symmetric gravitational field of the Sun or the Earth (neglecting rotation) and that the metric chosen to obtain equation 16 is isotropic: $g_{\alpha\beta} = (g_{00}, g_{ik})$, where $g_{ik} = -\eta_{ik} f$, so that $ds^2 = g_{00}x^0x^0 - f(x^1x^1 + x^2x^2 + x^3x^3)$. Using this metric, equation 16 is easily derived as a first-order approximation in the gravitational potential GMc^2/r from equation 87.3 of *Field Theory* by Lev D. Landau and Evgenii M. Lifshitz. As the final step of this derivation one has to change to the frame with the usual local rulers and clocks. The choice of an isotropic metric does not permit us to get rid of our force by using equivalence-principle elevators, and therefore one can say that the result for the light bending angle does arise from the global geometry of the central field—the point that is usually stressed in textbooks on gravity.

Engelbert Schucking from New York University has informed me that he has obtained a generalized exact formula for what he calls "the relativistic apple," valid in all approximations with respect to the potential GMc^2/r:

$$\mathbf{F}_g = -\frac{G_N M(E/c^2)}{r^3\left(1+\frac{G_N Mc^2}{2r}\right)^3} \times\left[\mathbf{r}\left(1+\beta^2+\frac{G_N Mc^2}{2r-G_N Mc^2}\right)-\beta(\beta\cdot\mathbf{r})\right]$$

(I'm grateful to Schucking for this communication. I am also grateful to him and to Mikhail Voloshin and Alexander Dolgov for very enlightening discussions.) The first-order approximation in gravitational coupling implicit in equation 16 is very good for the cases of the Sun and the Earth.

I have found equation 16 in only one book.[2] Unfortunately the formula is constructed there semiempirically, and the book itself is full of $E = mc^2$ and all that.

The lack of space and time didn't allow me to discuss in my article such important questions as the mass of a system of particles. I consider this and some other problems in more detail in an extended version of the article.[3]

I don't think we should try to banish $E = mc^2$ from T-shirts, badges and stamps. But in the textbooks it should appear only as an example of a historical artifact, with an explanation of its archaic origin.

References

1. M. G. Bowler, *Gravitation and Relativity*, Pergamon, Elmsford, N. Y. (1976).
2. R. S. Serway, J. S. Faughn, *Physics*, Saunders, Philadelphia (1989).
3. L. B. Okun, Usp. Fiz. Nauk. **158**, 511 (1989) [Sov. Phys. Usp. **32**, 629 (1989)].

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1/90

Broken Symmetry Can't Compare with Ferromagnets

I was sorry to see, in the otherwise excellent history of the "standard model" for particle theory by Paul Langacker and Alfred K. Mann (December, page 22), a repetition of the false analogy between broken symmetry and ferromagnetism that is very common among the writings of particle physicists.

In ferromagnetism, specifically, the ground state is an eigenstate of the relevant continuous symmetry (that of spin rotation), and as a result the symmetry is unbroken and the low-energy excitations have no new properties. Broken symmetry proper occurs when the ground state is not an eigenstate of the original group, as in antiferromagnetism or superconductivity; only then does one have the concepts of quasidegeneracy and of Goldstone bosons and the "Higgs" phenomenon. I have discussed the origins of the concept of broken symmetry elsewhere.[1]

Reference

1. P. W. Anderson, in *Gauge Theories and Modern Particle Theory*, R. Arnowitt, P. Nath, eds., MIT P., Cambridge, Mass. (1975), p. 311.

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12/89

Langacker and Mann reply: Our description of a ferromagnet as an example of a broken symmetry followed the language that is common in many books on condensed matter physics,[1] and the ferromagnet is a valid analog of what is called a spontaneously broken global symmetry in elementary-particle physics. It was not our intention to imply that the ferromagnet is an example of the "Higgs" phenomenon, and we apologize if the wording in the article was not sufficiently clear. We thank Philip Anderson for emphasizing the important distinction between ferromagnets (in which the order parameter commutes with the symmetry generators) and antiferromagnets.

Reference

1. See, for example, D. Forster, *Hydrodynamics, Fluctuations, Broken Symmetry, and Correlation Functions*, W. A. Benjamin, Reading, Mass. (1975).

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3/90

Where Did Einstein Lament Lambda?

We were very interested in the article "Landau's Attitude Toward Physics and Physicists" by Vitaly L. Ginzburg (May 1989, page 54). In the section headed "General Relativity" the author raises the issue of the introduction and renouncement by Einstein of the cosmological constant Λ and mentions that he tried to find an original paper on that subject. We recently tried to trace where and when Einstein gave up the idea of $\Lambda \neq 0$: The references can be found in the excellent biography by Abraham Pais, *'Subtle Is the Lord . . . ': The Science and the Life of Albert Einstein* (Oxford U. P., New York, 1982, page 288).

Einstein wrote that there is no need for a Λ term in his paper "Zum kosmologischen Problem der allgemeinen Relativitätstheorie."[1] There we read, "Unter diesen Umständen muss man sich die Frage vorlegen, ob man den Tatsachen ohne die Einführung des theoretisch ohnedies unbefriedigenden Λ-Gliedes gerecht werden kann" ("Under these circumstances, the question should be raised of whether one can satisfy the facts without introducing the Λ term, which anyway is theoretically unsatisfactory"), and, in the conclusion, "Bemerkenswert ist vor allem, dass die allgemeine Relativitätstheorie Hubbels neuen Tatsachen ungezwungener (nämlich ohne Λ-Glied) gerecht werden zu können scheint als dem nun empirisch in die Ferne gerückten Postulat von der quasi-statischen Natur des Raumes" ("It is remarkable that the theory of relativity seems to satisfy Hubble's new results more naturally [Pais translates this as "in an unforced way"], namely, without the Λ term, than the empirical postulate of a quasistatic space, now set aside"). One year later, in a paper with Willem de Sitter,[2] Einstein wrote (in English), "It now appears that in the dynamical case this end [the existence of a finite mean density in a static universe] can be reached without the introduction of Λ."

