Persistent band heads of second positive system of N_2 and First negative system of N_2^+ in the spectra of Lightning

Nayanjyoti Dehingia, Gaurangadhar Baruah

Department of Physics, Dibrugarh University, Dibrugarh, Assam, India

Abstract

The spectra of cloud to ground lightning flash data have been analyzed for the three year period 2005-2008, for a geographical area centered on Dibrugarh ($27^o.29^/$ N, $94^o.58^/$ E), Assam, India. Of the fifty spectra recorded on a Quartz spectrograph thirty exhibited only continuum. The remaining spectra indicated the clear presence of the persistent band heads of the second positive band system of molecular nitrogen. The spectra of lightning with reference to the (0,0) bands of the 2^{nd} positive system of nitrogen has been recorded for the first time with the help of a conventional Q-24 medium quartz spectrograph. It would follow that molecular nitrogen is the predominate species which reveals itself as a persistent band heads belonging to the 2^{nd} positive system. The (0,0) band of the second positive system is observed in most of the spectra, but with different intensities. In some cases the first negative system of singly ionized molecular nitrogen (N_2^+) is also observed. It is evident that the spectra photographed with lightning furnish information of great value in regard to the identification of the material present in the atmosphere.

Key words: Lightning, N_2, Second positive, (0,0) band

Introduction

The phenomenon which forms the subject of the present work is concerned with the spectroscopic observation of lightening made with the help of a spectrograph with photographic arrangement. The physics of lightning discharge still presents unsolved and mysterious puzzles. As Feynman[1] who gives a delightful account of lightning in his famous book, remarks "The fundamental origin of lighting is not really thoroughly understood. We only know it comes from thunderstorms". When talking about the practical use Raman[2] writes "the electrical energy dissipated in an average thunderstorm is quite a formidable one". The phenomenon itself is beautiful and the mystery associated with the phenomenon is still there. As is well known, it all started with the work of Benjamin Franklin, who demonstrated the idea put forward earlier by him that the lightning in clouds is an electric discharge of the same general nature as can be obtained on a much smaller scale in the laboratory. The study of atmospheric electricity has been continued by generation of physicists with unabated vigour and interest. Though the duration of lightning is small, the light from the lightning can be photographed with the help of a dispersing instrument like spectrographs. It is generally believed that the origin and evolution of the atmosphere are intimately related to the origin and evolution of life on our planet. It is generally believed that the simple molecules in the early atmosphere energized by atmospheric lightning and solar ultraviolet (UV) radiation abiotically formed complex organic molecules via atmospheric reactions.

Early laboratory experiments on chemical evolution using Jupiter like mixtures of CH4, NH3 and H2 exposed to lightning and solar UV radiation resulted in the production of complex organic molecules needed for the origin of life[3].

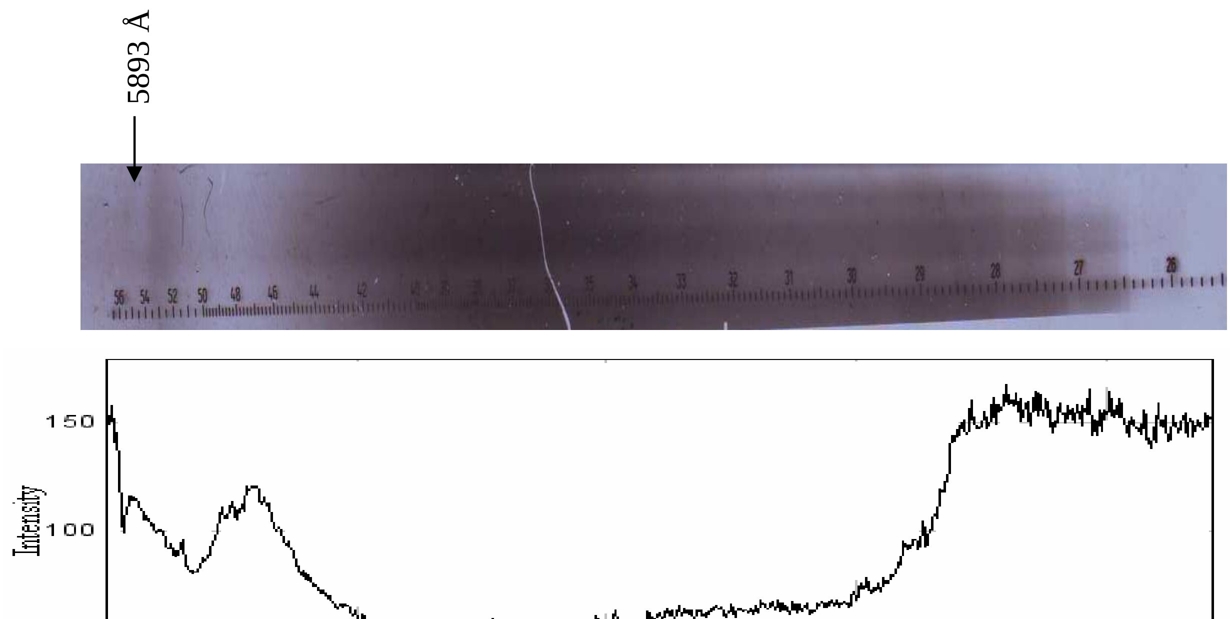
During the interval 1958-1962 a number of spectrograms of lightning were reported [4-6]. An analysis the spectrograms recorded by early workers indicates the presence of nitrogen, singly ionized nitrogen (N_2^+), Ne, H_α, O_2 and many unidentified features. Apart from these there are also other workers who reported the spectra of lightning covering a range from 3000 to 9000Å. We may emphasize here that the spectra of lightning discharge has been subject of continuous scientific study for nearly a century. These analyses had to cope with the problems of using photographic films as detector and its inherent nonlinear response to radiation as function of intensity and wavelengths. It is reasonable to believe that the spectra of lightning are dependent on environments. In this work we report the lightning flash spectra recorded during 2005-2008, for the geographical area centered on Dibrugarh ($27^0.29^/$N, $94^0.58^/$E). The dispersing instrument used is a Q-24 Medium Quartz spectrograph.

