THE ELECTROMAGNETIC SPECTRUM OF THE COSMIC BACKGROUND RADIATION

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INTRODUCTION

A difuse radio emission, extragalactic in nature, is detected in metric ($50 > \lambda > 0.5$ m) and in microwaves ($50 > \lambda > 0.05$ cm) wavelengths. The nature of the emission, in these wavelength bands, is very distinct. For the metric λs the emission can be entirely attributed to the integrated flux of the discrete extragalactic radio sources. At microwaves the observed emission is attributed to the cosmic background radiation, CBR, which can be approximately described by a Planck distribution with radiation temperature $T_R \sim 2.7$ °K, being not associated with discrete sources (Longair, (1)).

1 - THE RADIO AND MICROWAVES COSMIC BACKGROUND RADIATION

G.Gamow and collaborators- in 1949, concluded that there must be a background radiation of thermic nature with uniform distribution, which fill in the Universe as a whole (2, 3, 4, 5, 6, 7, 8, 9). They identified this radiation which should exist in equilibrium during the first stages of the Universe (considering the Universe according to the hot big-bang model which was very much redshifted). The Gamow and collaborators estimation was the result of trials to explain the elementar nucleosynthesis inside the primordial big-bang. They concluded that, according to this model, it would be impossible to explain the heavy elements abundance in the Universe, which was confirmed by recent studies.

The motivation for the CBR studies disappeared when it was suggested the nucleosynthesis in the stelar interior could explain the observed abundances of the heavy elements in the Universe. However, the important fact is that Gamow and collaborators concluded in a hot model for the Universe of the Friedman type (10), i.e. a cosmological model based on the Robertson (11, 12) and Walker's (13) metric, there should exist a background radiation having a thermic nature which was very redshifted and only possible to be observed at the radio band. The best radiation temperature estimation made by Gamow and collaborators was 10 °K.

Only by 1965, the CBR temperature was re-studied by Dicke, Peebles, Roll and Wilkinson (14). They believed that the Universe should have been, during some time in the past, hotter than 10^{10} °K. This is because the Universe expanded from a singularity with radius $R = 0$, or became sufficiently hot to dissociate the heavy elements from previous cycles. According to this last hypothesis, the Universe would evolve through cyclic oscillations between finite values of R. These hypothesis, however, do not fix a value for the present CBR temperature.

Dicke et al. (14) analysing the above assumptions computed that the CBR temperature should be at the order of $T<40$ °K. The most important aspect of their work was not this estimation, but the fact of re-starting the CBR studies. They prepared an experiment to measure T, using a radiometer in which the receiver, connecting one horn observing the sky and another directed to a bath of liquid helium, was switched on and off one hundred times per minute.

Before Dicke et al. (14) could complete their measurements of T, they learned that Penzias and Wilson (15) have observed a background signal, at the wavelength $\lambda = 7{,}35$ cm, detected with the great horn at Holmdel, New Jersey, which was constructed for the observation of the Echo satellite. The antenna temperature could be fitted by:

$$T_A(\theta) = 4.4\ ^{\circ}K + 2.3\ ^{\circ}K \sec(\theta) \tag{1}$$

where θ is the angle between the antenna axis and the zenit; the second part of (1) represents the radiation from our atmosphere. An additional temperature of 0.9 °K was estimated due to contributions of the antenna ohmic losses and the ground radiation which was detected by the antenna side lobes. Therefore, the net value for the CBR antenna temperature, at 7.35 cm, resulted in: 3.5 °K ± 1 °K. Since $kT_A >> h\nu$, this temperature is also equivalent to the black body temperature:

$$T\ (7.35\ \text{cm}) = 3.5\ ^{o}K \pm 1\ ^{o}K \tag{2}$$

This observations was published in 1965, under the title "A Measurement of Excess Antenna Temperature at 4080 MHz" (13), with a paper by Dicke et al. (14) explaining the fundamental importance of this measurement.

A homogeneous and isotropic hot big-bang Universe will produce a CBR spectrum purely Planckian - black body, distorted only by the radiation produced during the recombination of matter, occurred at an epoch corresponding to a redshift $Z \sim 10^3$.

