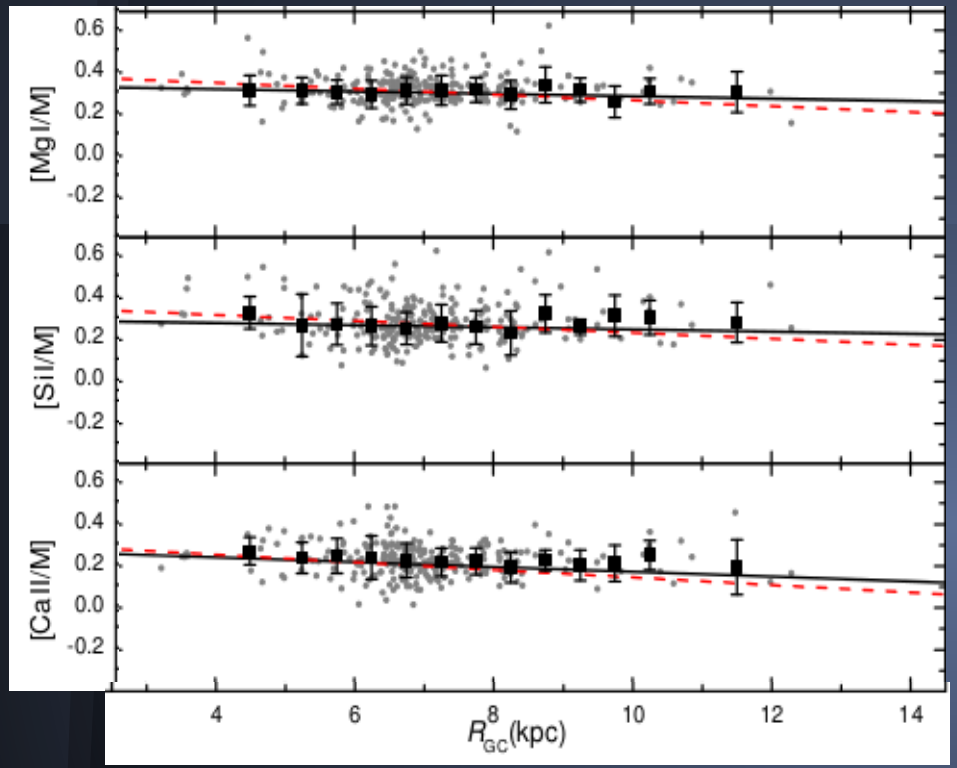

[Mg I/M]
[Si I/M]
[Ca II/M]
0.6
0.4
0.2
0.0
-0.2
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
|Z| (kpc)

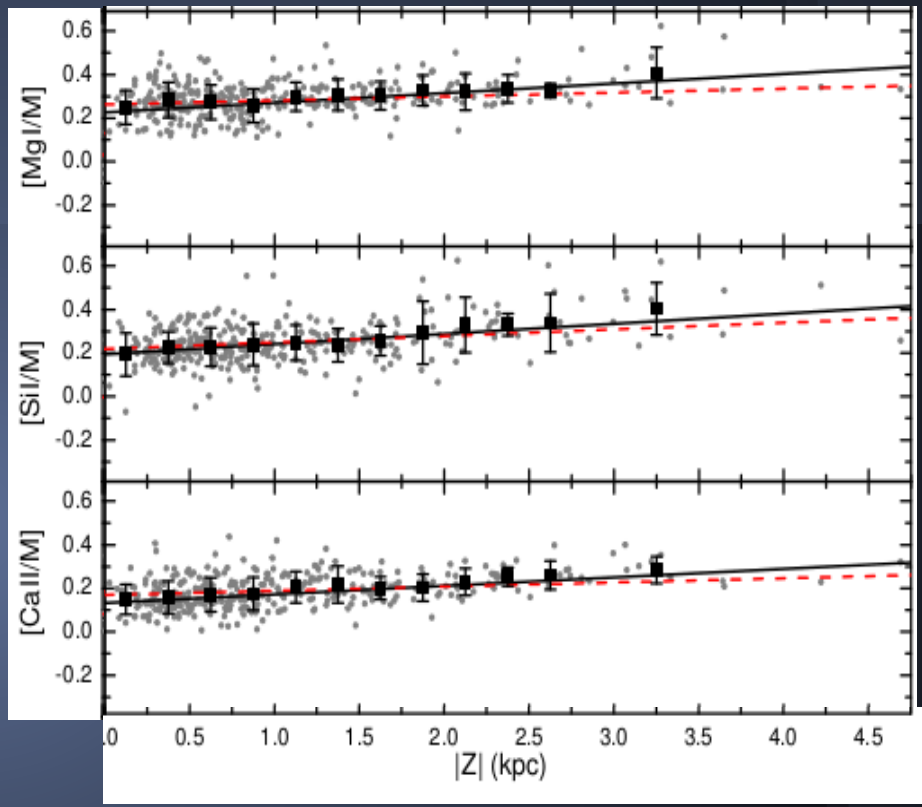

|Z| (kpc)
0
1
2
3
4
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
R (kpc)


[α/M]
no RADIAL [alpha/M] gradients
[M/H]
no RADIAL metalicity gradients
R^{8}_{GC}(kpc)


[α/M]
positive VERTICAL [alpha/M] gradients
[M/H]
negative VERTICAL metalicity gradients
|Z| (kpc)


|Z| (kpc)
R (kpc)

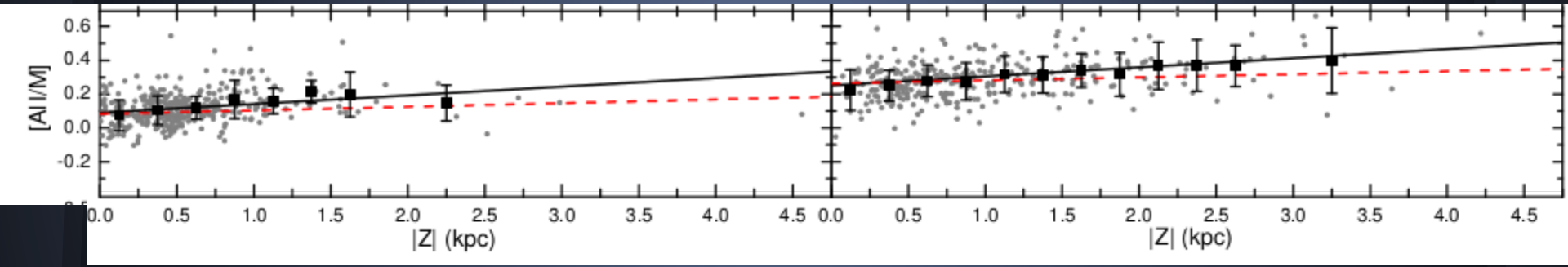

[MgI/M]
[SiI/M]
[CaII/M]
0.6
0.4
0.2
0.0
-0.2
4
6
8
10
12
14
R_{GC}(kpc)


[MgI/M]
[SiI/M]
[CaII/M]
0.6
0.4
0.2
0.0
-0.2
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
|Z| (kpc)