Materials and Methods

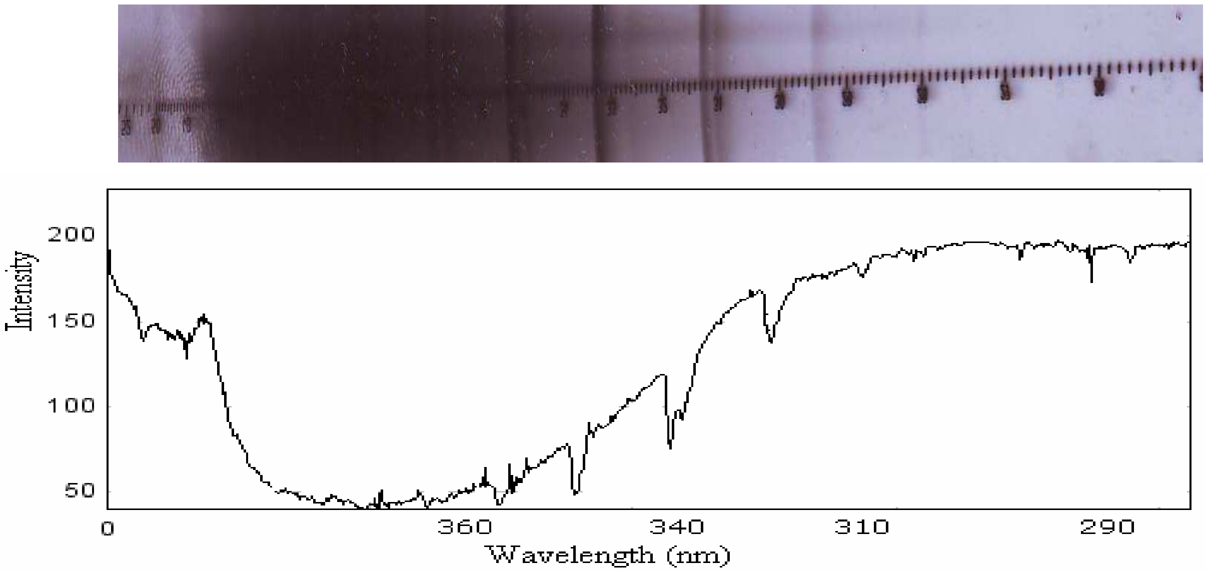
The spectra of cloud to ground lightning flash data have been analyzed for the period 2005-2008, for the geographical area centered on Dibrugarh ($27^o.29^/$ N, $94^o.58^/$ E),Assam, India. The dispersing instrument used is a Q-24 Medium Quartz spectrograph. The intensity of the bands have been measured with the help of a computer software available for the purpose. The experiments are conducted during night only and back ground lights such as those originating from street lights are avoided. The CG lightning flash is sufficiently intense which usually blackens a photographic film. We have used a condensing lens of quartz, and the flash from the lightning is allowed to fall on the condensing lens and a multimode optical fiber a so arranged that one side is kept just in front of the slit of the spectrograph and the other side is kept at the focus of the lens. With this simplified arrangement it is possible for the radiation from the lightning flash to be directed to the slit and illuminate it. Three to four flashes are needed to photograph the spectra on a commercially available film (Kodak 125 ASA). The intensity measurements of the bands are measured with the help of a computer software.

