Chapter 5

Conclusion

We have used the Millennium simulation (Springel et al. (2005) [106]) outputs to build a model for radio-emitting AGN based on semi-analytic model of galaxy formation and evolution by De Lucia et al. (2004) [37]. Two modes of BH growth are important: radio mode accretion and quasar mode accretion. The quasar mode accretion is the dominant mode of black hole growth and more effective at $z \gtrsim 1.0$ and for massive black holes $M \gtrsim 10^8 M_\odot$, while the radio mode is only effective at low redshifts. We obtained from the model the fraction of the total bolometric luminosity of the black hole which is turned into radio luminosity by assuming an average spectral energy distribution of the radio source. We have separately studied the distribution in cosmic time of low luminosity radio sources (BL Lacs and FRI radio galaxies) and high luminosity radio sources (blazars and FRII radio quasars). We assumed that the former are triggered by the radio mode accretion with radiatively inefficient accretion and the latter are triggered by major mergers, with the standard accretion efficiency $\varepsilon \simeq 0.1$. The redshift distribution of the simulated radio sources was compared with that of Dunlop & Peacock (1990) [39] model (Section (4.3)) which is consistent with recent data (CENSORS, Brookes et al. (2008) [18]). Then we reviewed the distribution of radio sources in massive clusters (Section (4.4) and (4.5)) with a minimum virial mass $2 \times 10^{14} h^{-1} M_\odot$ as this is the mass threshold of the ACT experiment for the SZE galaxy clusters survey. We did an estimation of the temperature fluctuations in CMB caused by the radio point sources and computed the corresponding fluxes (Section (4.6)) at different redshift and then identified the contaminants for the SZE signature of galaxy clusters.

We found in this work that our extended semi-analytic model is able to reproduce, within the error bars, the shape of the observed redshift distribution which is best described by the model RLF5 of Dunlop & Peacock (1990) [39]. The match is not very good at higher redshift ($z \gtrsim 1$) due to the uncertainty on the value of the accretion efficiency which is not yet well constrained by observations. We can improve the model by assuming an accretion efficiency which increases with redshift as it was suggested in the dynamical model of Croton (2006) [31]. Mo et al. (1998) [71] in addition claimed that disks of galaxies were more centrally concentrated in the past making the feeding of the black hole more efficient in the past. However we did not attempt to follow this prescription since the accretion efficiency depends not only on redshift but also with the black hole mass, the luminosity and its spins (see e. g. Volonteri et al. (2007) [117]) and is beyond the scope of this work.

We found that radio galaxies and blazars are concentrated near the centre of clusters at a distance $r \lesssim 0.1 r_{200}$ and they are more concentrated in low mass clusters. The total surface density profile of radio sources with a luminosity cut-off $P \geq 10^{23}$ W Hz^{-1} at 1.4 GHz at $r \lesssim 0.1 r_{200}$ is in good agreement with the model of Lin & Mohr (2007) [58]. The model underestimates the number of radio sources in the outskirts of clusters. There is a rapid drop off in FRI space density at redshift $z \gtrsim 0.2$. Both of these problems may be related to our assumption of a constant accretion efficiency.

Our model predicts a non negligible contamination of clusters SZE signature at redshift $z \lesssim 0.1$. The contaminants at this redshift made up with BL Lacs and FRI produce an average fluctuation in CMB temperature of orders 5 μK for lower mass cluster to ~ 45 μK for massive clusters at 145 GHz. This is at the same or above the level of the kinetic SZE expected for such clusters which is a few tens μK . At high redshifts $z \simeq 0.79$ and $z \simeq 1.03$, our model suggests that blazars produce fluctuations of $300 - 350$ μK for an average cluster mass which is larger than the expected thermal SZE signal of hundreds μK, but these results are preliminary which need further testing.

