General Relativity and the growth of a subdiscipline „gravitation“ in the German speaking physics community.

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Rennaissance of General Relativity in History

Conference of the Max-Planck Institute for the History of Science
Harnack Haus, Berlin
Dec. 4 2015

On the path to institutionalizing research on general relativiy

Creation of theory

Development of research

Professionalizing

Institutionalizing

Einstein, Hilbert: Field equations

***Nov. 1915*:** Field equations for metric g_{ij}

With **Ricci**-tensor $R^{ij} =: R^{l}_{ijl}(g)$, trace $R: = R^{ij} g_{ij}$

$$\mathbf{G^{ij} := R^{ij} - g_{ij} R = T_{ij}}$$

$\mathbf{T_{ij}}$ **Energy-Momentum tensor of Matter**

$\mathbf{R^{l}_{ijk}(g)}$ **Riemannian curvature tensor**

***1916*:** $$\mathbf{R^{ij} - g_{ij} R + \Lambda g_{ij} = T_{ij}}$$

Λ sog. **Cosmological Constant**

Early Results from General Relativity (1915-1919)

1915/16	Field of point mass	Schwarzschild, Droste
1916	Linearization (weak Field)	Einstein
1916	Geodetic Precession	de Sitter
1916/17	Cosmology	Einstein, de Sitter
1916/18	Gravitational Waves	Einstein
1918	Co-Rotation with central body Gravitation as Gauge Theory	Lense, Thirring, Weyl
1919	5-dimensional Theory (Gravitation + Electrodynamics)	Kaluza

External Influences on Research Activities (1915-1965)

World War I (military service)

- **Inter-war period (inflation, exodus of Jewish scientists from Germany/Austria)**
- **World War II (military service, destruction of research facilities)**
- **Post war/Cold-war period (increased manpower in physics, particular *private* and/or *governmental* financing)**

Criteria for Professionalizing

- **Number of published research papers**
- **Courses at Universities**
- **Textbooks**
- **Appointment of lecturers and professors with corresponding specialty**
- **Foundation of particular institutions or establishment of relations to institutions**

Early Lecture Courses/Seminars on General Relativity

- **Universität Wien: L. Flamm 1918**
- **Techn. Hochschule Aachen: L. Hopf 1918/19**
- **Universität Basel: W. Matthies 1918/19** *Sem.*
- **Universität Berlin: A. Einstein 1919**
- **Universität Heidelberg: A. Kopf 1919/20**
- **Universität Marburg: E. R. Neumann 1920/21**
- **Universität Rostock: W. Lenz 1921/22**

Geographical Distribution of research before 1933

Berlin: Akademie, KWI f. Physics (**Einstein**)
Charlottenburg: Polytechnical University (**Reissner**)
Göttingen: University, Mathematical Society (**Hilbert, Klein, Weyl**)
Wien: University, Polytechnical University (**Bauer, Behacker, Flamm, Kottler, Lense, Schrödinger, Thirring**)
Prag: Karls-Universität (1348-1945) (**Ph. Frank**)
Zürich: University, Polytechnical University (**Weyl**)
Bern: University (**Gruner**)
Leiden: University (**Lorentz, de Sitter, Droste**)

Financial Support for Einstein's coworkers

- **Jakob Grommer:** KWI für Physik, Rockefeller Foundation (?)
- **Cornelius Lanczos:** Notgemeinschaft der Deutschen Wissenschaft
- **Hermann Müntz:** (Teacher) Prussian State
- **Walther Mayer:** Prussian Academy of Sciences

Was there a move away from General Relativity after 1925/1926 ?

