Chapter 21

Solving the Carrier Mystery of Diffuse Interstellar Bands by CFLE Theory

21.1. Discovery and History

Diffuse interstellar bands (DIBs) are absorption features seen in the spectra of astronomical objects. The origin of DIBs has remained unknown for 90 long years and is hotly disputed.

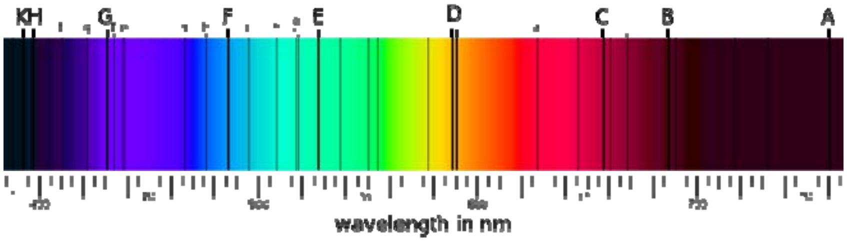


Figure 21-1-1. Usual absorptions features.
(Source: http://en.wikipedia.org/wiki/File:Fraunhofer_lines.svg)

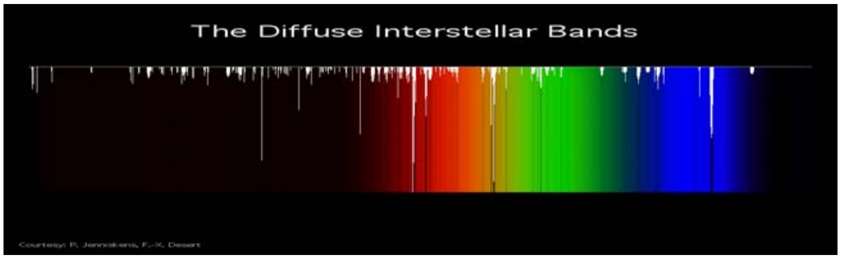


Figure 21-1-2. Absorption features of diffuse interstellar bands.
(Source: http://en.wikipedia.org/wiki/File:Diffuse_Interstellar_Bands.gif. © NASA)

The strongest DIB, at wavelength 4430Å, was initially observed by Annie Jump Cannon, the first astronomer to classify stars systematically by spectroscopy between 1911 and 1919. The first reports of DIBs observation occurred after 1919 and the first DIB publication appeared in 1922 by astronomer Mary Lea Heger (Figure 21-1-3A), then a graduate student at Lick Observatory. She noted the presence of two broad features at 5780Å and 5797Å that appeared to be interstellar in origin.

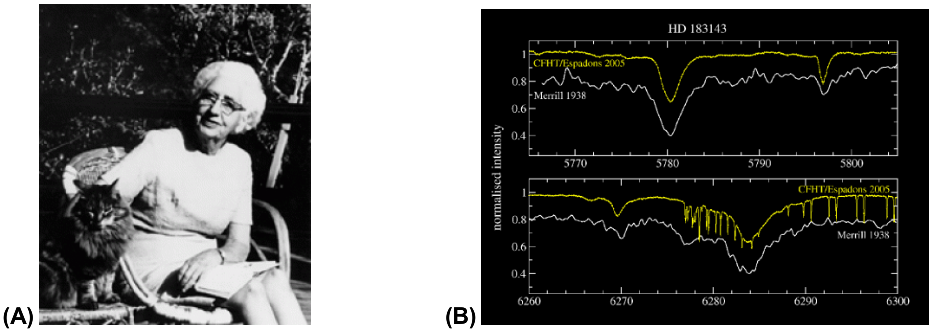


Figure 21-1-3. (A) Mary Lea Heger in 1969. (B) Merrill observed these DIBs. **(Source: (A) © UC Santa Cruz University Library. (B) http://cab.inta-csic.es/molecular_universe_2011/contributions/oral_id_127.pdf)**

More than a decade later Paul Merrill (1938) began the first of many systematic studies of these bands. Henry Norris Russell, Pol Swings, Meghnad Saha, and Otto Struve, all considered fathers of modern astrophysics, commented that the DIBs were likely to have molecular origins. Between the 1930s and 1970s, however, most astronomers interested in the DIB problems favored a non-molecular origin. Instead of gas-phase molecules in the interstellar medium, dust grains with impurity centers became the flavor of the day. Later, spectroscopy studies at higher spectral resolution and sensitivity discovered more and more DIBs.