The temperature fuctuations and fluxes caused by radio sources in galaxy clusters at the ACT frequencies can be modelled by a power law but before doing this we need to improve the model by adopting different shape of the spectral energy distribution of blazars and radio galaxies and choose an accretion efficiency that is constrained by observation. In future work it is really important to know how the accretion parameter which determines the efficiency of the conversion of mass to radiation varies with the central black hole properties.

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Appendix A

Spectral distribution of the scattered CMB

We use the Kompaneets equation to describe the rate of change of the number of photons scattered by a hot electron gas assuming a Maxwellian distribution in the non relativistic approximation. This equation is a Fokker-Planck approximation of the kinetic equation given by (see Peebles (1993) [84] for the derivations):

$$\frac{\partial n}{\partial t} = \frac{kT}{mc}\frac{\sigma_{\mathrm{T}} n_{\mathrm{e}}}{x^2}\frac{\partial}{\partial x}[x^4(\frac{T_{\mathrm{e}}}{T}\frac{\partial n}{\partial x} + n + n^2)] \tag{A.1}$$

where σ_{T} is the Thomson cross section ($h\nu \ll mc^2$), n_{e} the density of electrons, T_{e} the electrons temperature and $x = \frac{h\nu}{kT}$ the nondimensional frequency. k is the Boltzmann constant and T the temperature of the photons. Since $T_{\mathrm{e}} \gg T$ (hot electrons) we can neglect the second and third terms in the parenthesis. Then we obtain

$$\frac{\partial n}{\partial t} = \frac{kT}{mc}\frac{\sigma_{\mathrm{T}} n_{\mathrm{e}}}{x^2}\frac{\partial}{\partial x}[x^4(\frac{T_{\mathrm{e}}}{T}\frac{\partial n}{\partial x}]. \tag{A.2}$$

The expression of the occupation number of a Planckian photon radiation is (Rephaeli (1995) [90]):

$$n_{\mathrm{p}}(x) = \frac{1}{e^x - 1}. \tag{A.3}$$

If the scattering of the incident radiation is weak we can obtain an approximate solution of the equation (A.2) by substituting (A.3) on the right-hand side of the equation. The expression of the intensity of radiation is given by:

$$I = i_{\rm o} x^3 n \tag{A.4}$$

where $i_{\rm o} = 2\frac{(kT_{\rm o})^3}{(hc)^2}$. The spectral intensity change is obtained by integrating (A.2) along the path length through the cluster:

$$\Delta I = i_{\rm o}\ y g(x) \tag{A.5}$$

where

$$g(x) = \frac{x^4 e^x}{(e^x - 1)^2}[\frac{x(e^x + 1)}{e^x - 1} - 4] \tag{A.6}$$

is the spectral form of the thermal SZ effect and

$$y = \int (\frac{kT_{\rm e}}{mc^2}) n_{\rm e} \sigma_{\rm T} dl \tag{A.7}$$

the *Comptonization parameter* which characterises the spatial dependence of the effect. The function $g(x) = 0$ at $x_{\rm o} = \frac{h\nu_{\rm o}}{kT} = 3.83$ or at the frequency $\nu_{\rm o} \simeq 218$ GHz if we assume $T_{\rm o} = 2.726$ K (COBE/FIRAS, Mather et al. (1994) [67]). The temperature change caused by the scattering is given by

$$\Delta T = [\frac{x(e^x + 1)}{e^x - 1} - 4] T_{\rm o} y. \tag{A.8}$$

For the Rayleigh-Jeans (R-J) part of the spectrum $x \ll 1$. Hence

$$\frac{\Delta I}{I_{\rm o}} \simeq \frac{\Delta T}{T_{\rm o}} \tag{A.9}$$

$$\simeq -2(1 + \frac{x}{2}) y \tag{A.10}$$

$$\frac{\Delta T}{T_{\rm o}} \simeq -2(1 - \frac{x^2}{4}) y \tag{A.11}$$

to second order in x (Rephaeli (1995) [90]).

