Shining light on dust:

UVJ images of high-z simulated galaxies

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Avishai Dekel
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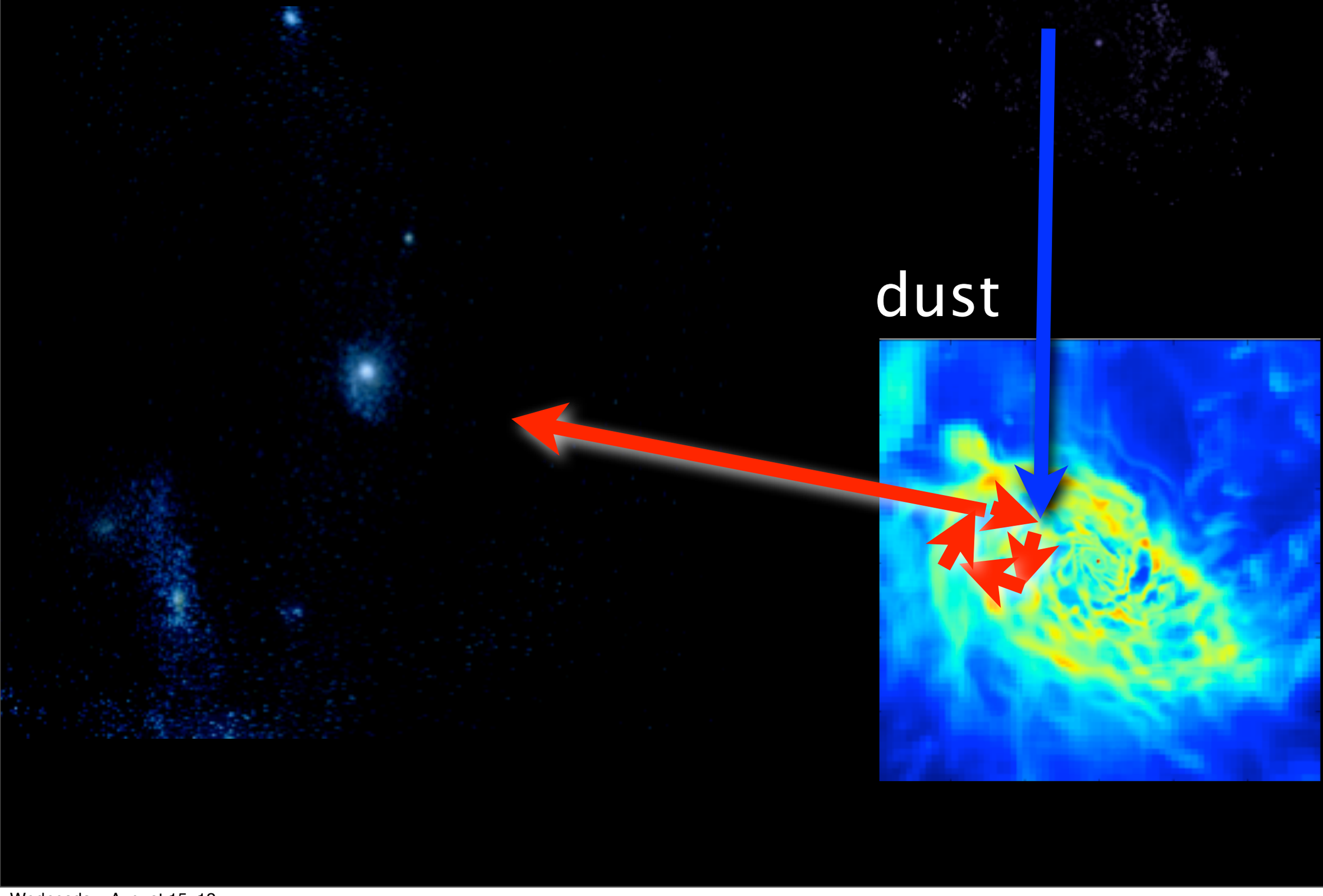
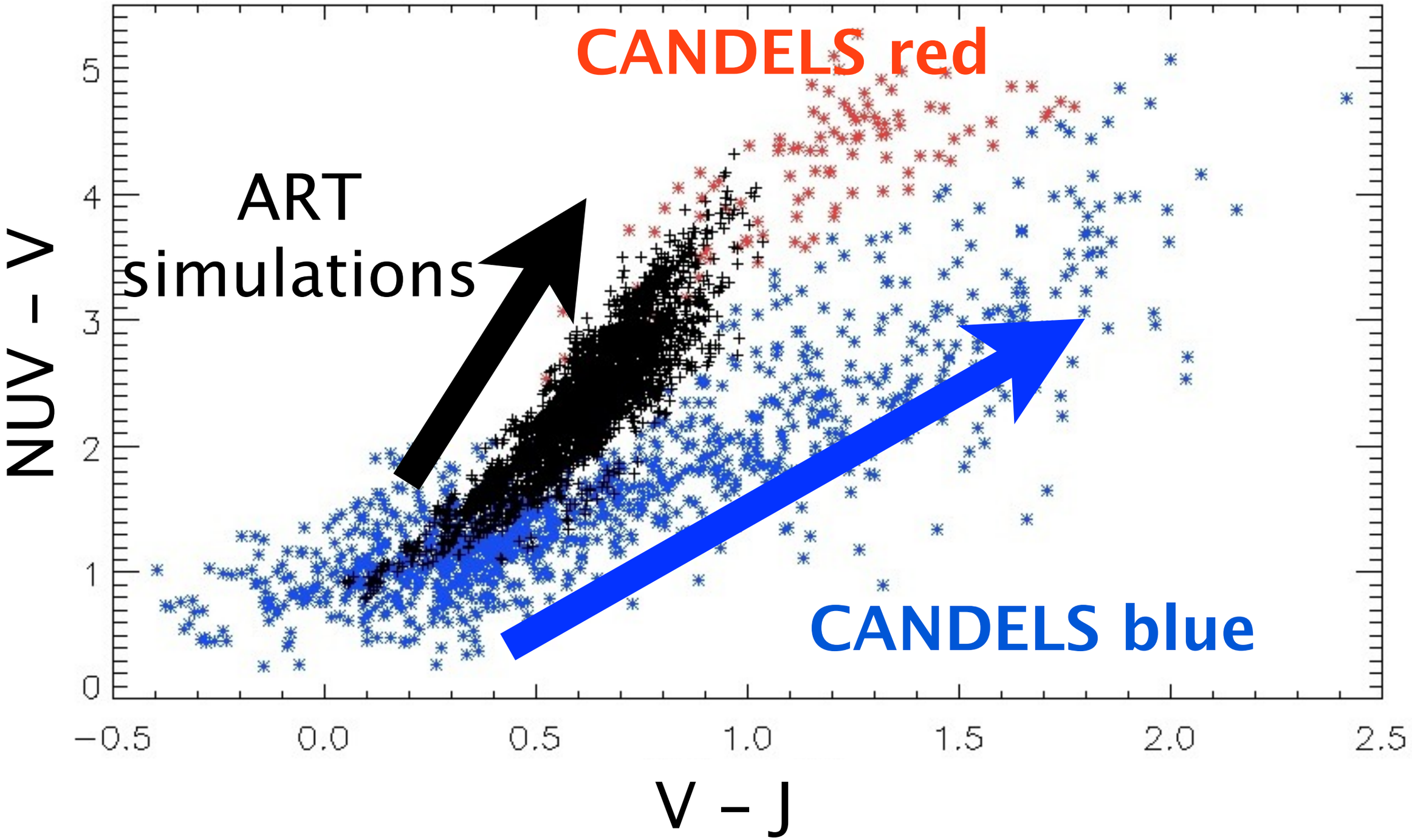
hydroART + Sunrise

