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Some new possible anticipated signals for existence of magnetic monopoles☆

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HIGHLIGHTS

- The model of supermassive object with magnetic monopoles is discussed in detail.
- The signals for existence of magnetic monopoles from recent astronomical observations are proposed.
- Gravitational waves, and the gamma-ray burst may support the existence of the RC mechanism, and the magnetic monopole.

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ABSTRACT

Most of physicists believe that the existence of magnetic monopoles had been ruled out by experiments. However, experiments only indicated that the flux of magnetic monopoles on the earth is too low to be observed. We summarize some predictions from the model of supermassive object with magnetic monopoles which match up with recent astronomical observations quantitatively. They may be the signals for existence of magnetic monopoles in the supermassive objects, such as one at the Galactic Center.

1. Introduction

In the primordial universe, the electromagnetic interaction between magnetic monopoles and plasma is so strong such that magnetic monopoles might store up in the center of quasars and active galactic nuclei (AGN) during the collapsing process of the original giant nebulae, including at the collapsed core of the Galactic Center (GC). Due to the Rubakov–Callan (RC) effect (Rubakov, 1981; Callan, 1983), magnetic monopoles may catalyze nucleon decay and is invoked as the energy source of quasars and AGN.

Based on a supermassive object infused with primordial magnetic monopoles, the supermassive object with magnetic monopoles (SMOMM) model is has been estimated in our paper (Peng and Chou, 2001). The fact that magnetic monopoles may catalyze nucleon decay (i.e., Rubakov–Callan effect) as predicated by the grand unified theory of particle physics is invoked as the energy source of quasars and active galactic nuclei. Recent study of this model revealed that the radius of the supermassive object located at the Galactic center is much larger than its Schwarzschild radius. We proposed that this supermassive objects could be the source of high-energy gamma-ray radiation, although the emitted radiation may be mainly concentrated in the infrared.

Really, we detailed discussed this question as early as 1985 due to the fact that this is a very interesting question (see our paper Peng (1985)). We discussed the number of monopoles in stellar objects in the paper. We noted that the number of monopoles possibly contained in a stellar object is closely related to the initial physical condition in the primary cloud from which the object was born. For example, in the interior of a protostar (the number density of hydrogen atoms $\sim (10^2–10^4)\text{cm}^3$ and temperature $\leq 10^2$K), the interaction of monopoles with neutral atoms is insignificant, and very few monopoles will be drawn by the neutral matter during the collapse of a primary cloud (molecular or neutral hydrogen). On the other hand, however, the huge primordial clouds (It collapses into quasars and AGNs) in the early universe were in a plasma state with high temperature $\sim 4 \times 10^3$K. The interaction of

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monopoles with plasma is so strong that many monopoles will be drawn into the quasars and AGNs during their formation.

The SMOMM model is based on a supermassive object infused with primordial magnetic monopoles. However, it is believed today that, due to their immense mass ($\sim 10^{20}$MeV/c^2), these monopoles could only have formed in the time interval between the Big Bang and inflation. Then, cosmic inflation would have diluted the monopole population so much that fewer than one would exist today within the observable universe. This argues against the existence of objects containing primordial monopoles. But from the symmetry and beauty of the Dirac equation, Dirac suggested the existence of magnetic monopoles which is the most natural explanation of the quantization of electric charge (Dirac, 1958).

In recent years, people always discuss the other possibilities, whether magnetic monopole would produce or not. Much literature exists on the creation of monopoles in the modern universe via ultra-high-energy particle collisions in the intense magnetic fields of compact objects. For example, Bonnardeau and Drukier (1979) detailed discussed the creation of magnetic monopoles in pulsars. These magnetic monopoles are believed to create by the very energetic particles in pulsars. These particles can interact between themselves and/or be smashed onto the neutron star surface to produce pairs of magnetic monopoles and antimonopoles. Pazameta also discussed a general-relativistic model of such a monopole-infused object (Pazameta, 2012). They described the final equilibrium state of compact objects infused with magnetic monopoles produced by proton-proton collisions within the intense dipolar magnetic fields generated by these objects during their collapse. Their model could be adapted to construct a physical model of the SMOMM. In any case, it is a fundamental problem in physics whether magnetic monopoles exist or not.

The plan of this letter is as follows. In Section 2, we will sketch the model of SMOMM and its predictions. In Sections 3–5, we will show some predictions of our model in agreement quantitatively or basically with some new astrophysical observations: a strong magnetic field around the GC, the observation of the rate of the emitted positrons, and the frequency of the spectrum peak of the thermal radiation from the GC. In the last Section, we will discuss and try to explain two recent observations with the model of the stars with the magnetic monopoles: the highly super-luminous supernova ASASSN-15lh and the gravitational waves GW150914.