Appendix B

Table of temperature fluctuations and fluxes of radio sources

Table B.1: *Temperature fluctuations and fluxes caused by BL Lacs low luminosity blazars at redshift* $z = 0.10$ *at* 145 GHz, 220 GHz *and* 270 GHz. *The clusters virial masses shown here are for* $M_{\rm vir} \geq 2 \times 10^{14} h^{-1} M_{\odot}$ *and with radio sources temperature fluctuations greater than* 0.1 μK.

$M_{\rm vir}$ $(10^{14} h^{-1} M_{\odot})$	$T_{145{\rm GHz}}$ (μK)	$S_{145{\rm GHz}}$ (mJy)	$T_{220{\rm GHz}}$	$S_{220{\rm GHz}}$	$T_{270{\rm GHz}}$	$S_{270{\rm GHz}}$
2.038	1.7	0.16	3.5	0.14	4.5	0.14
2.044	8.3	0.78	17.2	0.71	21.9	0.67
2.052	2.5	0.23	5.2	0.21	6.6	0.20
2.060	0.1	0.01	0.3	0.01	0.3	0.01
2.065	0.3	0.03	0.6	0.02	0.8	0.02
2.068	1.6	0.15	3.4	0.14	4.3	0.13
2.074	6.9	0.65	14.3	0.59	18.3	0.56
2.089	0.6	0.06	0.1	0.00	0.1	0.00
2.094	0.1	0.01	0.3	0.01	0.3	0.01
2.094	1.0	0.10	0.3	0.01	0.3	0.01
2.097	4.7	0.44	9.8	0.40	12.4	0.38
2.099	16.3	1.54	33.9	1.39	43.2	1.32
2.100	30.6	2.89	63.7	2.61	81.2	2.48
2.104	9.4	0.89	19.6	0.81	25.0	0.76
2.106	4.4	0.42	9.2	0.38	11.7	0.36
2.106	3.2	0.30	9.2	0.38	11.7	0.36
2.109	20.3	1.92	0.1	0.00	0.1	0.00
2.110	0.4	0.04	0.8	0.03	1.0	0.03
2.112	0.2	0.02	0.1	0.00	0.1	0.00
2.115	15.1	1.42	31.4	1.29	40.0	1.22
2.125	1.4	0.14	3.0	0.12	3.8	0.12
2.132	4.9	0.46	10.2	0.42	13.0	0.40
2.143	0.4	0.04	0.9	0.04	1.1	0.03

Table B.1 – continued.