stars

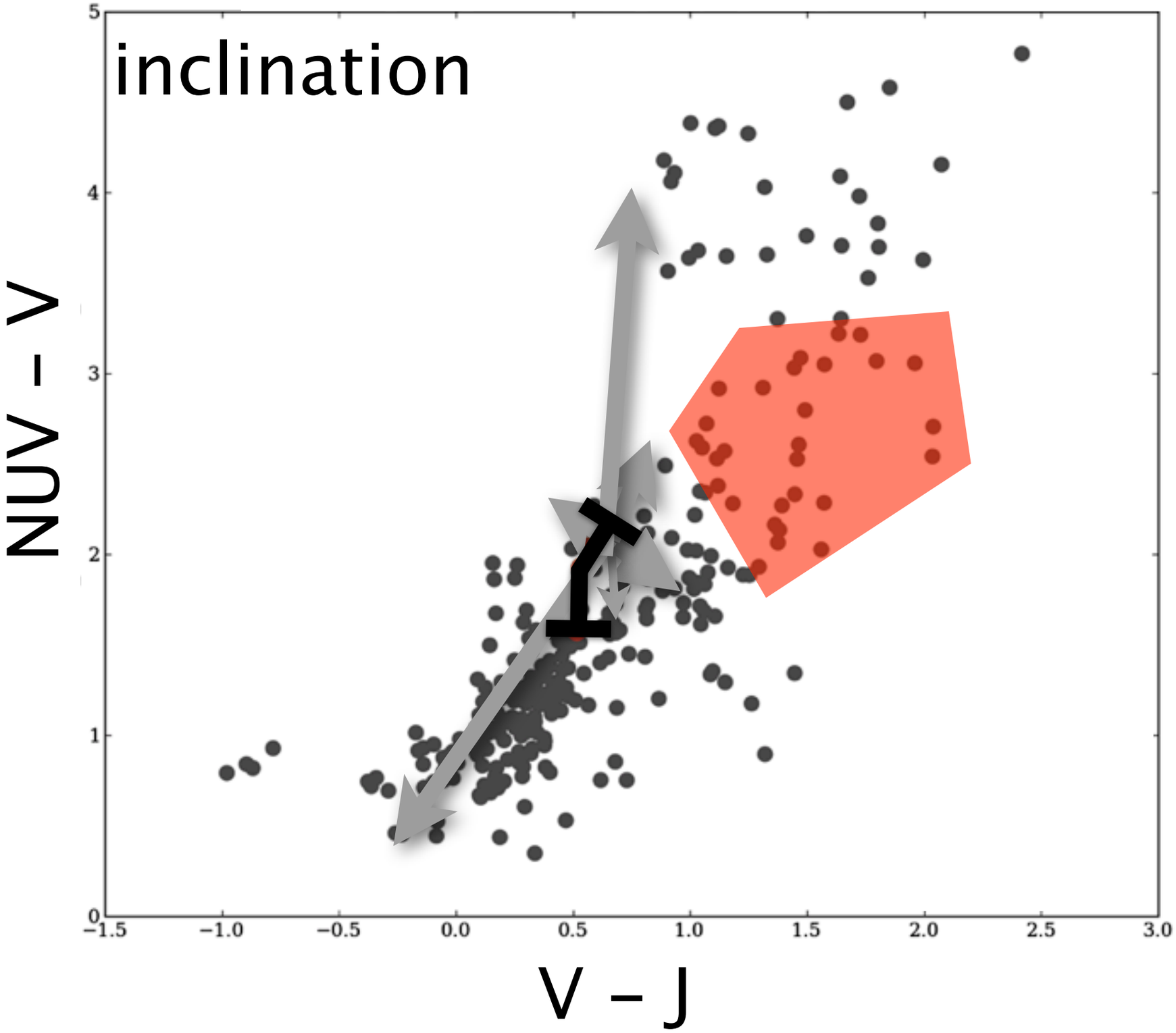
89nm

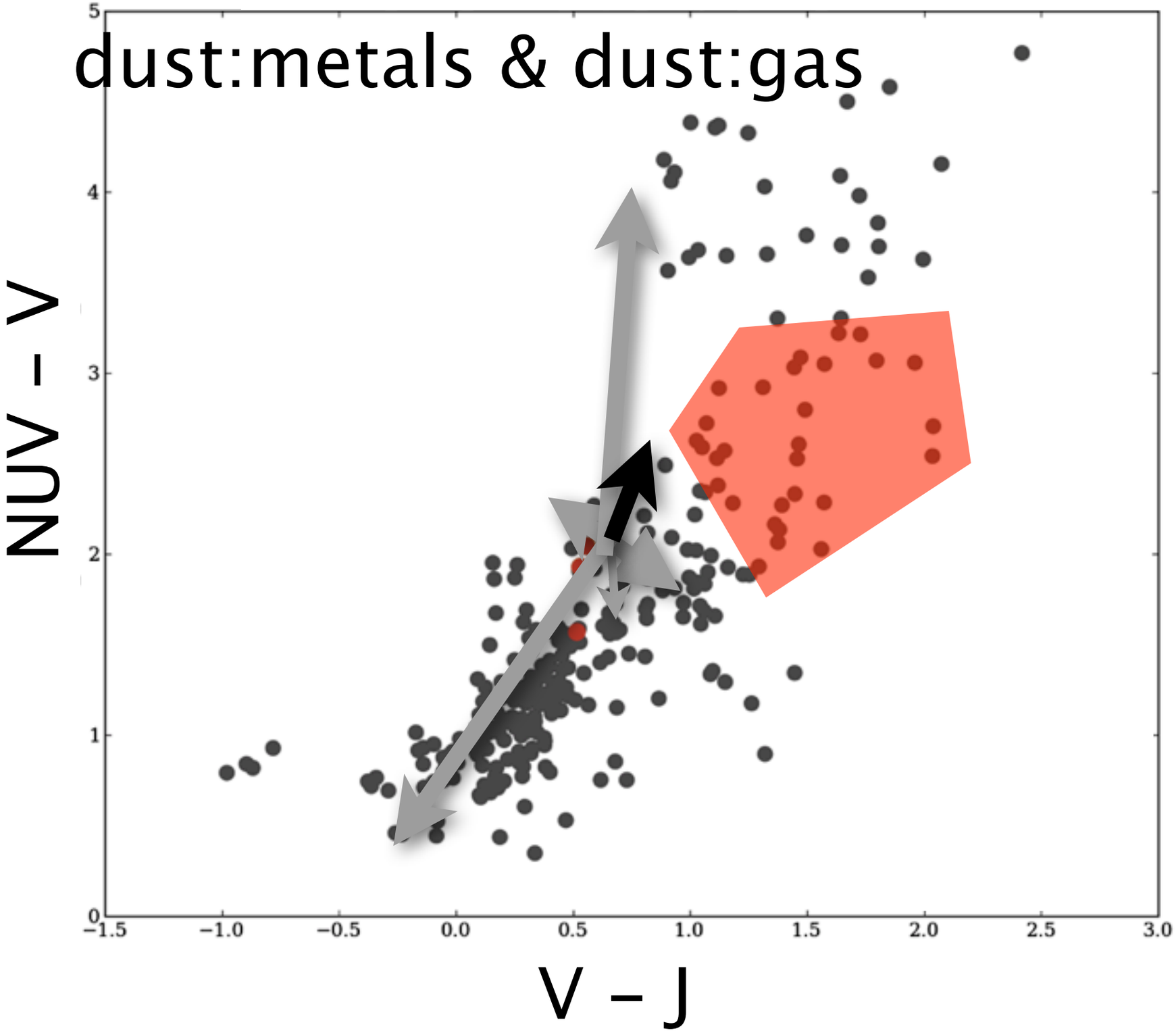
dust

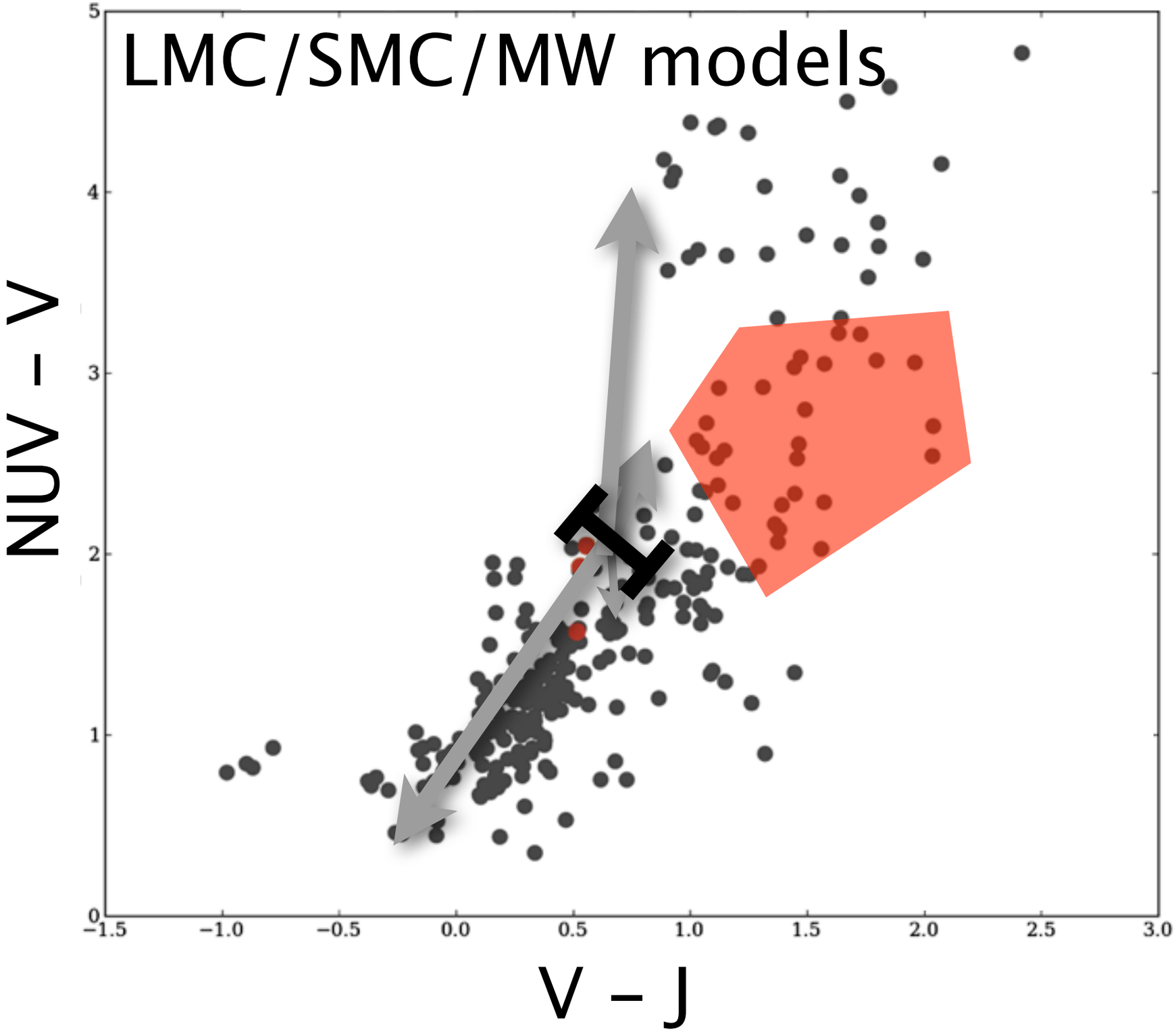


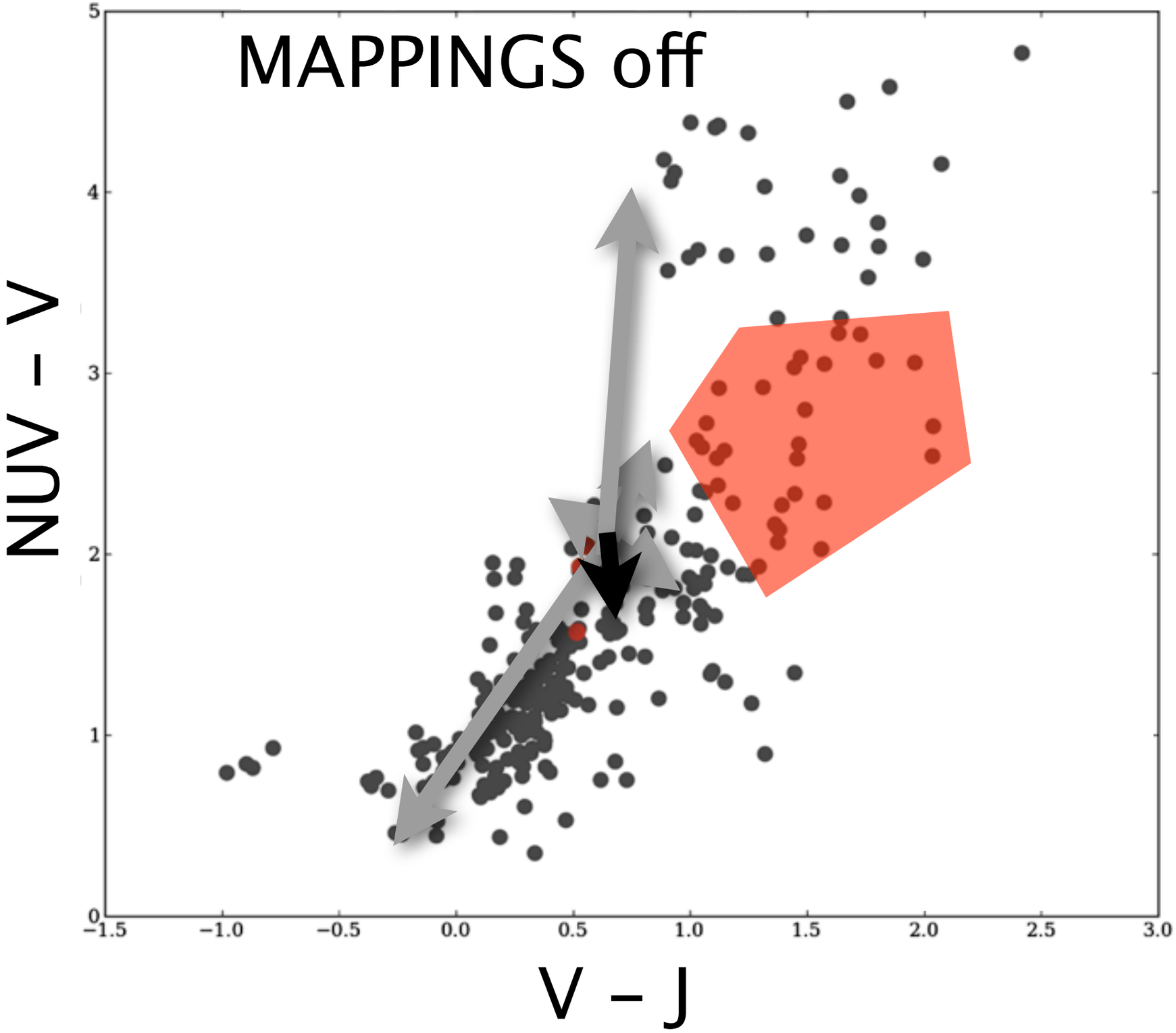


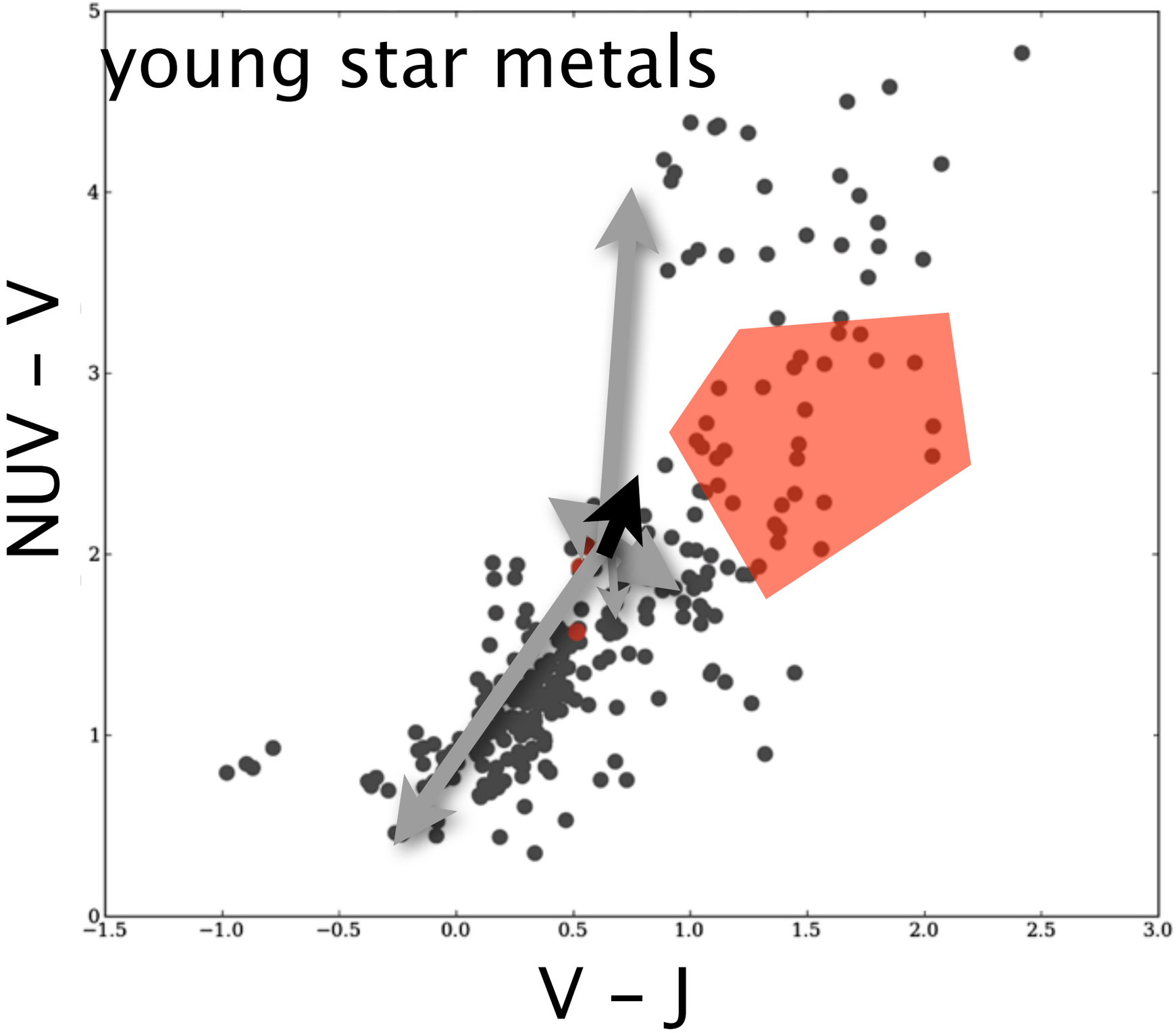
See also Wuyts et al. 2009

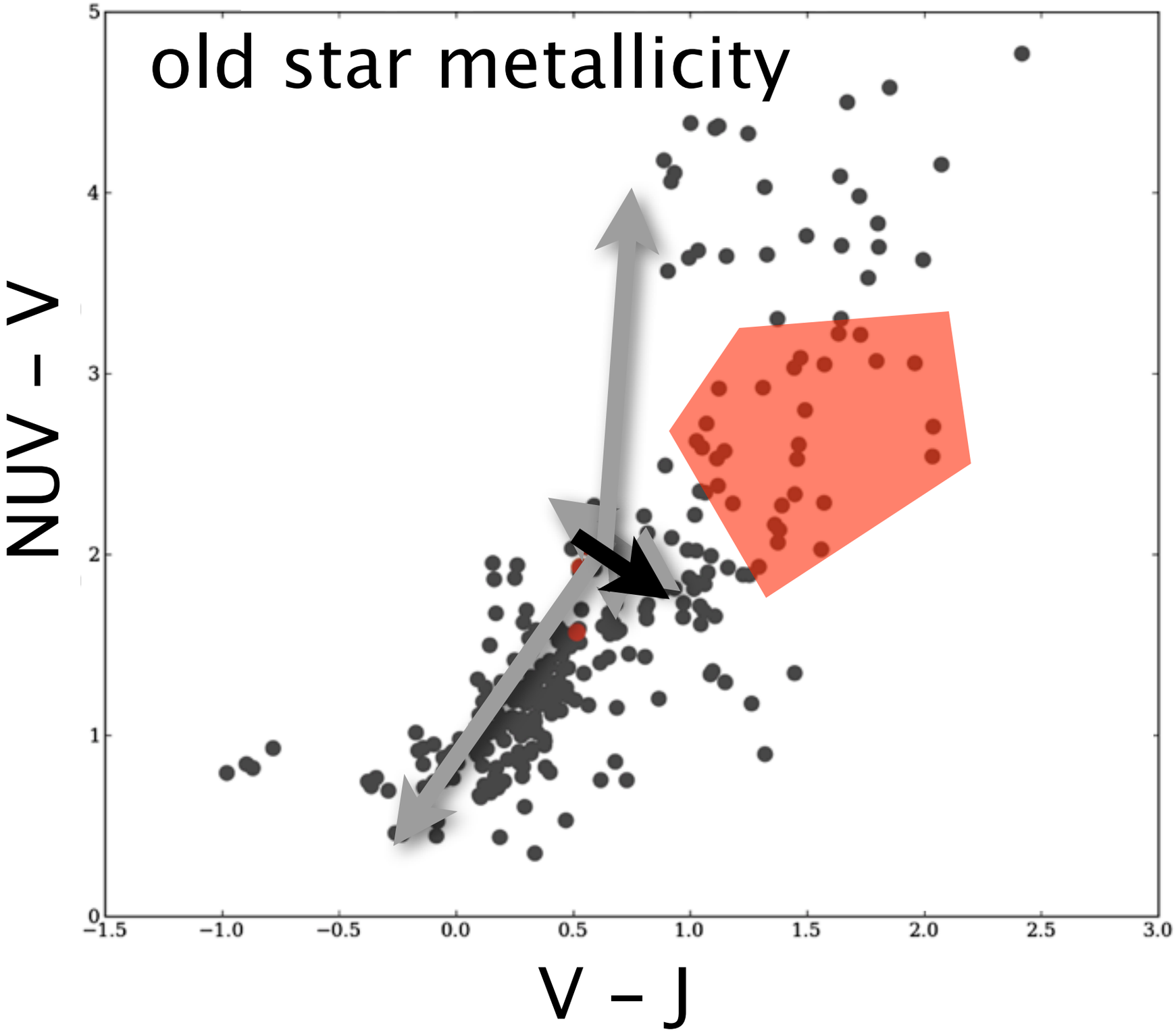

inclination
NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

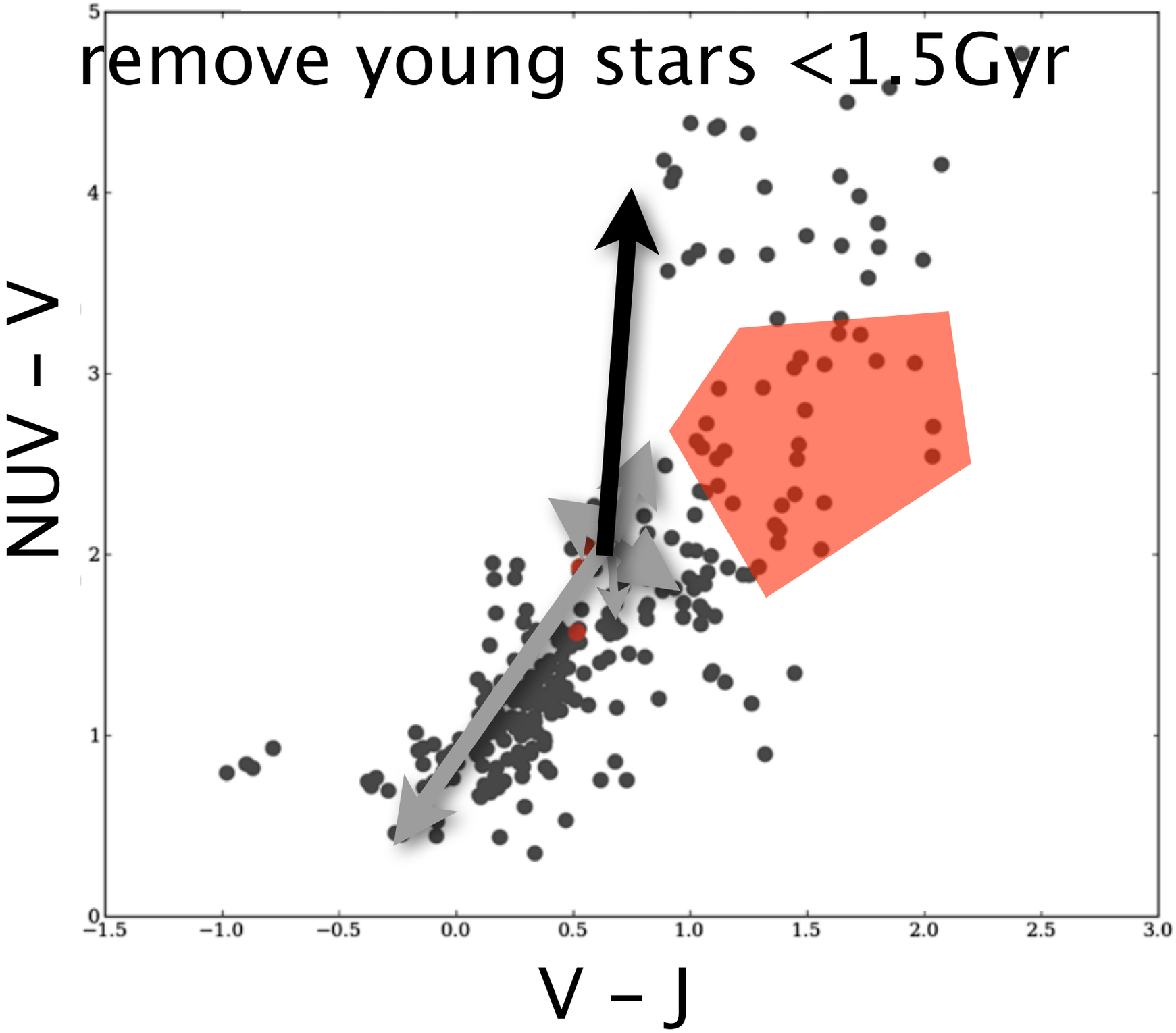

dust:metals & dust:gas
NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

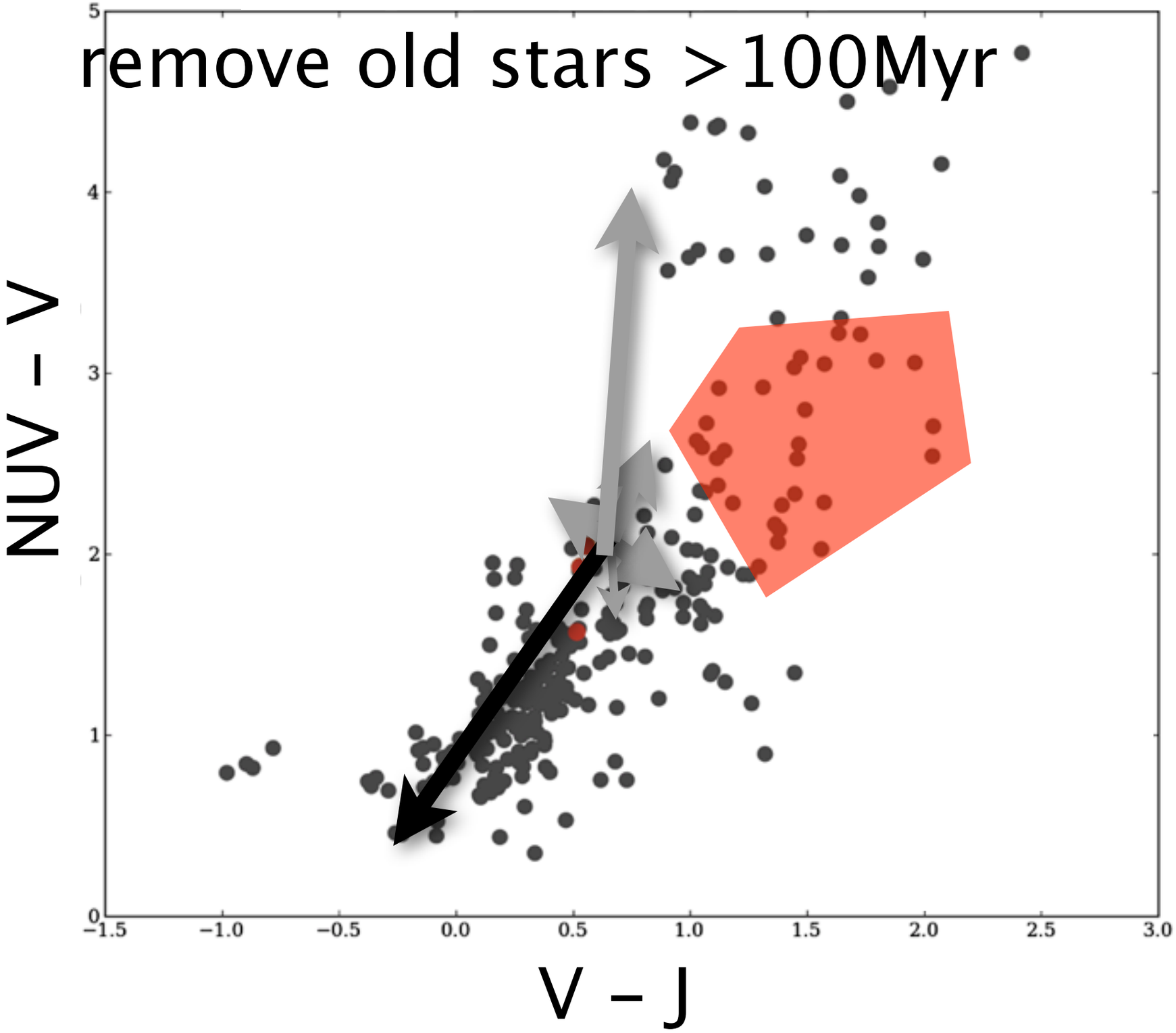

LMC/SMC/MW models
NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

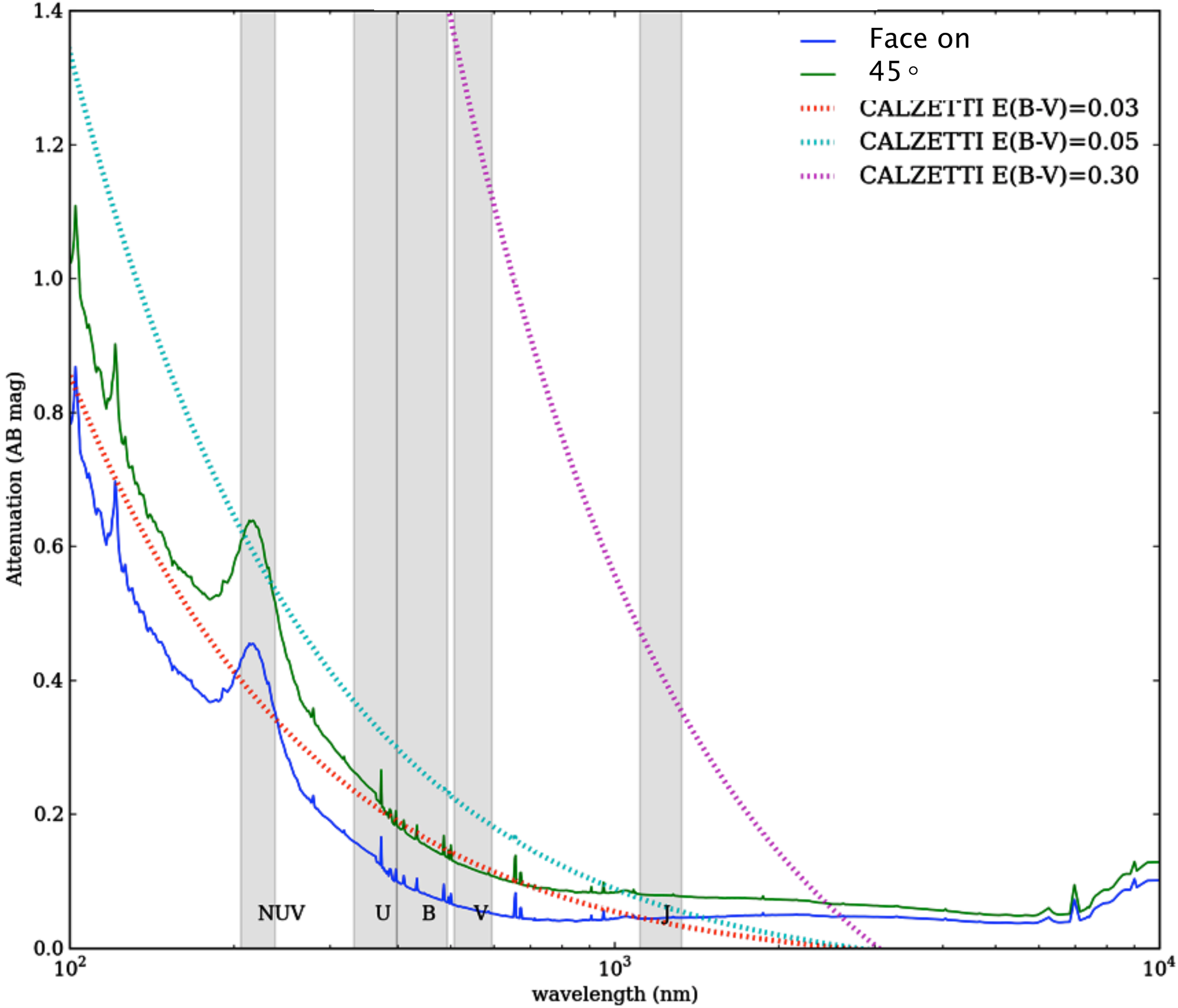

MAPPINGS off
NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

