Article

The Sun Is Electrically Charged & the Conundrum of the "Missing Mass" Is Explained

Bernard R. Bligh*

Abstract

A study of the Sun's corona reveals that the velocities of electrons are substantially higher than the velocity of escape and the velocities of protons are well below the velocity of escape. The Solar Wind contains equal proportions of electrons and protons, it follows that there must be a mechanism for ejecting protons from the surface of the Sun and for holding back most of the electrons. It is postulated here that the Sun and all hot stars have a net positive electric charge. If a galaxy as a whole is neutral it follows that there is a net negative charge in the interstellar space in a galaxy. This hypothesis is supported by the fact that electron clouds have been detected near the bulge of the Milky Way. The next step in the reasoning is that there are attractive electrical forces between these stars and the central bulge and that these attractive forces account for the pattern of velocities of stars in orbit in a galaxy (the so-called 'flat rotation curve'). It follows that there is no need for a hypothetical 'missing mass' to provide a gravitational force for this velocity pattern. There are presented 9 reasons to support the present hypothesis based on firm observational evidence; for example:

(1) In the corona of the Sun, oxygen ions, O^{5+} , are accelerated radially away from the Sun faster than protons; since oxygen ions are 16 times heavier than protons, this is not what we would expect from simple diffusion; a logical explanation is that the positive charge of the Sun causes the acceleration.

(2) This hypothesis **predicts** that stars which are **not hot enough** to have an ionized corona should **not be positively charged** and therefore they should have orbital velocities in the galaxy **below the flat rotation curve**. **This is in fact the case**.

(3) The rotational curves of many galaxies are not flat; there is a considerable scatter in star velocities. Therefore the concept of "dark matter" or "missing mass" is not self-consistent, - even on its own terms.

(4) Electrically charged stars in orbit create a magnetic field. Magnetic fields have been detected in galaxies. It is suggested here that there may be attractive and repulsive magnetic forces between galaxies.

Finally, it is **predicted** that spiral galaxies on opposite sides of voids between clusters will be found to have opposite orientations.

Key Words: Sun corona, Solar wind, velocities of electrons and protons and oxygen ions, Cosmology, Dark Matter, Missing Mass, Plasmas, Galaxy kinematics and dynamics.

* Correspondence: Bernard R. Bligh, 4 St. James's Avenue, Hampton Hill, Middlesex, TW12 1HH, U.K. brbligh@hotmail.com

Symbols.

c = velocity of a particle, m s^{-1},
d = distance between a 'shell' and the centre of the Sun, (see Appendix) ,
E = electric field, Newton $Coulomb^{-1}$,
k = Boltzmann constant = 1.381×10^{-23} J K^{-1} ,
m = mass of a proton = 1.673×10^{-27} kg,
or mass of an electron = 9.11×10^{-31} kg,
n = total number of particles in a system,
n_e = density of electrons, numbers per m^3 ,
Q = electric charge, Coulomb,

R = gas constant = 8314 J kg-$mole^{-1}$ K^{-1}
R_O = radius of the Sun = 6.96×10^8 m,
T = temperature, K
e = Electron charge = Proton charge = 1.602×10^{-19} Coulomb,

ε_O = permittivity in vacuum = 8.854×10^{-12} $Coulomb^2$ $Newton^{-1}$ m^{-2} ,
λ_D = Debye length, m

1. The Corona of the Sun.

The corona of the Sun is at a temperature of more than 10^6 K. It is instructive to study the nature of this hydrogen plasma. Figures 1 and 2 show the Maxwell-Boltzmann distribution for the speeds of electrons and protons for the temperature 1.1×10^6 K. The formula for the proportion of particles having velocities between c and (c + dc) is

$$dn_c/n = 4\pi(m/2\pi RT)^{3/2} \exp(-mc^2/RT)\, c^2\, dc \qquad (1)$$

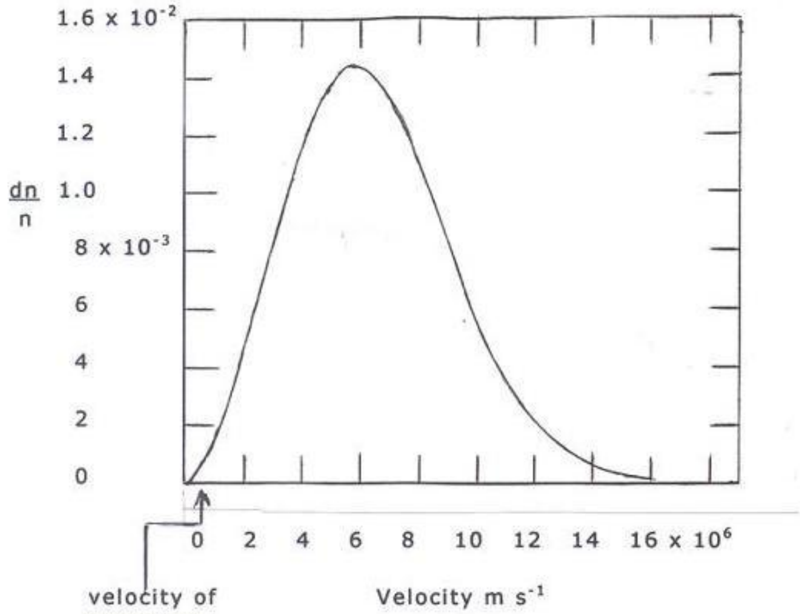
In the graphs presented (Figures 1 and 2), the increment dc is 100,000 m s^{-1} for electrons and 1,000 m s^{-1} for protons.