A catalog of 25 known DIBs was published in 1975, and a decade later the number had more than doubled. The first detection-limited survey was published by Peter Jennisken and Xavier Desert in 1994, which was read to the first conference on DIBs at the University of Colorado in Boulder, on 16 May 1994. Currently, more than 400 bands have been observed in the UV, visible, and IR wavelengths. Their characteristics were summarized by Snow and McCall in 2006. The movement away from molecular explanations was based primarily on the good correlation of DIB strength with interstellar dust extinction, and on perceived improbability of forming and maintaining a significant population of molecules in the diffuse interstellar medium where the DIBs reside. The literature on DIB/dust extinction was summarized by Friedman *et al.* in 2010.

Several hypotheses have been put forward for the origin of DIBs, the most prominent among these being the carbon chain and polycyclic hydrocarbon cations put forward by Herbig in 2000; the bare carbon chain suggested by Maier *et al.* in 2003; the naphthalene cations suggested by Iglesia-Groth *et al.* in 2008; and the diacetylene cations suggested by Krelowsky *et al.* in 2010.

21.2. Mysterious Properties and Problems of DIBs.

The following section lists the unsolved phenomena of DIBs.

1. DIBs were long believed to originate from polycyclic aromatic hydrocarbons (PAHs) and other large carbon-bearing molecules and fullerenes (Figure 21-2-1).

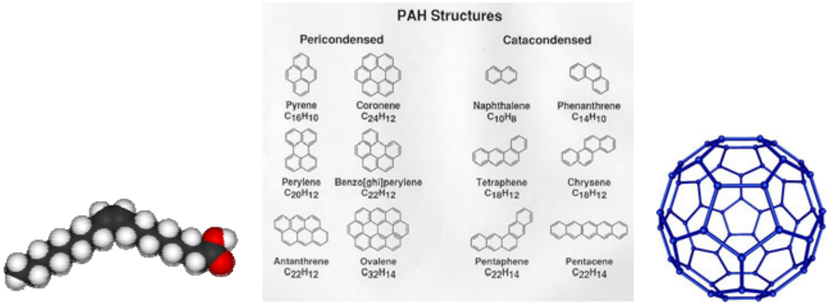


Figure 21-2-1

However, no agreement of the bands with any laboratory measurements or theoretical calculations could be found. The most apparent problem with DIBs was that their central wavelengths did not correspond with any ion or molecule. Therefore, the material responsible for the absorption could not be identified

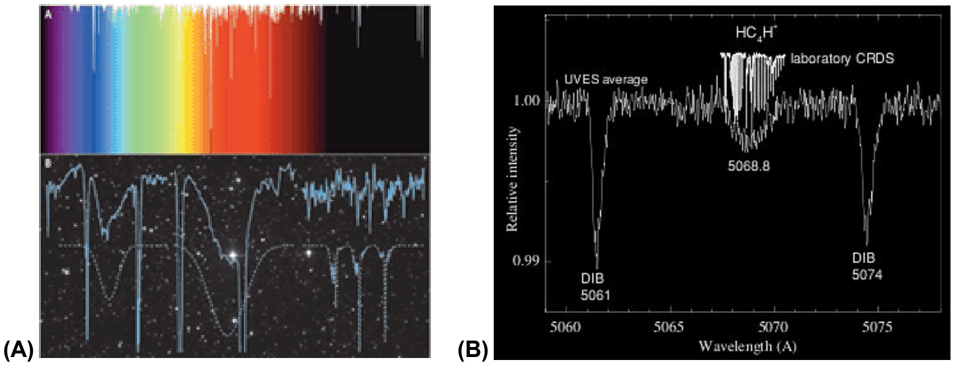
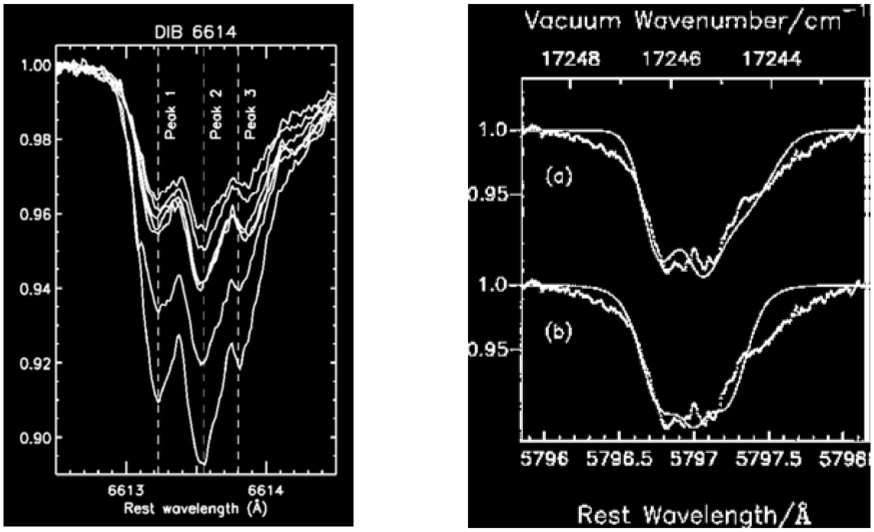