As for the oft-quoted sentence about Einstein that "the introduction of the cosmological term was the biggest blunder he ever made in his life," it is to be found only in George Gamow's autobiography *My World Line* (Vi-

king, New York, 1970, page 44) and probably does not represent exact words spoken by Einstein. Einstein did make a similar, mild statement in 1954, in a footnote to an appendix in the fifth edition of *The Meaning of Relativity*.

We thank Larry Abbott for a most interesting correspondence.

References

1. A. Einstein, Sitzungsber. Preuss. Akad. Wiss., 16 April 1931, p. 235.
2. A. Einstein, W. de Sitter, Proc. Natl. Acad. Sci. USA **18**, 213 (1932).

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Four Reasons for Forsaking the SSC

The January 1990 Washington Reports section has several stories concerning the SSC now planned to be built in Texas. I suggest this project be canceled for the following reasons.

First, the physics community is doing a poor job of educating people about physics. The $5 billion or more to be spent *initially* for the SSC should be spent on improving education for millions of students instead of building a research tool for the possible benefit of a few dozen researchers and for the economic benefit of Texas. In this time of greatly unbalanced national budgets, we can't do both, and the education of many is a far more important use of the funds at this time.

Second, if physics is such an international subject, and this facility will be used by scientists from all around the world, other countries should help pay for it.

Third, the news stories indicate the use of political muscle to put and keep the project in Texas, possible uncertainties in the design, and probable significant increases in the cost of the project. I for one have no confidence in the competence of the decision to put the project in Texas. I am sure it was "bought" by the most money and power in the White House and Congress, with little regard to national need. The Department of Energy, its predecessors and Congress have a miserable record for openness, honesty and competence.

Fourth, the physics community should remember that a project of this size is going to attract a crowd similar to the politicians, bankers and promoters who have cost the citizens of the United States a $100 billion tax bill through the financially irresponsible, incompetent and unethical operations of savings banks in Texas. This crowd will force the cost to rise significantly, the quality of construction to drop, or both. Whatever reputation the physics community has is going to go down as a result of this project.

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1/90 *Oxford, Ohio*

Memories of the First Texas Symposium

In his engaging reminiscences about the first Texas Symposium on Relativistic Astrophysics (August 1989, page 46), Engelbert Schucking recalls how "[John] Wheeler's magic produced an expression of utter disbelief on the face of a most distinguished relativist." But Schucking did not expand on the nature of this magic nor explain the reason for the disbelief.

Wheeler felt that the gravitational collapse that was the center of attention at the meeting could not go on indefinitely. He proclaimed that in such a collapse, "matter will be crushed out of existence." When pressed to elaborate, he suggested that the matter would be radiated away. This remark produced a strong reaction from those who objected to violations of baryon conservation. But Wheeler remained calm and repeated his extraordinarily prescient claim. For me, his remark was the most remarkable feature of that memorable conference.

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The high point of the first Texas relativistic astrophysics meeting occurred as Harlan Smith finished his talk on the variability of the quasar 3C273. Jesse Greenstein, the next speaker, slowly walked to the front of the room, climbed the one step to the platform, turned to face the audience and said dramatically, "If 3C273 is varying in brightness, I'll eat my hat!" Don't know if he did.

Vera C. Rubin
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Greenstein replies: A limited answer to Vera C. Rubin's letter is that I did not then, nor do I now, wear a hat. If I doubted Harlan Smith's discovery that 3C273 varies, I should by now have eaten many hats, ornamented with artificial bitter fruit. I do not recall the event Rubin mentions; my memory of that symposium is scientifically more nourishing.

However, I note that in a paper published from the symposium, Smith credits me with explaining variability as "explicable . . . [by] changing opacity in a substantial hydrogen cloud."[1] That explanation, alas, is also incorrect. My paper on 3C48 and 3C273 from the symposium, written with Maarten Schmidt, assumed the 3C273 variability to be real and sought for a physical cause.[2] We suggested that relativistic electrons that produced the optical synchrotron continuum decayed in about a year. The emitting region could be a light year in radius if it were at high electron density. In retrospect, we should have gone further, but black holes had not yet become as fashionable as dark matter is now.

If the unfortunate conservatism of many scientists is the message of Rubin's letter, her point is well taken. But many other scientists will have to eat many hats, plates or tapes when hindsight is the mode for criticizing the past.

References

1. H. Smith, in *Quasi-Stellar Sources and Gravitational Collapse*, I. Robinson, A. Schild, E. L. Schucking, eds., U. Chicago P., Chicago (1965), p. 221.
2. J. L. Greenstein, M. Schmidt, in *Quasi-Stellar Sources and Gravitational Collapse*, I. Robinson, A. Schild, E. L. Schucking, eds., U. Chicago P., Chicago (1965), p. 200.

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Landau's Brain Injury: A Fuller Account

I read with interest I. M. Khalatnikov's article about Lev Landau in your May 1989 issue (page 34). His account of the last part of Landau's life, however, is defective. Although the error concerns the least significant part of Landau's life for physicists, some of your readers may be interested in it.

Landau was in the rear of a friend's small car one icy winter evening when there was a mild collision, as I recall the account, with a truck, and Landau's head hit the right rear doorpost. Such incidents in which there is no cranial penetration are termed closed head traumas. One typical immediate consequence is edema, with the patient lapsing into a coma. At the time, few such patients survived, and it was only with heroic