These two diagrams show the curves for the distributions of velocities of electrons and protons at 1.1 million degrees Kelvin, which is the approximate temperature of the outer Sun. Note **the velocities of the electrons and protons compared with the velocity of escape.**

The velocity of escape from the Sun is 617000 m s^{-1} and it can be seen that almost all the electrons exceed this speed and virtually no protons do. Superficially this leads to the conclusion that the Sun would lose all its electrons and none of its protons. Obviously this does not happen. Therefore it is deduced that during the early history of the Sun, it lost a small proportion of its electrons such that it became positively charged; this net positive charge holds back most of the electrons from escaping into space and also this positive charge repels a small proportion of protons into space such that the Solar Wind contains an equal balance of electrons and protons.

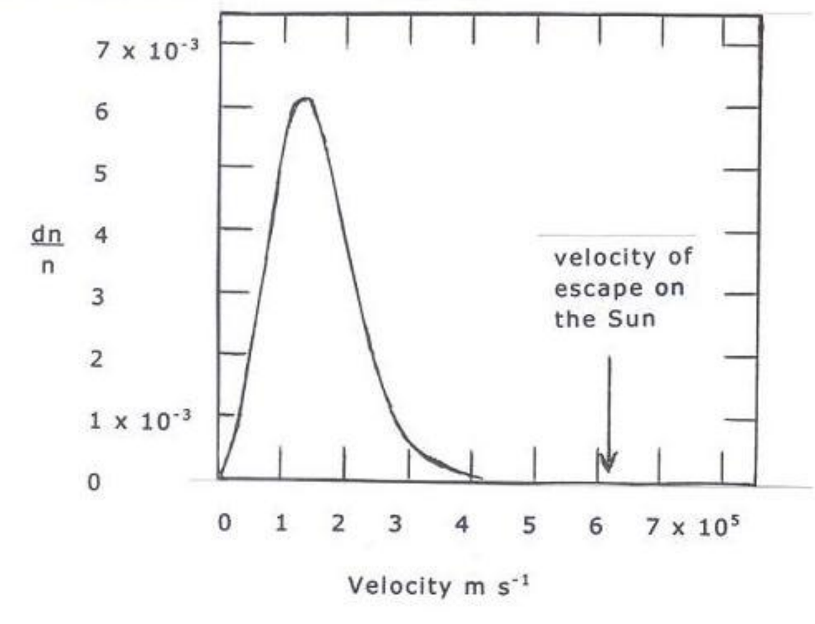
It is apparent that the Solar Wind must be neutral overall, otherwise the Earth, which is bathed in the Solar Wind, would acquire an electric charge over a period of time.

Figure 1



Maxwell-Boltzmann Distribution of velocities of electrons on the Sun at 1.1×10^6 K.

Figure 2



Maxwell-Boltzmann Distribution of velocities of protons on the Sun at 1.1×10^6 K.

It is required to estimate what the magnitude of this positive charge on the Sun might be and then ask the questions 'Does this concept of a net electric charge on the Sun make sense ?' 'In astronomical terms, what would be the effect in the Galaxy if most stars like the Sun were positively charged ?'

The Sun is a plasma and the nature of an electrostatically charged plasma is quite different from other electrostatically charged bodies. It so happens that there are observations that positively charged oxygen ions, O^{5+} , in the corona are accelerated radially away from the Sun even more than protons, and these data provide a means of estimating the charge on the Sun (Appendix).

The hypothesis is that the Sun needs to have a positive charge in order to repel protons to the speed of the Solar Wind. The provisional assumption is made that if the positive charge is large enough for this action, it will be large enough to hold back a substantial proportion of the electrons, such that the Solar Wind consists of equal numbers of protons and electrons.

The calculations in Appendix are only approximate; at the early stage in developing this theory we are only aiming at an order of magnitude for many of the properties of the plasma of the Sun.

In the chromosphere the protons must be accelerated to 6.2×10^5 m s^{-1} which is the velocity of escape.

The excess positive charge on the Sun is in the order of 7×10^{22} C see the Table in Appendix.

The mass of the Sun is 2×10^{30} kg, which is equivalent to 1.2×10^{57} protons and electrons in almost equal balanced proportions.

