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The Most-Cited 1985 Physical-Sciences Articles: Some Knots in Superstrings Untied and Quasicrystals Not So Quasi Anymore

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Every year since 1979 we have examined the papers in the life and physical sciences that were published two years earlier and identified the papers most cited during that two-year span. The majority of papers published each year will be cited just a few times—and many never at all. But a relatively small group of papers have an immediate, high impact on the research community. This usually indicates an exciting, new development, the emergence of a new research area, or a controversial topic.

In this essay, we discuss the list of 1985 physical-sciences articles that were most cited in 1985 and 1986—the "hottest" papers published in the physical sciences in 1985. It should be noted that although the term "physical sciences" is not limited to physics, we have chosen to discuss the most-cited 1985 papers for chemistry in a separate, future essay. Thus, articles from such top chemistry journals as the *Journal of the American Chemical Society* are not included in the list. This essay focuses on physics; for the modern distinction between the two interrelated disciplines, see our three-part essay on chemical-physics and physical-chemistry journals.[1]

The 104 papers in the Bibliography received an average of 54 citations each—9 in 1985 and 45 in 1986. The 13 least-cited papers received 32 citations—the threshold for inclusion. The most-cited paper published in 1985 was cited in over 300 articles and in 1987 has already received 159 citations through August (see the graph in Figure 1 for a bimonthly record of how the 1987 citations have accumulated).

It is important to remind readers, as we do in each of these essays, that the studies do not necessarily identify the *most important* papers published in the target year. Many significant papers may start out slowly but eventually achieve *Citation Classic®* status. Nevertheless, we are convinced that most of these early bloomers will go on to even greater heights.

Superstrings

Table 1 lists the research fronts that have at least two of the 1985 most-cited physical-sciences papers as core documents. In both the 1983 and 1984 lists of most-cited physical-sciences papers, a considerable number of research fronts concerned high-energy physics and materials science.[2,3] Both of these areas are still prominent in this year's study. But immediately apparent upon examining the titles in Table 1 is the virtual absence of high-energy experimental physics and the preponderance of fronts concerned with high-energy theories of strings and superstrings. Since research fronts generally indicate the cutting edge of research in a given area, they represent a verification of the importance and currency of the papers in this study.

Superstring theory is an attempt to reconcile Einstein's geometric description of gravity with quantum theory, in which the force of gravity is mediated by particles known as gravitons (the existence of which is conjectured rather than proven).[4] String theorists propose conceiving of elementary particles not as spatial points but as one-dimensional extended objects, or "strings."[5] String theory is usually expressed as "superstring theory." Superstrings usually incorporate the constraint of supersymmetry, which relates bosons (particles with quantum spins that can be expressed in whole integers) to fermions (particles with quantum spins that are expressed in half integers).[6] They also usually incorporate more than the four dimensions of length, width, depth, and time; the "extra" dimensions are "rolled up" into inconceivably small spaces.[7] (p. 150-61)

Superstrings can manifest themselves as subatomic particles: the different vibrations of the strings and whether they are "open" (like a curve) or "closed" (like a loop) account for the differences between particles.[6] They currently comprise the only theories mathematically capable of uniting the force of gravity with electroweak theory (which combines electromagnetism with the weak force, responsible for the transmutation of subatomic particles) and quantum chromodynamics (the description of the strong force that binds quarks permanently together inside nuclear particles) in a quantum model that describes all four forces as facets of a single, fundamental phenomenon.[8]

String and superstring theories have been around for several years but, according to Jeffrey A. Harvey, Princeton University, New Jersey, they had gone into "a sort of hibernation."[9] The emergence of superstring theory in this year's study represents an important new development in the field. An indication is the very prominence of the term "superstring." In our study of the 1983 papers most cited in 1983 and 1984,[2] not a single research front or paper contained the words "string" or "superstring" in its title. However, by the following year, in our study of the 1984 papers most cited in 1984 and 1985,[3] "superstrings" appeared in the title of one research front and in the titles of two papers. This year, "string" or "superstrings" appear in 24 article titles.

This terminology shift can be seen in a microhistory of the field, shown in Figure 2. Such a shift in terminology does not happen accidentally, and several other indicators signal that something important is going on in this field. For example, 4 of the 10 research fronts in Table 1 concern various aspects of string theory—including the two largest fronts, "Supersymmetry, compactification, supergravity, low-energy superstring models, and related superstring theory" (#86-0706), which has 736 citing documents, and "Two-dimensional conformal invariance and related superstring theory" (#86-0702), which has 487. Another sign of the heightened interest in string theory is that all 5 of the most-cited papers in the study are core to front #86-0706; it has a total of 38 papers in its core—14 of which appear in the Bibliography.

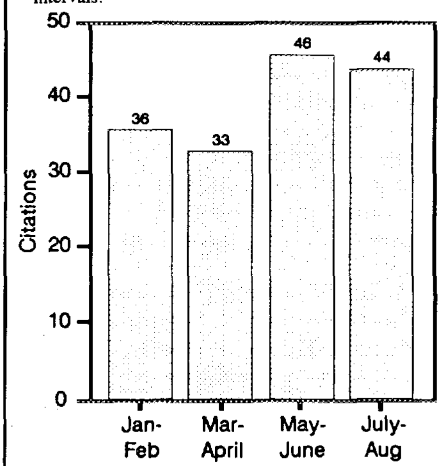
It should be noted, however, that there are several other large research fronts devoted to other topics. For example, "Diffusion-limited aggregates and fractal growth" (#86-1385) has 486 citing documents; 3 of its 55 core papers appear in the Bibliography, including articles by E. Ben-Jacob, University of Michigan, Ann Arbor, and colleagues; Johann Nittmann, Dowell Schlumberger Research and Development Center, St. Etienne, France, and colleagues; and Leonid A. Turkevich and Harvey Scher, Corporate Research Center, Standard Oil Company, Cleveland, Ohio. These papers concern the dynamics of the interactions between materials of different densities, such as the flow of a fluid through a denser fluid medium.

Another large research front in Table 1 is "Anderson localization, quantum oscillations, and electron-electron interaction in disordered systems" (#86-0097). This front has 475 papers published on this topic. There are 5 of its 37 core papers in the Bibliography. The core papers were written by M. Büttiker, IBM Thomas J. Watson Research Center, Yorktown Heights, New York, and colleagues; Patrick A. Lee, Massachusetts Institute of Technology, Cambridge, and T.V. Ramakrishnan, Banaras Hindu University, Varanasi, India; Lee and A. Douglas Stone, IBM Thomas J. Watson Research Center (the latter of whom also

Table 1: The 1985 and 1986 *SCI®/SSCI®* research fronts that include 1985 most-cited physical-sciences papers as core documents. The 1985 research fronts contain at least two papers from the Bibliography; 1986 research fronts contain at least three. A = number of papers in the Bibliography included in the core of each research front. B = total number of core documents. C = total number of citing documents for the year designated by the prefix in the research-front number.