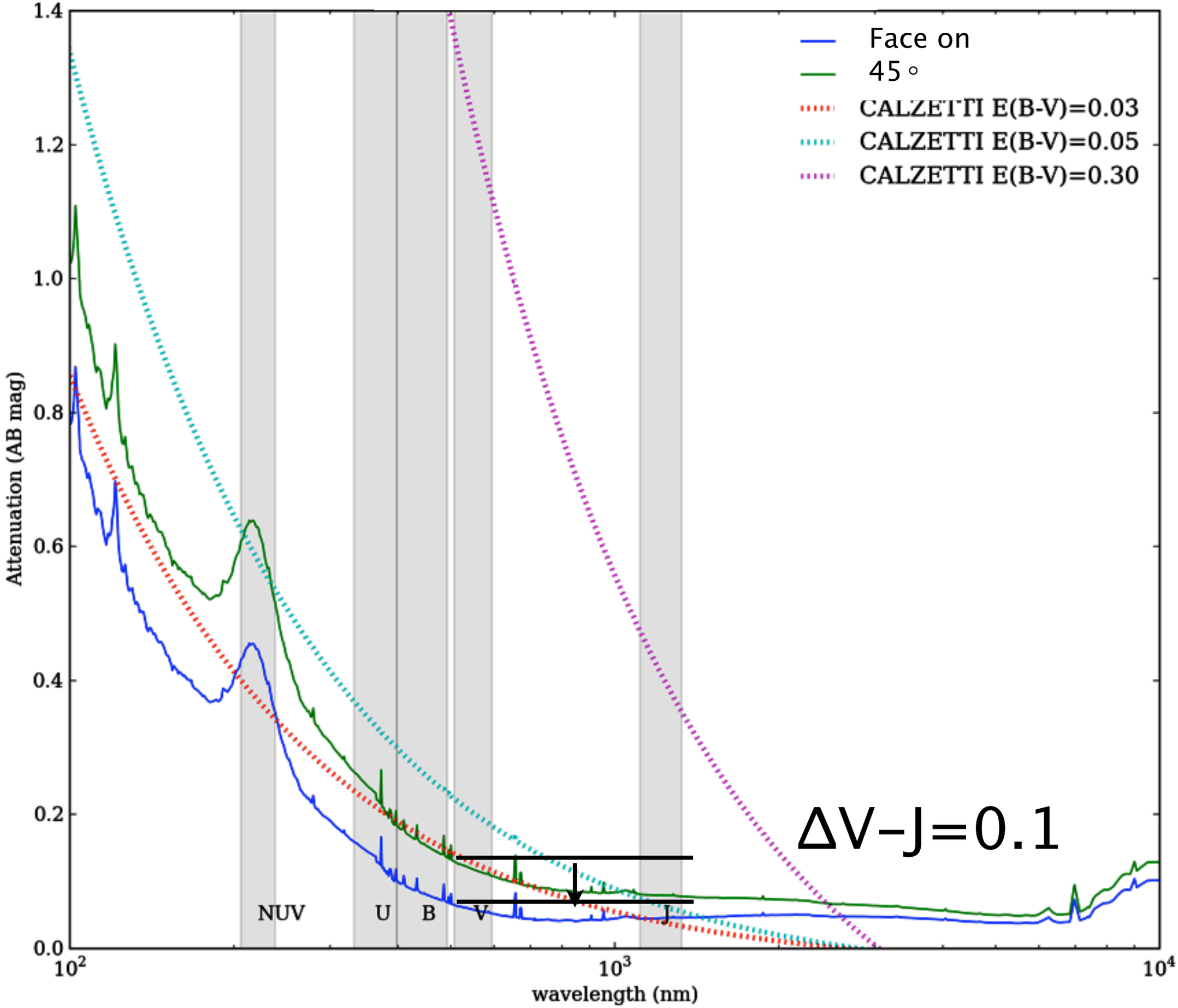

young star metals
NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

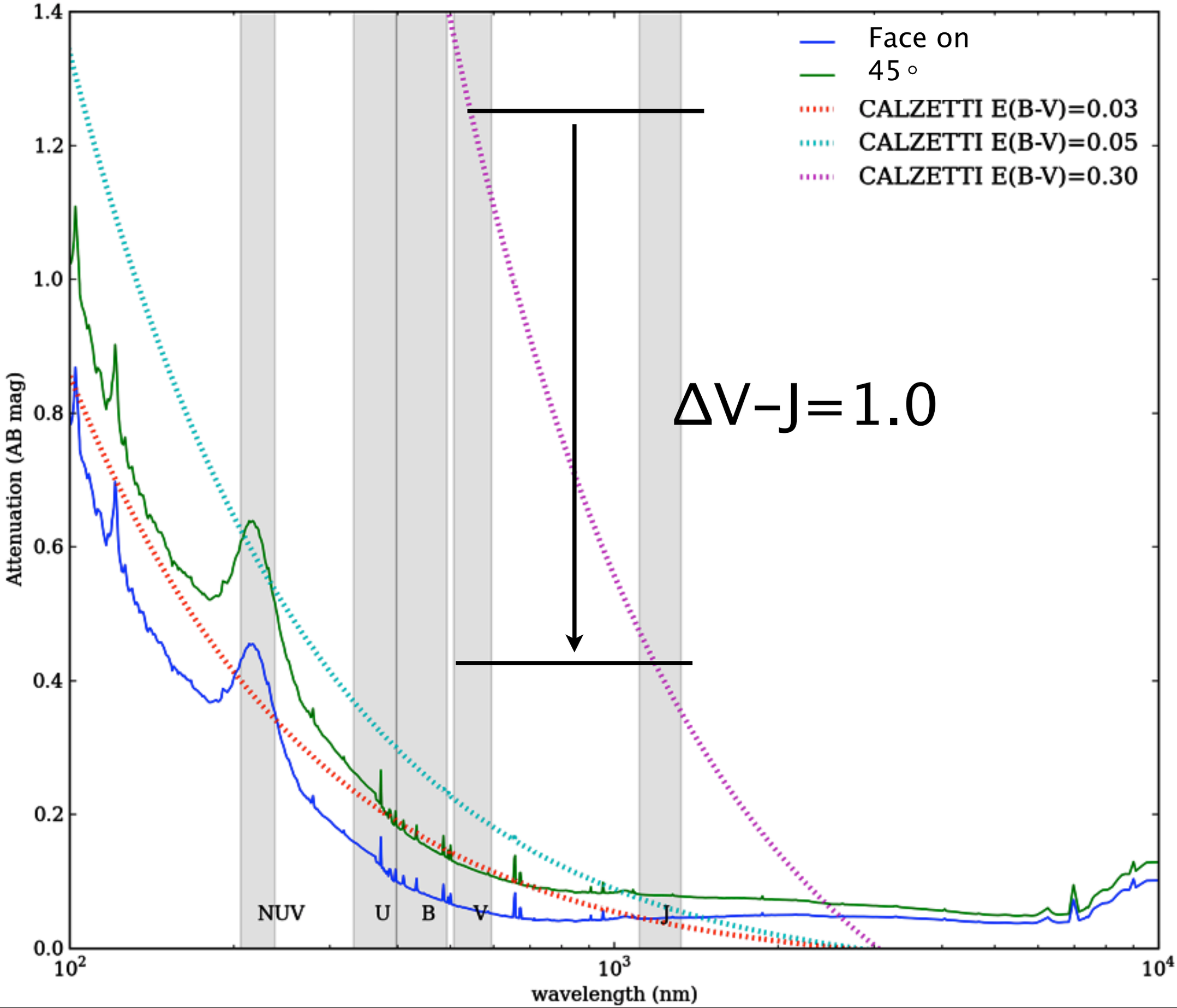

old star metallicity
NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

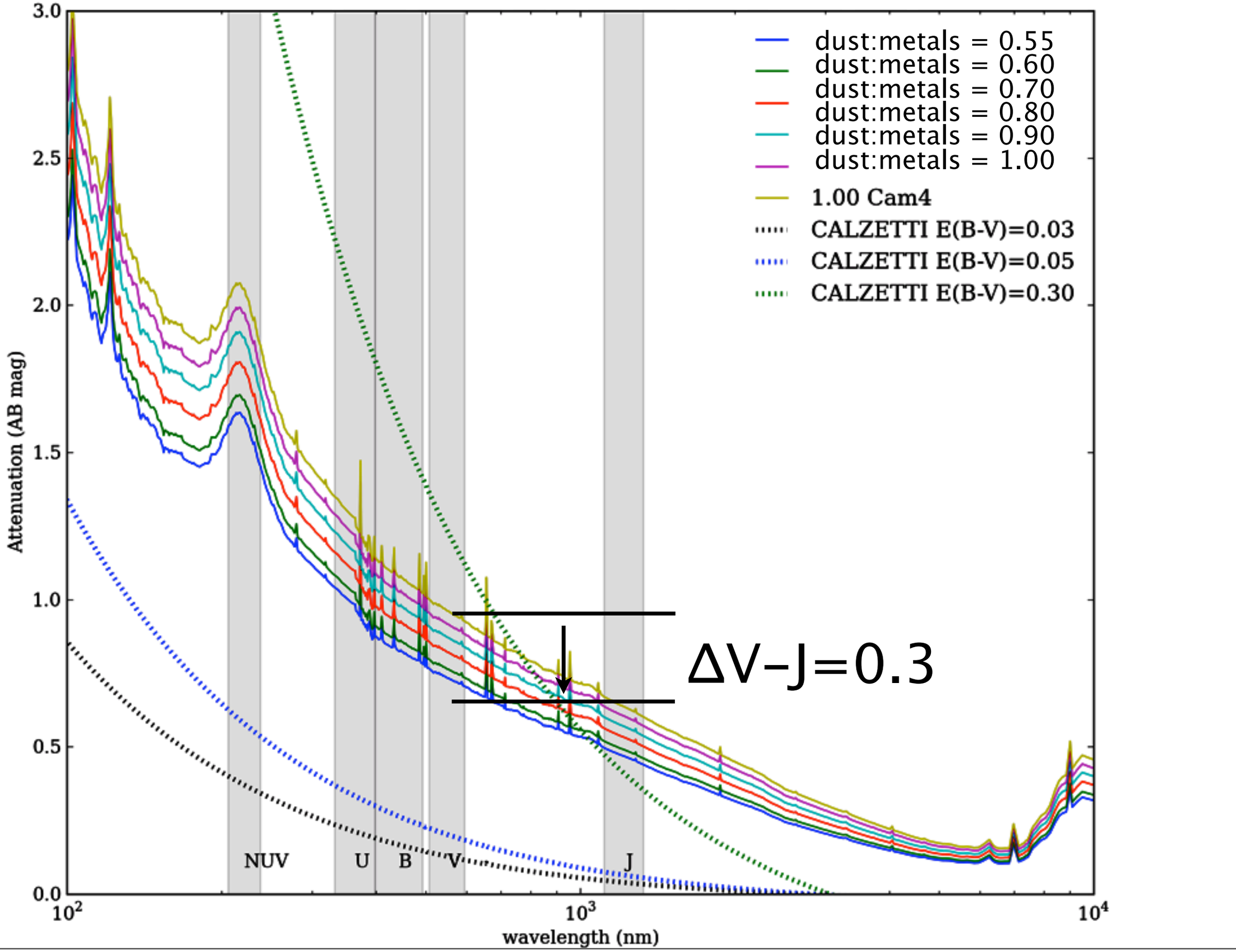

remove young stars <1.5Gyr
NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

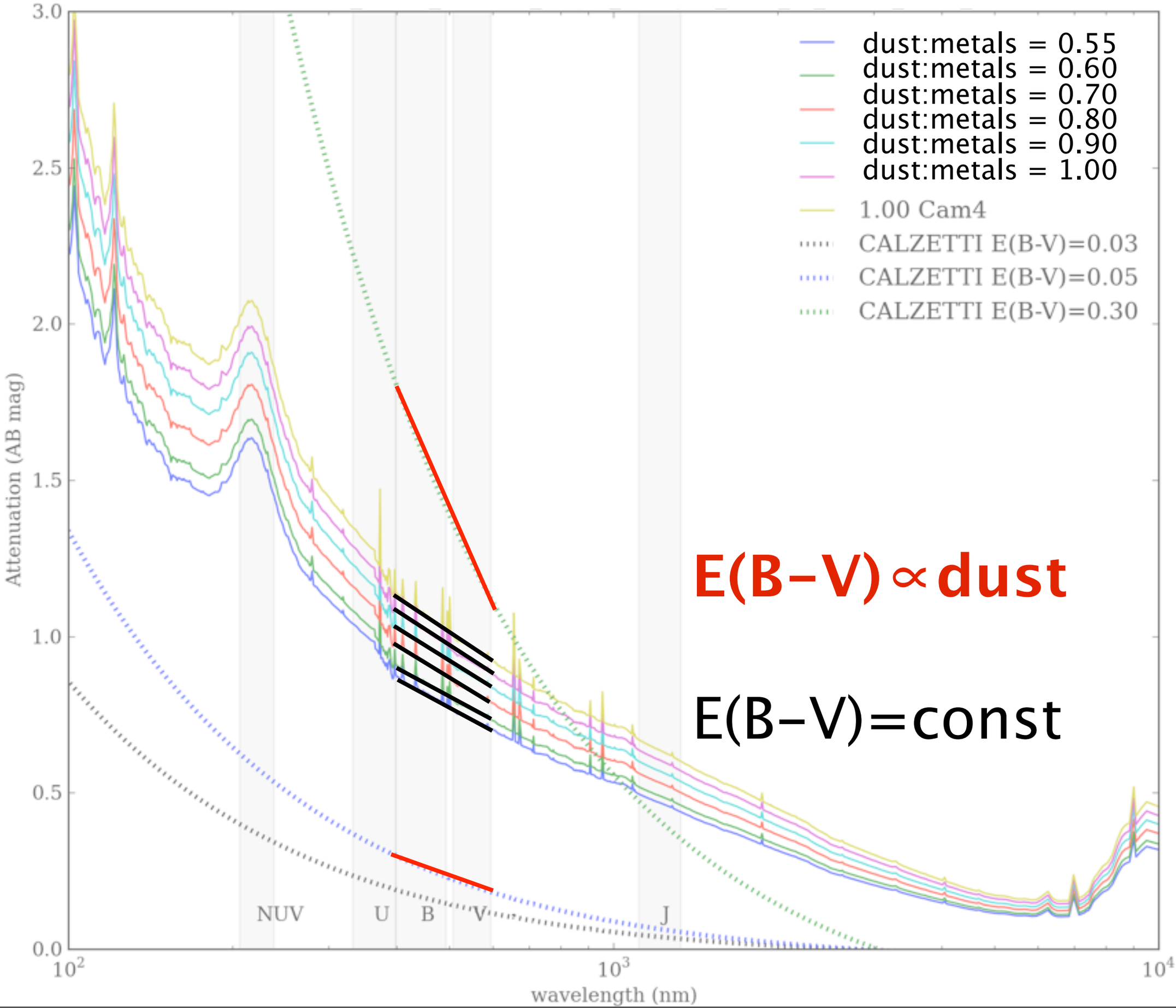

remove old stars >100Myr
NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0


Face on
45◦
CALZETTI E(B-V)=0.03
CALZETTI E(B-V)=0.05
CALZETTI E(B-V)=0.30
Attenuation (AB mag)
wavelength (nm)
NUV
U
B
V
J
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10^2
10^3
10^4


