
The History of Black Holes
Or to Physicists,
The History of Our Knowledge of Black Holes

1783

PHILOSOPHICAL

TRANSACTIONS,

OF THE

ROYAL SOCIETY

OF

L O N D O N.

VOL. LXXIV. For the Year 1784.

P A R T I.

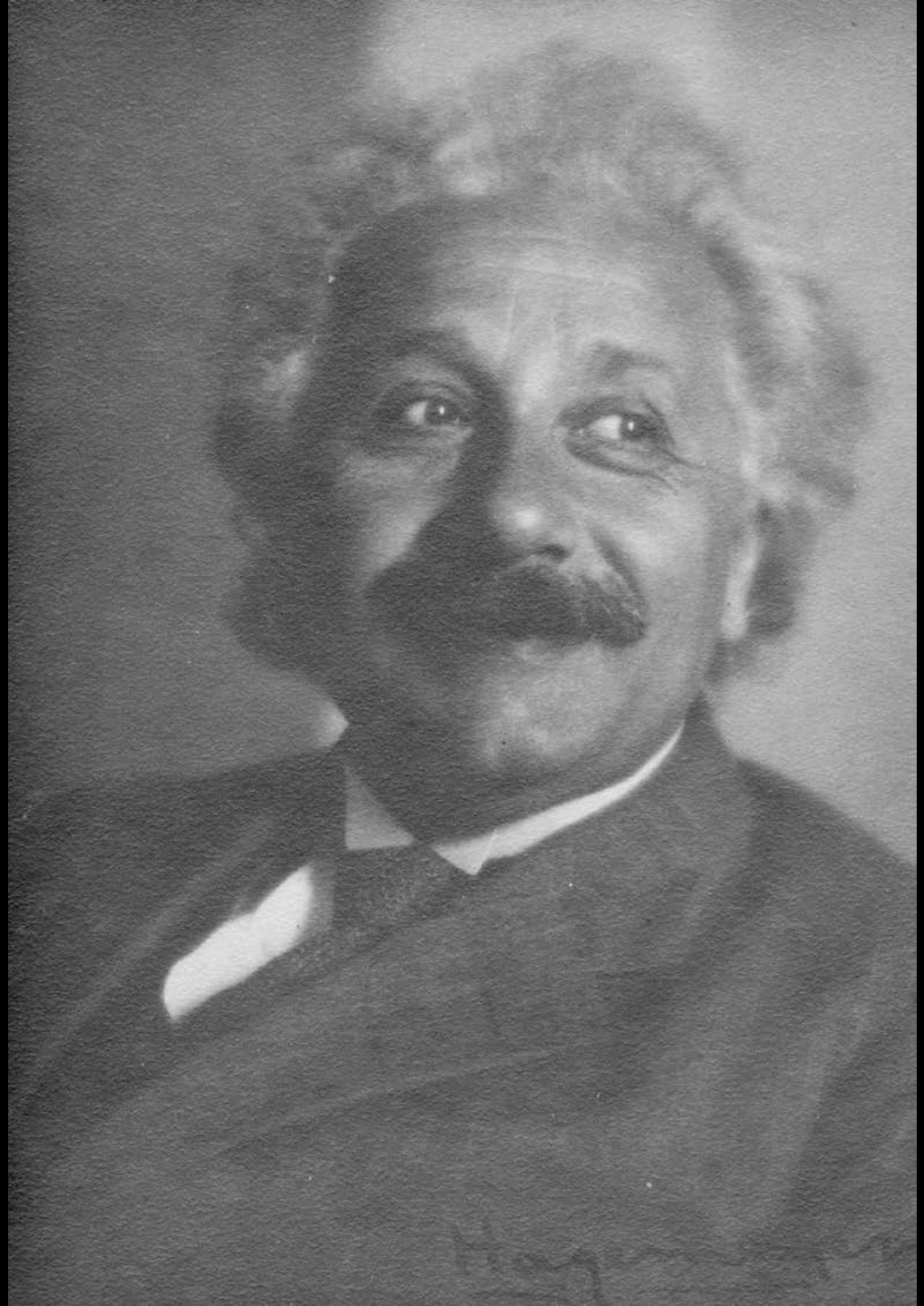
LONDON,

SOLD BY LOCKYER DAVIS, AND PETER ELMSLY,

16. Hence, according to article 10, if the ſemi-diameter of a ſphære of the ſame denſity with the ſun were to exceed the ſun in the proportion of 500 to 1, a body falling from infinite height towards it, would have acquired at its ſurface greater velocity than that of light, and conſequently, ſuppoſing light to be attracted by the ſame force in proportion to its vis inertiæ, with other bodies, all light emitted from ſuch body would be made to return towards it, by its own proper gravity.

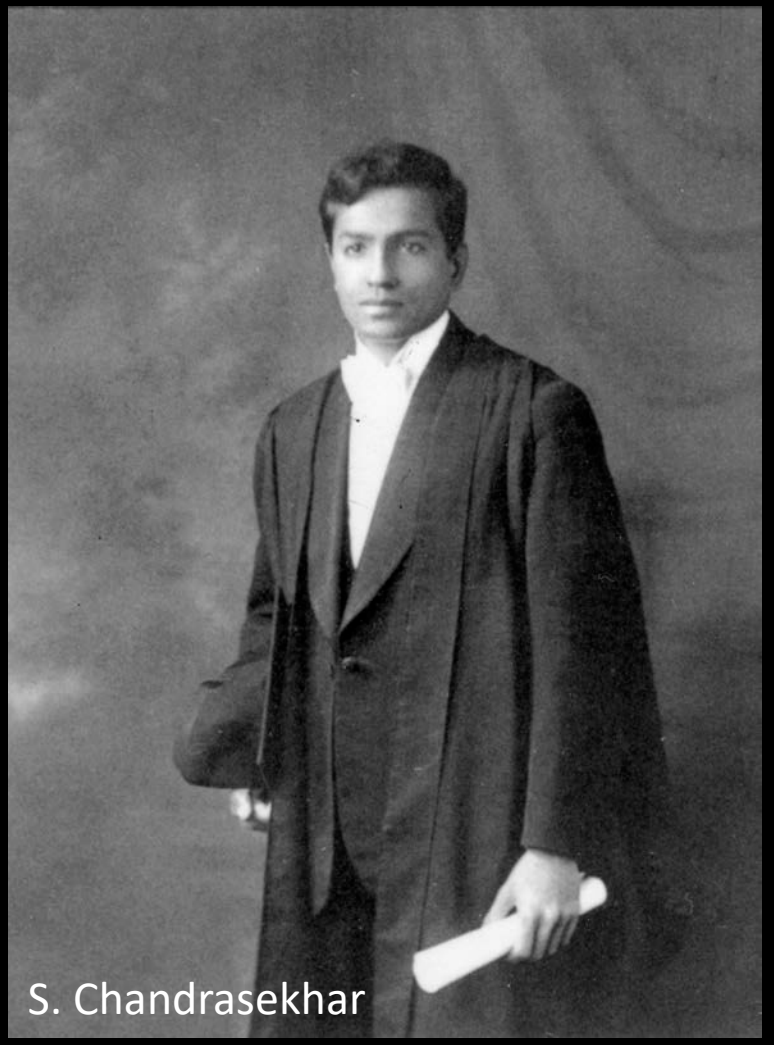
17. But if the ſemi-diameter of a ſphære, of the ſame denſity with the ſun, was of any other ſize leſs than 497 times that of the ſun, though the velocity of the light emitted from

