THE SUN'S LUMINOSITY AND AGE

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Two recent papers in the June 1980 issue of this journal by Hinderliter and Steidl provided excellent documentation on solar shrinking and the lack of solar neutrinos; and their combined testimony is against evolutionary astronomy and for creationist astronomy. This paper adds some additional information on current research and on the history of investigation into the sun's luminosity and age. The Helmholtz contraction theory, the meteoric bombardment theory, and the solar incandescence as the source of sun's luminosity are revisited. It is found that all, except possibly meteors, may individually provide for the observed luminosity. Particularly, it is argued that if the sun was created 6000 years ago as an incandescent body at about 6000 degrees Kelvin there would have been imperceptible dimunition in its temperature to the present.

Introduction

Hinderliter[1] and Steidl[2] have observed that the recently discovered solar shrinkage is amply sufficient to supply the solar luminosity and that this coupled with the apparent lack of solar neutrinos strongly suggests that the sun, and hence stars, do not burn nuclear fuel. Hence, they observe, that the enormous astrophysical ages given to stars can not be justified. These papers assume that the sun, indeed, is shrinking; however this question is being hotly debated, for nothing less than the foundations of evolutionary astronomy are at stake.

Eddy and Boornazian[3] find the decrease to be 2.25 and 0.75 arc seconds per century for the east-west and north-south diameters, respectively. Their figure is based on meridian crossings at the Greenwich Observatory for the years 1836 to 1953. The east-west diameter was obtained from the time for the solar disk to cross the local meridian and then corrected for the sun's distance and increase in right ascension. The north-south diameter was obtained by setting micrometer wires on the north and south solar limbs. They conjecture that the north-south diameter may be comparatively erroneous since it is influenced by atmospheric refraction. They report a similar shrinkage from the U.S. Naval Observatory observations for the years 1894 to 1950. They also find the circumstances of the 9 April, 1567 eclipse at Rome to confirm their results.

Eddy's figures have been challenged by several. Shapiro[4] used 23 transits of Mercury across the solar disk between the years 1736 to 1973. He found the shrinkage to be 0.05 ± 0.10, and hence regarded the solar diameter as constant. Morrison[5] independently examined Mercury transits from 1723 to 1973 and obtained similar results. Sofia[6] puts any possible solar shrinkage at less than 0.5 based on changes in the solar constant (i.e., the energy per unit area per unit time received above the atmosphere for all wavelengths).

The objections raised against Eddy and Boornazian's figures are that the industrial atmosphere at Greenwich has become increasingly polluted in the years 1836 to 1953 and that increased extinction would increasingly diminish the apparent solar disk. It is also objected that the timing methods used during much of this period are questionable. Of course, the major objection, whether spoken or not, is that shrinkage of such magnitude may well negate all of evolutionary astronomy.

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I favour actual shrinking for several reasons. 1) It is anti-evolutionary and compatible with the creationist view of a recently created, not evolved, sun. 2) The meridian observations are very numerous as compared to Mercury transits. 3) The reduction of meridian observations are much simpler than the reductions from Mercury transits or solar constant variations in that many more theoretical considerations enter into the experiment for the latter two cases.

An historical postscript to this controversy has been added by Prof. Wittmann of Gottingen, in the September 1980 issue of *Sky and Telescope*, in which Wittmann mentions that Gauss, in 1809, discounted solar shrinking in favor of observer errors even though meridian transit observations showed shrinking. He also cites Gething's 1955 study of transits showing a decided shrinking as opposed to Tobias Mayer's study in the mid 18th century showing no evidence for change.

Physical Quantities

Table 1 shows the values of physical quantities to be used subsequently. The sun radiates into space seeing an ambient temperature of space. The temperature, T_a, will be taken to be that of the famous 3 degree background radiation. The mean solar specific heat has been estimated from Eddington[7] as follows. Eddington's Γ approximates the ratio of the molecular specific heat under constant pressure to that under constant volume, i.e., $\Gamma \cong C_p/C_v \cong 4/3$. Eddington derives $C_v = N/(\Gamma\text{-}1)$ where $N = R/\mu$ and where R is the universal gas constant and μ the mean molecular weight. Taking $\mu = .6$ [8] gives $C = C_v \sim 4 \cdot 10^8$. The rate of change of the solar radius, $\dot{r}$, is taken from Eddy and Boornazian (3) as 2.25/2 arc seconds per century. The solar emissivity, ϵ, is the fractional amount by which the sun differs from a blackbody radiating at the solar temperature, i.e. $E = 4\pi r^2 \ \epsilon\sigma T^4$ gives $\epsilon = 100$. Figures in Table 1 not specifically mentioned may be found in references 11 and 12.

