THE STRONG MAGNETIC FIELD GALACTIC CENTER-AGN-QUASAR MODEL

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ABSTRACT: The energy storage and dynamics at the center of galaxies is explained using a new construct, the gravitationally bound current loop (GBCL), produced when the galaxy formed under gravitational collapse. Thin toroidal plasma around the slender intense relativistic current loop is bound to it by the Maxwell "frozen-field" condition, and also binds gravitationally to the central object (presumably a black hole). The Strong Magnetic Field model (SMF) explains directly the Milky Way (MW) galactic center radio observations of a vertical magnetic field perpendicular to the galactic disk and the extended radio arcs, as well as the production of successive radio blobs ejected from the compact cores of active galactic nuclei (AGN) or quasars.

1. INTRODUCTION

In the recent book by Zeldovich, Ruzmaikin and Sokoloff, they state "A major challenge is to understand strong magnetic fields whose energies greatly exceed that of hydrodynamic motions". The strong magnetic field model (SMF), introduced in 1961 and extended since then (Greyber 1961, 1962, 1964a,b, 1967a,b,c, 1984, 1988) deals with precisely that topic. SMF should not be confused with the standard kinematic dynamo theory discussed in "Cosmical Magnetic Fields " by E. Parker. However, it is significant that on his last page, Parker writes "In the extreme case, the magnetic activity is driven by some colossal energy source, such as gravitational collapse within the galaxy- -". This agrees with SMF.

There are only two axial vectors of importance for astronomy, rotation and magnetic field. The orthodox view of AGN and quasars (very rapidly rotating accretion disks) chooses rotation as the important axial vector. SMF is fundamentally different, choosing magnetic field, i.e. the gravitational energy from the collapse of a pregalactic gas cloud is stored in an almost radiationless form in a GBCL.

In SMF the general morphology, energy production and dynamics of objects of galactic dimension are determined by the ratio of magnetic field energy to rotational energy. This ratio is very high for quasars and BL Lac objects, then decreasing as one goes to radio galaxies, Seyfert galaxies, Markarians, ordinary spiral galaxies, until it is close to zero for ordinary elliptical galaxies.

However the activity is a function of the matter accretion rate at

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the time of observation. The fact that M31 is 1000 times more massive than our MW, yet far weaker in radio emission, is interpreted by SMF as lack of accretion in the M31 GBCL region at this time. A great number of such "quiet engines" may exist in the Universe.

2. EVIDENCE FOR THE SMF MODEL

To gain acceptance, any new construct like GBCL, must show (a) a generation mechanism, (b) equilibrium, (c) existence for times of interest, (d) stability, and (e) agreement with observations. In previous papers, (a) and (b) are demonstrated (Greyber 1962, 1967a). Equilibrium is simply the bursting force of the strong dipole magnetic field balancing the gravitational attraction between the toroidal plasma and the black hole.

The Greyber-Menzel result predicts magnetic field strengths at the GBCL center far greater than at the surface of a pulsar (i.e. 10^{13} gauss). This occurs for two reasons: 1. During the gravitational collapse, huge numbers of electrons are constantly accreted into individual current loops due to the "pinch effect", and 2. when the toroidal volume current (made up of vast numbers of current filament loops) undergoes gravitational collapse, one filament is forced through the magnetic field of the adjacent parallel filament, generating more current and more flux in the standard fashion according to Maxwell's equations.

Thus gravitational energy is converted, as myriads of current loops are forced to coalesce into a GBCL, into an extremely strong dipole magnetic field anchored around the black hole. $T_{\perp}$ in the GBCL beam is kept very low by cyclotron radiation. Relativistic electron beam energy is required so that Rutherford scattering off neutralizing background protons is extremely low.

Using Eqn. I.11 from a famous paper by Julian Schwinger on the classical radiation of accelerated electrons, we show that a completely coherent (undisturbed) relativistic current loop (ccrcl) around a black hole will radiate only due to its curvature, and thus last for times far longer than the age of the Universe. Table 1 shows numerical results.