$M_{\rm vir}$ $(10^{14}h^{-1}M_{\odot})$	$T_{\rm 145GHz}$ $(\mu{\rm K})$	$S_{\rm 145GHz}$ (mJy)	$T_{\rm 220GHz}$	$S_{\rm 220GHz}$	$T_{\rm 270GHz}$	$S_{\rm 270GHz}$
2.156	0.2	0.02	0.5	0.02	0.6	0.02
2.163	0.1	0.01	0.2	0.01	0.3	0.01
2.171	2.9	0.27	6.0	0.24	7.6	0.23
2.173	0.7	0.07	1.5	0.06	1.9	0.06
2.174	6.9	0.65	1.5	0.06	1.9	0.06
2.208	8.6	0.82	18.0	0.74	22.9	0.70
2.210	12.8	1.21	26.7	1.10	34.1	1.04
2.212	4.3	0.41	9.0	0.37	11.5	0.35
2.214	0.1	0.01	0.2	0.01	0.3	0.01
2.214	0.3	0.03	0.2	0.01	0.3	0.01
2.228	0.2	0.02	0.2	0.01	0.5	0.01
2.228	0.1	0.01	0.27	0.01	0.5	0.01
2.229	0.5	0.05	1.1	0.04	1.4	0.04
2.232	4.8	0.45	9.9	0.41	12.7	0.39
2.248	0.2	0.02	0.5	0.02	0.6	0.02
2.253	0.3	0.03	0.6	0.02	0.8	0.02
2.295	5.6	0.53	11.6	0.48	14.8	0.45
2.300	0.1	0.01	0.3	0.01	0.4	0.01
2.306	5.5	0.52	11.4	0.47	14.6	0.44
2.319	2.0	0.18	4.1	0.17	5.2	0.16
2.322	3.2	0.30	6.7	0.28	8.6	0.26
2.329	0.1	0.01	0.3	0.01	0.3	0.01
2.335	0.6	0.05	1.2	0.05	1.5	0.05
2.345	4.1	0.39	8.6	0.35	10.9	0.33
2.348	1.1	0.11	2.4	0.10	3.0	0.09
2.362	3.0	0.28	6.2	0.25	7.9	0.24
2.368	6.4	0.60	13.2	0.54	16.9	0.51
2.382	0.1	0.01	0.2	0.01	0.3	0.01
2.383	13.4	1.26	27.8	1.14	35.4	1.08
2.386	0.2	0.01	0.3	0.01	0.4	0.01
2.387	1.2	0.12	0.1	0.01	0.2	0.01
2.394	0.5	0.05	1.1	0.04	1.4	0.04
2.395	0.3	0.03	0.6	0.02	0.7	0.02
2.403	25.9	2.45	53.9	2.21	68.7	2.10
2.415	0.5	0.05	1.0	0.04	1.3	0.04
2.417	2.1	0.20	4.4	0.18	5.6	0.17
2.418	0.1	0.01	0.3	0.01	0.3	0.01
2.420	24.9	2.35	51.9	2.13	66.1	2.01
2.436	0.8	0.07	1.6	0.07	2.0	0.06
2.439	4.2	0.40	8.8	0.36	11.3	0.34
2.439	0.1	0.01	8.8	0.36	11.3	0.34
2.445	7.0	0.66	14.6	0.60	18.6	0.57
2.465	26.4	2.50	55.0	2.26	70.2	2.14
2.468	5.5	0.52	0.2	0.01	0.2	0.01
2.469	15.0	1.41	31.2	1.28	39.7	1.21
2.488	0.6	0.06	1.3	0.05	1.7	0.05

Table B.1 – continued.

$M_{\rm vir}$ $(10^{14}h^{-1}M_{\odot})$	$T_{145\rm GHz}$ (μK)	$S_{145\rm GHz}$ (mJy)	$T_{220\rm GHz}$	$S_{220\rm GHz}$	$T_{270\rm GHz}$	$S_{270\rm GHz}$
2.497	11.8	1.11	24.6	1.01	31.3	0.95
2.497	0.1	0.01	24.6	1.01	31.3	0.95
2.503	0.2	0.02	0.4	0.02	0.5	0.01
2.504	2.0	0.19	4.1	0.17	5.3	0.16
2.528	30.2	2.86	62.9	2.58	80.2	2.45
2.536	3.5	0.33	7.3	0.30	9.3	0.28
2.539	5.2	0.49	10.8	0.44	13.7	0.42
2.554	0.3	0.03	0.6	0.02	0.8	0.02
2.556	11.2	1.06	23.4	0.96	29.8	0.91
2.563	2.7	0.25	5.5	0.23	7.1	0.22
2.566	0.2	0.02	0.4	0.01	0.5	0.01
2.578	7.1	0.67	14.8	0.61	18.9	0.58
2.589	1.4	0.13	2.9	0.12	3.7	0.11
2.603	2.1	0.20	4.5	0.18	5.7	0.17
2.627	2.3	0.22	4.9	0.20	6.2	0.19
2.627	0.2	0.01	4.9	0.20	6.2	0.19
2.634	2.5	0.24	5.2	0.21	6.7	0.20
2.662	3.1	0.29	6.4	0.26	8.1	0.25
2.663	5.2	0.49	10.9	0.45	13.9	0.42
2.672	4.3	0.41	9.0	0.37	11.4	0.35
2.672	4.7	0.45	9.0	0.37	11.4	0.35
2.681	12.4	1.17	25.8	1.06	32.9	1.00
2.685	1.9	0.18	3.9	0.16	4.9	0.15
2.692	4.2	0.40	8.7	0.36	11.1	0.34
2.703	17.7	1.67	36.8	1.51	46.9	1.43
2.709	6.1	0.58	12.8	0.52	16.3	0.50
2.710	2.6	0.24	12.8	0.52	16.3	0.50
2.713	0.7	0.06	1.4	0.06	1.8	0.05
2.714	2.6	0.25	1.4	0.06	1.8	0.05
2.717	0.2	0.02	0.3	0.01	0.4	0.01
2.735	0.7	0.07	1.5	0.06	1.9	0.06
2.740	8.6	0.81	17.9	0.73	22.8	0.70
2.745	0.1	0.01	0.3	0.01	0.3	0.01
2.752	0.1	0.01	0.3	0.01	0.4	0.01
2.757	5.8	0.55	0.2	0.01	0.2	0.00
2.766	2.1	0.20	4.5	0.18	5.7	0.17
2.789	0.3	0.03	0.7	0.03	0.9	0.03
2.790	4.9	0.46	10.2	0.42	13.0	0.40
2.794	0.1	0.01	0.3	0.01	0.4	0.01
2.796	6.4	0.61	13.4	0.55	17.1	0.52
2.829	0.2	0.01	0.3	0.01	0.4	0.01
2.830	1.1	0.10	2.3	0.09	2.9	0.09
2.836	3.2	0.30	6.7	0.27	8.5	0.26
2.838	14.8	1.40	30.9	1.27	39.3	1.20
2.883	0.6	0.06	1.3	0.05	1.6	0.05
2.920	1.7	0.16	3.6	0.15	4.5	0.14