The excess positive charge of 7×10^{22} Coulombs is equivalent to

4.3×10^{41} protons.

Therefore the incremental excess number of protons over electrons is in the ratio

4.3×10^{41} : 1.2×10^{57}

i.e. one in 3×10^{15} .

Therefore it is not surprising that this extremely small excess positive charge has not yet been detected by astronomers.

Considerations for the Galaxy.

We now make the reasonable assumption that when the galaxy first formed, it was electrically neutral, i.e. there were equal numbers of protons and electrons. The same assumption applies to the birth of stars such as the Sun. If the Sun now has a net positive charge of 7×10^{22} Coulombs then it has lost that amount of negative electrons to interstellar space. Since there are believed to be in the region of 1.5×10^{11} stars in our galaxy, this suggests that the space in the galaxy contains in the order of 10^{34} Coulombs of surplus electrons.

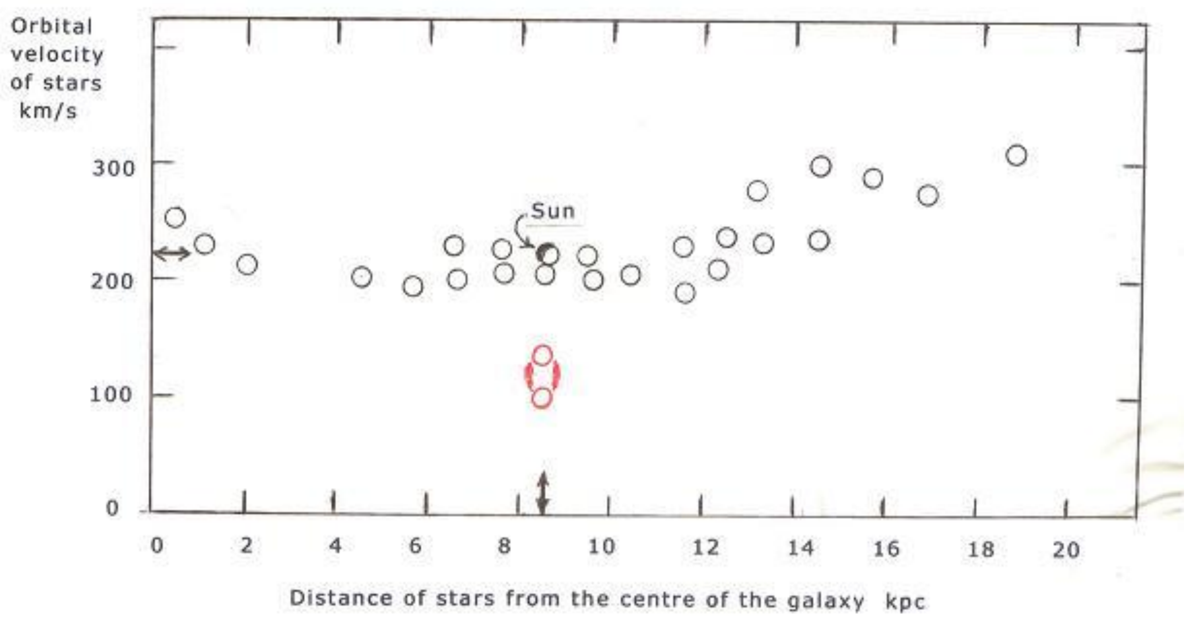
The model of our galaxy now develops in this way; the stars have a small positive charge - and this includes the stars in the central bulge; it follows that the negative electrons are attracted to some extent towards the centre of the galaxy, i.e. there is an electric field which decreases from the centre outwards. There is an attractive force between this negative electric field and the stars circulating in the galaxy. The hypothesis is put forward here that **it is this attractive force which is causing**

the characteristic star velocities in a galaxy and this velocity effect is NOT caused by the gravitational force of the 'missing mass'.

We need to consider some aspects of the "missing mass" theory in contradistinction to the new hypothesis. In most galaxies, but not all galaxies, the orbital velocities of the stars and the interstellar gas are approximately constant over a substantial range of radii of orbits. They are said to have a 'flat curve' , see Figure 3. This velocity pattern is contrary to Kepler's Third Law and therefore this anomaly is explained by an extra gravitational force provided by a "missing mass" or "dark matter".

Actually the missing mass theory fails on its own terms because if the orbital velocities were characterized by gravity, the rotation curve should be smooth in the way that planetary orbital velocities make a smooth curve as in Figure 4 and not the scatter as in Figure 3.