1915



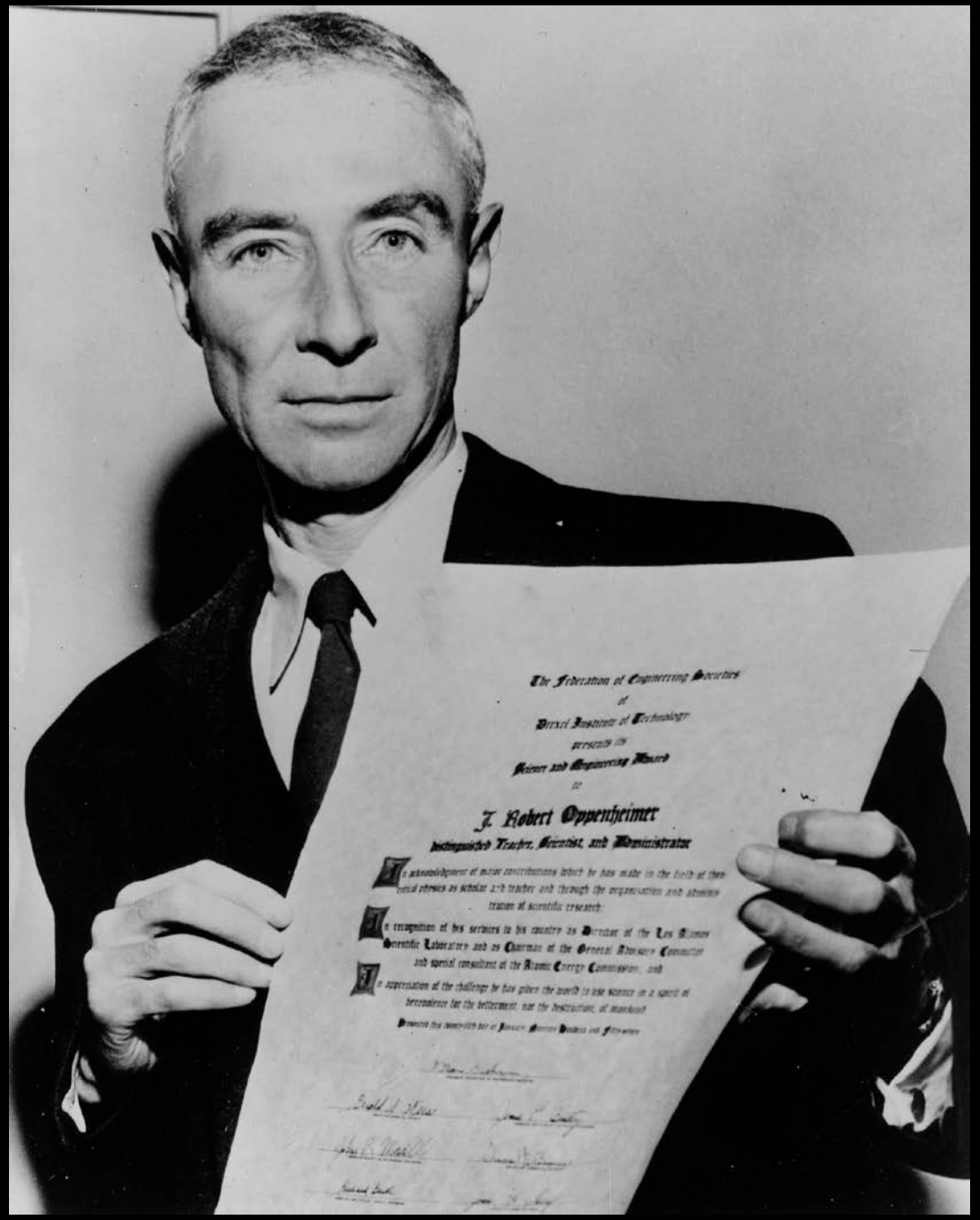
1935

A. Eddington



S. Chandrasekhar

1939



J.R. Oppenheimer

FEBRUARY 15, 1939 PHYSICAL REVIEW VOLUME 55

On Massive Neutron Cores

J. R. OPPENHEIMER AND G. M. VOLKOFF
Department of Physics, University of California, Berkeley, California

(Received January 3, 1939)

It has been suggested that, when the pressure within stellar matter becomes high enough, a new phase consisting of neutrons will be formed. In this paper we study the gravitational equilibrium of masses of neutrons, using the equation of state for a cold Fermi gas, and general relativity. For masses under $\frac{1}{3}\odot$ only one equilibrium solution exists, which is approximately described by the nonrelativistic Fermi equation of state and Newtonian gravitational theory. For masses $\frac{1}{3}\odot < m < \frac{3}{4}\odot$ two solutions exist, one stable and quasi-Newtonian, one more condensed, and unstable. For masses greater than $\frac{3}{4}\odot$ there are no static equilibrium solutions. These results are qualitatively confirmed by comparison with suitably chosen special cases of the analytic solutions recently discovered by Tolman. A discussion of the probable effect of deviations from the Fermi equation of state suggests that actual stellar matter after the exhaustion of thermonuclear sources of energy will, if massive enough, contract indefinitely, although more and more slowly, never reaching true equilibrium.