Table B.1 – continued.

$M_{\rm vir}$ $(10^{14}h^{-1}M_\odot)$	$T_{145\rm GHz}$ (μK)	$S_{145\rm GHz}$ (mJy)	$T_{220\rm GHz}$	$S_{220\rm GHz}$	$T_{270\rm GHz}$	$S_{270\rm GHz}$
2.922	0.1	0.01	0.3	0.01	0.3	0.01
2.931	2.6	0.24	5.3	0.22	6.8	0.21
2.955	0.6	0.06	1.3	0.05	1.6	0.05
2.955	8.8	0.83	1.3	0.05	1.6	0.05
2.963	3.5	0.33	7.2	0.29	9.2	0.28
2.971	6.3	0.59	13.0	0.53	16.6	0.51
2.972	1.2	0.12	13.0	0.53	16.6	0.51
2.989	2.7	0.26	5.7	0.23	7.2	0.22
3.006	7.5	0.71	15.6	0.64	19.9	0.61
3.010	0.5	0.05	1.0	0.04	1.3	0.04
3.013	4.5	0.43	9.4	0.39	12.0	0.37
3.062	2.1	0.19	4.3	0.18	5.4	0.17
3.107	3.3	0.31	6.8	0.28	8.7	0.27
3.127	28.5	2.69	59.4	2.43	75.7	2.31
3.143	0.2	0.02	0.4	0.02	0.5	0.02
3.151	0.1	0.01	0.3	0.01	0.3	0.01
3.156	6.3	0.60	13.2	0.54	16.8	0.51
3.160	4.6	0.43	9.5	0.39	12.2	0.37
3.169	0.8	0.07	1.6	0.07	2.0	0.06
3.170	1.2	0.12	1.6	0.07	2.0	0.06
3.171	0.8	0.08	1.7	0.07	2.1	0.06
3.173	0.5	0.05	1.1	0.05	1.4	0.04
3.177	8.1	0.76	16.8	0.69	21.5	0.65
3.182	15.8	1.49	32.9	1.35	41.9	1.28
3.186	0.1	0.01	0.3	0.01	0.4	0.01
3.193	7.6	0.71	15.7	0.65	20.1	0.61
3.204	4.3	0.41	9.0	0.37	11.5	0.35
3.263	0.1	0.01	0.3	0.01	0.4	0.01
3.289	1.2	0.11	2.4	0.10	3.1	0.09
3.317	9.7	0.92	20.3	0.83	25.9	0.79
3.351	0.4	0.04	0.8	0.03	1.0	0.03
3.367	9.1	0.86	18.9	0.78	24.1	0.74
3.378	0.1	0.01	0.3	0.01	0.4	0.01
3.400	114.6	10.82	238.4	9.78	303.9	9.26
3.421	10.1	0.95	20.9	0.86	26.7	0.81
3.423	7.7	0.73	16.1	0.66	20.5	0.62
3.440	4.7	0.44	9.7	0.40	12.4	0.38
3.455	5.6	0.53	11.7	0.48	14.9	0.45
3.481	0.2	0.02	0.5	0.02	0.6	0.02
3.489	4.4	0.42	9.3	0.38	11.8	0.36
3.513	0.1	0.01	0.2	0.01	0.3	0.01
3.524	0.3	0.03	0.7	0.03	0.9	0.03
3.539	4.5	0.42	9.3	0.38	11.9	0.36
3.544	7.5	0.71	15.6	0.64	19.9	0.61
3.547	5.5	0.52	11.4	0.47	14.6	0.44
3.558	0.7	0.06	1.4	0.06	1.8	0.05