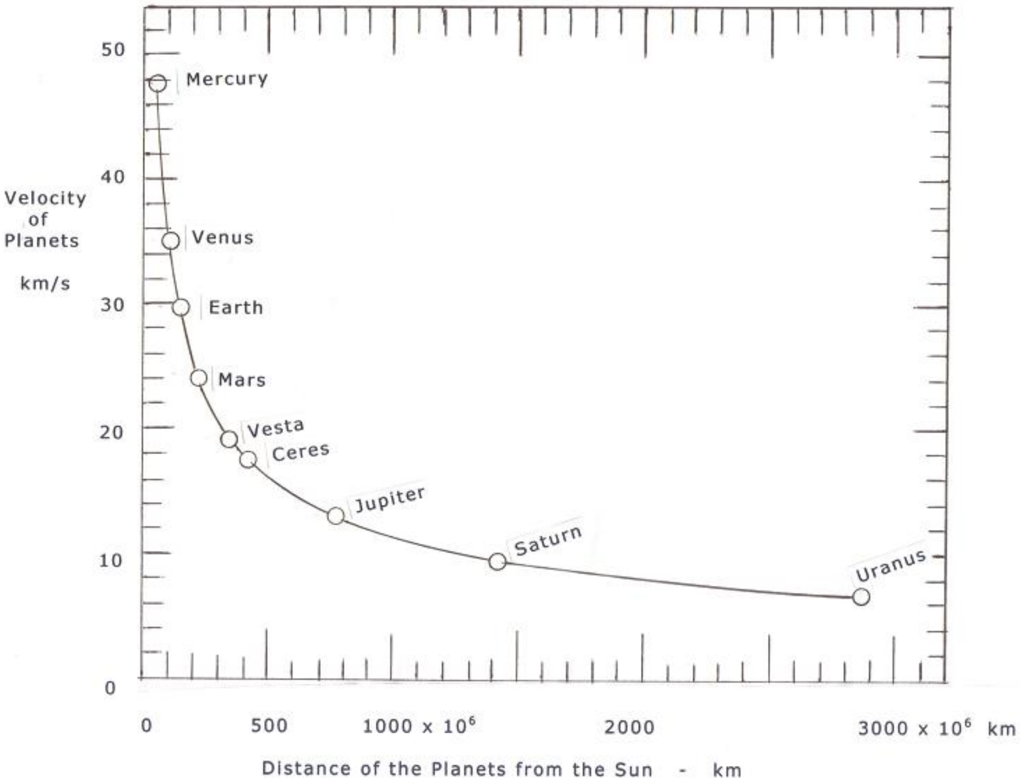
Figure 3



Notice that the stars are not on a smooth curve; they would be on a smooth curve if their velocities were determined purely by gravitational considerations. In reality there is considerable scatter (Ref. Schneider and Terzian, 1983, and Combes, 1996). This is in contrast to the smooth curve of the orbits of planets, whose velocities are Keplerian, i.e. determined by the laws of gravity. The scatter of star velocities comes about because the stars are electrically positively charged in varying degrees and electrical forces are added to the gravitational force in controlling the orbits.

The red circles represent over 100 brown dwarfs of low metalicity in the vicinity of the Sun and which all have orbital velocities less than the Sun and other stars (Ref. Fuchs et alia. 1999). Brown dwarfs have a relative low temperature and have little or no electric charge.

The position of the Sun, i.e. the Local Standard of Rest is at 8.5 kpc and an orbital velocity of 220 km/s.



Notice that there is a smooth curve and that there is no scatter of planetary velocities.

The attractive electrical force between hot stars and the bulk of the galaxy accounts for the pattern of velocities of stars in orbit in a galaxy (the so-called 'flat rotation curve'). It follows that there **is no need for a "missing mass" to provide a gravitational force for this velocity pattern.**

Figure 3 demonstrates a powerful argument which supports this new theory, namely that I **predicted** that stars which are **not hot enough** to have an ionized corona should **not be positively charged** and therefore they should have orbital velocities in the galaxy **below the so-called flat rotation curve**. I then found data showing that this is in fact the case.

Brown dwarfs are such stars. Data on their orbital velocities was found in the reports by Fuchs, Jahreiss and Wielen (1999). They '*determined reliable space velocities of 560 nearby subdwarfs'*, i.e. nearby to the Sun. The variation in their velocities is so wide that there is no way they could be accommodated on a 'flat curve'.

Before giving additional detailed reasons behind the new theory there is presented **A Summary of the Observations in favour of the new theory.**

(1) In the corona of the Sun, oxygen ions, O^{5+} , are accelerated radially away from the Sun faster than protons.

(2) The distributions of electrons in interstellar space in our Galaxy are close to the stars in the bulge and in the spiral arms.

(3) Clouds of positively charged ions in interstellar space move faster than un-ionized gas.

(4) As mentioned above, - unattached brown dwarfs, which are marked red in Figure 3 have rotation velocities below the other stars; the explanation is that they are not hot enough to eject electrons and therefore they do not have a net positive charge. **This was predicted.**

(5) The rotational curves of cepheids in the Milky Way are used as tracers. Cepheids are comparatively cool stars and therefore they do not carry a large positive charge. There is a clear trend that H II regions (protons) are rotating faster than cepheids.