Aluminium - vertical gradients

Thin disk

Thick disk

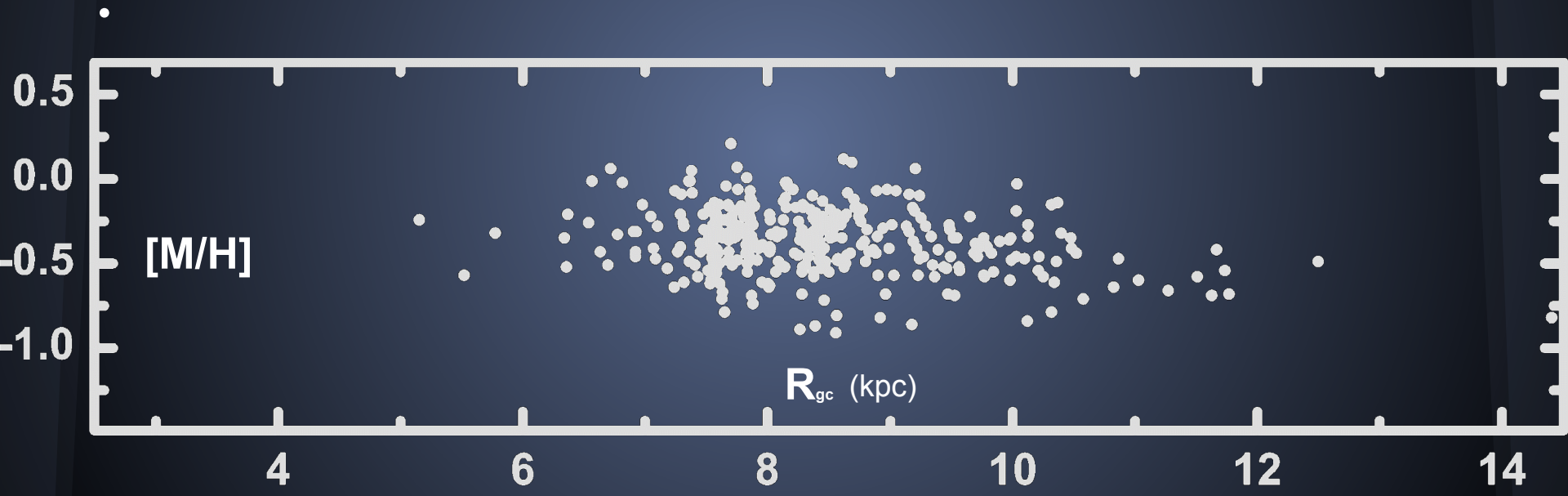


Positive vertical gradients of Aluminium

Conclusions about gradients

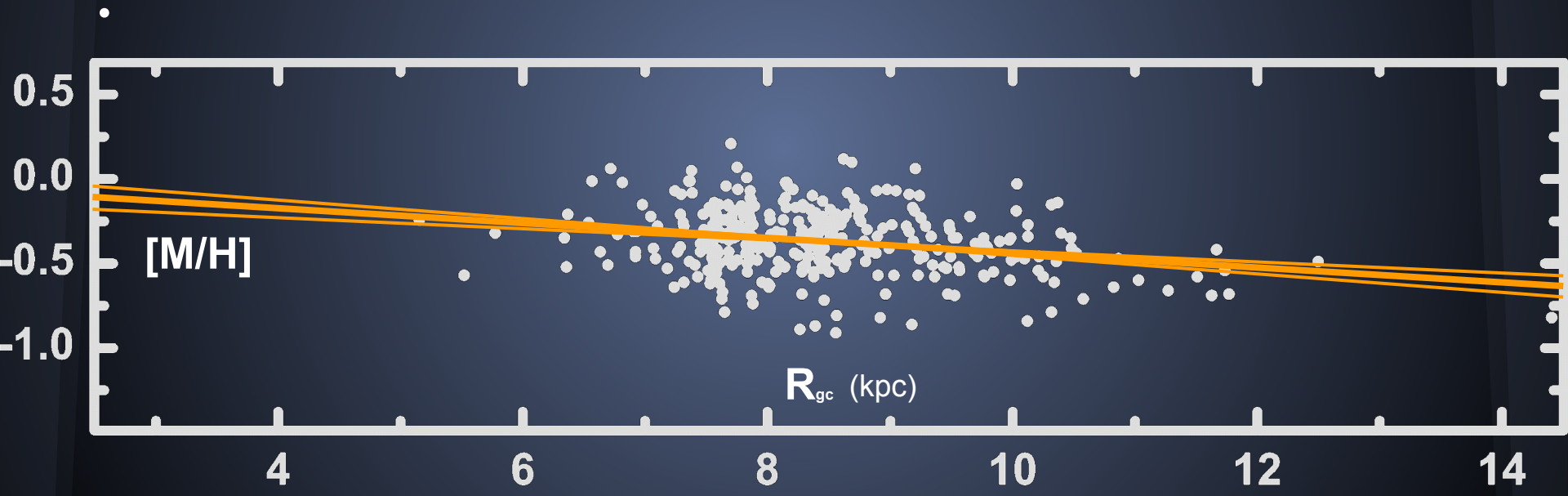
Galaxy evolutionary models

Thin disk evolution test



Chiappini et al. 1997; Alibés et al. 2001b,a; Cescutti et al. 2007

Thin disk evolution test



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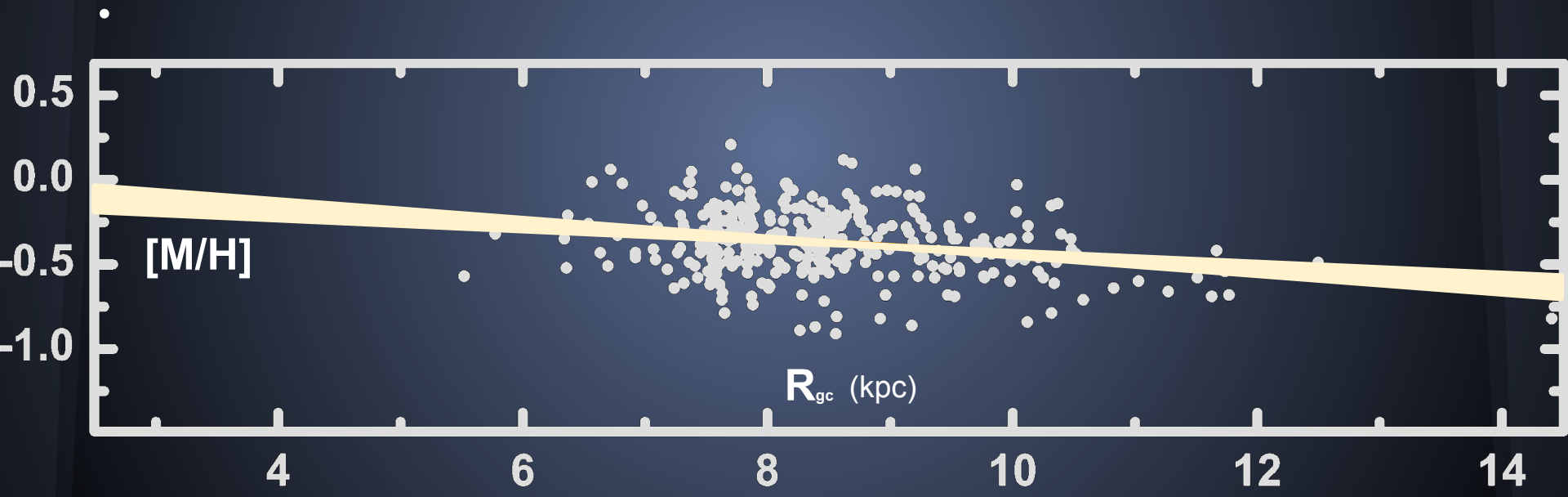

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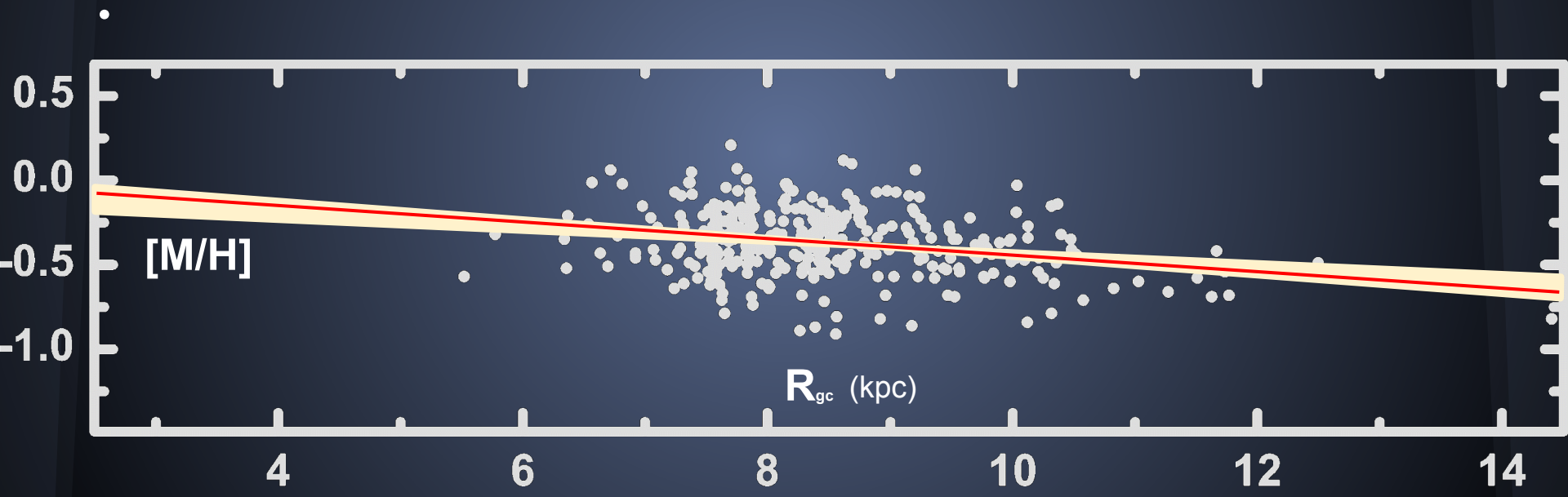
Thin disk evolution test



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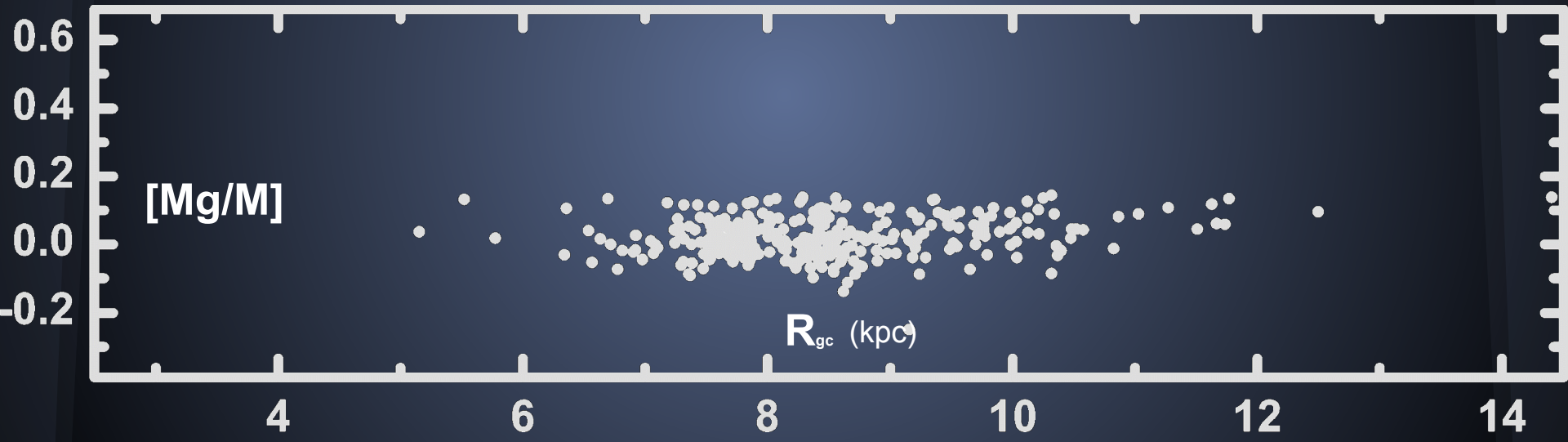
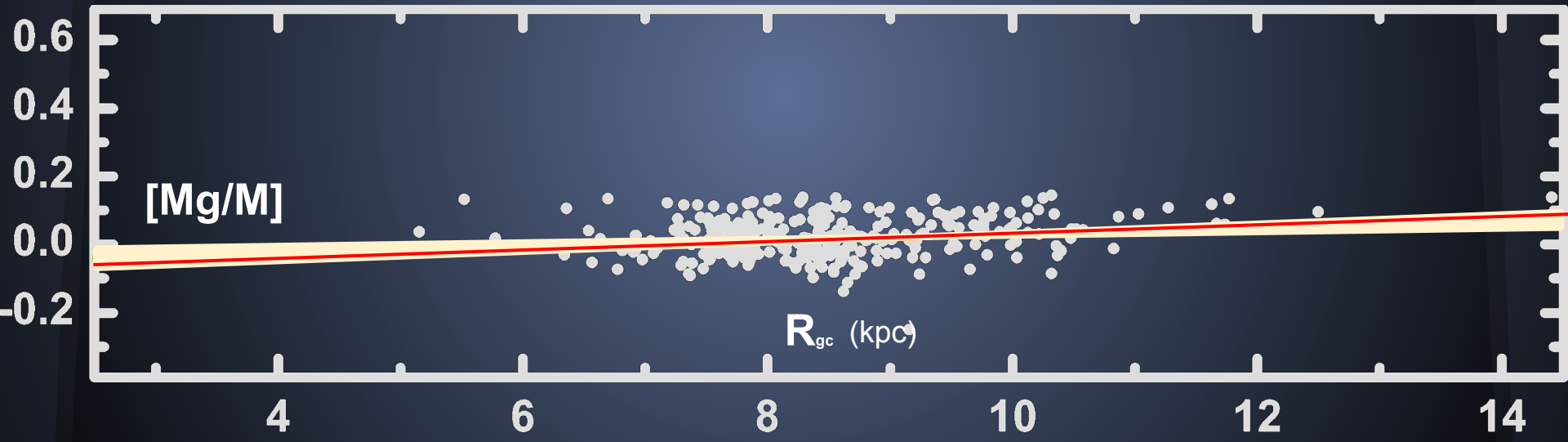
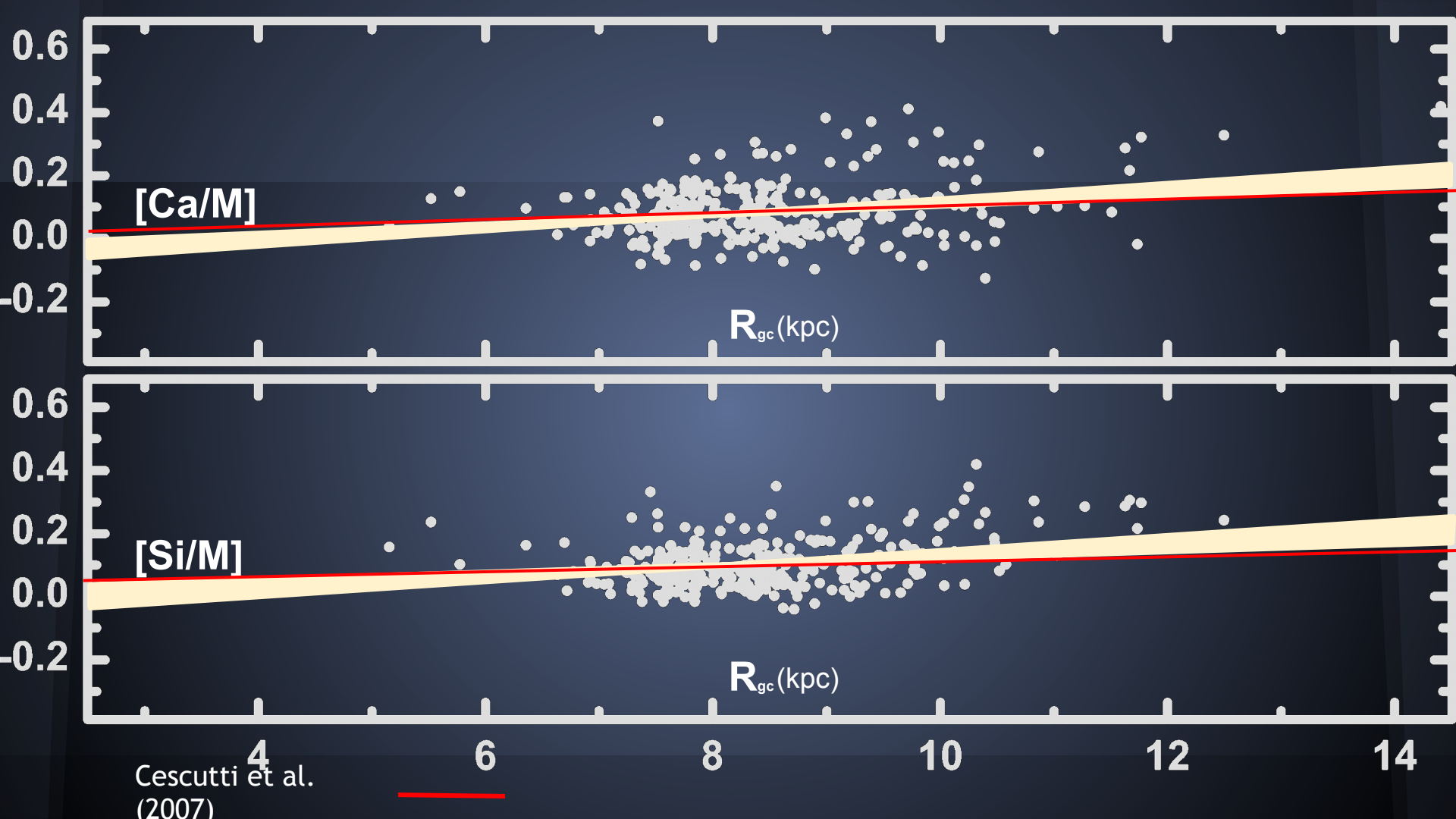
Thin disk evolution test

