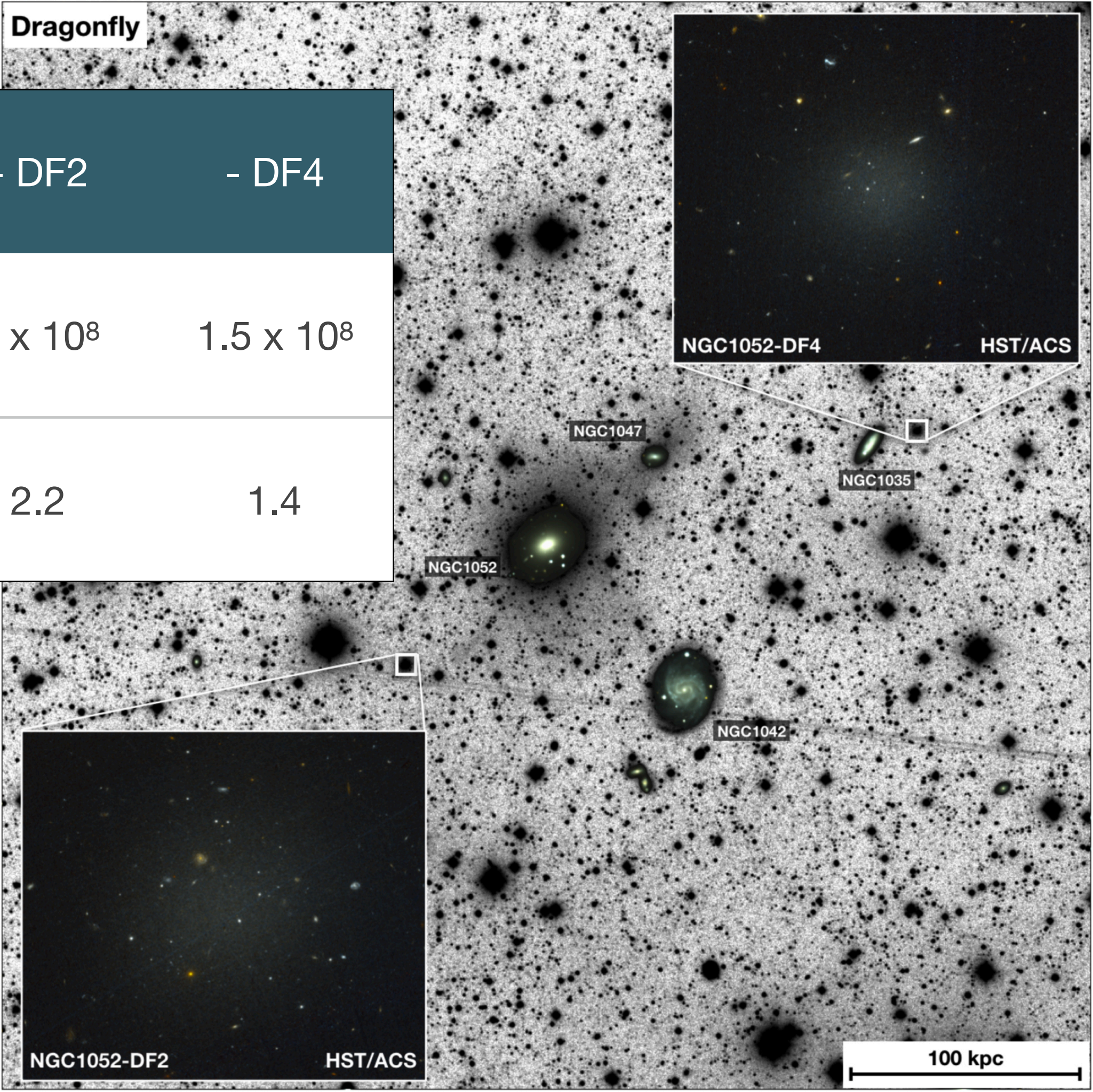


GLOBULAR CLUSTERS IN DARK MATTER DEFICIENT GALAXIES

Zili Shen
Yale Astronomy
2022/03/16

Dragonfly

NGC 1052	- DF2	- DF4
M_* ($M_\odot$)	2×10^8	1.5×10^8
R_{eff} (kpc)	2.2	1.4



vD+19,
Danieli+20

NGC1052-DF2

•101

•98

92••93

•91

•85

•T3

•77

•73

•71

•59

•39

10''

1 kpc

NGC1052-DF4

•6571

•5675

Known GC

New 20191124

•926

•6129

•1755

•3602

•4045

•97

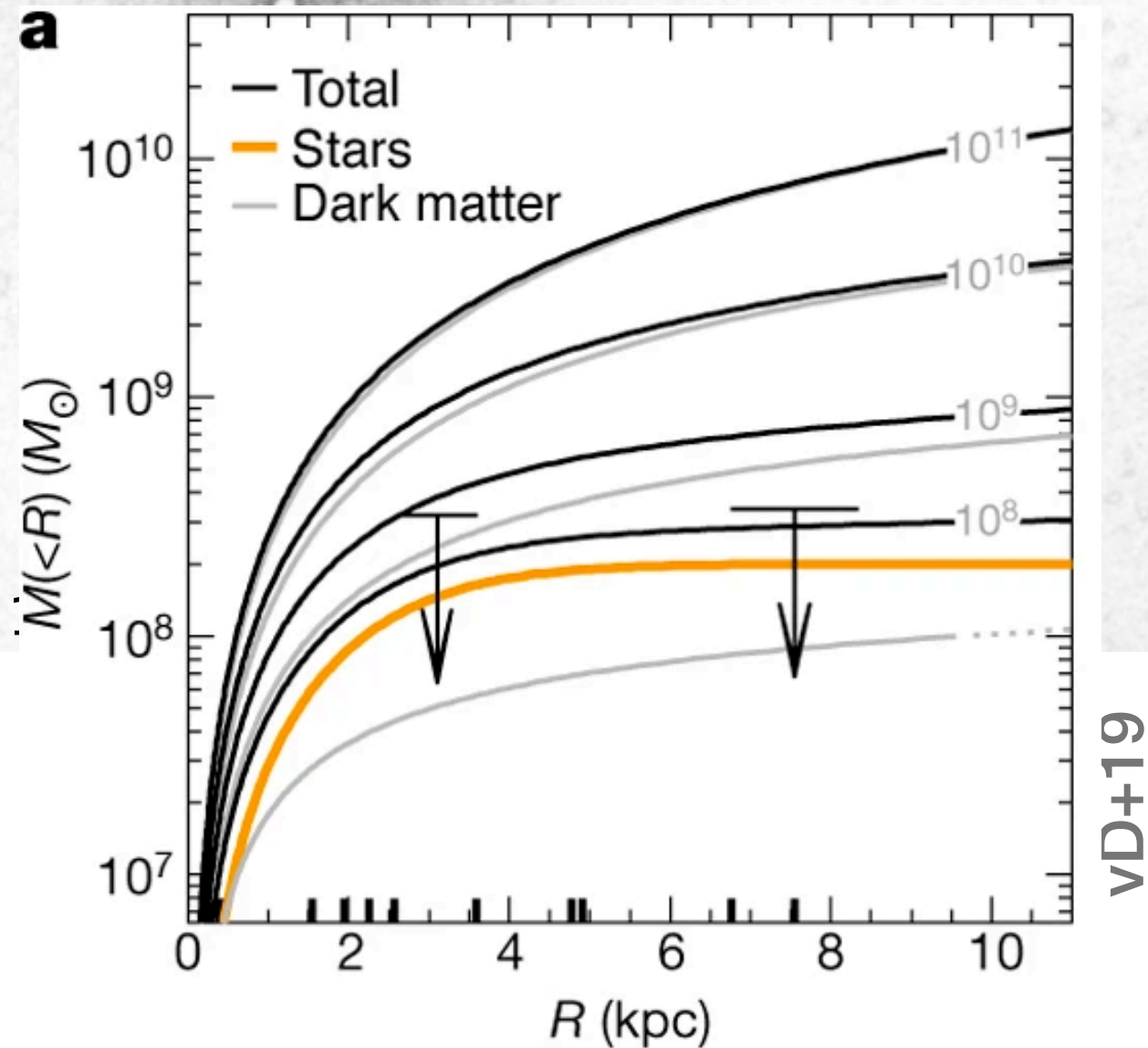
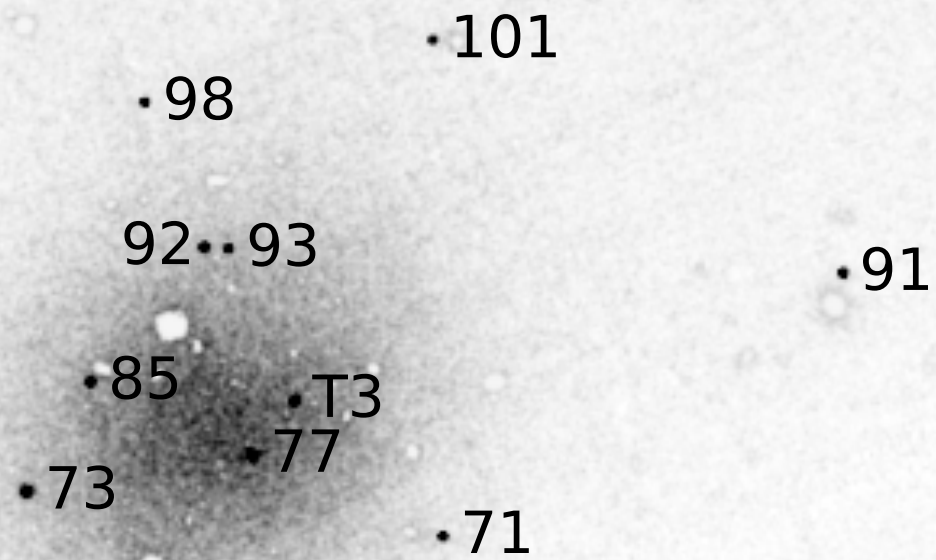
•1403