Number	Name	A	B	C
85-0507	Icosahedral order and symmetry properties of quasicrystals and crystals	2	22	164
85-1259	Levitation, confinement, and cooling of atoms, aerosols, and particles by laser radiation pressure	2	27	196
85-2347	Compactification, supersymmetry, and anomalies in the superstring theory of supergravity	2	10	183
86-0097	Anderson localization, quantum oscillations, and electron-electron interaction in disordered systems	5	37	475
86-0523	Structure and stability of icosahedral Al-Mn alloys, Penrose tilings, and other quasicrystals	12	44	345
86-0527	Ultrashort optical pulses and mode-locking of various lasers	3	53	325
86-0702	Two-dimensional conformal invariance and related superstring theory	5	35	487
86-0706	Supersymmetry, compactification, supergravity, low-energy superstring models, and related superstring theory	14	38	736
86-1385	Diffusion-limited aggregates and fractal growth	3	55	486
86-1690	Covariant and gauge-invariant string field theories	4	20	202

Figure 1: The 1987 citations to the paper by Gross D J in *Phys. Rev. Lett.* 54:502-5, 1985, at bimonthly intervals.

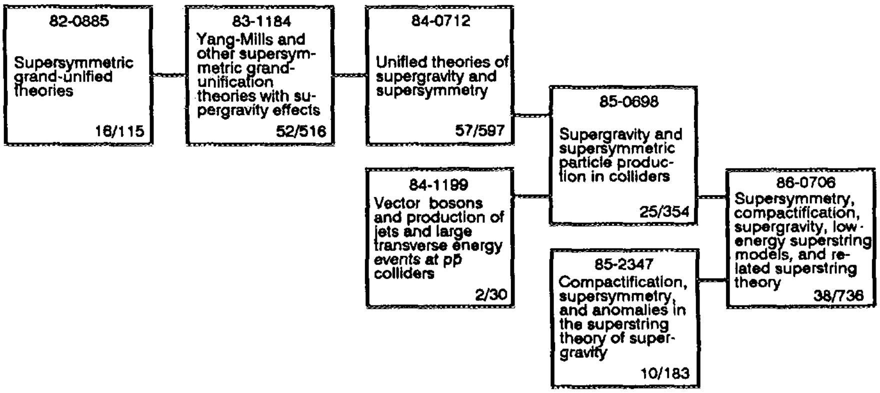


was the sole author of another core paper); and R.A. Webb and colleagues, all of the IBM Thomas J. Watson Research Center. These articles concern the properties and conditions that affect electrical conductance in various materials.

Nevertheless, this year's study is dominated by papers concerning string theory. And perhaps the most dramatic indication that something important has occurred in the superstring field is that the five top-cited papers are all related and that three have received an unprecedented number of citations for a two-year study in the physical sciences. The most-cited paper on this year's list received 304 citations. But more typical of past studies were the 170 citations collected in two years by the paper announcing the discovery of the W^+ and W^- particles.[10] These particles mediate the weak force, and their discovery constituted experimental proof of the electroweak theory. Incidentally, Sheldon Glashow, Harvard University, Cambridge, Massachusetts; Steven Weinberg, University of Texas, Austin; and Abdus Salam, Imperial College of Science and Technology, University of London, UK, and the International Centre for Theoretical Physics, Trieste, Italy, shared the 1979 Nobel Prize in physics for developing the theory.[11] Carlo Rubbia of Harvard and the multinational European Organization for Nuclear Research (CERN), Geneva, Switzerland, and Simon van der Meer, also of CERN, won the prize in 1984 for designing CERN's Proton-Antiproton Supercollider and confirming the theory.[12]

The superstring field had been plagued by competing theories, all of which had mathematical difficulties and none of which seemed more plausible than any of the others. But as so often happens in science, one discovery set the stage for the advances that followed. In a breakthrough paper entitled "Infinity cancellations in SO(32) superstring theory," Michael B. Green, Queen Mary College, University of London, and

Figure 2: Historiograph showing the development of superstring theories and the shift in terminology from "supersymmetry," "supergravity," and "Yang-Mills theories" to "superstrings." Numbers at the bottom of each box refer to the number of cited/citing papers for each research front.



John H. Schwarz, California Institute of Technology, Pasadena, demonstrated that a particular variant of superstring theory was free of mathematical anomalies, thus strengthening the theory's claim to validity.

As noted by Frank E. Close, formerly the senior principal scientist, Rutherford Appleton Laboratory, Oxfordshire, UK, and Queen Mary College, now (thanks to the brain drain) of the Oak Ridge National Laboratory, Tennessee, this marks "the first time...that a unique mathematical structure had been imposed on the theories, as if the universe itself actually required this structure and no other."[4] Green and Schwarz's description also "required a detailed interdependency of [gravity and the other three fundamental forces of nature], making unification of the forces both a profound and necessary ingredient in superstring theory."[4] Their paper, published in January 1985, received 28 citations in that year and 87 in 1986 for a total of 115. Schwarz, by the way, was named to a fellowship by the John D. and Catherine T. MacArthur Foundation in 1986 and will receive $280,000 over the next five years.[13]

However, the superstring theory for which Green and Schwarz provided such compelling mathematical evidence did not fully describe the reality of electric charges and other attributes of subatomic particles.[4] This problem was solved, however, less than a month later (in February 1985), when this study's most-cited paper, a letter on "Heterotic string," was published. It was coauthored by David J. Gross, Harvey, Emil Martinec, and Ryan Rohm, Joseph Henry Laboratories, Princeton—a group also known as the Princeton string quartet.[14]

The theory is called "heterotic" because it borrows "desirable features from the Green-Schwarz theory to make a vigorous hybrid"[4] with another type of string theory, known as bosonic string.[9] Heterotic string shows that it is possible to construct a model from Green and Schwarz's description that not only disposes of anomalies naturally but also may account for the observed physical phenomena of the real universe—although, as pointed out by Heinz R. Pagels, adjunct professor of physics, The Rockefeller University, New York, and executive director, New York Academy of Sciences, "it is difficult to connect these string theories with observations. [However, although] string theories have made no experimental predictions, their structure is leading physicists into new areas of mathematics."[6] Gross and colleagues conclude that heterotic string theory "is perhaps the most promising candidate for a unified field theory."

In addition to being core papers for research front #86-0706, the paper by the

Table 2: The number of authors per paper for the 1985 physical-sciences articles most cited in the *SCI®*, 1985-1986.

Number of Authors per Paper	Number of Papers
29	1
19	1
16	1
14	1
13	2
11	1
8	1
7	3
6	4
5	7
4	20
3	19
2	25
1	18

Princeton group and the one by Green and Schwarz are also core to the 1985 front on "Compactification, supersymmetry, and anomalies in the superstring theory of supergravity" (#85-2347), which has eight other core papers. Gross and colleagues also published an article in *Nuclear Physics B*, entitled "Heterotic string theory," in which they give a fuller treatment of the theory outlined in their letter to *Physical Review Letters*; published in July 1985, it was cited only 7 times that year but 192 times in 1986. Gross, incidentally, was also the 1986 recipient of a five-year MacArthur Foundation fellowship of $285,000.[13]

The features of the heterotic string theory are so fertile and promising that they have opened up many new avenues of research. Some of this work was done in the other two top-cited papers in the Bibliography, which build on the work by Green and Schwarz and the Princeton quartet.