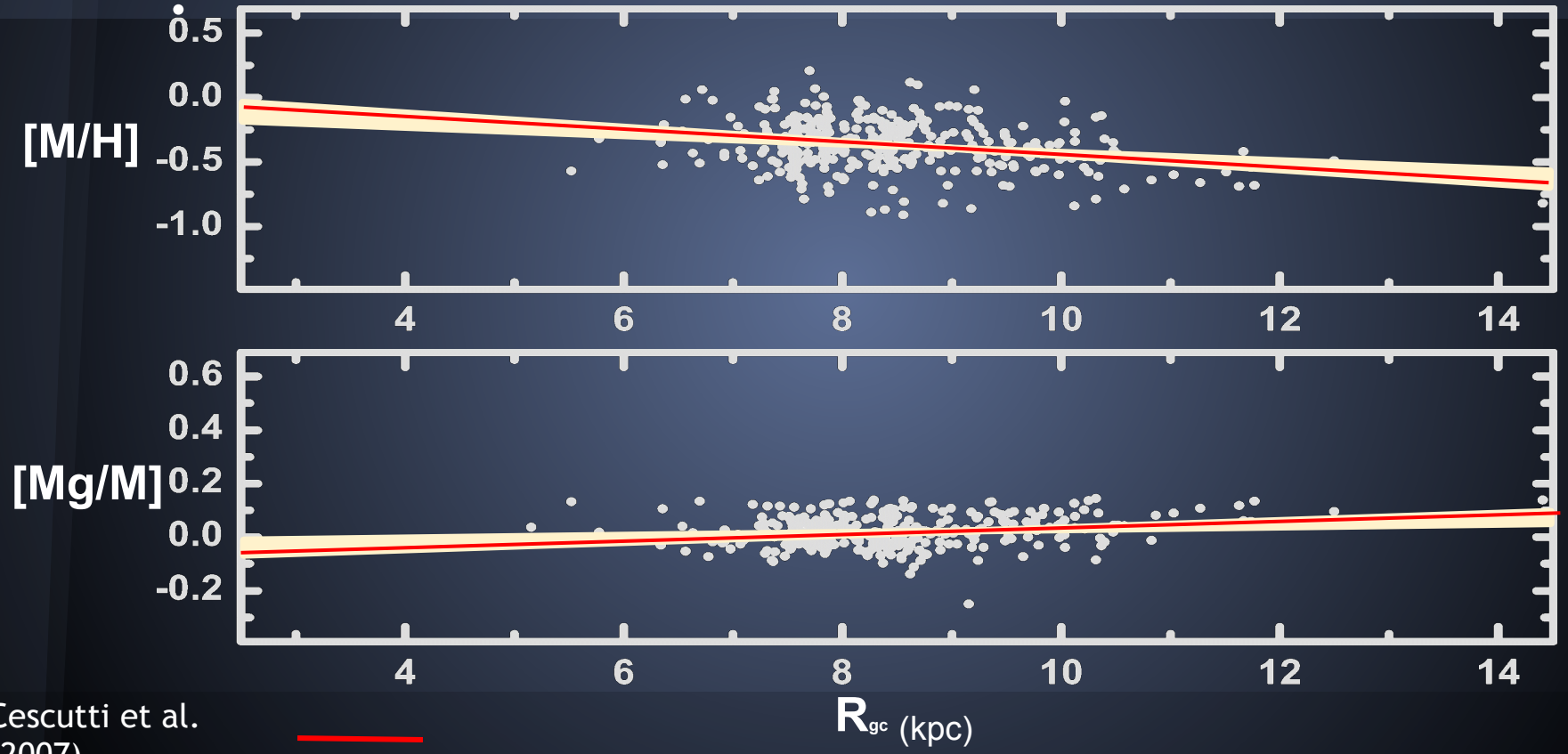


Thin disk evolution test



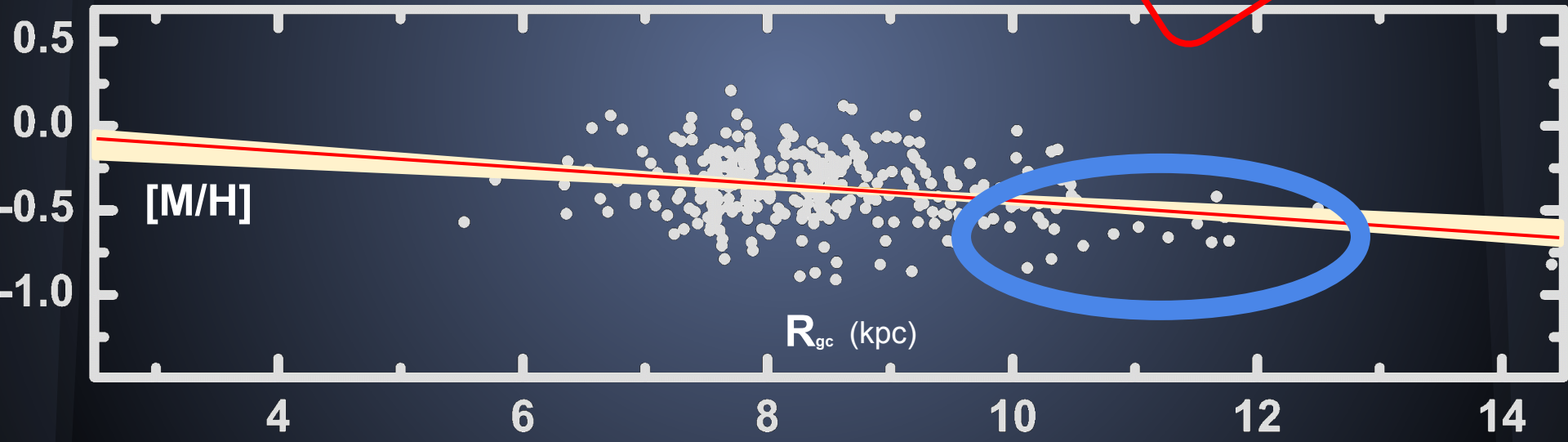

0.6
0.4
0.2
0.0
-0.2
[Ca/M]
R_{gc}(kpc)
0.6
0.4
0.2
0.0
-0.2
[Si/M]
R_{gc}(kpc)
4
6
8
10
12
14
Cescutti et al. (2007)

Inside-out scenarios of thin disk Chiappini et al. 1997; Alibés et al. 2001b,a; Cescutti et al. 2007



Outside-in scenario

Haywood et al. (2013) (outside-in)



More by Misha Haywood this afternoon!

Thick disk study

4 scenarios to test:

Thick disk study

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(I) Heating of a pre-existing thin disc by a violent merger

e.g. Quinn et al. (1993) Kazantzidis et al. 2008; Villalobos & Helmi 2008; Qu et al. 2011)

(II) Merger of small satellites that deposit their stars into a thick disc

Abadi et al. (2003)

(III) Formation of a thick disc in situ following accretion of gas

Brook et al. (2004), Bournaud et al. (2009)

(IV) Radial rearrangement of the disc via radial mixing

Schönrich & Binney (2009a,b), Roškar et al. (2008), Minchev & Famaey (2010), Minchev et al. (2013)

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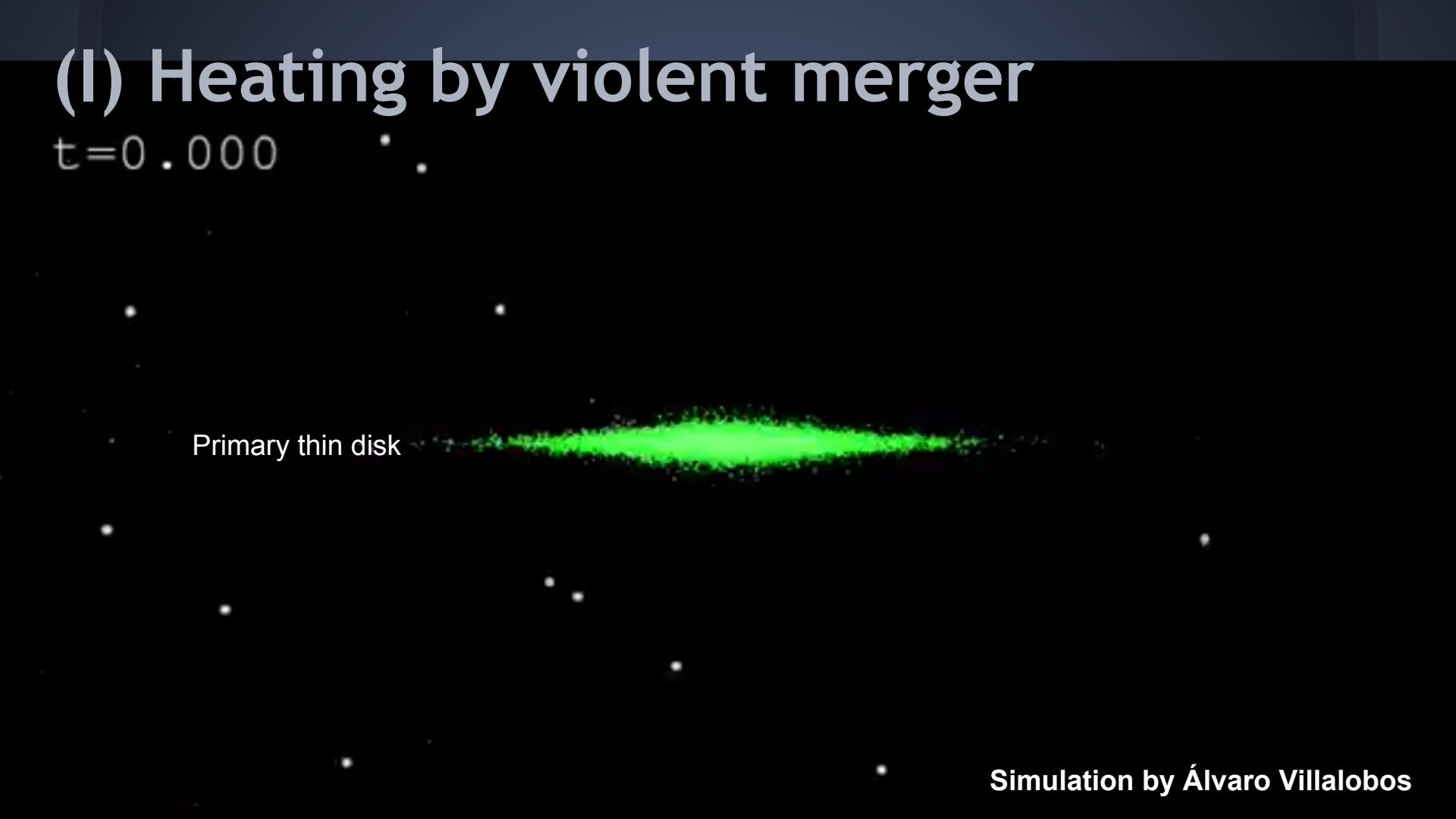
“Approved” by our data