•4366

•1092

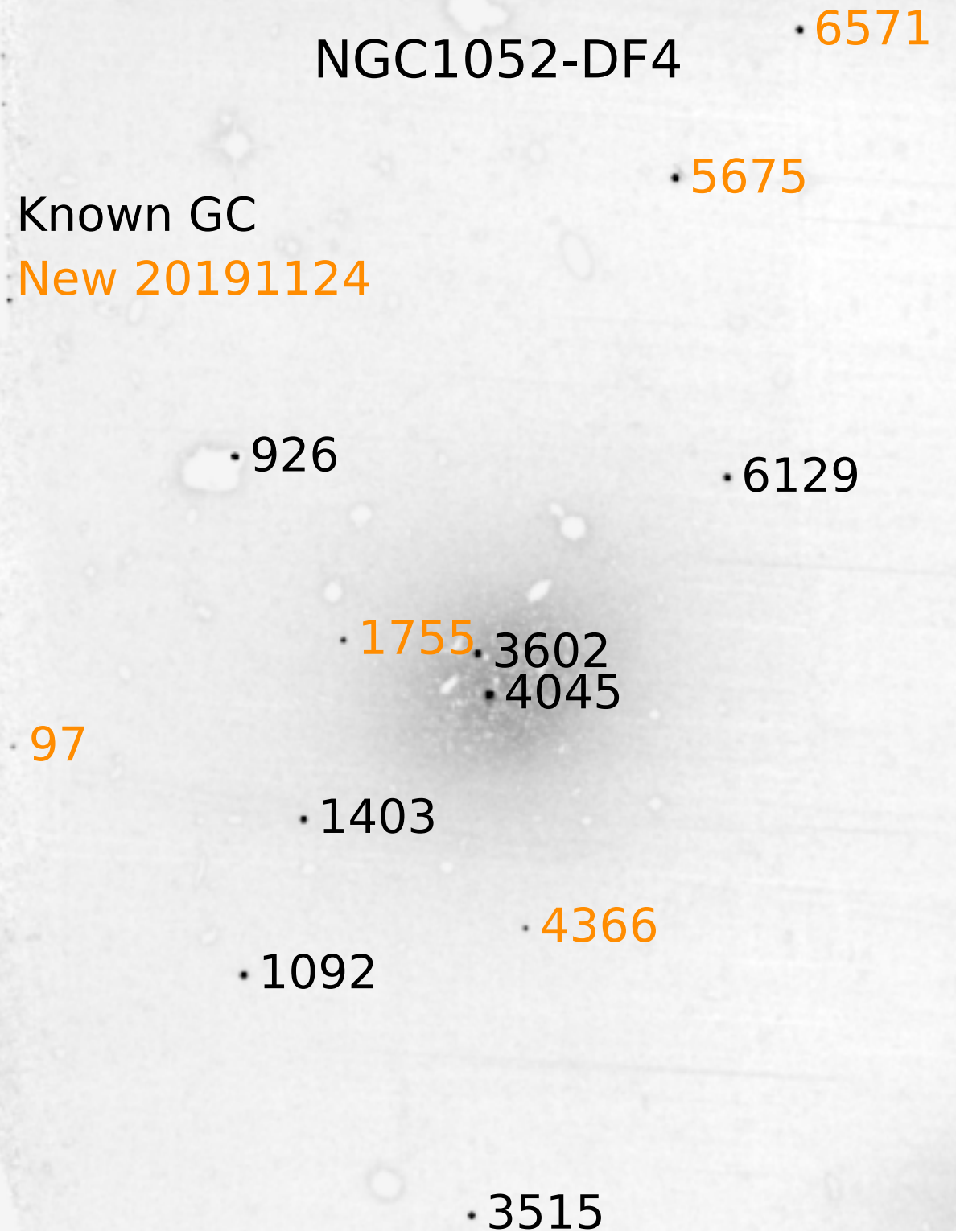
•3515

NGC1052-DF2



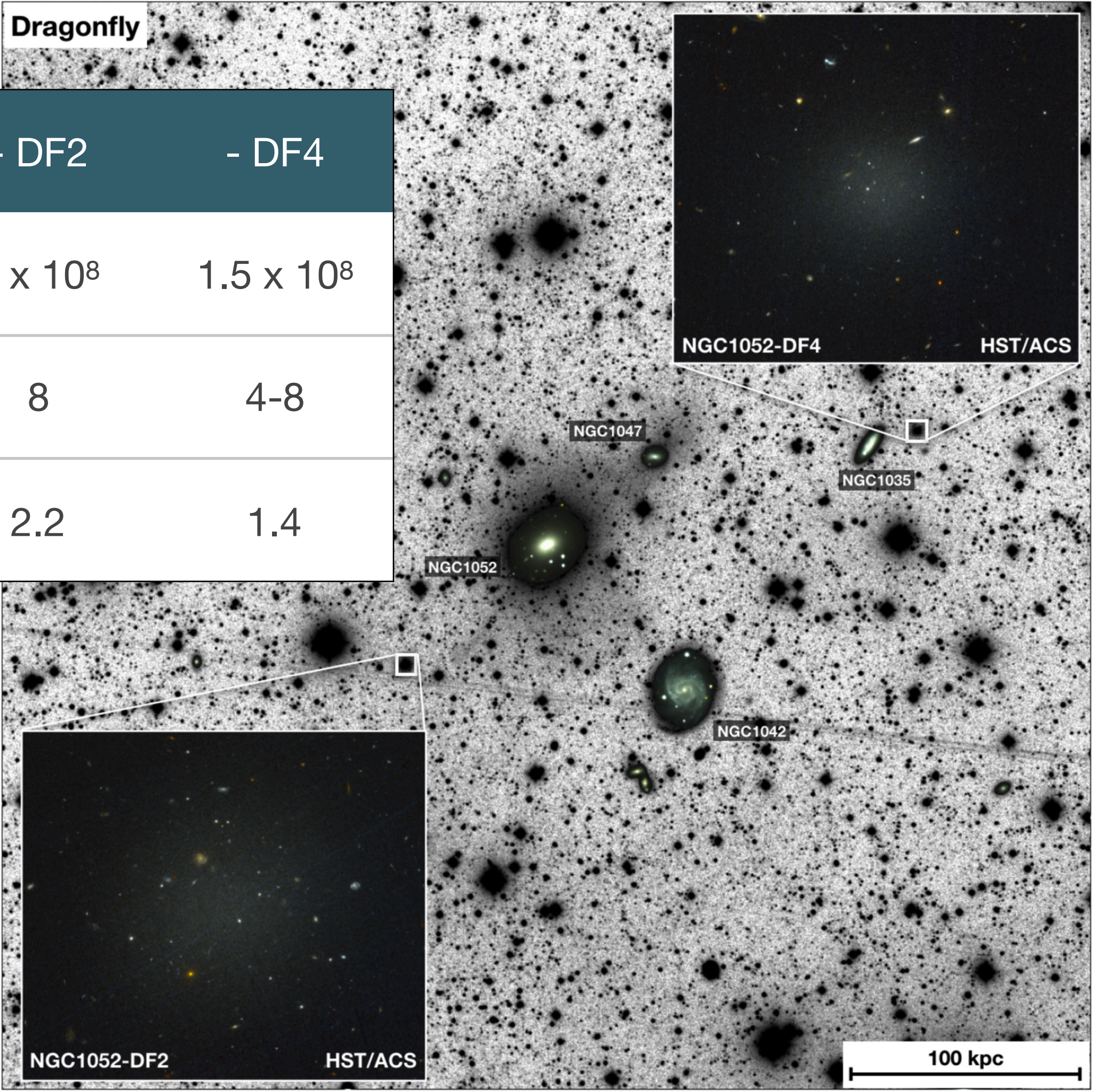
NGC1052-DF4

Known GC
New 20191124



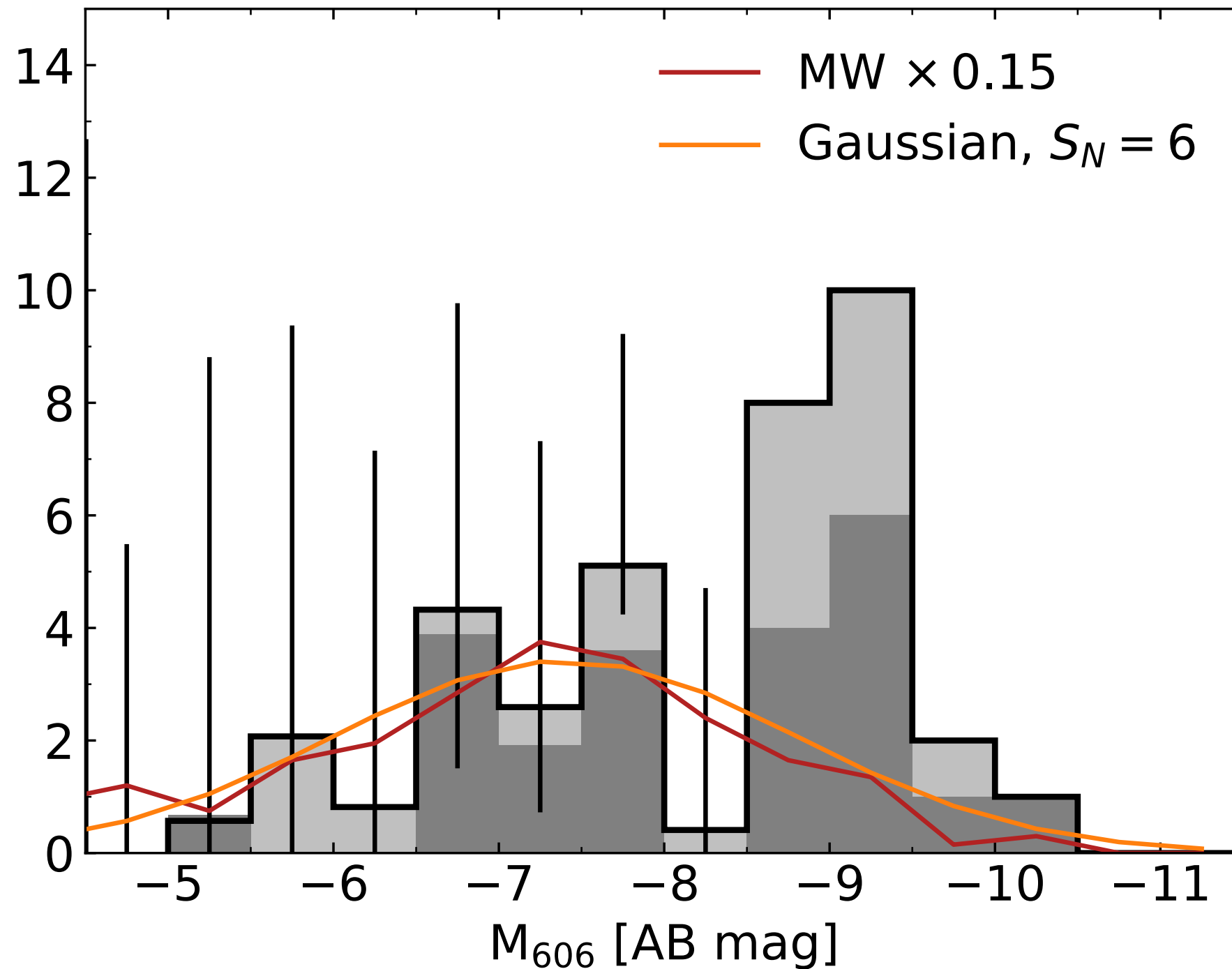
Dragonfly

NGC 1052	- DF2	- DF4
$M_* (M_\odot)$	2×10^8	1.5×10^8
$\sigma \text{ (km s}^{-1}\text{)}$	8	4-8
$R_{\text{eff}} \text{ (kpc)}$	2.2	1.4



vD+19,
Danieli+20

- Combined GCLF in DF2 and DF4:



Can distance explain DF2?