Possible *Internal* Reasons

- **Discovery of quantum/wave mechanics (Heisenberg, Born, Jordan, Dirac, Schrödinger)**
- **Einstein's growing interest in unified field theory**
- **Possible *External* Reasons**
- **Bad economic conditions (inflation)**
- **No university positions for researchers in General Relativity in Germany /Austria**

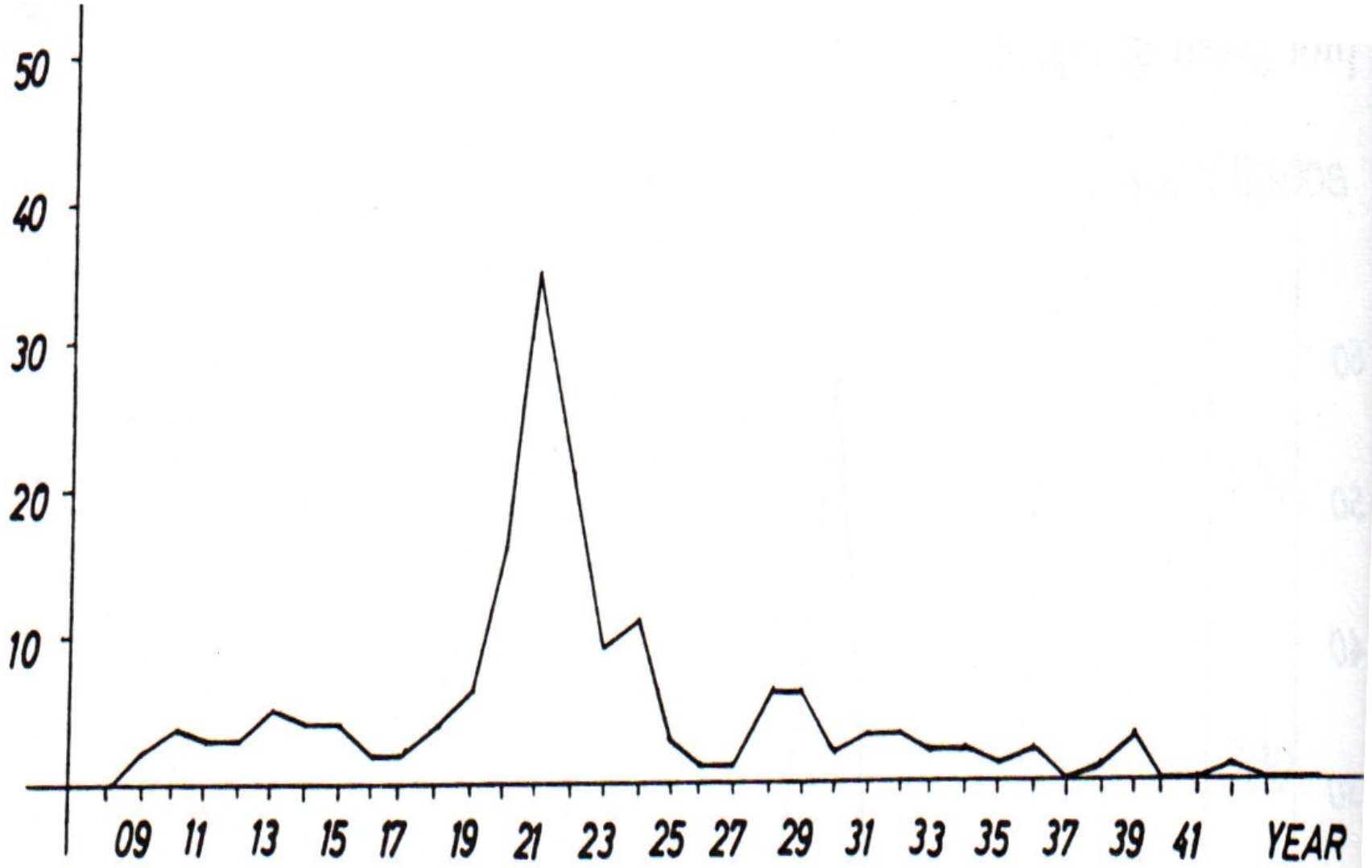


FIGURE 3. Yearly distribution of German books on relativity by relativists.