Figure 21-2-2. (A) DIBs of the star HD 183143. Laboratory data for $l - C_3H_2$ shown as dashed line. (Source: Takeshi Oka and BJ McCall, "Disclosing Identities in Diffuse Interstellar Bands." *Science* 2011; 331: 293; © Palomar Optical Sky Survey.) (B) DIBs of the diacetylene cation. (Source: Krelowski *et al.* "Evidence For Diacetylene Cation As The Carrier Of A Diffuse Interstellar Band. "*The Astrophysical Journal Letters*, 2010, 714: L64-67; doi:10.1088/2041-8205/714/1/L64 © AAS). Reproduced with permission.

A large number of theories were advanced as the number of known DIBs grew, but determining the nature of the absorptions material (the carrier) still ended in failure. Therefore, the carrier problem has become a crucial mystery in physics and especially astrophysics.



Cami *et al.* 2004 **Kerr *et al.* 1996**

Figure 21-2-3. Examples of DIB spectra: Strong evidence for large carbonaceous gas-phase molecules. **(Source: *left panel:* Cami *et al.* "The Rotational Excitation Temperature of the λ6614 Diffuse Interstellar Band Carrier."*The Astrophysical Journal*, 2004,** 611, **L113; doi:10.1086/423991. © AAS. *Right panel*: Kerr *et al.* "Molecular rotational contour fitting of ultra-high-resolution profiles of diffuse interstellar bands."*Monthly Notices of the Royal Astronomical Society* 1996, 283(4): l105-l109; © OUP.). Reproduced with permission.**

2. DIBs are significantly better correlated with atomic hydrogen than molecular hydrogen.
3. Some narrow DIBs show a structure possibly consistent with rotational bands. Broad DIBs generally do not show structure.
4. DIBs have very small depth. There are none 20% down from the continuum. Most are less than 5% below continuum and less than 30 mÅ in equivalent widths.

   The strongest DIBs detected have equivalent widths of over 2000 mÅ, and the weakest detected so far is less than 1 mÅ. All known DIBs are detected between 4000 and 10,000 Å, except for two in the infrared region at 1.18 and 1.32 μm (Joblin *et al.*1990).

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5. Most are in the red range, and almost none are in the blue range. They are almost in the limited wavelength region.
6. DIBs display a large range in width, central depth, and equivalent width. The narrowest lines have full width at half maximum (FWHM) less than 1 Å, whereas the broad DIBs have FWHM in the order of 30 Å.
7. Several DIBs have been studied in searches for polarization, with no positive results.
8. Between DIBs, there are poor correlations. Only one pair of DIBs comes close to being perfectly correlated. This means that there are many carriers. To date, more than 400 DIBs have been discovered.
9. Several studies of various types of stars with circumstellar material do not show DIBs, despite many searches.
10. DIBs central wavelengths show little to no shift between sightlines. Namely, they have invariant central wavelengths.
11. DIBs in emissions have only been observed in the red rectangle and toward one other star. DIBs can be founded rarely in emissions.
12. No DIBs have shown emission wings in any environment.
13. All DIBs, whether strong or weak, grow linearly with increasing extinction. This means that in DIBs, there is lack of saturation.
14. All correlations with extinction are good (i.e., the correlation coefficients are generally 0.7), including UV extinction.
15. Slightly different sets of DIBs are seen in different environments. They are not constant everywhere. One factor seems to be cloud density, from diffuse to translucent.
16. Many DIBs are asymmetric, although some of the broad ones are symmetric. The profiles are invariant in most lines of sight

21.3. Solving the Mysterious Properties of DIBs by CFLE Theory

All of such mysterious properties of DIBs can be explained qualitatively and quantitatively by introducing the galactom and galactomic elements (see §11).