Face on
45◦
CALZETTI E(B-V)=0.03
CALZETTI E(B-V)=0.05
CALZETTI E(B-V)=0.30
ΔV–J=0.1
NUV
U
B
V
J
Attenuation (AB mag)
wavelength (nm)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10^2
10^3
10^4


Face on
45◦
CALZETTI E(B-V)=0.03
CALZETTI E(B-V)=0.05
CALZETTI E(B-V)=0.30
ΔV−J=1.0
NUV
U
B
V
J
Attenuation (AB mag)
wavelength (nm)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10^2
10^3
10^4


dust:metals = 0.55
dust:metals = 0.60
dust:metals = 0.70
dust:metals = 0.80
dust:metals = 0.90
dust:metals = 1.00
1.00 Cam4
CALZETTI E(B-V)=0.03
CALZETTI E(B-V)=0.05
CALZETTI E(B-V)=0.30
ΔV−J=0.3
NUV
U
B
V
J
Attenuation (AB mag)
wavelength (nm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10^2
10^3
10^4

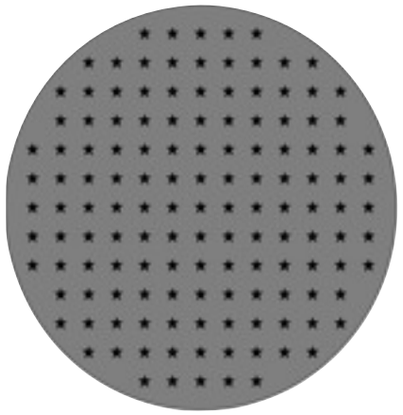

dust:metals = 0.55
dust:metals = 0.60
dust:metals = 0.70
dust:metals = 0.80
dust:metals = 0.90
dust:metals = 1.00
1.00 Cam4
CALZETTI E(B-V)=0.03
CALZETTI E(B-V)=0.05
CALZETTI E(B-V)=0.30
E(B-V)∝dust
E(B-V)=const
Attenuation (AB mag)
wavelength (nm)
NUV
U
B
V
J
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10^2
10^3
10^4

dust & star distributions

Calzetti

E(B−V)
(attenuation slope)

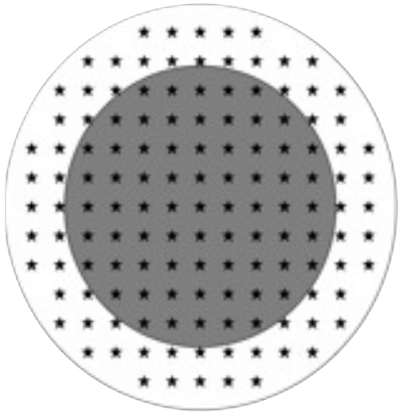
redder



Sims

bluer

scattering



reddening

dust mass ⟶

Witt & Gordon 2000

Conclusions

Nature has a very specific, quite universal, dust law reproduced by foreground models.

Large variations in dust & radiation models do not yield correct dusty UVJs.

Is this a failure of the in simulations, or dust models?

Solution: add Calzetti to Sunrise & study dust attenuation separately

Sunrise Scorecard

Local SINGS galaxies: (Jonsson et al. 2006)
- ok: FUV,NUV, IRAC, MIPS
- no: 160/850 μm colors

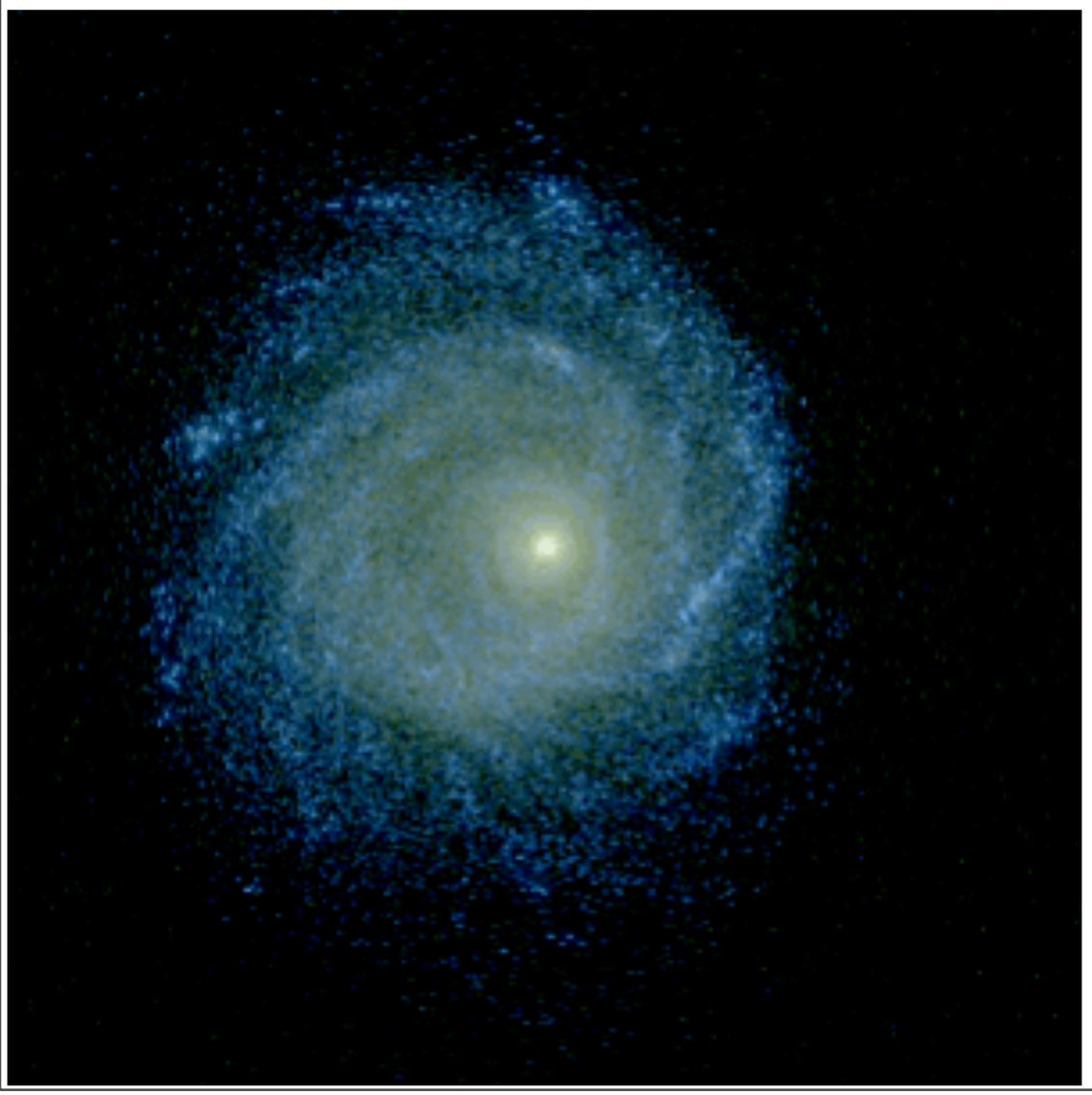
Metallicity gradients match SINGS: (Rocha et al. 2008)
- Range of simulations with B-band mags from -16 to -22
- ok: Total IR:UV

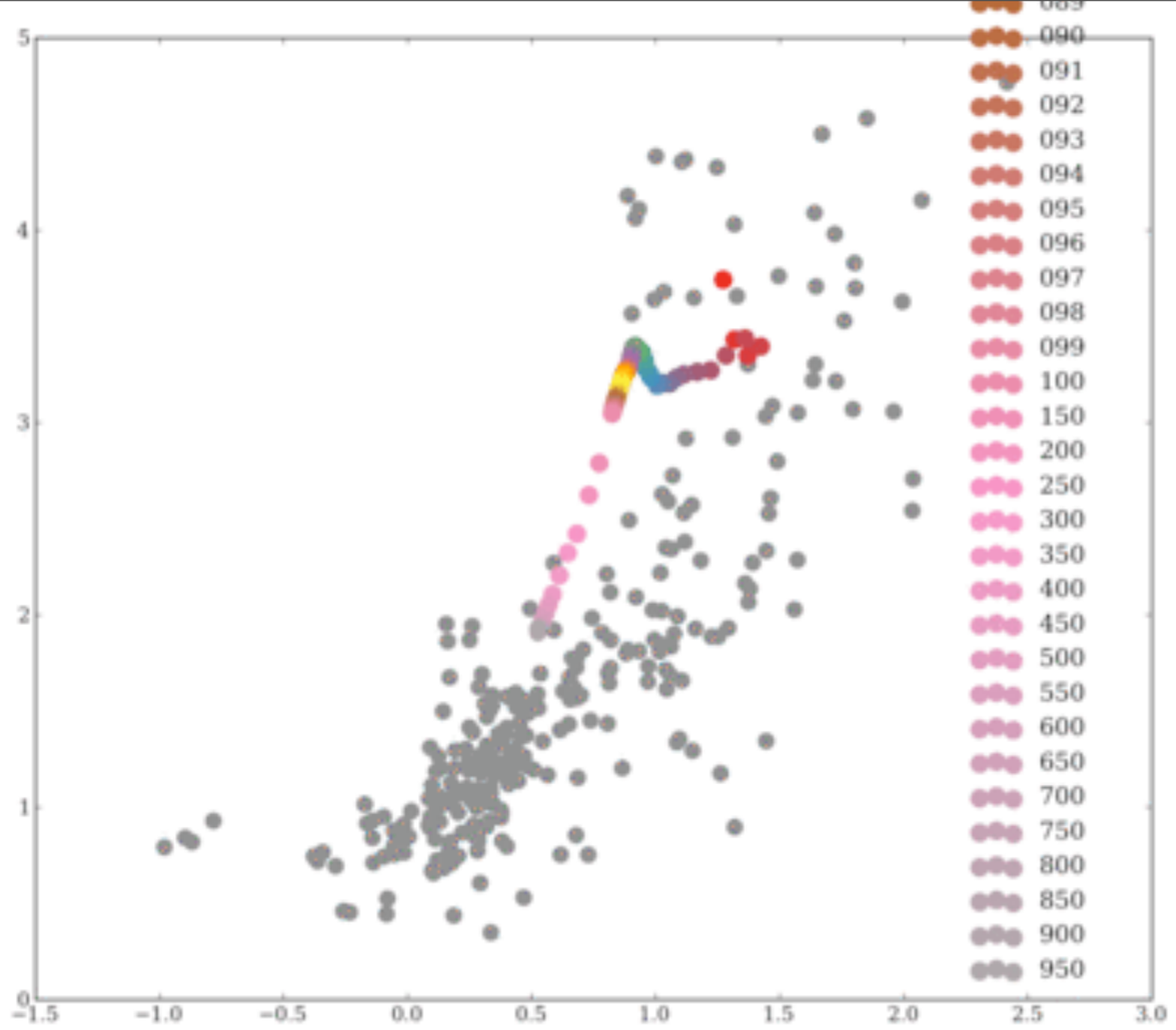
High-z galaxies:
- ULIRGs & SMGs match far-IR fluxes (Hayward et al. 2009)
- UVJs fail in isolated galaxy simulations in Gadget (Wuyts et al. 2009)

NUV – V

V – J

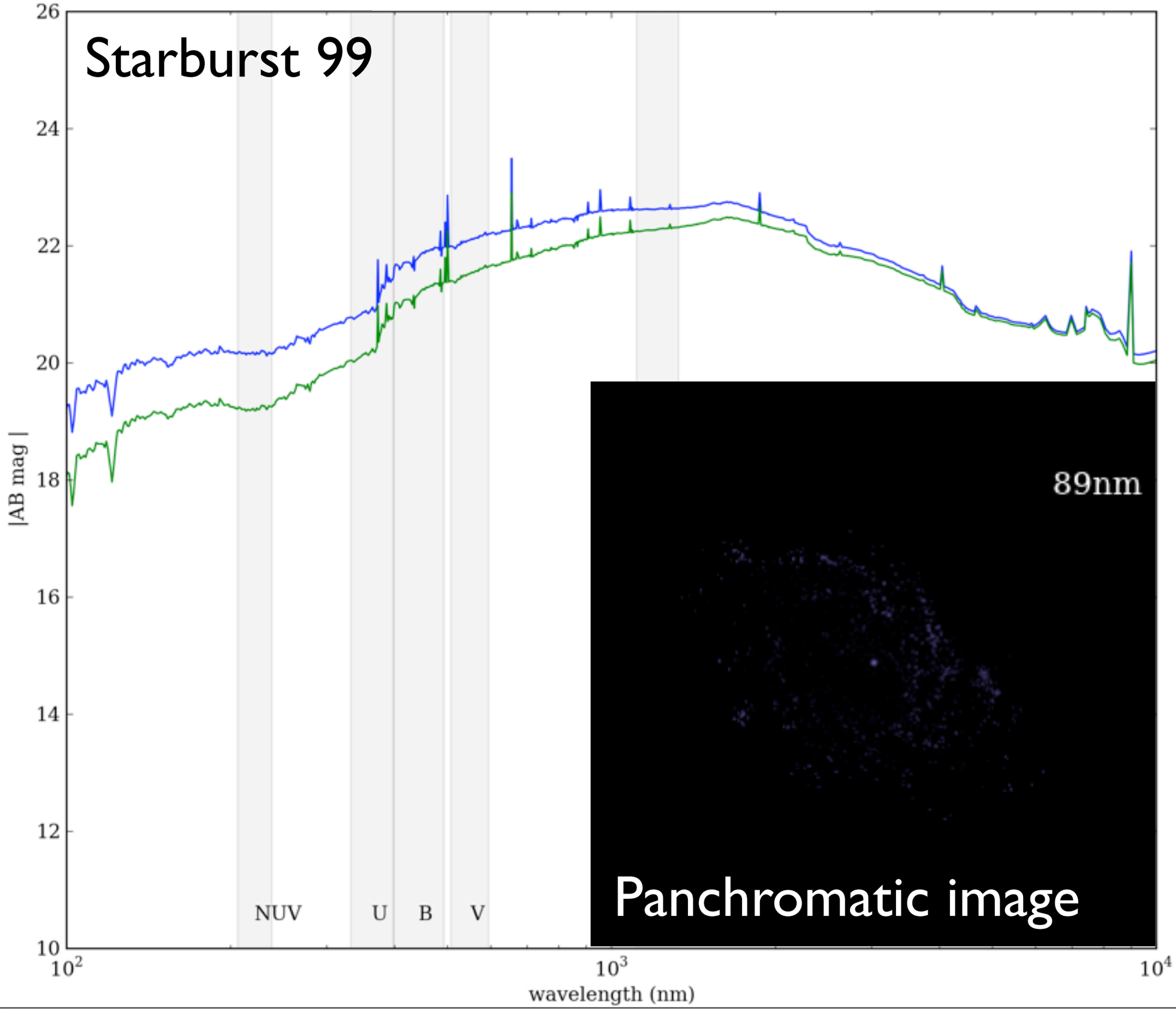
Bulge is in the red cloud
Disk ends up in the blue cloud





V – J

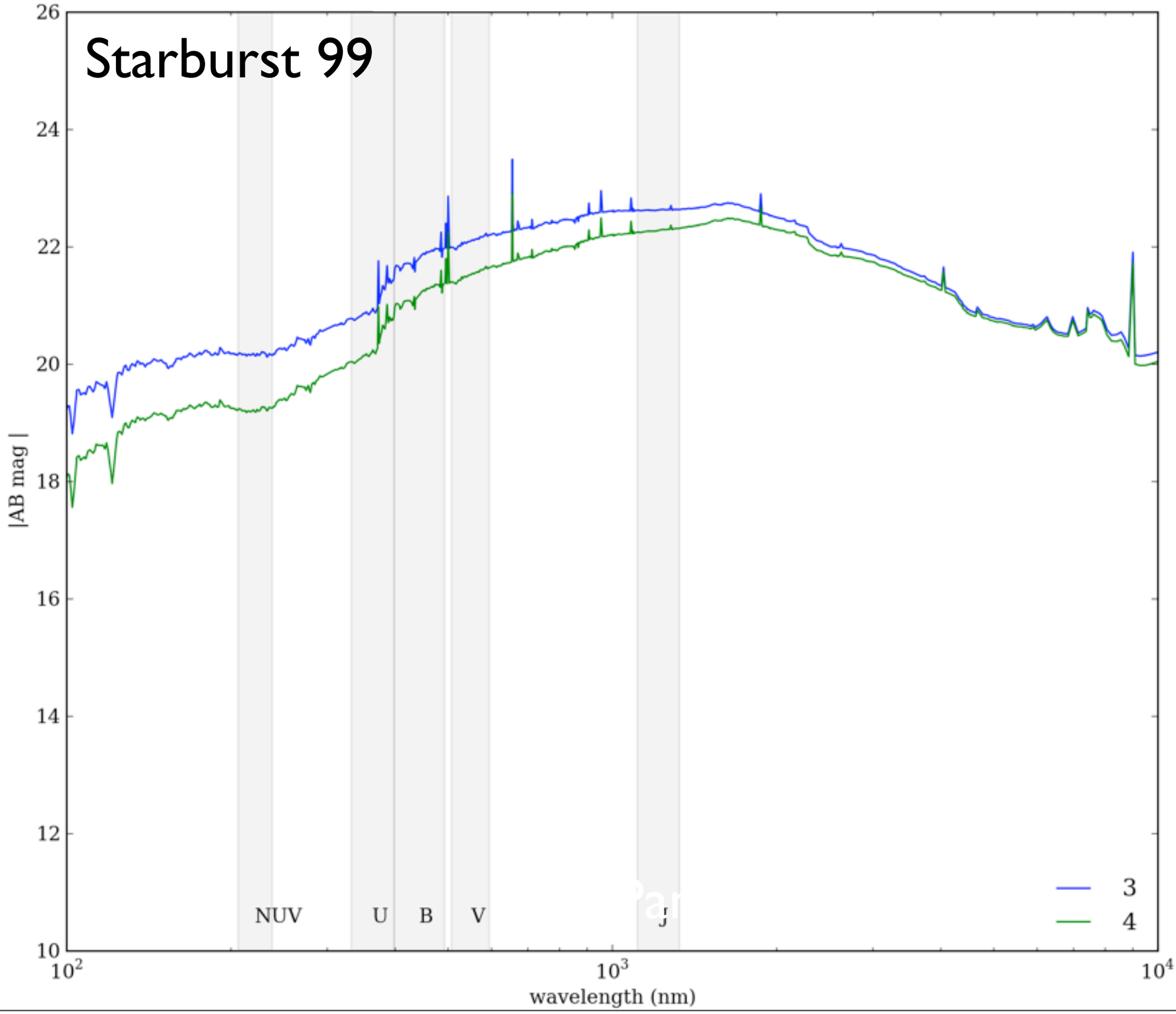
Bulge is in the red cloud
Disk ends up in the blue cloud