Although Penzias and Wilson (15) have presented their results as an "excess antenna temperature", it is important to remind that they measured the radiation flux at only one wavelength. It was necessary yet to verify the Planck's relation for the radiation spectral intensity:

$$I_\nu\ d_\nu = \frac{2h\nu^3}{c^2} \cdot \frac{1}{e^{(\frac{h\nu}{KT})}-1} \tag{3}$$

or the Planck's black body radiation density law:

$$\rho_\nu = \frac{8\pi h\nu^3}{c^3} \cdot \frac{1}{e^{(\frac{h\nu}{KT})}-1} \tag{4}$$

where:

$$T = \frac{T(t)_R R(t)_R}{R_o} \tag{5}$$

$T(t)_R$ - scalar factor of the Einstein's field equations.

t_R - epoch of the recombination (hydrogen).

t_0 - present epoch.

2 - THE DETERMINATION OF THE SPECTRUM OF CBR AT RADIO AND MICROWAVES

Since it is impossible to modulate the CBR signal, it is very difficult to obtain an absolute measure of the CBR. The CBR is therefore the residual, i.e., what was left after the application of all the corrections. The value of the CBR's observations, is determined by the quality of these corrections and by the precision and confiability of the measurements. The development of the experiments made until the present, to determine the spectrum of the CBR, shows very well these difficulties.

The direct measurement of the spectrum of the CBR can be divided into two classes:

- low frequencies observations in the Rayleigh-Jeans region of the spectrum.
- high frequencies observations covering the pic and the Wien region of the black body spectral distribution.

This division results from the necessity of applying different tecnologies in both regions and because of the different contributions of the earth's atmosphere at these frequencies.

At low frequencies, in the interval $74 > \lambda > 0.5$ cm standard radioastronomic techniques have been used to detect weak signals in the presence of noise (coherent receivers). The observational problems are such that, for long wavelengths, $\lambda > 30$ cm, the background radiation is dominated by the emission of discrete sources and also by the continuum radiation of the Galaxy, which has a significant contribution but in an anisotropic way. However, since both components have spectra approximately $I_\nu \propto \nu^{-0.8}$, for $\lambda < 1$ m, and the CBR is in the Rayleigh-Jeans region of the Planck distributio, i.e., $I_\nu \propto \nu^2$, these problems become insignificant for wavelengths $\lambda < 30$ cm.

The high frequency observation have been made using infrared techniques which are not well developed: incoherent detectors, wide band filters, Fourier transform spectrometers, which are transported in balloons and rockets. The high frequency observations are particularly important because, in these λs, the spectrum of a Planckian distribution, having $T_R = 2.7$ °K, depart from the Rayleigh-Jeans distribution, which is the region of the Planck's spectrum which has the highest energy density. The biggest problem at high frequency, is that the atmosphere becomes an intense source radiation (molecule lines), so that conventional radio astronomic receivers can not be applied for $\lambda < 0.5$ cm. The most successful experiments were carried on in balloons at high altitudes using total power detectors. During the last few years, the spectral resolutions of the receivers systems have been improved with the use of Michelson interferometers.

Before the advent of the experiment using balloons an alternative method to estimate the temperatures of the CBR at millimeter wavelengths was used, i.e., observations of some absorption molecule lines in the visible region of the spectrum were made.

The most successful observations of these kind were made with the radical CN (cyanide) which forms a visible absorption line at 3874 Å, corresponding to the transition between the rest electronic configuration to an excited electronic configuration.

Both configurations are divided into rotational energy levels, distinguished by the rotational angular momentum J, in such a way that the absorption line mentioned above is divided into a number of components (the most significant are shown in Fig. 1) (16). These transitions are governed by a dipole selection law, $\Delta J = \pm 1$.

In 1941, McKeller (17) discovered the CN radical in an interstellar cloud between us and the star ζ Ophiuchi. This cloud was absorbing the stellar light, not only at the transition R(0) of the rest state $J = 0$, but also at the transition R(1) of the first excited rotational state $J = 1$, which is at an excitation energy corresponding to $\lambda = 2.64$ mm.The intensity of these lines are directly proportional to the populations of the corresponding rotational levels, and the ratio of the intensities gives information about the ratio of these populations:

$$\frac{n_1}{n_0} = \{\frac{g_1}{g_0}\} \exp - \{\frac{h\nu_{10}}{kT_{ex}}\} \tag{6}$$

where g_1 and g_0 are the statistical weigths of the two levels and ν_{10} is the frequency of the rotational transition of these two levels ($\nu_{10} = 1.1 \times 10^{11}$ Hz or $\lambda = 2.63$ mm). It turns out that for the radical CN, in difuse interstellar clouds, were these lines are observed, the collision excitation is negligible and therefore the rotation levels must be in equilibrium with the background radiation having a wavelength of 2.64 mm. Therefore, the determination of T_{ex} gives a radiation brigthness temperature. The results are 2.78 ± 0.10 °K at 2.64 mm and 2.9 (+ 0.5 - 0.8) °K at 1.32 mm.