The Helmholtz Contraction Theory

In 1854, Helmholtz reported his contraction theory whereby the contractions of a homogeneous gas sphere will produce temperatures on the order of the solar surface temperature[9,10] Helmholtz assumed that all gas particles fall radially inward and their loss of gravitational potential energy is completely converted to ther-

Table 1. This table contains physical quantities used in this paper.

Symbol	Value	Units	Definition
T	5785	deg k	The solar temperature
T_a	~ 3	deg k	The ambient temperature of space
r	$6.91 \bullet 10^{10}$	cm	Present radius of the sun
p	1.41	$gm \bullet cm^{-3}$	Solar mean density
c	~ 4.10^{8}	$erg\text{-}gm^{-1}\text{-}k^{-1}$	Solar mean specific heat
ϵ	1.00		Solar emissivity
a	$-1.73 \bullet 10^{-15}$	$rad\text{-}sec^{-1}$	Rate of change of solar radius(3)
σ	$5.67 \bullet 10^{-5}$	$erg\text{-}cm^{-2}\text{-}sec^{-1}\text{-}k^{-4}$	Stefan-Boltzman constant
M	$2.0 \bullet 10^{33}$	gm	Solar mass
G	$6.67 \bullet 10^{-8}$	$dyne\text{-}cm^{2}\text{-}gm^{-2}$	Gravitational constant
R	$8.31 \bullet 10^{7}$	$erg\text{-}k^{-1}\text{-}mol^{-1}$	Universal gas constant
μ	.6		Solar mean molecular weight
E	$3.86 \bullet 10^{33}$	$erg\text{-}sec^{-1}$	Solar luminosity
D	$1.50 \bullet 10^{13}$	cm	Sun-earth distance
r	$-2.60 \bullet 10^{-2}$	$cm\text{-}sec^{-1}$	aD, = $8.18 \bullet 10^{5}$ $cm\text{-}yr^{-1}$ (3)
M_e	$5.97 \bullet 10^{27}$	gm	Earth's mass

mal energy. Under these assumptions Helmholtz derived the following expressions for a stellar temperature rise ΔT, and increased internal energy, ΔQ,

$$\Delta T = (2.47.10^{3})\ (1 + r/\Delta r)^{-1}\ [(GM)/(cr)] \qquad (1)$$

$$\Delta Q = (3/5)\ (1 + r/\Delta r)^{-1}(M^{2}/r) \qquad (2)$$

where the star shrinks from radius $r + \Delta r$ to r, G is the gravitional constant, M the stellar mass, and c the specific heat.

It now remains to associate a rate of shrinkage with the relative shrinkage $\Delta r/r$. Note that $r/\Delta r >> 1$ and that $\Delta Q = -E\Delta t$, $\Delta r = \dot{r}\Delta t$ where it is assumed that all the internal energy, ΔQ, contributes to the luminosity. In this case ΔT is the temperature rise if ΔQ is retained. Hence, ΔQ becomes, $\Delta Q \cong (3/5)\ GM^{2}r^{-2}\Delta r$ and on dividing by Δt one gets $E = -\Delta Q/\Delta t = -(3/5)GM^{2}r^{-2}$ $(\Delta r/\Delta t)$; which on solving for $\dot{r}$ gives $\dot{r} = -(5/3)\ Er^{2}/(GM^{2})$ Evaluating this expression gives $-1.15 \bullet 10^{-4}$ $cm\text{-}sec^{-1}$ $= -3.63 \bullet 10^{3}$ $cm\text{-}yr^{-1}$.

