A perfect proposal

Daniel Kleppner, and Paul Horowitz

Citation: Physics Today **69**, 1, 48 (2016); doi: 10.1063/PT.3.3053
View online: https://doi.org/10.1063/PT.3.3053
View Table of Contents: https://physicstoday.scitation.org/toc/pto/69/1
Published by the American Institute of Physics

Daniel Kleppner is the Lester Wolfe Professor of Physics Emeritus at the MIT–Harvard Center for Ultracold Atoms in Cambridge, Massachusetts.
Paul Horowitz is a professor of physics and of electrical engineering, emeritus, at Harvard University in Cambridge, Massachusetts.

A perfect proposal

Daniel Kleppner and Paul Horowitz

A 1950 grant application that helped launch hydrogen-line radio astronomy provides a model for the clarity, economy, and integrity attainable in such requests.

Serious scientists rarely use the word "perfect," so we leave it to you to decide whether that is indeed an appropriate adjective for the proposal from Edward Purcell to the American Academy of Arts and Sciences in January 1950. Personally, we believe that the proposal—for an experiment to detect the microwave signature of interstellar hydrogen—comes as close to perfect as one could hope.

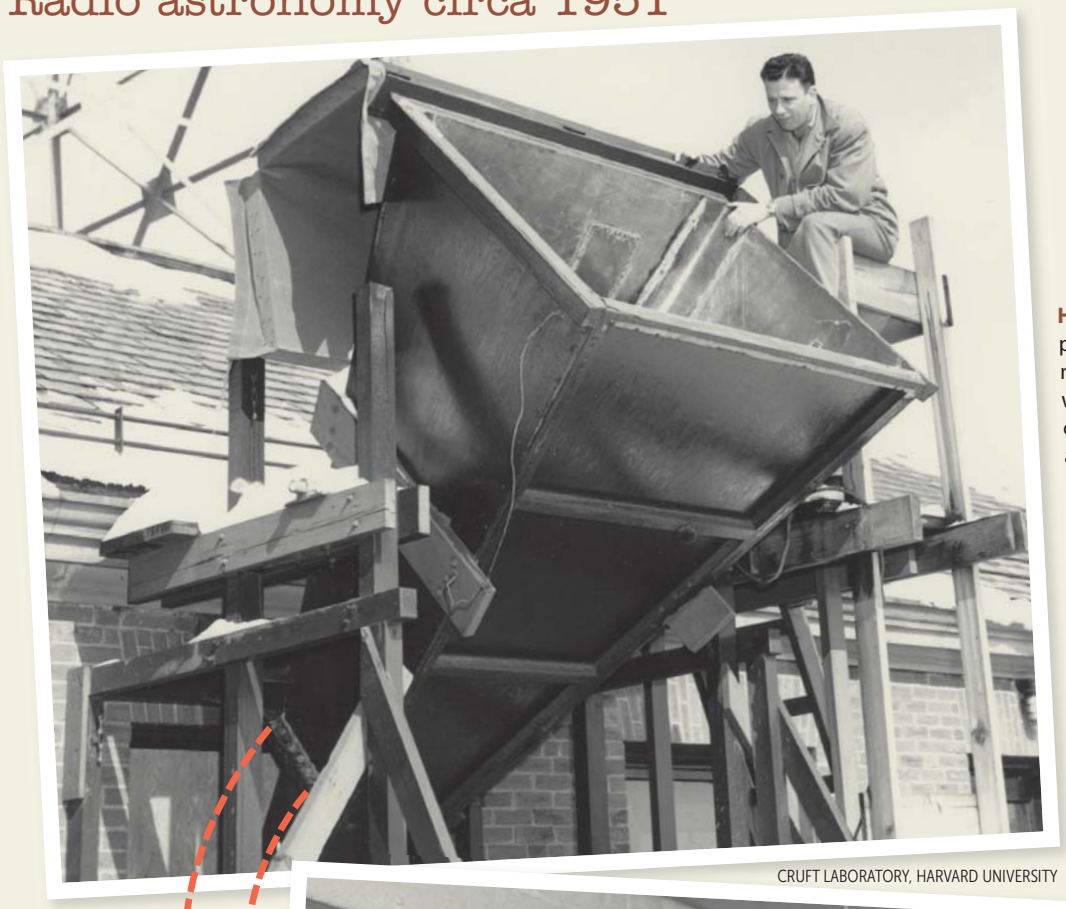
Purcell, who was on the physics faculty at Harvard University, addressed the proposal to Harlow Shapley, a distinguished astronomer and former president of the academy. A copy of the original in its entirety is reproduced on pages 50–51. In a handful of short paragraphs Purcell describes