Results and Discussion

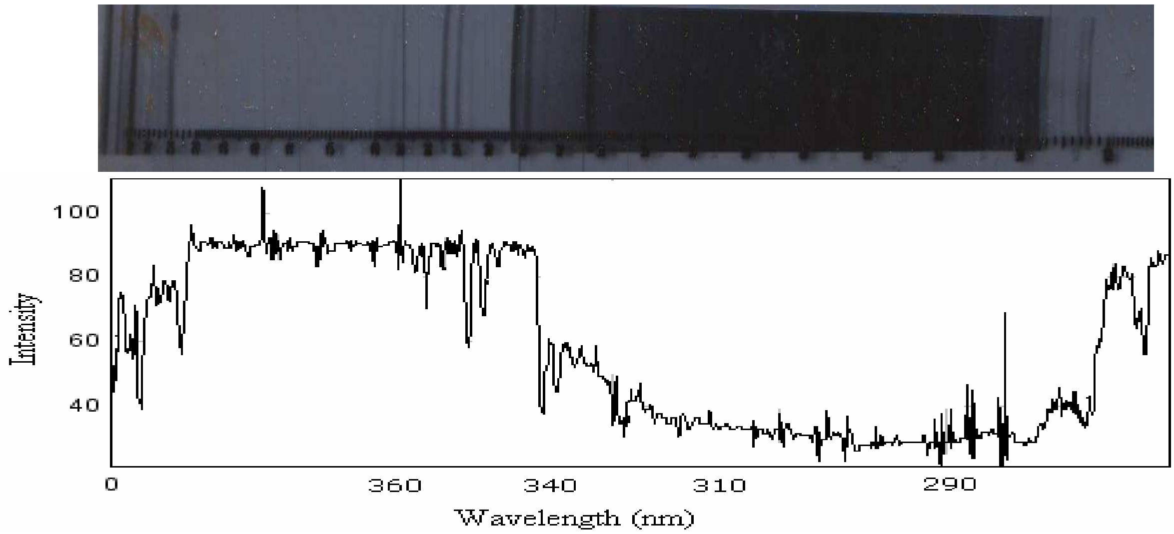
Out of fifty spectra recorded on a Quartz spectrograph only nine spectra exhibited some band structure, with the remaining showing only continuum. The spectra which showed some discrete band structure are exhibited in Fig. 1(a, b, c, d, e, f). Fig.2 shows the 1st and 2nd positive band systems of molecular nitrogen excited with the help of transformer discharge and photographed on the same dispersing instrument (Q-24 Medium Quartz Spectrograph). The intensity measurements of the bands are shown along with the spectra for convenience. The spectrum of N_2 photographed on a Quartz spectrograph is used for proper identification of the persistent band heads which appear in the spectra of lightning. Thus the 2nd and 1st positive band systems of N_2 molecule are serving as reference for identification in our present work related to the spectra of lightning. It may be noted that there are more than 2000 persistent lines and band heads in the range of wavelength 1000Å-2000Å, which are originating from specific molecules and radicals, and well documented in literature [7]. The objective of this table [7] is to provide a clue to the nature of the unknown band system as quickly as possible, so that it may be compared directly with the appropriate detailed list.