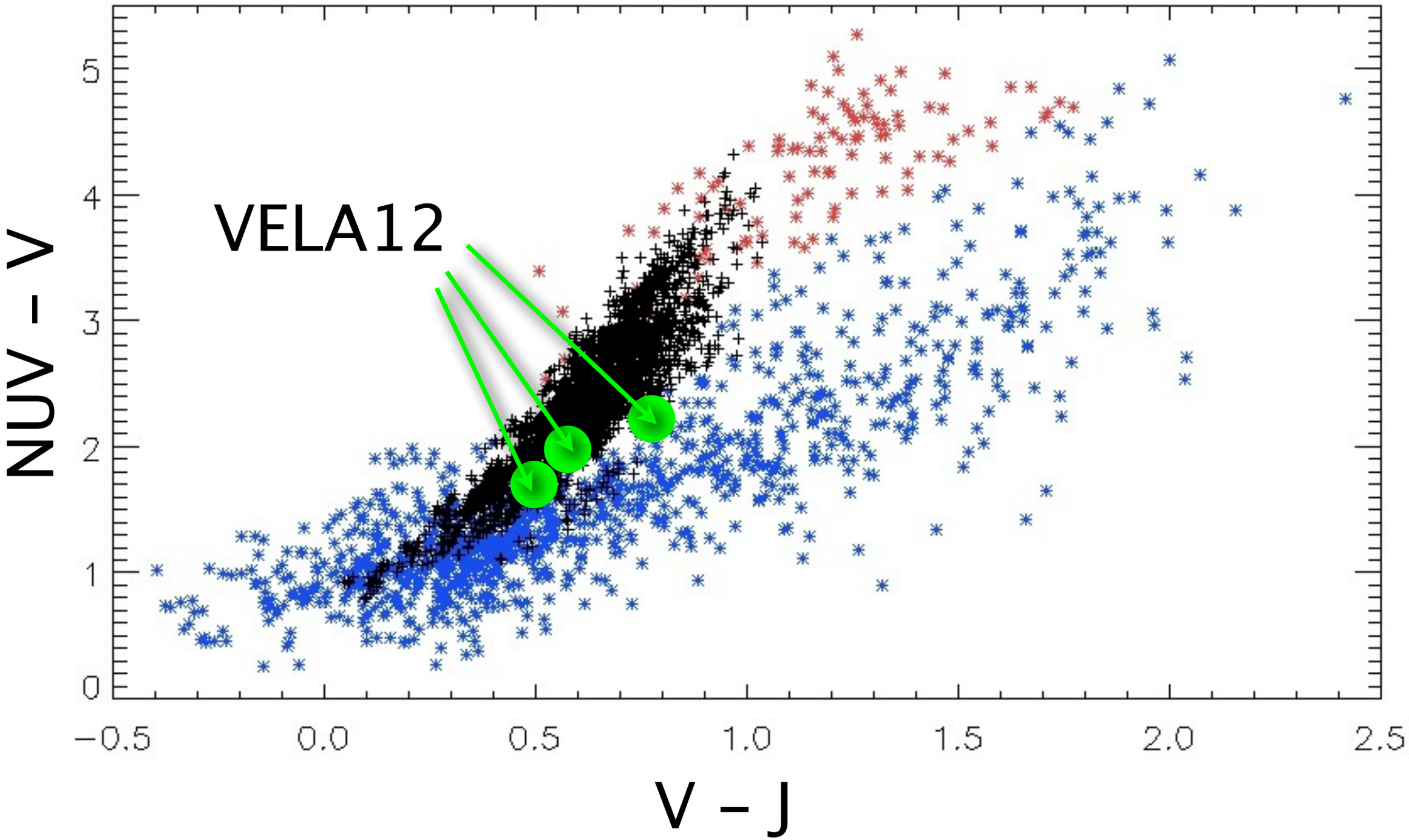

Starburst 99
26
24
22
20
18
16
14
12
10
|AB mag |
NUV
U
B
V
10^2
10^3
10^4
wavelength (nm)
89nm
Panchromatic image

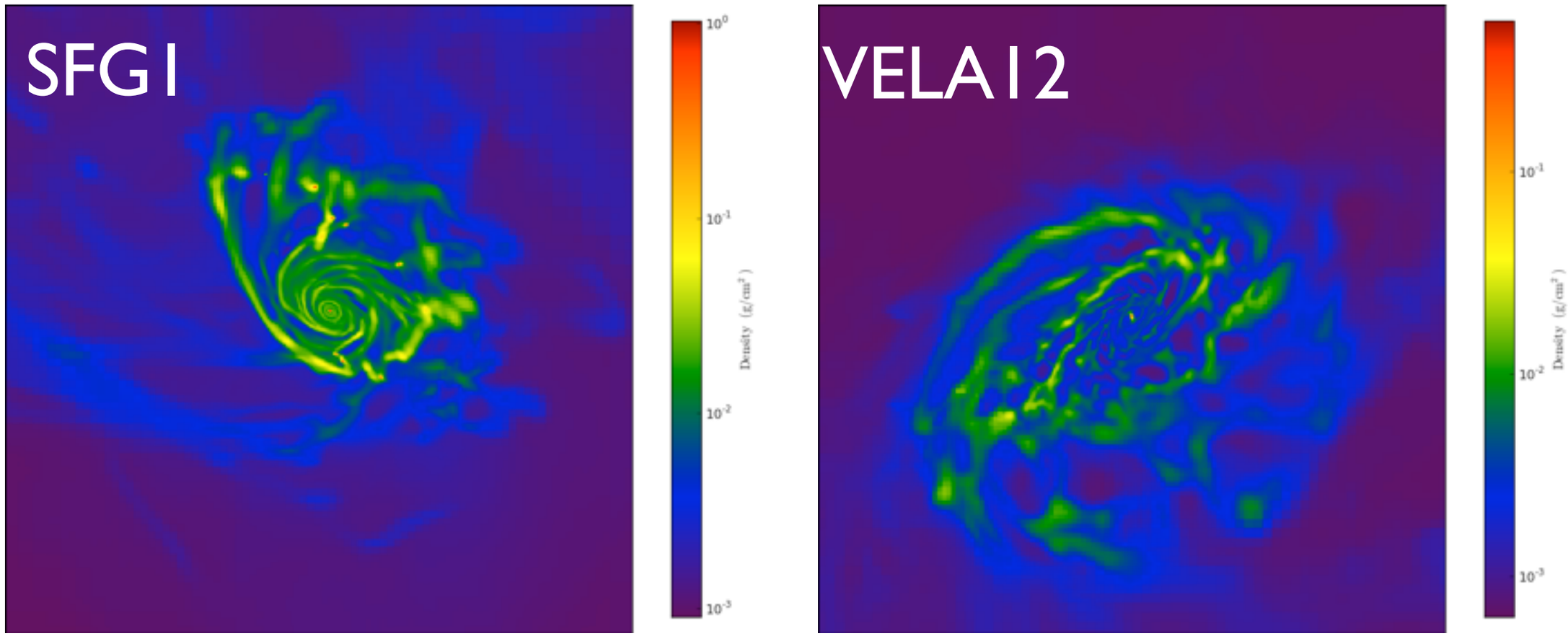
VELA12

inertial frame

edge-on


Starburst 99
26
24
22
20
18
16
14
12
10
|AB mag |
NUV
U
B
V
J
3
4
10^2
10^3
10^4
wavelength (nm)

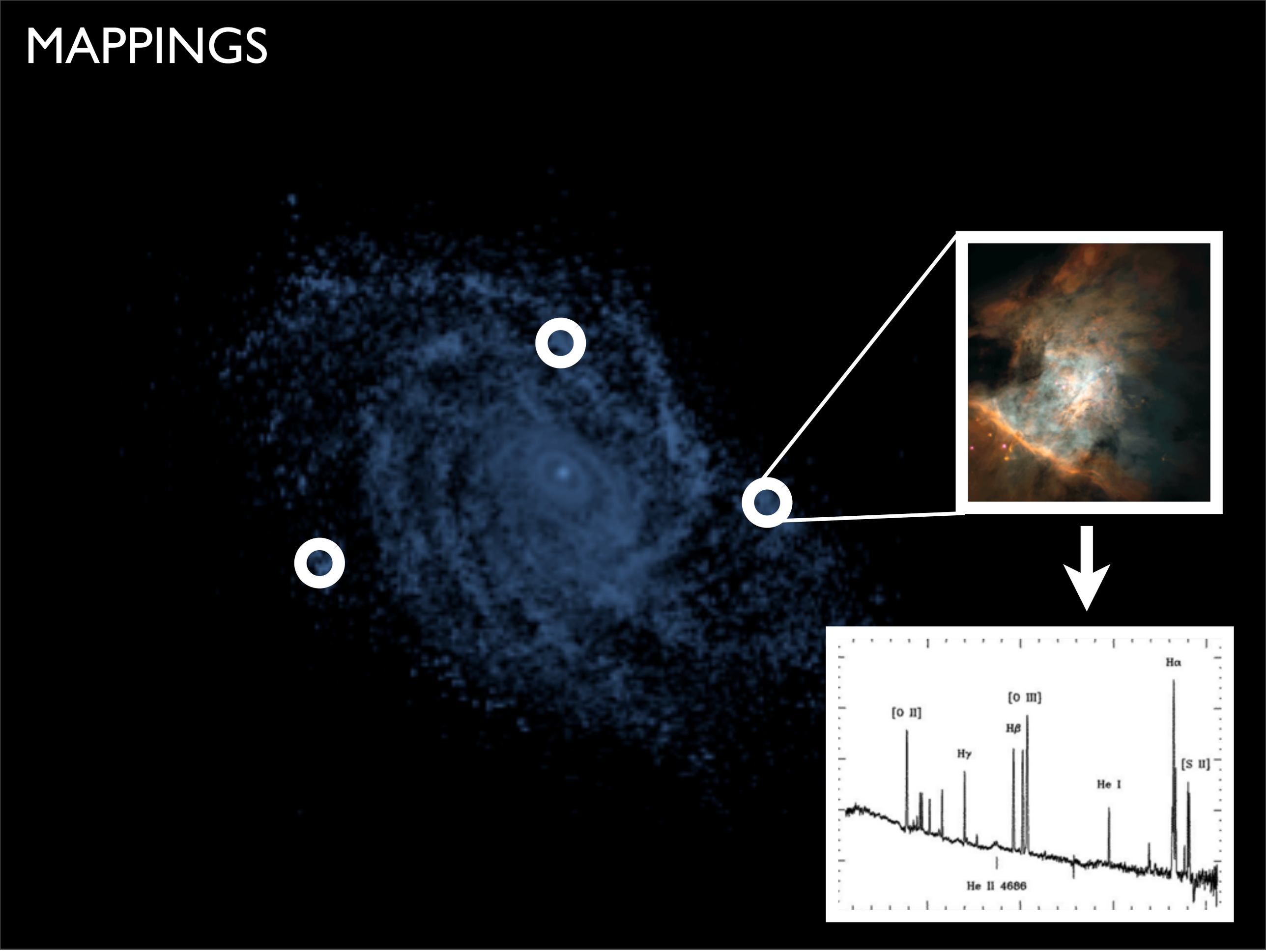

VELA12
NUV – V
V – J
5
4
3
2
1
0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5

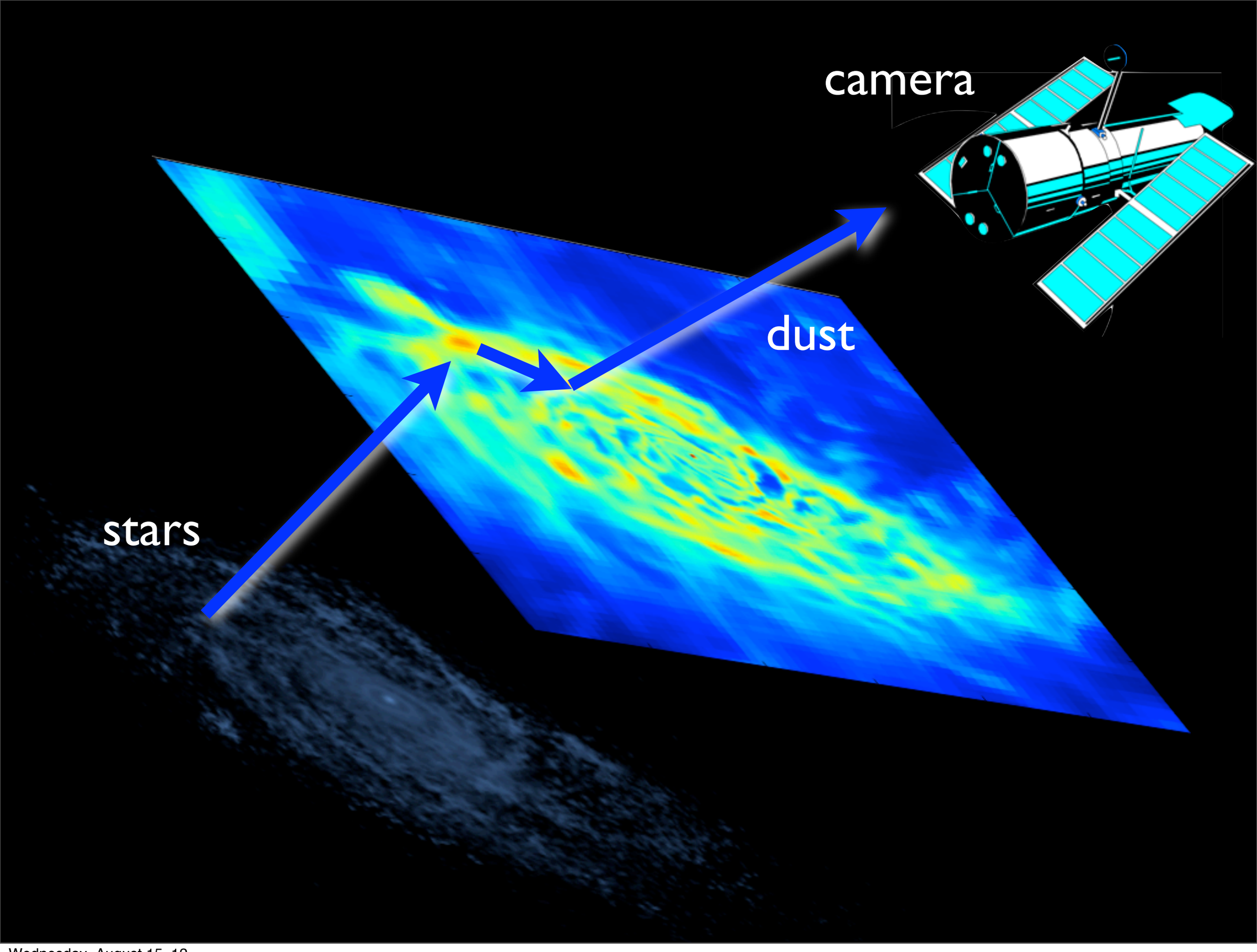


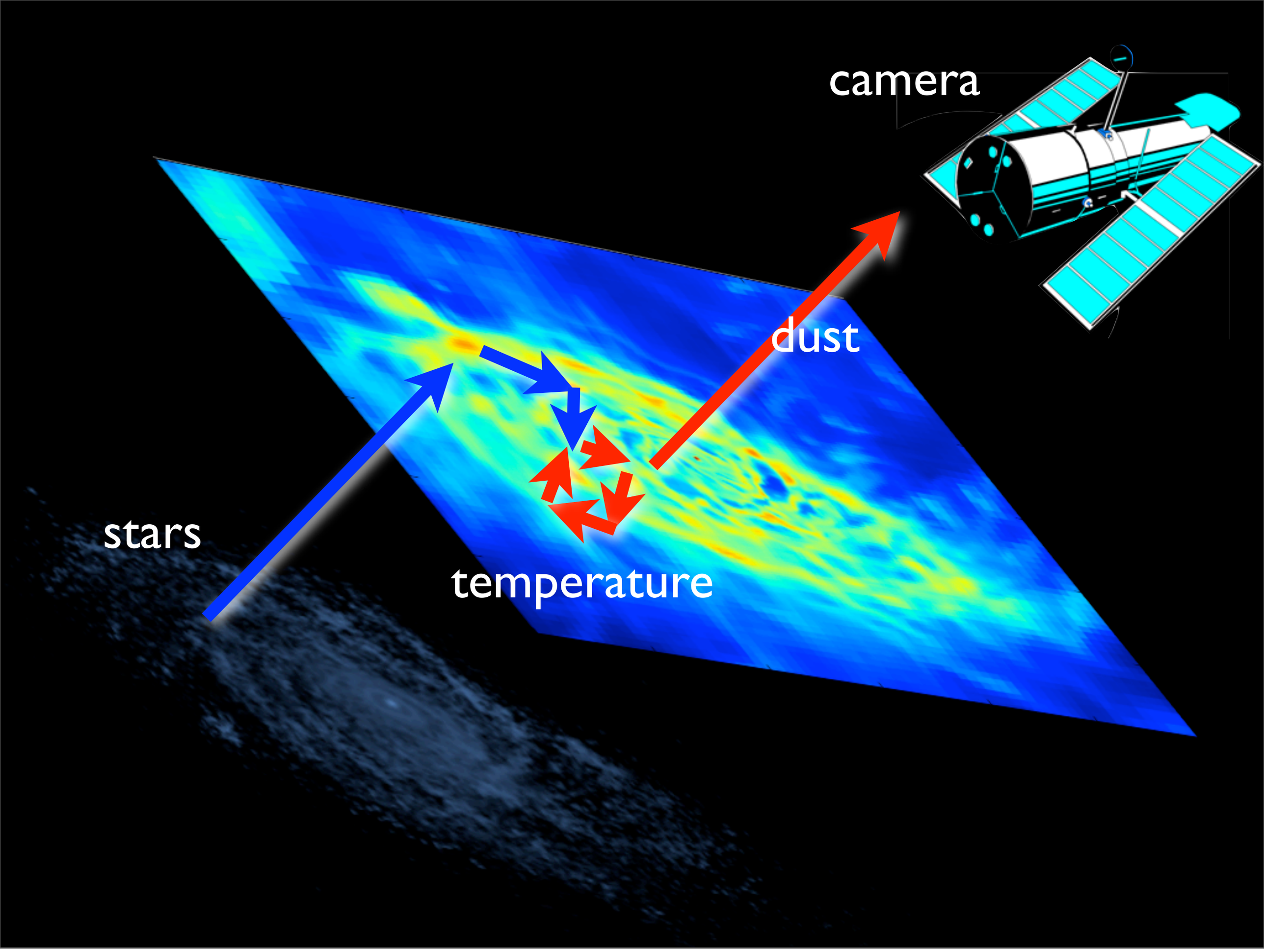
high SF
2.3×10^{12} (z=1)

