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Grand unified theory, lepton stars and gamma-ray bursts, quasars*

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Abstract: The grand unified theory of particle physics is applied to the supermassive stars, whose energy scale is large enough to take an infinitely collapsing process. A new model is proposed that after nucleon-decays, a supermassive star will convert nearly all its mass into energy, and become a lepton star that might possibly be substable or unstable. According to the model the ultrahigh energy cosmic rays and these puzzles in astrophysics at high energy: quasars and gamma-ray bursts, etc., may be explained. A lepton star is probably a true white hole.

Key words: grand unified theory; gamma-ray bursts; quasars; particle physics; cosmology

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So far, the origins of ultrahigh energy cosmic rays are not distinct. Recently, Kalashev, et al. (00) discussed that the Z-burst mechanism produces ultrahigh energy cosmic rays. Isola, et al. (00) proposed the Centaurus A as the source of ultrahigh energy cosmic rays, which relate to viability of primordial black holes as short period gamma-ray bursts. These rays connect probably with two notable puzzles in astrophysics[1]: gamma-ray bursts (GRB) and quasars. Some hundred models have been proposed, but none is confirmed fully. Some energy-sources of quasars convert mass of quasars into kinetic energy, with nearly 100% efficiency[ ]. A mechanism for the conversion is gravitational collapse (Hoyle, et al. 1963), but the calculations of such high efficiency are very difficult (Dyson, 1969; Leibovitz, et al. 1970). The most important model is that a neutron star collides with a black hole or two neutron stars coalesce. But, a probability of these collisions should be very small in the Universe, although it will increase much in the core of Galaxy. Moreover, various models of different stars have been introduced.

The grand unified theory (GUT) may unify strong, electromagnetic and weak interactions in particle physics. For example, in Coleman-Weinberg SO(10) GUT[3]

$$SO(10) \xrightarrow{M_X} G \xrightarrow{M_R} SU(3)_c \otimes SU(\ )_L \otimes U(1)_Y, \tag{1}$$

where M_X is of order 10^{15}—10^{16} GeV to be compatible with the lower limit on proton decay, G is one of the intermediate symmetry groups, and the scale M_R is the one relevant for neutrino physics. Based on GUT, this paper proposes the lepton star model, and applied to the problems of quasars, GRB and ultrahigh energy cosmic rays, etc.

1 High energy astrophysics and lepton stars

In astrophysics it is very successful that GUT is used to determine the symmetry breaking in the very early universe. A characteristic energy scale of the simplest SU(5) GUT model is of order 10^{15} GeV,

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corresponding 10^8 K. It is an ultrahigh temperature, which corresponds the initial 10^{-36} second in the Big Bang Universe. Recently, Albright, et al. (00), discussed the relation between SO(10) GUT and neutrino oscillation. Now GUT comes to a standstill, and is difficult in the application of astronomy because of ultrahigh energy and proton-decays. Weinberg(1979) has proposed that the rates of baryon-nonconserving processes, like proton decay, are very small at ordinary energies. But if the slowness of these processes is due to the large mass of intermediate vector of scalar "X bosons" which mediate baryon nonconservation, then at very high temperatures with $kT \cong M_X$, the baryon-nonconserving processes would have rates comparable with those of other processes. Weinberg discussed this possibility for $kT \geqslant M_X$. We analyze these cases, and think that GUT and the lepton star model may solve these difficulties.

1.1 The energy scale For supermassive stars the theory indicates that there is nothing that can stop the cores of these heavyweight stars from collapsing indefinitely[1]. It is a certainty that a black hole will fall finally into a singularity, although some gravitational theories, for instance, quantum gravity and superstring theory, may solve the problem of singularity, and the quantum effects can prevent a star from collapsing to a singularity (Mukhanov, et al. 199). A gravitational collapsing process from a supermassive star to black hole and singularity is very similar with a big bang process, only the former is a time-reversal evolution with in much smaller space scale and mass scale. Both end points are the singularities with an infinite density, and the two processes pass through various energy scales. For black holes, the Planck scale 10^{19} GeV and the Planck density 10^{94} $g \cdot cm^{-3}$ have been discussed, which will pass through a GUT's energy scale necessarily. In this collapsing process, the Pauli's exclusion principle must be inapplicable[4, 5].

Moreover, the energy scale of other GUT's models, except SU(5) model, may be different. For example, supersymmetric SO(10) GUTs have the intermediate scale 10^{10}—$10^{1\ }$ GeV (Sato 1996), E_6 model has 10^4—10^6 GeV (Pati, et al. 1978), and general supersymmetric models with the B-nonconserving processes could proceed between 10^{16} GeV and 100 GeV depending upon the concrete model. Now the highest energy of cosmic rays is above 10^{11} GeV(Bhattacharjee 1998).