The galactron mass is

$$m_{\text{gal}} = 1.084224 \times 10^{-23} \text{ kg} \qquad 21\text{-}3\text{-}1$$

The galactric charge of the galactron is

$$e_{\mathrm{gal}} = -1 \tag{21-3-2}$$

The relativistic electric charge of the galactron to the proton is

$$e_{\mathrm{gal}}^{\mathrm{ele}} = -1 \tag{21-3-3}$$

Galacton mass is

$$m_{\mathrm{gal}} = 1.990799 \times 10^{-20}\ \mathrm{kg} \tag{21-3-4}$$

The galactric charge of the galacton is

$$e_{\mathrm{gal}} = +1 \tag{21-3-5}$$

The relativistic electric charge of the galacton to the proton is

$$e_{\mathrm{gal}}^{\mathrm{ele}} = +1 \tag{21-3-6}$$

The system of the galactom is as shown in Figure 21-3-1.

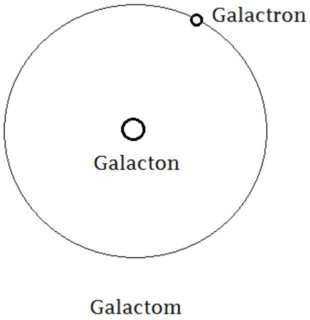


Figure 21-3-1

However, despite that the galactron's tremendous mass does not occur by curved force lines (meaning it is without substructure), at the same time this particle can behave as a regular electric solar atomic nucleus that usually has a mass bigger than an electron by curved force lines (meaning with substructure), instead of the curved space–time continuum, as mentioned in §7.

That is,

$$R = \frac{m_{\mathrm{galactron}}}{m_{\mathrm{proton}}} = \frac{1.084224 \times 10^{-23}\mathrm{kg}}{1.672648 \times 10^{-27}\mathrm{kg}} = 6.482081 \times 10^{3} \tag{21-3-7}$$

However, this ratio is only that between the gravitational rest mass of two particles by the gravitational force line, as a final force line, without the concern of the correspondent nuclear mass at the relativistic electric charge ($e_e = -1$) state of the galactron. In this ratio rest state, any particle cannot feel regular unit electricity. For a relativistic ratio to be reached between the correspondent nuclear mass at the relativistic electrical charge $e_e = -1$ state of the galactron and proton, this ratio is changed as much as

$$\begin{aligned} R_e^m &= \frac{6.482081 \times 10^3}{g_m^8 \cdot g_e^8 \cdot g_g^8} \\ &= \frac{6.482081 \times 10^3}{(8)\,(8)\,(8)} \\ &= 12.660315 \qquad \text{21-3-8} \end{aligned}$$

where g_m^8 is the possible maximum relativistic change of the gravitational force line curve to the proton; g_e^8 is the possible maximum relativistic change of the electrical force line to the proton; and g_g^8 is the possible maximum relativistic change of the galactic force line curve from the flat force line state $g = 1$ of the galactron rest mass to $g = 8$ for the correspondent nuclear mass of the galactron to the proton, which from this galactron mass state starts to exert a strong influence as the electric charge ($e_e = -1$) moves around the galactron with almost near relativistic light speed.

Because the gravitational and electrical permittivities by the three kinds of force line are

$$Q = 0.016774, \quad x_g = 1.016774, \quad x_g^3 = 1.051171 \qquad \text{21-3-9}$$

$$Q = 0.000589, \quad x_e = 1.000589, \quad x_g^3 = 1.001768 \qquad \text{21-3-10}$$

The total difference by the permittivity is

$$\begin{aligned} x_g \cdot x_e &= (1.051171)\,(1.001768) \\ &= 1.053029 \qquad \text{21-3-11} \end{aligned}$$

The final correspondent nuclear mass at the starting state of the relativistic electric charge of the galactron ($e_{gal}^e = -1$) to the proton is

$$e_{gal}^{e.m} = \frac{12.660314}{1.053029}$$

$$= 12.022759 \approx 12 \qquad 21\text{-}3\text{-}12$$

Among the solar atomic elements, only carbon (C_6^{12}) can have an electric charge of $e_e = \pm 1$ with mass number $A \approx 12$.

With this result of CFLE theory, therefore, we can finally explain the property of DIBs described in §21.1, and why many spectroscopists and chemists have believed for 90 long years that the main carrier of DIBs should be carbon.

But because the relativistic electric charge of galactrons is $e_{\text{galactron}}^{12} = -1$, a galactron can attract one hydrogen nucleus that has the electric charge $e_{\text{hydrogen}}^{1} = +1$.

Therefore, the final system of the galactom is as depicted in Figure 21-3-3.