I. INTRODUCTION

FOR the application of the methods commonly used in attacking the problem of stellar structure[1] the distribution of energy sources and their dependence on the physical conditions within the star must be known. Since at the time of Eddington's original studies not much was known about the physical processes responsible for the generation of energy within a star, various mathematically convenient assumptions were made in regard to the energy sources, and these led to different star models (e.g. the Eddington model, the point source model, etc.). investigation would afford some insight into the more general situation where the generation of energy is taken into account. Although such a model gives a good description of a white dwarf star in which most of the material is supposed to be in a degenerate state with a zero point energy high compared to thermal energies of even 10^7 degrees, and such that the pressure is determined essentially by the density only and not by the temperature, still it would fail completely to describe a normal main sequence star, in which on the basis of the Eddington model the stellar material is nondegenerate, and the existence of energy sources and of the consequent temperature

SEPTEMBER 1, 1939 PHYSICAL REVIEW VOLUME 56

On Continued Gravitational Contraction

J. R. Oppenheimer and H. Snyder
University of California, Berkeley, California
(Received July 10, 1939)

When all thermonuclear sources of energy are exhausted a sufficiently heavy star will collapse. Unless fission due to rotation, the radiation of mass, or the blowing off of mass by radiation, reduce the star's mass to the order of that of the sun, this contraction will continue indefinitely. In the present paper we study the solutions of the gravitational field equations which describe this process. In I, general and qualitative arguments are given on the behavior of the metrical tensor as the contraction progresses: the radius of the star approaches asymptotically its gravitational radius; light from the surface of the star is progressively reddened, and can escape over a progressively narrower range of angles. In II, an analytic solution of the field equations confirming these general arguments is obtained for the case that the pressure within the star can be neglected. The total time of collapse for an observer comoving with the stellar matter is finite, and for this idealized case and typical stellar masses, of the order of a day; an external observer sees the star asymptotically shrinking to its gravitational radius.

I

RECENTLY it has been shown[1] that the general relativistic field equations do not possess any static solutions for a spherical distribution of cold neutrons if the total mass of the neutrons is greater than $\sim 0.7\odot$. It seems of interest to investigate the behavior of nonstatic solutions of the field equations.

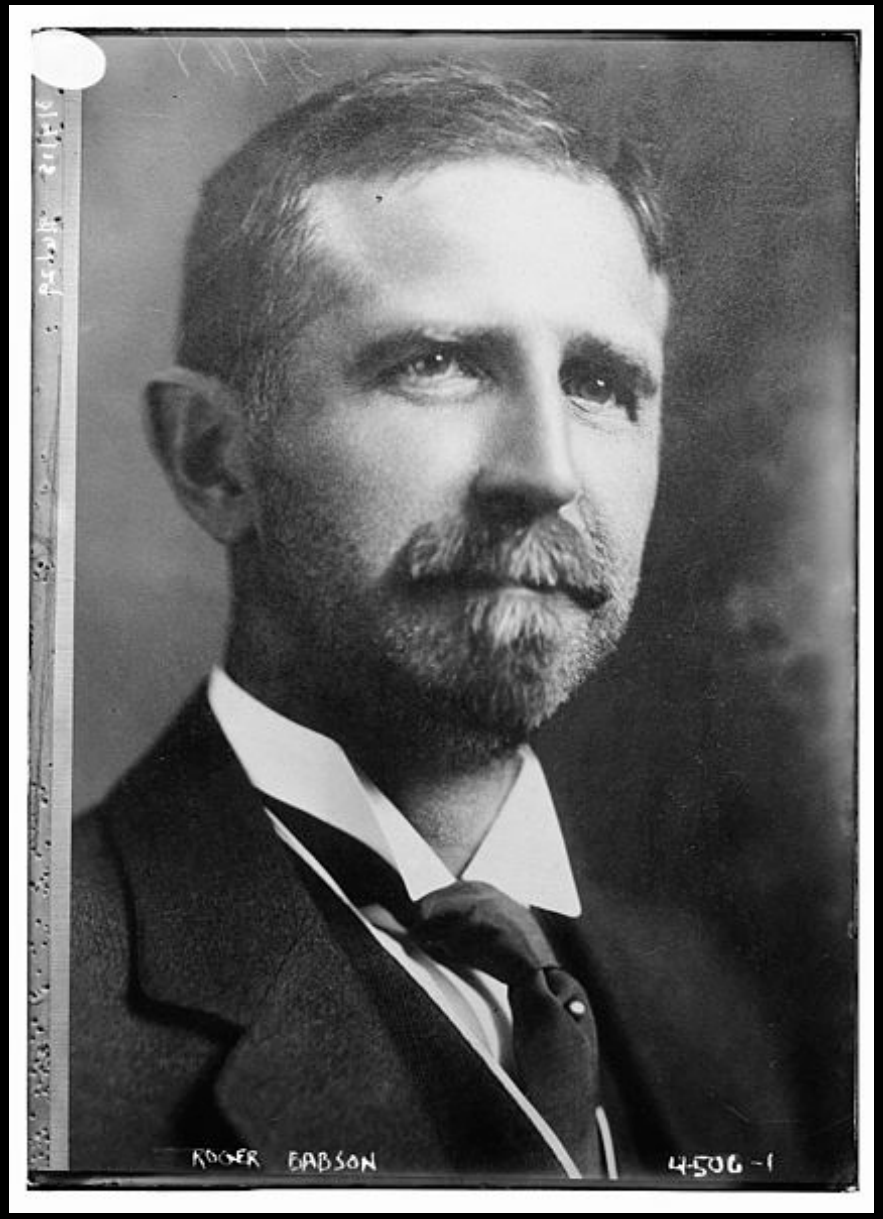
In this work we will be concerned with stars which have large masses, $>0.7\odot$, and which have used up their nuclear sources of energy. A star under these circumstances would collapse under the influence of its gravitational field and release energy. This energy could be divided into four parts: (1) kinetic energy of motion of the particles in the star, (2) radiation, (3) potential and kinetic energy of the outer layers of the star which could be blown away by the radiation, (4) rotational energy which could divide the star into two or more parts. If the mass of the original star were sufficiently small, or if enough of the star could be blown from the surface by radiation, or lost directly in radiation, or if the angular momentum of the star were great enough to split it into small fragments, then the remaining matter could form a stable static distribution, a white dwarf star. We consider the case where this cannot happen.