After the discovery of the 3.5 °K radiation at 7.35 cm by Penzias and Wilson (15),Field (18) and Shklovsky (19) independently concluded that the ζ Ophiuchi observation made by McKellar (17) really could be a measure of the BRT (background radiation temperature) and not only a determination of an upper limit of it. This was confirmed by theoretical analysis which rejected all the other rotational excitation mechanisms (18, 20). New measurements were repetead taking into account the absorption line P(1), later detected for a number of stars (21). With these measurements it was not obtained any determination of the radiation temperature with precision, only an indication that T_R, at $\lambda = 2.64$ mm, lays in the range 2.7°K and 3.7 °K. The radicals CH and CH^+ can also suply upper limits for T_R, at $\lambda = 1.32$ mm, 0.559 mm and 0.359 mm, from their absorption lines produced by different rotational excited states.

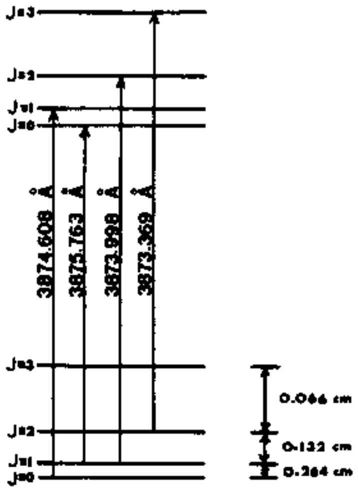

FIGURE 1 - Interstellar transitions for the radical CN used in the temperature determination of the CBR. The lower-lying levels are rotational levels in the electronic and vibrational ground state, and the upper ones are rotational levels in the first excited electronic level of the vibrational ground state.

The standard radiometer used for all the measurements of the CBR at low frequencies is shown in Figure 2.

Different experiments may differ in details, but all the radiometers have the same components, i.e., a coherent receiver, a primary calibrator of absolute reference and an antenna. The experiment consists in comparing the radiation which enters in the antenna with that emitted by the primary calibrator. The gain of the receiver is determinated by the variation of the temperature of the primary reference or by the injection of a signal of know power at the receiver frontend. Weiss (22) gives detailed literature reference of the problems and techniques of observation used in the determination of the CBR spectrum at low frequencies.

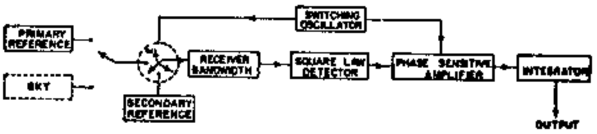

FIGURE 2 - Schematic diagram of a basic absolute radiometer used for the measurements of the CBR at low frequencies (Weiss (22), p.490,fig. 1).

The sources of sistematic errors in the determination of the BRT, can be substantially reduced by operating with all the receiver frontend and the calibrator under criogenic temperatures. The atmosphere even been a dominant noise source, can be taken into account at the spectrum regions where the total atmosphere absorption is small, less than ∿ 10%. This emissions can be measured at different zenital angles, using scan techniques (one must take into consideration that the atmosphere emission is linearly proportional to the emitters column density). The result depends only on the hipothesis that the atmosphere has a laminar structure (been homogeneous in each layer) and not depending upon other specific models. The temperature inhomogeneities, pressure and their constituints are in fact the largest sources of noise in the experiments made at the earth's surface. However, these inhomogeneities do not contribute as a sistematic error, unless the observation site is quite anisotropic. The contribution of the atmosphere and the CBR on the total brightness can in this case be separated without more measurements or modelling.

Since, at low frequencies, the atmosphere contribute primarily as a randon source of noise, it is expected to improve the measurements of the CBR with the improving of the receivers quality. Once the atmosphere becomes selfabsorber at high frequencies, its modelling becomes imperative (22).

Table 1 summarizes the CBR results from 16 research groups, using heterodine receivers for wavelengths between 73.5 > λ > 0.33 cm.