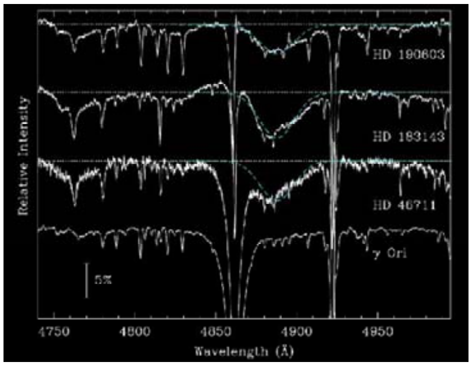


Figure 21-3-2. Strong evidence for H_2CCC (Source: Maier *et al*. "Identification of H2CCC as a Diffuse Interstellar Band Carrier" *The Astrophysical Journal*, 2011, 726: **41. doi:10.1088/0004-637X/726/1/41 © AAS. Reproduced with permission.)**

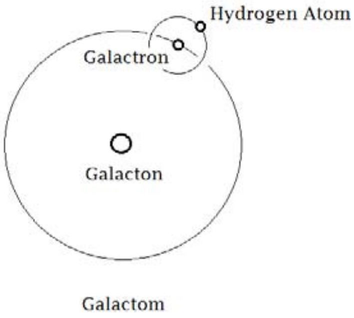


Figure 21-3-3. The galactom system.

This system has similarity with the galaxy system depicted in Figure 21-3-4.

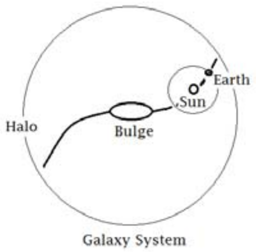


Figure 21-3-4. The galaxy system.

The positively charged galactom plays the role of the center of the galaxy, while the negatively charged galactron plays the role of the Sun. Meanwhile, the positively charged hydrogen atom plays the role of Earth.

Here, the very important difference is that in the solar atomic system, the electron plays the role of the transition particle upon energy absorption; but in the galactomic system on the galactron, the hydrogen atom plays this role of the transition particle.

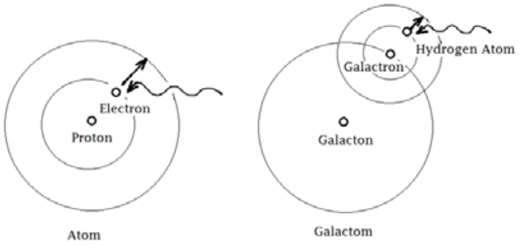


Figure 21-3-5

Because the maximum force line curve of a galacton is also $g = 6.545979$ by the correspondence principle of CFLE theory, the maximum permitted quantum number for hydrogen transition is

$$n = 2(6)^2$$

$$= 72 \qquad 21\text{-}3\text{-}13$$

According to Schrödinger’s equation, the electronic transition energy is separated by the quantum number and spin number by as much as

$$E = \frac{\mu Z^2 e^4}{(4\pi\varepsilon_0)^2 2\hbar^2 n^2}$$

$$= \frac{-13.6\ \mathrm{eV}}{n^2} \Rightarrow \frac{-13.6\ \mathrm{eV}}{36} \Rightarrow \text{after Dirac's spin}$$

$$\Rightarrow \frac{-13.6\ \mathrm{eV}}{2 \times 36} \Rightarrow \frac{-13.6\ \mathrm{eV}}{72} \qquad \text{21-3-14}$$

However, the protonic transition on the galactron is different, because the proton mass is 1836 times bigger than the electron mass. Therefore, the excitation strength of the hydrogen atom is weaker than that of the electron by as much as the ratio of the masses between the two particles, despite the same given energy. That is,

$$R_{\mathrm{strength}} = (72)\left(\frac{1}{1836}\right) = \frac{1}{25.5} = 0.04 \quad \Rightarrow \quad R_{\mathrm{strength}} = 4\% \qquad \text{21-3-15}$$

The observed ratio between the DIB strength and continuum strength is

$$R_{\mathrm{strength}} < 5\% \qquad \text{21-3-16}$$

With this quantitative result from CFLE theory, we can confirm the galactron particle is pulled toward the hydrogen atom. Thus, we can explain properties #2 and #3 listed in §21.2, that DIBs are significantly better correlated with atomic hydrogen than with molecular hydrogen, and that some narrow DIBs show a structure possibly consistent with rotational bands.

