Completeness estimates of SDSS searches for MW satellites: The luminosity function of MW satellites

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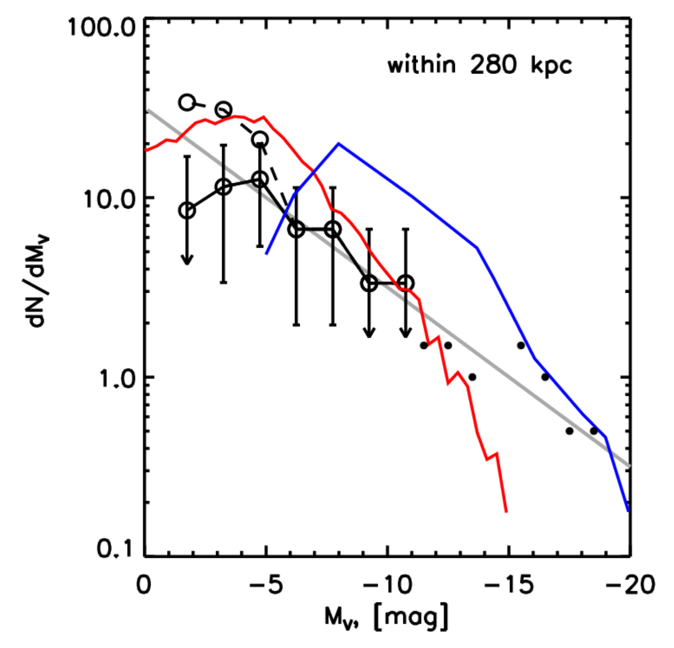

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ApJ submitted

The motivation of the work

- Large set of recent discoveries (Belokurov, Zucker, Willman, Irwin 2005-2007)
- What are the limits of current searches for dwarfs in the MW halo ?
- What are the selection biases of current sample of dSph?
- Do we expect to find more MW satellites ?
- Do these discoveries solve the missing satellites problem?
- Unbiased census of MW satellites

The outline of the work

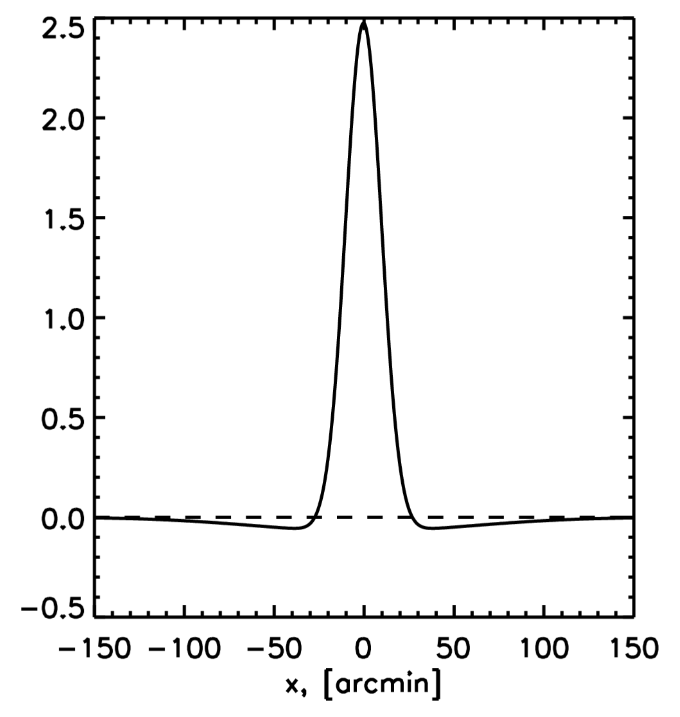
- Algorithm, searching for overdensities
- Application of the algorithm to the DR5 data and finding all currently known objects
- Testing of the algorithm by trying to find fake galaxies in DR5
- The detection efficiency of the algorithm on galaxies of different M_V, and sizes and at different distances
- Correcting the census of MW satellites for the incompleteness: Luminosity function of MW satellites

The algorithm

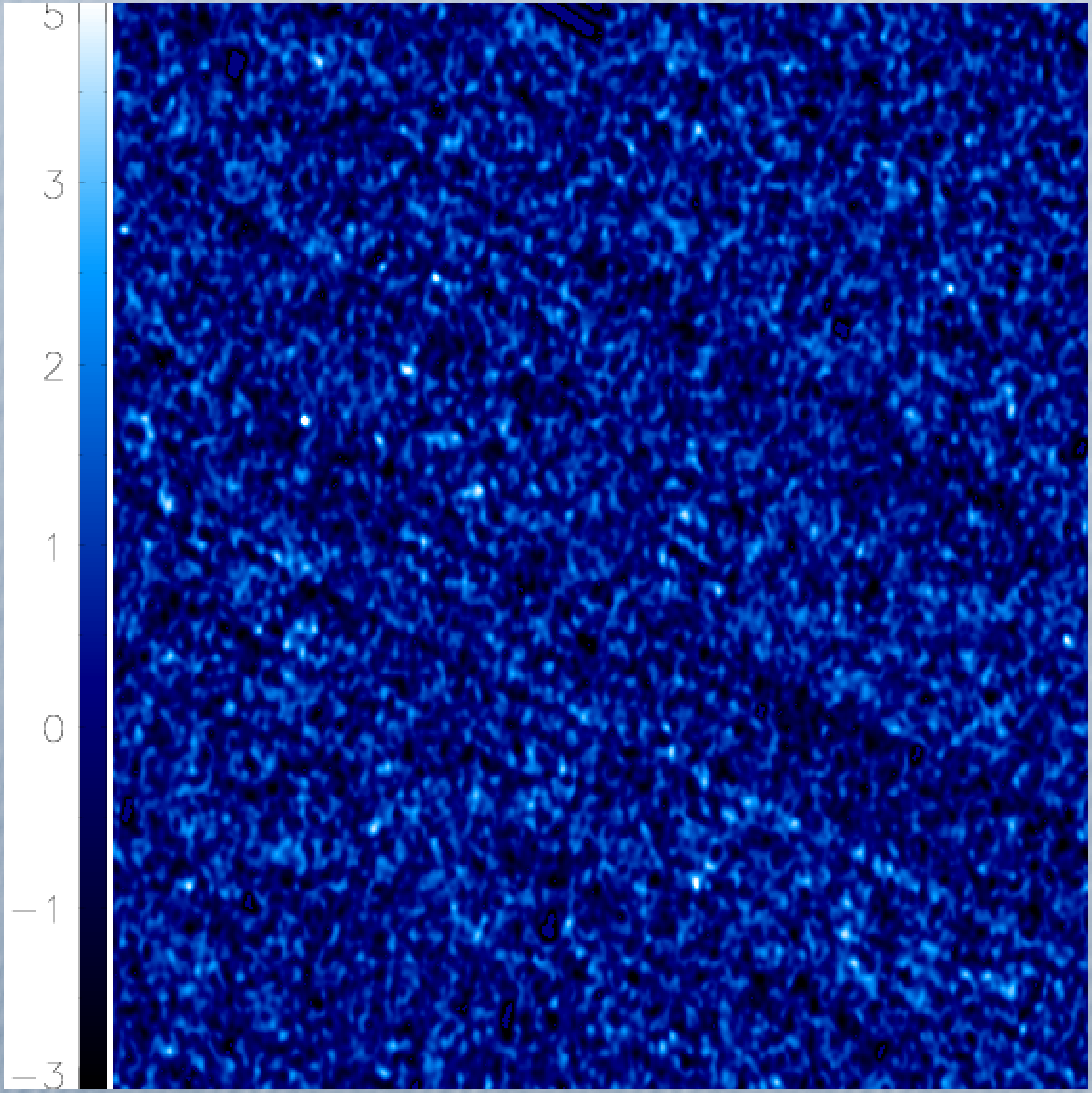
$$L(x,y,\sigma)=I(x,y)*g(x,y,\sigma) \qquad g(x,y,\sigma)=\frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right)$$

$$\Delta L(x,y,\sigma_{1,}\sigma_2)=L(x,y,\sigma_1)-L(x,y,\sigma_2)=I(x,y)*(g(x,y,\sigma_1)-g(x,y,\sigma_2))$$