The high frequency experiments have passed through two generation of observational techniques. The first was the observations made using wide-band criogenic radiometers transported by rockets and balloons which were used for the technological development of the second and present generation of criogenic spectrometers of high resolution power. Reviews of the wide-

REFERENCE	λ (cm)	f (GHz)	ν (cm^{-1})	ALTITUDE (km)	BEAM WIDTH	CBR THERMODYNAMIC TEMPERATURE
Howell & Shakeshaft (23)	73.5	0.41	0.014	0	15	3.7 ± 1.2
	49.2	0.61	0.020			
Penzias & Wilson(24)	21.2	1.415	0.047	0	-	3.2 ± 1.0
Howell & Shakeshaft (25)	20.7	1.41	0.048	0	13 x 15	2.8 ± 0.6
Penzias & Wilson(15)	7.35	4.08	0.136	0	-	3.3 ± 1.0
Penzias (26)						
Roll & Wilkinson(27)	3.2	9.37	0.313	0	20	3.0 ± 0.5
Stokes et al. (28)	3.2	9.37	0.313	3.8	4	$2.69^{+0.16}_{-0.21}$
Stokes et al. (28)	1.58	19.0	0.633	3.0	4	$2.78^{+0.12}_{-0.17}$
Welch et al. (29)	1.5	20.0	0.666	3.8	12	2.45 ± 1.0
Ewing et al. (30)	0.924	32.5	1.08	3.8	20	3.09 ± 0.26
Wilkinson (31)	0.856	35.05	1.168	3.8	4	$2.56^{+0.17}_{-0.22}$
Puzano et al. (32)	0.82	36.6	1.22	0	4	3.7 ± 1.0
Kislyakov et al (33)	0.358	83.8	2.79	3	10	2.4 ± 0.7
Boynton et al. (34)	0.33	90.0	3.00	3.44	-	$2.46^{+0.40}_{-0.44}$
Millea et al. (35)	0.33	90.4	3.00	3.1 2.8	6.6	2.61 ± 0.25
Boynton & Stokes(36)	0.33	90.0	3.00	14.9	-	$2.48^{+0.50}_{-0.54}$

TABLE I - Heterodyne measurements of the CBR spectrum at low frequencies and microwaves.

band experiments are presented by Thaddeus (37) and Weiss (22). The worst and inevitable problems concerned to the high frequency measurements result from the fact that absolute observations are made by remote control, which require substancial engineering, resulting,in most of the cases, in very costy projects. In a second level of difficulties one has the interaction of the following facts: small periods of time for the observations, bad test facilities and low sensitivity detectors.

Since the environment where the experiment is made is not in thermic equilibrium, it is very difficult to simulate it on the ground. As a consequence the final tests for the detection of sistematic errors and calibration need to be made, in principle, during the development of the experiment, with the same observation conditions. The total observation time for the observations made by rockets is of the order of few minutes and about 10 hours for those made on balloons. For very high observations on balloons, the observational time falls to few hours because of stratosphere irregularities and strong winds.

Until the present time, all the spectroscopic observations of the CBR at high frequencies, have been made by Fourier transform spectrometers - Michelson interferometers. In these apparatus the incident radiation is divided into two directions, and later recombined after one part of the radiation is delayed since it needs to travel a path which is longer than the other. As a function of the time delay, the output is the radiation autocorrelation function which becomes the power spectrum after the Fourier transform (fig. 3).

The high frequency observations, $\nu > 10^{11}$ Hz ($\lambda < 3$ mm), were made only by the Queen Mary College, QMC, (41) and the Berkeley (42) groups.

The QMC's and Berkeley's deduced temperatures are respectively $2.7^{+0.2}_{-0.3}$ °K and $2.99^{+0.07}_{-0.14}$ °K. Apparently these data are similar; however, a careful analysis of the observed spectrum cods the spectations (43, 44). The problem remains in the way the atmosphere residual contribution was estimated and in its later substraction from the observations. Both groups criticised heavily each other about the techniques used and the uncertainty of the atmosphere contribution on the experiments.