Distance dependent	D = 20 Mpc	Expectation	D = 13 Mpc
Stellar mass	2×10^8	$M_{\text{dyn}} \sim 2 \times 10^8$	6×10^7
Physical size	2.2 kpc	~ 1 kpc	1.4 kpc
GC physical size	6.2 pc	$3.6 \sim 4.3$ pc*	4 pc
GC absolute magnitude	-8.5	-7.5	-7.5

vD+19

*Harris96,
Georgiev+09

Trujillo+19

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vD+19

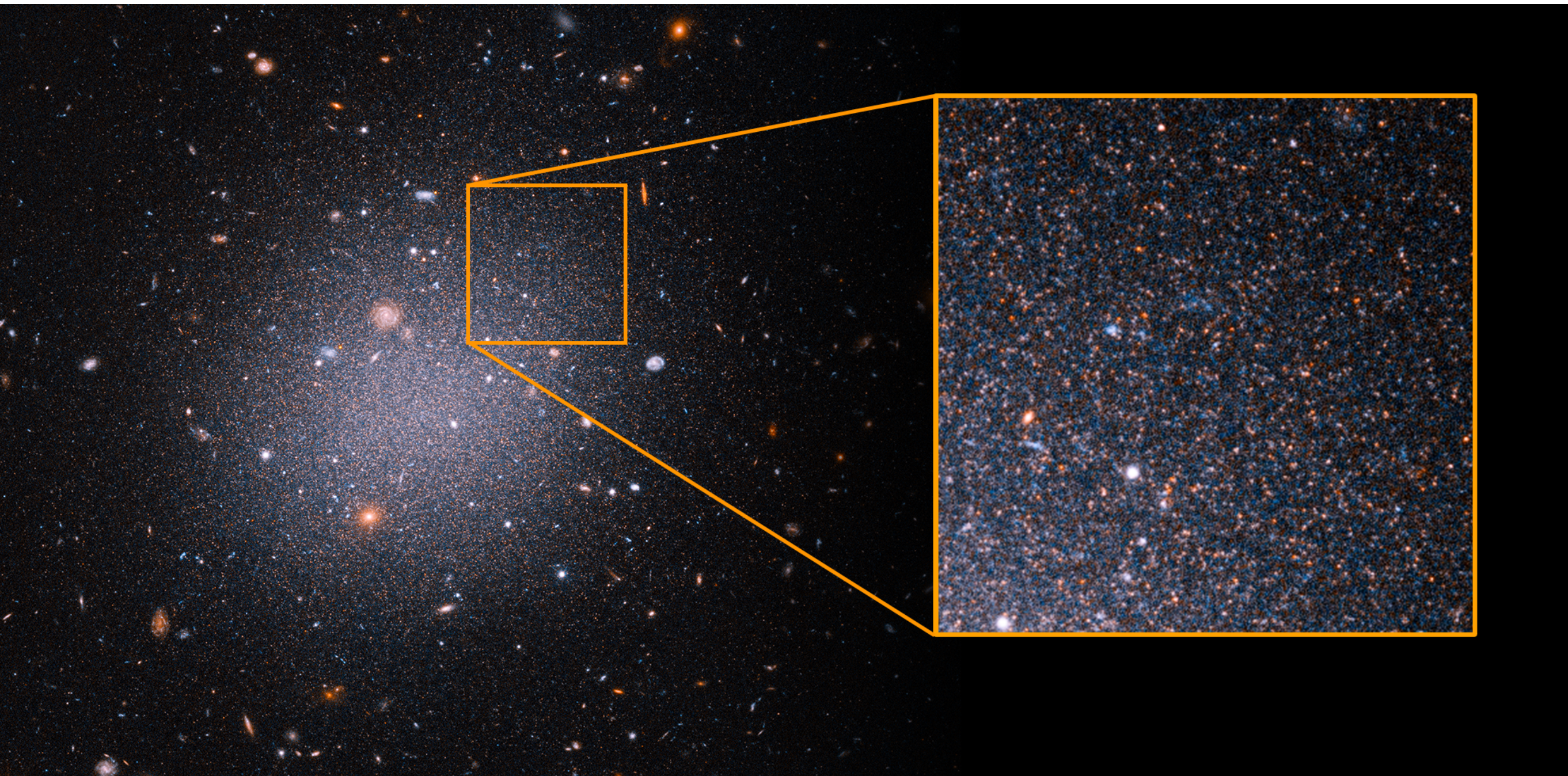
*Harris96,
Georgiev+09

Trujillo+19

TRGB DISTANCE FOR DF2: 22 MPC

Shen+21

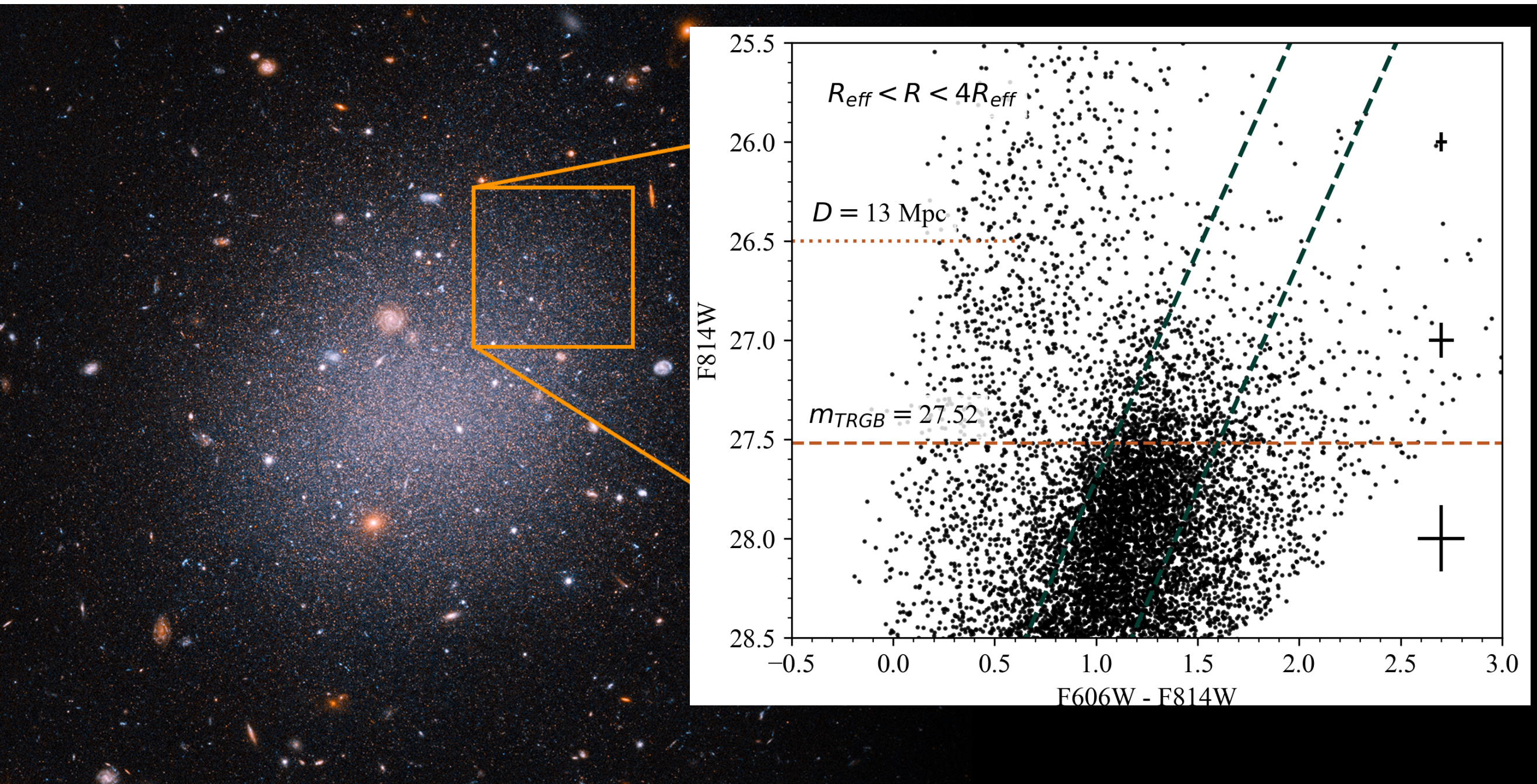