1.2 The transition processes In a collapsing process the temperature of stars will rise, rise violently. So long as GUT appears in an evolutionary process of star, protons and neutrons will decay

$$\mathrm{p} \rightarrow \mathrm{e}^+ + \pi^0 \ldots;\ n \rightarrow \nu + \pi^0 \ldots \qquad (\ \ )$$

Detailed calculations show that the decay-branches are

$$\mathrm{p} \rightarrow \begin{array}{cccc} \mathrm{e}^+\pi^0 & \mathrm{e}^+\omega & \mathrm{e}^+\rho & \mathrm{e}^+\eta \\ 30\% & 30\% & 14\% & 4\% \end{array} \cdots \qquad (3)$$

and

$$\pi^0 \rightarrow \gamma\gamma(98.8\%),\quad \gamma \mathrm{e}^+\mathrm{e}^-(1.\ \ \%), \qquad (4)$$

$$\omega \rightarrow \pi^+\pi^-\pi^0(89.6\%),\quad \gamma \mathrm{e}^+\mathrm{e}^-(8.7\%) \cdots \qquad (5)$$

Such, a supermassive star will convert mass into huge energy, with efficiency up to $(m_\mathrm{p} - m_\mathrm{e})/m_\mathrm{p} = 1\,834/1\,835 = 99.95\%$, and will become a lepton star, in particular, an electron star. It is a type of substable or unstable stars, in which leptons (electrons, etc.) are either emitted or collected as a core of lepton star, respectively. Lepton stars may not be observed due to its very small mass. For the existence of lepton star, the most important clue is that conditions of nucleon-decay must be satisfied. It does not depend on GUT's concrete model or energy scale.

1.3 The event horizon The Kerr-Newman black hole is the most general stationary black hole with parameters M (mass), J (angular momentum) and Q (charge). Its radius is

$$R_\pm = \frac{GM}{c} \pm \frac{1}{c}\sqrt{(GM) - GQ - \left(\frac{cJ}{M}\right)}\ . \qquad (6)$$

It is one of Schwarzschild black hole $R = GM/c$ in a case that $Q = J = 0$. On the other hand, when

$$(GM) - GQ - (cJ/M) < 0, \qquad (7)$$

i. e
$$Q + \sqrt{Q^4 + (cJ)} > GM > Q - \sqrt{Q^4 + (cJ)}, \qquad (8)$$

this has not an event horizon. Thus an external observer can see all processes, in which a black hole collapses to a singularity and transforms into a lepton star, which should include charge because of the massive leptons with charges.

The condition (8) can hold completely. For instance, it becomes

$$Q > GM > 0, \qquad (9)$$

for a black hole with charge Q and without rotation i. e., $J = 0$. It is namely a static electric force larger than a gravitational force of the same distance.

A collapsing process from star to black hole (esp. without the event horizon) and singularity may possibly repeat many processes of the Big Bang Universe.

1. 4 Mass of lepton stars Total energy of Sun is $E = mc = \times 10^{33} \times 9 \times 10^{0}$ g•cm•s^{-1} = 1. 8 × 10^{47} J. The known power of quasars is about 10^{40} J•s^{-1}, so continuously emitting energy of quasars per year is 3. 1536 × 10^{47} J, which consumes only about $m_\odot$. If we take that the energy put out by Sun in its whole life (10 billion years) is 10^{44} J[1], the mass of quasars will be of the order 1 000 $m_\odot$. While the quasar superstar model may include 10^6—10^8 solar masses[1], in some other models even as much as 10^{15} $m_\odot$ (Lee 1987).

1. 5 Characteristics A lepton star should be an ultrahot collapsing star. Its case is, perhaps, situated between that of neutron star and that of black hole. Its mass is larger than a maximum mass of a stable neutron star, which is of order 3 $m_\odot$ that depends only on the validity of the general relativity[1]. But its radius doesn't reach that of a black hole. Its characteristics are: a. Emission photons and neutrinos, etc., with ultrahigh energy, because

$$\pi^0 \to \gamma\gamma, \quad E(\gamma) = (140/\ )\,\mathrm{MeV} = 70\,\mathrm{MeV}, \qquad (10)$$

$$\gamma\gamma \to e^+ e^- \to \text{any hadrons}, \quad e^+ e^- \to \gamma\gamma \to \mu^+ \mu^- \ \ldots \qquad (11)$$

b. Disappearance of stars with 100% or near 100%. These processes (10) and (11) are going on again, then the photon energies decrease continually. Such lepton stars may correspond to quasars, gamma-ray burst and some sources of ultrahigh energy cosmic rays.

1. 6 Evolutionay results on stars Usually it is supposed that a supermassive star must collapse into a black hole. The star will become so hot during the collapsing process. A possibility is that it will explode, and become supernovae, but an ultrahot star should be able to form a lepton star before its radius reaches that of a black hole. We propose that for different supermassive stars there will be different results as following:

Late stages of supermassive stars

$$\to \left\{ \begin{array}{ll} \text{supernovae} \to \left\{ \begin{array}{l} \text{neutron stars} \\ \text{black holes} \end{array} \right. & \text{for lower temperature} \\ \text{lepton stars} \to \left\{ \begin{array}{l} \text{quasars} \\ \text{GRB} \end{array} \right. & \text{for ultrahigh temperature} \end{array} \right\}. \qquad (1\ )$$

Of course, some black holes may probably introduce quasars and GRB, etc.

