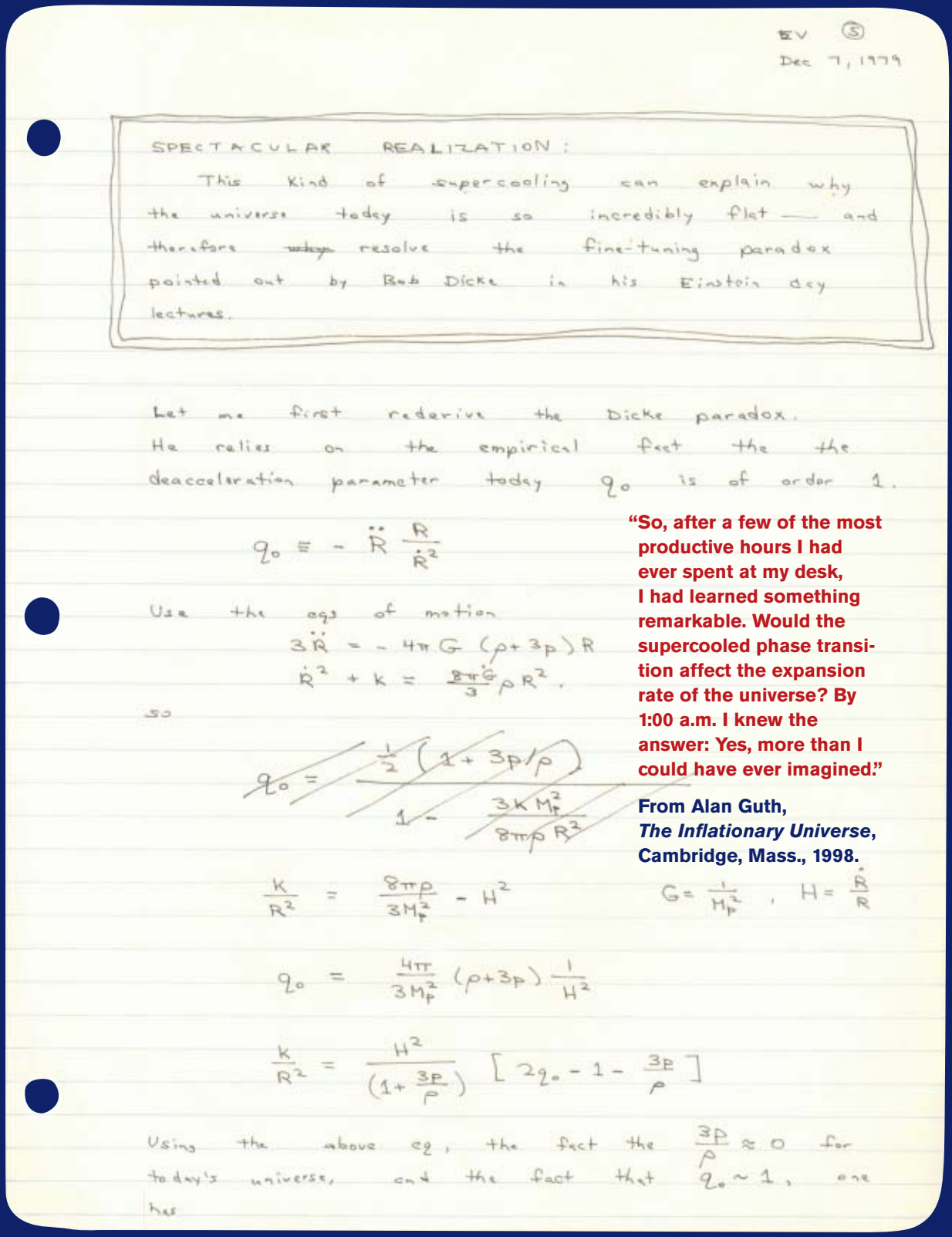
logbook: inflation



EV ⑤
Dec 7, 1979

SPECTACULAR REALIZATION:

This kind of supercooling can explain why the universe today is so incredibly flat — and therefore ~~why~~ resolve the fine-tuning paradox pointed out by Bob Dicke in his Einstein dey lectures.

Let me first rederive the Dicke paradox. He relies on the empirical fact the the deacceleration parameter today q_0 is of order 1.

$$q_0 \equiv -\ddot{R}\frac{R}{\dot{R}^2}$$

Use the eqs of motion

$$3\ddot{R} = -4\pi G(\rho + 3p)R$$
$$\dot{R}^2 + k = \frac{8\pi G}{3}\rho R^2.$$

so

$$q_0 = \frac{\frac{1}{2}(1 + 3p/\rho)}{1 - \frac{3kM_p^2}{8\pi\rho R^2}}$$

$$\frac{k}{R^2} = \frac{8\pi\rho}{3M_p^2} - H^2$$

$$G = \frac{1}{M_p^2}, \quad H = \frac{\dot{R}}{R}$$

$$q_0 = \frac{4\pi}{3M_p^2}(\rho + 3p)\frac{1}{H^2}$$

$$\frac{k}{R^2} = \frac{H^2}{(1 + \frac{3p}{\rho})}\left[2q_0 - 1 - \frac{3p}{\rho}\right]$$

Using the above eq, the fact the $\frac{3p}{\rho} \approx 0$ for today's universe, and the fact that $q_0 \sim 1$, one has

"So, after a few of the most productive hours I had ever spent at my desk, I had learned something remarkable. Would the supercooled phase transition affect the expansion rate of the universe? By 1:00 a.m. I knew the answer: Yes, more than I could have ever imagined."

From Alan Guth, *The Inflationary Universe*, Cambridge, Mass., 1998.

Image courtesy of Alan Guth

In 1978 Alan Guth heard about the "flatness problem" of the universe while attending a talk on cosmology—a field he was only marginally curious about—by Princeton University's Robert Dicke. A year later, working late at night as a postdoc at SLAC, Guth found a solution. At the beginning of the big bang, for an incredibly small fraction of a second, the universe could have expanded exponentially fast, rapidly transforming curved space into flat one. Quickly running out of energy, the expansion would slow down, eventually reaching today's sluggish pace. Such an initial explosive rush, which Guth later called inflation, could solve a number of cosmic paradoxes (see story on page 12).

Although scientists still debate the driving force behind inflation—Guth soon realized his original idea of "supercooling" wouldn't work—the concept of inflation has become the leading theme and the crux of modern cosmology.

Guth's notebook is now part of a permanent exhibit at the Adler Planetarium and Astronomy Museum in Chicago.