Because 30 mÅ is the weakest width in equivalent widths, the strongest width is

$$W_{\mathrm{strongest}} = (30\mathrm{m\AA})\,(72)$$

$$= 2160\ \mathrm{m\AA} \qquad \text{21-3-17}$$

The observed value is in fact

$$W_{\mathrm{strongest}} > 2000\ \mathrm{m\AA} \qquad \text{21-3-18}$$

This strength is only for a proton as a hydrogen atom. Because the galactron mass is 12 times heavier than that of the hydrogen atom, the weakest strength for one galactron that observed as a carbon nucleus is

$$W_{\mathrm{weakest}} = \frac{30\ \mathrm{m\AA}}{12.023}$$

$$= 2.495\ \text{mÅ} \qquad 21\text{-}3\text{-}19$$

However, because the galactron spin is $s = \frac{1}{2}$ and, by the correspondence principle of CFLE theory, the galactic force line gradient difference between the neutron and galacton is d_g= 1.5, and the usual galacton is the electric force line curve difference d_g= 1.5 between the neutron and proton (cf. §5, §14), the given energy can be more separated.

Therefore, the weakest DIB strength from galactron is

$$W_{\text{weakest}} = \frac{2.495\ \text{mÅ}}{2 \times 1.5}$$

$$= 0.832\ \text{mÅ} \qquad 21\text{-}3\text{-}20$$

The observed value so far is

$$W_{\text{observed}} < 1\ \text{mÅ} \qquad 21\text{-}3\text{-}21$$

This quantitative result from CFLE theory helps to explain properties #4 and #5 listed in §21.2, that DIBs have very small depth. There are none 20% down from the continuum. Most are less than 5% below the continuum and less than 30 mÅ in equivalent widths. The strongest DIBs detected have equivalent widths over 2000 mÅ, and the weakest detected so far are less than 1 mÅ. All known DIBs are detected between 4000 and 10 000 Å, except for two in the infrared at 1.18 and 1.32 μm (Joblin *et al.* 1990). Most are in the red range, and almost none are in the blue range. They are almost in the limited wavelength region.

Now, because the broad DIBs have full width at half maximum (FWHM) in the order of 30 Å, most narrow lines must have FWHM at

$$W_{\text{narrowest}} = \frac{30\ \text{Å}}{72}$$

$$= 0.42\ \text{Å} \qquad 21\text{-}3\text{-}22$$

The observed value is

$$W_{\text{observed}} < 1\ \text{Å} \qquad 21\text{-}3\text{-}23$$

With this quantitative result from CFLE theory, we have explained property #6 in §21.2, that DIBs display a large range in width, central depth, and equivalent width. The narrowest lines have an FWHM of less than 1 Å, whereas the broad DIBs have in the order of 30 Å.

The galactomic system is like an atom. However, because this system is surely not a grain, absorptions feature from this particle system cannot have feature of any polarizations (whether linear or circular). After all, this system is not a kind of perfect molecule, but rather can only be observed as a molecular-like system; namely, it could be called an observable pseudo-molecule. Therefore, the absorption features of this particle system can build its band features. This qualitative result from CFLE theory explains property #7 (cf. §21.2) of DIBs, why several DIBs have been studied in searches for polarization, with no positive results.

These explanations and confirmations by CFLE theory about properties #1–7 of DIBs convince us that those carriers of DIBs are the galactron and the hydrogen atom in the galactom system.

But in the center of each galactom, galactons act as a galactomic nucleus (cf. Figure 21-3-3).

As mentioned before, the permitted number of solar atomic elements is

$A = 2n^2 = 92(\text{Uranium, } \mathrm{U}_{92}^{238.03})$

$n = 6.782330 = g = \text{electric force line curve of nucleus}$ 21-3-24

Because the galactom builds the galactic force with galactic force line and its curve is $g = 6.782330$ by the correspondence principle of CFLE theory, the permitted number of galactomic elements is

$A = 2(2n)^2$

$= 2(2 \times 6.782330)^2 = 368(\text{Galacuranium, } \mathrm{U}_{g_{368}}^{952.12})$ 21-3-25

To date, the number of observed DIBs is

$N > 400$ 21-3-26

Because of the ionization of both galactoms (omission of galactron) and galactrons (omission of hydrogen atom) and the isotopes of galactoms, there can exist more than 368 DIBs

With this quantitative result from CFLE theory, we explain property #8 (§21.2), that there are poor correlations between DIBs. Only one pair of DIBs comes close to being perfectly correlated. This means that there are many carriers. Hence the more than 400 DIBs discovered to date.

It should be noted that these galactomic elements are not building blocks of stars, but only those of the basic galaxy system. For example, the building block of the center of the galaxy (inside of bulge = nucleus of galaxy).

Therefore, several studies of various types of stars with circumstellar material do not show DIBs, despite many searches. This property of DIBs is none other than #9 described in §21.2.