One is entitled "Vacuum configurations for superstrings" and was written by Philip Candelas, Center for Theoretical Physics, University of Texas, and the Institute for Theoretical Physics, University of California, Santa Barbara; Gary T. Horowitz, University of California, Santa Barbara; Andrew Strominger, Institute for Advanced Study, Princeton; and Edward Witten, Joseph Henry Laboratories. The authors consider some of the implications that must necessarily result if heterotic string theory is indeed valid and perform calculations that support the theory. Their paper, published in August 1985, collected only 11 citations that year but 258 in 1986. Witten was the sole author of the other top-cited paper, entitled "Symmetry breaking patterns in superstring models," that further explores the implications of heterotic string. It was also published in August 1985. It was cited only 3 times that year but received 110 more in 1986.

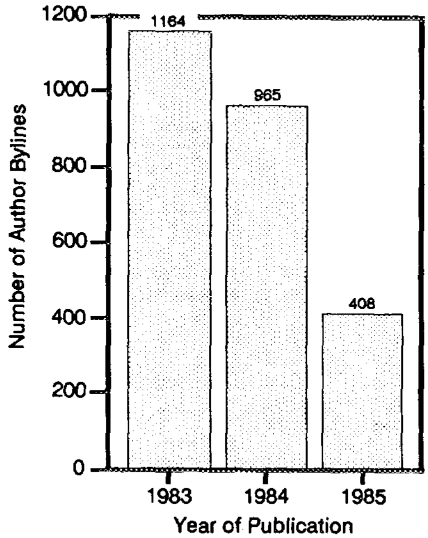
It is worth noting that Witten has consistently been among the most prolific authors in our physical-sciences studies over the last few years. Along with Martinec, one of the authors in the Princeton quartet, Witten has more papers in this year's Bibliography—four—than any other author. This is the same number of papers he had in the Bibliography of last year's essay;[3] he also had four papers in the Bibliography of the study of the 1983 articles most cited in 1983 and 1984.[2] Witten received a MacArthur fellowship in 1982.[13]

Dearth of High-Energy Experimental Physics Affects Study Statistics

The virtual absence of high-energy experimental physics papers from this year's list had several effects on the statistics we usually report in these studies. For instance, since such papers generally have a large number of authors (three of those by CERN's UA1 Collaboration that appeared in last year's study had over 130 authors *each*), the average number of authors per paper in the study of the 1983 papers[2] was over 11 and for the essay on the 1984 papers[3] was almost 9. In this year's study, however, the average dropped to just under four (see the graph in Figure 3 for a year-by-year comparison of the total number of author bylines from 1983-1985). There are 367 unique authors in this year's study—see Table 2 for a complete breakdown of the number of authors per paper.

In addition, in last year's study,[3] the most-cited paper was produced by the UA1 Collaboration at the multinational CERN fa-

Figure 3: Year-by-year comparison of the total number of author bylines for the most-cited physical-sciences papers from 1983 to 1985.



cility, which topped the list of institutional affiliations appearing in both the 1983 and 1984 Bibliographies.[2,3] This year, however, the many campuses of the University of California were first, with 18 papers. AT&T's Bell Laboratories in Murray Hill, Holmdel, and Crawford Hill, New Jersey, was next with 13 papers. CERN, which had 15 papers in last year's study, has 7 in this one. Table 3 lists the national affiliations of the institutions listed by authors in the Bibliography.

The table shows some other interesting features of the national affiliations in this year's study. For example, India, which was absent from our reports from the previous six years, appears in this year's Bibliography with one paper; the same is true of New Zealand. Also noteworthy is the number of countries that appeared in the 1984 study[3] but have dropped out of this year's essay: the People's Republic of China, Finland, Greece, Spain, Sweden, and Venezuela. Since many of the authors from these countries in the 1984 study[3] participated in the large, international collaborations in high-energy experimental physics, the disappearance of such papers from this year's report was a key factor influencing the number of papers these countries placed on our list.

The same two journals that have dominated our physical-sciences studies for many years once again published a majority of the papers in this year's study (Table 4 lists the journals and gives a breakdown of the number of papers each placed in the study). *Physical Review Letters* published 38 out of 104 papers (36.5 percent), and *Physics Letters B* published 18 (17.3 percent) for a total of 53.9 percent of all the articles in the study.

Quasicrystals

Another exciting, emerging area of interest reflected in this year's study concerns quasicrystals, a new phase of solid matter never seen before.[15] At least a dozen articles and two research fronts concern the structure and properties of quasicrystals. One front is entitled "Icosahedral order and symmetry properties of quasicrystals and crystals" (#85-0507) and has 22 core papers; the other is named "Structure and stability of icosahedral Al-Mn alloys, Penrose tilings, and other quasicrystals" (#86-0523), with 44 core papers (12 of which appear in this study).

Icosahedral structures and coordination in liquids and glasses have long been discussed.[16] Crystallographer Alan L. Mackay, Birkbeck College, University of London, has compiled a 695-item bibliography of this literature.[17] Icosahedral alloys were discovered in 1984 by D. Shechtman and I. Blech, Department of Materials Engineering, Israel Institute of Technology, Haifa; D. Gratias, Center for the Study of Chemical Metallurgy, CNRS, Vitry, France; and J.W. Cahn, Center for Materials Science, National Bureau of Standards, Gaithersburg, Maryland, and were reported in a paper[18] that appeared in last year's physical-sciences hit parade.[3] They are unique for several reasons.

A crystal is a solid in which the atoms or molecules are arranged in a regularly repeating pattern.[19] To be more precise, according to Mackay, atoms or molecules in a crystal "are repeated by translations in three non-coplanar directions that generate a three-dimensional lattice. Each lattice point has identical surroundings, and the crystal is assumed to have so many repetitions that the presence of a surface makes no appreciable difference. A lattice can belong to only 1 of 14 different types with various symmetries; none of these lattices has symmetries other than two-, three-, four-, and six-fold axes. Accordingly, none but these symmetry axes appear in diffraction patterns from crystals."[16]

One way in which crystals may be grown in the laboratory is through the solidification of a molten metal.[20] In metals, crystalline structure is typically based on cubic (four-sided) or, at most, hexagonal (six-sided) symmetry.[21] But Shechtman and colleagues discovered that, when very rapidly cooled, certain alloys of aluminum with specific percentages of manganese, iron, or chromium form crystals with diffraction effects that have the full symmetry pattern of an icosahedron[16]—that is, they have a three-dimensional symmetry that includes six five-fold symmetry axes.[22] Shechtman and Blech have also coauthored a paper that appears in this year's Bibliography.