Steidl's formula[3] on page 64 appears to estimate the loss in potential energy of a gaseous sphere as it uniformly collapses from fr to $fr + \Delta r$ for effective radius fr

$$\Delta Q = E\Delta t = -M[GM(fr)^{-1} - GM\ (fr + \Delta r)^{-1}]$$
$$\cong -(1/f)\ GM^{2}r^{-2}\Delta r \qquad (3)$$

where, again, it is assumed that all the loss of gravitational potential energy somehow is converted into radiative energy. Hence, solving for $\dot{r} = \Delta r/\Delta t$ gives $\dot{r} = fEr^{2}/(GM^{2})$ which for $f = 0.5$ is a factor of 12/5 larger than Helmholtz's value. Eddington (7, p. 289) quotes a coefficient of 3/2.

If Eddy and Boornazian *et al* are correct, then the observed solar contraction is about 200 to 20 times larger than necessary in order to provide the solar luminosity. Some caution must be exercised in using Helmholtz's figures since some part of the gravitational energy of contraction must be absorbed by ionization, electron excitation, convection, mass rotation, particle translation, etc. However, the observed contraction is in such excess that the very possible reality of stellar luminosity being a result of gravitational contraction can not be denied. It is interesting to note Eddington's (7 pp. 289-291) summarial dismissal of the contraction mechanism based on the surety of evolutionary time based on the usual circular arguments from biological and geographical evolutionary time. One very interesting aspect of Helmholtz's theory is that it benignly assumes, though it does not require, the star to have nearly constant temperature throughout, or at least not the enormous temperature variation predicted by astrophysical theory. I find this to be compatible with the very simple incandescent explanation of the solar luminosity during its 6000 years of existence. Some of the more comprehensive early papers on the contraction theory were written by some of the most emminent theoretical astronomers of the 19th century.[13]

Meteoric Bombardment Theory

Moulton (10, pp. 59-63) notes that meteors travel at great speeds (about 40 $km\text{-}sec^{-1}$ near the earth) and that a sizable portion of their kinetic energy might be converted into caloric energy upon striking the sun. Moulton estimates that if the sun's luminosity is due to meteoric impact then "the earth should receive 1/236 as much heat from the impact of meteors as from the sun. This is certainly millions of times more heat than the earth receives from meteors." This is raw speculation on Moulton's part. We must also speculate but from the vantage point of much aero-space research into the meteoric flux distribution within the solar system. From even before the beginning of the space era, in 1957, primary interest was given to the meteoric flux. Before 1957, non-orbiting rockets were used.

The following numbers found in reference (18) permit an estimate of the total meteoric kinetic energy available to the sun,

$$\Sigma\ mv^{2} = (10^{-12})\ (10^{2})\ [4\pi(6.91 \bullet 10^{10})^{2}]\ (1.3 \bullet 10^{-6})$$
$$(10^{4})\ (3.3 \bullet 10^{5})\ (10^{2})\ (6.1 \bullet 10^{7})^{2} = 9.6 \bullet 10^{33}\ erg\text{-}sec^{-1} \qquad (4)$$

These factors left to right are defined as follows. 1) The estimated near earth meteoric flux in $particles\text{-}cm^{-2}$ $\text{-}sec^{-1}$ $\text{-}2\pi ster^{-1}$ (18, p. 268); 2) The measured flux average frequently showed increases by a factor of 170 for extended periods of time. Hence, this factor is optimistically included (p. 269); 3) This factor is the area of the sun's surface in cm^{2}; 4) This factor is the average meteoric particle mass in grams (p. 269); 5) The factor 10^{4} results from both observational and theoretically considerations for determining the earth enhancement as a gravitational particle sink (p. 222); 6) The ratio of the sun's mass to the earth's mass is used to convert the earth enhancement to the solar enhancement; 7) A factor of 10^{2} is further included to account for the Poynting-Robertson enhancement (p. 222); 8) The velocity of a particle falling from infinity is taken as the representative velocity.

We note that this figure is about twice the solar luminosity thus indicating that, perhaps, meteoric bombardment cannot be dismissed as the source, or partial source, of the sun's luminosity.

