for a slowly rotating Venus, in order that the required greenhouse effect be achieved. As a check, the method was applied to the earth; the correct terrestrial water vapor abundance was predicted. The Venus model atmosphere has an ice-crystal cloud layer about 36 km above the surface. For rapid rotation, the predicted cloud layer is at the bolometric temperature, but has five times more water vapor above it than observed by Strong; for slow rotation, the cloud layer is 14 K° cooler than the bolometric temperature, but has 2×10^{-3} g cm⁻² above it, as observed by Strong. If the mean cloud albedo is >0.75, the overcast is <0.90. At gaps in the clouds, there are windows near 8.7 μ , and also at many wavelengths in the near infrared and visible.

The absence of surface liquid water inhibits the establishment of the Urey equilibrium, and, incidentally, greatly reduces tidal friction. If the earth had been placed in the orbit of Venus in primitive times, the same atmospheric carbon dioxide content as on Venus would have resulted, but the surface temperature and water vapor abundance would have been much greater; thus, the earth must have been formed with >10⁴ times more water than was Venus.

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On The Trumpler Shift in Early Stars. E. A. SPIEGEL, *Princeton University Observatory*.—In 1930 Trumpler measured radial velocities of late O and early B stars in order to obtain masses from the gravitational red shifts of these stars. His results indicated masses which are considerably above the masses expected for such stars, both on theoretical and observational grounds. In this note a possible explanation for Trumpler's observation is suggested.

For stars of the type studied by Trumpler (about B0) there is reason to believe that convective turbulence is moderately active (Speigel, University of Michigan Dissertation, 1958). The origin of the convection is in the HeII ionization zone near the surfaces of such stars. By the familiar arguments in such situations, one expects that lines formed primarily in rising hot elements will be shifted to the violet and those formed in the descending cooler elements will show a corresponding red shift. It is difficult to find lines meeting the requirements for clearly showing such an effect, but where the convection is due to He ionization, the He lines should be good examples. In particular, they would be expected to show a red shift compared to the mean of the other lines. Since Trumpler's measurements

were primarily of He lines, we might then expect that this mechanism could affect his results.

The magnitude of the red shift must surely be less than that given by the speed of sound in early-star atmospheres, about 20 km/sec. Indeed, Trumpler's shifts correspond to about 7 km/sec and this is consistent with what might be expected.

It is not difficult to check the foregoing suggestion observationally by measuring radial velocities for lines of different excitation potential. A preliminary study has been made by Struve (unpublished) on two high dispersion plates of 10 Lac (O9.5). The observations seem to corroborate the foregoing explanation to within the experimental accuracy.

Theory of the Orbit of an Artificial Satellite with Use of Spheroidal Coordinates.

JOHN P. VINTI, *National Bureau of Standards, Washington, D. C.*—The author has developed the orbital theory for an artificial satellite, using a gravitational potential, (Vinti, 1959, *J. Research Nat. Bur. Standards* **63B** 105) in spheroidal coordinates, ρ , η , ϕ , which leads to quadrature solutions. This procedure accounts for all of the second harmonic (of coefficient J_2) and for most of the fourth, but omits entirely the local anomalies, drag, lunar-solar perturbations, and the odd harmonics when the origin is chosen at the earth's center of mass.

A previous report (Vinti, 1960, *Bull. Am. Phys. Soc.* **5**, 8) outlined a solution for the secular motions of ω and Ω . The complete orbital solution now requires evaluation of the integrals in the kinetic equations and their subsequent solution for ρ and η ; all other quantities follow readily from these. Only the ρ integrals cause trouble; if $\rho_1 \cdots \rho_4$ are the zeros of a certain quartic $F(\rho)$ that they all involve, one must first find $\rho_1 + \rho_2$, $\rho_3 + \rho_4$, $\rho_1 \rho_2$, and $\rho_3 \rho_4$, where ρ_1 and ρ_2 are those zeros of $F(\rho)$ which would reduce to the perigee and apogee radii if J_2 vanished. With this fact as a start, a method of successive approximations leads to power series in J_2 for these sums and products, the present treatment stopping with J_2^2 .

Expressions of order J_2^2 follow readily for the ρ integrals and the η integrals, the former involving two angles closely related to v and E , the latter involving two other angles closely related to $\omega + v$ and $\phi - \Omega$. Here v and E are the true and eccentric anomalies, ω is the argument of perigee, and ϕ and Ω are the right ascensions of the satellite and the node. The constants that appear are all expressible in terms of initial conditions. A method of successive approximations, started by neglecting terms involving J_2 , then leads to the solution for ρ and η as functions of time, through terms of order J_2^2 . Calculation of the polar coordinates is then easy.