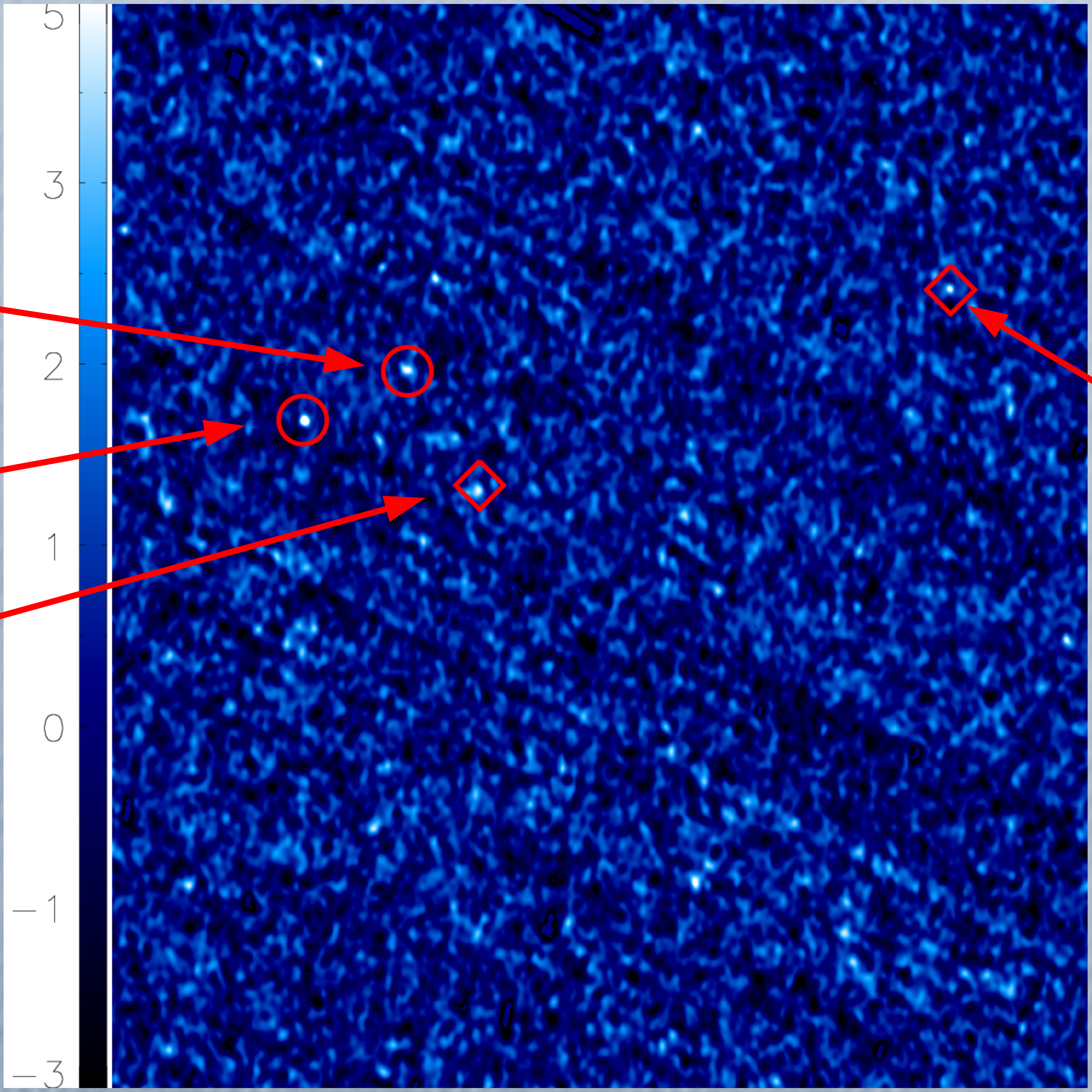
- The kernel has zero integral.
- It has two parameters the width of the inner Gaussian and the width of the outer Gaussian.
- After the normalization the map has a variance of 1.



The map of significances of overdensities in stars



The map of significances of overdensities in stars



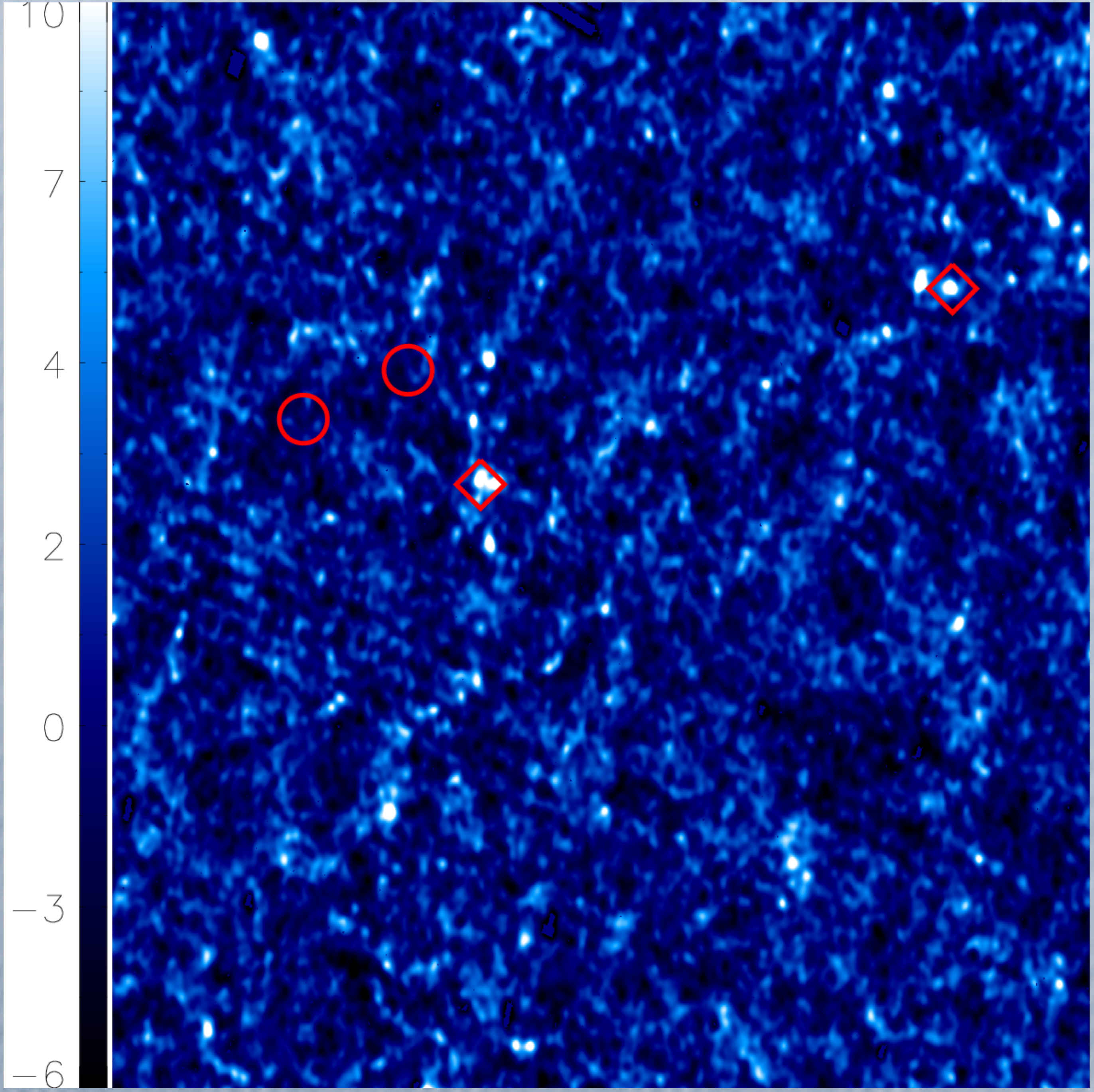
Willman 1

UMa I

Abell 773

Abell 1000

The map of significance of overdensities in galaxies



Detecting objects in DR5

- Contaminants due to galaxy clusters
- RC3 contaminants
- We successfully detect all known dSphs, globulars at high level of significance.

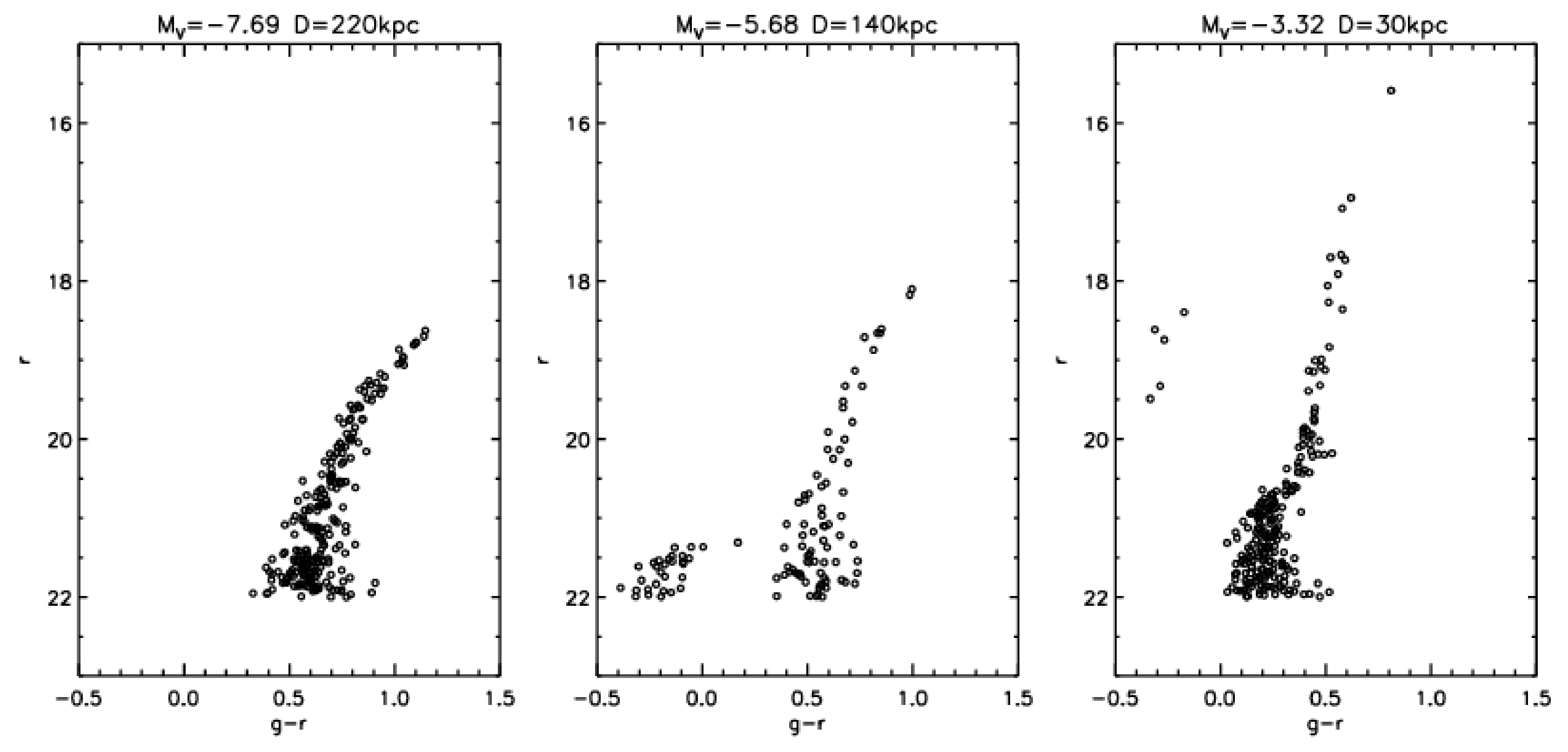
RA	DEC	Sstar	Sgal	Name
205.53	28.48	165.0	3.19	NGC 5272
168.45	22.14	145.3	7.59	Leo II
198.22	18.26	142.8	7.76	NGC 5024
211.46	28.53	110.8	2.46	NGC 5466
199.10	17.79	104.0	1.59	NGC 5053
229.00	-0.13	97.8	8.02	Pal 5
250.41	36.56	96.5	2.89	NGC 6205
260.03	57.91	87.0	3.84	Draco
-37.51	12.25	78.8	5.91	NGC 7078
152.09	12.38	75.5	3.36	Leo I
182.51	18.54	70.2	2.89	NGC 4147
-36.88	-0.87	62.7	-0.91	NGC 7089
114.53	38.97	60.2	1.64	NGC 2419
187.77	12.41	50.5	0.43	NGC 4486
202.00	33.65	30.4	-0.69	Cvn I
114.61	21.67	26.9	-2.07	NGC 2420
187.43	8.08	24.8	-0.41	NGC 4472
190.79	2.78	23.2	1.72	NGC 4636
259.02	43.16	21.1	-1.98	NGC 6341
149.83	30.74	18.0	4.61	Leo A
190.82	11.66	15.2	-0.52	NGC 4649
183.90	36.30	14.1	3.53	NGC 4214
185.04	29.38	13.7	0.08	NGC 4278
186.49	12.91	12.8	-0.03	NGC 4374
178.81	23.47	12.7	9.83	1413 Abell
210.01	14.52	10.3	-0.82	Boo
151.47	0.07	10.1	1.98	Pal 3
242.73	14.95	9.7	-0.99	Pal 14
172.31	29.06	8.8	-0.04	Pal 4
162.31	51.04	8.5	-0.47	Willman 1
210.72	54.39	8.3	4.74	NGC 5457
186.44	33.52	8.1	5.34	NGC 4395
132.92	63.12	7.8	-0.35	Uma II
247.86	12.89	7.6	0.09	Her
188.90	12.65	7.6	-1.08	NGC 4552
186.31	18.20	7.4	-1.77	NGC 4382
186.85	23.90	7.4	0.03	Com
197.97	-1.33	7.3	11.51	1689 Abell
194.38	34.39	7.2	-2.03	CVnII
186.13	7.34	6.9	-0.47	NGC 4365
143.71	17.05	6.6	1.29	Leo T