(6) Observers have presented rotational velocity diagrams for over 40 galaxies. There is substantial variation in the shapes of these velocity profiles; some of these are 'flat' curves and some are not. We would not expect that degree of variation for a universally distributed 'missing mass'.

(7) There is a wide scatter of velocities of stars in the Galaxy and yet astrophysicists choose to draw an almost smooth horizontal curve through these scattered points.

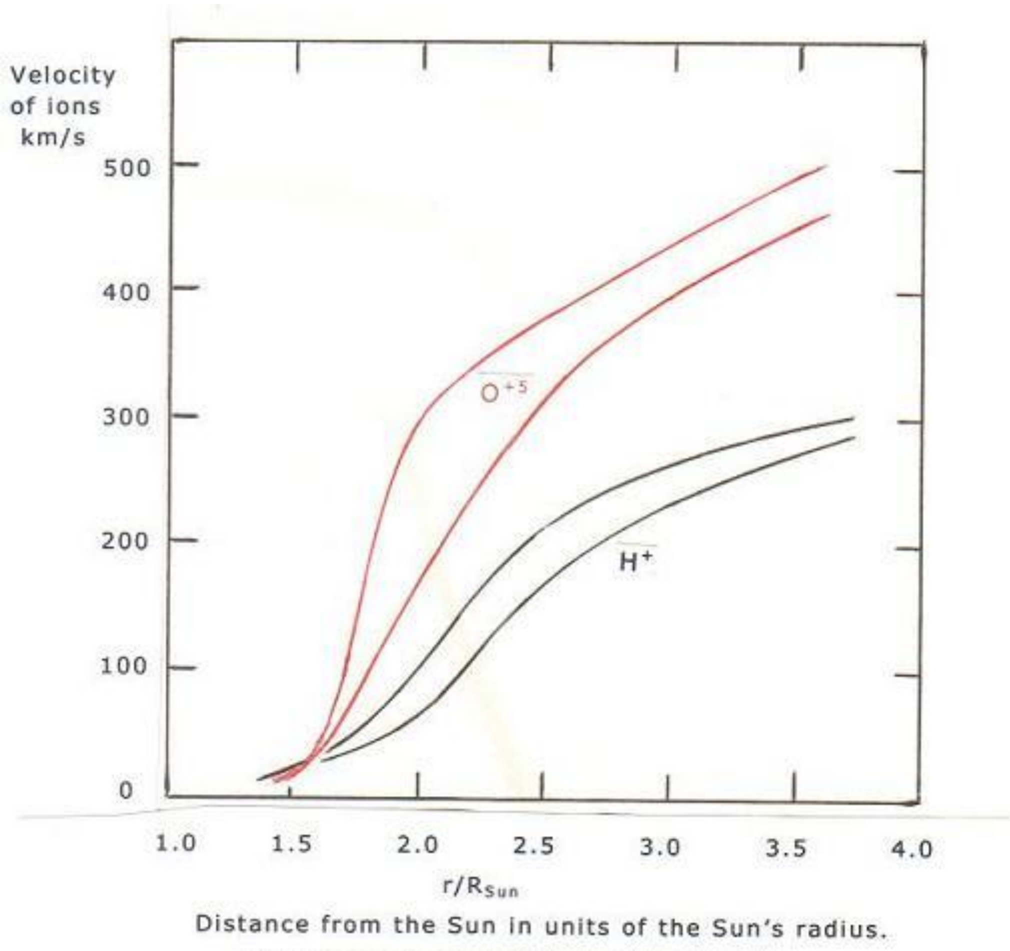
(8) Galaxies display a magnetic field.

Detailed arguments.

(1) In the corona of the Sun, oxygen ions, O^{5+} , are accelerated radially away from the Sun faster than protons, (Kohl et al. (1998) and Aschwanden et al. (2001)). Since oxygen ions are 16 times heavier than protons, this unexpected phenomenon cannot be explained by simple diffusion. The logical explanation is that that the oxygen ions with the higher positive charge are being accelerated by a positive electric field.

(2) Taylor and Cordes (1993) have studied the distribution of electrons in interstellar space in our Galaxy. Because electrons repel each other, we might expect this distribution to be widely dispersed spherically but this is not the case. Electrons keep closely to the disk and are concentrated in the central bulge of the Galaxy and in the spiral arms where most of the stars are concentrated. The diagrams of Taylor and Cordes are quite clear and unambiguous on this point. This observation presents a strong argument in favour of the new theory because there is the easy explanation, that the negative electrons are attracted to positively charged stars. Weisberg et al (1995) confirm the electron densities of Taylor and Cordes.

(3) In this hypothesis we would expect that a cloud of ionized gas would move faster than a cloud of un-ionized gas, and this has actually been observed in NGC 4214 (Wilcots and Thurow, 2001). Wilcots and Thurow give a different explanation from the one proffered here, - but then they were not looking for the possibility that there might be an attractive force between the ionized cloud and a net negative charge towards the centre of the galaxy NGC 4214.