- From 40 orbits of HST imaging



TRGB DISTANCE FOR DF2: 22 MPC

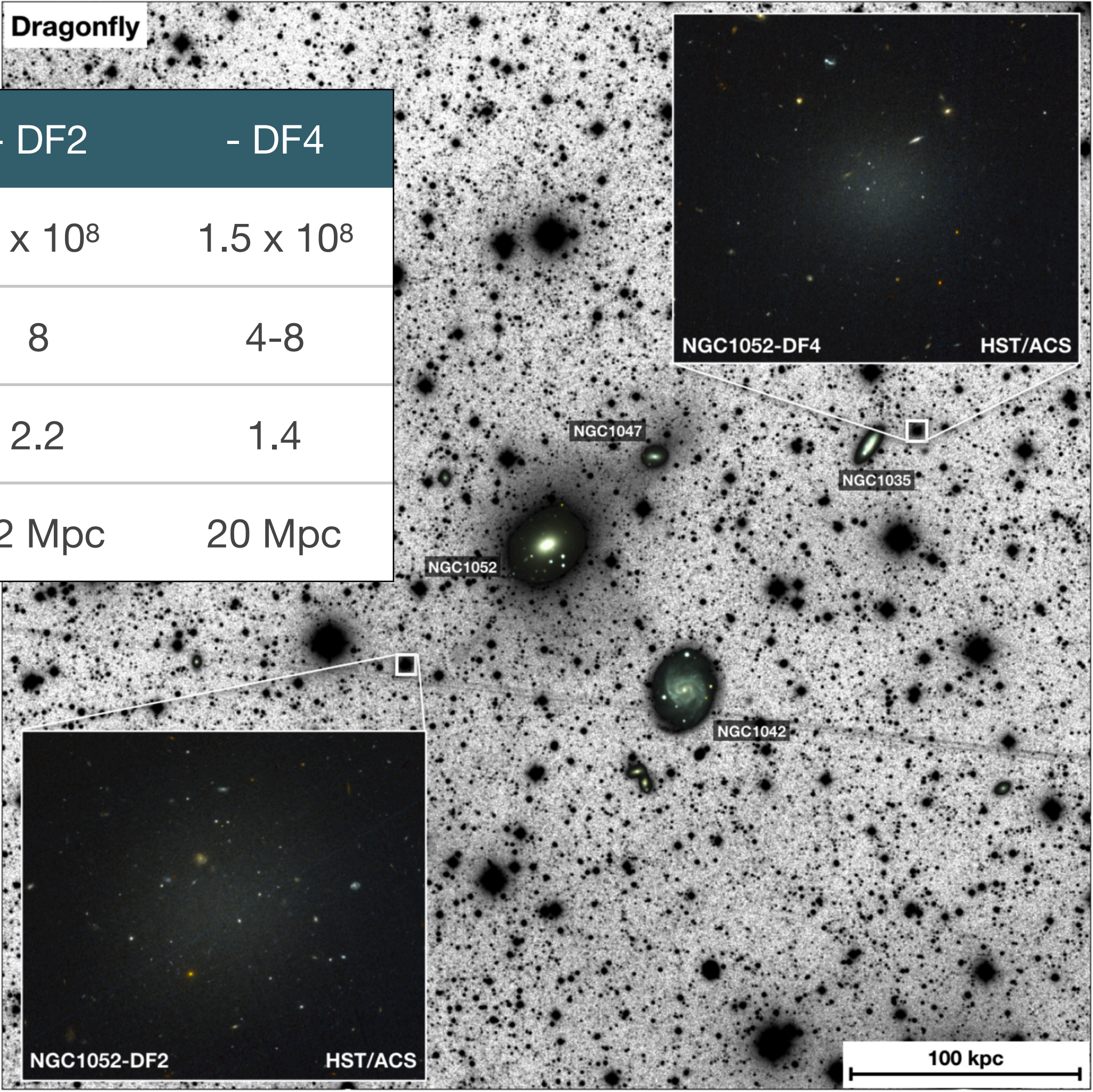
Shen+21

- From 40 orbits of HST imaging



Dragonfly

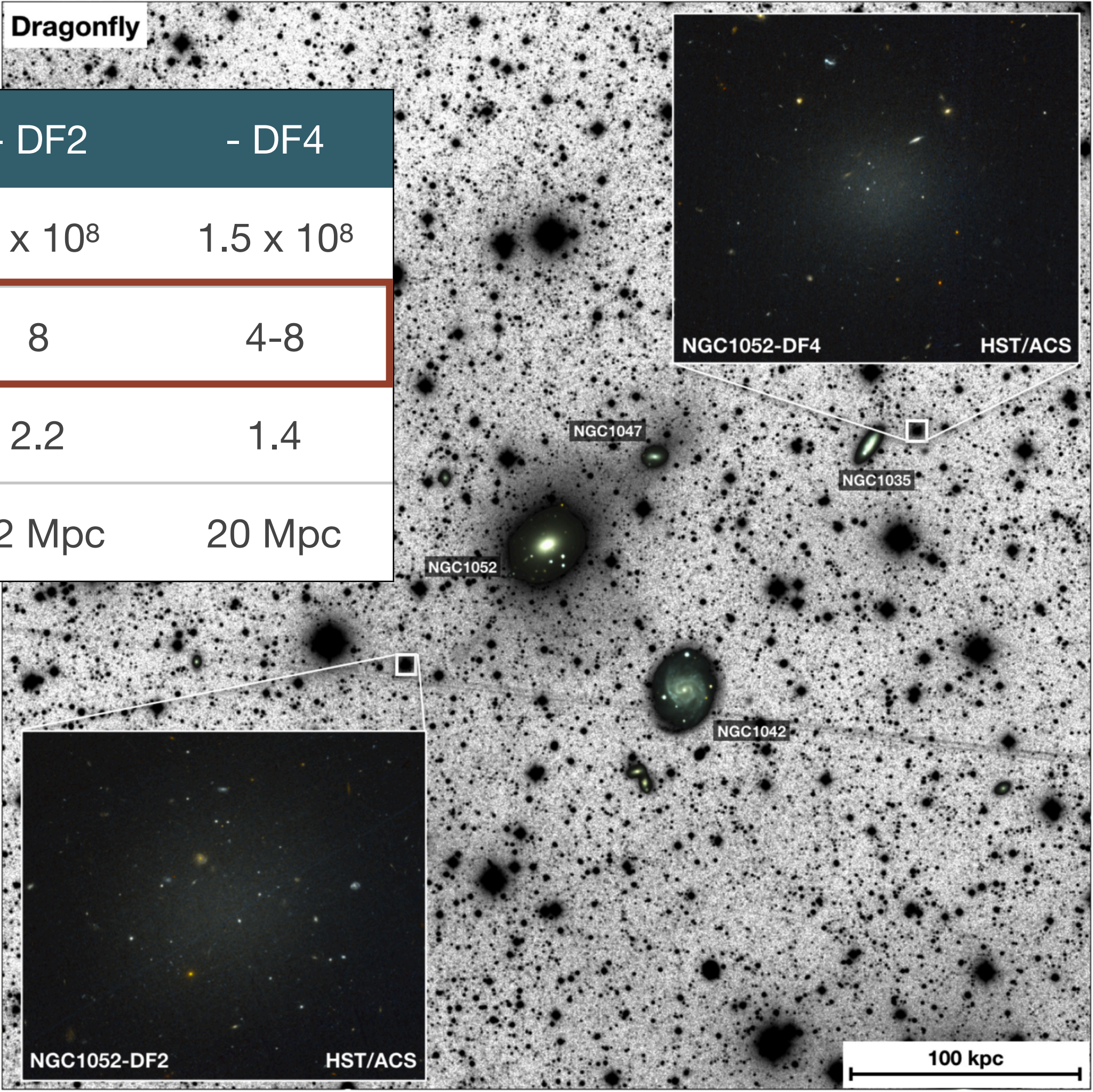
NGC 1052	- DF2	- DF4
$M_* (M_\odot)$	2×10^8	1.5×10^8
$\sigma \text{ (km s}^{-1}\text{)}$	8	4-8
$R_{eff} \text{ (kpc)}$	2.2	1.4
Distance	22 Mpc	20 Mpc



vD+19
Danieli+20

Dragonfly

NGC 1052	- DF2	- DF4
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Distance	22 Mpc	20 Mpc