- **the goal:** to detect interstellar atomic hydrogen by searching for a microwave signal at its 21-cm line, the spectral wavelength of the atom's ground-state hyperfine transition.
- **the significance:** multifold, yet conveyed in only a few lines of text because Shapley was an astronomer fully aware of the importance of such a discovery.
- **the method:** adapting established radio astronomy techniques to observe a sharp spectral line. Purcell succinctly explains everything from the origin of the radiation to the experimental technique.
- **the state of the field:** other groups with the same goal could well make the discovery first.
- **the need:** a detailed list of required equipment, totaling $500.

The proposal was accepted on 28 February 1950. Purcell and his graduate student Harold "Doc" Ewen observed a signal at the hydrogen-line frequency on 25 March 1951. They submitted a letter to *Nature*, but Purcell asked the

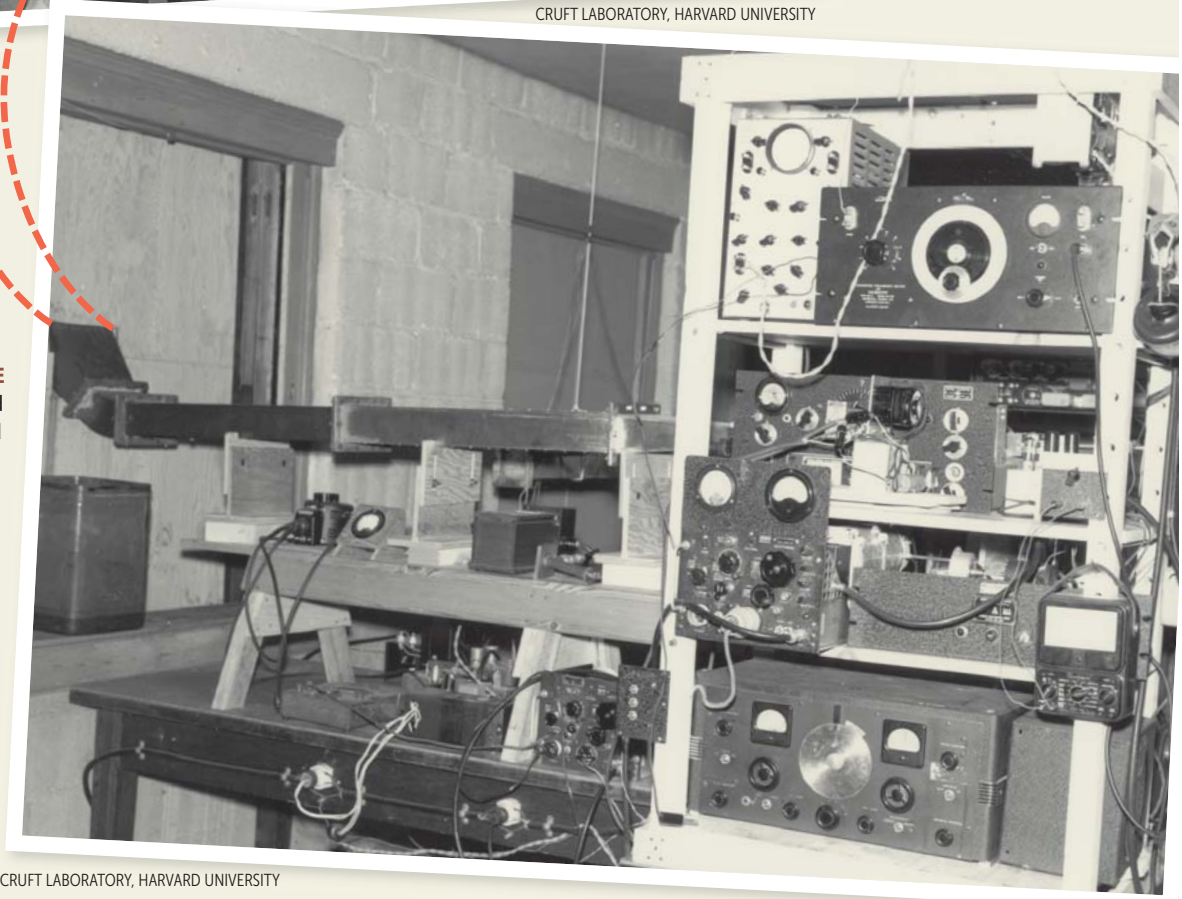
continued on page 52

Radio astronomy circa 1951



CRUFT LABORATORY, HARVARD UNIVERSITY

HAROLD "DOC" EWEN provides scale for the microwave horn antenna, which was made from copper-clad plywood and set on the fourth-floor parapet of Harvard University's Lyman Laboratory. Ewen added the canvas cover after the horn funneled a rainstorm into the lab (which Ewen remarked was his first "signal from space"). He and Edward Purcell used the horn to detect the 21-cm spectral line of interstellar atomic hydrogen.



CRUFT LABORATORY, HARVARD UNIVERSITY

ON THE OTHER SIDE of the plywood-covered window, signals carried in from the horn by the waveguide at left were mixed with the output of a war-surplus local oscillator and detected with an amateur communications receiver. The frequency was swept slowly by a gear motor and simultaneously modulated at 30 Hz to enable synchronous, "lock-in" detection.

HARVARD UNIVERSITY

DEPARTMENT OF PHYSICS

January 12, 1950

LYMAN LABORATORY OF PHYSICS
CAMBRIDGE 38, MASSACHUSETTS

Dr. Harlow Shapley
Harvard College Observatory
Cambridge 38, Massachusetts

Dear Dr. Shapley:

This letter is an application for a grant from the Rumford Fund of the American Academy of Arts and Sciences. The research project for which assistance is sought is an effort to detect, in the microwave radiation from interstellar space, a sharp line at the frequency associated with the hyperfine structure of the ground state of atomic hydrogen. The experiment has been undertaken as a Ph.D. thesis problem by Mr. Harold I. Ewen, a graduate student in the Department of Physics, under my direction. I shall outline briefly the background of the problem, and the method we plan to use.