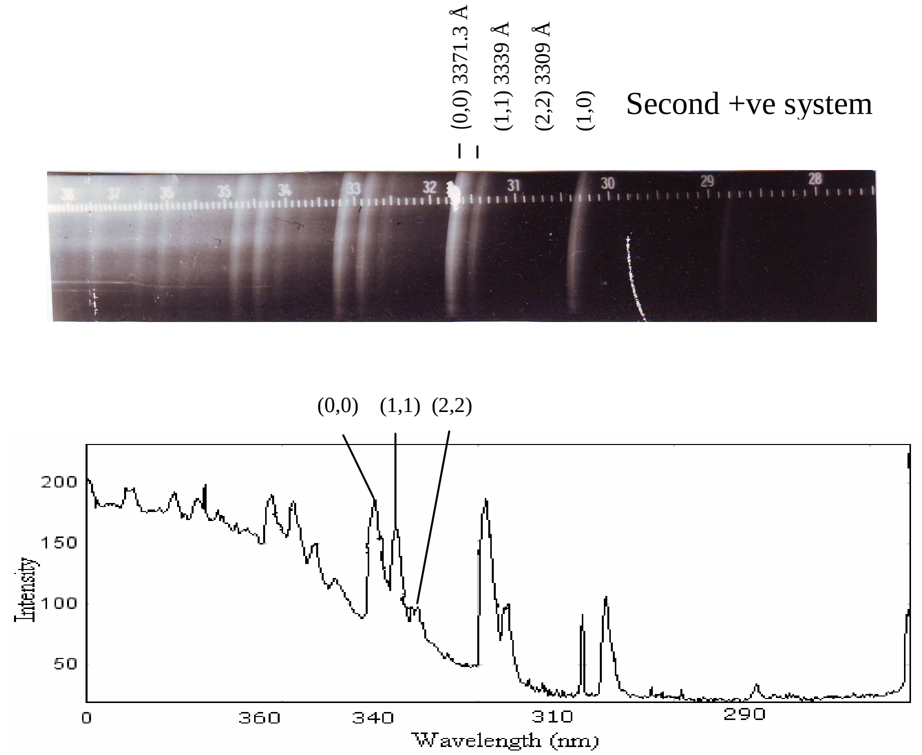
(a)


Intensity
200
150
100
50
0
360
340
310
290
Wavelength (nm)

(b)

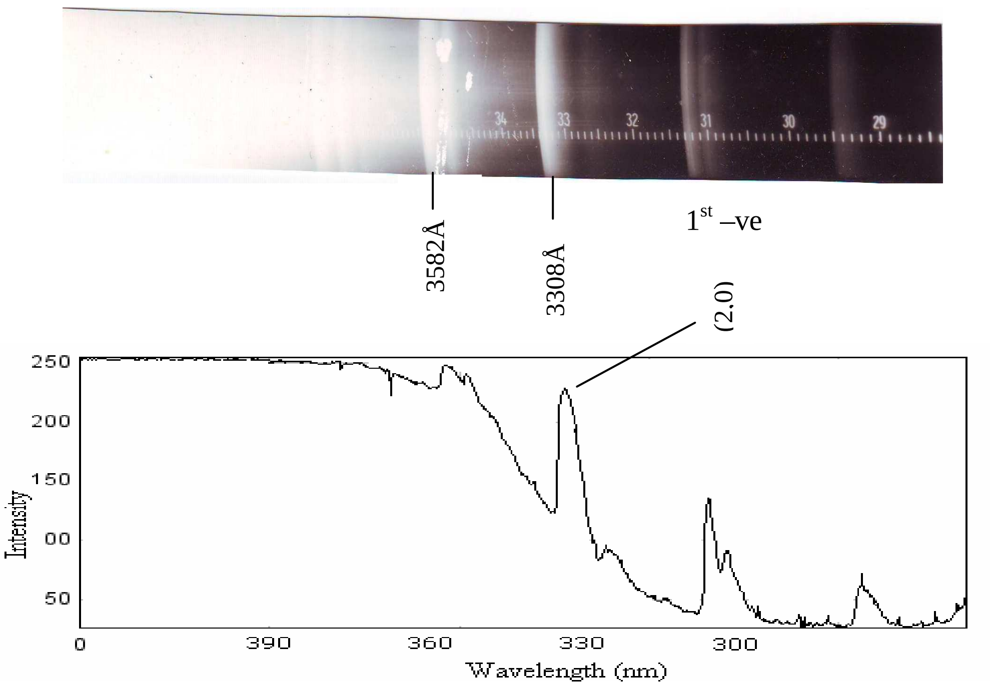

Intensity
100
80
60
40
0
360
340
310
290
Wavelength (nm)

(c)



(d)

First Negative



(e)