For a true crystal, this icosahedral arrangement is not merely unusual; it is impossible.[18,22] Mackay and other crystallographers have pointed out that a tendency for atoms to arrange themselves icosahedrally during the formation of certain crystals is familiar. However, it is common knowledge among crystallographers that as the crystal grows, the 20-sided arrangement is abandoned.[22]

Mathematicians and others have nevertheless been attracted to the problem of calculating the structure of a "forbidden," icosahedral "quasicrystal."[22] Among those who did so, Dov Levine and Paul J. Steinhardt, University of Pennsylvania, Philadelphia, proposed the leading model to explain icosahedral alloys. They also coined the term "quasicrystal" and were the first to suggest the model and compute its diffraction pattern.[23] This model is based on constructions of mathematician Roger Penrose, University of Oxford, UK, who in 1974 proposed what he termed a "randomly periodic" arrangement of geometrically shaped tiles.[24] Another well-known version of Penrose's tiling pattern appeared in an article by science writer Martin Gardner in 1977.[25]

Table 3: National locations of the institutional affiliations listed by authors in the Bibliography, according to total appearances (column A). B = number of papers coauthored with researchers affiliated with institutions in other countries. C = national locations of institutions listed by coauthors.

Country	A	B	C
US	78	16	Canada, France, FRG, India, Israel, New Zealand, Switzerland, UK
Switzerland	10	7	France, FRG, Italy, US
France	8	6	The Netherlands, Switzerland, UK, US
FRG	7	3	Switzerland, US
UK	7	4	France, US
Canada	3	1	US
Japan	3	0	
Israel	2	2	US
Italy	2	2	Switzerland
USSR	2	0	
Denmark	1	0	
India	1	1	US
The Netherlands	1	1	France
New Zealand	1	1	US

Mackay states that, in three dimensions, the Penrose tiling is an arrangement of two kinds of rhomohedra—a cube elongated along its body diagonally and the same cube compressed along its diagonal axis.[16] "Penrose described definite rules for the construction of a tiling [pattern] of infinite extent that was not periodic," Mackay said. "It was regular, having rules, but was not a crystal lattice, not having translational symmetry."[16] Indeed, according to Steinhardt, the arrangement of tiles that Penrose devised is quasiperiodic, not "randomly periodic" as he described it.[23]

Thus, according to Mackay, this Penrose tiling arrangement has the same diffraction pattern as the icosahedral symmetry observed by Shechtman and his colleagues for their alloy.[16] It also proved useful to Levine and Steinhardt in performing the theoretical work necessary to properly identify the quasiperiodic translational order that could

Table 4: The 21 journals that published the papers listed in the Bibliography. The numbers in parentheses are the 1985 impact factors for the journals. (The 1985 impact factor equals the number of 1985 citations received by the 1983-1984 articles in a journal divided by the number of articles published by the journal during that same period.) Data were taken from the *JCR*®. The figures at the right indicate the number of papers from each journal that appears in the list.

Journal	Number of Papers
Phys. Rev. Lett. (6.91)	38
Phys. Lett. B (3.92)	18
Phys. Rev. B—Condensed Matter (3.58)	9
Nucl. Phys. B (5.18)	6
Astrophys. J. (3.51)	4
Phys. Rev. D—Part. Fields (2.65)	4
J. Chem. Phys. (3.10)	3
Nature (12.86)	3
Phys. Rep.—Rev. Sect. Phys. Lett. (6.24)	3
Rev. Mod. Phys. (20.74)	3
Appl. Phys. Lett. (3.59)	2
J. Appl. Phys. (1.92)	2
J. Phys. Soc. Jpn. (1.63)	1
J. Vac. Sci. Technol. A (2.49)	1
Met. Trans. A—Phys. Met. Mater. Sc. (1.27)	1
Nucl. Phys. A (2.49)	1
Optics Letters (2.57)	1
Phil. Mag. B (2.94)	1
*Pisma Zh. Eksp. Teor. Fiz. (1.51)	1
Phys. Rev. A—Gen. Phys. (2.35)	1
Annu. Rev. Astron. Astr. (9.84)	1

*translated in JETP Lett.—Engl. Tr. (1.51)

be extended to explain icosahedral and other symmetries.[23] (In case you wondered, the original 1974 Penrose paper has been cited only about 80 times since its publication.)

Although Levine and Steinhardt published their paper detailing this diffraction pattern at about the same time that Shechtman and colleagues announced their discovery, the two knew nothing of the work of the Shechtman group.[26] Nevertheless the Levine-Steinhardt diffraction pattern was virtually identical to that of the "crystal" that Shechtman's group had grown.[22] Levine and Steinhardt's paper[26] was in the Bibliography of last year's study,[3] and the two were among a group of six authors who wrote a paper appearing in this year's Bibliography. A similar mathematical discussion of the properties of icosahedral symmetry, but one that took note of both the Shechtman discovery[18] and the 1984 Levine-Steinhardt paper,[26] was coauthored by P.A. Kalugin, A.Yu. Kitaev, and L.S. Levitov, L.D. Landau Institute of Theoretical Physics, Academy of Sciences of the USSR, Moscow; it also appears in this year's Bibliography.

Even in the paper in which they announced the discovery of an icosahedral crystal, Shechtman and colleagues argued that crystals "cannot and do not exhibit the icosahedral point-group symmetry."[18] They immediately investigated the possibility that the diffraction pattern was due to twinning, a phenomenon in which several different crystals grow together but appear to be a single crystal.[22]

In fact, just such an explanation for the occurrence of quasicrystals was proposed by Nobel laureate Linus Pauling, Linus Pauling Institute of Science and Medicine, Palo Alto, California, whose paper appears in the Bibliography. However, further study with electron microscopes showed that this was not the case—that, although quasicrystals could not be true crystals (hence the name), they nevertheless exhibited a highly organized structure and each one grew outward from a single center, like an ordinary crystal.[22] Quasicrystals, in fact, have a regular, crystalline formation along some axes of rotation but lack the periodic arrangement of atoms that true crystals have in *all* directions.

Astrophysics

Several interesting papers in astrophysics appear on this year's list. Two concern the celestial object known as Cygnus X-3, an object in the Cygnus constellation that is an intense, periodic source of X rays. Cygnus X-3 is thought to be a binary system in which one partner is a massive neutron star (a star composed of degenerate matter in which the electrons have been crushed gravitationally into the nuclei) and the other is a relatively normal companion.[27] The system generates a shower of X rays so energetic that they are more properly known as gamma rays; indeed, Cygnus X-3 is the most powerful known source of such radiation in the galaxy.