2. The model of SMOMM

The model of SMOMM (Peng and Chou, 2001) suggested that an amount of magnetic monopoles stored up in the center of quasars and AGNs, including at the collapsed core of the GC during the collapsing process of the original giant nebulae in the primordial universe because the electromagnetic interaction between magnetic monopoles and plasma was so strong. Due to the RC effect (Rubakov, 1981; Callan, 1983), nucleon decay may be catalyzed by magnetic monopoles,

$$p + M \rightarrow M + e^+ + \pi^0 + \text{debris (85\%)}, \tag{1}$$

$$p + M \rightarrow M + e^+ + \mu^+ + \mu^- + \text{debris (15\%)}. \tag{2}$$

In this model, the RC effect is invoked as the energy source. In the case of GC, the SMOMM is located at the center with the radius of about 8.1×10^{15}cm $\sim 1.2 \times 10^4 R_S$ (R_S is its Schwarzschild radius). The total mass of the SMOMM is derived to be $2.5 \times 10^6 M_\odot$ (now taken as $4.6 \times 10^6 M_\odot$) from the observed luminosity of Sgr A*(1×10^{37} ergs s^{-1}).

The gravitational effect around SMOMM in the GC is similar to the model of supermassive black holes. In the black hole model, accretion of matter results in the huge luminosity, but the energy source in the model of SMOMM is supplied by the RC effect.

The main predictions of the model of SMOMM are as follows (Peng and Chou, 2001).

1. The production rate of positrons emitted from the SMOMM in the model is $\sim 6.5 \times 10^{42} e^+$/s.
2. High-energy gamma-ray radiation has energy higher than 0.5 MeV. The integrated energy of these radiations would be much greater than both the bolometric luminosity and the energy of positron annihilation line.
3. The radial magnetic field at the surface of the SMOMM is estimated to be $H(R) \sim (20–100)$G.
4. The strong radial magnetic fields of the high-speed rotating SMOMM transforms a strong electric field for a distant observer in the rest frame. A variety of produced particles (e^+, $\mu^\pm$, $\pi^\pm$) would be accelerated by the strong electric field to very high energy, say $E_\gamma \sim 10^{21}$eV or greater. We predict that these could just be the observed ultra-high-energy cosmic rays which have an initial energy of several hundred MeV produced from the SMOMM.
5. The surface temperature of the SMOMM is derived to be about 121 K and the corresponding spectrum peak of the thermal radiation is at 10^{13} Hz in the sub-mm wavelength regime.

3. A strong magnetic field around the galactic center

The recent observation (Eatough et al., 2013) in 2013 indicated that there is a dynamically important magnetic field near the black hole. In particular, at $r = 0.12$ pc the lower limit of the outward radial magnetic field near the GC is

$$B \geq 8\left[\frac{RM}{66.960\,\text{m}^{-2}}\right]\left[\frac{n_0}{26\ \text{cm}^{-3}}\right]^{-1}\text{mG}, \tag{3}$$

where n_0 is the number density of electrons there, and RM denotes the measurement of the Faraday rotation near the GC. The lower limit of the observed data is in agreement with the prediction 3 in the model of SMOMM because the magnetic field strength decreases as the inverse square of the distance from the source and has $B \approx (10–50)$mG at $r = 0.12$pc. Up to now no other physical mechanism can produce this strong radial magnetic field.

As analyzed in Zamaninasab et al. (2014), “jet magnetic field and accretion disk luminosity are tightly correlated over seven orders of magnitude for sample of 76 radio-loud active galaxies”. They pointed out that the black hole models “may require significant changes”, and “models of the Galactic Center accretion disk may also need to be revised, as a dynamically important magnetic field has been reported (Eatough et al., 2013) within a distance of $\sim 3 \times 10^7 r_g$ from the central black hole.”

4. Rate of emitted positrons

New observation (Knödlseder et al., 2003) reported that the measured 511 keV line flux located at the GC at a distance of 8.5kpc converts into an annihilation rate of $(3.4 - 6.3) \times 10^{42}$s^{-1}. “The observed flux is compatible with previous measurements (Share et al., 1999; Cheng et al., 1997; Purcell et al., 1997; Milne et al., 2000; 2001) that have been obtained using telescopes with small or moderate fields-of-view, yet it is on the low side when compared to OSSE measurements” (Knödlseder et al., 2003). Those observations are in agreement with the prediction 1 in the model of SMOMM quantitatively.

5. Frequency of spectrum peak of the thermal radition from the galactic center

A review paper (Falcke and Markoff, 2013) pointed out that the radio flux density S_ν from the GC shows a flat-to-inverted spectrum. i.e., it raised slowly with frequency of the power peaking