Table B.1 – continued.

$M_{\rm vir}$ $(10^{14}h^{-1}M_\odot)$	$T_{\rm 145GHz}$ (μK)	$S_{\rm 145GHz}$ (mJy)	$T_{\rm 220GHz}$	$S_{\rm 220GHz}$	$T_{\rm 270GHz}$	$S_{\rm 270GHz}$
3.561	0.5	0.04	0.9	0.04	1.2	0.04
3.613	0.4	0.04	0.9	0.04	1.2	0.04
3.642	1.7	0.16	3.5	0.14	4.5	0.14
3.650	0.4	0.04	0.8	0.03	1.0	0.03
3.680	0.1	0.01	0.2	0.01	0.3	0.01
3.696	67.0	6.33	139.5	5.72	177.7	5.42
3.704	8.0	0.76	16.6	0.68	21.2	0.65
3.767	9.1	0.86	18.9	0.78	24.1	0.74
3.776	14.6	1.38	30.4	1.25	38.8	1.18
3.845	0.2	0.01	0.3	0.01	0.4	0.01
3.887	10.9	1.03	22.7	0.93	29.07	0.88
3.889	7.8	0.73	16.1	0.66	20.6	0.63
3.914	8.4	0.80	17.6	0.72	22.4	0.68
3.923	8.3	0.78	17.2	0.71	21.9	0.67
3.937	2.3	0.21	4.7	0.19	6.0	0.18
3.938	0.2	0.01	0.3	0.01	0.4	0.01
3.942	7.4	0.70	15.4	0.63	19.6	0.60
3.950	0.1	0.01	0.3	0.01	0.3	0.01
3.950	4.7	0.44	0.3	0.01	0.3	0.01
3.969	0.9	0.09	1.9	0.08	2.5	0.08
3.995	0.2	0.02	0.5	0.02	0.6	0.02
4.005	17.9	1.69	37.2	1.53	47.4	1.45
4.021	5.8	0.55	12.0	0.49	15.3	0.47
4.031	77.8	7.34	161.9	6.64	206.3	6.29
4.033	19.9	1.88	41.5	1.70	52.9	1.61
4.095	30.8	2.90	64.0	2.63	81.6	2.49
4.101	1.2	0.12	2.6	0.11	3.3	0.10
4.147	2.6	0.24	5.4	0.22	6.9	0.21
4.165	0.7	0.07	1.5	0.06	1.9	0.06
4.217	1.2	0.12	2.5	0.10	3.2	0.10
4.220	0.1	0.01	0.3	0.01	0.3	0.01
4.232	31.6	2.98	65.7	2.70	83.8	2.55
4.243	6.2	0.58	12.9	0.53	16.4	0.50
4.268	54.2	5.12	112.9	4.63	143.9	4.39
4.294	5.7	0.54	11.8	0.49	15.1	0.46
4.316	2.6	0.25	5.5	0.22	7.0	0.21
4.336	0.2	0.02	0.5	0.02	0.6	0.02
4.343	11.5	1.08	23.9	0.98	30.4	0.93
4.368	31.8	3.01	66.2	2.72	84.4	2.57
4.386	0.5	0.04	0.9	0.04	1.2	0.04
4.390	20.1	1.90	41.8	1.71	53.2	1.62
4.401	0.1	0.01	0.2	0.01	0.3	0.01
4.452	2.1	0.20	4.5	0.18	5.7	0.17
4.495	14.8	1.40	30.8	1.26	39.2	1.19
4.532	15.8	1.49	32.9	1.35	41.9	1.28
4.550	0.5	0.05	1.1	0.05	1.4	0.04