Hinderliter[1], along with Thomson in 1854, objects that meteoric accretion would increase the solar mass and thereby measurably change the length of the year. The year, P, may be defined by Kepler's law as $P = 2\pi r^{3/2}[G(M+M_e)]^{-1/2}$. If P and M are considered as being time varying, then differentiating gives,

$$\dot{P} = -2\pi r^{3/2} G^{-1/2} (M+M_e)^{-3/2} \dot{M}$$

$$= -.5P\dot{M}\ (M+M_e)^{-1} \cong -.5P\dot{M}\ /M \cong -2.\ \text{sec-cent}^{-1} \qquad (5)$$

Hence, one may question whether a loss of 2 seconds in a century is measurable. I would say it is not. Furthermore, any increase in meteoric mass may well be offset or overwhelmed by a large ejection of mass.

The theory that meteors or other interplanetary material are responsible for the stellar luminosity well predated Moulton. For example Newton, in his 1713 edition of the Principia, added; "So fixed stars, that have been gradually wasted by the light and vapors emitted from them for a long time, may be recruited by comets that fall upon them . . . ".

Incandescence

It is invariably and tacitly assumed that if the sun were simply a glowing body that it would perceptibly have cooled down in the recent centuries during which it has been astronomically observed. The contrary is suggested here; i.e., it is argued that if the sun, or a star, were created with the temperature they now have that due to their enormous thermal mass they would appear much the same and maintain their luminosity throughout the 6000 years since the creation.

Let it be assumed that the loss of internal energy of the sun is counterbalanced by an associated radiation. This energy balance is given by, $(4/3)\pi r^3\ pcdT + 4\pi r^2\ \sigma\epsilon(T^4 - T_a^4)dt = 0$ where a temperature decrease, dT, occurs in time interval, dt. Let $T(0) = T_0$ be the temperature at time $t = 0$. Separating the variables gives

$$(T^4 - T_a^4)^{-1} dT = -3\sigma\epsilon(pc)^{-1}(\dot{r}t + r_0)^{-1} dt \qquad (6)$$

where the sun's radius is assumed to vary as $\dot{r}t + r_0$. This equation can be integrated; however the resulting expression introduces mathematical complexity. If T_a is neglected then integrating from time T_0 to T gives

$$T = T_0\,[1 + z\ \ln(1 + (\dot{r}/r_0)t)]^{-1/3} \qquad (7)$$

where

$$z = 9\sigma\epsilon\ T_0^3\ (pc\dot{r})^{-1}$$

Setting $r_0 = r$ and $T_0 = T$ and taking t = 6000 yr = 1.892 10^{11} sec gives $T = .8741\ T_0$. For 100 years this becomes $.9973\ T_0$ Hence, by this model, it would seem that the solar temperature would have changed imperceptibly during the last century of solar astronomical observing; and that even over 6000 years the change would be small. This result is sensitive to the parameter z; e.g. if $c = 1.8$ then for $t = 6000$ yr, $T = .9561\ T_0$. One might argue for increasing c, but this might be offset by a decreased value for r.

If this analysis is, in any way, correct then the mechanism for the light of the sun and stars is, indeed, simple and does not require the myriads of unproved assumptions and mathematical developments required by modern astrophysics which has as its underlying assumptions enormous periods of time.

The model used here is essentially identical to the procedure for measuring specific heats in the laboratory[19] whereby the change in temperature, dT, is for each point of the body, or may be thought of as a mean value. Note that by this analysis we may infer that if the sun or a star were created isothermal it would stay nearly that way, which is, also, in direct contradiction to evolutionary astrophysics.

Thomson[17], gave no calculations, but stated that the sun through conduction-convection would cool down about 1K-yr.$^{-1}$ Thomson was writing in 1854, several years before the Stefan-Boltzmann radiation law was known; and so, it would seem, he had the wrong boundary conditions.

Concluding Remarks

Contrary to popular belief it is found that gravitational contraction, meteoric bombardment and incandescence may all three individually account for the sun's continuing luminosity for the 6000 years since creation. This, also, applies to stars in general. It would seem that the problem is that there is too much energy available, instead of the evolutionary problem of finding enough energy for sustaining luminosity for billions of years. The incandescence theory would probably have been the explanation in pre-Copernican times. This is another example of the frequent superiority of pre-Copernican astronomy over the present Copernican-evolutionary views.

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