However, even more energetic radiation may be pouring out of the Cygnus X-3 system, and in huge quantities. M.L. Marshak and colleagues, University of Minnesota, Minneapolis, and the Argonne National Laboratory, Illinois, reported that high-energy particles, the nature of which is unknown but which seem to be responsible for the production of muons at the surface of the earth, are being generated by Cygnus X-3. A group from various locations throughout Italy and Switzerland, headed by G. Battistoni, National Laboratory, National Institute of Nuclear Physics, Frascati, Italy, independently confirmed the Marshak group's observations. If the Marshak group's evidence (that Cygnus X-3 is emitting radiation of a type not produced in the solar system) is established conclusively, it may have profound implications for theoreticians striving toward a grand unified theory.

Another paper in astrophysics concerns cold dark matter, which is thought to make up the bulk of matter in the universe. Cold dark matter is material that has mass but that is invisible at virtually all wavelengths of the spectrum. One of the main reasons that theoreticians have been led to postulate the existence of such peculiar matter is that "the gravitational dynamics of galaxies and clusters of galaxies seem to be inconsistent unless there is additional mass present beyond that seen," according to Harvey.[9] He notes that support is lent to this idea by the inflationary model of the universe.[23] This model predicts that the universe has a certain total mass density—a value that would require a great deal more mass than has yet been observed. Indeed, the mass of all the observable stars is not enough to generate the gravitational force necessary to hold galaxies in their observed shapes; similarly, the gravity created by the mass of galaxies themselves is not great enough to result in the observed distribution of galaxies in large "clusters" and "superclusters" throughout the universe.[28]

To account for the "missing mass," as well as the observed structure of galaxies and their distribution throughout the universe, theoreticians have made various suggestions concerning gas and dust. But for a number of reasons, astronomers have ruled out the possibilities that the matter might be composed of such ordinary forms of matter. In fact, the idea that cold dark matter might be made of enormous quantities of exotic quantum particles—such as neutrinos, gravitinos, photinos, or axions—has been gaining acceptance in recent years, and the calculations presented by Marc Davis, Institute for Theoretical Physics, and colleagues support this conclusion.

The Earth's Atmosphere

One of the controversial topics that appeared in the study of the 1984 papers[3] discussed the effects of massive injections of smoke into the atmosphere after a global thermonuclear war.[29] Another paper that concerns a controversy over the effects human activity may have on the atmosphere also appears in this year's list—observations of the ozone layer over Antarctica by J.C. Farman, B.G. Gardiner, and J.D. Shanklin, British Antarctic Survey, Natural Environment Research Council, Cambridge, UK. Ozone, a relatively rare form of oxygen (O_3 instead of O_2), is a natural component of the upper atmosphere and helps protect life on the earth's surface by absorbing the sun's ultraviolet radiation.[30]

However, ozone is broken down by natural chemicals (such as volcanic chlorine) and pollutants (such as the chlorofluorocarbons found in refrigerants and aerosol propellants). In recent years, concern has grown that the vital ozone layer is being depleted or even destroyed by such chemicals. A prolonged reduction in atmospheric ozone would permit more and more ultraviolet radiation to reach the earth and might result in an increase in the incidence of certain forms of cancer and conditions caused by genetic damage. The mechanics of ozone formation and circulation in the atmosphere are poorly understood, making interpretation of the British Antarctic Survey team's results problematic; but the team's data do show a sharp drop from October 1980 through March 1984—"a feature entirely lacking in the 1957-1973 data set," according to the authors. We plan to discuss earth's ozone layer and its possible depletion in a future essay.

Prospects for Future Studies

In speculating about what highly cited papers may grow out of those appearing in this essay, we must take into account that some fields will probably be able to take advantage of the advances in this year's group of hot papers more quickly than others. For example, we may have to await the completion of the Superconducting Super Collider for even indirect experimental confirmation of the tenets of superstring theory, but the study of quasicrystals may have immediate implications in the field of materials technology. As usual, only time will tell which of these fields will continue at a high rate of activity over the next few years and which will be subsumed by new, as-yet-undreamed-of fields.

* * * * *

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REFERENCES

1. **Garfield E.** Journal citation studies. 46. Physical chemistry and chemical physics journals. Parts 1-3. *Current Contents* (1):3-10, 6 January 1986; (2):3-10, 13 January 1986; (3):3-12, 20 January 1986.
2. ------------. The 1983 articles most cited in 1983 and 1984. 2. Physical sciences. *Essays of an information scientist: ghostwriting and other essays.* Philadelphia: ISI Press, 1986. Vol. 8. p. 480-96.
3. ------------. The most-cited 1984 physical-sciences articles—high-energy physics dominates. *Current Contents* (47):3-17, 24 November 1986.
4. **Close F E.** Superstrings. (Calhoun D, ed.) *1988 yearbook of science and the future.* Chicago, IL: Encyclopaedia Britannica, 1987. p. 44-57.
5. **Trigg G L, Brown S, Terwilliger R & Wells G.** Personal communication. 15 September 1987.
6. **Pagels H R.** Personal communication. 29 September 1987.
7. **Davies P.** *Superforce.* New York: Simon & Schuster, 1984. 255 p.
8. **Weinberg S.** Particles, fields, and now strings. (de Boer J, Dal E & Ulfbeck O, eds.) *The lesson of quantum theory.* New York: Elsevier Science, 1986. p. 227-39.
9. **Harvey J A.** Personal communication. 7 October 1987.
10. **Arnison G et al. (UA1 Collaboration).** Experimental observation of isolated large transverse energy electrons with associated missing energy at $\sqrt{s}=540$ GeV. *Phys. Lett. B* 122:103-16, 1983.
11. **Garfield E.** Are the 1979 prizewinners *of Nobel class*? *Essays of an information scientist.* Philadelphia: ISI Press, 1981. Vol. 4. p. 609-17.
12. ------------. The 1984 Nobel Prize in physics goes to Carlo Rubbia and Simon van der Meer; R. Bruce Merrifield is awarded the chemistry prize. *Ibid.*, 1986. Vol. 8. p. 432-43.
13. **Cowen R.** Taking a measure of MacArthur Prize. *THE SCIENTIST* 13 July 1987. p. 4; 28.
14. **Garfield E.** The crime of pun-ishment. *Current Contents* (27):3-7, 6 July 1987.
15. **Frazier K.** The year in science: an overview. (Calhoun D, ed.) *1988 yearbook of science and the future.* Chicago, IL: Encyclopaedia Britannica, 1987. p. 303-11.
16. **Mackay A L.** Personal communication. 14 September 1987.
17. ------------. A bibliography of quasicrystals. *Int. J. Rapid Solidification* 2(4):S1-41, 1987.
18. **Shechtman D, Blech I, Gratias D & Cahn J W.** Metallic phase with long-range orientational order and no translational symmetry. *Phys. Rev. Lett.* 53:1951-3, 1984.
19. **Hobbs H H.** Crystal. (Parker S P, ed.) *McGraw-Hill encyclopedia of physics.* New York: McGraw-Hill, 1983. p. 192.
20. **Fowler W B.** Crystal defects. (Parker S P, ed.) *McGraw-Hill encyclopedia of physics.* New York: McGraw-Hill, 1983. p. 195-200.
21. **Dekeyser W C.** Crystal structure. (Parker S P, ed.) *McGraw-Hill encyclopedia of physics.* New York: McGraw-Hill, 1983. p. 205-12.
22. **Schwarzschild B M.** Forbidden fivefold symmetry may indicate quasicrystal phase. *Phys. Today* 38(2):17-9, 1985.
23. **Steinhardt P J.** Personal communication. 14 September 1987.
24. **Penrose R.** The rôle of aesthetics in pure and applied mathematical research. *Bull. Inst. Math. Appl.* 10:266-71, 1974.
25. **Gardner M.** Mathematical games. *Sci. Amer.* 236:110-21, 1977.
26. **Levine D & Steinhardt P J.** Quasicrystals: a new class of ordered structures. *Phys. Rev. Lett.* 53:2477-80, 1984.
27. **Maddox J.** What happens on Cygnus X-3? *Nature* 322:591, 1986.
28. **Pagels H R.** *Perfect symmetry.* New York: Bantam, 1986. p. 122-5.
29. **Covey C, Schneider S H & Thompson S L.** Global atmospheric effects of massive smoke injections from nuclear war: results from general circulation model simulations. *Nature* 308:21-5, 1984.
30. **Kerr R A.** Has stratospheric ozone started to disappear? *Science* 237(4811):131-2, 1987.