Table B.1 – continued.

$M_{\rm vir}$ $(10^{14}h^{-1}M_\odot)$	$T_{\rm 145GHz}$ (μK)	$S_{\rm 145GHz}$ (mJy)	$T_{\rm 220GHz}$	$S_{\rm 220GHz}$	$T_{\rm 270GHz}$	$S_{\rm 270GHz}$
4.558	12.6	1.19	26.3	1.08	33.5	1.02
4.733	1.0	0.09	2.0	0.08	2.6	0.08
4.935	30.8	2.91	64.1	2.63	81.7	2.49
4.961	0.9	0.09	2.0	0.08	2.5	0.08
5.012	51.2	4.84	106.6	4.37	135.9	4.14
5.106	1.4	0.13	3.0	0.12	3.8	0.11
5.311	0.3	0.03	0.6	0.03	0.8	0.02
5.406	0.5	0.04	1.0	0.04	1.3	0.04
5.411	8.7	0.82	18.1	0.74	23.0	0.70
5.476	22.0	2.08	45.8	1.88	58.3	1.78
5.481	16.4	1.55	34.2	1.40	43.6	1.33
5.768	1.4	0.13	2.9	0.12	3.7	0.11
5.939	1.4	0.13	3.0	0.12	3.8	0.11
5.985	13.1	1.23	27.2	1.12	34.7	1.06
6.077	3.1	0.29	6.4	0.26	8.1	0.25
6.237	9.5	0.90	19.8	0.81	25.2	0.77
6.314	138.4	13.07	288.1	11.81	367.1	11.19
6.447	18.9	1.79	39.4	1.62	50.2	1.53
6.684	1.3	0.13	2.8	0.11	3.5	0.11
6.707	1.1	0.10	2.3	0.09	2.9	0.09
6.725	1.0	0.09	2.1	0.08	2.6	0.08
6.742	2.7	0.25	5.6	0.23	7.1	0.22
6.882	0.6	0.05	1.1	0.05	1.5	0.04
6.902	25.9	2.45	54.0	2.21	68.8	2.10
8.092	1.4	0.13	2.8	0.12	3.6	0.11
8.268	16.1	1.52	33.4	1.37	42.6	1.30
8.664	11.8	1.12	24.6	1.01	31.4	0.96
8.973	17.0	1.61	35.4	1.45	45.2	1.38
9.010	0.9	0.09	2.0	0.08	2.5	0.08
9.104	12.1	1.14	25.2	1.03	32.1	0.98
9.988	174.2	16.45	362.6	14.87	462.1	14.09
10.229	118.3	11.17	246.3	10.10	313.8	9.57
10.254	54.0	5.10	112.3	4.60	143.1	4.36
11.197	3.0	0.28	6.2	0.25	7.8	0.24
12.697	48.9	4.61	101.7	4.17	129.6	3.95
21.141	159.3	15.04	331.4	13.59	422.4	12.88