If then, for the late stages of contraction, we can neglect the gravitational effect of any escaping radiation or matter, and may still neglect the deviations from spherical symmetry

[1] J. R. Oppenheimer and G. M. Volkoff, Phys. Rev. **55**, 374 (1939).

SEPTEMBER 1, 1939


MANHATTAN PROJECT
BOMB



The Gravity Research Foundation Monument at Tufts University. Similar monuments exist at other locations across the country.

Institute of Field Physics at UNC Chapel Hill

WEATHER
Generally fair and cold with diminishing winds. Expected high 37 to 43.

The Daily Tar Heel

EDUCATION
Is the child growing away from its parents? See editorial, page 2

VOL. LVII NO. 80 | Complete (AP) Wire Service | CHAPEL HILL, NORTH CAROLINA, FRIDAY, JANUARY 11, 1957 | Offices in Graham Memorial | FOUR PAGES THIS ISSUE

FOR 'PERSONAL REASONS'

UNC LIBRARIAN ANDREW HORN RESIGNS POST

Air Force To Fly Foreign Physicists To United States

Scientists To Attend Gravitation Meet Here

By PETE IVEY

The U. S. Air Force will fly foreign scientists from Europe, the Middle East and the Orient into the United States next week where they will attend in Chapel Hill the first "World Conference on Gravitation" ever to be held in America, Jan. 18 to 24.

Forty internationally-known physicists who are working in the area of gravitational physics will conduct work sessions at Chapel Hill and will pool information relating to the role of gravity in physics.

The Air Force is one of the sponsors of the conference. Other sponsors include the National Science Foundation, the Institute of Field Physics of which Agnes Bahnson of Winston-Salem is chairman, and the French Department of Foreign Affairs.

Dr. Bryce DeWitt and Dr. Cecile M. DeWitt of UNC are hosts to the conference. The DeWitts are in charge of the year-old gravitation project at the University.

Among the foreign scientists expected to attend are: Herman Bondi, of Kings College, London; S. Deser, of Copenhagen, Denmark; Mademois lle Yvonne Foures, of Marseille, France; Jules Geneniau, of Brussels; Behram Kursunoglu, of Ankara, Turkey; Bertel Laurent of Stockholm; A. Lichnerowicz of the College de France; A. Papapetrou of East Berlin; F. A. E. Pirani of Kings College, London; N. Rosen of Haifa, Israel; L. Rosenfeld of the University of Man-

Dr. Bryce Dewit and Dr. Cecil M. Dewitt
. . . host and hostess to physicists

Installation Of Dorm Phones Will Be Resumed Next Week

Telephone installation in dormitories desiring additional phones will be resumed next week, according to an announcement at Wednesday night's Interdormitory Council meeting.

Installation of phones on the second and fourth floors of men's dormitories were halted temporarily due to a disturbance arising from placing of long-distance calls from non-pay phones.

Dorm residents have signed pledges that no such calls will be placed from non-pay phones. Thus installation has been resumed.

ENDORSEMENT

The Council also endorsed Mardi Gras weekend—Feb. 15-16. The event is being co-sponsored by Graham Memorial and the Germans Club.

Mardi Gras weekend, according to Chairman Jim Armstrong, who announced its organization to Council members, will feature:

(1) A concert by the Mitchell-Ruff Duo on Friday night.

(2) A dance held in conjunction with the Germans Club on Saturday night.

$2 tickets will entitle any couple to attend both functions, according to Chairman Armstrong.

NEW COBB POLICY

Other action which appeared on the Council agenda included announcement of a new policy governing Cobb Dormitory basement.

The basement, which has some-

LIBRARIAN ANDREW HORN
. . . leaving, after two and one-half years here

UN Creates Committee To Study Revolution

UNITED NATIONS, N. Y. — (AP) — A special truth committee to investigate the tragedy of Hungary's abortive revolution was created yesterday by the U. N. Assembly despite Soviet refusal to cooperate in any manner.

The assembly voted 59-8 for a resolution introduced by the United States and 23 other U. N. members setting up a committee composed of Australia, Ceylon, Denmark, Tunisia and Uruguay.

The committee was ordered to search out the facts anywhere it could and report back as soon as possible. It cannot go inside Hungary nor any Red Bloc country since Moscow continued its stubborn policy of defying U. N. actions and resolutions on Hungary.

Then countries abstained on the vote. Chile was the only country that the action was not nearly strong enough to stem the situation.

U. S. Chief Delegate Henry Cabot Lodge Jr. had urged the Assembly to approve the resolution as a way of ascertaining the truth about Hungary. He acknowledged the action might appear mild but said the truth must be known and the truth will prevail.

Resignation Set For Action Soon

By FRED POWLEDGE

University Librarian Andrew H. Horn has resigned.

This was learned Thursday by The Daily Tar Heel from several top officials of the University who refused to let their names be made public.

Dr. Horn's resignation will be handed to a meeting of the Executive Committee of the Board of Trustees next week. Until then, the University will not release information on his leaving.

Dr. Horn resigned for "personal reasons." It was not known what those reasons were.

Questioned yesterday about reports of his resignation, Dr. Horn said a University regulation requires that all such information come from the chancellor, not from the person resigning.

Chancellor Robert House, asked about the resignation, had no comment.

However, it was known that the resignation will be considered at the Executive Committee meeting next week.

There was speculation Dr. Horn resigned out of despair because the state Legislature cut Library appropriations in half for the present biennium (This was done two years ago). But reports from other quarters said his resignation came purely for personal reasons.

Dr. Horn has ben here for two and one-half years.

He is director of University Libraries. Specifically, his main job has ben the operation of the University's Wilson Library.

Dr. Horn, 42, was born in Ogden, Utah. He has ben an instructor of history at several institutions, and has written numerous documents concerning library work.

Between 1948 and the summer of 1954, Dr. Horn was employed in the University of California (Los Angeles) libraries, where he held the titles of assistant librarian and associate librarian.

In the summer of 1954 he came to North Carolina as head librarian here.

There were no definite reports Thursday as to who would be chosen to replace Dr. Horn, or where Dr. Horn will go. It appeared his resignation had been kept under cover for several weeks.

Grail Gives Grants For Self-Help

The Order of the Grail awarded $1,300 in scholarships to deserving freshman self-help students at its Monday night meeting.