E in BeV	R in meters	ΔE in MeV over 10^{10} years
1	1.5×10^{12} (10 A.U.)	0.6
0.1	1.5×10^{12} (10 A.U.)	0.6×10^{-4}
1	1.5×10^{14} (1000 A.U.)	0.6×10^{-4}
10	1.5×10^{12} (10 A.U.)	6000
1	1.5×10^{10} (0.1 A.U.)	6000

TABLE 1: Classical Radiation Loss from a completely coherent relativistic current loop (ccrcl). (From Schwinger 1949.)

The first four lines in Table 1 demonstrate that in the energy range below 10 BeV, for reasonable GBCL radii for galactic center nuclei, the loop will last for times far longer than the age of the Universe. The fifth line is merely to illustrate the case of a ccrcl around a newly forming star which will be discussed in a future paper.

While both thick and thin rotating accretion disks have been found to possess many serious instabilities, O. M. Blaes (1985), analyzing constant specific angular momentum tori, shows that any instability becomes vibrational (i.e. stable) for extremely slender tori such as GBCL.

Also one notes that a ccrcl, once formed, has a unique stabilizing property, as follows. Due to coherence, one part of the ccrcl does not radiate in the magnetic field of another part. However, if a fluctuation or "bump" occurs somewhere along the loop, the electrons in the "bump" will suddenly radiate furiously in the extremely strong ccrcl magnetic field, the energy in the fluctuation will dissipate very rapidly and the GBCL will quickly return to its undisturbed configuration. Another relevant fact is that the largest external perturbation to a GBCL is limited to solid matter, i.e. chunks not much larger than the planet Jupiter, - since stars,made of plasma,would break up before penetrating close to the extremely intense magnetic field of the GBCL.

3. AGREEMENT WITH OBSERVATION

Table 2 compares the SMF model with the rotating accretion disk model for 18 important conclusions drawn from hundreds of papers. Clearly SMF is favored by a wide margin. Details can be found in the Greyber (1988) paper. However two observational conclusions are described below.

First is the conclusion by Kellerman (1985) that "typical morphology shows a compact core with one or more (radio) blobs moving away in a single direction". Wiita (1985) notes "the VLBI maps (of 3C120) showed that several different blobs have been ejected from the core at a rate of about one per year...there is weak evidence that they may be accelerating at surprisingly large distances from the core." Figure 1 illustrates the SMF model when a large accretion of matter has occurred. The diamagnetic effect of the bulk plasma distorts the field lines producing topological magnetic mirrors above and below the plane of the GBCL.

Suddenly, as accretion proceeds, when at the throat of one of the magnetic mirrors,the plasma pressure (nkT) becomes larger than the magnetic field pressure ($B^2/8\pi$) , the mirror's field lines are pushed back opening the throat, and a huge blob of hot plasma is explosively ejected. The bulk plasma pressure then drops and the magnetic field returns to the mirror configuration. Simultaneously the loop contracts very slightly, and the blob is accelerated by the effect of an increasing dipole magnetic field. Klein and Brueckner (1960) analyzed this plasma acceleration effect in detail for laboratory devices.

The succession of explosively ejected blobs forms the clumpy relativistic jets observed. SMF explains the extreme straightness and confinement of many radio jets over tens of thousands of parsecs by the influence of the large-scale dipole magnetic field. It is relevant to note that Yusef-Zadeh, Morris, Slee and Nelson (1986) state that a low energy jet emanating from our MW galactic nucleus "results from the continuous or frequent injection of mildly relativistic particles from the Galactic nucleus."