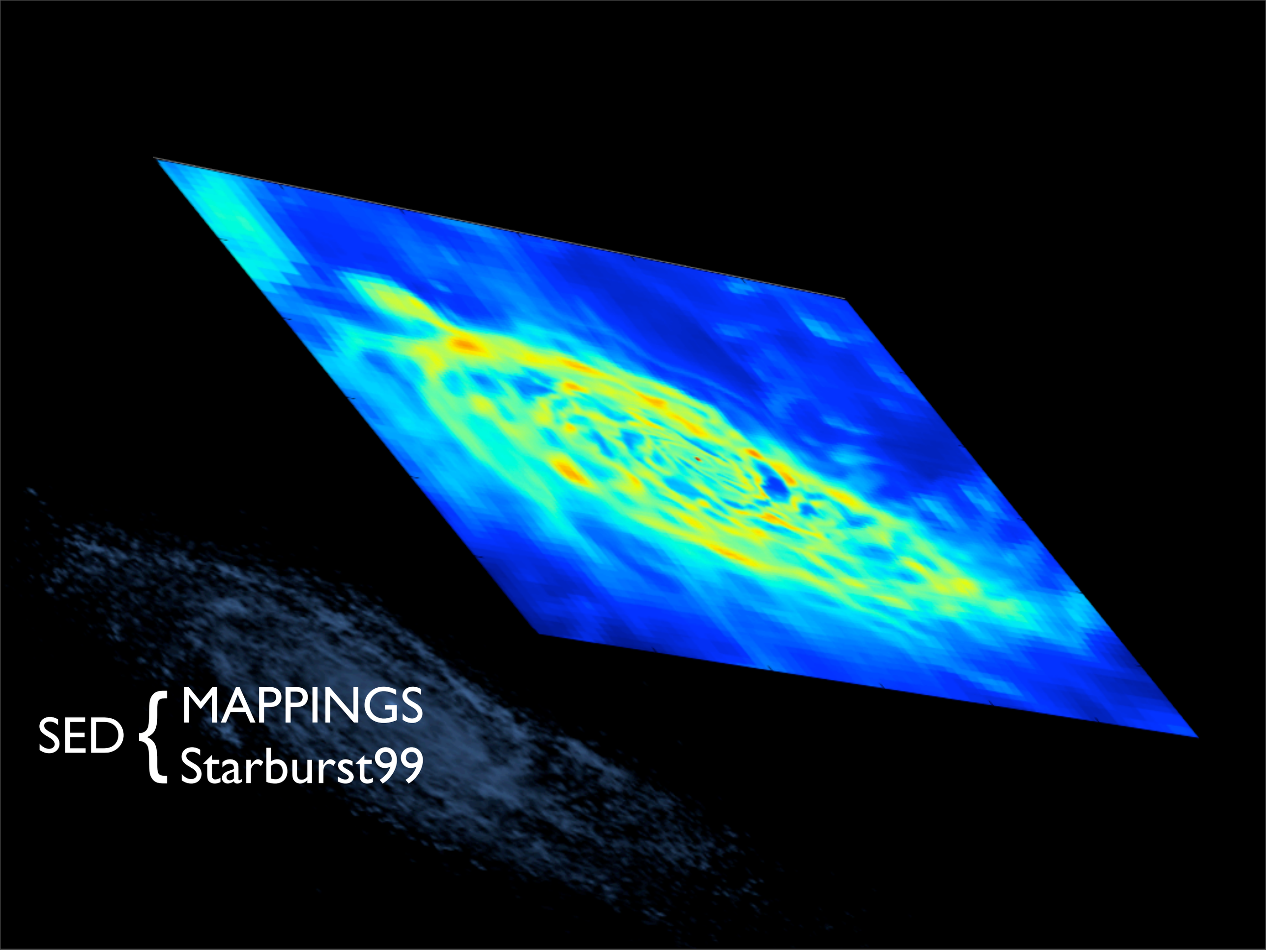
low SF efficiency
3.6×10^{11} (z=0.8)