Because a galactron is 1.190208×10^7 times heavier than an electron, there is only basic transition energy for the galactron from the ground to the excited states, where minimum unit energy of transition is

$$E = [(-13.6\text{ eV})\,(1.190208 \times 10^7)] \sim [(\frac{-13.6\text{ eV}}{72})\,(1.190208 \times 10^7)]$$

$$= -1.62 \times 10^8\text{ eV} \sim -2.25 \times 10^6\text{ eV} \qquad 21\text{-}3\text{-}27$$

This transitions energy is not regular electronic transitions energy, but rather only galactronic transitions energy. Therefore, every galactom cannot be excited by electronic transition energy.

Because the orbital energy of every galactron is tremendously strong, transition of the galactron cannot occur by the usual electromagnetic energy. This means that a galactron's orbital is relatively very strongly fixed.

Therefore, the central wavelengths of DIBs show little to no shift between sight lines. Namely, they have invariant central wavelengths. This very strange property of DIBs is property #10 described in §21.2.

In the earliest state of galaxy synthesis by galactomic elements, the galactomic gas remained outside of the galaxy center. At that time, they emitted galactic energy by very strong gravitational condensation, as bundles of gractromagnetic force lines and electromagnetic force lines. Namely, they lost many of their galactic force lines and electric force lines. Nowadays, they remain in the ground state for a long time without any excitation by galactromagnetic energy. However, with the plentiful electromagnetic energy produced by extinction in the interstellar medium, they can only absorb weak electromagnetic energy as a preceding phase of galactronic excitation.

Therefore, DIBs in emission have only been observed in the red rectangle and toward one other star. DIBs can rarely be found in emission (property #11; §21.2).

For the same reason, no DIBs have shown emission wings in any environment (property #12); and all DIBs, whether strong or weak, grow linearly with increasing extinction. This means there is lack of saturation in DIBs (property #13). By this reason, all correlations with extinction are good (meaning, the correlation coefficient is generally 0.7), including UV extinction (property #14), and slightly different sets of DIBs are seen in different environments. Therefore, they are not constant everywhere. One factor seems to be cloud density, from diffuse to translucent (property #15).

In the galactomic system, each galactron follows Pauli's exclusions principle (see Figure 21-3-8 below). Therefore, each galactron should occupy a different quantum state.

But every hydrogen atom on each galactron does not need to follow Pauli's exclusions principle, as shown in Figure 21-3-6, because each galactron attracts the same hydrogen atom with the same force in the different quantum states.

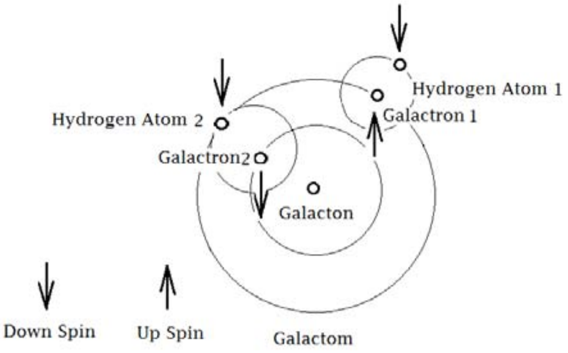


Figure 21-3-6

Therefore, every hydrogen atom on each galactron cannot build spin-spin couplings like in proton nuclear magnetic resonance. If spin-spin couplings between every hydrogen atom and each galactron exist, the line of the spin-spin splitting should always be building a symmetric feature (Figure 21-3-7).

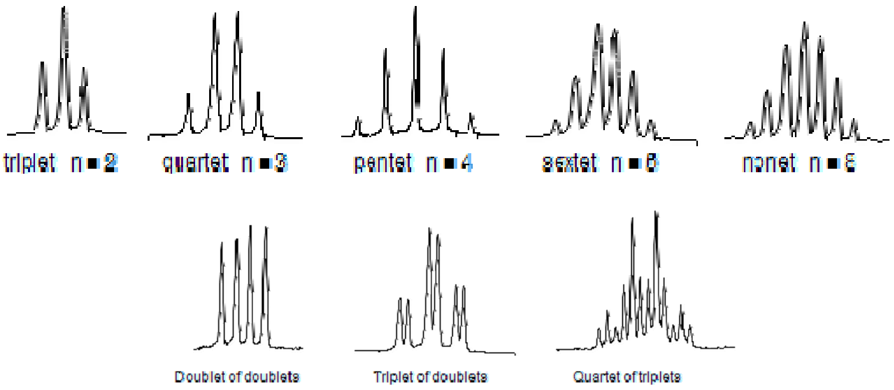


Figure 21-3-7

It is because of these unmatched spin-spin couplings that the important phenomenon of DIBs (property #16 in §21.2) occurs; that many DIBs are asymmetric, although some of the broad ones are symmetric. The profiles are invariant in most lines of sight.