Freshmen receiving scholarships

Colds Halt Attendance

Air Force To Fly Foreign Physicists To United States

Scientists To Attend Gravitation Meet Here

By PETE IVEY

The U. S. Air Force will fly foreign scientists from Europe, the Middle East and the Orient into the United States next week where they will attend in Chapel Hill the first "World Conference on Gravitation" ever to be held in America, Jan. 18 to 24.

Conference On Gravitation Opens Here This Morning

The International Conference on the Role of Gravitation in Physics opens here today with physicists from 11 nations participating.

The first official session will open at 10 a.m. today in Carroll Hall with Dr. Bryce DeWitt of the UNC Physics Department presiding. Technical discussions will be held during two morning and afternoon sessions.

Gov. Luther H. Hodges will preside at a luncheon Friday in the Morehead Planetarium. The 40-odd conferees will attend along with special representatives of the seven agencies sponsoring this six-day conference.

The layman will have an opportunity "to find out what the world's foremost scientists are currently doing" at a Friday night program. Entitled a "Popular Symposium," the non-technical public address will be held at 8 p.m. in Carroll Hall.

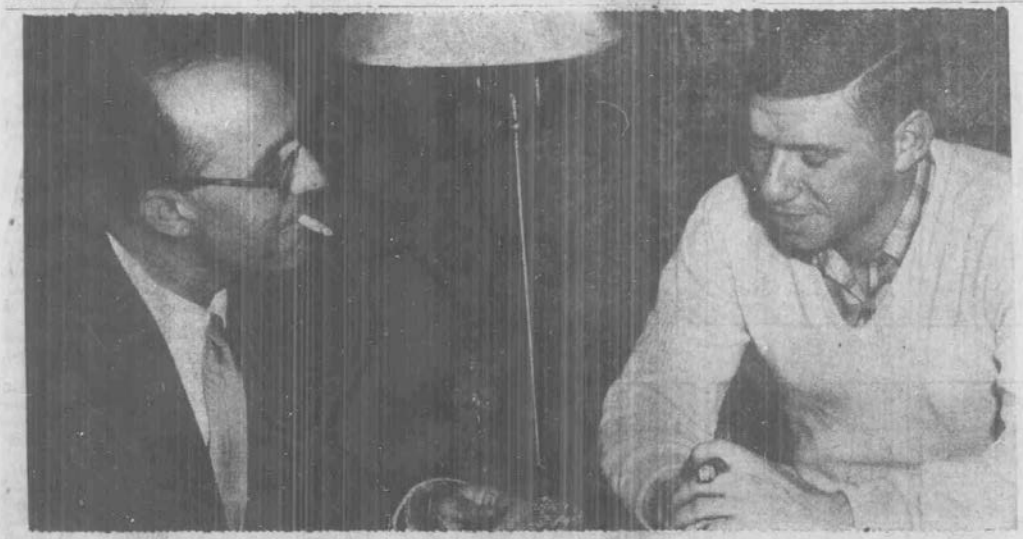
Speakers will include Dr. T. Gold of Royal Greenwich Observatory, England; Dr. L. Rosenfeld of the University of Manchester, England; and Dr. J. A. Wheeler of Princeton University, formerly of UNC.

Dr. Cecile DeWitt, secretary of the conference steering committee, announced that special guests at today's luncheon will include these men:

Dr. Raymond J. Seeger of Washington, D. C., representing the National Science Foundation of which he is acting assistant director.

Dr. Joshua N. Goldberg of Dayton, Ohio, a conference participant, representing the Wright Air

(See PHYSICS Page 3)



Pysicist A nd Layman

Bob Myers, right, undaunted by Einstein's Theory on Gravitation, hears Dr. Behram Kursunoglu of Turkey discuss anti-matter as it may exist in another universe. Myers, a journalism student and an employee of the News Bureau, admitted frankly that he is puzzled by gravitation. However, Myers was very perceptive in an interview with Dr. Kursunoglu. He observed that the Turkish physicist was wearing two wrist watches—one Ankara, Turkey, time and the other American Eastern Standard time.

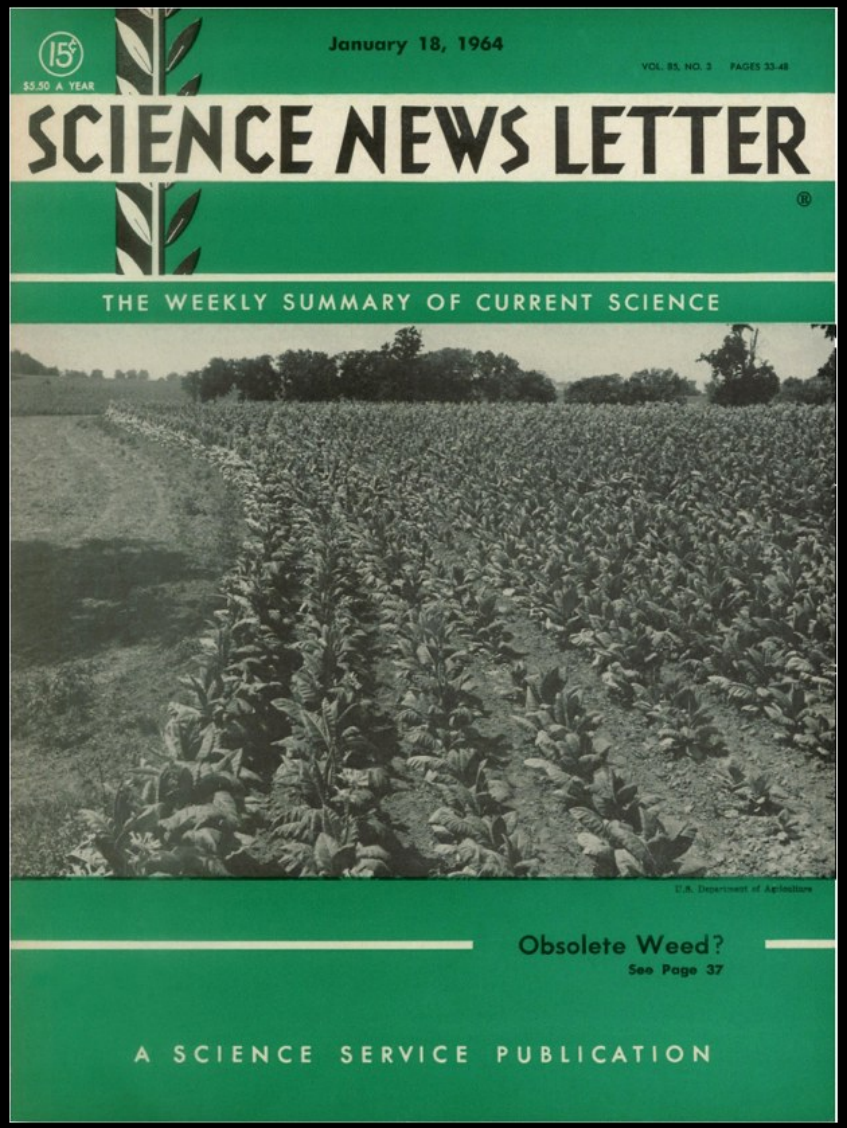
Two Doctors DeWitt, a scientific husband-wife team, will host an international conference on gravitation in Chapel Hill Jan. 18 to 24.