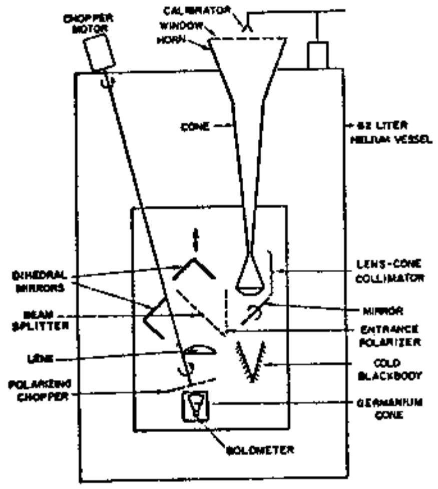

FIGURE 3 - The Berkeley polarizing Michelson interferometer (Weiss (22) p. 512, fig. 5).

In a CBR review, Weiss (22) criticise the QMC experiment pointing out the difficulties in weighting the results of the experiments of this group because of the inconsistency of the data and the incompleteness of the data related to the incident radiation on the instrument. He points out that the atmosphere emission estimation was not published by the QMC group. According to Weiss (22) the results of the second experiment using balloon, made by Berkeley are, at the present, the most precise measurements of the spectrum of the CBR, at high frequencies, using a Michelson interferometer (fig. 3). The results corrected for the instrument transform function are given in Table 2 and Figure 4 (Woody and Richards (40)).

A recent CBR results compilation has been made by Weiss (22), Fig. 10, which is here reproduced as Fig. 5. This figure gives an effective black-body source temperature when emitting the measured flux in the different experiments. The flux error bars are related to the temperature uncertainties by:

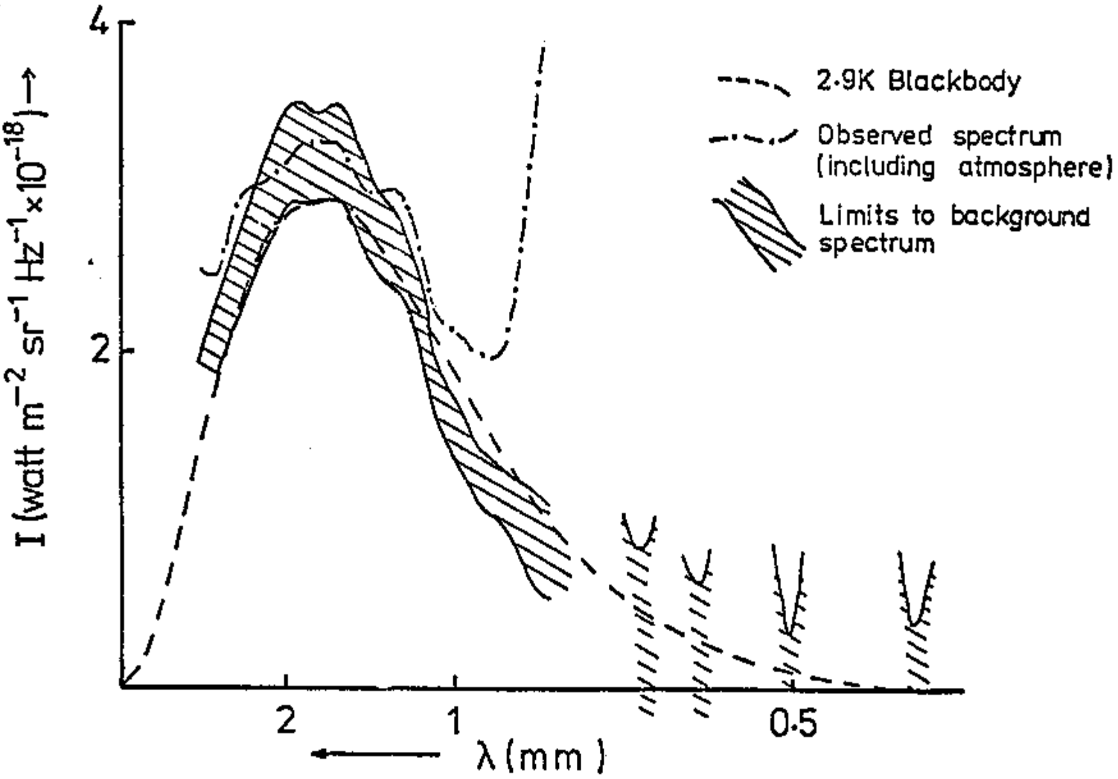

FIGURE 4 - Spectrum of the microwave background radiation. Gaps are due to the strong atmospheric absorption (Wood and Richards (40)).