Most-Cited 1985 Physical-Sciences Articles

Bibliography: The 1985 physical-sciences articles most cited in the *SCI*®, 1985-1986. Articles are listed in alphabetic order by first author. Numbers following the bibliographic entry indicate the 1985 and 1986 *SCI/SSCI*® research-front specialties for which these are core papers. A = number of 1985 citations. B = number of 1986 citations. C = total number of 1985-1986 citations.

A	B	C	Bibliographic Data
7	40	47	**Ahlrichs R, Scharf P & Ehrhardt C.** The coupled pair functional (CPF). A size consistent modification of the CI(SD) based on an energy functional. *J. Chem. Phys.* 82:890-8, 1985. 86-0333
10	22	32	**Bachelet G B & Christensen N E.** Relativistic and core-relaxation effects on the energy bands of gallium arsenide and germanium. *Phys. Rev. B—Condensed Matter* 31:879-87, 1985.
28	66	94	**Bak P.** Phenomenological theory of icosahedral incommensurate ("quasiperiodic") order in Mn-Al alloys. *Phys. Rev. Lett.* 54:1517-9, 1985. 85-0507, 86-0523
2	32	34	**Balantekin A B, Bottcher C, Strayer M R & Lee S J.** Production of new particles in heavy-ion collisions. *Phys. Rev. Lett.* 55:461-4, 1985. 86-1214
14	96	110	**Bancel P A, Heiney P A, Stephens P W, Goldman A I & Horn P M.** Structure of rapidly quenched Al-Mn. *Phys. Rev. Lett.* 54:2422-5, 1985. 85-0507, 86-0523
7	29	36	**Bando M, Kugo M, Uehara S, Yamawaki K & Yanagida T.** Is the ϱ meson a dynamical gauge boson of hidden local symmetry? *Phys. Rev. Lett.* 54:1215-8, 1985. 86-0249
16	16	32	**Barger V, Hagiwara K, Keung W-Y & Woodside J.** Testing supersymmetry interpretations of anomalous missing-p_T events observed at the CERN $p\bar{p}$ collider. *Phys. Rev. D—Part. Fields* 31:528-38, 1985.
16	24	40	**Batey J, Wright S L & DiMaria D J.** Energy band-gap discontinuities in GaAs:(Al,Ga)As heterojunctions. *J. Appl. Phys.* 57:484-7, 1985. 86-0923
7	29	36	**Battistoni G, Bellotti E, Bloise C, Bologna G, Campana P, Castagnoli C, Castellina A, Chiarella V, Ciocio A, Cundy D, D'Ettorre-Piazzoli B, Fiorini E, Galeotti P, Iarocci E, Liguori C, Mannocchi G, Murtas G, Negri P, Nicoletti G, Picchi P, Price M, Pullia A, Ragazzi S, Rollier M, Saavedra O, Satta L, Serri P, Vernetto S & Zanotti L.** Observation of a time modulated muon flux in the direction of Cygnus X-3. *Phys. Lett. B* 155:465-7, 1985. 86-1054
0	41	41	**Bendersky L.** Quasicrystal with one-dimensional translational symmetry and a tenfold rotation axis. *Phys. Rev. Lett.* 55:1461-3, 1985. 86-0523
3	30	33	**Ben-Jacob E, Godbey R, Goldenfeld N D, Koplik J, Levine H, Mueller T & Sander L M.** Experimental demonstration of the role of anisotropy in interfacial pattern formation. *Phys. Rev. Lett.* 55:1315-8, 1985. 86-1385
7	32	39	**Bernstein R H, Bock G J, Carlsmith D, Coupal D, Cronin J W, Gollin G D, Keling W, Nishikawa K, Norton H W M, Winstein B, Peyaud B, Turlay R & Zylberstejn A.** Measurement of ϵ'/ϵ in the neutral kaon system. *Phys. Rev. Lett.* 54:1631-4, 1985. 86-0318
15	34	49	**Bhatt R N & Young A P.** Search for a transition in the three-dimensional $\pm J$ Ising spin-glass. *Phys. Rev. Lett.* 54:924-7, 1985. 86-0032
6	30	36	**Black J K, Blatt S R, Campbell M K, Kasha H, Mannelli M, Schmidt M P, Schwarz C B, Adair R K, Larsen R C, Leipuner L B & Morse W M.** Measurement of the *CP*-nonconservation parameter ϵ'/ϵ. *Phys. Rev. Lett.* 54:1628-30, 1985. 86-0318
5	34	39	**Bloomfield L A, Freeman R R & Brown W L.** Photofragmentation of mass-resolved $Si^{+}_{2\text{-}12}$ clusters. *Phys. Rev. Lett.* 54:2246-9, 1985. 86-2748
6	36	42	**Brandenberger R H.** Quantum field theory methods and inflationary universe models. *Rev. Mod. Phys.* 57:1-60. 86-0054
2	56	58	**Breit J D, Ovrut B A & Segre G C.** E_6 symmetry breaking in the superstring theory. *Phys. Lett. B* 158:33-9, 1985. 86-0706
10	22	32	**Broido D A & Sham L J.** Effective masses of holes at GaAs-AlGaAs heterojunctions. *Phys. Rev. B—Condensed Matter* 31:888-92, 1985. 85-2598, 86-3290
8	32	40	**Buttiker M, Imry Y, Landauer R & Pinhas S.** Generalized many-channel conductance formula with application to small rings. *Phys. Rev. B—Condensed Matter* 31:6207-15, 1985. 86-0097
0	55	55	**Callan C G, Friedan D, Martinec E J & Perry M J.** Strings in background fields. *Nucl. Phys. B* 262:593-609, 1985. 86-0702
11	258	269	**Candelas P, Horowitz G T, Strominger A & Witten E.** Vacuum configurations for superstrings. *Nucl. Phys. B* 258:46-74, 1985. 86-0706
6	39	45	**Cecotti S, Derendinger J-P, Ferrara S, Girardello L & Roncadelli M.** Properties of E_6 breaking and superstring theory. *Phys. Lett. B* 156:318-26, 1985. 86-0706