Simulations

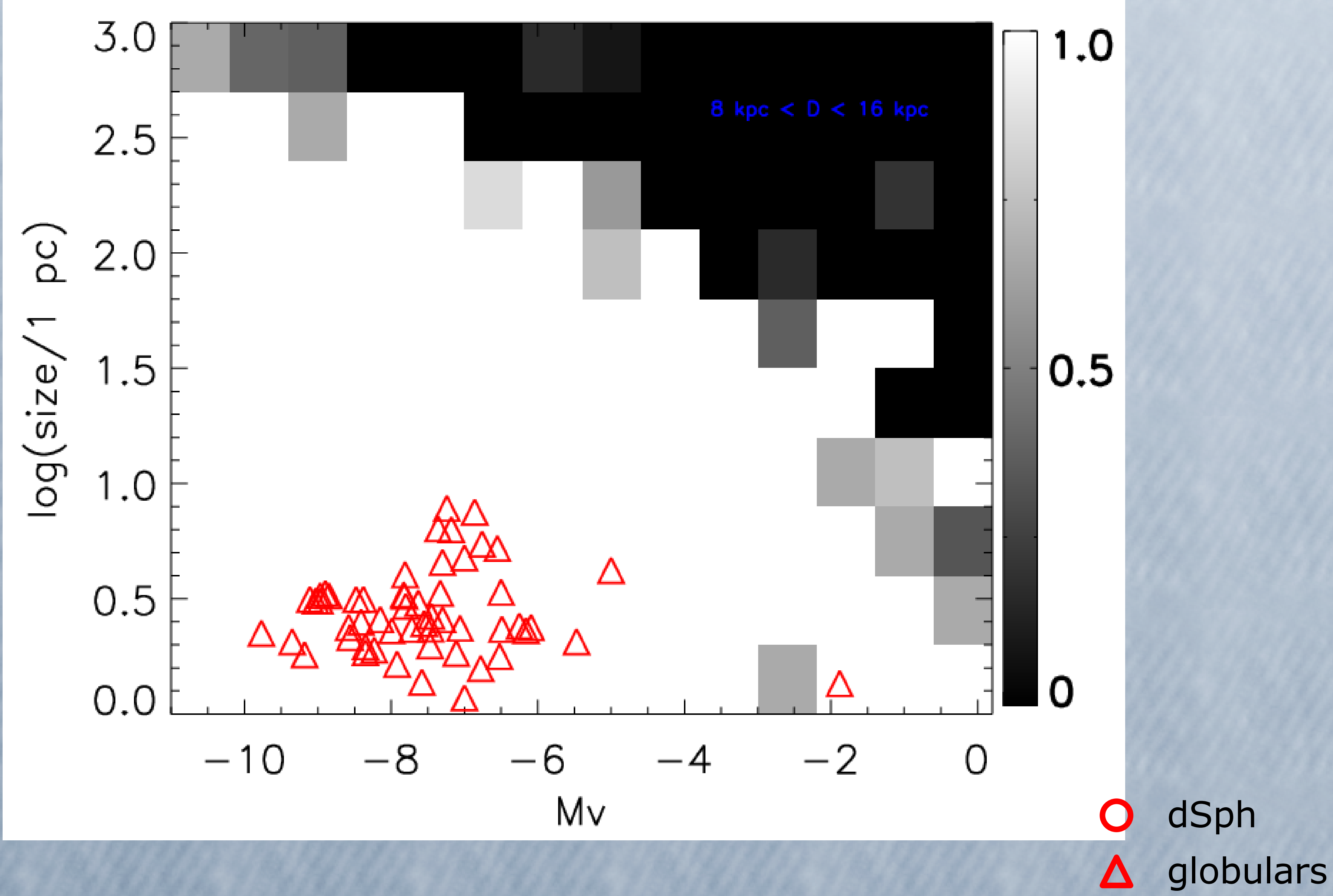
- The template for the stellar populations: M92
- Plummer profiles
- SDSS photometric errors
- The range of parameters:

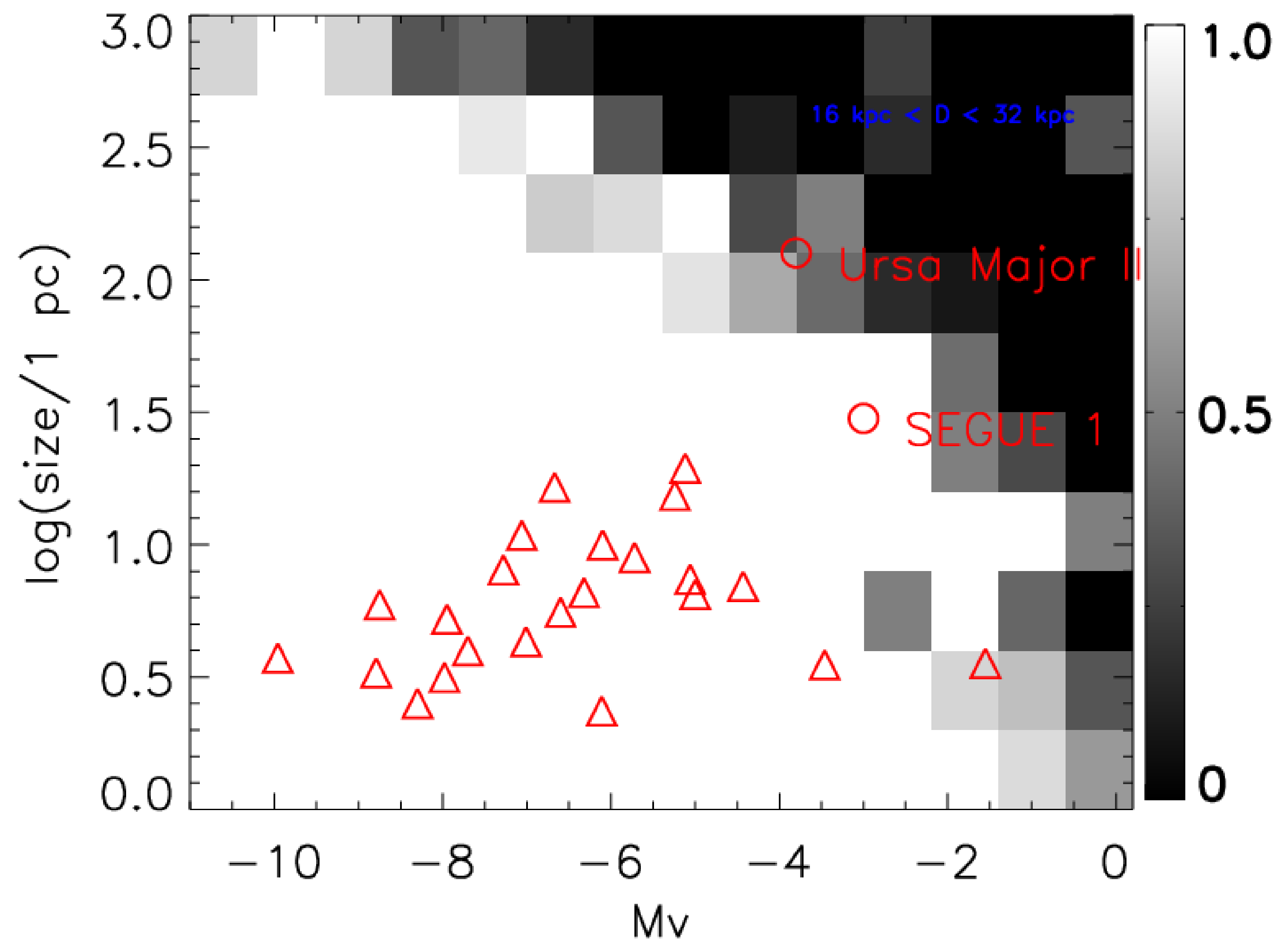
$10\text{kpc} < \text{Distance} < 1\text{Mpc}$, $1\text{pc} < r_h < 1\text{kpc}$, $-11^m < M_V < 0^m$