DR. DEWITT
... big conference

Dr. Bryce DeWitt and Dr. Cecile M. DeWitt are in charge of the year-old gravitation project at the University. Their guests for the conference will include forty internationally known physicists who are working in the area of gravitational physics. They will work sessions at the conference, and will pool information relating to the role of gravity in physics.

DR. DEWITT
... planning a...

Sponsoring the conference are the Air Force, the National Institute of Field Physics, the National Science Foundation and the French Dept. of Foreign Affairs.



1964

SCIENCE NEWS LETTER *for January 18, 1964*

ASTRONOMY

"Black Holes" in Space

The heavy densely packed dying stars that speckle space may help determine how matter behaves when enclosed in its own gravitational field—By Ann Ewing

1967

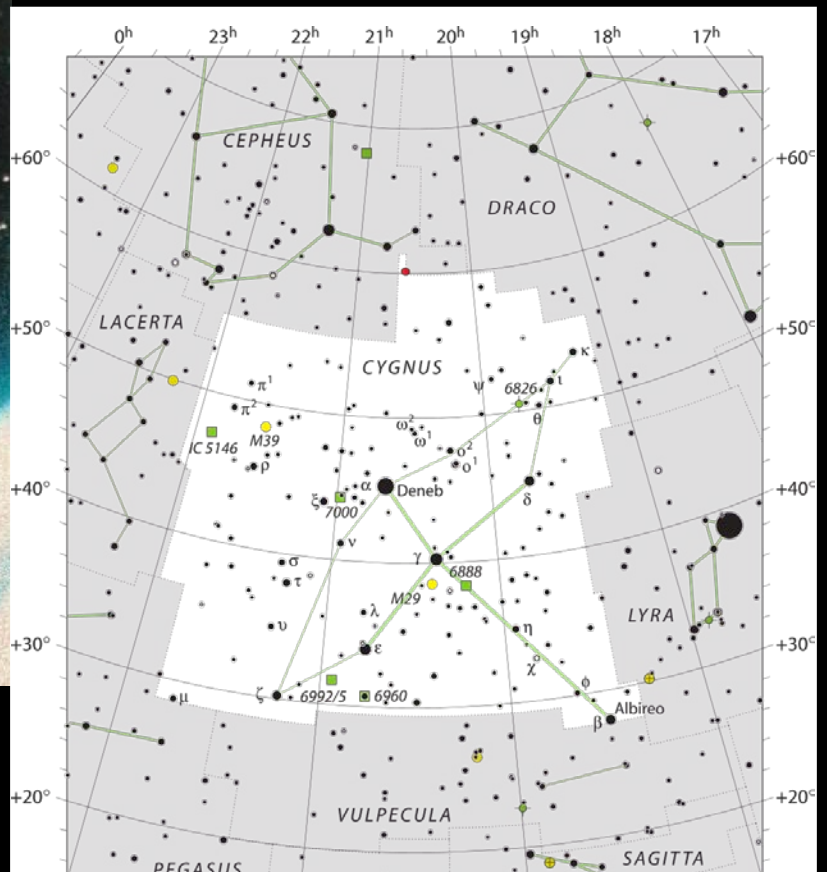
- Discontinuity
- Catastrophic sphere
- Magic circle
- Dark Star
- Continued Gravitational Contraction
- Frozen star
- Gravitationally Collapsed Star

1971

Explore 42 or Uhuru

search & discovery

Evidence accumulates for a black hole in Cygnus X-1



1978

Hale Telescope at Palomar Observatory

New data on two galaxies are consistent with black holes

How is energy supplied in the active centers of radio galaxies and quasars? This intriguing question lies at the heart of various overlapping and competing astrophysical theories, including those that propose the existence of a black hole. Now two separate sets of observations—of an apparent supermassive object[1,2] at the center of galaxy M 87 and of a small narrow radio jet parallel to a much larger jet[3] in NGC 6251—are being welcomed as a chance to test some of these ideas.

The elliptical galaxy M 87, part of the Virgo cluster, was observed by two optical techniques. One set of experiments, done at the Hale Observatories, involves photometry with sensitive TV-type detectors; the other set are spectroscopic measurements at the 4-meter Kitt Peak telescope, done with a different TV image-amplification technique newly applied to astronomy. The combined data point to a supermassive object, possibly a black hole, as a probable explanation for the excess mass-to-light ratio at the center of M 87. In the other experiment, the Caltech radioastronomers who observed the center of NGC 6251 used very long baseline interferometry, with radio dishes at the Owens Valley Radio Observatory (Big Pine, California), the National Radio Astronomy Observatory (Green Bank, West Virginia) and the Haystack Observatory (Westford, Mass). They found an unresolved core and a small (1.7-parsec) jet, pointing in the same direction as a previously discovered 200-kiloparsec jet. Their results appear to support the "beam" theory of energy supply, and are also consistent with the existence of a black hole at the galactic center.

Theorists are interested in M 87 be
cause it is an active radio source wit
compact central components, is fairl
close to us and is known to have a je
emitting polarized optical light. Th
photometric observations of M 87 ar
reported by Peter Young, James West
phal, Jerome Kristian, Christopher Wil
son (all of the Hale Observatories, Pasa
dena) and Frederick Landauer (Jet Pro
pulsion Laboratory). They used tw
types of sensitive two-dimensiona
imaging devices: commercially availabl
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The CCD, developed by Texas Instru
ments for the Jet Propulsion Laboratory
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the Jupiter orbital probe. It is, Kristia

0031-9228/78/3108-0017$0.50

1999

LIGO AND THE DETECTION OF GRAVITATIONAL WAVES

Large detectors on opposite sides of the country are about to start monitoring the cosmos for the gravitational waves that general relativity tells us should be emanating from catastrophic astrophysical events.