vD+19
Danieli+20

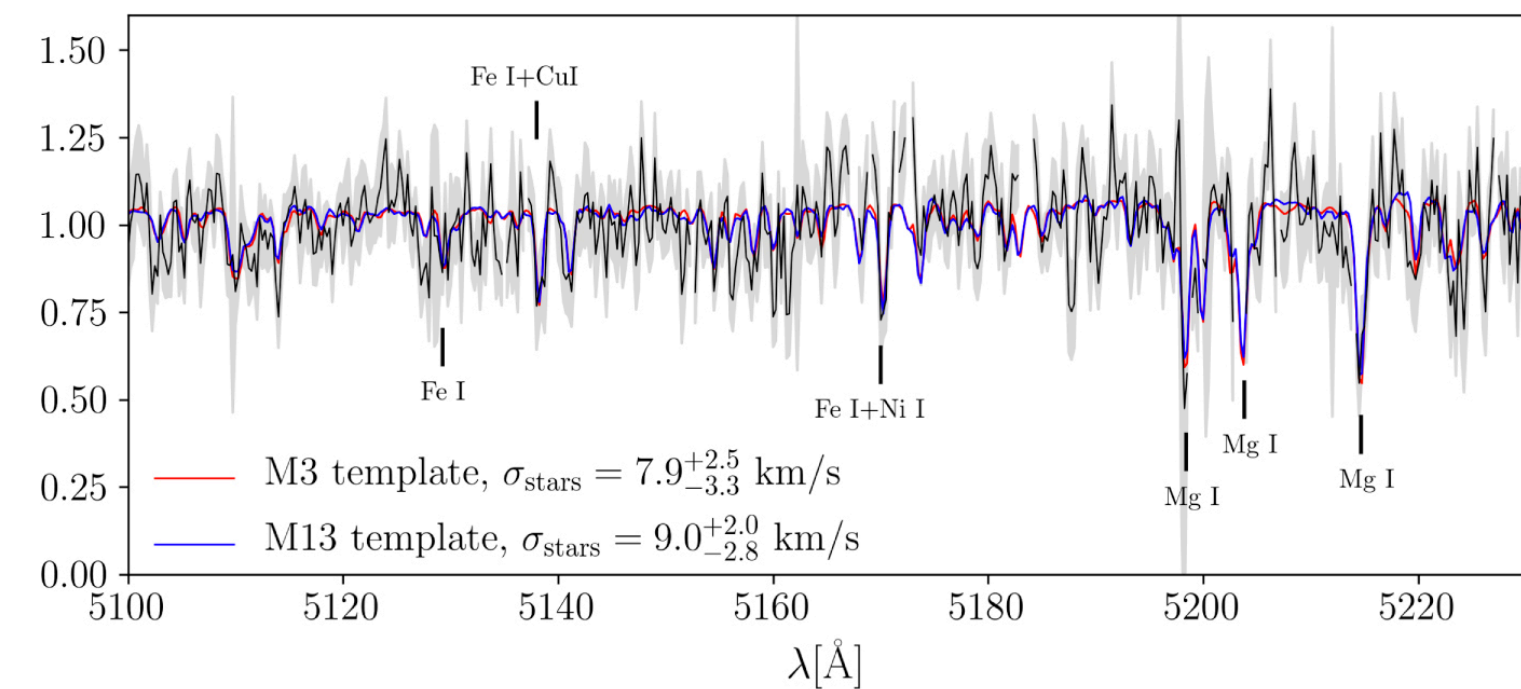
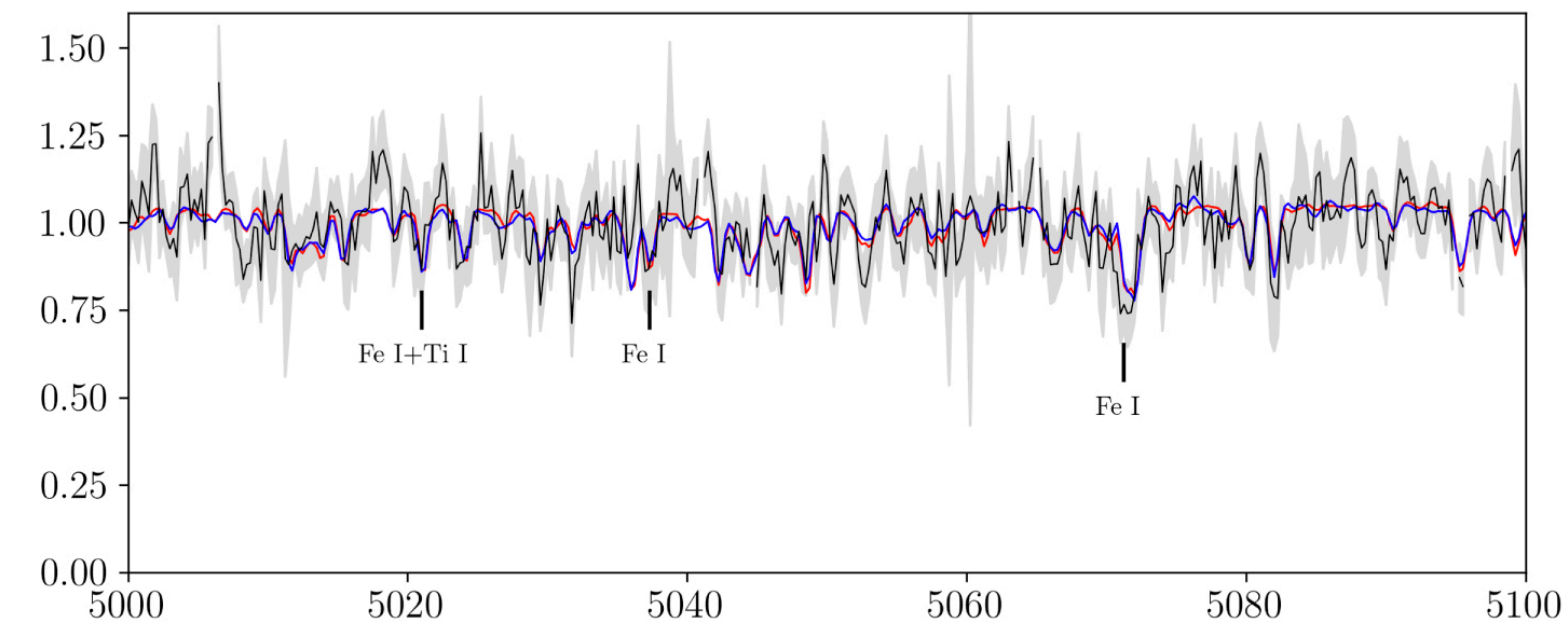
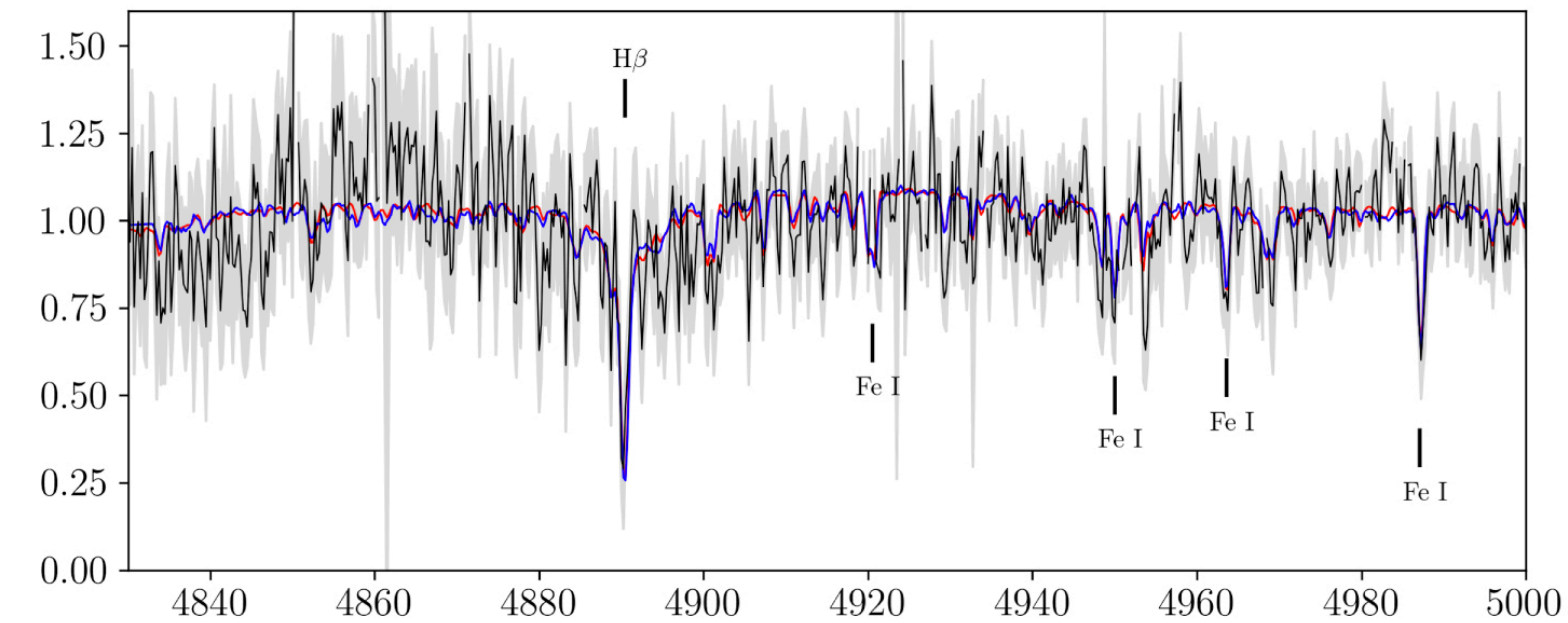
STELLAR VELOCITY DISPERSION

➤ NGC1052-DF2

➤ 2.5 hours on Keck / KCWI

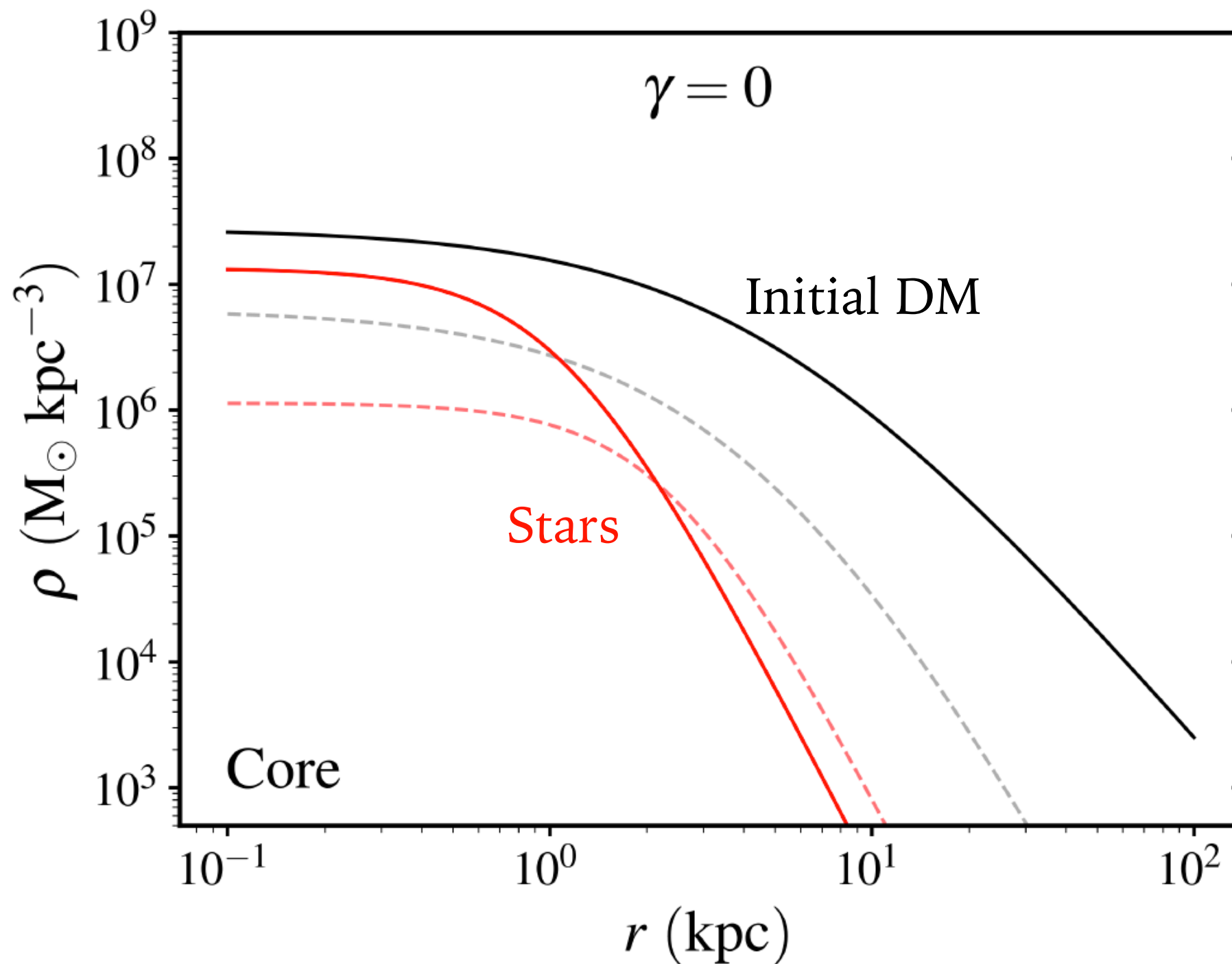
➤ Result: $\sigma_* = 8.5^{+2.3}_{-3.1}$ km/s

