of our complete ignorance with respect to the evolution of the universe.

3. *Ions in super-novae*

If super-novae are giant analogues to ordinary novae we may expect that ionized gas shells are expelled from them at great speeds. If this assumption is correct, part of the cosmic rays should consist of protons and heavier ions. Direct tests by cloud chamber experiments at high altitudes are desirable in order to test this conclusion. Also the problem suggests itself to investigate how much energy corpuscular particles lose on their long journey through space. On the picture of an expanding universe this loss has been computed by R. C. Tolman.

4. *Fluctuations of cosmic rays*

In our original papers we have calculated the change in intensity of cosmic rays caused by flare-ups of super-novae in nearby galaxies. The estimates given are perhaps too optimistic in view of the fact that the velocities of different particles are different. If various particles are ejected simultaneously at the time $t=0$ from a galaxy which is 10^6 L.Y. away the times t of arrival on the earth are

$t=10^6$ years for light if its velocity does not depend on the frequency.

$t_1=10^6$ years $+410$ seconds for 10^{11} volt electrons.
$t_2=$ " $+47.6$ days " 10^9 " "
$t_3=$ " $+44$ years " 10^{11} " protons.

These time lags t_i-t would tend to smear out the change of intensity caused by the flare-up of individual super-novae. Dr. R. M. Langer in one of our seminars was the first to call attention to the straggling of simultaneously ejected particles.

5. *The super-nova process*

We have tentatively suggested that the super-nova process represents the transition of an ordinary star into a neutron star. If neutrons are produced on the surface of an ordinary star they will "rain" down towards the center if we assume that the light pressure on neutrons is practically zero. This view explains the speed of the star's transformation into a neutron star. We are fully aware that our suggestion carries with it grave implications regarding the ordinary views about the constitution of stars and therefore will require further careful studies.

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May 28, 1934.

Doubly-Excited States in Helium

The authors have been interested in the calculation of energy levels in doubly-excited helium with the purpose of verifying the identifications of far ultraviolet helium lines suggested by Kruger[1] and by Compton and Boyce,[2] and Rosenthal's[3] theory of the corona spectrum. Variational calculations of the states $(2s)(2p)^1P$ and $(2s)(2p)^3P$ (with the use of two-parameter trial functions as accurately orthogonal as possible to the functions of all the lower states) places $(2s)(2p)^1P$ at 296,118 cm^{-1} above $(1s)^+$ (the limit of single ionization) and $(2s)(2p)^3P$ at 274,526 cm^{-1} above this limit. We have found that the combinations $(1s)(2s)^3S-(2s)(2p)^3P$ and $(1s)(2p)^1P-(2s)(2p)^1P$ correspond with good accuracy to the lines 320.39A and 309.04A, respectively. The first transition gives a calculated wave-length 319.51A, agreeing with the experimental value to 3 parts in a thousand. The second gives 309.32A, agreeing with the experimental value to one part in a thousand.

The first transition is a perfectly good permitted transition and would be expected to appear prominently in the far ultraviolet spectrum. The error has the correct sign; that is, a more accurate calculation of the level, $(2s)(2p)^3P$ would place it slightly lower, thus increasing the corresponding wave-length and improving the agreement. We thus agree with Compton and Boyce, who suggested that this line is $(1s)(2s)-(2s)(2p)$ without specifying singlet or triplet and with Kruger only in the fact that we make it a triplet. (Kruger has $(1s)(2p)^3P-(2p)^2\,{}^3P$ for the 320 line.)

The assignment of $(1s)(2p)^1P-(2s)(2p)^1P$ for the 309 line we suggest tentatively simply because of the very good numerical agreement and are perfectly aware of the objections to it. In the first place the error has the wrong sign for a variational method which uses a trial function orthogonal to the lower state wave functions. Such a method should place the level higher than the true level. If this assignment is correct, our calculated level is lower than the correct level. This fact, however, is not serious, because one can never be sure of the orthogonality and may thus overshoot the mark. In the second place the transition violates the Laporte rule and would thus have to be attributed to quadrupole radiation or to electric field-perturbed dipole radiation. Compton and Boyce state that their light source was field-free and Kruger does not find the line.

A rough calculation of $(2s)^2\,{}^1S$ places this level at about 275,000 cm^{-1} above $(1s)^+$. $(1s)(2s)^1S-(2s)^2\,{}^1S$ thus becomes about 307,000 cm^{-1}. Kruger gives 279,715 cm^{-1} for the 357 line, which he attributes to $(1s)(2s)^1S-(2s)^2\,{}^1S$. Our calculation thus casts doubt upon this assignment.

Rosenthal[3] has suggested that the corona lines are due to jumps between levels of doubly-excited helium, corresponding to lines of the ordinary helium spectrum with the inner electron a $2s$ rather than a $1s$ electron. He selects the corona lines 5303.12, 3986.88 and 3600.97 as forming a series and attributes them to the transitions $(2s)(2p)^3P-(2s)(nd)^3D$, with $n=3$, 4, 5, respectively. Using a Hicks formula, he computes the series limit, obtaining for $(2s)(2p)^3P$ a figure which corresponds to 296,904 cm^{-1}

[1] P. G. Kruger, Phys. Rev. **36**, 855 (1930).
[2] K. T. Compton and J. C. Boyce, J. Frank. Inst. **205**, 497 (1928).
[3] A. H. Rosenthal, Zeits. f. Astrophysik. **1**, 115 (1930).