2 Ultrahigh energy cosmic rays and GRB, quasars

Klebesadel, et al. (1973) first observed gamma-ray burst (GRB) based on an analysis of data produced by the Vela defense satellites. Now the great majority of astronomers believe that the bursts located at the cosmological distance. While cosmological models require both enormous total energy and the concentration of that energy into a small mass. The sources emitted energies during a few seconds or a few minutes larger than that emitted by Sun during 10^{10} years, and disappeared mystically. The energies emit for GB971 14 and

GB9901 3 even up to 3×10^{46} J and 3.4×10^{47} J ≈ 1.94 $m_{\odot}$. Magnetic fields of GRBs may exceed 10^{15} G and particles may be accelerated up to $\geqslant 10^{\ 0}$ eV, and bursts at very high redshift[6]. This implies that the source must be a compact object, perhaps accreting black hole of stellar size. GRB' s photon energy may be 170 KeV — 1 GeV (Kouveliotou, et al. 1994).

Usually a standard model of the compact radio cores causes a rotating supermassive (10^{8}—10^{10} $m_{\odot}$) black hole and accretion disk[7]. Astronomers proposed the neutron star accreting model, the shock emission model (Meszaros, et al. 199), the neutron starquakes as a potential local model and very rapid accretion into a black hole model. The usually adopted at present models are mainly the neutron star-neutron star merging model and the black hole-neutron star merging model.

Many quasars are radio sources, which come from compact clouds of electrons moving with approximate light speed. The models of quasars include colliding stars, quasar superstars, pulsars and black hole theory, etc. The present theories suppose that the quasars are created in early stages of evolutionary universe. We think that quasars are simply lepton stars, whose differences from quasars produced by black holes are ultrahigh temperature and terminal into almost nothing. It agrees with following characteristics of quasars[1]: ① Ultrahigh energy sources. Quasars can outshine the entire Milky Way by a factor of 1 000. While nearly all mass of a lepton star may transform into energy. ② High speed electrons and photons may produce large redshifts, caused either by a local explosion, or from powerful gravitational fields within the objects themselves[ ]. Then photon energy decreases, $E(\gamma) = 14$ MeV for a redshift $z = 4$. ③ The $\pi^{0}\to\gamma\gamma$ produce two symmetric gamma-ray sources, which like "two engines model". Other decays of nucleons will also form some particular directions of emitted energies. ④ Intermittent bursts of quasars correspond to continual collapse of a lepton star with some layers, which is analogous to the structure of neutron star (Shapiro & Teukolsky, 1983). A part of star achieves the condition of lepton star, and this part bursts. ⑤The powerhouse is a small object. ⑥ Rapid motion is associated with the production of energy.

Further, lepton stars are possibly some GRB' s sources. It may also explain some GRB' s characteristics, in particular, with enormous total energy and mystical disappearance.

Finally, it is interesting to compare the white hole[8], which was first suggested in 1964 by I. Novikov and M. Hjellming as a possible source of quasar energy. White hole is a time-reversed black hole, but it is a mathematical creature[1]. Lepton stars possess some properties of the white holes, in which baryon-number is nonconservation. Perhaps, lepton star is a true white hole. Research of lepton star will also promote the GUT' s development.

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Abstract: The monthly standard deviation of outgoing longwave radiation(OLR) was obtained in terms of the data around 75°S—75°N and 0°—360° in 1980— 001. The results show that the OLR variation over low-latitude area is one order larger than that over middle- and-high latitude area in terms of the zonal average in the year. The area where the OLR has obvious interannual variation about 15 W/m is located at tropical middle eastern India Ocean, the western Pacific warm pool and middle eastern Pacific. The OLR interannual variation over the warm pool is the biggest one. The next to it is that one over the tropical middle eastern Pacific, and then the smallest one among the three is that over the tropical middle eastern India Ocean. The OLR interannual variation in summer, which is around 11 W/m , is smaller than that in winter, which is around 15 W/m . The OLR variation also has obvious seasonal abrupt change. The OLR abrupt changes occur in May and June, and in October. The area of the maximum OLR interannual change is confirmed.

Key words: outgoing longwave radiation field; interannual change; time-spacial distribution; standard deviation

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大统一理论, 轻子星和 γ 射线暴, 类星体*

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摘要: 在超重质量星无限塌缩的过程中, 其能量标度达到足够大时, 此时就可以应用粒子物理中的大统一理论, 并提出一个新的模型: 核子衰变后一个超重质量星将把它的几乎所有质量转化为能量, 从而变为可能是亚稳定或不稳定的轻子星. 按照这一模型, 就可以解释超高能宇宙射线和高能天体物理中的下列疑难: 类星体和 γ- 射线暴等. 轻子星也许就是真实的白洞.

关键词: 大统一理论; γ 射线暴; 类星体; 粒子物理; 宇宙学

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