The Media Hype (1920-1924)

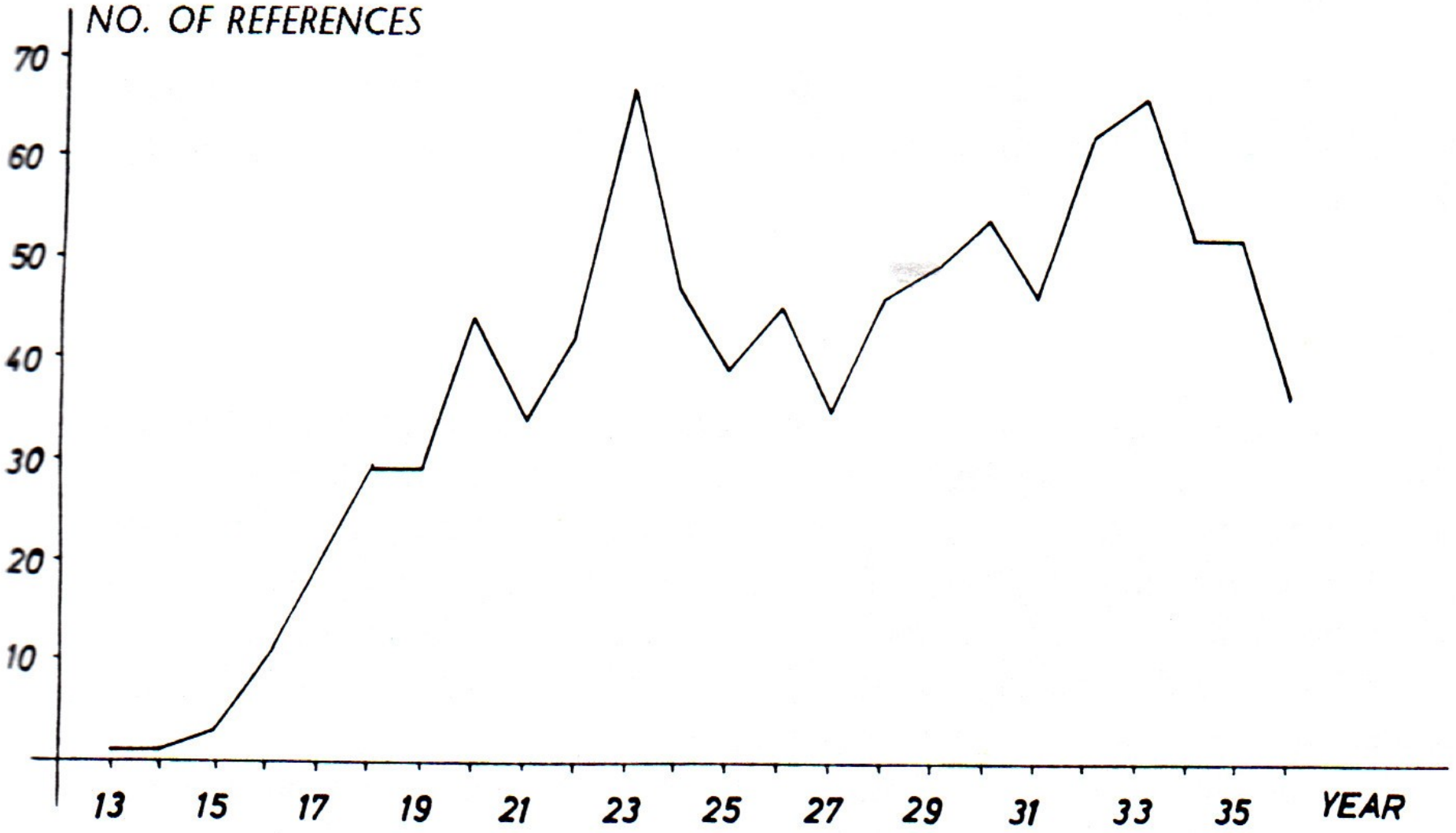


FIGURE 6. Combridge's statistics concerning research papers on relativity and differential geometry.