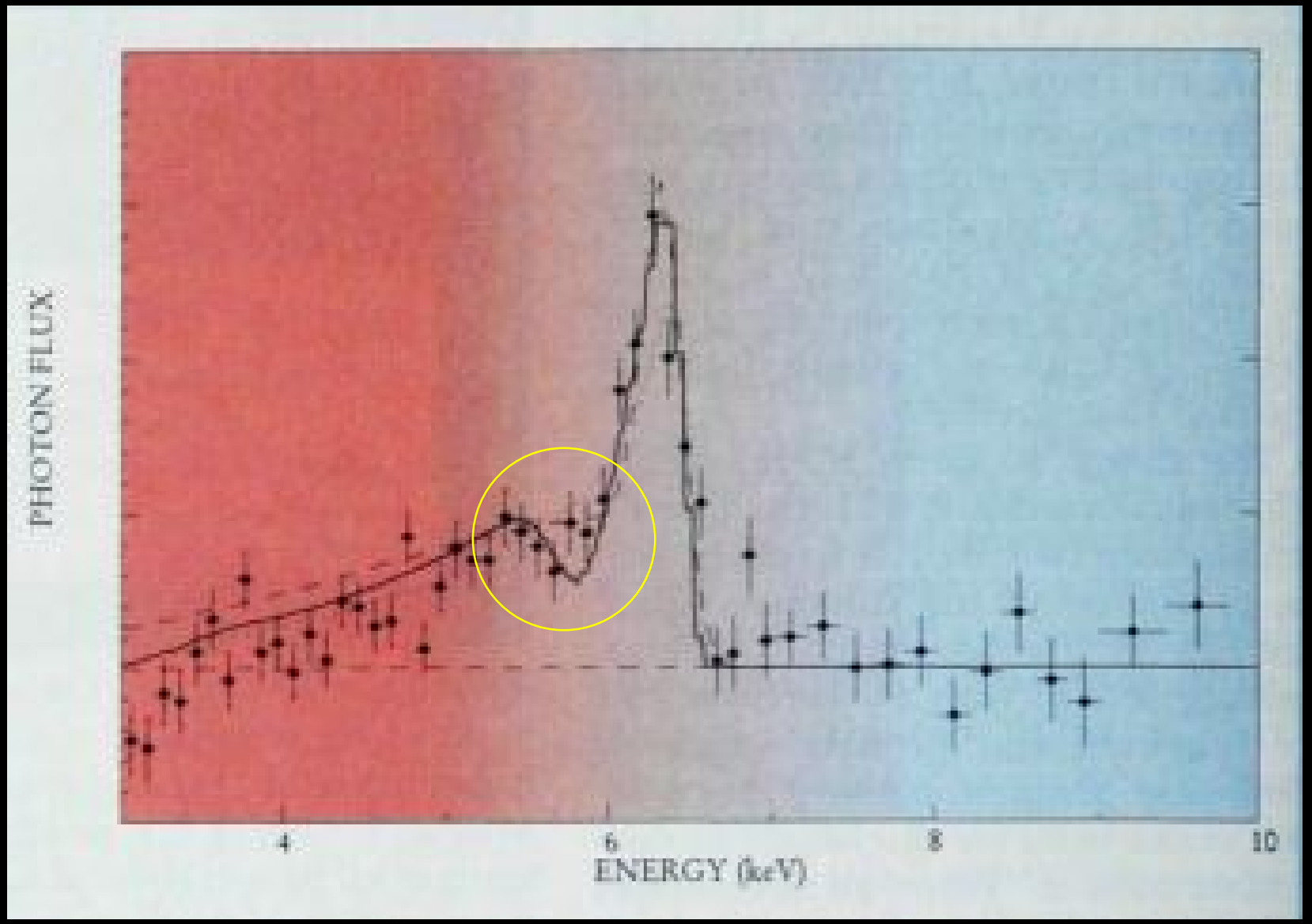
Barry C. Barish and Rainer Weiss

The idea of gravitational waves was already implicit in the 1905 special theory of relativity, with its finite limiting speed for information transfer. The explicit formulation for gravitational waves in general relativity was put forward by Einstein[1,2] in 1916 and 1918. He showed that the acceleration of masses generates time-dependent gravitational fields that propagate away from their sources at the speed of light as warpages of spacetime. Such a propagating warpage is called a gravitational wave.

