Of Quantities and Qualities

The article by Victor F. Weisskopf "Of atoms, mountains, and stars: A study in qualitative physics" (21 Feb., p. 605) exploring the qualitative approach to the material phenomena around us based on a quantum mechanical understanding of the atomic domain is like a particularly elegant Persian rug. To see the design of nature constructed from a few "simple—but subtle" motifs is to appreciate what is most attractive about the scientific endeavor and to rue how rarely articles like this are written.

And, as if not to insult the gods with the weaving of a perfect rug, two minor errors in the formulas occurred. The formula for the earth's radius, R_E (p. 609), should be

$$R_E \sim \left(\frac{N_E}{A}\right)^{1/3} R$$

instead of

$$R_E \sim \frac{N_E}{A}^{1/3} R$$

Also the expression for σ (p. 609) should be $\xi' \gamma Ry/\pi f^2 a_0^2$ instead of $\xi' \lambda Ry/\pi f^2 a_0^2$.

CHARLES R. CONNELL
Department of Chemistry, University of Washington, Seattle 98195

Weisskopf's article is a fine discussion of the basic properties of atoms, mountains, and stars. Without the help of detailed calculations, he derives some important results. However, one point needs to be clarified. Weisskopf gives a simple calculation for finding what he calls the minimum mass of a star, but what he has actually computed is the minimum mass of a main sequence star. Main sequence stars are objects that are going through the hydrogen-burning stage of stellar evolution. During the preceding phase of gravitational contraction, nuclear reactions involving the destruction of deuterium, lithium, beryllium, and boron may also produce some energy. The minimum mass on the main sequence is obtained by finding the mass at which the hydrogen burning is just sufficient to support the luminosity of the star. According to my calculations (*1*), the value of the minimum mass for Population I main sequence stars is approximately 0.07 solar mass ($M_\odot$). Weisskopf has redone this calculation without using detailed evolutionary models.

Luminous stars of mass less than 0.07 $M_\odot$ can and do exist. Two examples are the members of the visual binary system Wolf 424 (*2*). Each member in this system has a mass slightly less than 0.07 $M_\odot$. Several other luminous stars which are thought to have masses less than 0.07 $M_\odot$ have been observed in recent years. These stellar objects shine for periods as long as 1 billion years before they become too faint to be seen with our telescopes. The source of their energy output is the gravitational potential energy and the destruction of deuterium, lithium, beryllium, and boron. Because of electron degeneracy, the contraction phase of these stars comes to an end, and they eventually become extremely faint.

The approximate numerical value of the minimum mass of a star is 0.01 $M_\odot$ (*3*). Stars are formed from interstellar clouds with different masses, and the minimum mass is the mass that a star must have at the time of its formation in order to survive as a separate entity. The number of luminous and nonluminous stars with masses in the range of 0.01 to 0.07 $M_\odot$ is thought to be very large, and they may even make a significant contribution to the total mass of the Milky Way Galaxy and other galaxies (*3, 4*).

SHIV S. KUMAR
Department of Astronomy, University of Virginia, Charlottesville 22903

References

1. S. S. Kumar, *Astrophys. J.* **137**, 1121 (1963).
2. W. D. Heintz, *Astron. J.* **77**, 160 (1972).
3. S. S. Kumar, *Astrophys. Space Sci.* **17**, 218 (1972).
4. W. M. Napier and B. N. G. Guthrie, *Mon. Notic. Roy. Astron. Soc.* **170**, 7 (1975).

I highly appreciate the kind words and the corrections which the two contributors have expressed in the above letters. Of course I agree with them, and I am sorry that the errors which Connell mentions were overlooked and that I did not explicitly state, as Kumar points out, that my considerations apply only to "ordinary" stars, that is, those on the main sequence. Even so, I find it remarkable that the lower limit for the mass of a luminous star, according to the more general considerations of Kumar, is only a factor of 100 away from the fundamental number $(hc/GM^2)^{3/2}$.

May I take this opportunity to point out a further numerical error in the article. At the bottom of the third column on page 611, in the expression of the lower limit of N^*/N_0, $\pi^2/2$ should be replaced by $\pi^2/4$. The following sentence then should read: "The number of protons in a star must be at least $0.35\eta^{3/4}$ times the number N_0."

VICTOR F. WEISSKOPF
Department of Physics, Massachusetts Institute of Technology, Cambridge 02139