Further theoretical progress

(Shift to the United States after 1933)

1922/24	Expanding Universe (Friedman)
1925 – 33	Universe as exploding “Ur-atom“ (Lemaître)
1932	Expanding Universe (Einstein-deSitter)
1938	Equations of Motion for Point-Masses (EIH) (Einstein, Infeld, Hoffmann)
1939	Gravitational Collapse (Oppenheimer, Snyder, Volkoff)
	TOV- Limit for Mass of Neutron Stars (Tolman, Oppenheimer Volkoff)
1938-1943	Non-Existence of Regular Stationary Solutions (Lichnerowicz, Einstein & Pauli)

Implications for General Relativity from Nazi take-over and World war II

- **1933** (Last?) German dissertation in General Relativity (**M. Kohler/M. v. Laue**)
- Anti-Einstein (-relativity) campaign (**Ph. Lenard, J. Stark**)
- **1942** End of political campaign against relativity theory (**Seefeld discussions**)
- **1939/1940** Research work in General Relativity (**H . Hönl, A. Papapetrou**; TH Stuttgart)
- **1943/44** **W. Lenz**, University Hamburg: Lecture Course Relativity

Research groups in Germany after World War II (1945-1980).

GDR (DDR) Deutsche Demokratische Republik:

- Berlin/Potsdam (Akad. d. Wissenschaften; **H.-J. Treder**)
- Jena (University; **E. Schmutzer**)

GFR (BRD) Bundesrepublik Deutschland:

- Univ. Hamburg (**P. Jordan, O. Heckmann**)
- Freie Univ. Berlin (**G. Ludwig**)
- Univ. Braunschweig/Göttingen (**M. Kohler**)
- Univ. Freiburg (**H. Hönl, H. Dehnen, K. Westpfahl**)
- Univ. Würzburg (**R. Ebert**),
- Somewhat later: MPI für Physik München (**J. Ehlers**), Univ. zu Köln (**F. W. Hehl**), Univ. Göttingen **(H. Goenner)**

Research topics concering gravitation in Germany after World War II

- **Treder & coworkers**: Many topics in classical general relativity, affine theory, quantization
- **Schmutzer's group**: Generation and investigation of exact solutions, scalarism
- **Jordan/Heckmann**: Scalar-tensor theory; mathematical formulation of relativity theory
- **G. Ludwig**: Projective Relativity (5-dimensional)
- **M. Kohler**: Bi-metric gravitational theory
- **Hönl, Dehnen, Westpfahl**: Mach's Principle; equations of motion

Institutional Situation in BRD until 1979

- **1946-1979 Various groups at universities around a professorship**
- **3 full professors (**Freiburg, Konstanz, Würzburg**) + 2 equivalent professors (**Bundeswehr-Hochschule Hamburg and Max-Planck Institute for Physics, Munich)
- **3 associate profs. (**Göttingen, Köln, Bonn**)**
- **Including assistants and postdocs about 20 positions available for doing research on general relativity**

Institutional Situation in DDR until 1979

- **Treder's group** (Zentralinstitut für Astrophysik, Einstein-Laboratorium)
- **1 full professor** and member of Academy of science (H.-J. Treder) + 2 **profs.** (D.-E. Liebscher, E. Kreisel)
- **Schmutzer's group (**University of Jena**)**

  1 full professor (group leader) and **2 further professors** (D. Kramer, H. Stephani)

  + **1 professor in** relativistic thermodynamics (G. Neugebauer) **With all scientific coworkers about 20 positions as well**

Did „Relativistic Astrophysics“ lead to new institutional possibilities for research in General Relativity?