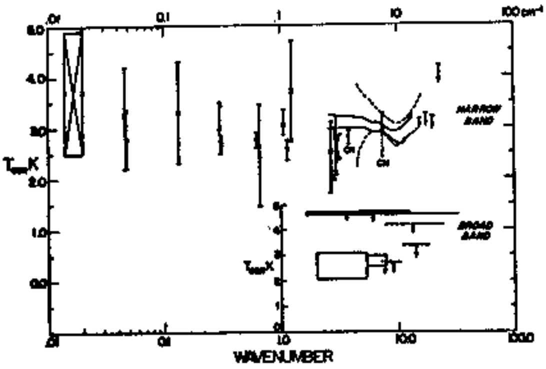

FIGURE 5 - Summary of the measurements of the thermodynamic temperature of the CBR as a function of frequency (Weiss (22), p. 518, figure 10).

$$\frac{\Delta T}{T} = \frac{x}{[\ell n(1+x)] - (1+x)} \cdot \frac{\Delta B}{B} \qquad (7)$$

where

$$x = (e^{h\nu/kT} - 1) \qquad (8)$$

Resuming one can say that the general shape of the microwave BCR spectrum is of thermic nature, characterised by only one parameter, the temperature. Considering the moderate precision of the observations at low frequencies and the uncertainties at high frequencies it is still to early to demonstrate, in a not compromising manner, the nature of the microwave spectrum of the CBR. In reality, because of the lack of agreement between the experiments at the submillimeter region, even the curvature point of the spectrum is still open to discussion. However, the observational data suggest that the shape of the CBR spectrum, at microwaves, is probably Planckian. From these observations one can see that it is to early to make a carefull analysis of the existing observational results, with the goal of determing possible spectral distortions and from this to infer models for the thermic evolution of the Universe.

ν (cm^{-1})	AVERAGE FLUX ($10^{-12} w/cm^2$ sr cm^{-1})	FLUX LIMITS 1σ min.	 max.	T_{CBR} LIMITS (K) 1σ min.	 max.
2.38	8.74	7.76	9.99	3.05	3.57
3.40	12.13	11.02	13.67	2.95	3.29
4.41	14.81	13.65	16.51	2.97	3.22
5.42	16.05	14.81	17.89	2.97	3.18
6.44	16.09	14.86	17.94	2.98	3.16
7.45	13.89	12.76	15.57	2.91	3.07
8.46	12.42	11.36	13.98	2.92	3.07
9.48	8.63	7.71	9.89	2.79	2.94
10.49	6.64	5.21	7.75	2.76	2.91
11.50	5.52	4.48	6.74	2.75	2.95
12.52	4.07	2.69	5.47	2.66	2.97
13.53	4.92	2.82	7.15	2.80	3.23
15.20	1.87	-	4.10	-	3.15
17.28	0.96	-	3.07	-	3.27
20.03	0.70	-	1.81	-	3.36
22.89	0.48	-	5.76	-	4.21

TABLE 2 - Results of the Berkeley experiments for the T_{CBR} measurements at microwaves (Weiss (22), table 3).

3 - THE GENERAL SHAPE OF THE CBR ELETROMAGNETIC SPECTRUM

The cosmic background radiation spectrum with the corresponding integrated energy densities for the different spectral regions, all frequencies, was estimated by Longair and Sunyaev (45) (see Fig. 6 and Table 3).

It is important to stress that the CBR was only detected at radio, microwave, X-ray and γ-ray frequencies; at the other regions such as infrared, optical, ultraviolet and soft X-rays, there are only upper limits or theoretical estimations of the contributions produced by point sources (Longair (1)).

One can see on Table 3, that the CBR energy density at microwaves, 0.25 eV cm^{-3} or 400 fotons. cm^{-3}, exceeds, by a large factor, the energy densities at the other regions where the CBR