(I) Heating by violent merger
(IV) Radial migration

“Disapproved” by our data

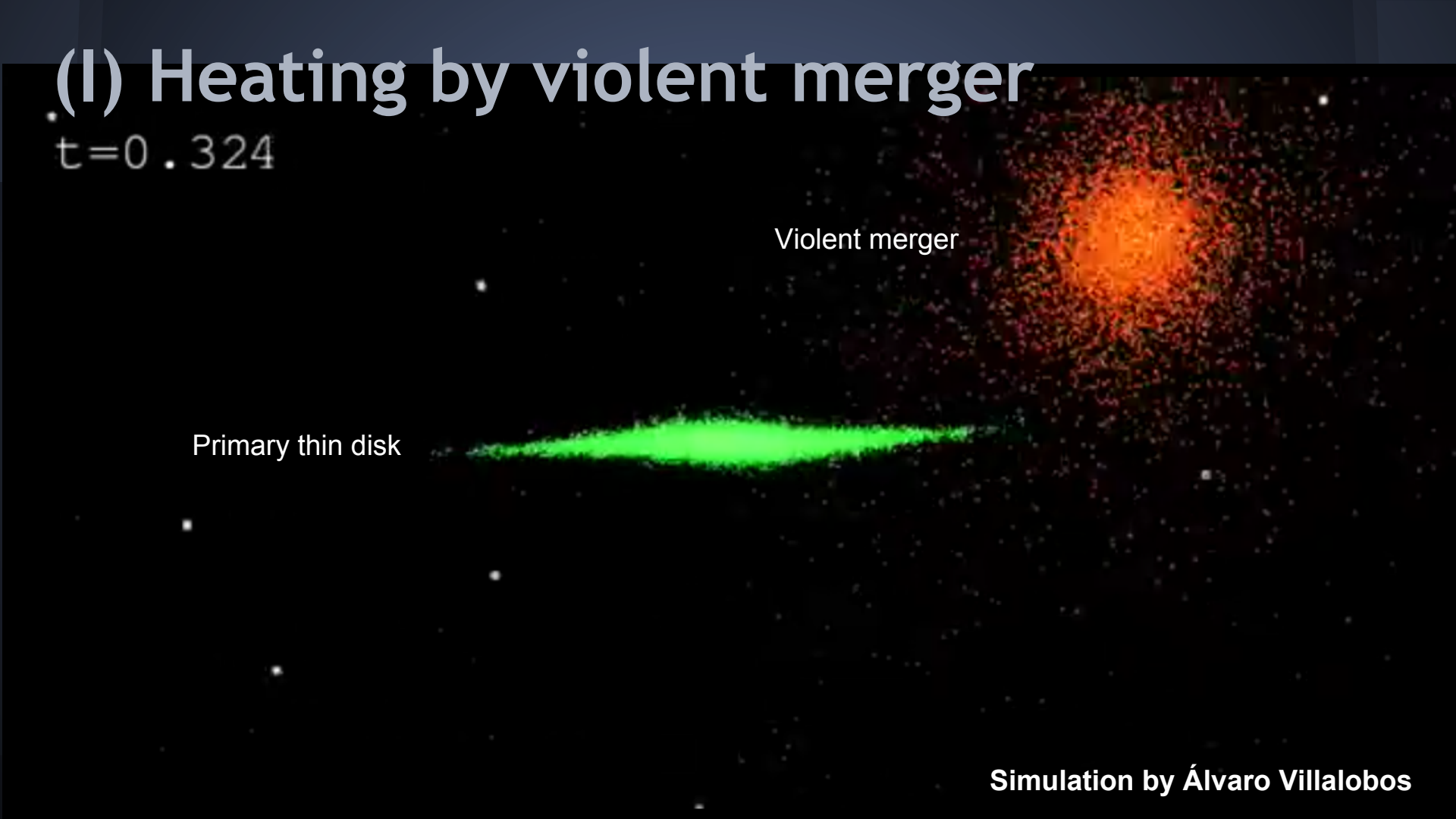
(II) Merger of small satellites
(III) Formation of a thick disc in situ

(I) Heating by violent merger



Simulation by Álvaro Villalobos

(I) Heating by violent merger



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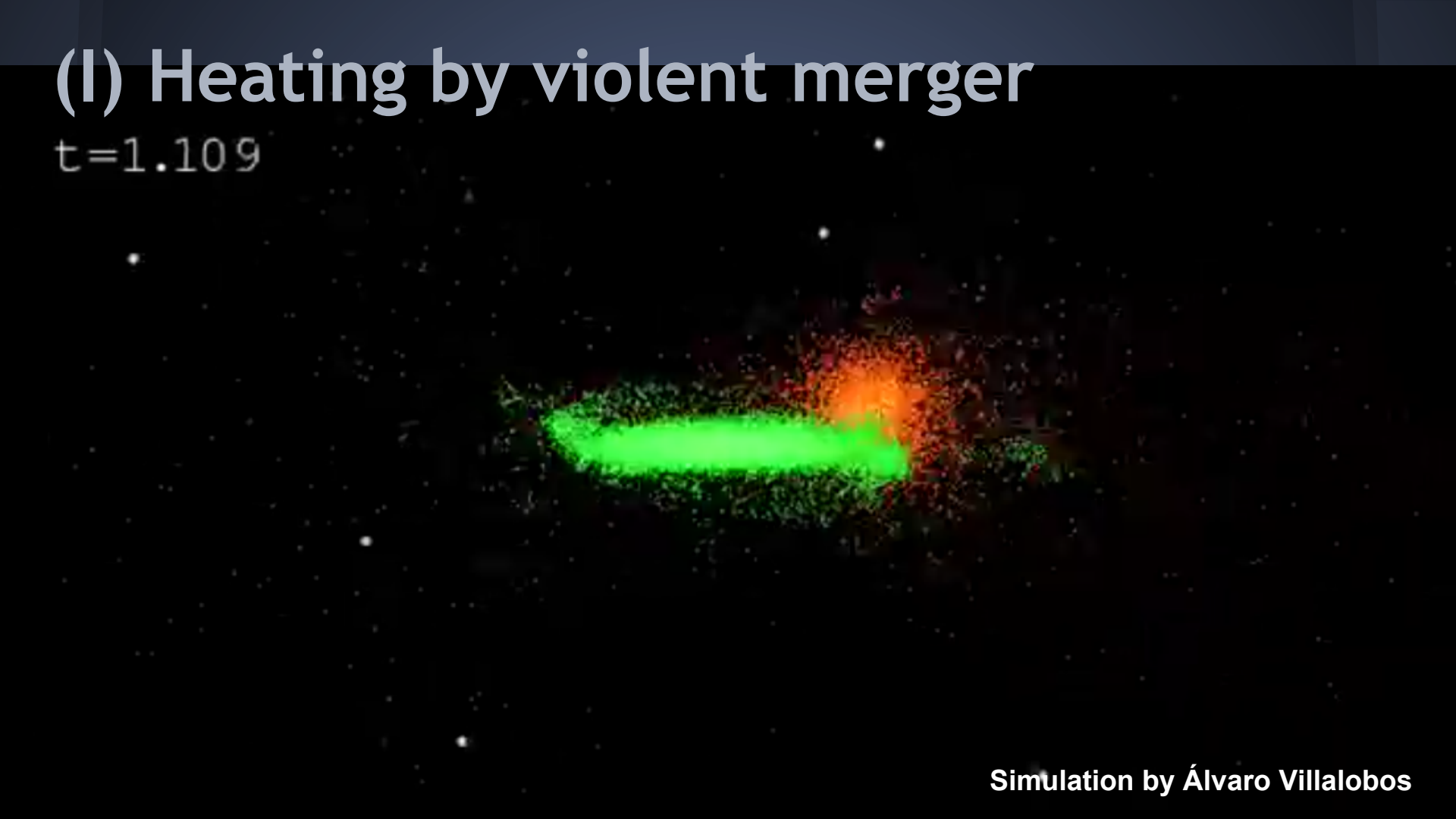

Simulation by Álvaro Villalobos

(I) Heating by violent merger

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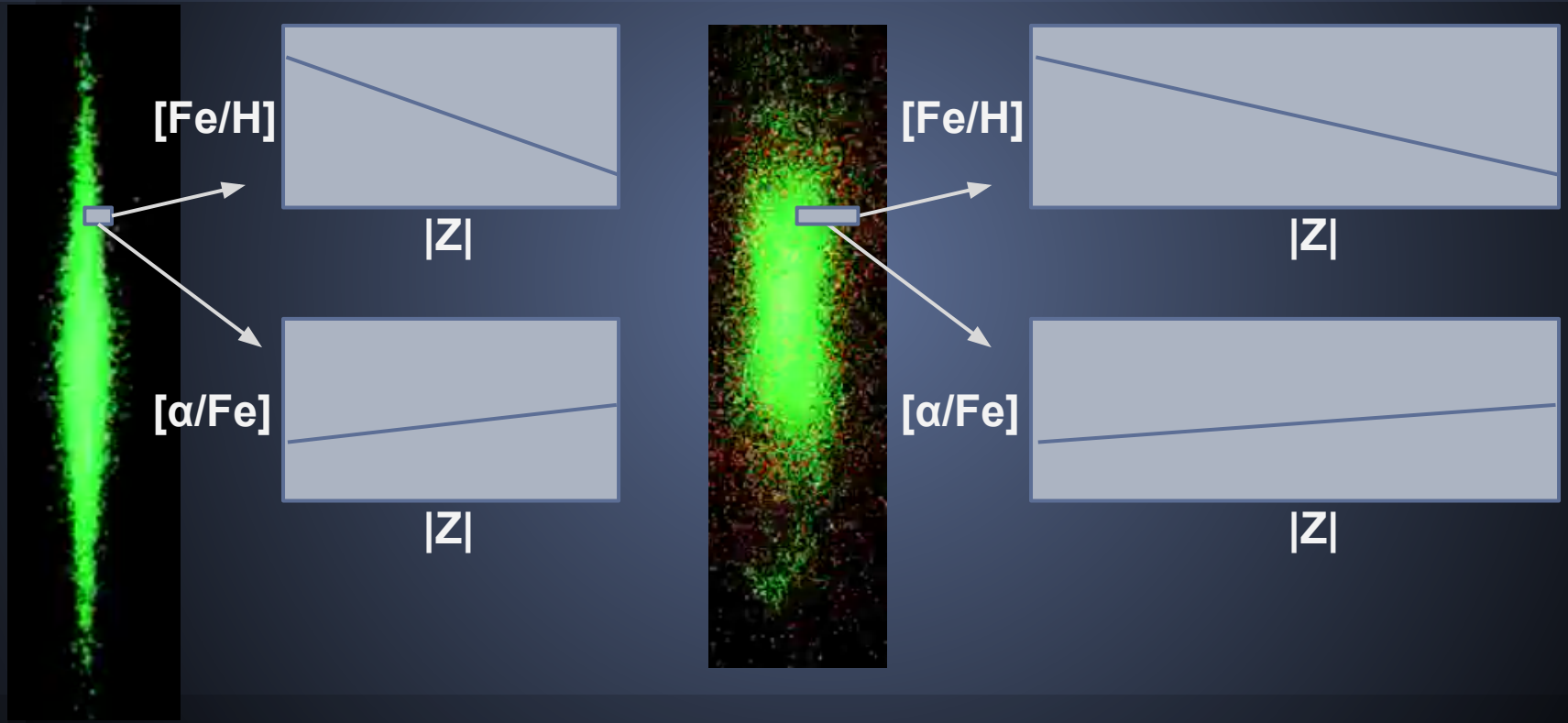


(IV) Radial mixing

More by Thomas Bensby soon!