➤ Previously from 10 GCs:
 $\sigma_{GC} = 7.8^{+5.2}_{-2.2}$ km/s



FORMATION OF DF2 AND DF4

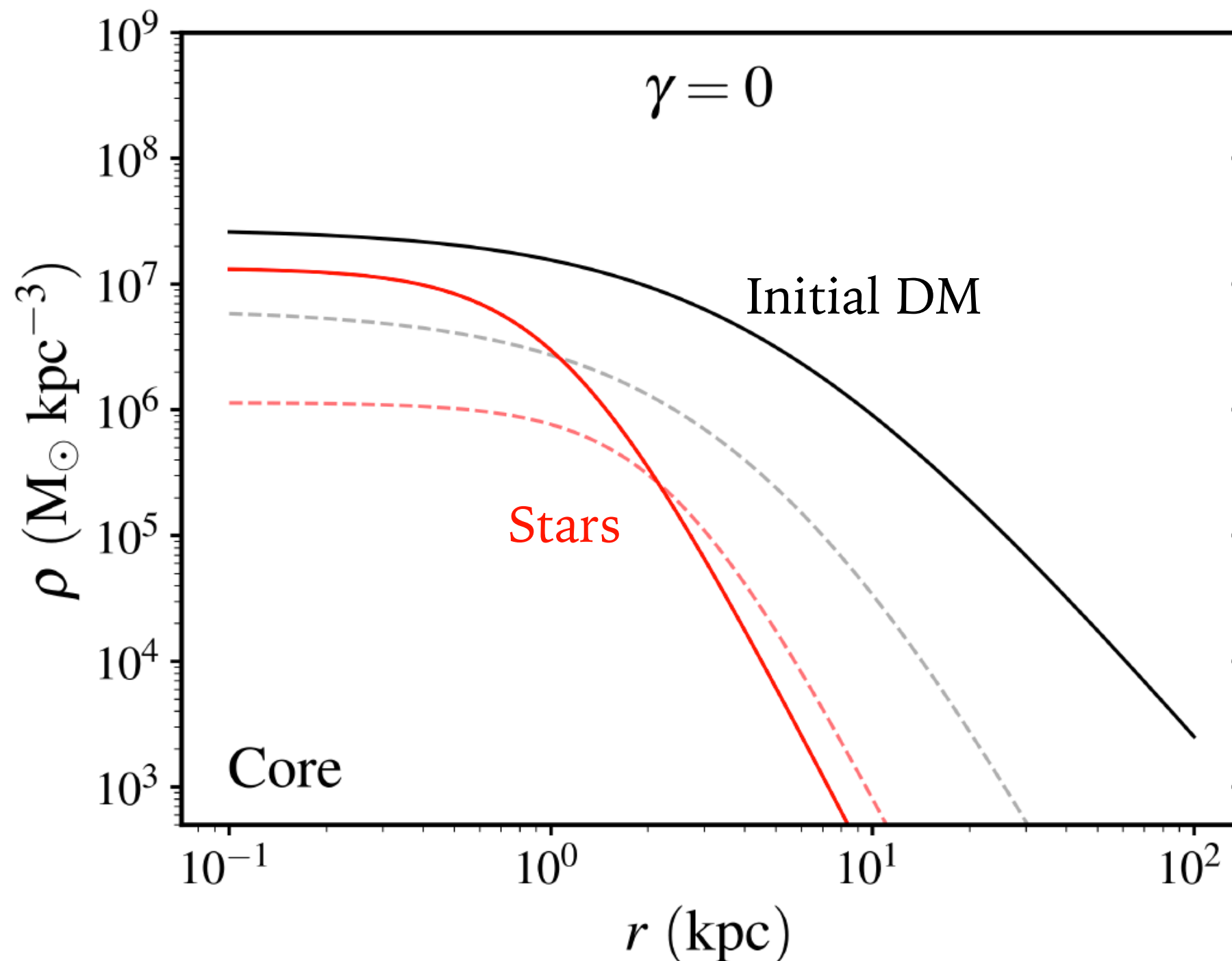
Cored DM halo + tidal disruption



FORMATION OF DF2 AND DF4

Cored DM halo + tidal disruption

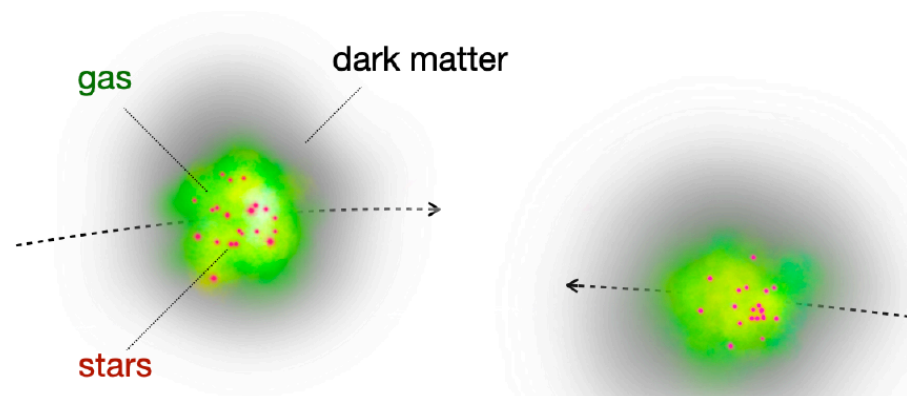
Prediction: $\sigma \approx 10$ km/s



FORMATION OF DF2 AND DF4

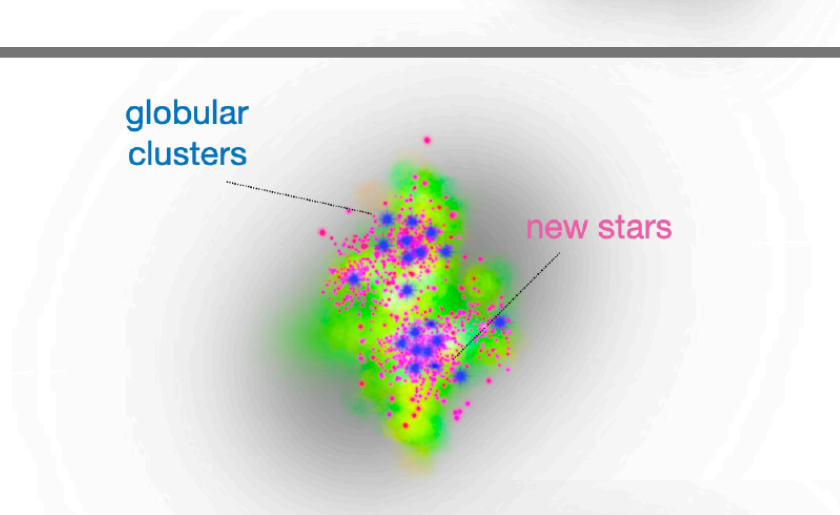
Mini Bullet Cluster

1



3

2

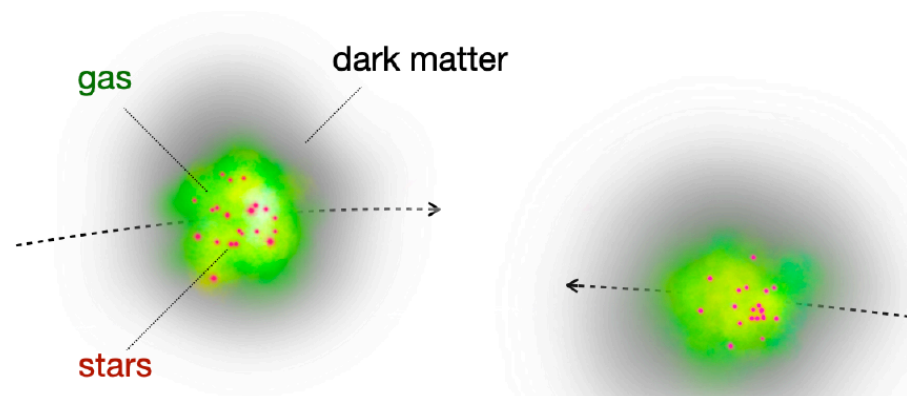


4