In some broad DIBs where the galactron is in or near the ground state, the positively charged galactomic nucleus repulsively influences the positively charged hydrogen atom. Therefore, this hydrogen atom can place different spin quantum states against the usual other hydrogen atoms that always stay in their usual same spin quantum state (Figure 21-3-8).

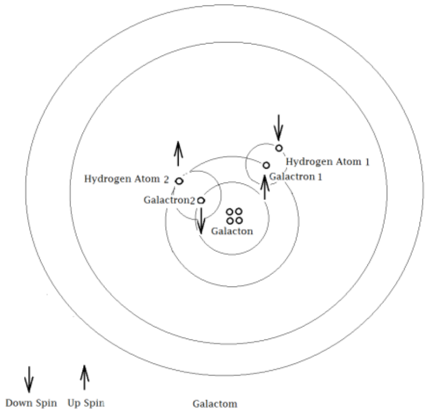
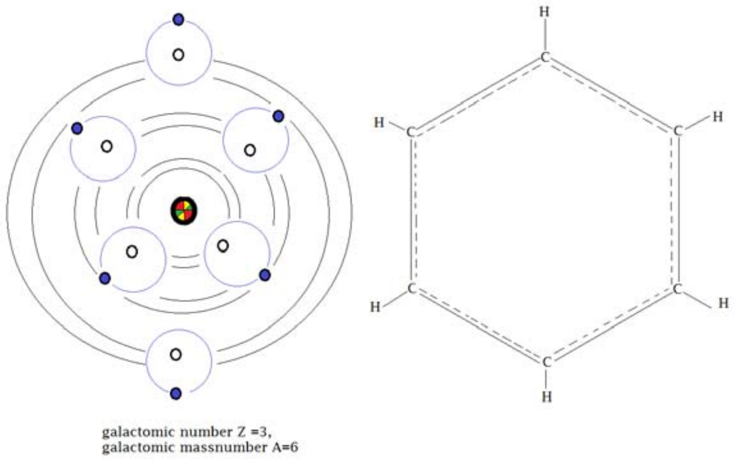


Figure 21-3-8

In such a galactomic system, spin-spin couplings are possible and consequently shape the symmetrical absorption features of DIBs. In

Figure 21-3-9, the spin state of 6 galactrons is 3 up spins and 3 down spins.



galactomic Element

Benzene

Figure 21-3-9

Therefore, these spin states of galactrons can build spin-spin couplings. But the spin state of 6 hydrogen atoms (blue color) is very different. The spin state of 4 hydrogen atoms is usually all down spins, and that of 2 hydrogen atoms in the ground state is unusually up spins by the repulsive galactomic nucleus. Therefore spin-spin couplings of 6 hydrogen atoms cannot appear, and consequently the line symmetry of spin-spin splitting is broken. However, the 6-galactron configuration of galactomic element G_3^6 reveals why spectroscopists believed for a long time that the carrier of DIBs is polycyclic aromatic hydrocarbons and the related fullerene (cf. Figure 21-2-1).

21.4. Conclusion and Historical Meaning of Present Astronomical and Chemical Spectroscopy

New Particles Exist!!! As carriers of DIBs, which are called galactomic elements.

Spectroscopists had in fact found important evidences of these new particles 90 years ago.

Historically speaking, when Bohr wanted to build his atomic model, he had to satisfy the crucial conditions that spectroscopists Balmer, Rydberg, and Paschen presented about the hydrogen atom (because the Bohr model predicted other spectral series, Lyman, Pfund, Brackett, and Humphreys discovered other spectral series). Such conditions were satisfied by Bohr, who was also a spectroscopist, and opened the door to a new age of general physics, with spectroscopy developing especially widely. In consequence, spectroscopists had to work harder and busier than before.

Now, another door to a new age—which after opening nobody can reclose—is opening historically for spectroscopy and spectroscopists. Already in recent years, very high-resolution spectrographs on the world's most powerful telescopes are available to spectroscopists to observe and analyze DIBs. Spectral resolutions of 0.005 nm are now commonplace, using instruments at observatories such as the European Southern Observatory at Cerro Paranal, Chile, and the Anglo-Australian Observatory in Australia. And at these high resolutions, many DIBs are found to contain valuable information about new particles. But even this is not enough for that we can expect to solve about the unknown solar spectrum, which 100 years of full-scale research has been dedicated to and without full success despite that the Sun is the only nearest star to planet Earth.