The ground state of the hydrogen atom is split into two "hyperfine-structure" levels by the interaction between the spinning electron and the magnetic moment of the proton. The frequency associated with transitions between these levels has been measured very precisely by Nafe and Nelson at Columbia, using Rabi's method of atomic beams. It is 1420.41 megacycles/second, corresponding to a wavelength of 21.10 centimeters. Microwave radiation of this wavelength can be absorbed or emitted by free neutral hydrogen atoms, of which interstellar space contains a supply abundant for our purpose. We propose to search for this transition by studying the apparent noise temperature, in the neighborhood of the wavelength in question, of a microwave antenna directed toward the Milky Way. At this sharply defined wavelength we expect to find either a peak (bright line) or a dip (Fraunhofer line) in the apparent temperature, depending on whether the temperature of the hydrogen is higher or lower than that of the background of galactic radiation in this part of the spectrum. It is conceivable that the temperature of the hydrogen is so close to that of the background that no effect will be detected, but it seems unlikely that this situation will prevail in every direction. I have computed the transition probability and, on the basis of available astrophysical evidence, I believe there is a good chance that the line can be observed.

The techniques to be used are those now familiar in radio-astronomy with an important simplification permitted by the fact that we are here - for the first time - dealing with a sharp spectral line. The antenna itself will consist of an electromagnetic horn mounted outside the upper floor of the Lyman Laboratory. The associated equipment consists of waveguides, a microwave oscillator and superheterodyne receiver, and various auxiliary microwave and low frequency circuits.

I need not point out to you the astrophysical implications of the experiment, if successful; it would give fairly direct access to the condition of the interstellar hydrogen, since by suitable calibration a direct temperature measurement would be possible. It would be interesting also to study the red shift of this line. As physicists we have another reason to be interested

HARVARD UNIVERSITY

DEPARTMENT OF PHYSICS

LYMAN LABORATORY OF PHYSICS
CAMBRIDGE 38, MASSACHUSETTS

in the transition, as in any property of the hydrogen atom that can be measured with precision: our best values of the fundamental atomic constants are based, in part, on the measured frequency of this transition. It is possible that the interstellar line, because of the absence of collision broadening, will afford an even more precise determination of the frequency.

An experiment of the sort described has been in the minds of many people, I am sure, and it is not unlikely that someone will beat us to it. However, we have been in touch with the principal radio-astronomy projects in this country, and it appears that although exploration of the 1400 Mc region is included on some of the long-range programs, the present effort is going in other directions. We have set ourselves the limited objective of detecting the line, if possible. Clearly, once the existence of the effect is established, many more elaborate investigations would suggest themselves.