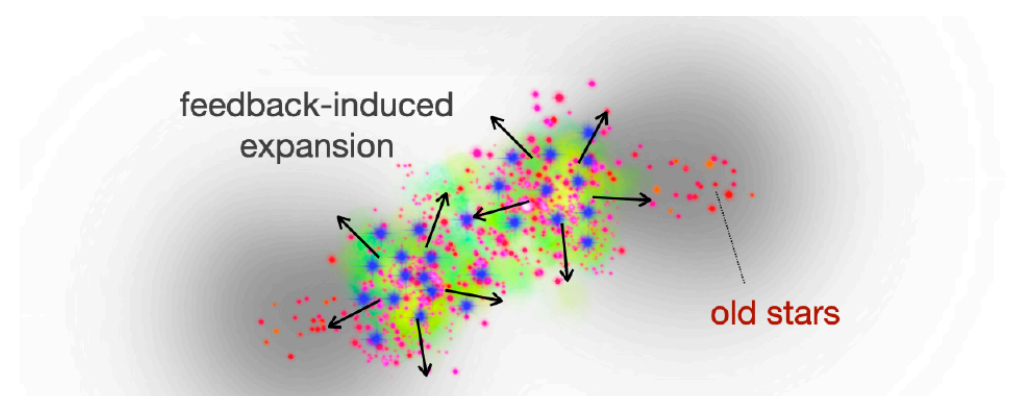
FORMATION OF DF2 AND DF4

Mini Bullet Cluster

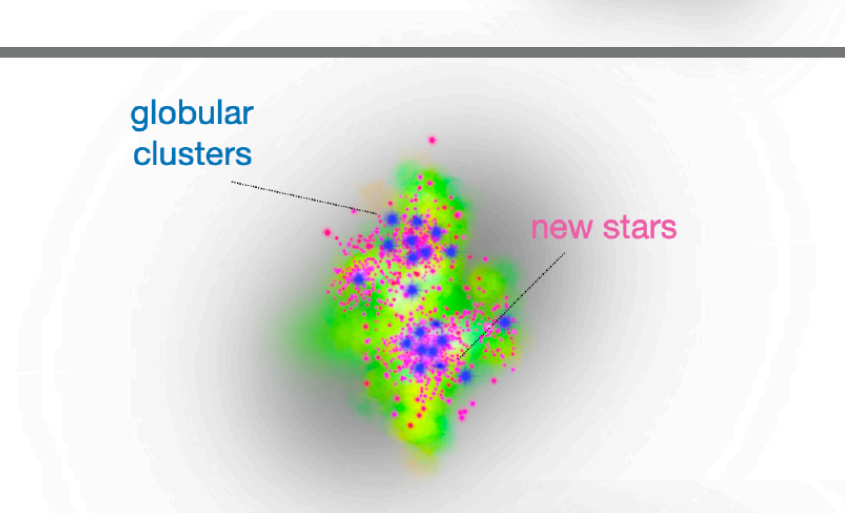
1



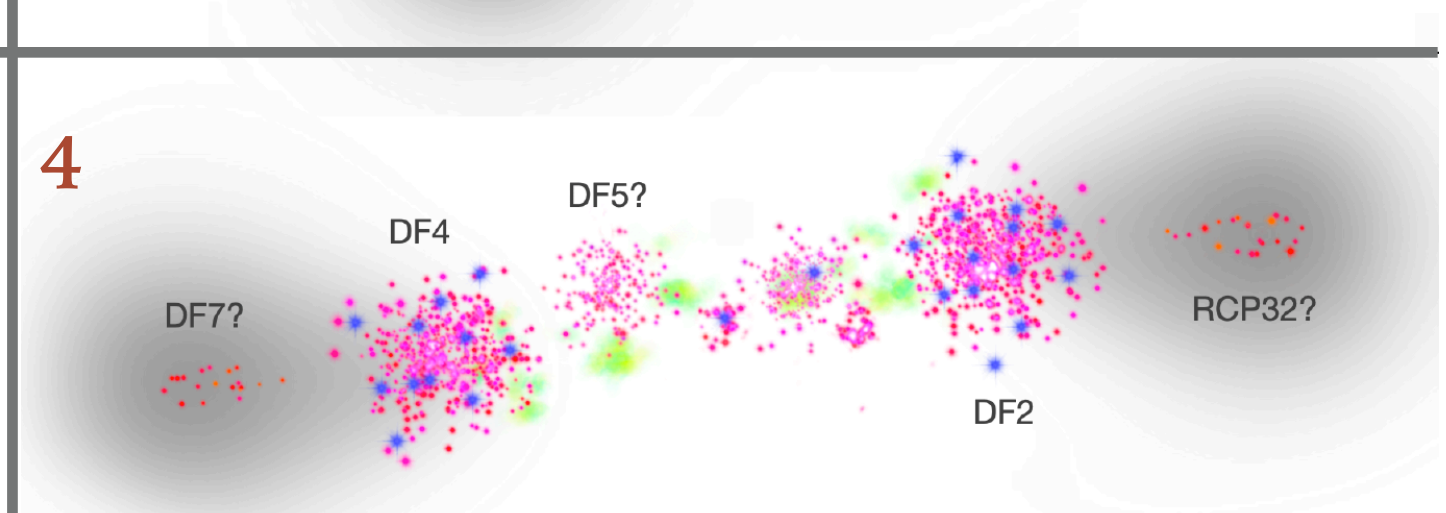
3



2



4

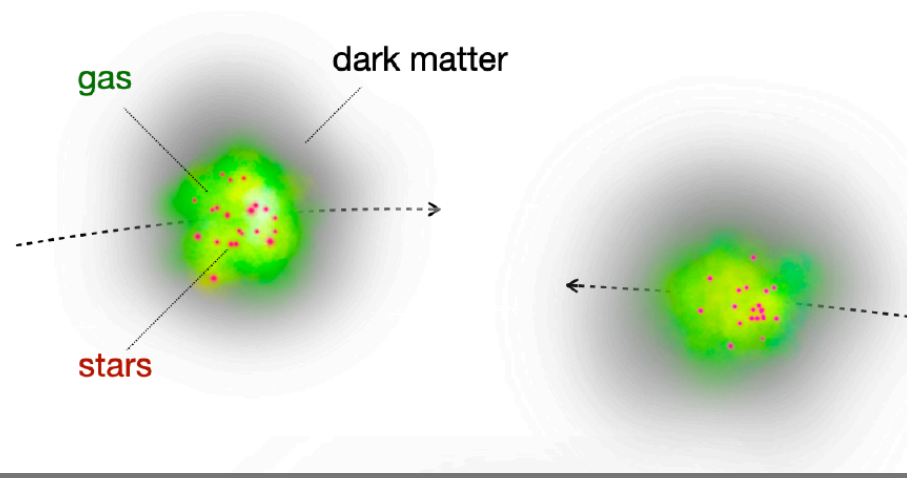


FORMATION OF DF2 AND DF4

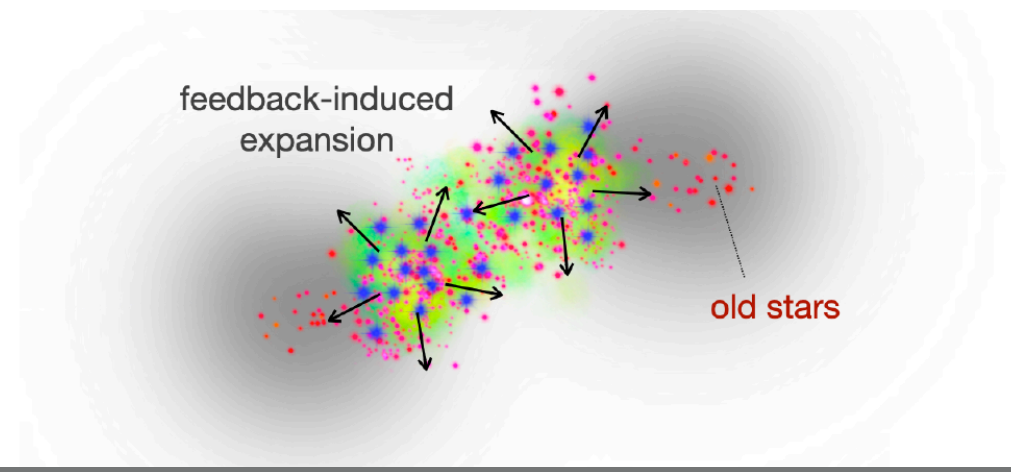
Mini Bullet Cluster

Prediction: $\sigma \approx 6$ km/s

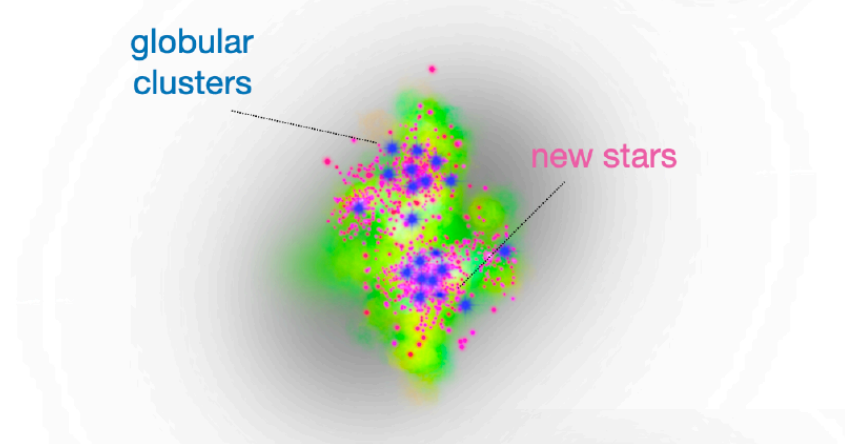
1



3

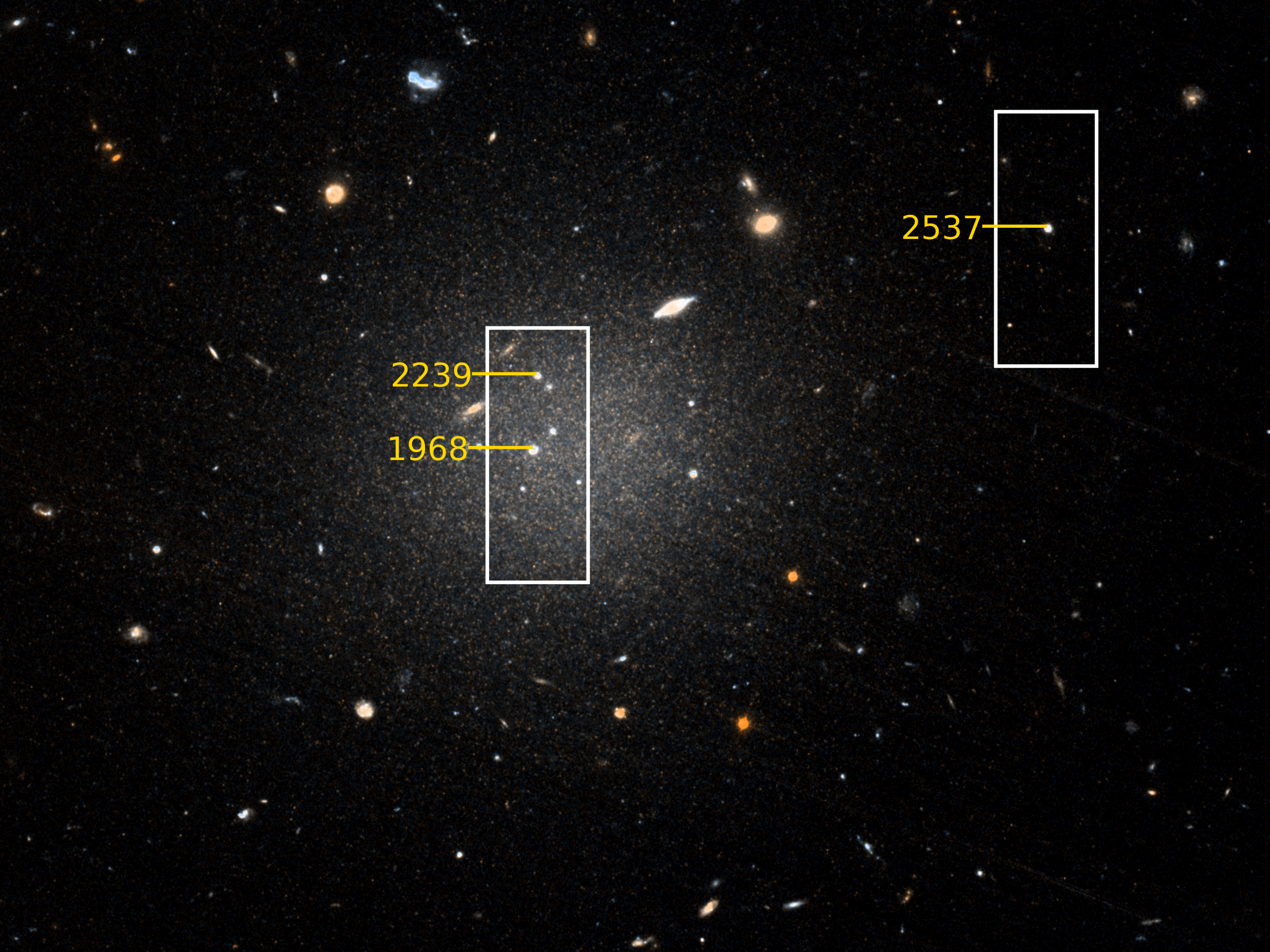


2



4

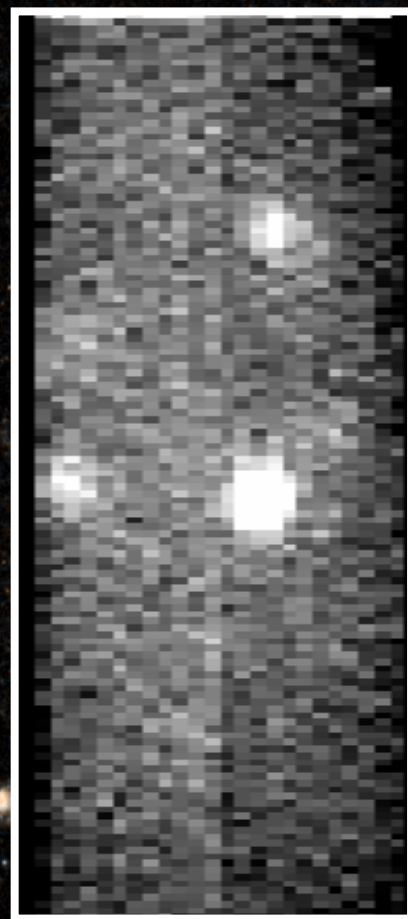