1963 New concept: „Relativistical Astrophysics“

1963 **Quasar** (Quasi-stellar Object)
e.g., Nucleus of Radio Galaxies

1967 **Pulsar** (Pulsating Source of Radio-Emission)
PSR B1919+21; Thomas Gold 1968/69: rotating neutron star

1971 **Neutron star** (e. g., X-ray source Cen X-3)
interpreted as rotating, hot neutron star in an orbit around another star.

1998 **Magnetar** (magnetized neutron star), e. g., CXOU J164710.2-45516 in star-cluster Westerlund 1 in constellation Ara

Renaissance of General Relativity in 1955-1965?

1955 Bern Jubilee Conference: starting point for **series of conferences on gravitation**

- **1963** ``Texas Symposium on Relativistic Astrophysics'' (biannually)
- **1970 First issue of GRG-journal**
- **1971 Foundation of International Society for Relativity and Gravitation**
- **1972** International School of Cosmology and Gravitation ``Etore Majorana'', Erice
- **1975** ``Marcel Grossmann''-Conferences

Renaissance of General Relativity in 1955-1965?

Papers on general relativity in the prestigious French Journal Comptes Rendus grew from a yearly total of **10** in **1957** to a maximum of **23** in **1959** and stayed at about this yearly rate until **1964**.

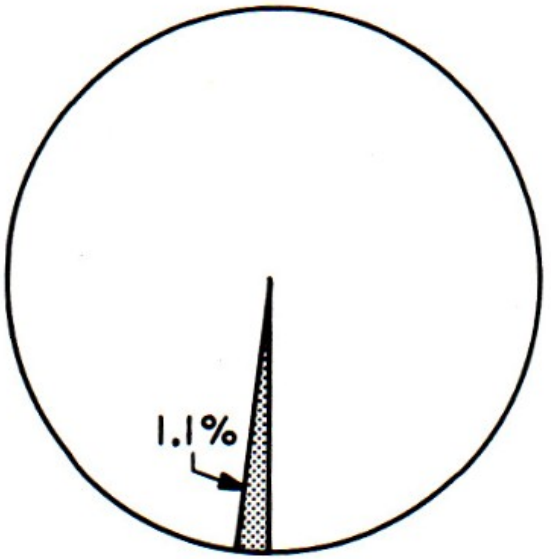
- Counting in Zeitschrift der Physik, Annalen der Physik (Physical Review) still to be done

GROSS NATIONAL PRODUCT (BILLIONS OF DOLLARS) —·—·—
FEDERAL SUPPORT TO UNIVERSITIES AND COLLEGES FOR ACADEMIC SCIENCE (BILLIONS OF DOLLARS) — — —
NUMBER OF STUDENTS SUPPORTED BY FEDERAL FELLOWSHIPS OR TRAINEESHIPS (THOUSANDS) ——
0
200
400
600
800
1000
1200
1400
0.5
1.0
1.5
2.0
2.5
3.0
0
10
20
30
40
50
60
1960
1962
1964
1966
1968
1970
1972
YEAR
TOTAL FEDERAL SUPPORT R and D + STUDENTS
FEDERAL SUPPORT TO ACADEMIC R and D ONLY
ALL FINANCIAL DATA IN EQUIVALENT 1968 DOLLARS
DATA FROM NATIONAL SCIENCE FOUNDATION

ASTROPHYSICS AND RELATIVITY

PHYSICS MANPOWER IN 1970

N = 36,336



FUNDS FOR BASIC
RESEARCH IN PHYSICS IN 1970

FEDERAL

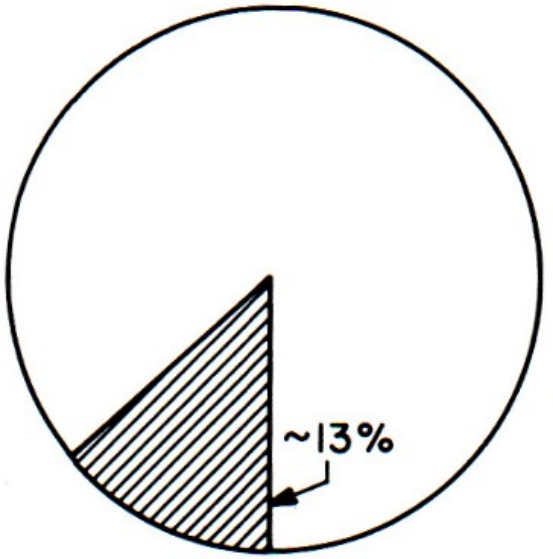


FIGURE 4.78 Manpower and funding in astrophysics and relativity in 1970.