The second conclusion relates to the pioneering research by P. P. Kronberg (1987) who finds surprisingly high magnetic fields (approaching the milligauss level) in very young evolving galaxies out to the distances of quasars, up to Z around 2.5 . This is a definite prediction

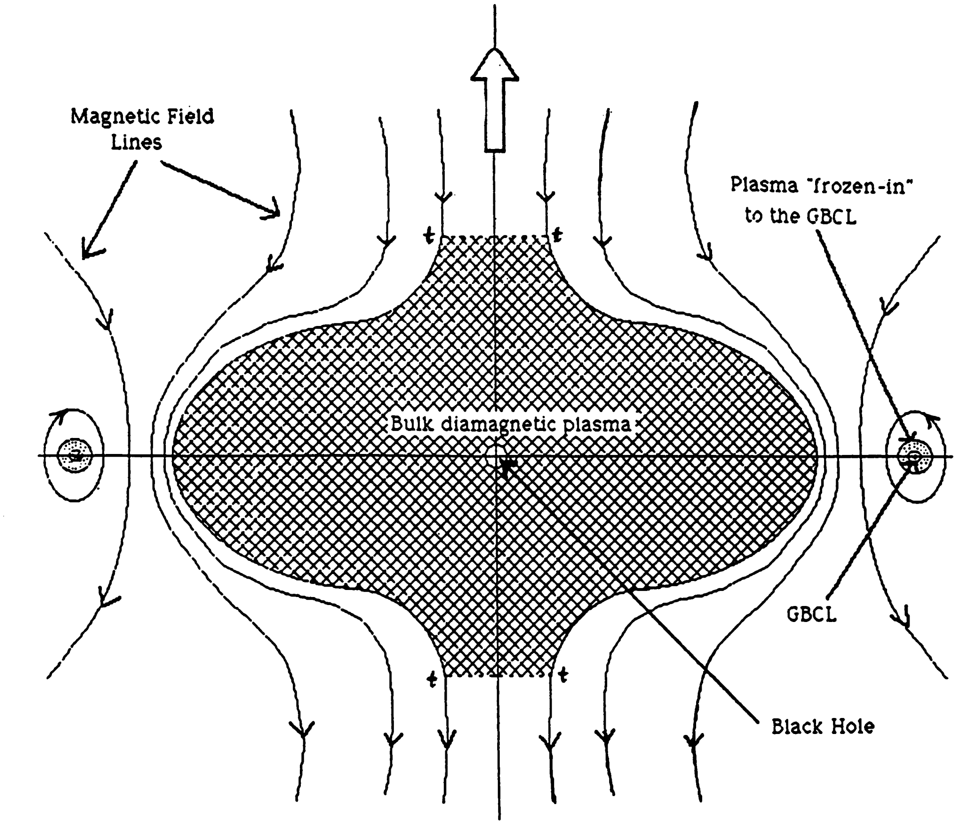

Figure 1: Model for a Quasar, BL Lac object or AGN when a very large accretion of matter around the black hole has occured, t-t is the throat of the magnetic mirrors. Arrow shows the direction of the motion of the explosively ejected hot plasma blob after upper throat suddenly opens. As accretion continues, process repeats every few years.

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of SMF since the GBCL is formed right at gravitational collapse. However, as A. Wolfe commented, "the prevalent dynamo model for the formation of magnetic fields leads one to expect that the fields do not form until much later , after a galaxy has completed several full rotations."

4. SUMMARY AND ACKNOWLEDGMENTS

As Table 2 emphasizes, the orthodox view, where energy is stored in very fast rotating plasma disks, has grave problems, but the SMF model fits the facts. W. G. Mathews (1982) concluded " In fact, there is no direct and unambiguous evidence for rotation in the observed spectra of quasars at the present time". Sgr A* has been identified as a unique compact nonthermal radio source with a size smaller than 2×10^{14} cm. located at the Galactic Center. SMF predicts that with better resolution, at the microarcsecond level and below, one should find evidence for a weak, small GBCL around Sgr A*. The present GBCL in our MW Galaxy is merely a remnant of the current loop present at gravitational collapse.