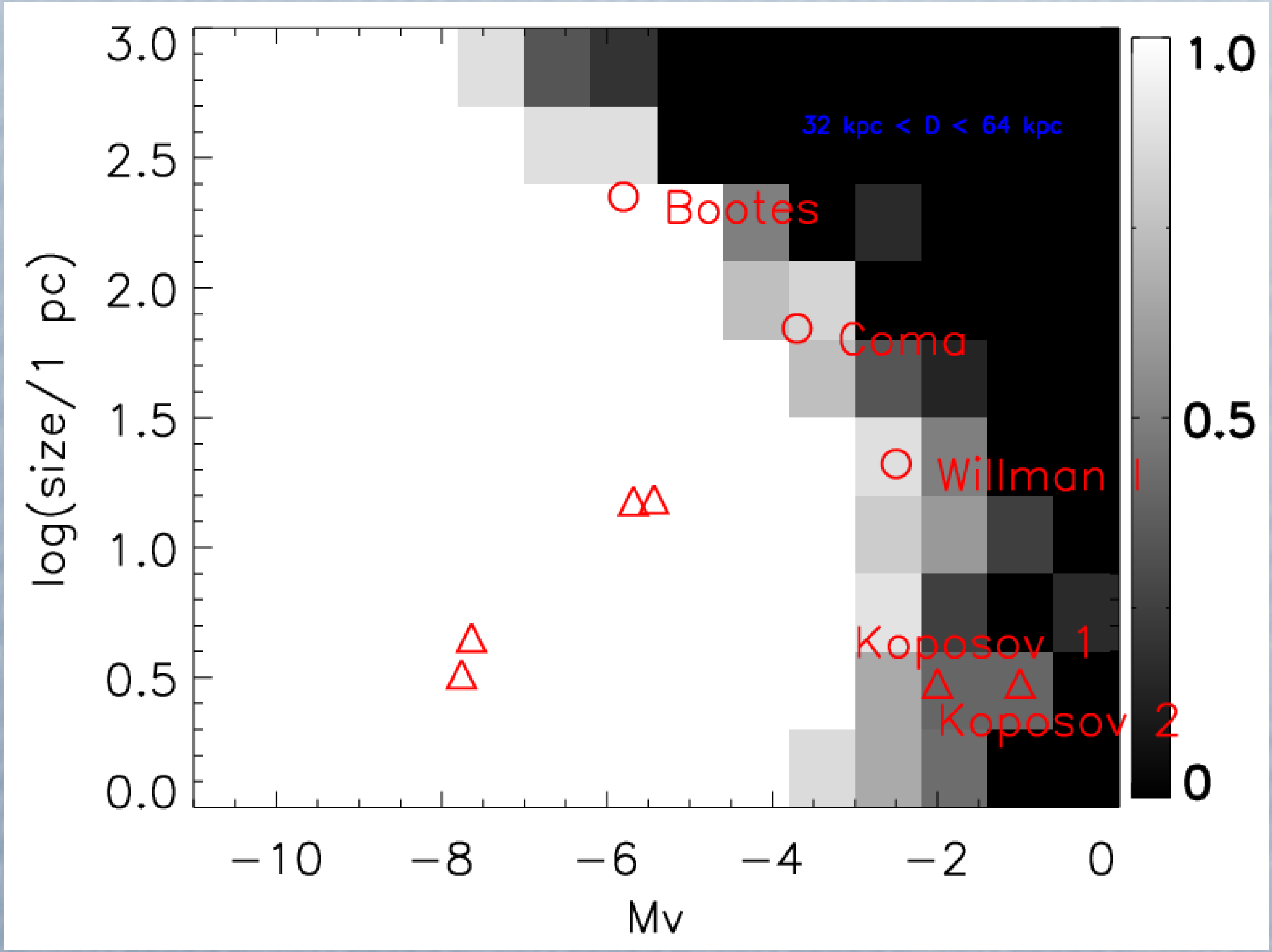
The simulated CMDs mimicking CanVen I, Her I, Uma II