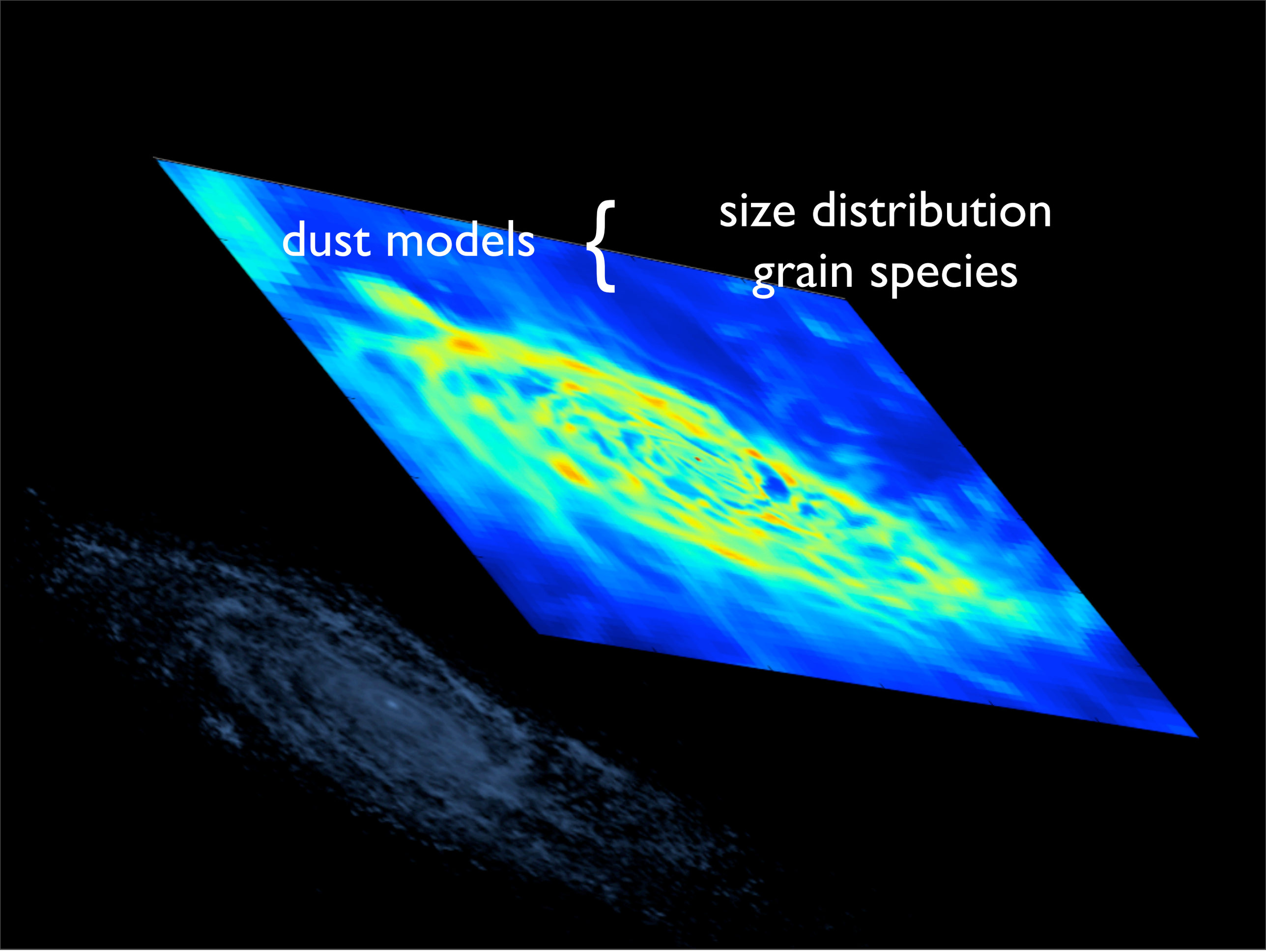
MAPPINGS



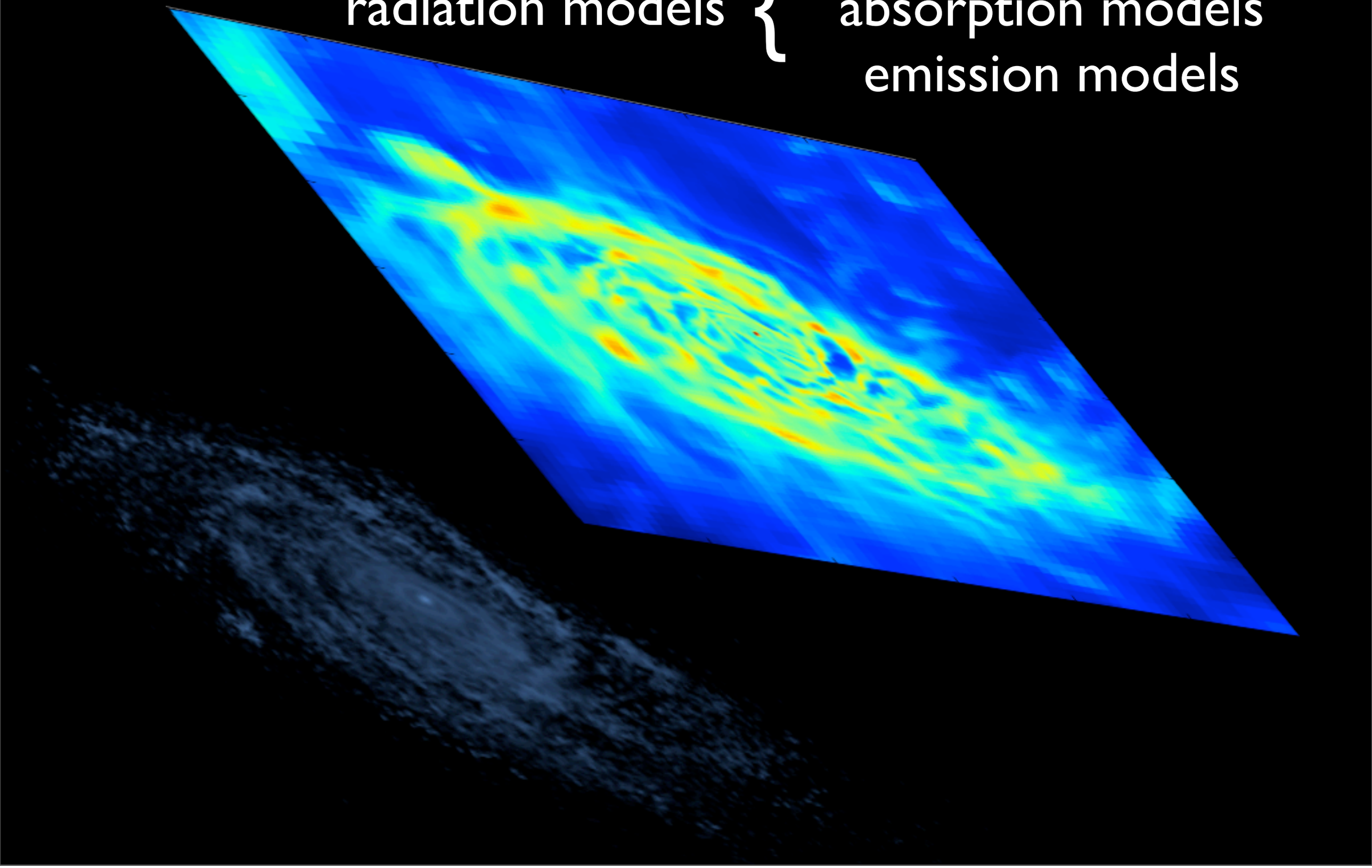

camera
dust
stars


camera
dust
stars
temperature

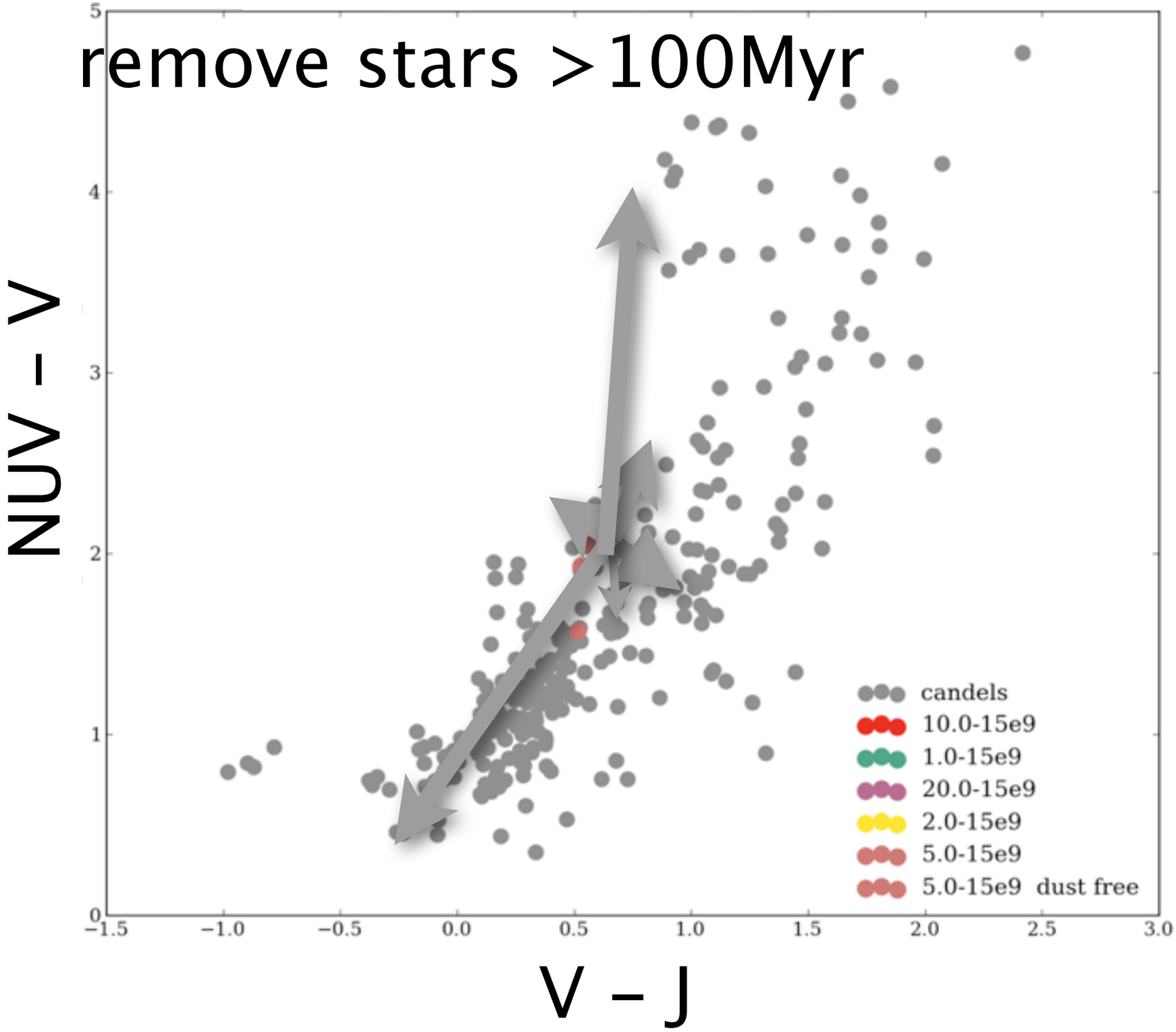

SED
MAPPINGS
Starburst99

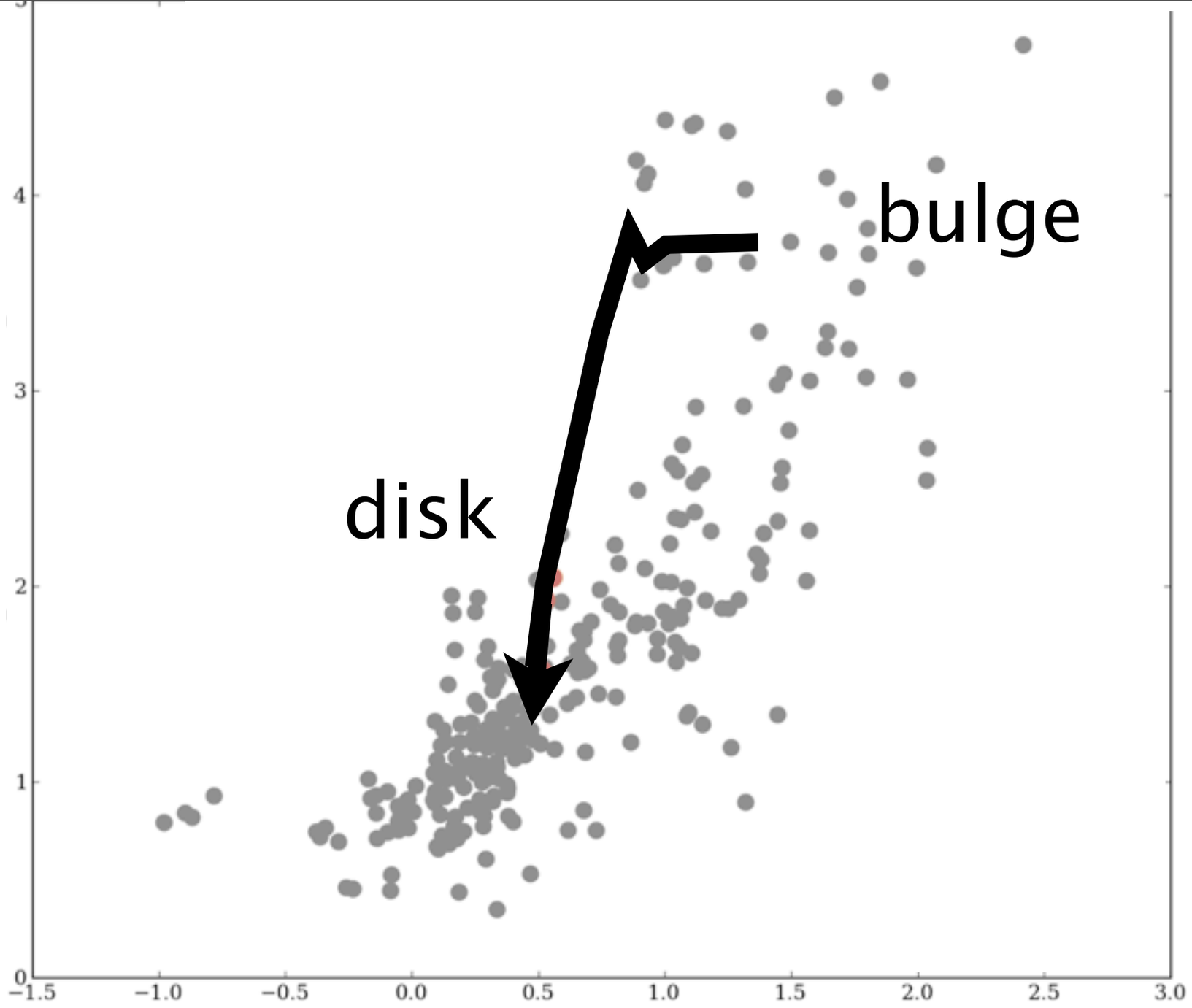

dust models
{
size distribution
grain species

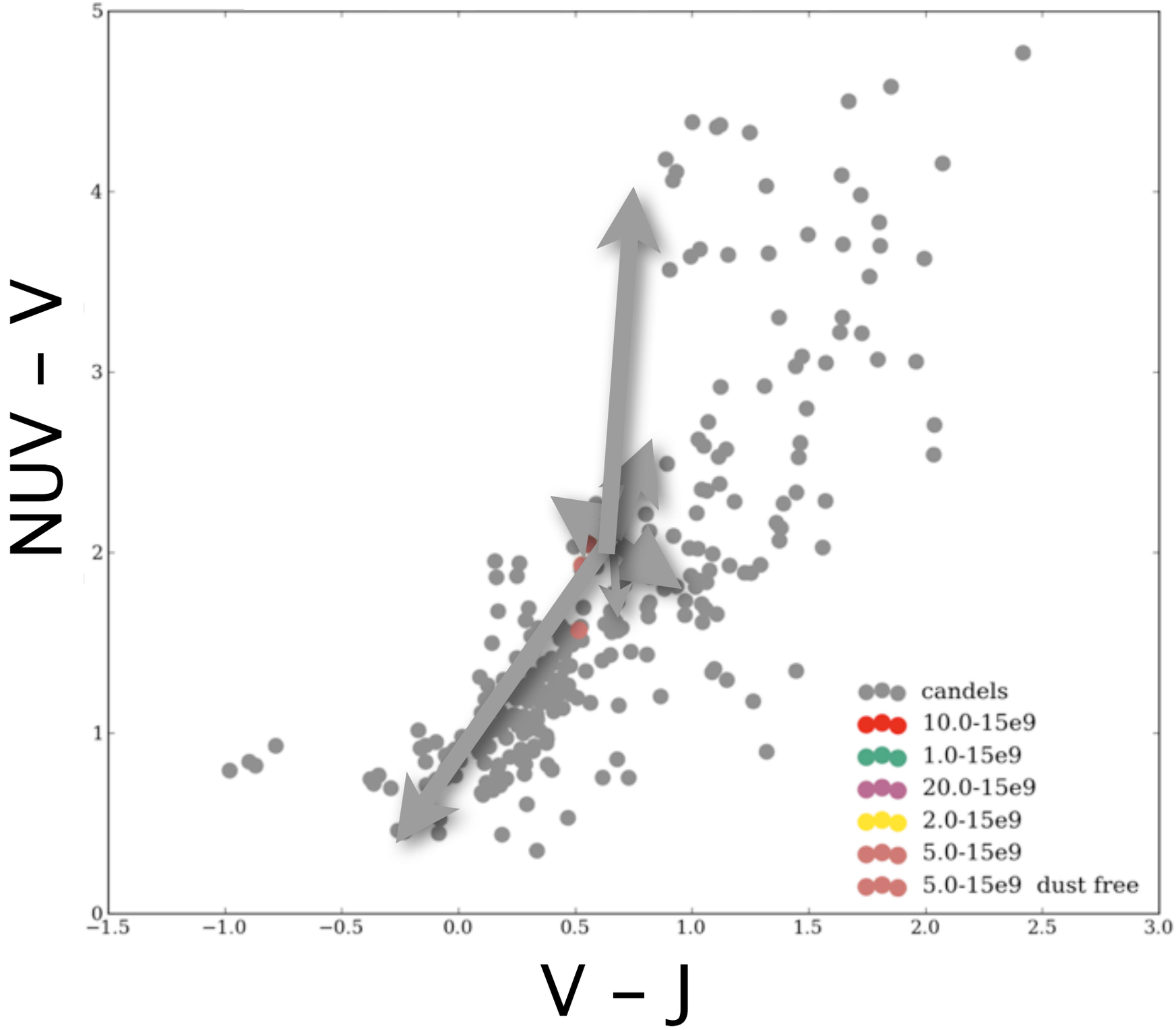
radiation models { scattering crossection
absorption models
emission models

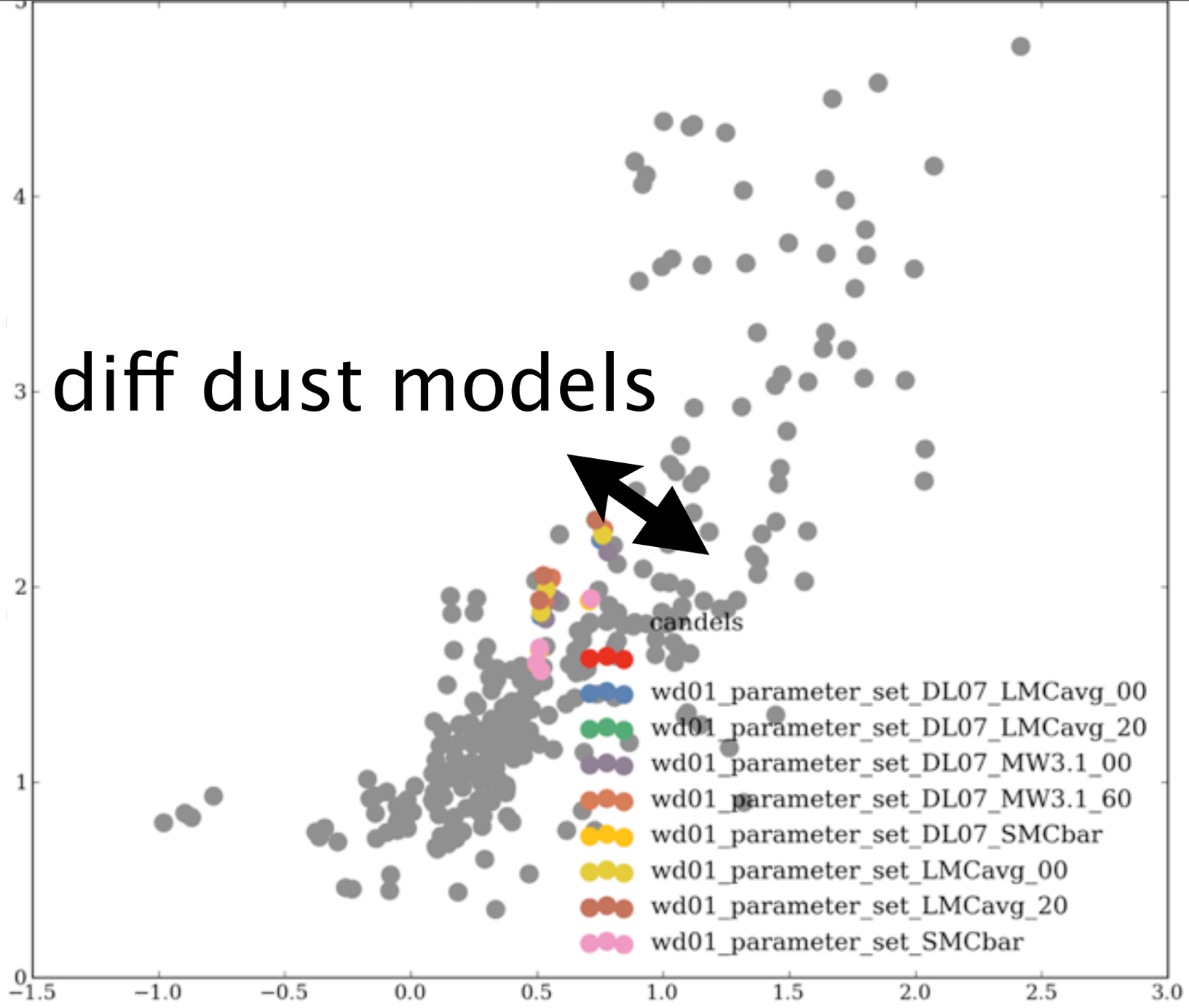


remove stars >100Myr

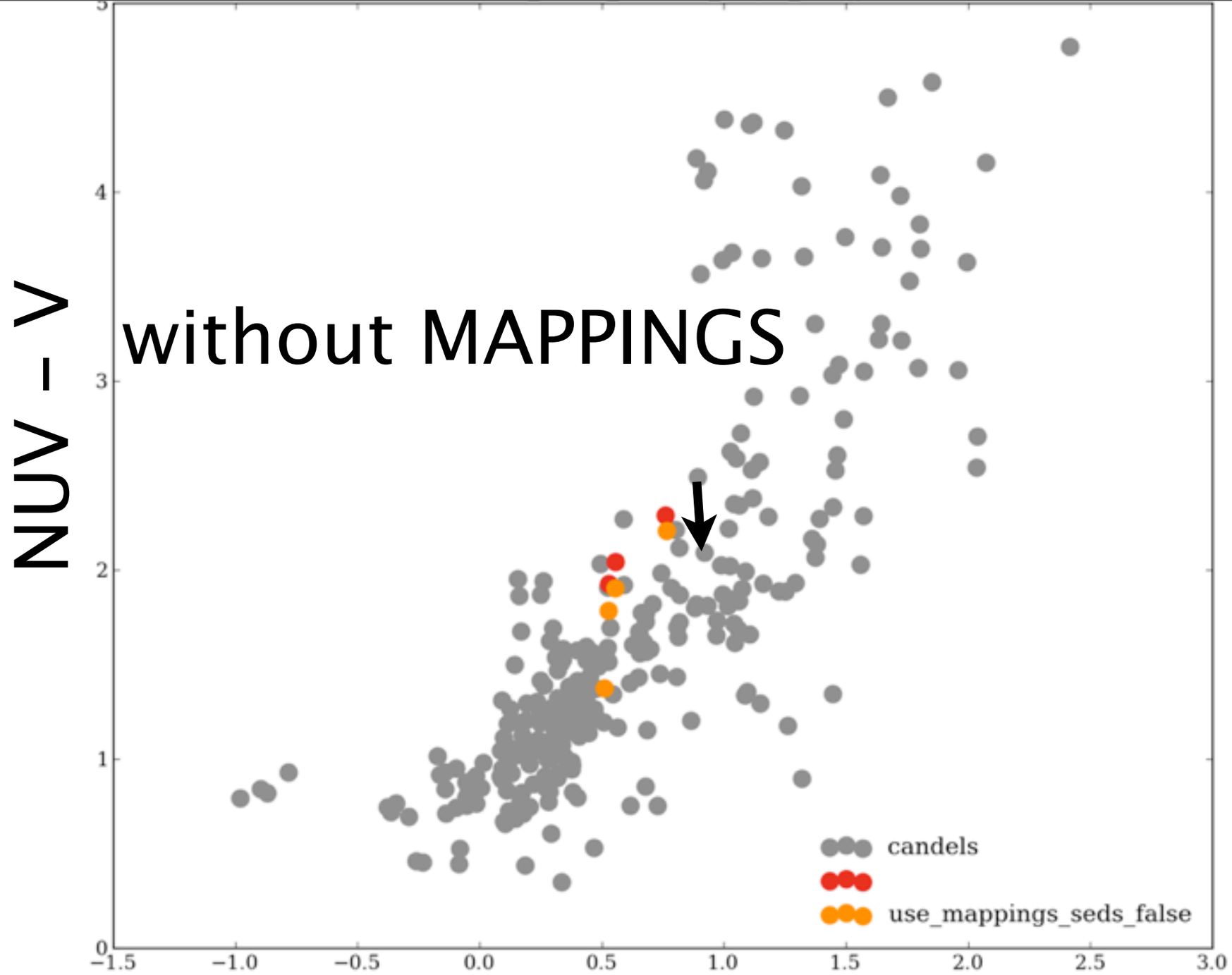



bulge
disk
NUV – V
V – J
0
1
2
3
4
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

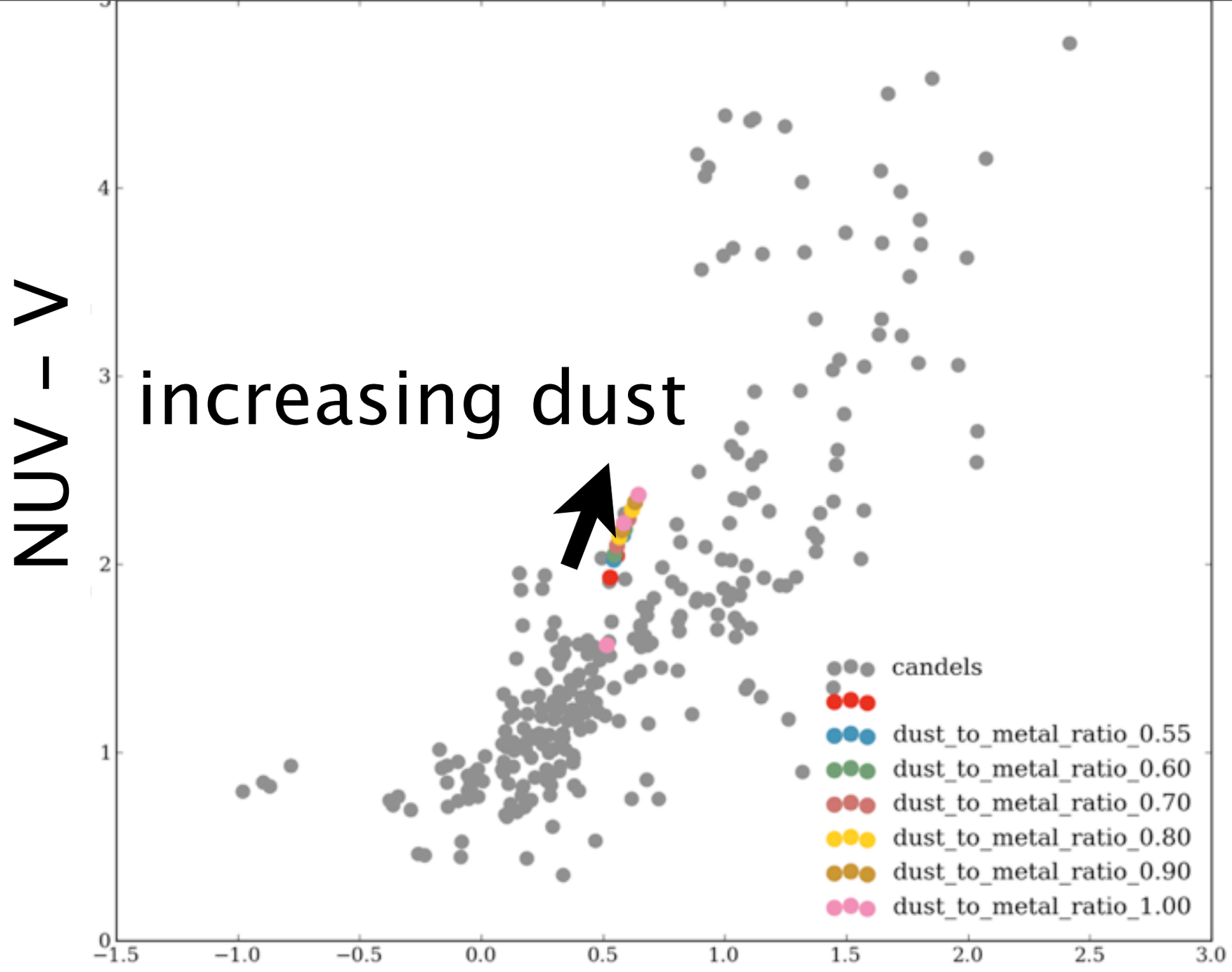

NUV – V
V – J
5
4
3
2
1
0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
candels
10.0-15e9
1.0-15e9
20.0-15e9
2.0-15e9
5.0-15e9
5.0-15e9 dust free



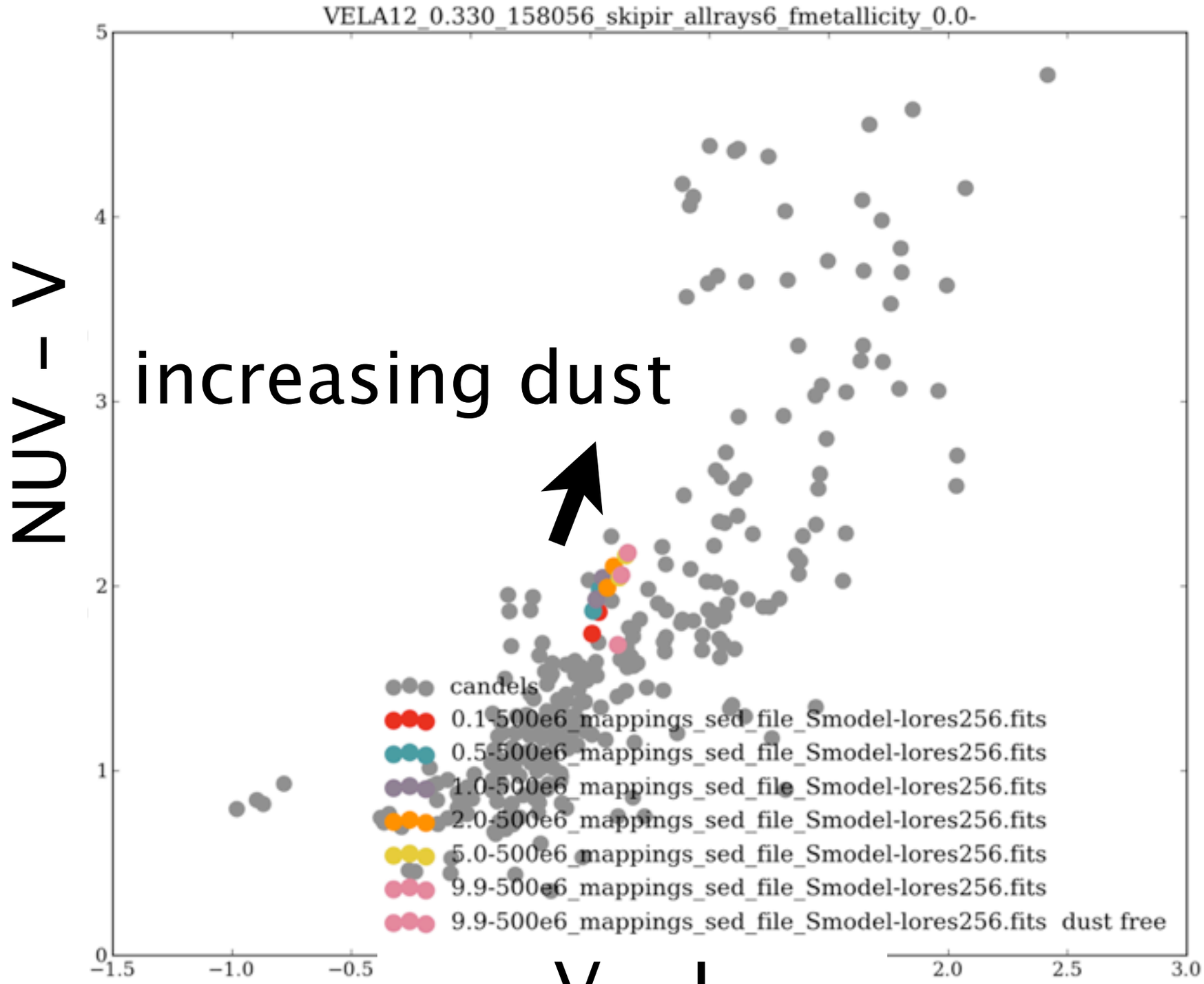
varying dust models yields only small changes