Other interesting scenarios

Bekki & Tsujimoto (2011) (violent merger + stellar bar)

initial vertical metallicity gradient of the primary thin disc

+

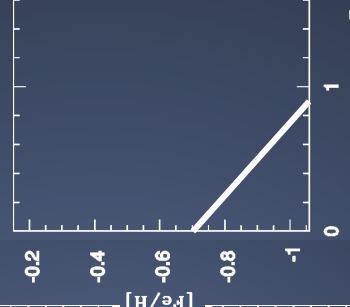
dynamical influences of minor mergers and the stellar bar

=

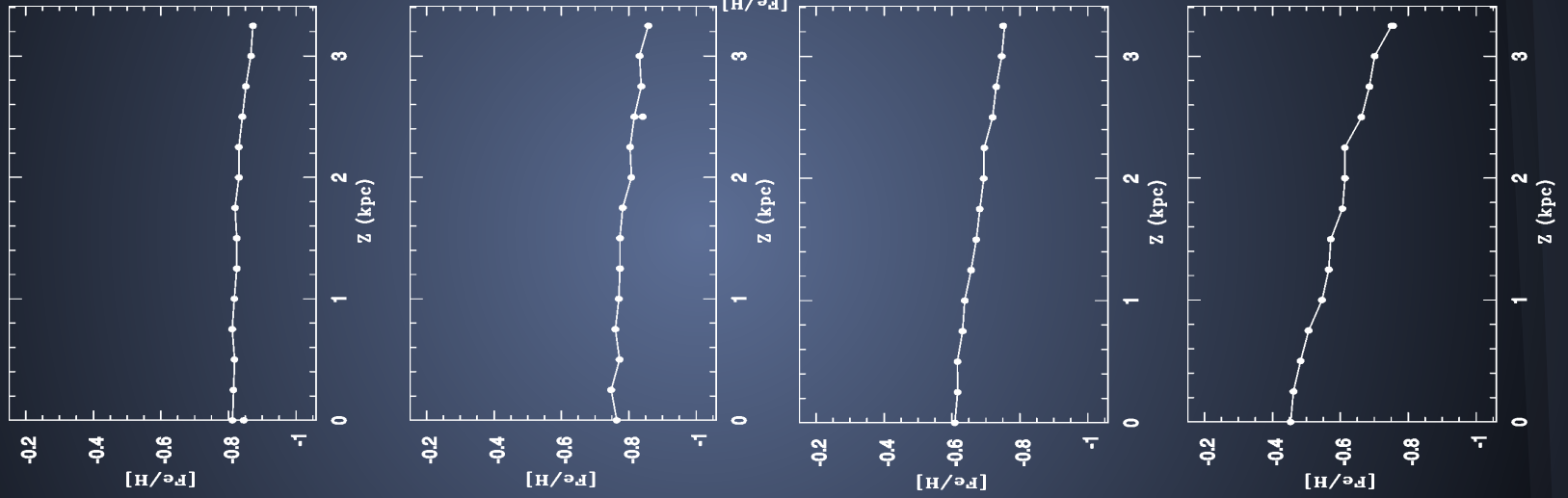
final vertical metallicity gradient of thick disk

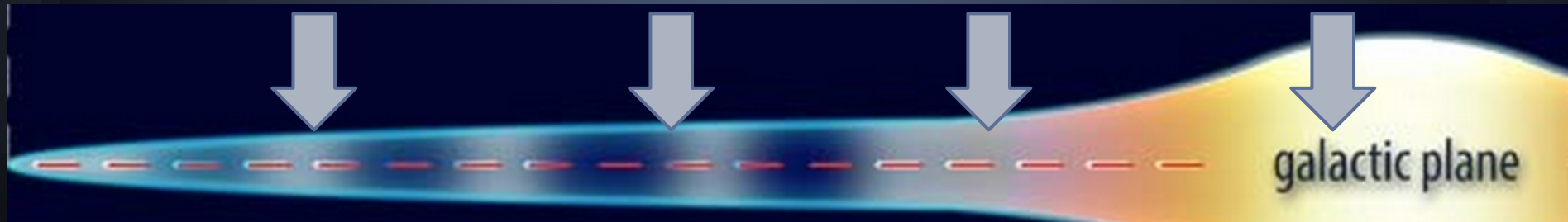
COMPATIBLE

First generation thin disk



Thic disk





Other interesting scenarios

Michev et al. (2014) (radial migration + mergers)

disk exposed to

stellar migration triggered by mergers in the early epochs, and then by bar and spiral arms

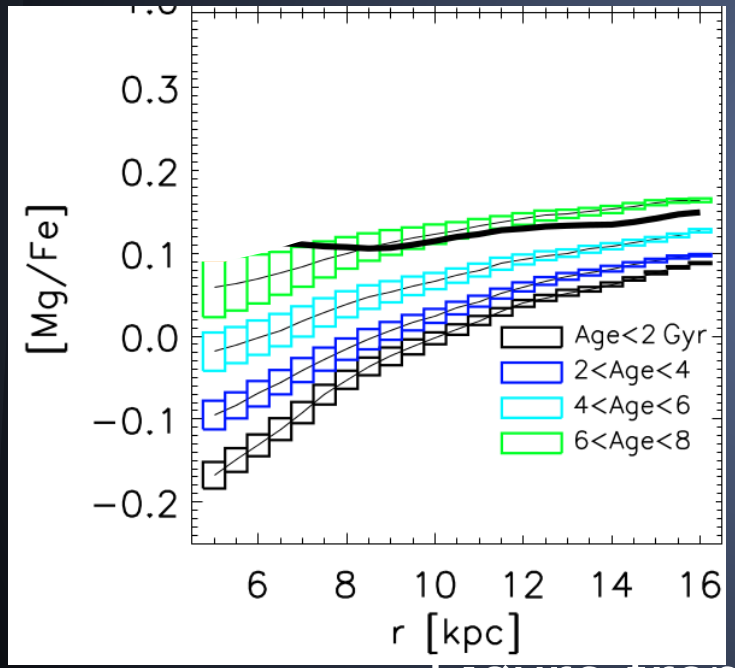
=

final shallow radial metallicity and alpha abundance gradients of disks

COMPATIBLE

Other interesting scenarios

Thin disk



Thick disk

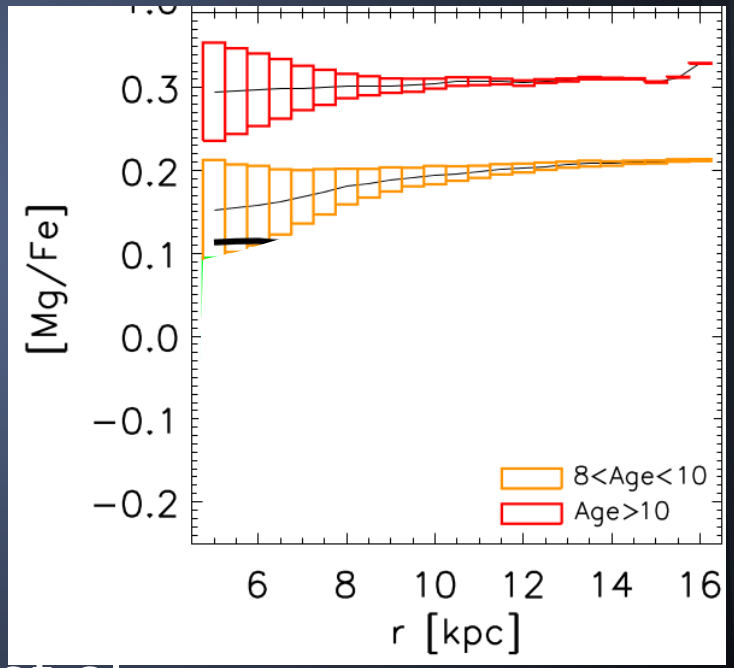


Figure from Michev et al. (2014)

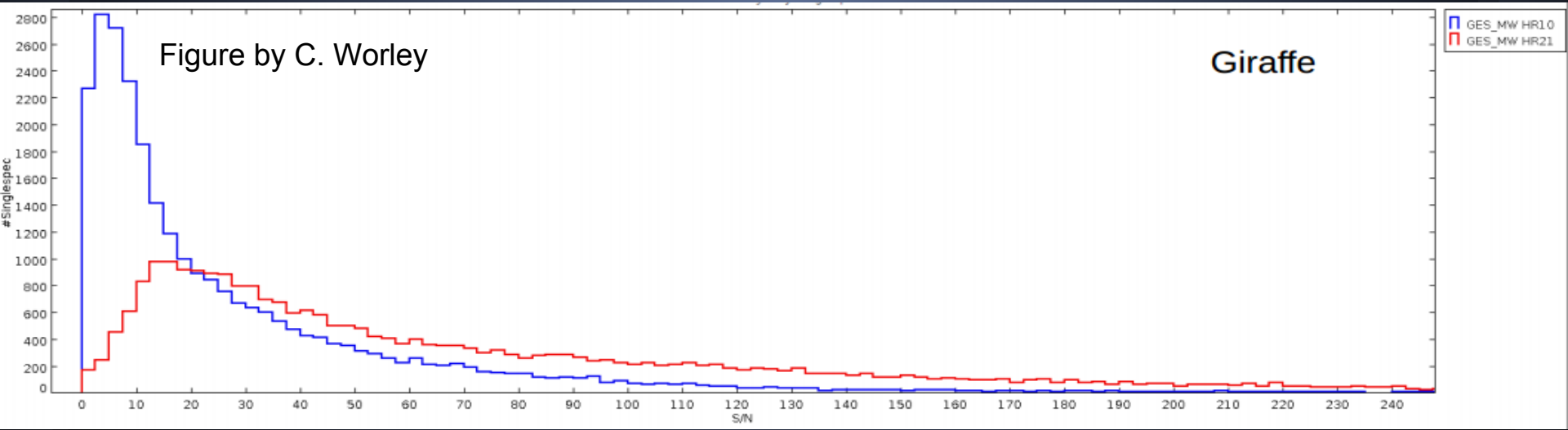
Instead of conclusion

Chemical analysis is a powerful tool
Recovering chemical patterns of Galaxy
Geometrical extents and structure
Gradients

Testing models of Galactic substructures

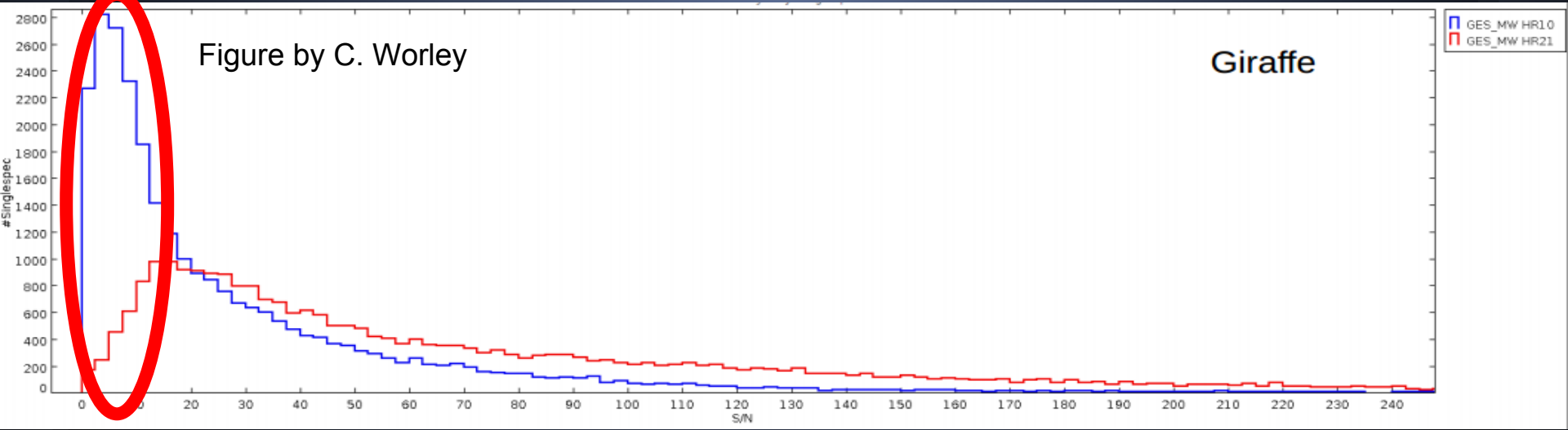
Instead of conclusion

Caution now we remove 50% of stars from our samples because of the S/N !!!