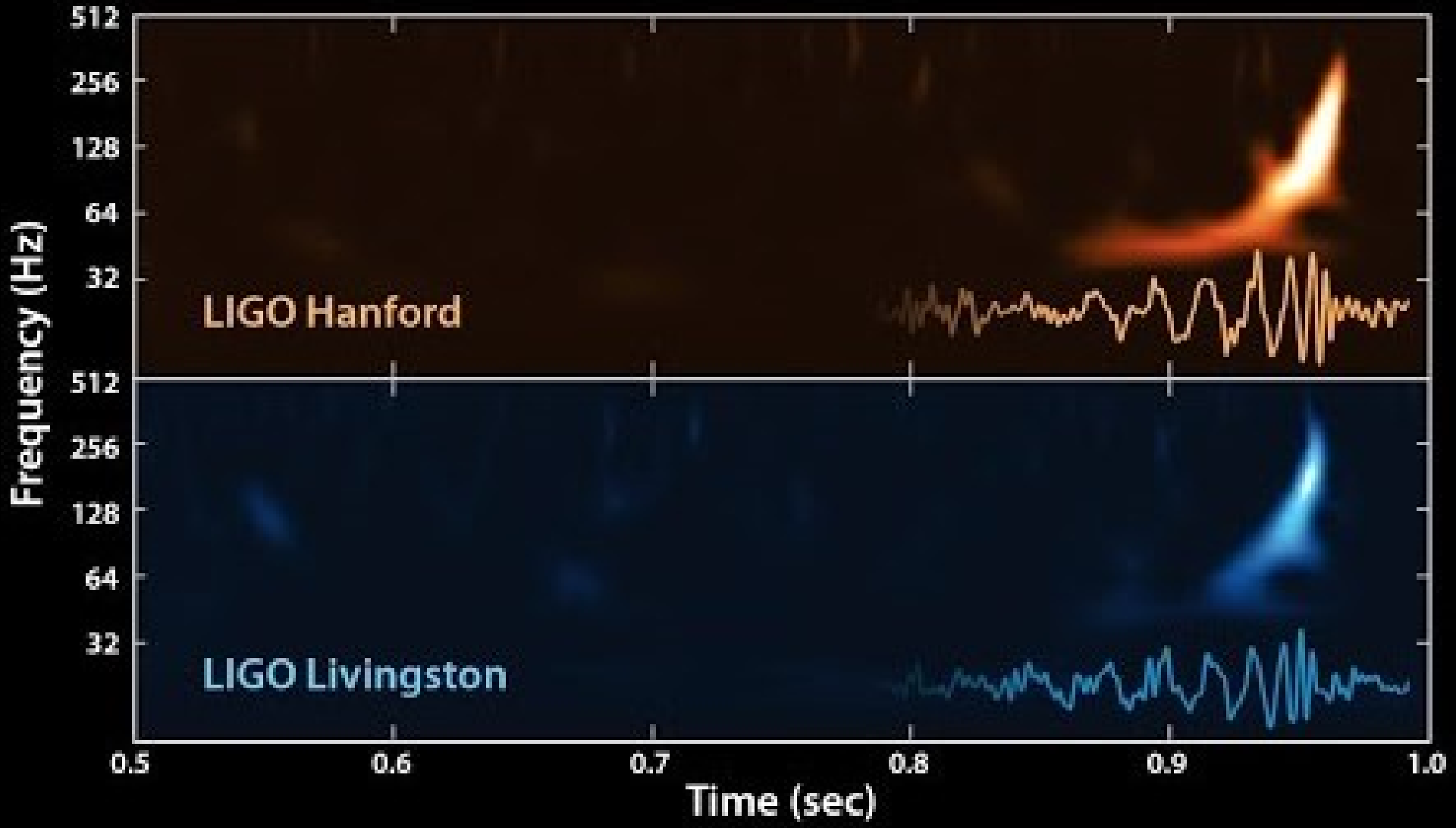
regions of the astrophysical source. Probing the universe in this very different way, gravitational radiation is likely to bring us exciting surprises and unanticipated new astrophysics.

A new generation of detectors based on suspended mass interferometry promises to attain the requisite sensitivity for observing gravitational waves. (See figure 1.) These new detectors are the fruit of a quarter-century of worldwide technology development, design, and construction. The US effort, called LIGO (Laser

1999



2016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Thank you to …

Niels Bohr Library and Archives

Society of Physics Students

UNC Wilson Library

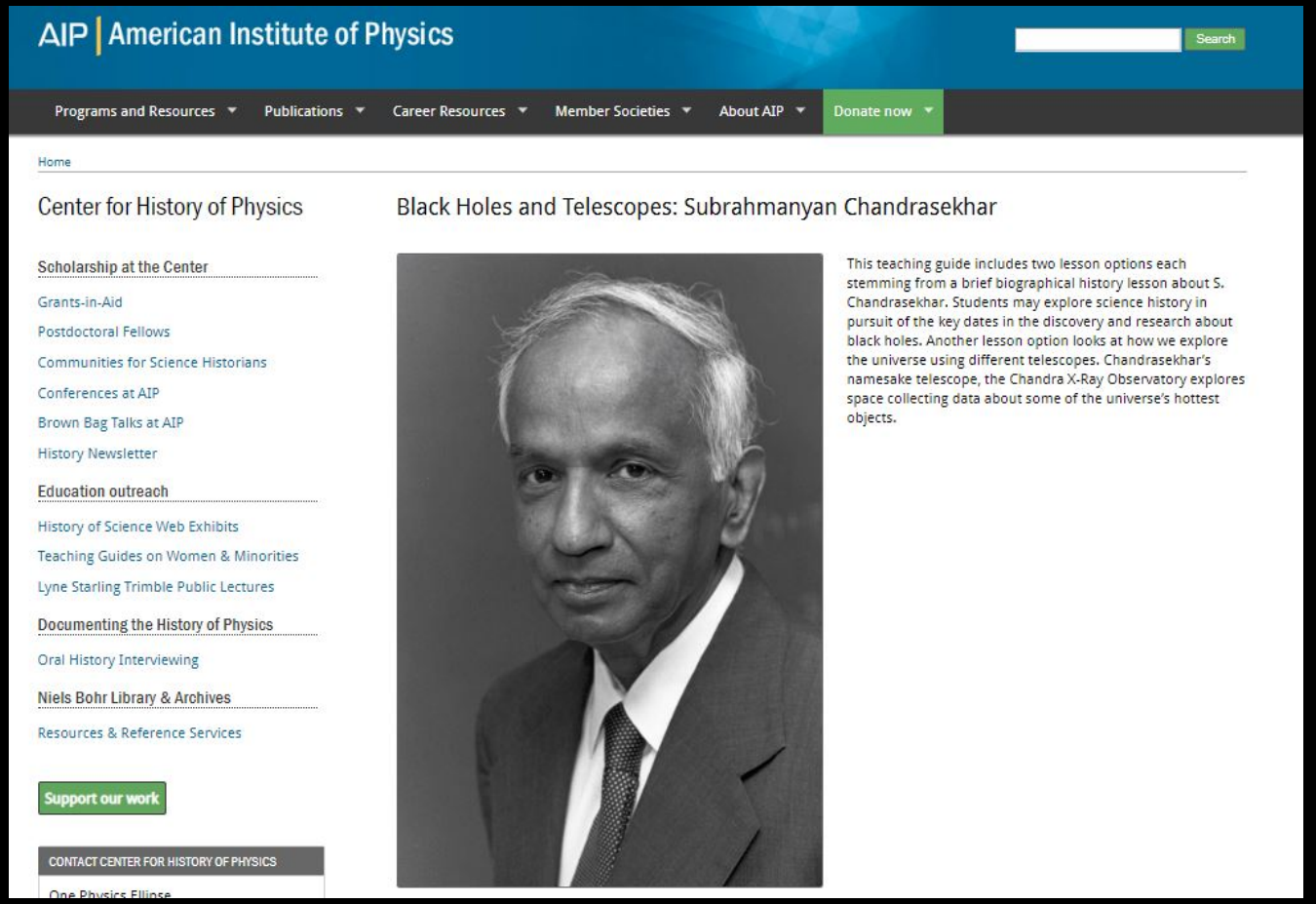
Physics Today

Science News

And my


Questions?

What else did I work on this summer



What else did I work on this summer