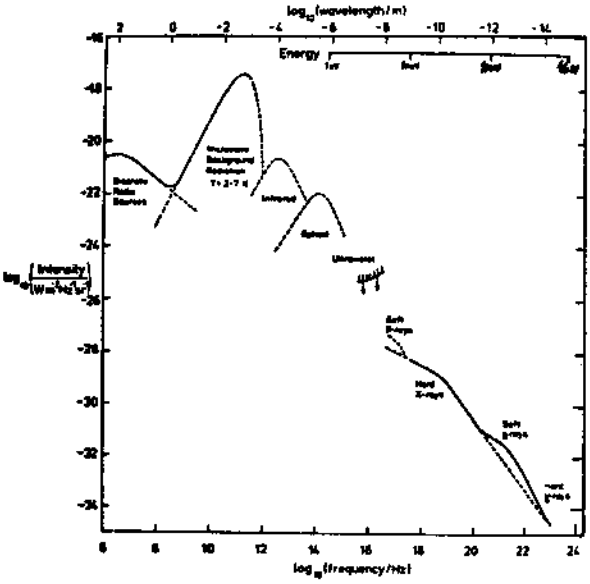

FIGURE 6 - The spectrum of the eletromagnetic background. Full lines represent observations and broken lines model expectations (Longair (1), p.139, fig. 2).

was detected. It is probable that the energy density of the CBR, at microwaves, is larger by a substancial factor than the corresponding energy densities of the optical and infrared regions. The energy density estimate for the optical region, given on Table 3, is close to the upper limits of the CBR intensity in these regions(Longair (1)). Longair (1) also points out that if the CBR at microwaves was due to discrete sources, they should be much more energetic than all known sources os radiation in all other spectral regions.

The CBR spectrum, at soft X-rays, is consistent with that expected by bremsstrahlung emission (Marshall et al. (46)) which is produced by the existence of hot intergalactic gas (Field and Perrenod (47)). McKee (48) concluded that only about 10% of the CBR could be produced by this way. It was suggested by Brecher and Morrison (49) that the X-ray photons could have been produced by Compton scattering between high energy electrons with CBR fotons, at microwaves. Nowadays, however, the attention is been concentrated on the idea that the CBR, at these frequencies, is produced by the integrated emission produced by active galaxies and clusters of galaxies.

WAVELENGTH RANGE	ENERGY DENSITY OF RADIATION (ev cm^{-3})	NUMBER DENSITY OF PHOTONS (cm^{-3})
1 - Radio		
a - Metre wavelengths	3×10^{-8}	0.3
b - Microwave background radiation	0.25	400
2 - Infrared	$\sim 10^{-2} - 10^{-3}$*	$\sim 0.1 - 1$*
3 - Optical	$\sim 3 \times 10^{-3}$*	$\sim 10^{-3}$*
4 - X-rays		
a - Soft X-ray energies (ε<1 keV)	$\sim 10^{-4} - 10^{-5}$	$\sim 3 \times 10^{-7} - 3 \times 10^{-8}$
b - Hard X-rays (1<ε<200 keV)	4×10^{-4}	10^{-8}
5 - γ-rays		
a - Soft γ-rays (1<ε< 10 MeV)	$10^{-4} - 10^{-5}$	$3 \times 10^{-11} - 3 \times 10^{-12}$
b - Hard γ-rays (ε < 30 MeV)	10^{-5}	10^{-12}

TABLE 3 - The energy density and number density of photons of the isotropic background radiation. These estimates are approximate

(*) Rough theoretical estimates (Table 2, from Longair (01), p. 138).

Astrophysicists are now attempting to estimate the contributions to the CBR, at X-rays, by:

- Seyffert galaxies: (Avni (50); Elvis et al. (51); Tananbaum et al. (52); Schwartz (53); Veron (54); Mushotzky et al. (55)).
- Young galaxies: (Bookbinder et al. (56)).
- Clusters of galaxies: (Rowan-Robinson & Fabian (57); Schartz (53)).
- Quasars: (Rowan-Robinson and Fabian (57); Setti & Waltzer (58); Tananbaum et al. (52); Bonoli et al. (59)).

In all these cases, however, it is been found there is a lack in the reproductivity of the CBR spectral shape and its intensity estimates in any particular frequency.

At γ-ray frequencies ($\nu > 10^{20}$ Hz), Strong, Wolfendale and Worrall (60) concluded that all the CBR from 1 - 10 MeV could be attributed to radio-galaxies if these objects had the same X-ray and radio luminosity ratios as the galaxy Cen A. Bignami et al. (61) pointed out that most of the CBR between 1 - 150 MeV could be explained by the emission of Seyfert galaxies, even though not considering the effects of evolution; however, Cheney and Rowan - Robinson (62) showed that Begnami et al. (61) based their studies on upper limits obtained from the γ-ray regions for Seyferts, so that this contribution is a maximum contribution.