A	B	C	Bibliographic Data
13	22	35	**Close F E, Jaffe R L, Roberts R G & Ross G G.** Change of confinement scale in nuclei: predictions for structure functions confront electroproduction data. *Phys. Rev. D—Part. Fields* 31:1004-13, 1985. 86-0107
0	32	32	**Cohen E, Ellis J, Enqvist K & Nanopoulos D V.** Experimental predictions from the superstring. *Phys. Lett. B* 165:76-82, 1985. 86-0706
2	31	33	**Cohen E, Ellis J, Enqvist K & Nanopoulos D V.** Scales in superstring models. *Phys. Lett. B* 161:85-90, 1985.
5	45	50	**Cowan T, Backe H, Begemann M, Bethge K, Bokemeyer H, Folger H, Greenberg J S, Grein H, Gruppe A, Kido Y, Kluver M, Schwalm D, Schweppe J, Stiebing K E, Trautmann N & Vincent P.** Anomalous positron peaks from supercritical collision systems. *Phys. Rev. Lett.* 54:1761-4, 1985. 86-1214
6	26	32	**Dai H L, Korpa C L, Kinsey J L & Field R W.** Rotation-induced vibrational mixing in $\tilde{X}^1A_1$ formaldehyde: non-negligible dynamical consequences of rotation. *J. Chem. Phys.* 82:1688-701, 1985. 86-4218
12	47	59	**Davis M, Efstathiou G, Frenk C S & White S D M.** The evolution of large-scale structure in a universe dominated by cold dark matter. *Astrophys. J.* 292:371-94, 1985. 86-0054
18	18	36	**Dawson S, Eichten E & Quigg C.** Search for supersymmetric particles in hadron-hadron collisions. *Phys. Rev. D—Part. Fields* 31:1581-637, 1985.
7	27	34	**Derendinger J P, Ibanez L E & Nilles H P.** On the low energy $d=4$, $N=1$ supergravity theory extracted from the $d=10$, $N=1$ superstring. *Phys. Lett. B* 155:65-70, 1985.
10	56	66	**Dine M, Rohm R, Seiberg N & Witten E.** Gluino condensation in superstring models. *Phys. Lett. B* 156:55-60, 1985. 86-0706
1	61	62	**Dine M, Kaplunovsky V, Mangano M, Nappi C & Seiberg N.** Superstring model building. *Nucl. Phys. B* 259:549-71, 1985. 86-0706
9	83	92	**Duneau M & Katz A.** Quasiperiodic patterns. *Phys. Rev. Lett.* 54:2688-91, 1985. 86-0523
1	37	38	**Eckmann J-P & Ruelle D.** Ergodic theory of chaos and strange attractors. *Rev. Mod. Phys.* 57:617-56, 1985.
3	62	65	**Elser V.** Indexing problems in quasicrystal diffraction. *Phys. Rev. B* 32:4892-8, 1985. 86-0523
0	47	47	**Elser V & Henley C L.** Crystal and quasicrystal structures in Al-Mn-Si alloys. *Phys. Rev. Lett.* 55:2883-6, 1985. 86-0523
9	26	35	**Ertmer W, Blatt R, Hall J L & Zhu M.** Laser manipulation of atomic beam velocities: demonstration of stopped atoms and velocity reversal. *Phys. Rev. Lett.* 54:996-9, 1985. 85-1259, 86-1250
0	54	54	**Farman J C, Gardiner B G & Shanklin J D.** Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. *Nature* 315:207-10, 1985. 86-1604
14	31	45	**Fisher D S.** Sliding charge-density waves as a dynamic critical phenomenon. *Phys. Rev. B—Condensed Matter* 31:1396-427, 1985. 86-1744
2	38	40	**Fradkin E S & Tseytlin A A.** Effective field theory from quantized strings. *Phys. Lett. B* 158:316-22, 1985. 86-0702
21	42	63	**Freund P G O.** Superstrings from 26 dimensions. *Phys. Lett. B* 151:387-90, 1985. 86-0706
10	42	52	**Friedan D, Qiu Z & Shenker S.** Superconformal invariance in two dimensions and the tricritical Ising model. *Phys. Lett. B* 151:37-43, 1985. 86-0702
0	38	38	**Friedan D, Shenker S & Martinec E.** Covariant quantization of superstrings. *Phys. Lett. B* 160:55-61, 1985. 86-1690
12	32	44	**Girvin S M, MacDonald A H & Platzman P M.** Collective-excitation gap in the fractional quantum Hall effect. *Phys. Rev. Lett.* 54:581-3, 1985. 86-0922
5	28	33	**Goddard P & Olive D.** Kac-Moody algebras, conformal symmetry and critical exponents. *Nucl. Phys. B* 257:226-52, 1985. 86-0702
2	35	37	**Godfrey S & Isgur N.** Mesons in a relativized quark model with chromodynamics. *Phys. Rev. D—Part. Fields* 32:189-231, 1985.
3	35	38	**Gott J R.** Gravitational lensing effects of vacuum strings: exact solutions. *Astrophys. J.* 288:422-7, 1985. 86-1182
28	87	115	**Green M B & Schwarz J H.** Infinity cancellations in SO(32) superstring theory. *Phys. Lett. B* 151:21-5, 1985. 85-2347, 86-0706
7	192	199	**Gross D J, Harvey J A, Martinec E & Rohm R.** Heterotic string theory. *Nucl. Phys. B* 256:253-84, 1985. 86-0706
65	239	304	**Gross D J, Harvey J A, Martinec E & Rohm R.** Heterotic string. *Phys. Rev. Lett.* 54:502-5, 1985. 85-2347, 86-0706
7	47	54	**Gruner G & Zettl A.** Charge density wave conduction: a novel collective transport phenomenon in solids. *Phys. Rep.—Rev. Sect. Phys. Lett.* 119:117-232, 1985. 86-1744
2	52	54	**Guyot P & Audier M.** A quasicrystal structure model for Al-Mn. *Phil. Mag. B* 52:L15-9, 1985. 86-0523
32	66	98	**Haber H E & Kane G L.** The search for supersymmetry: probing physics beyond the standard model. *Phys. Rep.—Rev. Sect. Phys. Lett.* 117:75-263, 1985. 86-0706

