Project: Galactic rotation curve and the NFW dark matter halo model

KIAS-SNU winter camp, Feb 2014

The NFW profile is a mass density distribution of dark matter fitted to haloes identified in N-body simulations by Julio Navarro, Carlos Frenk and Simon White. The NFW profile is one of the most commonly used model profiles for dark matter halos thus you may use it in this project. The NFW profile has two free parameters, a standard density ρ_0 and the scale radius R_s, and looks like [1]:

$$\rho(r) = \frac{\rho_0}{\frac{r}{R_s}(1+\frac{r}{R_s})^2} \tag{1}$$

1 Mission-1: Milky way galaxy

- Find the radius at which $d\ln\rho/d\ln(r/R_s) = -2$.
- Find the analytic expression for mass function $M(r)$ inside a shell of the radius r. With the parameters $R_s = 16.1 \pm 10$ kpc and $\rho_0 = (1.4 \pm 1) \times 10^7 \mathrm{M}_\odot/\mathrm{kpc}^3$, find the total mass of Milky way galaxy (w.r.t the solar mass, $M_\odot$) if the 'size' of the galaxy is $31 - 37$ kpc.
- Draw the galactic rotation curve, $v(r)$[km/sec] vs r[kpc]. What's the velocity and the density of dark matter at the location of solar system $r = R_\odot \simeq 8.1$ kpc ?

2 Mission-2: fitting real data

- Use the attached data in the next page for velocities in plane of galaxies [2].
- Choose at least 3 sets of galaxy data in the table and analyze.
- Fit each data using NFW profile and find (ρ_0, R_S) which gives the smallest $\chi^2/d.o.f$.

3 Reference

1. J. F. Navarro, C. S. Frenk and S. D. M. White, "The Structure of cold dark matter halos," Astrophys. J. **462**, 563 (1996), [astro-ph/9508025].
2. V. C. Rubin, W. K. Ford, jr., N. Thonnard, Astrophysical Journal, Part 1, vol. 238, (1980) http://adsabs.harvard.edu/abs/1980ApJ...238..471R

VELOCITIES IN PLANE OF GALAXY (km s^{-1})

R kpc \ NGC4605	1035	4062	2742	701	2608	3495	1087	U3691	4682	3672	1421	2715	4321	I467	7541	7664	2998	753	801	U2885
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	37	41	70	68	52	115	35	50	19	62	14	75	58	135	41	168	-	88	140	-	-
1.0	58	59	91	83	60	117	53	87	34	87	32	102	71	133	53	168	137	103	149	-	208
1.5	66	74	102	104	68	116	68	100	47	101	52	127	82	114	67	167	142	115	156	123	272
2.0	69	87	113	116	78	112	77	108	58	112	71	149	91	124	79	167	145	126	160	154	287
2.5	80	98	122	126	86	105	87	114	69	119	92	163	98	140	84	167	149	136	163	177	285
3	93	108	128	133	94	98	98	117	79	124	117	171	103	158	97	167	153	145	167	193	270
4	(101)	119	142	142	112	93	115	117	92	133	152	174	115	182	112	167	164	167	177	218	251
5		122	153	150	129	98	126	114	91	143	173	163	127	188	121	168	174	187	192	232	241
6		126	158	157	143	103	131	110	96	151	182	151	135	190	127	171	185	203	207	228	239
7		128	160	161	151	108	[120]	119	103	158	184	146	142	193	128	175	193	198	206	216	239
8			162	164	(150)	113	143	125	108	164	185	146	147:	197	127	182	194	190	204	208	242
9			163	167		118	162	132	111	169	187	149	147:	199	129	188	191	187	203	212	244
10				169		123:	158	137	122	173	188	152	144	201	132	194	186	190	202	220	246
12				(171)		(132)	173	(140)	128	178	191	162	133	204	152	208	183	204	204	230	250
14							179		134	172	192	175	[121]	208	[137]	219	183	219	216	[213]	250
16										(168)	192	183	133	(210)	138	225	(183)	205	220	218	250
18											(192)	197	157		151	232		194	213:	225	250
20												208	(160)		152	239		212	205	228	250
22															(152)	242		228	207	226	250
24																(247)		219:	216	220	250
26																	(230)	211:	(221)	[209]	250
28																	187	206		203	255
30																		222		204	263
32																		215		212	274
34																		209		208	283
38																				202	285
42																				204	275
46																				208	268
48																				(211)	270
52																					279
56																					283:
62																					321
66																					[289]
70																					[275]
74																					[259]
78																					262
82.3																					273

Figure 1: Rotation velocity data [2]