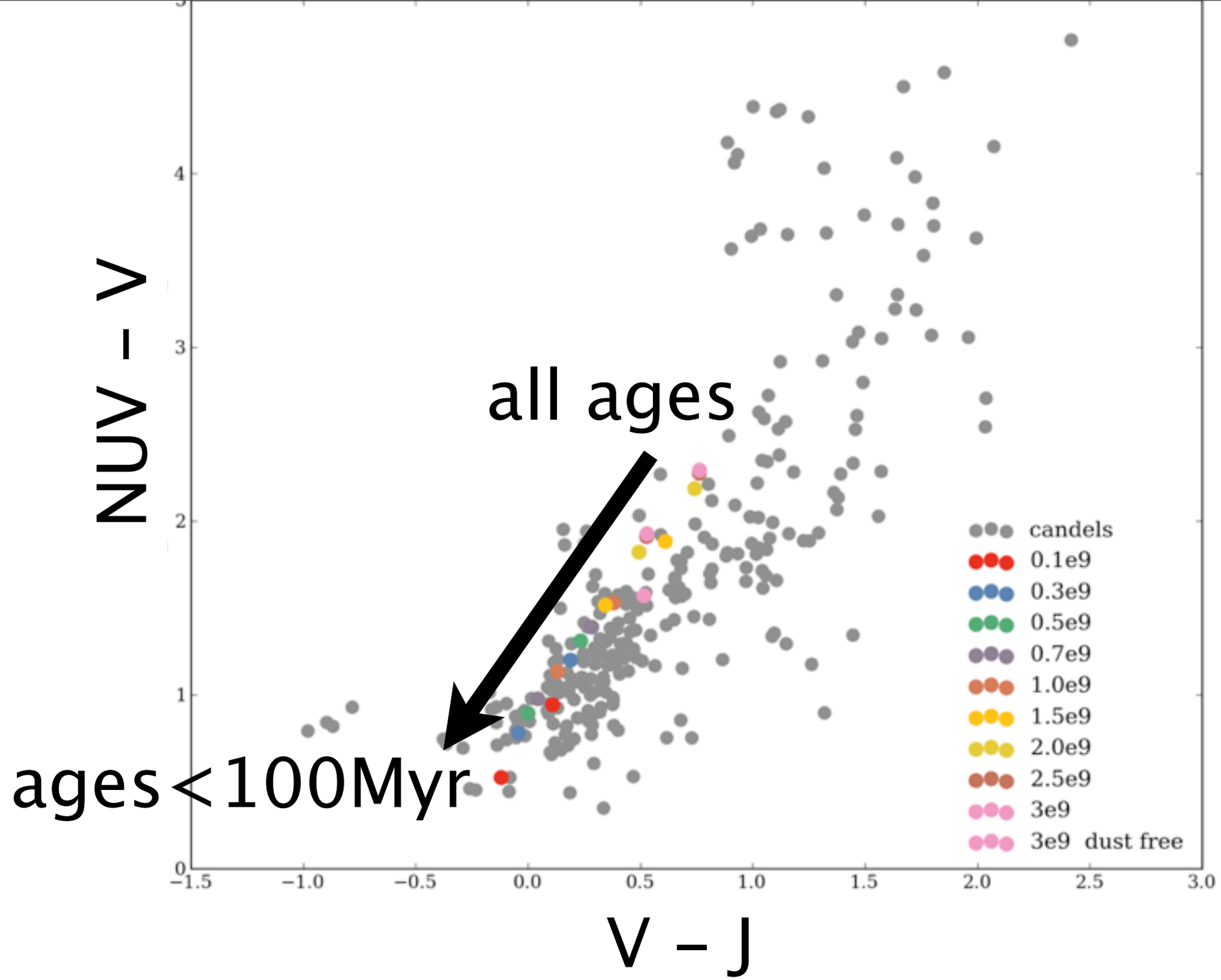
MAPPINGSIII on/off



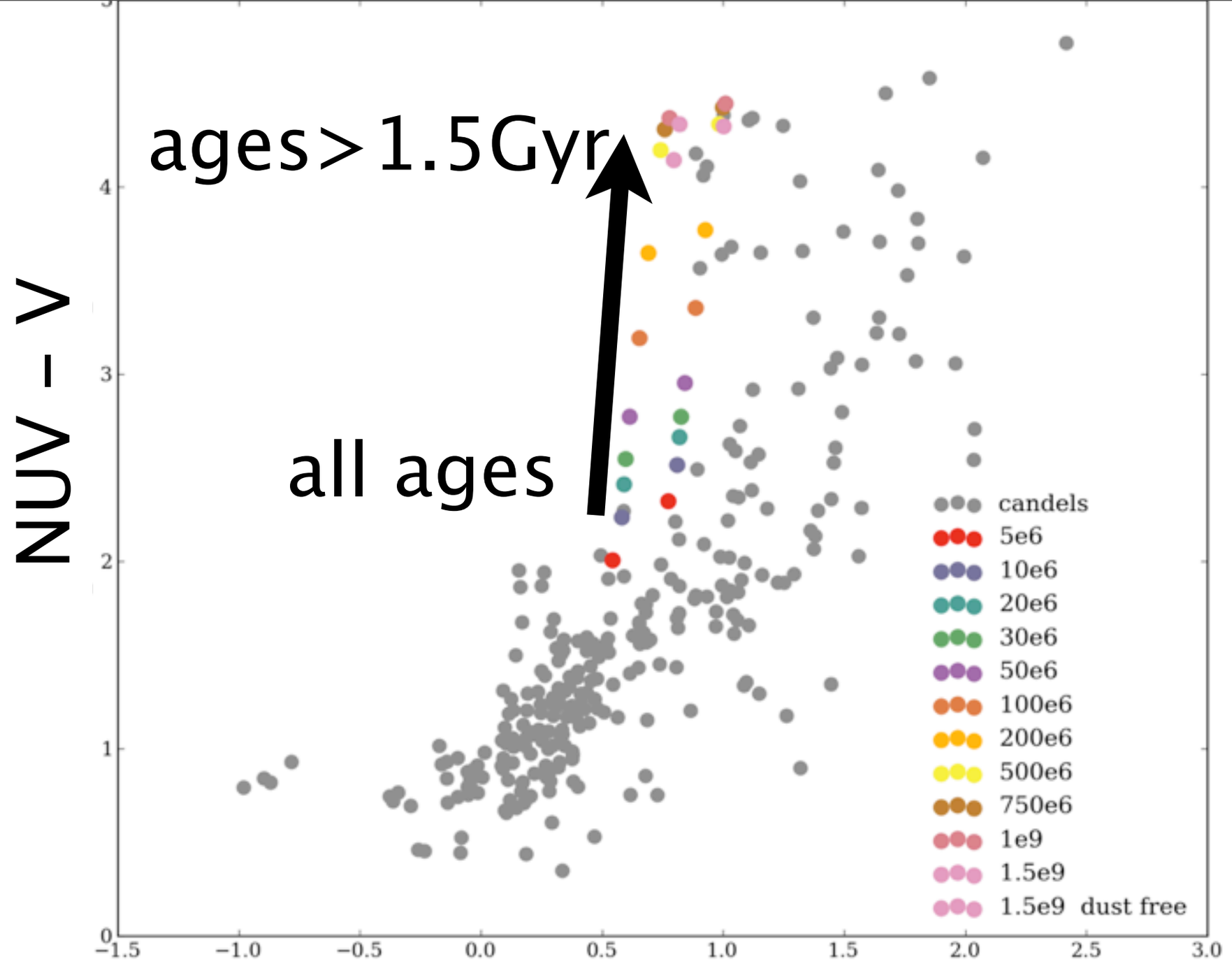
extreme variations in dust:metals



extreme variations in dust:metals

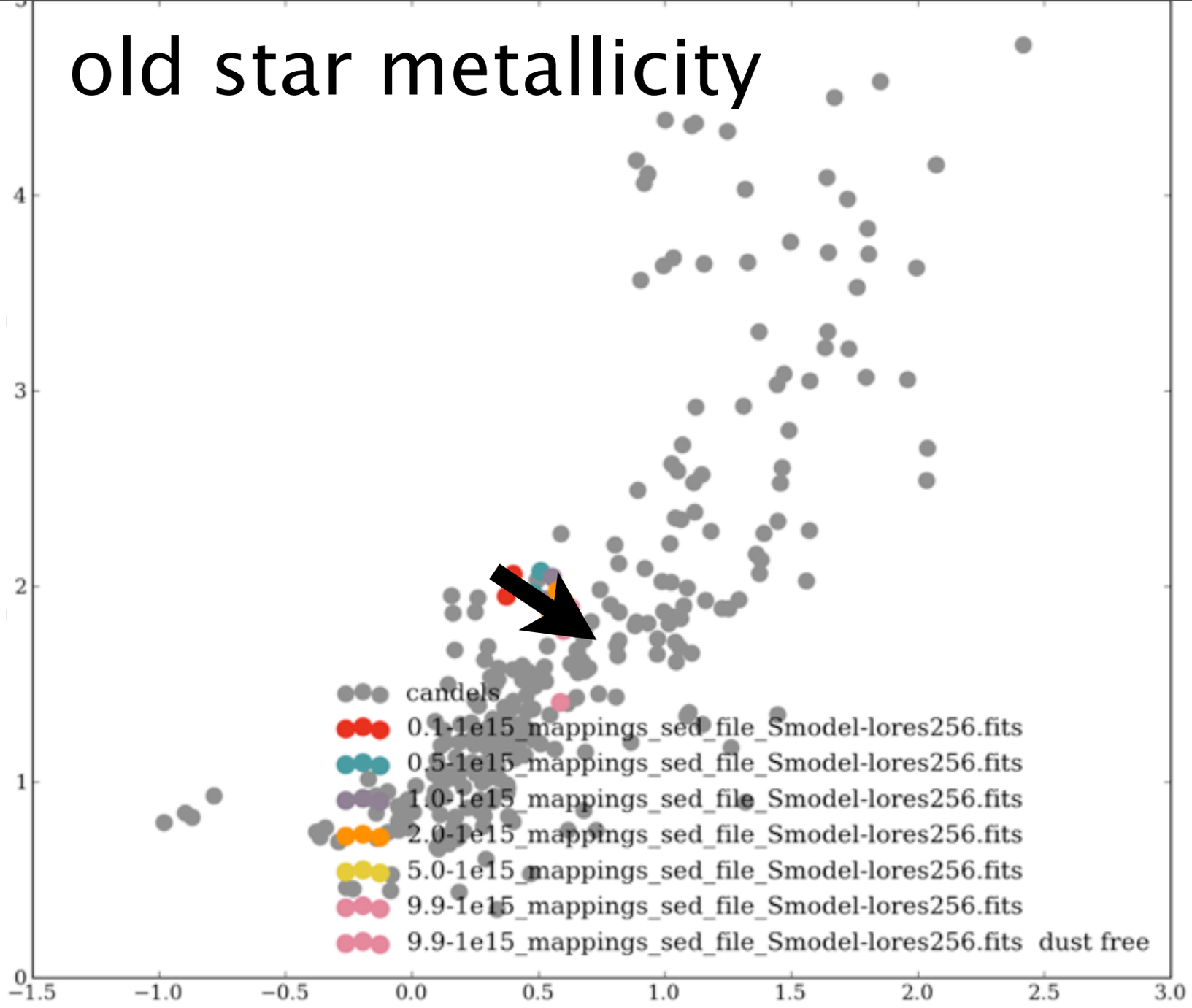


What if we remove the old stars?

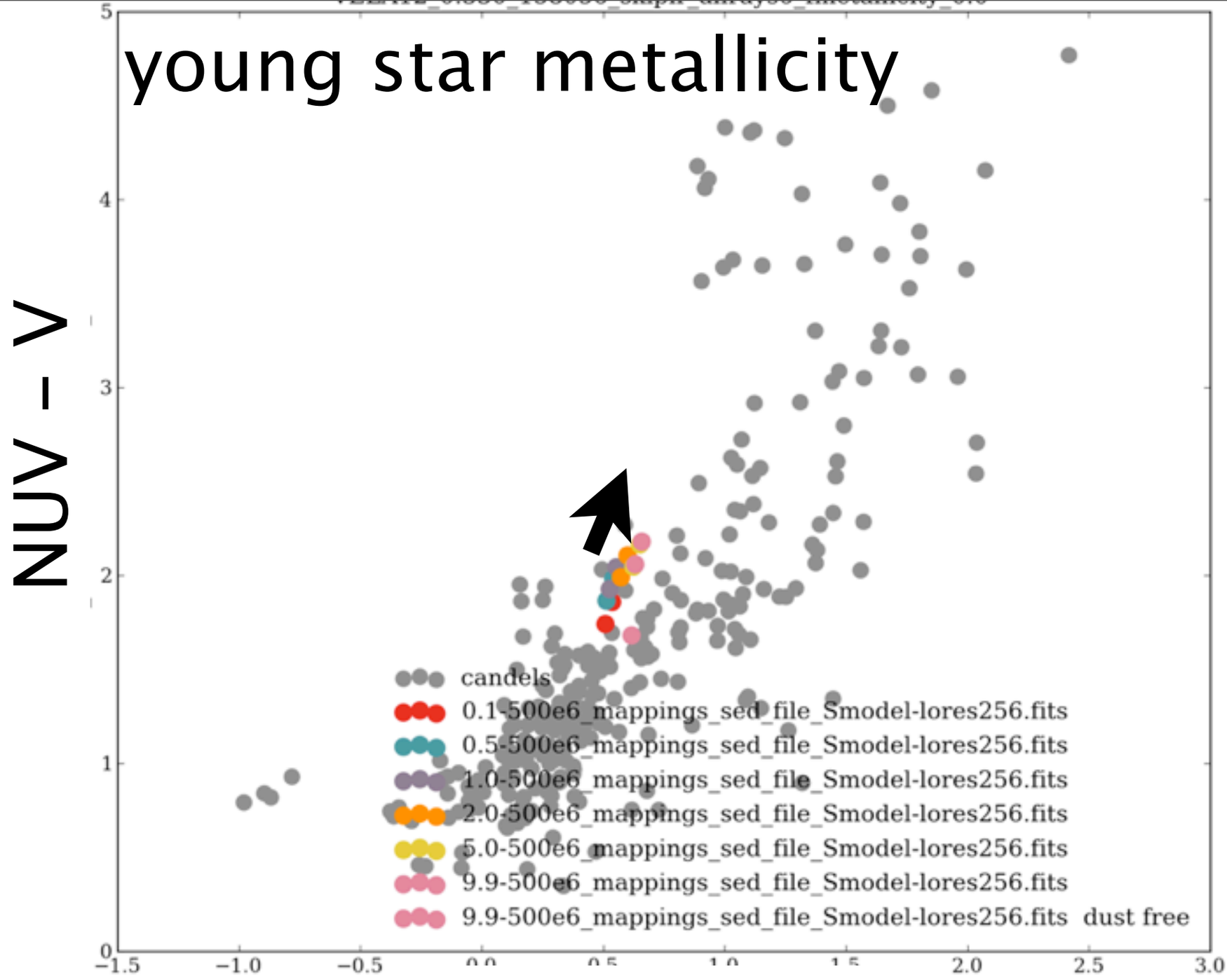


What if we remove the old stars?

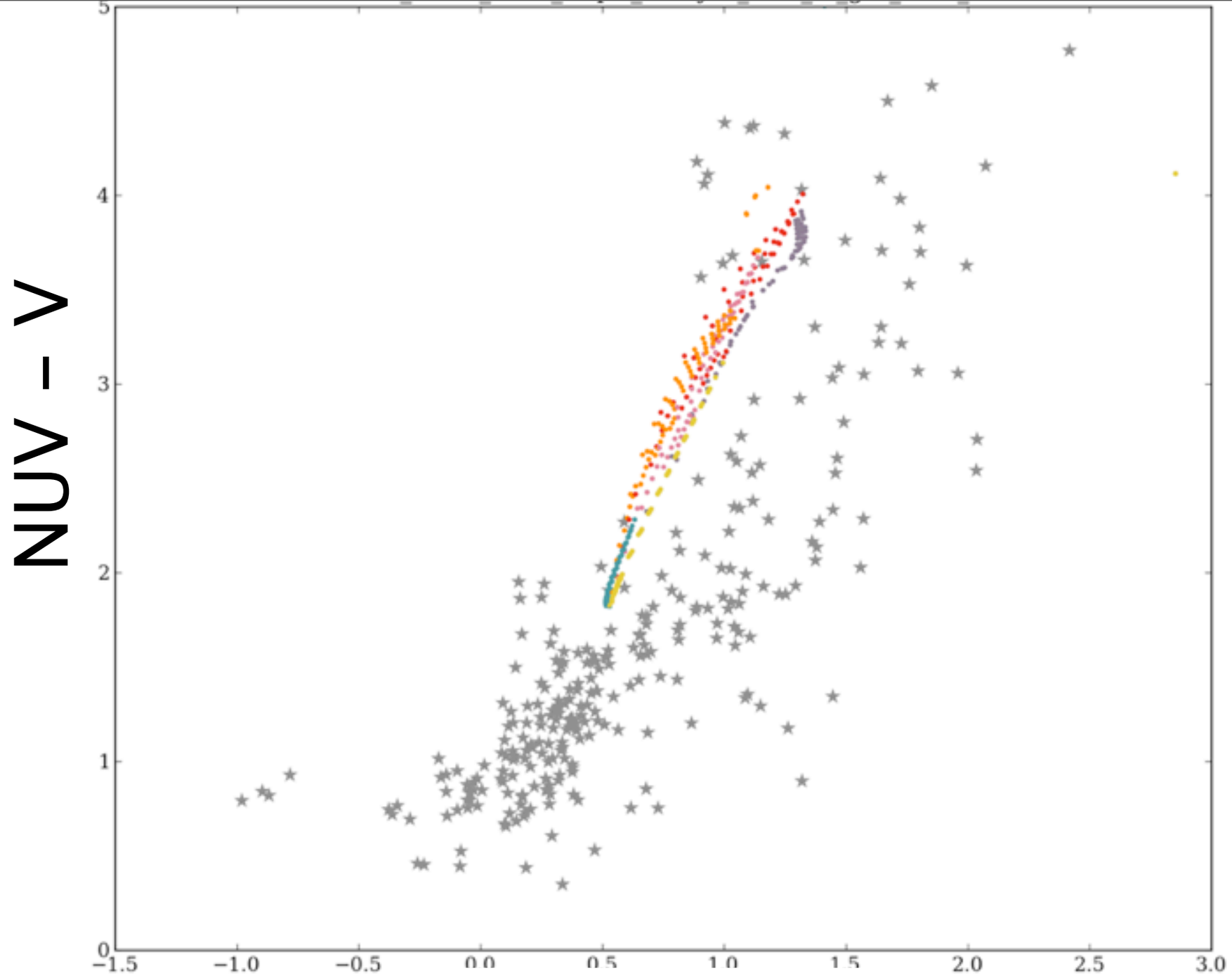
old star metallicity



What if we remove the old stars?



What if we remove the old stars?



extreme variations in dust:metals & dust:gas