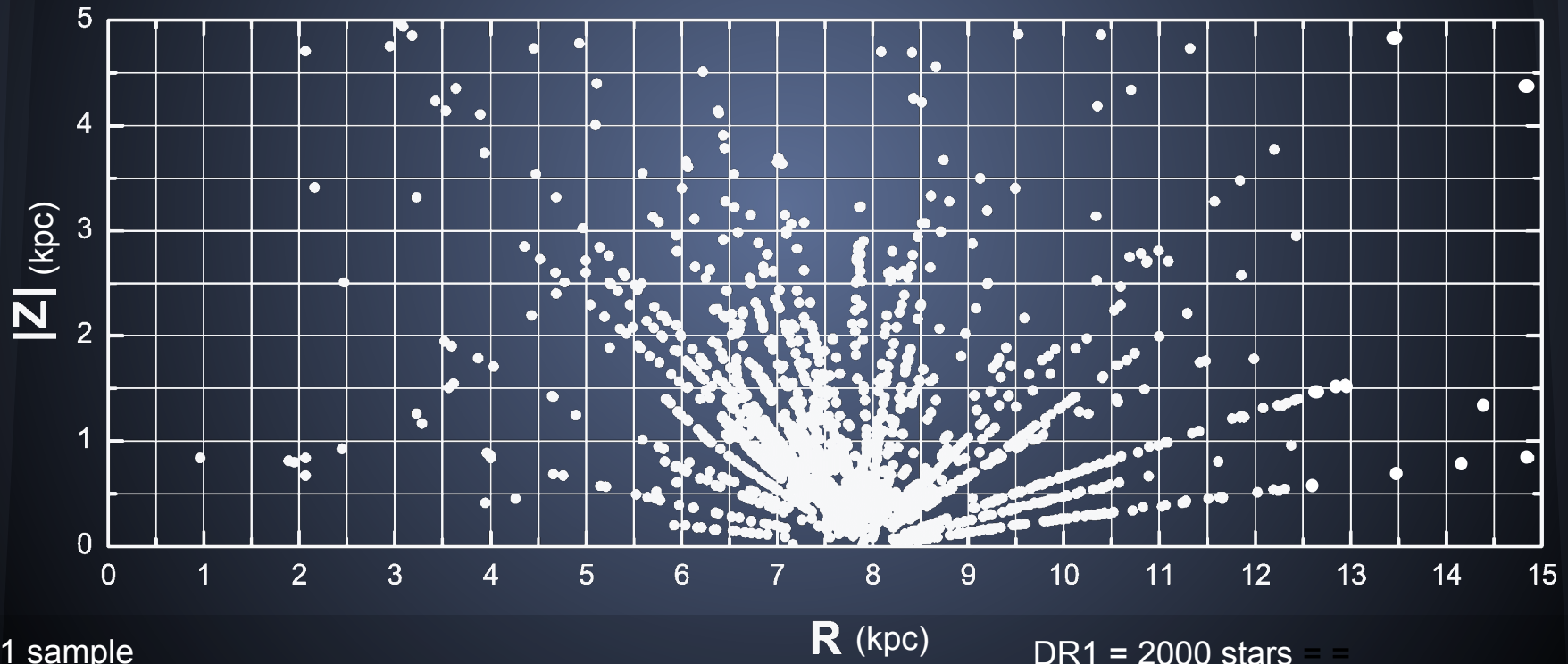


Instead of conclusion

Maybe we are losing too many stars?



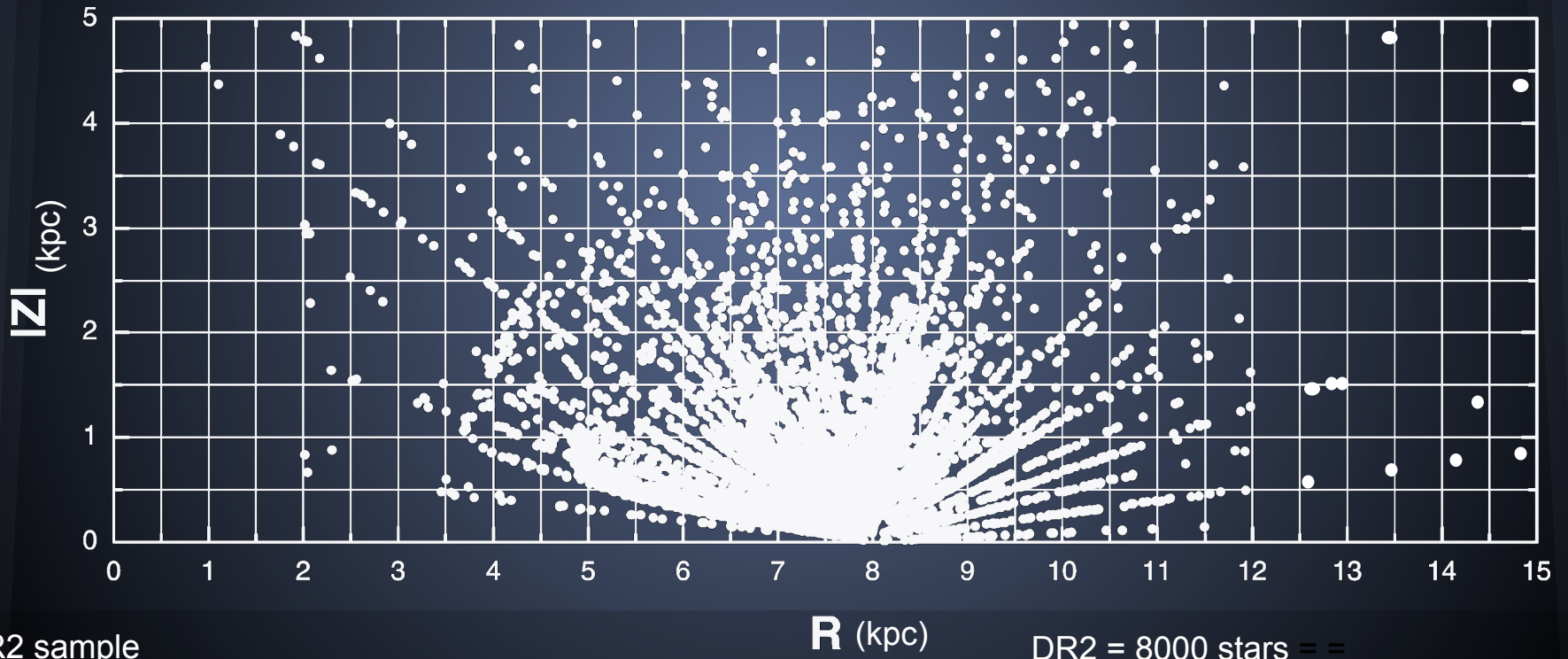
What do we want from the future?



DR1 sample

DR1 = 2000 stars = =

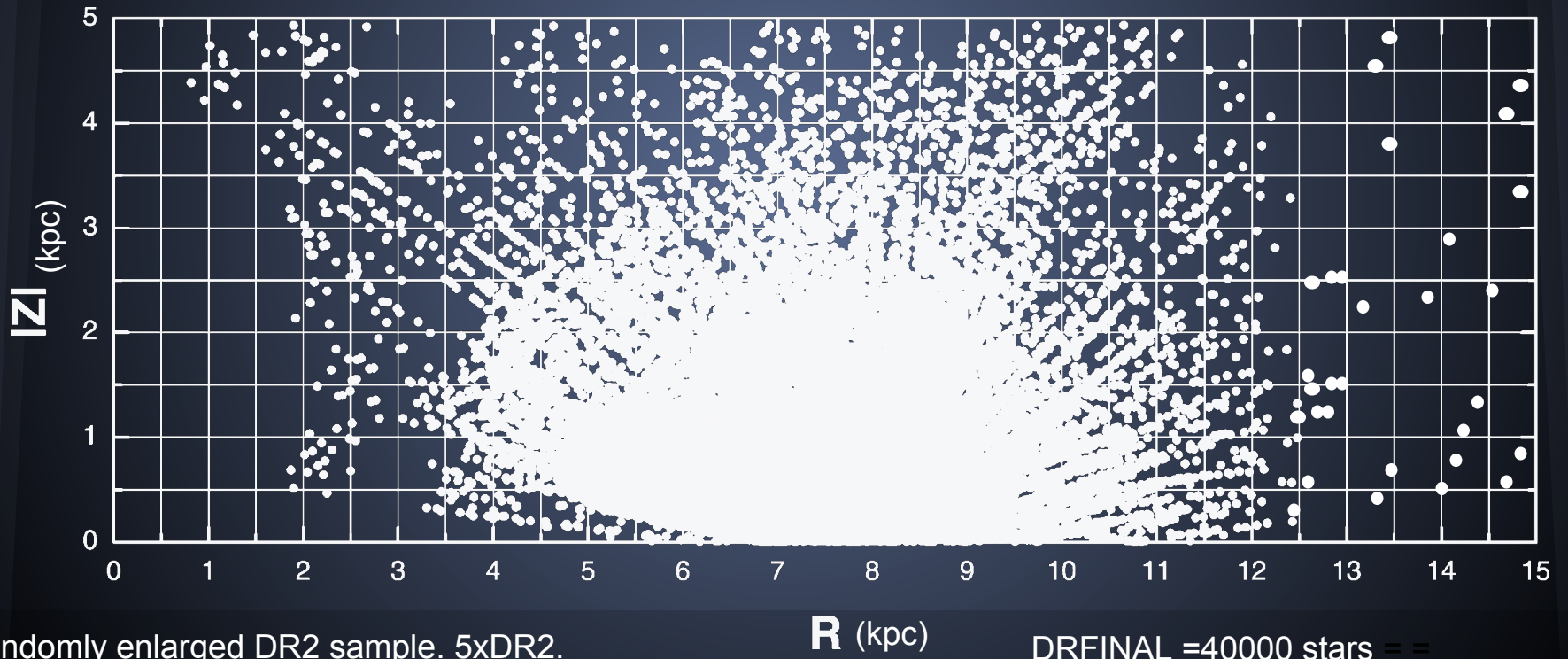
What do we want from the future?