The outflow of particles from the Sun.

The oxygen O^{+5} ions have velocities in the range between the red curves and the protons have velocities between the black curves. Even at a distance of 3.5R the oxygen ions are continuing to accelerate away from the Sun, indicating that the Sun has a positive electrical charge which is repelling the positive ions.
Copied from Kohl et al (1998) and Aschwanden et al (2001)

This effect has also been observed in NGC 891 (Swaters, Sancisi and van der Hulst 1997). They report that there is neutral hydrogen in a halo up to 5 kpc from the plane of the disk and the rotation of this hydrogen is 25 to 100 km s^{-1} **slower** than the gas in the plane.

(4) It has already been explained that if the velocities of hot stars around the galaxy are governed largely by their electrical positive charge, then it follows that cold stars, which are not hot enough to have an ionized corona, should not behave in this way, - and this is the case.

The point is that if the concept of “missing mass” were valid, then the orbital velocities of the stars, including brown dwarfs, would be on a smooth curve in the way that the velocities of the planets lie on a smooth curve. The missing mass theory has no explanation for the velocities of brown dwarfs.

(5) Cepheids are another example of relatively cool stars. Pont et al (1997) report a study of the rotational curve of the Milky Way using cepheids as tracers. For the galactic radii 6 to 16 kpc the results show widely scattered rotational velocities, - hardly a 'flat curve', - but there is a clear trend that H II regions (protons) are rotating faster than cepheids. This can be explained if the cepheids, which are comparatively cool stars, have lost part of the positive charge which they had originally.

The point here is that in a hot star such as the Sun, there is an equilibrium created by its positive charge such that there is a balance between ejecting some protons and holding back the fast moving electrons. When a star cools down the equilibrium will be re-adjusted; relatively fewer electrons need to be held back and more protons will be repelled until there is a lower net positive charge on the star.

(6) Kent (1986) presented rotational velocity diagrams for 37 galaxies and Sanders and Verheijen (1998) give velocity diagrams for 6 galaxies. There is substantial variation in the shapes of these velocity profiles; some of these are 'flat' curves and some are not. We would not expect that degree of variation for a universally distributed 'missing mass'.

(7) Brand and Blitz (1993) have studied the velocity field in the outer Galaxy. Most of the objects observed are nebulae of positively charged hydrogen or of neutral hydrogen. Their Figure 3 shows 'Circular velocity as a function of galactocentric distance'. There is a wide scatter of velocities from 165 km s^{-1} to 345 km s^{-1} but they have chosen to draw an almost horizontal smooth curve through these scattered points. In spite of this scatter, there is a clear trend for the regions with H^+ ions having greater velocities than neutral hydrogen.

Kulkarni, Blitz and Heiles (1982) also present data with a wide scatter of rotational velocities. This wide variation in orbital velocities cannot be explained in terms of the gravitational attraction of a 'missing mass' but it can be explained by the hypothesis that different nebulae or different stars have different positive charges.

An important point is that it is quite possible for different stars to have evolved with different positive charges, therefore there will be different forces of attraction between the stars and the electric charge in the bulk of the galaxy. This feature would cause a different orbital velocities, i.e. the scatter of orbital velocities is not a problem for the new theory.

(8) Galaxies display a magnetic field.
One consequence of a positively charged Sun orbiting the galaxy is that it creates a magnetic field; Parker (1979) devotes a chapter in his book on the magnetic field of the Galaxy and there are many other references, e.g. Beck, (2000), Wielebinski, (1993).

It is standard Physics that electrons moving through a conductor create a magnetic field; clearly the moving of a massive body such as the Sun is not the same action. Nevertheless a moving electrical charge must produce a magnetic field of some kind. The direction of the magnetic field will be at right angles to the orbit of the Sun and other hot stars. Where two stars are orbiting together, there will be some lines of force between the two stars near the plane of the galaxy, and these have been detected. Stars at the edge of a spiral will generate a magnetic field at right angles to the plane of the Galaxy. The implication of this is that neighbouring galaxies will be attracted to each other if their magnetic fields become linked. This will happen if the spirals have the same "chirality".

There is some supporting observational evidence from the "Galaxy Zoo" project. Jimenez et al (2010) report that "*neighbouring spiral galaxies* which have similar star forming histories, also *have their spins aligned*" (my emphasis).

Now magnetic fields can also cause **repulsion**, unlike gravity, which is always an attractive force. It follows that if two neighbouring galaxies have their rotations in opposite directions, they will repel each other.

I predict that it will be found that spiral galaxies separated by voids between clusters will be found to have opposite orientations, because over immense times, such galaxies will have repelled each other. Substantial voids between galaxy clusters are known to exist.

Eddington's Errors.