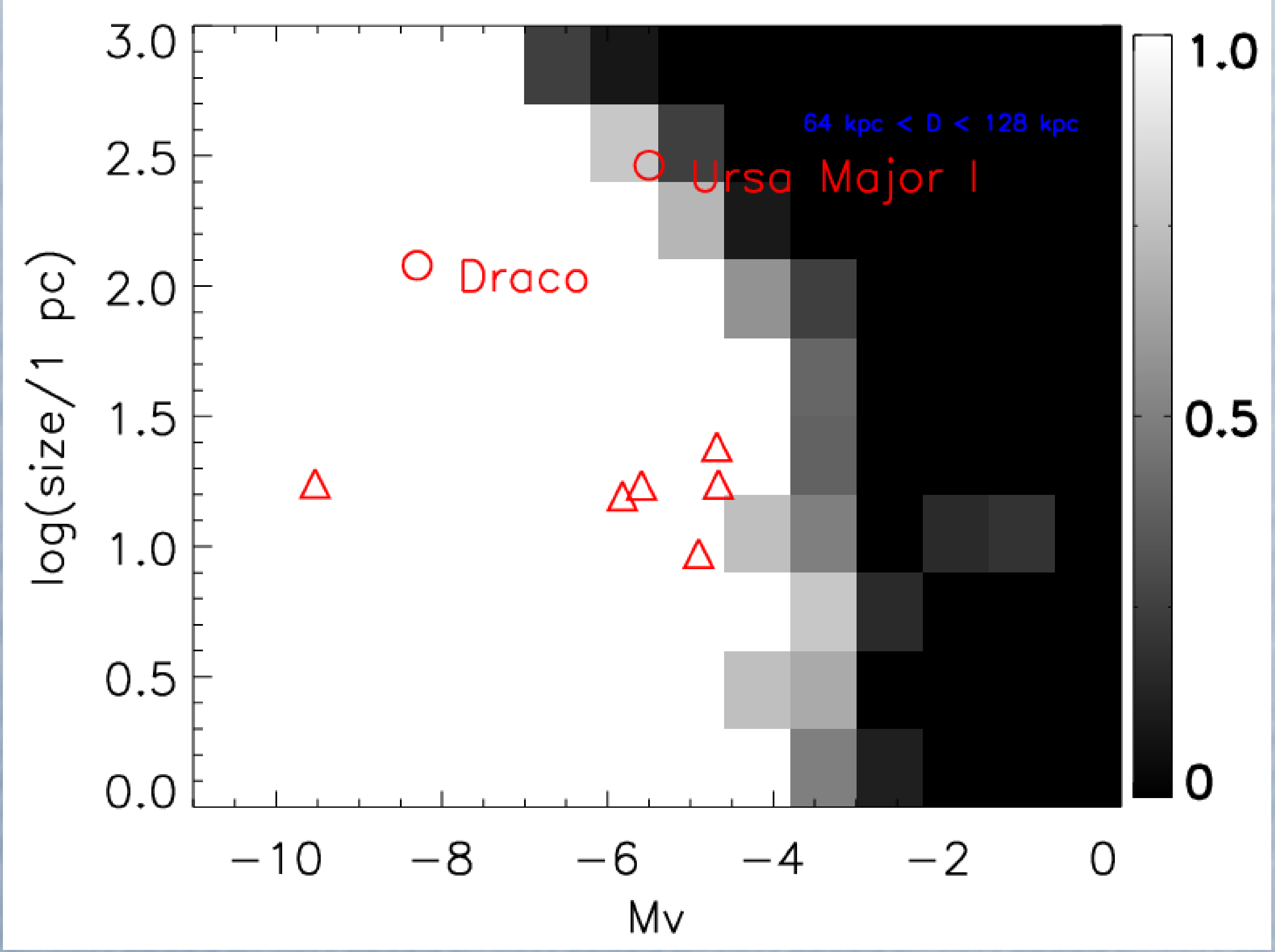


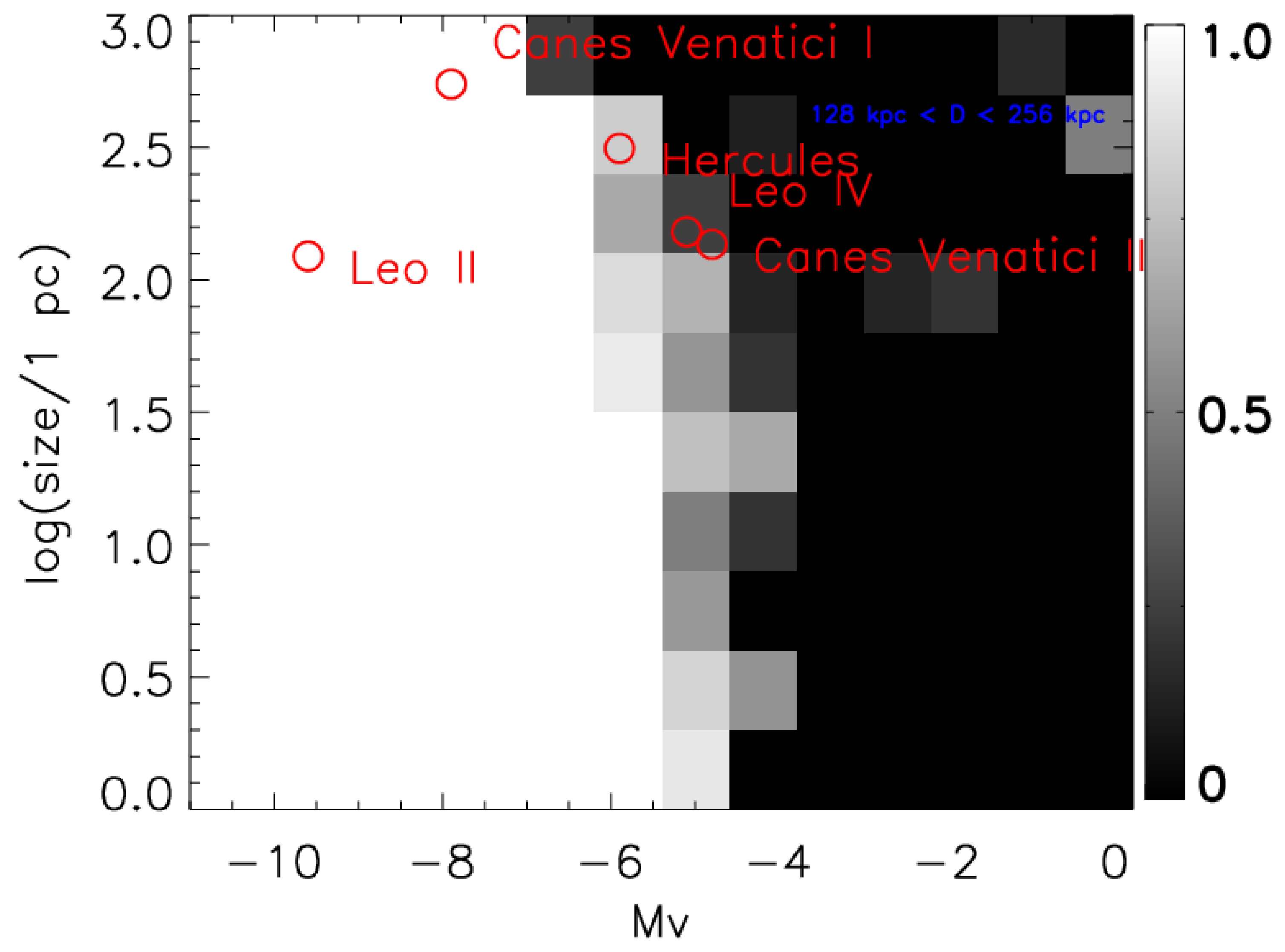
Detection efficiency maps for different distance slices

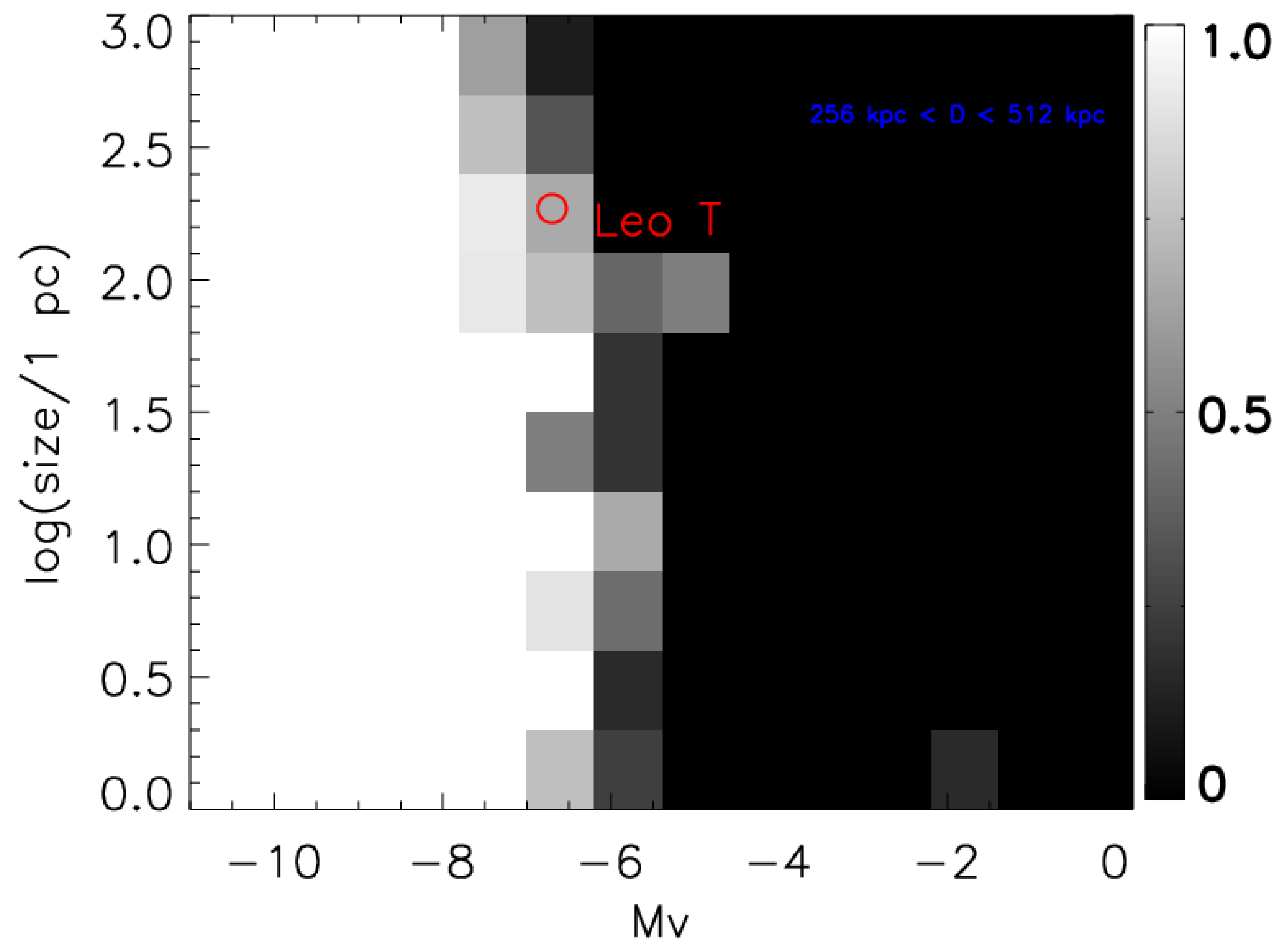


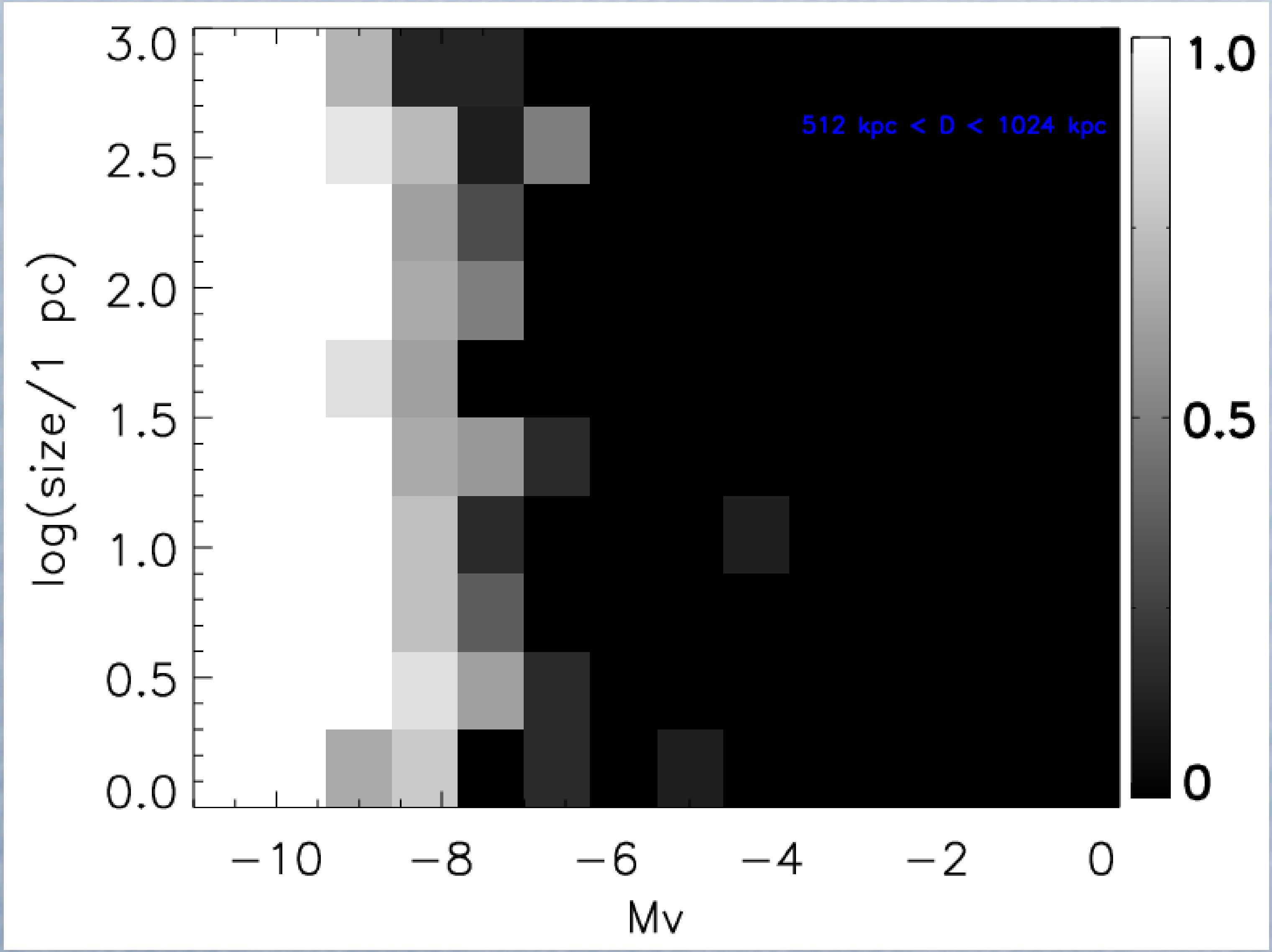

16 kpc < D < 32 kpc
Ursa Major II
SEGUE 1
log(size/1 pc)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Mv
−10
−8
−6
−4
−2
0
1.0
0.5
0