DR2 sample

DR2 = 8000 stars = =

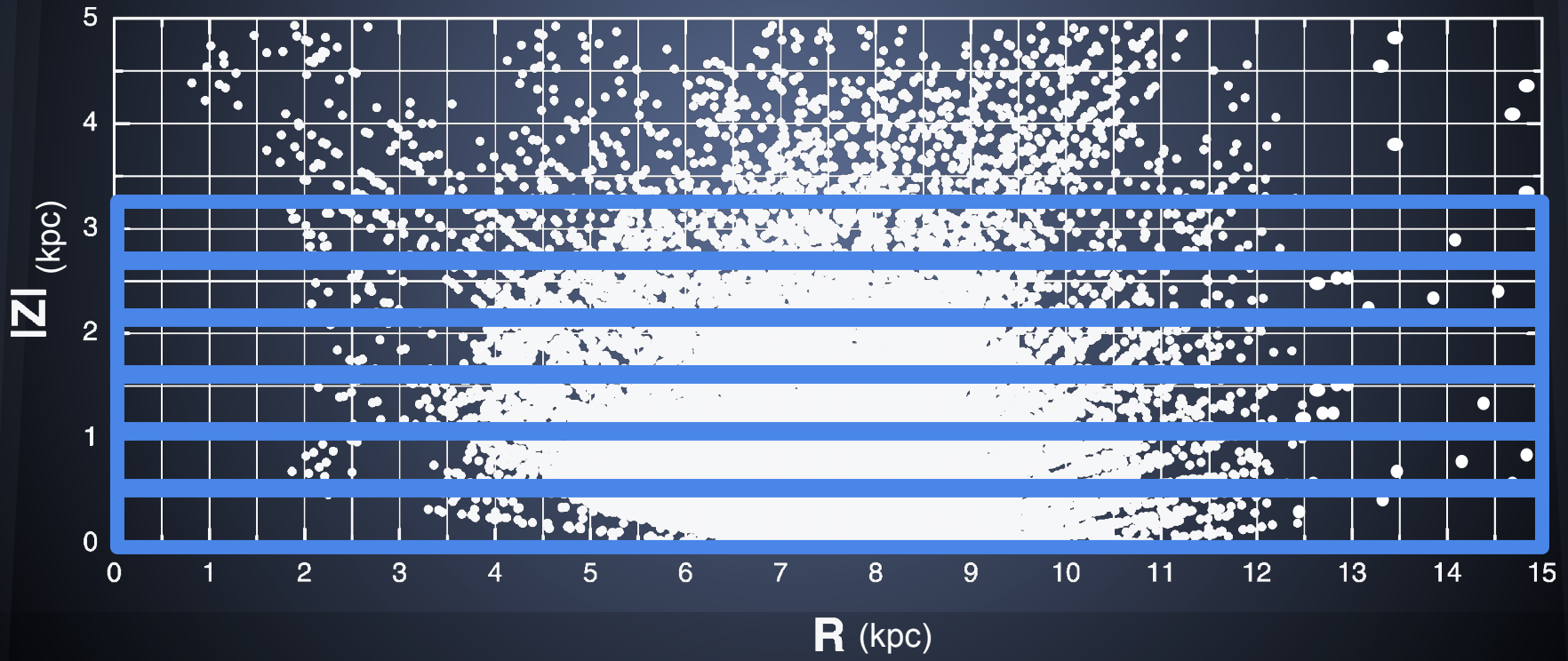
What do we want from the future?



Randomly enlarged DR2 sample. 5xDR2.

DRFINAL =40000 stars = =

What do we want from the future?



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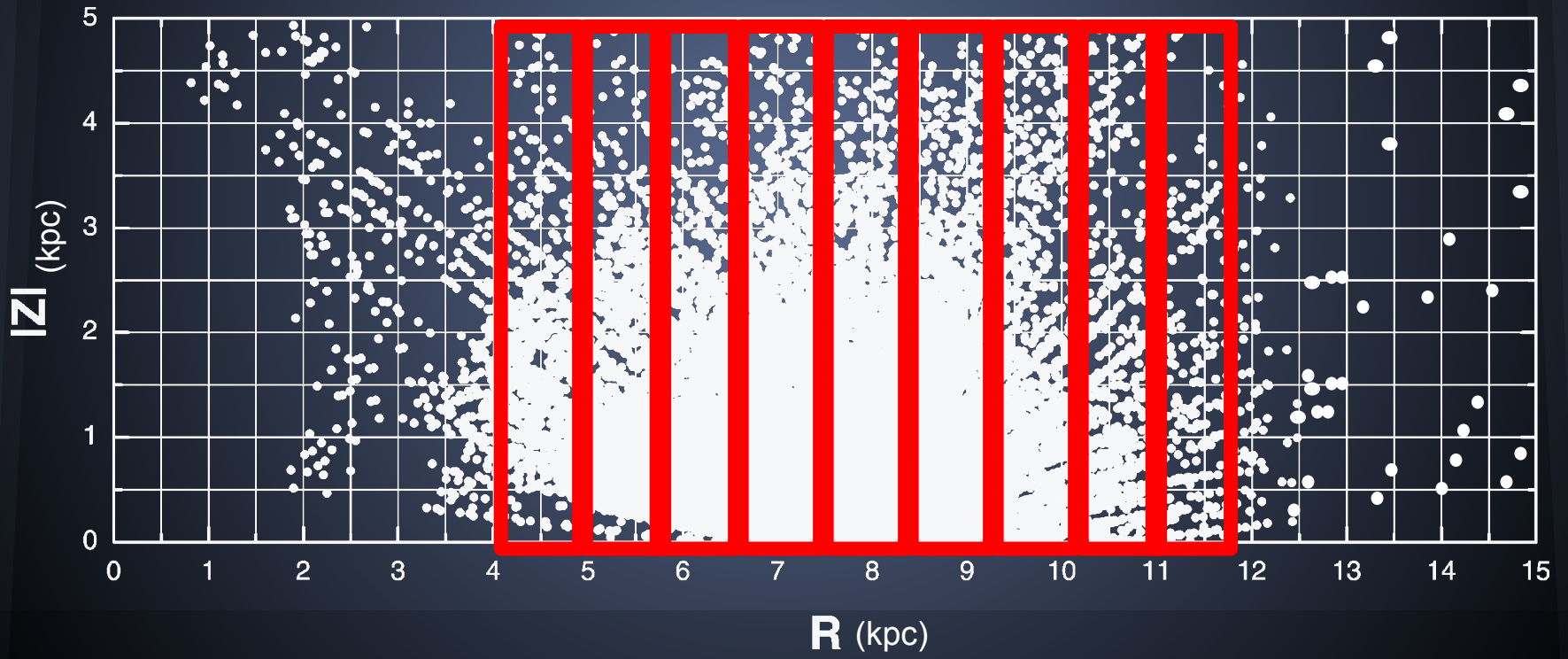
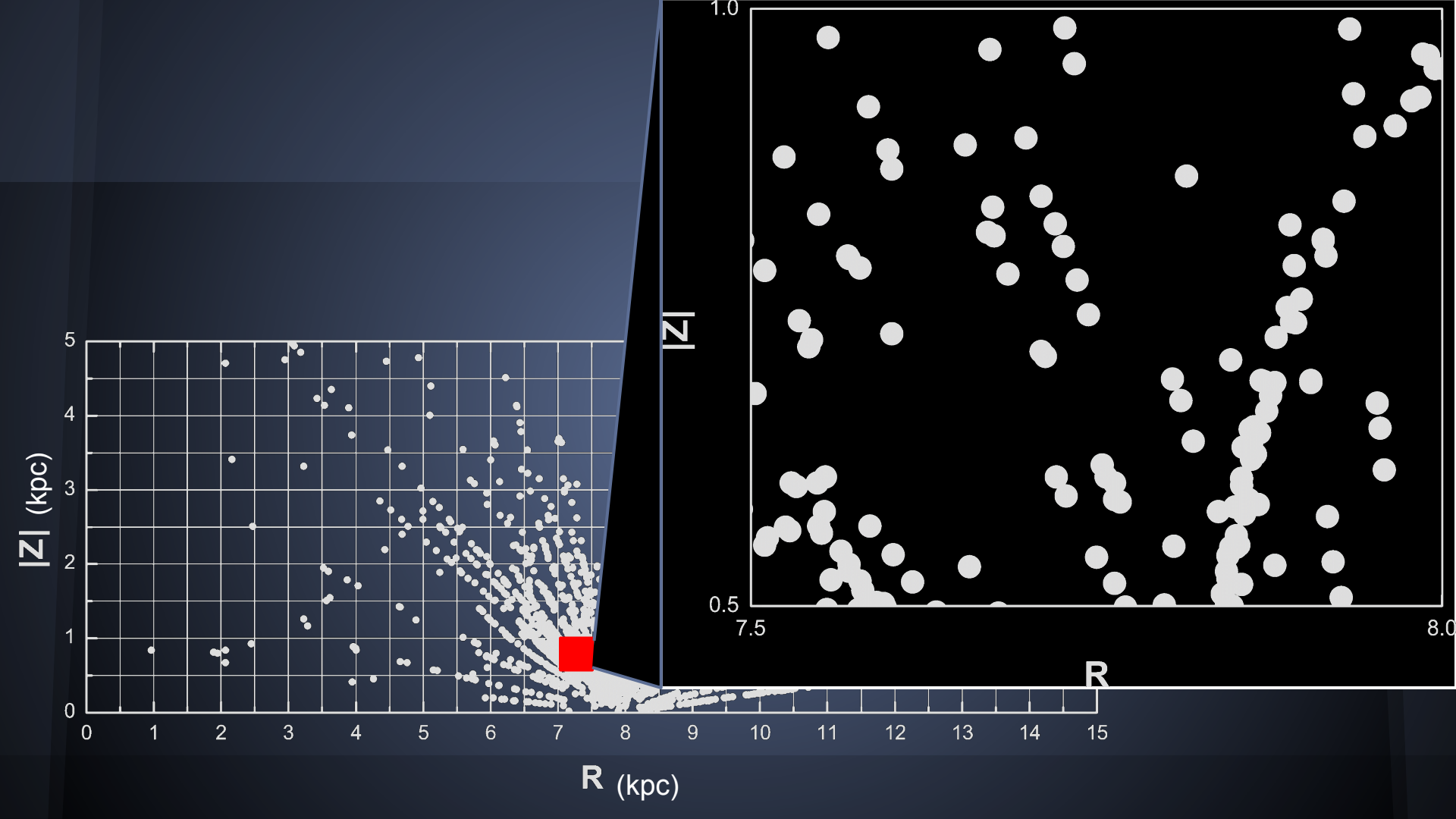
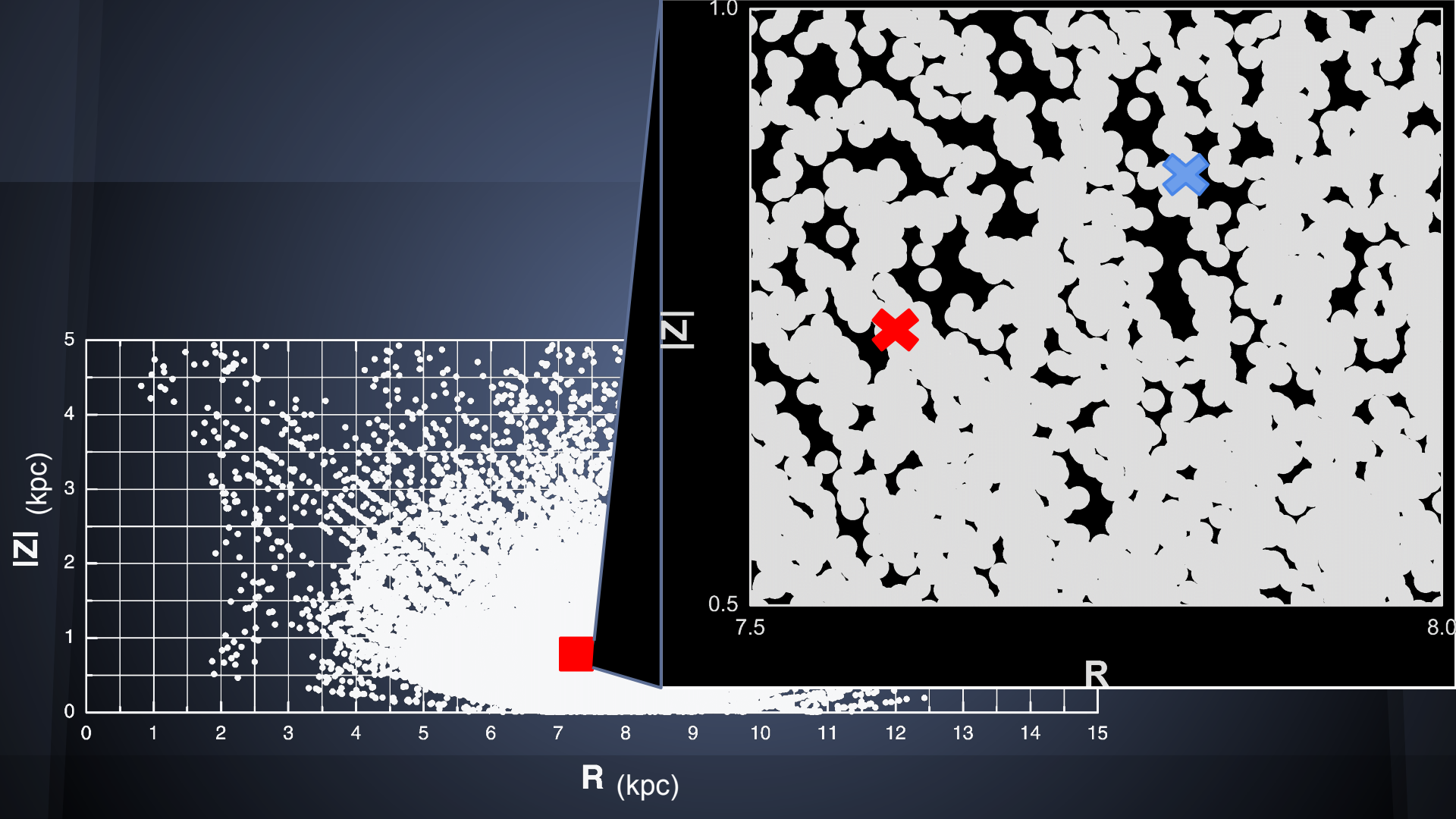
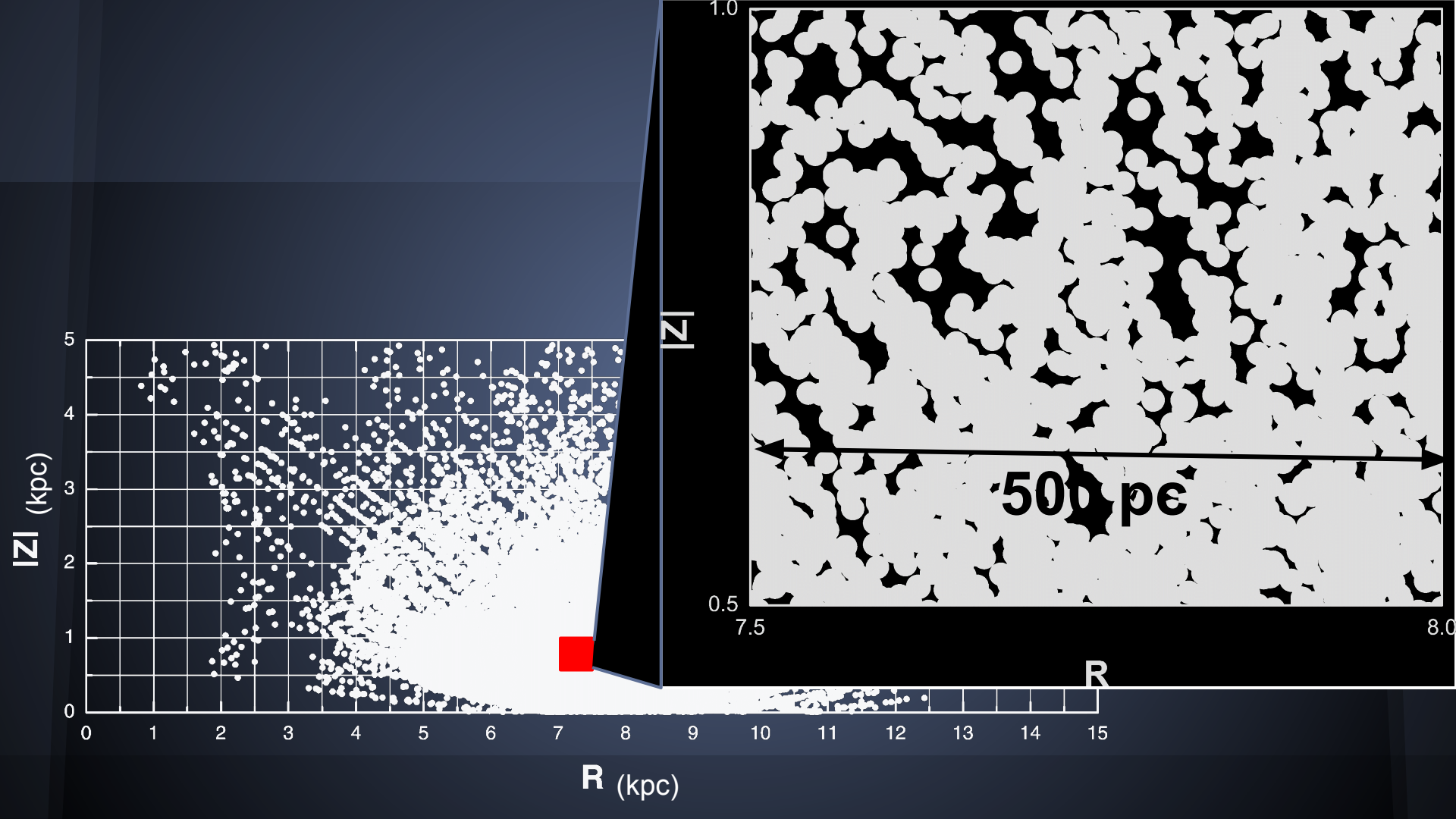
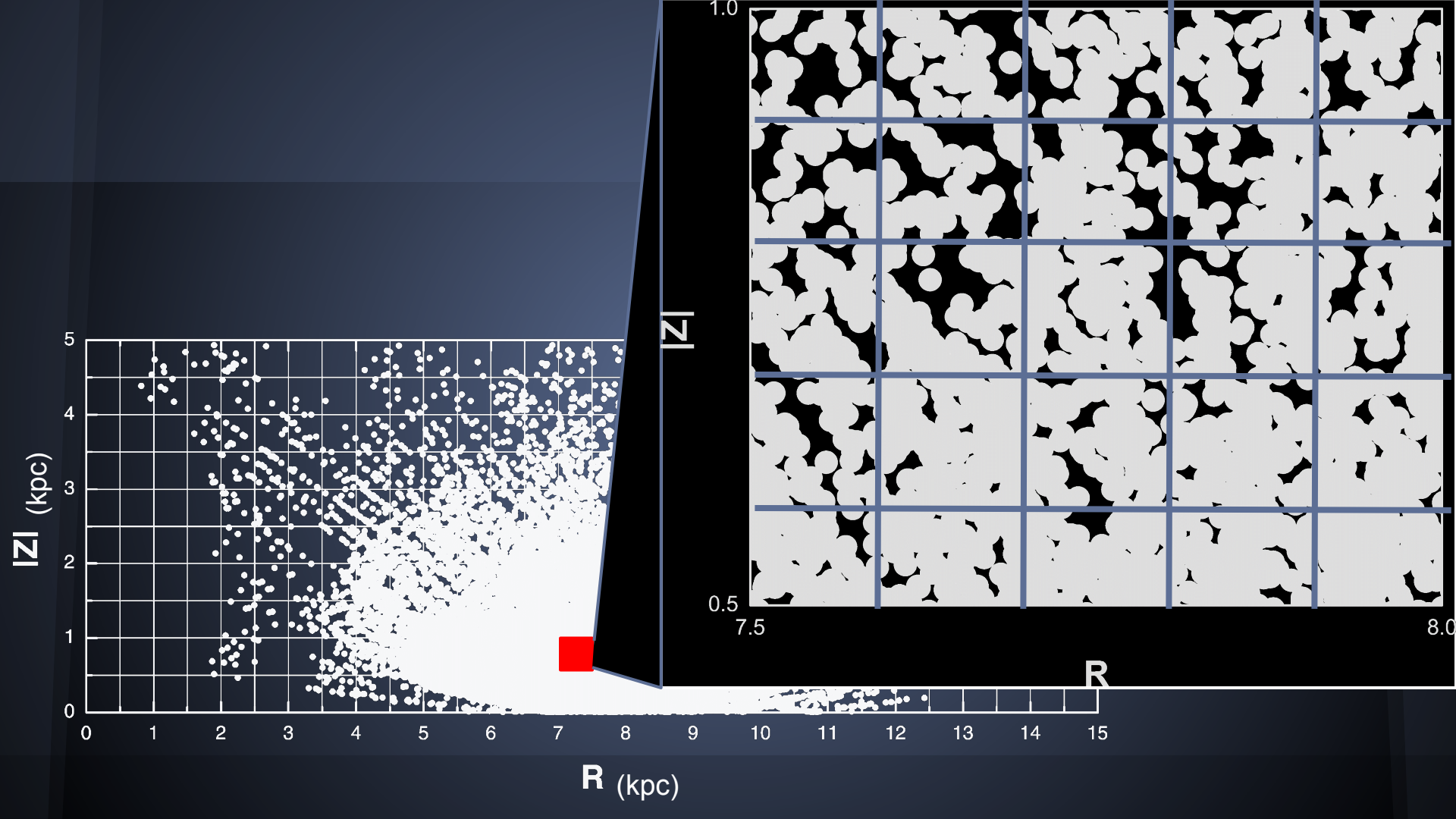
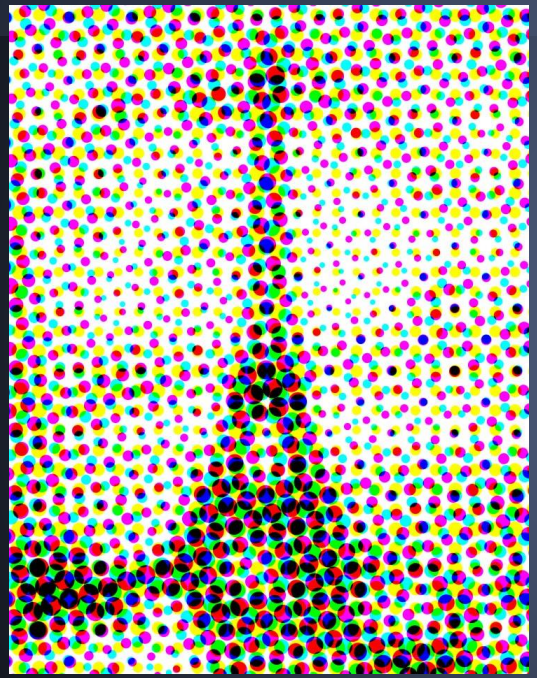