Of the equipment mentioned above, some parts are already available, and some can be borrowed. Certain critical items must be purchased or built in the laboratory, and it is to defray these expenses that I request a grant, in the amount of $500, to be spent approximately as follows:

Construction and mounting of horn	$150
Purchase of war surplus transmitter (APT-5) for use as local oscillator	100
Material for and construction of power supply for oscillator	75
Construction of microwave mixer	100
Construction of special waveguide circuit elements	75
Total	$500

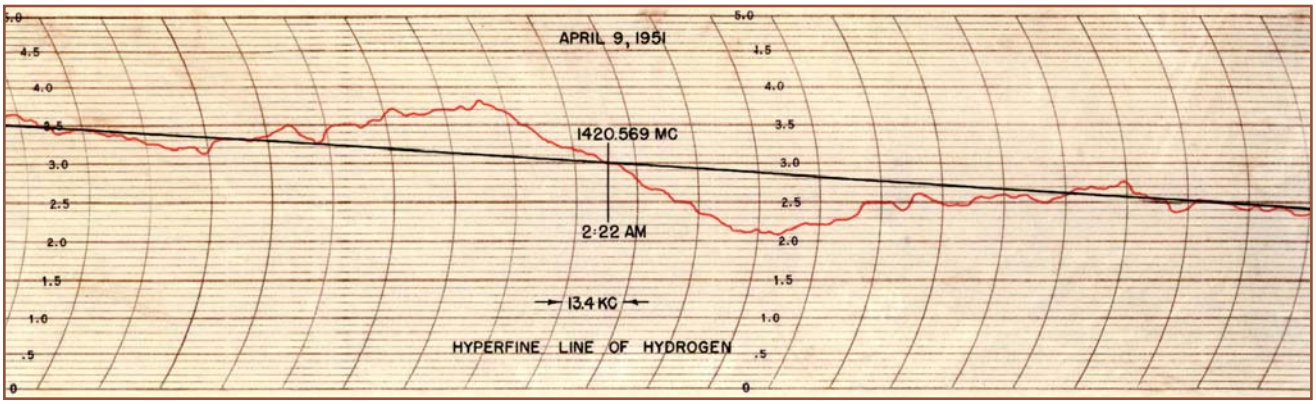
Any apparatus of permanent value so obtained would be suitably marked as acquired by a grant from the Rumford Fund, and would be made available subsequently to other researches, or disposed of in any way you might designate. None of the funds requested would be used to pay research assistants. Money budgeted for items requiring construction would be used to defray machine shop and carpenter shop charges.

I hope that the Rumford Committee will feel that this project is a suitable one for support by the Rumford Fund and is worthy of the assistance requested. Naturally I shall be very happy to provide any additional information the Committee may need.

Sincerely yours,

E. M. Purcell
Professor of Physics

EMP/pb



THE GALACTIC HYDROGEN EMISSION SIGNAL at 1420 MHz (21 cm), as traced in red on an electromechanical chart recorder less than three weeks after its discovery. The modulation technique causes the trace to have a positive and then a negative peak. The sloping black line approximates the receiver's drift over the 20-minute observation. (Reproduced from H. I. Ewen, "Radiation from galactic hydrogen at 1420 megacycles per second," PhD thesis, Harvard U., 1951, fig. 18.)

editor to delay publication to allow time for his colleagues Jan Oort (Netherlands) and Joseph Pawsey (Australia) to confirm and extend the discovery. Purcell freely shared the details of the new technique of phase-sensitive detection, whereupon Oort's group quickly observed the line. The three groups published side-by-side letters in *Nature* on 1 September 1951. The discovery marked the origin of hydrogen-line radio astronomy, a field that has grown into a major branch of astronomy.

We regard the proposal as perfect because of its lofty goal, its clarity of vision, its transparency, its honesty, and its respect for other citizens of the scientific community. Anyone lucky enough to have known Purcell will recognize his voice and will delight in the grace and simplicity of his style.

ADDITIONAL RESOURCES

- E. Purcell, oral history interview, session 1, http://www.aip.org/history-programs/niels-bohr-library/oral-histories/4835-1.
- H. Ewen, oral history interview, http://www.aip.org/history-programs/niels-bohr-library/oral-histories/6659.
- W. T. Sullivan III, *Cosmic Noise: A History of Early Radio Astronomy*, Cambridge U. Press (2009).

PT