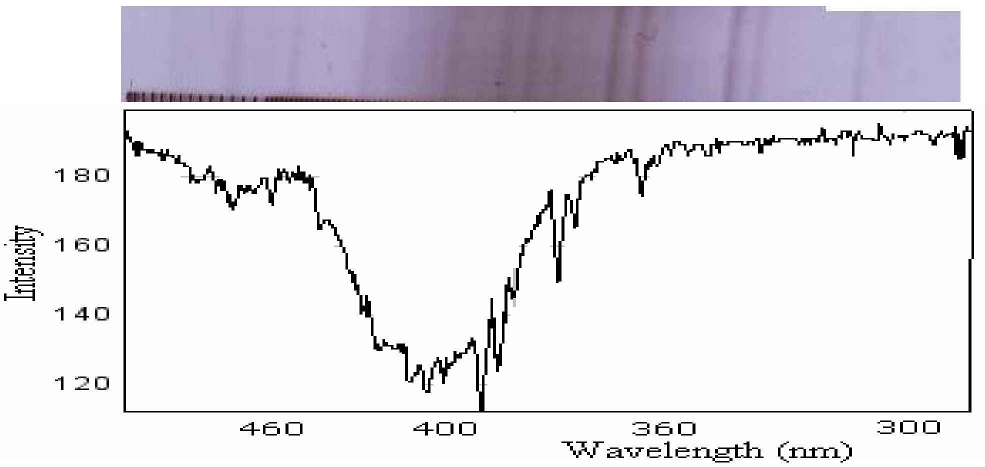


Fig.1(a,b.c,d,e,f): The spectra of lightning recorded with the help of a Q-24 medium quartz spectrograph.

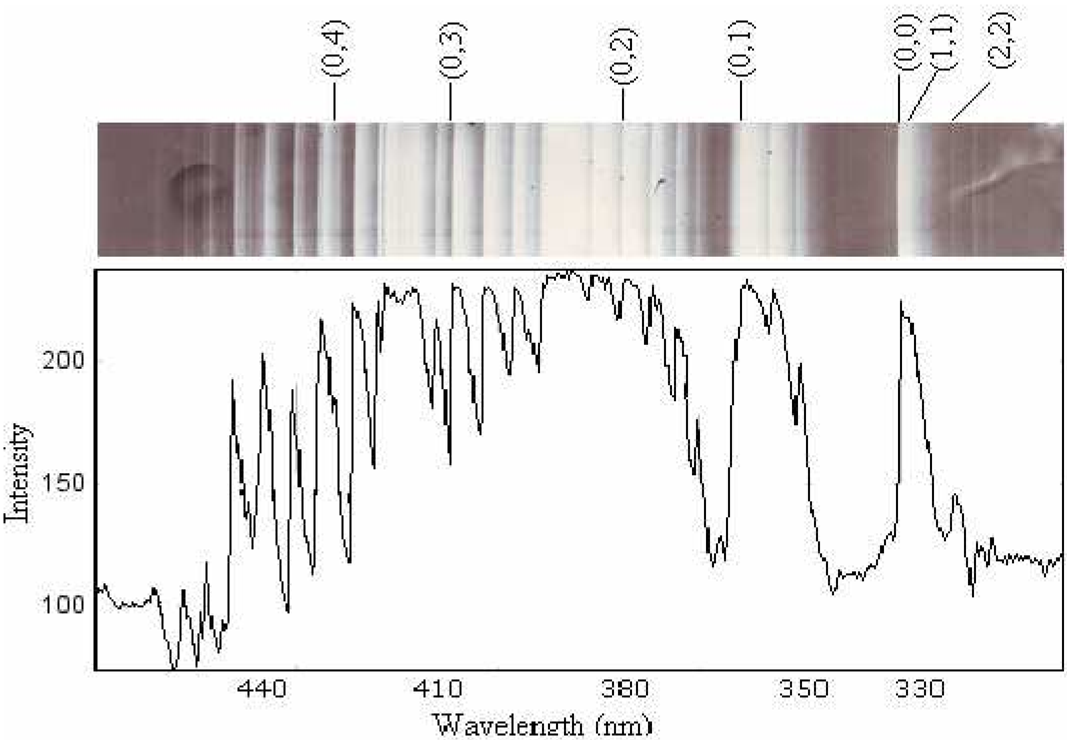


Fig.2: The second positive band system of molecular nitrogen observed with the help of a Q-24 medium quartz spectrograph using a discharged tube containing nitrogen gas at low pressure.