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5. REFERENCES

Blaes, O. M. (1985) M.N.R.A.S. 212, 37
Greyber, H.D. (1961) Trans. Int. Astron. Union, 11B, 332
Greyber, H.D. (1962) 'On the Steady State Dynamics of Spiral Galaxies', U.S.A.F.O.S.R. Research Report, No. 2958
Greyber, H.D. (1964) Astron. J. 69, 542
Greyber, H.D. (1964) Chapter 31, 'Dipole Magnetic Fields of Galactic Dimensions' in Quasar-Stellar Sources and Gravitational Collapse, Univ. of Chicago Press
Greyber, H.D. (1967) 'A Unified Theory for Spiral and Radio Galaxies' in Instabilite Gravitationelle et Formation des Etoiles, des Galaxies et de leurs Structures Caracteristiques, Memoirs of the Royal Society of Sciences of Liege, XV, 189
Greyber, H.D. (1967) 'Magnetic Field Configuration in Galactic Spiral Arms' in Ibid., XV, 197
Greyber, H.D. (1967) 'On the Nature of Cosmic Radio Sources', Publ. Astron. Soc. Pacific, 79, 341
Greyber, H.D. (1984) 11th Texas Symp. on Relativistic Astrophysics, Annals New York Academy of Sciences, 422, 353
Greyber, H.D. (1988) in Supermassive Black Holes, Cambridge University Press, p.360
Kellerman, K. (1985), Comments on Astrophysics, 11, No.2, 69
Klein, M.M. & Brueckner, K. (1960), Jour. Appl. Physics, 31, 1437
Kronberg, P.P. (1987) in Interstellar Magnetic Fields, Springer-Verlag
Mathews, W.G. (1982) Ap. J. 258, 425
Parker, E.N. (1979) in Cosmical Magnetic Fields, Oxford University Press, p. 816

Schwinger, J. (1949), Phys. Rev. 75, 1912
Wiita, P.J. (1985), Comments on Astrophysics, 10, No.5, 199
Yusef-Zadeh, F. et al (1984), Nature 310, 557
Yusef-Zadeh, F., Morris, M., Slee, O.B. and Nelson, G.J. (1986), Astrophys. Jour. 300, Jan. 15, L47
Zeldovich, I.B., Ruzmaikin, A.A. and Sokoloff, D.D. (1983) in "Magnetic Fields in Astrophysics", Gordon & Breach, p.8

TABLE 2: COMPARISON OF THE STRONG MAGNETIC FIELD MODEL (SMF) WITH THE ROTATING ACCRETION DISK MODEL

	Strong Magnetic Field Model (SMF)	Rotating Accretion Disk Model
ENERGY SOURCE	Gravit. Collapse + accretion	Accretion
ENERGY STORAGE	Gravit. Bound Current Loop	Velocity of Accreting Material
EXPLAINS:		
Very frequent injection of high energy relativistic electrons	Yes	No
Millions of points where relat. electrons inject into strong mag. field	Yes	No
Production of successive radio blobs	Yes	No
Shape of giant double lobe radio sources	Yes	No
One-sided jets in strong sources	Yes	No
Strong magnetic field in very young (i.e. high Z) galaxies	Yes	No
Largest polarization near the innermost radio blob	Yes	No
Core-halo polarization difference in Core-Halo radio galaxies	Yes	No
Morphology of Objects of Galactic Dimension	Yes	No
Extremely rapid time variations observed (50-100 seconds)	Yes	No
Remarkable straightness of jets	Yes	?
Remarkable confinement of jet material over huge distances	Yes	No
Lack of evidence for rotation in the spectra of quasars	Yes	No
Production of jet	Yes	Yes- with assumed funnel
Radio-quiet quasars	Yes	?
Stability of configuration	Yes	No
Generation Mechanism	Yes	Yes
Existence for times of interest	Yes	?

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