Cheney and Rowan-Robinson (62) in their paper "The contribution of quasars to the 2 keV - 100 MeV background radiation and the X-ray source counts at 2 keV" concluded: "if we take into account the effects of the evolution which is required to explain optical counts of quasars to faint magnitudes, we conclude that a substantial amount, if not all, of the diffuse background in the energy range 2 keV - 100 MeV can be attributed to the quasar population. We can produce a reasonable fit to the observed background spectrum with our standard model over the whole range considered. This model also predicts that 30 per cent of the sources observed with the Einstein Observatory and 50 per cent of the unidentified Ariel V sources are due to quasars. We believe that the remaining sources are active galaxies of lower optical luminosity which have a higher ratio of X-ray to optical power than their optically more luminous counterparts, quasars, and which contribute a few per cent to the X-ray background at 2 kEv".

Since there is still doubt about the reality of the observed CBR spectrum curvature, at 10^{21} Hz (Trombka et al., (63)), Cheney and Rowan-Robinson (62) believe that their model reproduces very well the CBR intensity spectrum shape.

The above discussed fact associated to the observation that nowadays there is in the Universe more mass in the form of matter than radiation and that the existing amount of radiation in the Universe is still very large, together with the indication that the special shape of the CBR, at microwaves, is probably Planckian, incline the astrophysicists to believe strongly in the concept that the CBR, at microwaves, has a primordial origin not associated to discrete sources.

4 - THE CBR OBSERVATION ON THE OUTERSPACE

The CBR observation in the infrared, optical and ultraviolet regions must be made at the exterior space, using satellites or space platforms.

THE CIRBS PROJECT

The CIRBS project (Cryogenic Infrared Background Spectrometer) installed in a space platform "Spacelab", is an European Space Agency Project - ESA/SPICE with the participation of the University of London (Queen Mary College, Physics Department, QMC); the S.d'Aeronomie and L.P.Stellaire et Planetaire Laboratories of CNRS at Verrieres; the Instituto Ricerche sulle onde Eletromnetische of CNR at Firenze, IROE; the Space Science Department of ESTEC at Noordwijk, SSD; and the SRC, Appleton and Rutherford Laboratories at Chilton. The launch of

CIRBS is planned for January 1984 (Martin and Beckman (64)).

The principal objective of the CIRBS project is to measure the absolute intensity of the microwave background over the spectral range 3 - 50 cm^{-1} (0.2 - 2 mm) in order to:

I - establish (or refute) the near-Planckian character of the cosmic spectrum and determine its corresponding temperature with precision;

II - search for small deviations from the exact Planckian form;

III - investigate the variations of Galactic background (dust) emission with Galactic latitude and longitude;

IV - investigate the anisotropy of the cosmic spectrum in a large angular scale and, if possible, in the direction of clusters of galaxies;

V - make such other observations with the radiometer as may be possible during those periods of the mission when the above measurements (I to IV) are ruled out (extended sources in the Galactic plane).

THE_COBE_PROJECT

The COBE project (Cosmic Background Explorer) consists in one experiment of the USA Spacial Agency - NASA - with the goal of measuring the spectrum of the CBR, especially at high frequencies and its large angular scale intensity distribution. The NASA plan is to fly the COBE mission in the early 1985, and conclude it by 1986.

The FIRAS (Far Infrared Absolute Spectrophotometer) should measure the spectrum of the CBR. It consists of a Michelson interferometer devided into two bands, 1 - 20 cm^{-1} and 20-100cm^{-1}, with a minimum resolution width of 0.2 cm^{-1} at long wavelengths and a 5% resolution at short wavelengths. The beam is 7^o. The expected sensitivity for each field of view, in a one year mission is ~ 10^{-13} $W/cm^2.sr$.

The DIRBE (Diffuse Infrared Background Experiment) is incorporated in the COBE project in order to:

I - measure the interstellar dust emission which may contaminate the CBR spectrum;

II - perform an all-sky survey of the diffuse infrared background from 1 to 250 microns.

The instrument is a multiband filter absolute photometer with a 1^o field of view. Four differential radiometers operating at 23, 31, 53 and 90 GHz are included. Each radiometer compares the radiation of two patches of the sky 60^o apart. The expected sensitivity in a one year mission is 0.3 mK in each of 1000 independent elements of the sky (Weiss, (22)).

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