32 kpc < D < 64 kpc
Bootes
Coma
Willman 1
Koposov 1
Koposov 2
log(size/1 pc)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−10
−8
−6
−4
−2
0
Mv
1.0
0.5
0


64 kpc < D < 128 kpc
Ursa Major I
Draco
log(size/1 pc)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−10
−8
−6
−4
−2
0
Mv
1.0
0.5
0

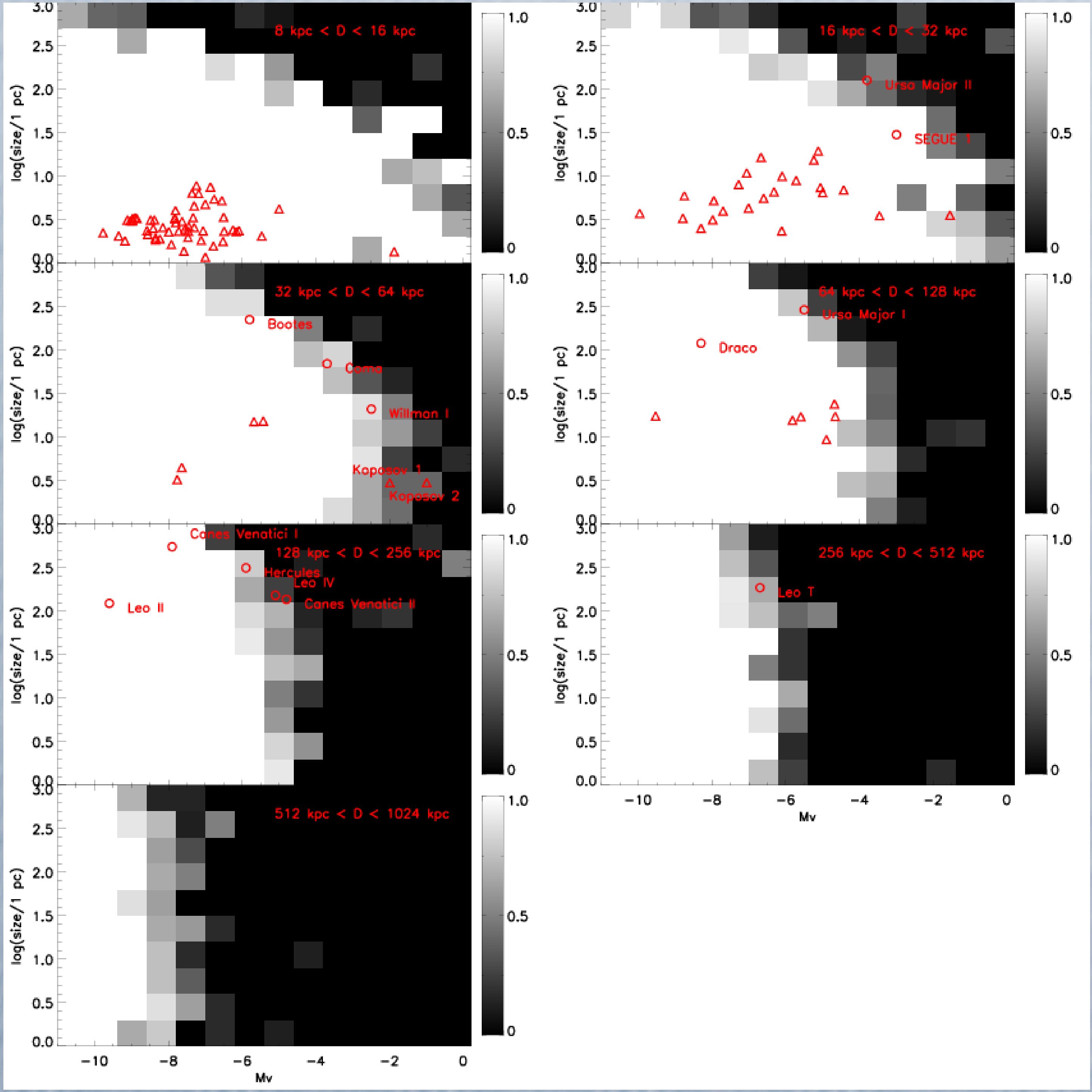

Canes Venatici I
128 kpc < D < 256 kpc
Hercules
Leo IV
Canes Venatici II
Leo II
3.0
2.5
2.0
1.5
1.0
0.5
0.0
log(size/1 pc)
−10
−8
−6
−4
−2
0
Mv
1.0
0.5
0


log(size/1 pc)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−10
−8
−6
−4
−2
0
Mv
1.0
0.5
0
256 kpc < D < 512 kpc
Leo T


512 kpc < D < 1024 kpc
log(size/1 pc)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−10
−8
−6
−4
−2
0
Mv
1.0
0.5
0

The detection efficiencies for different heliocentric distances

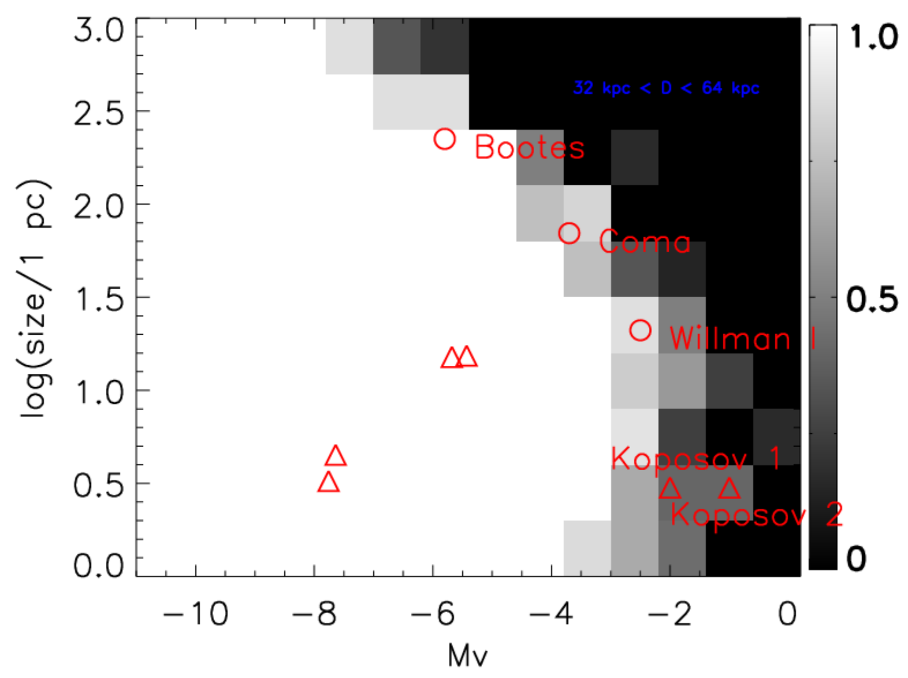
- The maps are either black or white – no gray
- The known objects lie within the detection boundaries
- Large white areas with 100% detection efficiency
- New object lie close to the boundaries
- The radial dependence of the GC distribution
- The characteristic shape of the efficiency pattern