above $(1s)^+$. This disagrees violently with our value 274,526 cm^{-1} for $(2s)(2p)^3P$, but agrees rather well with our value 296,118 for $(2s)(2p)^1P$, suggesting that the assignments may be correct if one makes them singlets rather than triplets. To test this point, we have calculated (without variation) $(2s)(3d)^1D$ and $(2s)(3d)^3D$ (by integrating the exact energy operator over a properly symmetrized hydrogenic wave function with the $2s$ electron moving in the unshielded field of the nucleus and the $3d$ electron in the field of a charge $(Z-1)e$). We place $(2s)(3d)^1D$ at 309,428 cm^{-1} above $(1s)^+$ and $(2s)(3d)^3D$ at 308,018 cm^{-1} above $(1s)^+$, thus obtaining $(2s)(2p)^3P-(2s)(3d)^3D$ equal to 33,492 cm^{-1} as against the experimental value 18,852 cm^{-1} for the corona line 5303 supposed to be due to this transition. Also $(2s)(2p)^1P-(2s)(3d)^1D$ comes out 13,310 cm^{-1}, disagreeing almost as violently. The disagreement is so bad that it is quite clear that a more accurate calculation of these levels would not lead to a check. This series assignment of Rosenthal seems thus to be definitely untenable.

Most of the computations involved in this work were done by one of us (F. G. F.) and will appear later as a separate paper, with further work on the same general problem.

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June 4, 1934.

Disintegration of H^2 and the Stellar Abundance of H^2 and H^3

The nuclear disintegration processes

$$H^2+H^2 \rightarrow H^3+H^1 \quad (1)$$

and

$$H^2+H^2 \rightarrow He^3+n^1 \quad (2)$$

are characterized by high efficiency even for low projectile energies. (The efficiency of (1) is about 10^{-6} at 0.1 m.e.v.)[1] Therefore, appreciable disintegration of H^2 should occur at the temperatures assigned to stellar interiors and during the time usually given for the age of the stars. This implies that reactions (1) and (2) will influence the stellar abundance of the nuclear particles concerned. Among the expected results are the following:

(a) Reactions (1) and (2) will tend to reduce the stellar abundance ratio $H^2:H^1$. Now it is known that the $H^2:H^1$ ratio is abnormally low in stellar atmospheres. Though $H^2:H^1=1:5000$ on the earth, the value for the stars is estimated as $H^2:H^1<1:600{,}000$ and $H^2:H^1<1:100{,}000$ by Menzel[2] and by Unsold[3] from their unsuccessful attempts to find H^2 by means of the isotope effect in stellar line spectra.

The discrepancy between the stellar and the terrestrial abundance ratio $H^2:H^1$ may be accounted for, solely on the basis of reactions (1) and (2) if we assume that

(1) At the time of its formation the earth obtained representative amounts of the H^2 and H^1 then present in the star.

(2) These reactions (1) and (2) have been proceeding in the star for at least 3×10^9 years.

(3) The temperature and density of some inner layer of the star are sufficiently high to yield an overall efficiency of about 10^{-14} for (1) and (2). (The temperature and density required are not unreasonably high.)

(4) There is transfer of material from such a layer to the stellar surface.

(5) There are no nuclear processes which replenish the star's supply of H^2 as rapidly as it is reduced by reactions (1) and (2). (No processes which yield H^2, let alone efficiently, are known as yet.)

This explanation does not require that the terrestrial $H^2:H^1$ ratio change appreciably with time. It also fits the current astronomical belief that the age of the sun is not much greater than that of the earth.

Reactions (1) and (2) have been emphasized though there are several other known disintegrations with capture of deutons which would help to lower the stellar $H^2:H^1$ ratio. However, an examination of the excitation curves for these reactions[4] indicate that they play only a minor rôle in stellar interiors.

The difference between the $H^2:H^1$ ratio on the earth and on the stars may also be ascribed, as Menzel has pointed out, to the differential escape of H^2 and H^1 from the earth. This would result in a higher terrestrial $H^2:H^1$ ratio. However, Russell and Menzel[5] have shown that it is probable that a very large proportion of gases as heavy as N_2 has escaped from the earth, and in this case it is hard to see how any great relative concentration of H^2 relative to H^1 could occur. Quite apart from this difficulty, Menzel's explanation forces one to assume, in the light of the occurrence of reactions (1) and (2), that either the H^2 supply is recreated in the star or the escape of H^1 from the earth affects the abundance ratio to a greater extent than the disintegration of H^2 in the stars.

(b) Reaction (1) will tend to increase the stellar abundance ratio $H^3:H^2$. This suggests that H^3 may be more abundant than H^2 in the stars despite an approximate ratio $H^3:H^2=1:200{,}000$ on the earth. One immediately thinks of a search for H^3 in stellar spectra. This is likely to be rendered difficult by the interference of relatively intense and broad neighboring lines, since the maximum abundance of $H^3:H^1$ to be expected from reaction (1) is about $1:20{,}000$. Thus if one takes the most favorable examples, the $H\alpha$ and $H\beta$ lines in the solar spectrum, the calculated isotope shift gives $H^3\alpha=6560.428$ and $H^3\beta=4859.575$. These lines will probably be masked, especially in the absorption (Fraunhofer) spectrum, by the telluric H_2O vapor

[1] Oliphant, Harteck and Rutherford, Proc. Roy. Soc. **A144**, 692 (1934).
[2] Menzel, Publ. Astr. Soc. of the Pacific **44**, 41 (1932).
[3] Unsold, Naturwiss. **20**, 936 (1932).
[4] Cockroft and Walton, Proc. Roy. Soc. **A144**, 704 (1934).
[5] Russell and Menzel, Proc. Nat. Acad. Sci. **19**, 997 (1933).