National Research Council: Physics in Perspective, vol 1. Washington, D.C.: National Academy of Sciences (1972), p. 255

New way of funding research for gravitation in BRD

- ***Collective*_Funding through German Research Foundation**

  From 1949 on: support for **“Forschergruppen“**, from mid 1960: for **“Schwerpunktprogramme“** in addition to funding of individual requests

- **Research in General Relativity supported by**
- 1972-73 Schwerpunktprogr. **Stellar Astronomy**
- 1974-1979 Schwerpunktprogramm **Relativistic Astrophysics (Coordinator J. Ehlers)**

New way of funding research:
Expectations by proponents

1. **Attraction of more students to the field of general relativity**

2. **Increase of competitiveness of university-research with respect to research at Max-Planck-Institutes**

3. **Stimulation of the interest of more universities toward establishing research groups/positions for (relativistic) gravitation**

No. 3 turned out to be a complete failure!

New way of funding research:
What really happened

5-year period 1974-1979

Funded Projects:

- **Total** (100%) **71**
- For non-relativ. astrophysics (57%) 41
- **Relevant to General Relativity (43%) 30**
- Of these, support went to:
- **Hamburg group** (Kundt, Schmidt) (14%) 10
- **Munich group** (MPI, Ehlers, Schmidt) (7%) 5
- **Others** (21%) 15

Foundation of a subdivision (Fachverband) Gravitation and Relativity

Preliminary discussions:

Sept. 1983 **Meeting at Ringberg castle** Tegernsee
(Ehlers, B.G. Schmidt, M. Walker)

June 1984 **Cologne-Göttingen Colloquium**
(Audretsch, Dehnen, Goenner, Hehl)

October 3/4, 1984 **Actual Foundation** in Conference Center of DPG ``Physikzentrum Bad Honnef'' with the presence of the then president of German Physial Society (DPG), J. Treusch.

Situation after German Re-Unification 1990

GDR (DDR):

- **Phaseout of Einstein Laboratory**
- ``Wissenschaftler-Integrationsprogramm'' (2-year contracts followed by partial takeover of scientists)
- **Jena group fully conserved** due to establishment of a working group of Max-Planck Society

GFR (BRD):

- Initiative for an **International Einstein-Institute** on the basis of a German-Israeli cooperation (Hehl, Goenner) **FAILED**
- ***Science Council***: Asks for a **national Max-Planck Institute for Gravitation** (→ Ehlers) **SUCCEEDED**

Establishment of a new Max-Planck Institute for Gravitational Physics

- **Febuary 1991** Memorandum Hehl-Goenner for

  International Einstein Center (supported by German Physical Society)
- **July 1991** German Science Council suggests a working group within **Max-Planck Society** for the foundation of an Albert-Einstein-Institute
- **October 1991 J. Ehlers** chairman of group
- **September 1993** Presentation of Memorandum during an International Symposium in Munich
- **1995** Opening of MPI für Gravitationsphysik in Potsdam with **J. Ehlers** as one of its 3 directors

Conclusions

As of today, *institutionalizing* of research on relativistic gravitation has been *achieved* in Germany through:

- ***Topical section of German Physical Society***
- ***Max-Planck Institute for Gravitational Physics (Albert-Einstein-Institute), Golm***
- **Not achieved:**

  Better standing of the field in the physics community: No further positions created at universities. There are even less now than at the beginning of this century