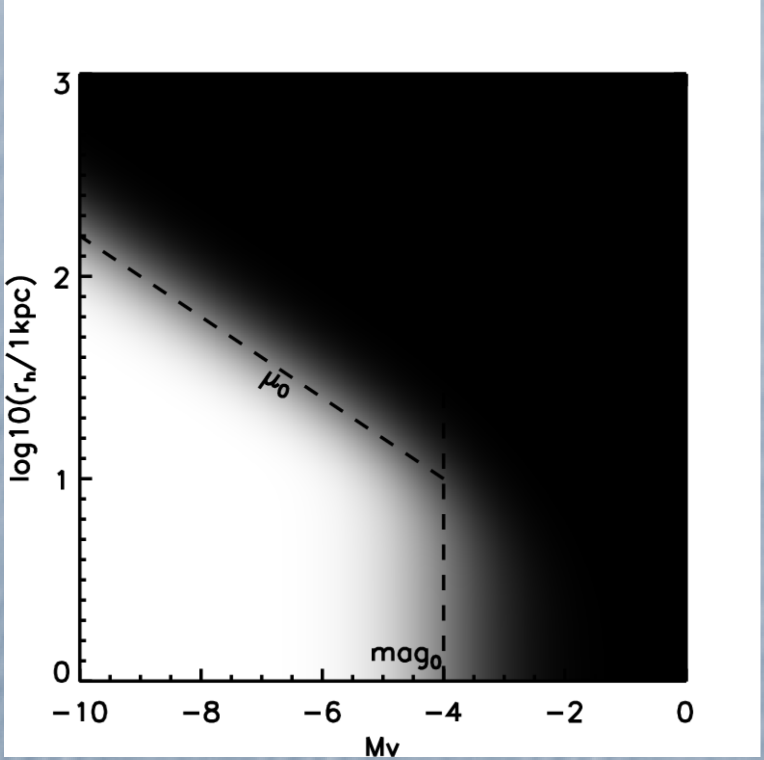


Fitting of the efficiency maps

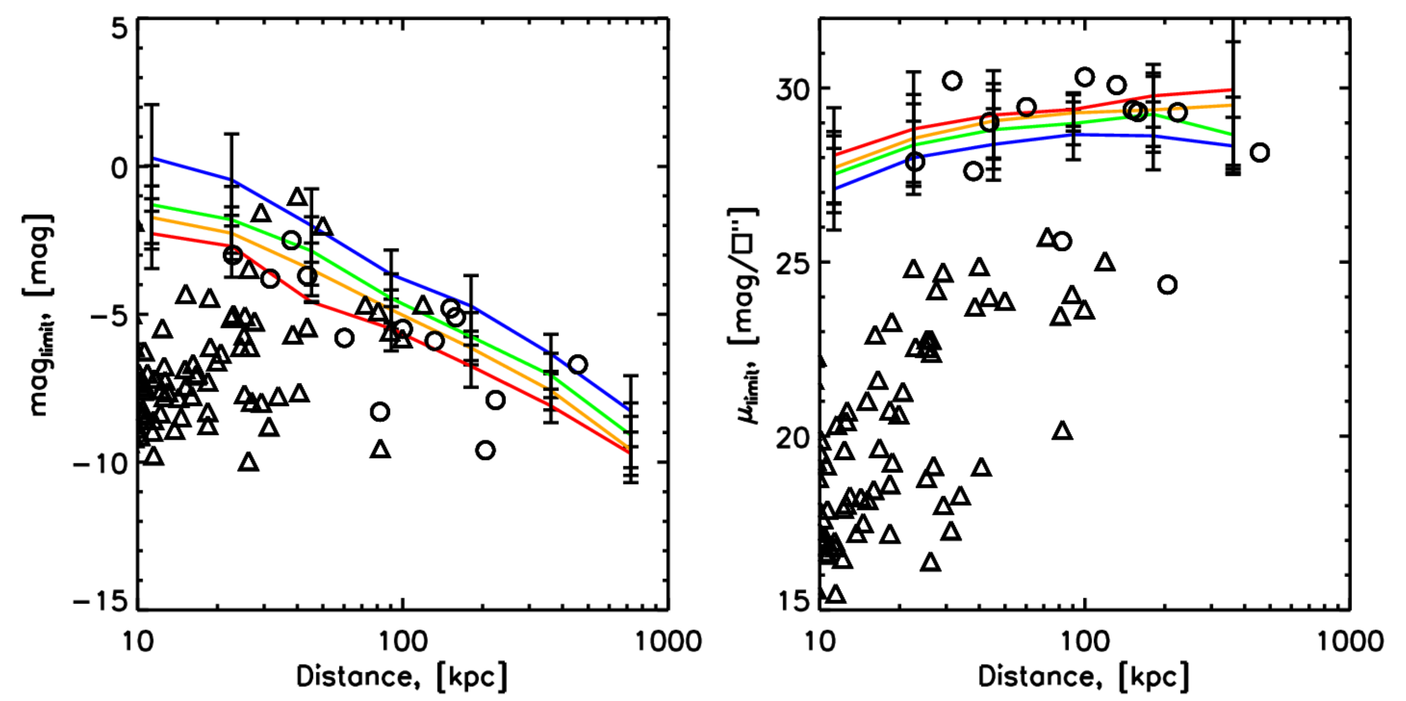
Two main parameters:

- limiting magnitude
- limiting surface brightness



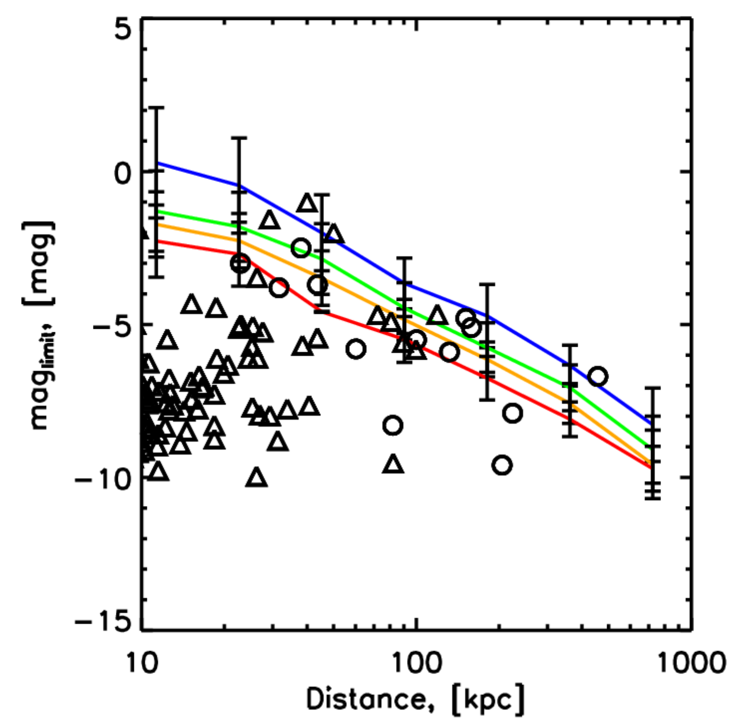


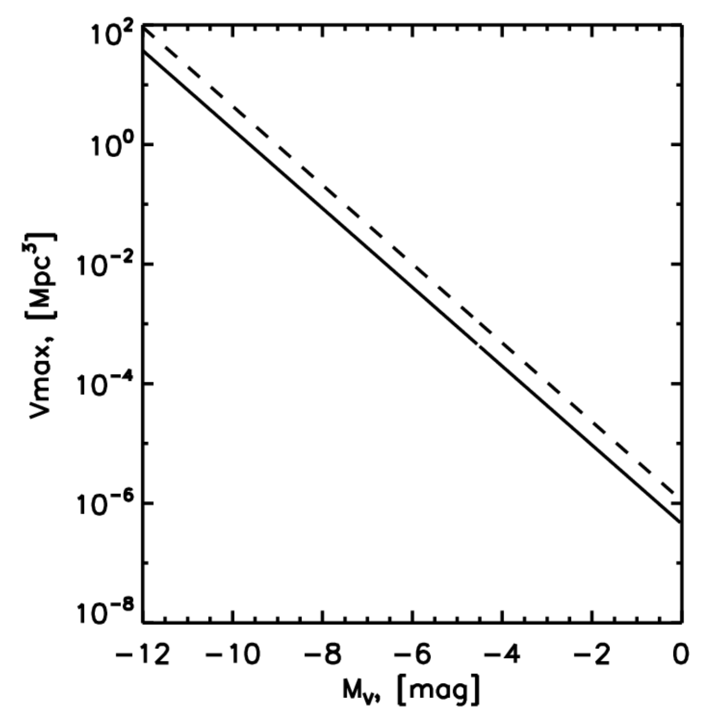
The limiting magnitude and limiting surface brightness as a function of distance.



2' kernel
4' kernel
6' kernel
10' kernel

The surveyed volume within DR5 as a function of luminosity

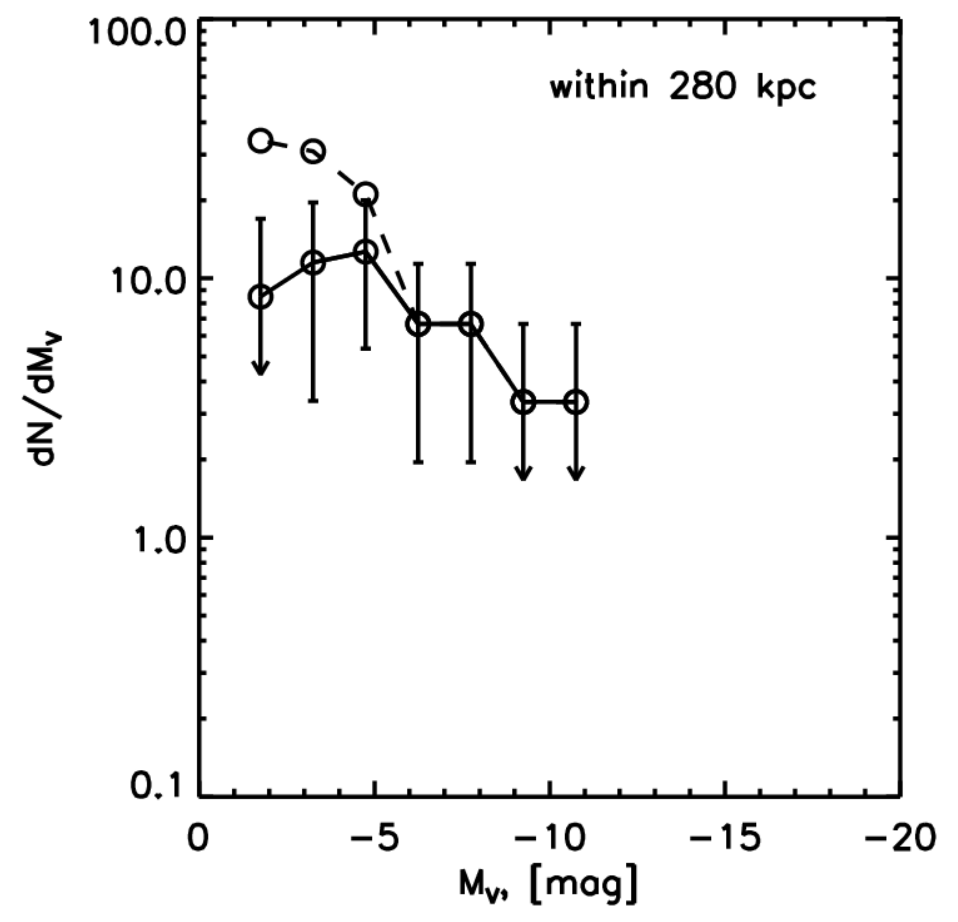




The luminosity function of MW satellites from SDSS DR5 corrected for the incompleteness

LF for galaxies with SB<29mag/sq. arcsec^2

We compute the number of satellites within virial radius of MW halo (280 kpc) (assuming 1/R^2 and NFW-like distribution of satellites)