It has been objected that the possibility that the Sun is positively charged has been studied previously by Eddington (1926 and 1959) and by Mestel (1999) and they showed that the effect is infinitesimal.

Mestel simply copies the result of Eddington without going through the reasoning. Eddington's book of 1959 is identical with the first edition of 1926 and his analysis of the velocities of ions in the Sun is flawed.

First he takes the Maxwell-Boltzmann equation for velocity distribution of ions and integrates it over all velocities. But we are not concerned with *all velocities*, we are concerned with velocities greater than the escape velocity from the Sun, *which Eddington never mentions*.

Second, Eddington uses the Maxwell-Boltzmann equation to calculate *densities* of ions, but the Maxwell-Boltzmann distribution of velocities is independent of the density of fluids, therefore this is an inappropriate application of that equation.

Thirdly, as has been shown above, there is a considerable amount of evidence that oxygen ions (O^{5+}) are being *accelerated outwards* more than protons. (Antonucci, Dodero and Giordano 2000, and Kohl et al 1998, Aschwanden et al. 2001). Now, how can that come about? As has been pointed out above, oxygen ions are 16 times heavier than protons so the natural explanation is that the high positive charge is the cause of that acceleration, i.e. the Sun must have an effective positive charge.

The velocities of the oxygen ions and protons are "strongly anisotropic", (Kohl et al. 1998) i.e. the velocities radially outwards are more than the velocities in other directions; this is not consistent with Eddington's findings, and the high acceleration of oxygen ions is contrary to his results.

Finally it should be pointed out that the **Solar Wind was not known in 1926**, when Eddington wrote his book, so he did not extend his analysis to the concept that ions would actually leave the Sun in substantial quantities.

A Criticism

It might be argued against this theory that the Sun could not retain a steady state of positive charge simultaneously with producing a neutral Solar Wind. The system is in a state of dynamic equilibrium. Suppose a mass ejection threw out an extra quantity of positive ions, then the net charge on the Sun would decrease; but it is this net charge which holds back electrons; therefore a temporary decrease in positive charge would release more electrons because their velocities are greater than the velocity of escape.

The state of the Sun would then revert to its previous steady state.

The Solar Wind might well have fluctuations in its electrical charge, but on balance it remains neutral. Indeed it is these fluctuations which **are known to affect adversely the electrical systems such as power lines on Earth.**

Final Discussion and Conclusion.

The "received wisdom" about the missing mass is expressed in the paper 'Baryonic Dark Matter' by B. Carr (1994) :-

'The evidence for dark matter on all scales from star clusters to the Universe itself has built up steadily over the last 50 years. Although the strength of evidence on different scales varies considerably, there is now little doubt that only a small fraction of the mass of the Universe is in visible form.

'The best evidence for dark matter in galaxies comes from the rotation curves from spirals.'

Then again, Blitz (1995) describes the evidence of dark matter from the measurement of flat galaxy rotation curves as *'compelling'.*

It is shown here that the evidence for dark matter is far from "compelling" in view of the fact that brown dwarfs and cepheids do not fit the flat rotation curves, and furthermore the rotation velocities display a wide scatter which is inconsistent with the theory.

The evidence that the Sun and hot stars are positively electrically charged is extremely strong in the light of the nine reasons given, whereas the 60 year search for "dark matter" has failed.

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Appendix:

The observations that O^{5+} ions in the corona are being accelerated away from the Sun provide a means of estimating the electric field in the Sun. It should be noted that this acceleration is anisotropic, that is to say, it is definitely directional away from the Sun. (Refs. Antonucci et al. (2000), Kohl, J.L. et al. (1998))

For the purposes of this calculation the corona is divided into concentric zones with radii, R_o , 1.5 R_o, 2.0 R_o, 2.5 R_o, 3.0 R_o, 3.5 R_o, 4.0 R_o . We take the example, 3.0 to 3.5 R_o ; Figure 5 from Kohl et al (1998).

Radial velocity outwards increases from 430 to 490 km s^{-1} from which it can be calculated that the acceleration is 79 m s^{-2} ; the acceleration due to gravity at 3.25 R_o (average) is 26 m s^{-2} .

Therefore the force on the O^{5+} ions is mass x acceleration

= $1.673 \times 10^{-27} \times 16 \times (79 + 26)$

= 2.8×10^{-24} N.

The electric charge on O^{5+} ion is $1.602 \times 10^{-19} \times 5$

= 8.01×10^{-19} Coulomb

Electric field = Newton/Coulomb

= $2.8 \times 10^{-24} / 8.01 \times 10^{-19}$

= 3.5×10^{-6} N/C.

Because all the particles in a plasma are electrically charged, a plasma cannot support an electrostatic field in the manner we experience in a terrestrial laboratory. The Debye length, λ_D , is an important parameter because it provides a measure of the distance over which a charged particle is influenced by other charged particles. Typically, the force on a charged particle is only related to other charged particles within a distance of about 2 λ_D (Feynmann).

$$\lambda_D = \{\varepsilon_O kT/e^2 n_e\}^{1/2}$$

(refer to the beginning of this paper for the meaning of all the symbols).