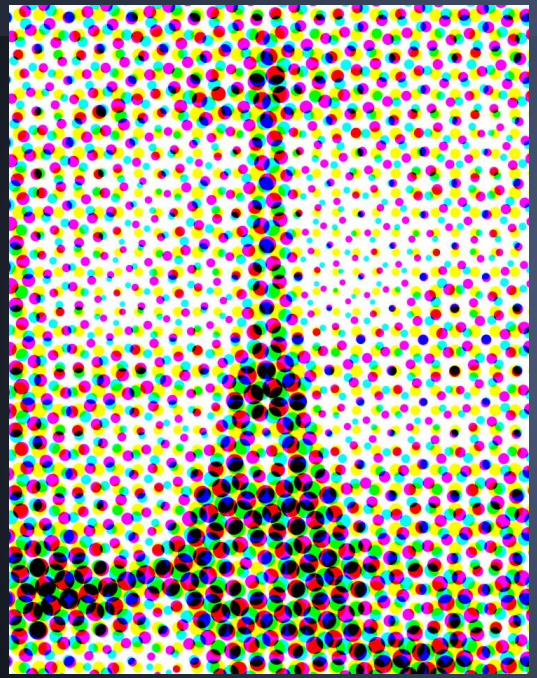

|Z| (kpc)
R (kpc)
|Z|
R
1.0
0.5
7.5
8.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


|Z| (kpc)
R (kpc)
|Z|
R
1.0
0.5
7.5
8.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


|Z| (kpc)
R (kpc)
|Z|
R
1.0
0.5
7.5
8.0
500 pc


|Z| (kpc)
0
1
2
3
4
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
R (kpc)
|Z|
1.0
0.5
7.5
8.0
R





Pixel radius
differs
5 times

Outline

What we have?

What can we do?

What is done?

What it says?

What can be done in the future?

Are we best? Yes. For now.

What do we have?

We have all YEAR on VLT.

Resolution.

Number of stars.

How we compare with others?

Lets invent SURVEY QUALITY PARAMETER.

So, now we are becoming the best!

What we do with our tool

All Positions

All Chemistry

What is done?

Up till now we derived abundances for about 10 000 stars.

What we do with abundances and positions?

Map the stars in the field.

Make statistics in every corner of the Galaxy.