2239

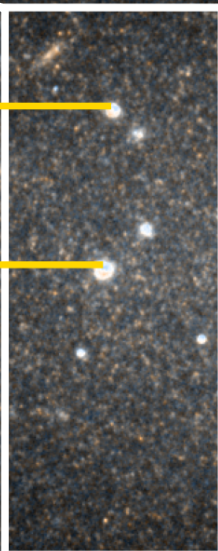
1968

2537

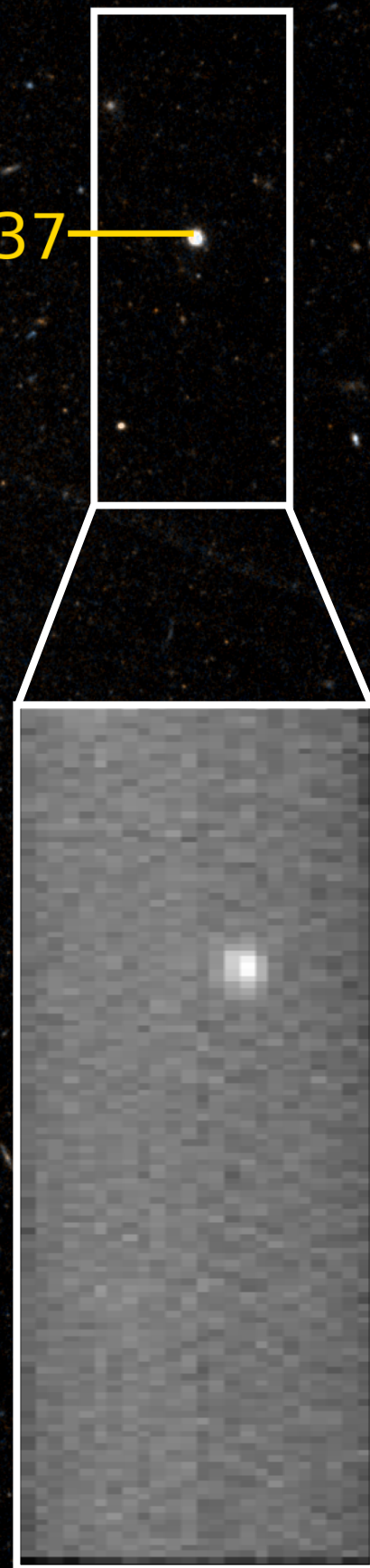


2239

1968

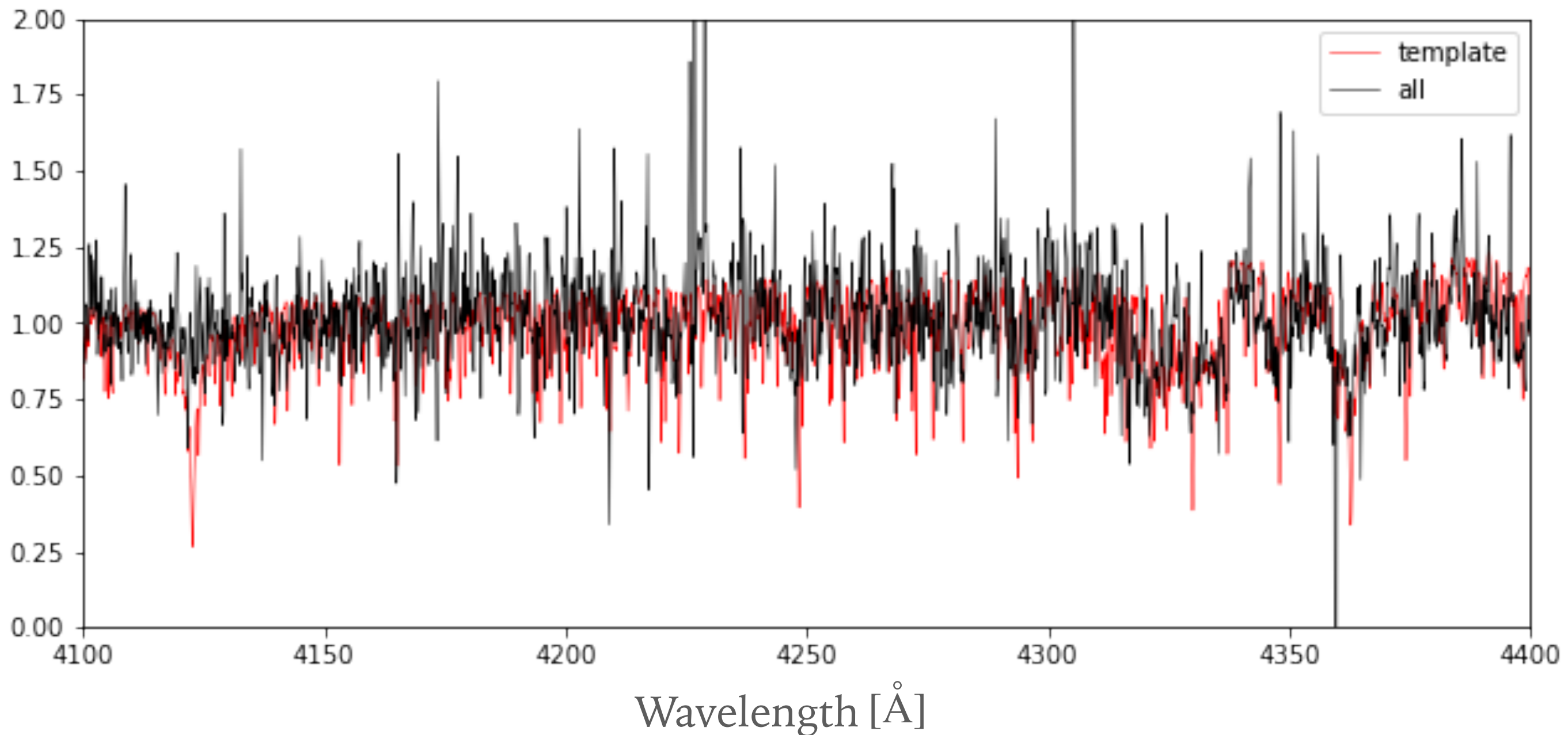


2537



PRELIMINARY EXTRACTED SPECTRUM

- 14 hr science + 20 hr sky
- Template for $Z=-1.5$ and age = 9 Gyr



RCP26

RCP21

New Galaxy

RCP17

NGC1052-DF4

NGC1052-DF7

A FORMATION THEORY THAT CAN EXPLAIN ALL THE ANOMALIES?

RCP32

NGC1052-DF2

RCP28

Ta21-12000

NGC1052-DF5

LEDA4014647



THANK YOU! QUESTIONS