In the present example, $T = 1.1 \times 10^6$ K

n_e , the density of electrons, = 4×10^{10} m^{-3} (Esser and Sasselov, 1999).
(Note, some of the values entered here are approximate; at this stage in developing a theory, we are only concerned with orders of magnitude).

λ_D = 0.4 m

A typical O^{5+} ion is only accelerated by other positive ions within a distance of about 2 λ_D = 0.8 m

We now set up a model of the corona consisting of a family of concentric spheres, or shells, each with a thickness of 2 λ_D . Our O^{5+} ion is accelerated outwards through each imaginary shell and it follows that the positive electric charge in each shell is *greater* than the next one further out, - otherwise the outward force would not exist.

We now apply Gauss's Theorem. There is a sense in which each shell is independent of every other shell because of the characteristic of a plasma as explained above. We note that the average radius in the zone of our calculation is 3.25 R_o = $3.25 \times 6.96 \times 10^8 = 2.26 \times 10^9$ m

$$E = Q/4\pi \varepsilon_O d^2$$

Substituting

$E = 3.5 \times 10^{-6}$ N/C

$\varepsilon = 2 \times 8.854 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$ approximately

$d = 2.26 \times 10^9$ m

Therefore $Q = 2.0 \times 10^3$ C

What this calculation means is that the O^{5+} ion is being accelerated by a positive charge of 2×10^3 Coulomb as though that charge were in the centre of the Sun (Gauss's Theorem) although in fact that charge is in our "shell" and this shell has a thickness of about 0.8 m.

The concentric "zone" of this calculation (3.0 R_o to 3.5 R_o) has a thickness $0.5 \times 6.96 \times 10^8$ m = 3.48×10^8 m.

Therefore the number of notional concentric shells in this zone is

$3.48 \times 10^8 /0.8$

$= 4.4 \times 10^8$

As O^{5+} passes from a shell outwards, each shell contains a charge, Q, which is 2×10^3 C *more* than the next shell. By means of summing an arithmetic progression one can calculate the total positive charge in this zone.

$\frac{1}{2} n\{ 2a + (n - 1)z \}$

a is the cumulative positive electric charge at radius 3.5 R_O

which is 6.4×10^{11} C (from a previous calculation for the zone 3.5 R_O to 4.0 R_O not given here)

z is the incremental charge in each notional shell = 2.0×10^3 C

n = the number of shells = 4.4×10^8,

the positive charge in this zone, 3.0 to 3.5 R_O, is 3.3×10^{20} C.

This calculation is repeated for all the zones in increments between the radii, R_o , 1.5 R_o , 2.0 R_o , 2.5 R_o , 3.0 R_o . 3.5 R_o , 4.0.R_o .

It is a reasonable assumption that the positive charge at 4R_o is negligible and therefore our summation of the charge is done from 4R_o inwards. No great accuracy is claimed for these calculations, we are merely trying to estimate the order of magnitude for the positive charge on the Sun.

The results of these calculations are given in the Table. Added to this table is an estimate of the excess electric positive charge in the Sun below the radius R_o. It is assumed that this charge density is uniform, and there is some justification for this assumption because the acceleration of O^{5+} ions at the photosphere is very small, and the acceleration of the O^{5+} ions comes from the gradient of charge density.

TABLE FOR ELECTRIC CHARGE ON THE SUN

Radial Distance Zone	Acceleration due to gravity $m\ s^{-2}$	Acceleration of O^{5+} $m\ s^{-2}$	Sum of Accel terms $m\ s^{-2}$	Electric field $N\ C^{-1}$	Electric charge in shell C	Debye length m	Electric charge in zone C
R_O -> $1.5\ R_O$	175	0.1	175	5.9×10^{-6}	4.9×10^{2}	0.03	32×10^{21}
$1.5\ R_O$ -> $2.0\ R_O$	90	112	202	6.8×10^{-6}	1.1×10^{3}	0.13	4.7×10^{21}
$2.0\ R_O$ -> $2.5\ R_O$	55	84	139	4.7×10^{-6}	1.3×10^{3}	0.3	1.6×10^{21}
$2.5\ R_O$ -> $3.0\ R_O$	36	69	105	3.5×10^{-6}	1.4×10^{3}	0.4	0.8×10^{21}
$3.0\ R_O$ -> $3.5\ R_O$	26	79	105	3.5×10^{-6}	2.0×10^{3}	0.4	0.3×10^{21}
$3.5\ R_O$ -> $4.0\ R_O$	19	44	63	2.1×10^{-6}	1.6×10^{3}	0.4	0.1×10^{21}
Centre -> R_O							27×10^{21}
					Total electric charge		66.5×10^{21}

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