— NFW density profile

– – 1/R^2 density profile

— Somerville 2002

— Benson 2002

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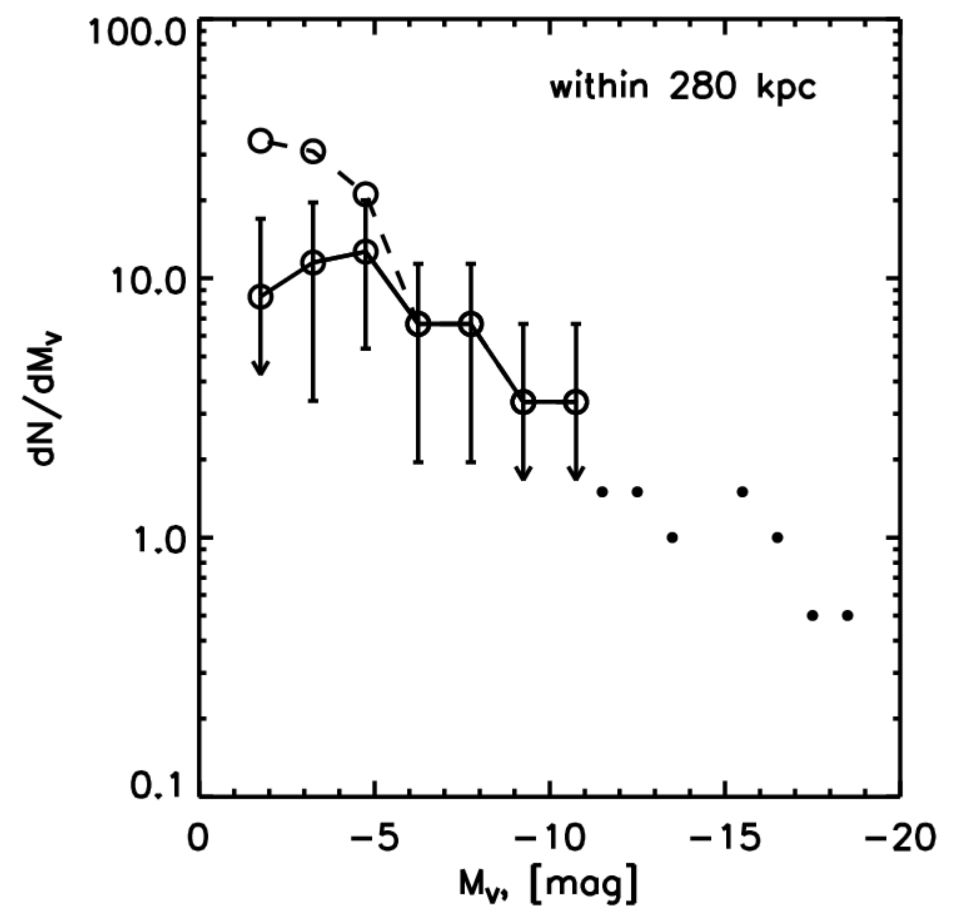

— NFW density profile

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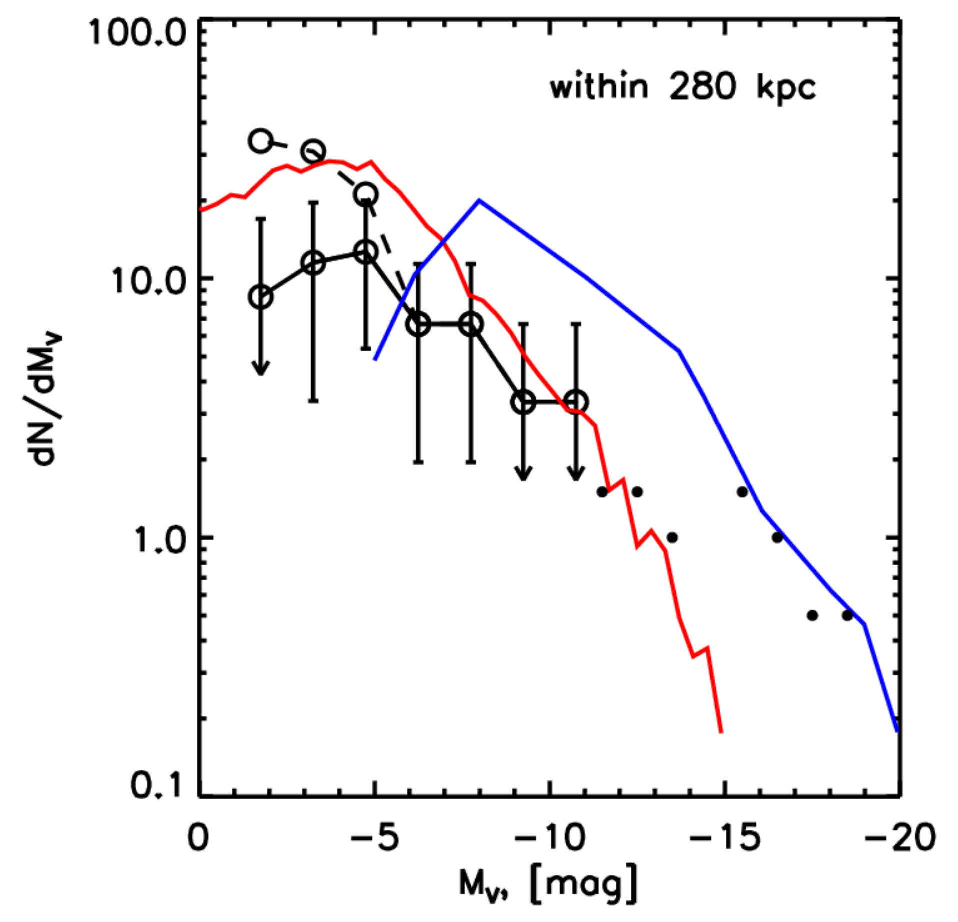
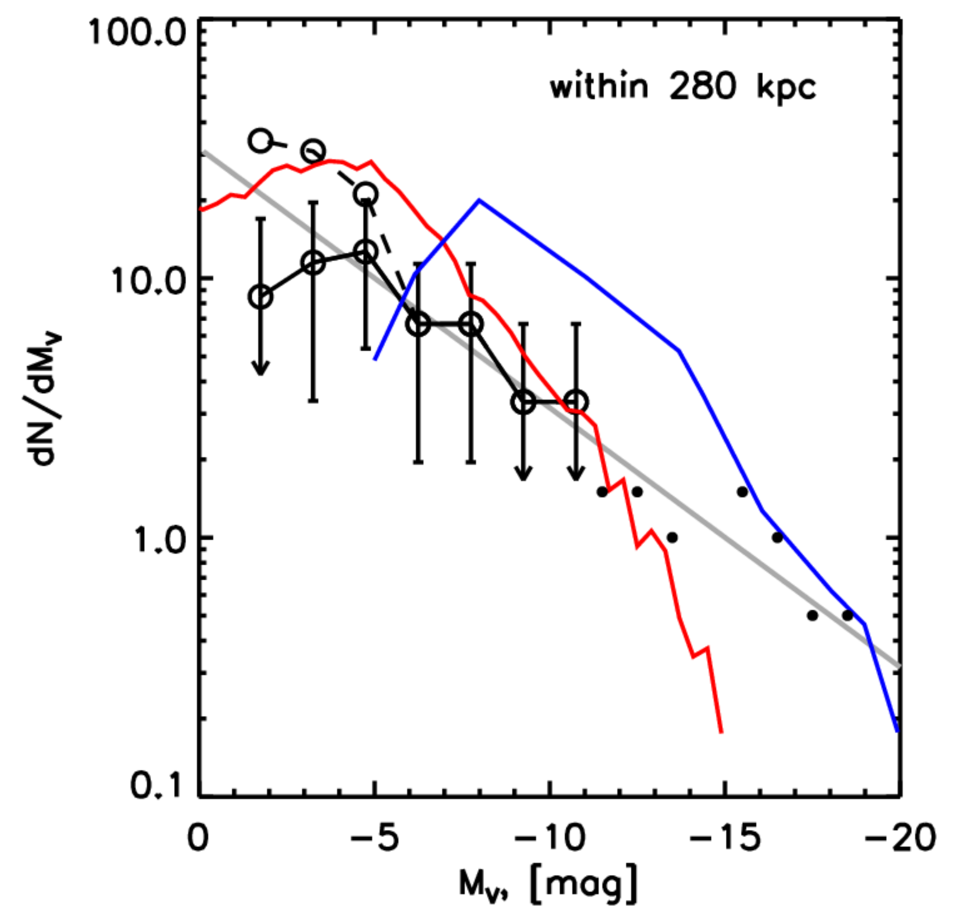


—	NFW density profile	—	Somerville 2002
– –	$1/R^2$ density profile	—	Benson 2002

The luminosity function of MW satellites from SDSS DR5 corrected for the incompleteness

LF for galaxies with SB<29mag/sq. arcsec^2

We compute the number of satellites within virial radius of MW halo (280 kpc) (assuming 1/R^2 and NFW-like distribution of satellites)



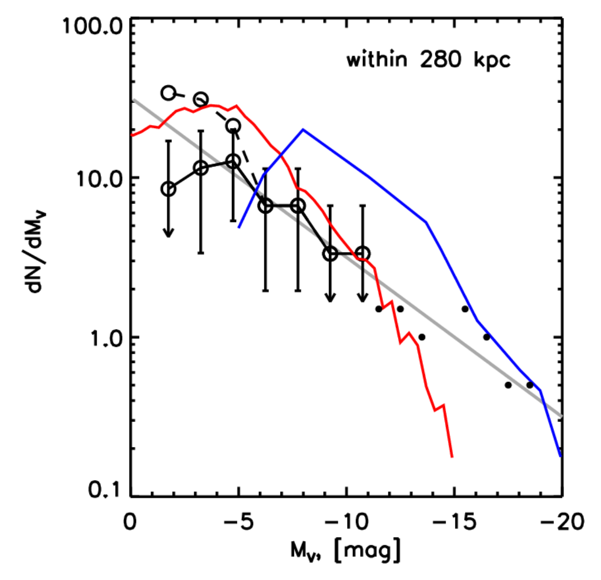
— NFW density profile

– – 1/R^2 density profile

— Somerville 2002

— Benson 2002

Conclusions



- We determine the completeness limits of
- the searches for dwarf galaxies in SDSS
- The efficiency maps cover significant fraction of parameter space, where we would
- have detected objects if they had existed
- We determined the LF (corrected for incompleteness) of MW satellites which could be directly compared with the models
- The recent results show that the significant fraction of recently discovered dwarfs lie close to the surface brightness detection limits. Only future surveys will allow to understand whether the galaxies fainter than these limits exists...

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