Under normal conditions it would have been difficult to identify the spectra of the lightning, but the spectra of lightning reported by earlier workers made it reasonably easier to identify the spectra in the present work. Actually, there is no difficulty what ever in perceiving and recognizing the N_2 band heads which appear even with feeble intensity and sometimes with continuous background. As may be inferred from

Fig.1(a) there is a continuous emission in the wavelength region of 3000-4500 Å. In the visible range there are few discrete bands in the region of wavelength 5000 to 5900 Å. It is difficult to identify these bands. They are presumably not the First positive system of bands of molecular nitrogen. But it is similar to Gaydon's green system [7] which lies in the range 5047.0 Å to 6336.3 Å. From Fig.1(b) we observe that the (0, 0), (1, 0) and (0, 1) band heads of N_2 second positive system appear prominently. The long wavelength system also exhibits three distinct bands similar to those seen in the spectrum exhibited in Fig.1(a). This feature is also to be seen in Fig.1(c). Fig.1(c) also shows the spectra representing the band heads of the second positive system of molecular nitrogen but there are other bands in the lower wavelength side which are marked by continuous background. It is of sufficient interest to examine critically the spectra as exhibited in Fig.1(d) and Fig.1(e). The spectrum as shown in Fig.1(d) shows clearly the persistent band heads of molecular nitrogen at 3371.3 Å (0, 0), 3339 Å (1, 1), 3809 Å (2, 2) along with other band heads belonging to the second positive system ($C^3\prod \rightarrow B^3\prod$). However the spectrum as shown in Fig.1(e) is identified as belonging to the First negative system due to ionized species N_2^+[8-10]. The transition is $B^2 \sum^+_u \rightarrow X^2\Sigma^+_g$. The persistent band heads at 3582 Å (1, 0) and 3308 Å (2,0)can be easily identified. Appearance of the band heads belonging to N_2^+ is supported by the observations of the earlier workers. It is worthwhile to note that the (2, 0) band at 3308 Å is sufficiently strong. It is also worthwhile to note the persistent band heads belonging to the violet system of CN ($B^2 \sum$ — $A^2\prod$) were observed at 3883.4 (0, 0), 3871.4 (1, 1), 3861.9 (2, 2), 3854.7 (3, 3) and 3850.9 Å (4, 4) by earlier workers in the spectra of lightning. In the present work we observe that there is a strong continuum in this region and hence the presence of the persistent band heads corresponding to the (0, 0) band and the sequence bands (Δv=0) could not be identified. Generally the CN violet system occurs in carbon arc in air, in discharge tube containing nitrogen and carbon compounds and when carbon compounds are introduced into active nitrogen. These bands also occur in arcs between carbon poles, in shocks, flames and in many stellar sources, spectra as represented in Fig.1(f) also show the features similar to those exhibited by the persistent band of molecular nitrogen.

Conclusion

The spectra of lightning with reference to the band heads of the 2^{nd} positive system of nitrogen has been recorded for the first time in North-East India using a conventional Q-24 medium quartz spectrograph. From the considerations set forth above, it would follow that molecular nitrogen is the predominate species which reveals itself as a persistent band heads belonging to the 2^{nd} positive system. In some cases ionized species (N_2^+) are also detected. It is evident that the spectra photographed with lightning furnish information of great value in regard to the identification of the material present in the atmosphere. In the present work, we could identified only few species. Though in the spectra of lightning revealed the presence of additional species like CN, C_2 and triply lionized Nitrogen. Our work is concerned with lightning at Dibrugarh only. The Q-24 medium quartz spectrograph has a good light gathering power and is reasonably good for the purpose. Though it is a classical spectrograph we have coupled the spectra recorded with the computer software for measurement of intensity. This gives us an additional advantage as compared to some modern equipments equipped with CCD devices.

Acknowledgment

Authors are thankful to UGC for a research grant F. No. 33-18/2007 (SR) dated 28th Feb. 2008.

References

1) Feynman R. P.: *Lecturers in Physics* (Addison-Westley, Reading, Mass, USA, **1964**) Vol. 2, Chapter9.
2) Venkataraman G.: *Journey into Light, Life and Science of C.V. Raman*, Penguin Books India (**1994**).
3) Millar S. L **1953**, *Science*, 117, 528-529.
4) Wallace L., *J. Geophys*. Res. 6, No 65, 1211 (**1960**).
5) Wallace L., *Ap J. Suppl*, 6, No 62 (**1962**)
6) Barasch G.E., *J. Geophys*. Res. 75, 1049-1057 (**1970**).
7) Pearse RWB and Gaydon A. G., *The identification of Molecular Spectra* (zd; London, Chapman and Hall) **1950**.
8) Merton T. R., and Pilley J. G.: *Phil. Mag*. **50**,195 (1925).
9) Herzberg G., *Ann. Phys. Lpz*. **86**, 189 (1928).
10) Douglas A. E., *Astrophys. J*., **117**, 380 (1953).