A	B	C	Bibliographic Data
11	27	38	**Haldane F D M & Rezayi E H.** Finite-size studies of the incompressible state of the fractionally quantized Hall effect and its excitations. *Phys. Rev. Lett.* 54:237-40, 1985. 86-0922
12	33	45	**Halperin B I, Feng S & Sen P N.** Differences between lattice and continuum percolation transport exponents. *Phys. Rev. Lett.* 54:2391-4, 1985.
14	21	35	**Hickmott T W, Solomon P M, Fischer R & Morkoc H.** Negative charge, barrier heights, and the conduction-band discontinuity in $Al_xGa_{1-x}As$ capacitors. *J. Appl. Phys.* 57:2844-53, 1985. 86-1963
8	28	36	**Kalugin P A, Kitaev A Yu & Levitov L S.** $Al_{0.86}2Mn_{0.14}$: a six dimensional crystal. *JETP Lett.—Engl. Tr.* 41:145-9, 1985. (Translated from *Pisma Zh. Eksp. Teor. Fiz.* 41:119-21, 1985.) 86-0523
11	34	45	**Kennedy A D, Kuti J, Meyer S & Pendleton B J.** Where is the continuum in lattice quantum chromodynamics? *Phys. Rev. Lett.* 54:87-91, 1985. 86-1689
3	31	34	**Knapp G R & Morris M.** Mass loss from evolved stars. III. Mass loss rates for fifty stars from CO $J = 1\text{-}0$ observations. *Astrophys. J.* 292:640-69, 1985. 86-3013
3	33	36	**Knox W H, Fork R L, Downer M C, Stolen R H, Shank C V & Valdmanis J A.** Optical pulse compression to 8 fs at 5-kHz repetition rate. *Appl. Phys. Lett.* 46:1120-1, 1985. 86-0527
13	24	37	**Kruse H, Jacak B V & Stocker H.** Microscopic theory of pion production and sidewards flow in heavy-ion collisions. *Phys. Rev. Lett.* 54:289-92, 1985.
1	33	34	**Lada C J.** Cold outflows, energetic winds, and enigmatic jets around young stellar objects. *Annu. Rev. Astron. Astrophys.* 23:267-317, 1985. 86-1645
5	96	101	**Lee P A & Ramakrishnan T V.** Disordered electronic systems. *Rev. Mod. Phys.* 57:287-337, 1985. 86-0097
2	35	37	**Lee P A & Stone A D.** Universal conductance fluctuations in metals. *Phys. Rev. Lett.* 55:1622-5, 1985. 86-0097
18	41	59	**Levine D, Lubensky T C, Ostlund S, Ramaswamy S, Steinhardt P J & Toner J.** Elasticity and dislocations in pentagonal and icosahedral quasicrystals. *Phys. Rev. Lett.* 54:1520-3, 1985. 86-0523
8	25	33	**Maple M B, Chen J W, Lambert S E, Fisk Z, Smith J L, Ott H R, Brooks J S & Naughton M J.** Upper critical magnetic field of the heavy-fermion superconductor UBe_{13}. *Phys. Rev. Lett.* 54:477-80, 1985. 86-0707
14	35	49	**Marshak M L, Bartelt J, Courant H, Heller K, Joyce T, Peterson E A, Ruddick K, Shupe M, Ayres D S, Dawson J, Fields T, May E N, Price L E & Sivaprasad K.** Evidence for muon production by particles from Cygnus X-3. *Phys. Rev. Lett.* 54:2079-82, 1985. 85-4845, 86-1054
4	33	37	**Martins J L, Buttet J & Car R.** Electronic and structural properties of sodium clusters. *Phys. Rev. B—Condensed Matter* 31:1804-16, 1985. 86-2748
20	64	84	**Matthews D L, Hagelstein P L, Rosen M D, Eckart M J, Ceglio N M, Hazi A U, Medecki H, MacGowan B J, Trebes J E, Whitten B L, Campbell E M, Hatcher C W, Hawryluk A M, Kauffman R L, Pleasance L D, Rambach G, Scofield J H, Stone G & Weaver T A.** Demonstration of a soft x-ray amplifier. *Phys. Rev. Lett.* 54:110-3, 1985. 85-1056, 86-1717
8	31	39	**Mau R V, Lacombe M, Loiseau B, Cottingham W N & Lisboa P.** The static baryon—baryon potential in the Skyrme model. *Phys. Lett. B* 150:259-64, 1985. 86-0249
22	47	69	**Mermin N D & Troian S M.** Mean-field theory of quasicrystalline order. *Phys. Rev. Lett.* 54:1524-7, 1985. 85-0507, 86-0523
8	24	32	**Meschede D, Walther H & Muller G.** One-atom maser. *Phys. Rev. Lett.* 54:551-4, 1985. 86-6722
4	40	44	**Miller D A B, Chemla D S, Damen T C, Gossard A C, Wiegmann W, Wood T H & Burrus C A.** Electric field dependence of optical absorption near the band gap of quantum-well structures. *Phys. Rev. B—Condensed Matter* 32:1043-60, 1985. 86-1937
10	50	60	**Murata K, Tokumoto M, Anzai H, Bando H, Saito G, Kajimura K & Ishiguro T.** Superconductivity with the onset at 8 K in the organic conductor β-$(BEDT\text{-}TTF)_2I_3$ under pressure. *J. Phys. Soc. Jpn.* 54:1236-9, 1985. 86-2094
9	37	46	**Nemeschansky D & Yankielowicz S.** Critical dimension of string theories in curved space. *Phys. Rev. Lett.* 54:620-3, 1985. 85-4255, 86-0702
1	31	32	**Neveu A, Schwarz J & West P C.** Gauge theories of the free bosonic string field theory. *Phys. Lett. B* 164:51-4, 1985. 86-1690
24	34	58	**Nittmann J, Daccord G & Stanley H E.** Fractal growth of viscous fingers: quantitative characterization of a fluid instability phenomenon. *Nature* 314:141-4, 1985. 85-2982, 86-1385
19	41	60	**Ogielski A T & Morgenstern I.** Critical behavior of three-dimensional Ising spin-glass model. *Phys. Rev. Lett.* 54:928-31, 1985. 86-0032

A	B	C	Bibliographic Data
12	20	32	**Overhauser A W & Appel J.** *s-f* hybridization model of UBe_{13}. *Phys. Rev. B—Condensed Matter* 31:193-202, 1985. 86-0707
1	31	32	**Pauling L.** Apparent icosahedral symmetry is due to directed multiple twinning of cubic crystals. *Nature* 317:512-4, 1985. 86-0523
13	20	33	**Price P B, Stevenson J D, Barwick S W & Ravn H L.** Discovery of radioactive decay of ^{222}Ra and ^{224}Ra by ^{14}C emission. *Phys. Rev. Lett.* 54:297-9, 1985. 86-4946
9	23	32	**Prodan J, Migdall A, Phillips W D, So I, Metcalf H & Dalibard J.** Stopping atoms with laser light. *Phys. Rev. Lett.* 54:992-5, 1985. 85-1259, 86-1250
8	30	38	**Reid M D & Walls D F.** Generation of squeezed states via degenerate four-wave mixing. *Phys. Rev. A—Gen. Phys.* 31:1622-35, 1985. 86-3094
8	26	34	**Richtsmeier S C, Parks E K, Liu K, Pobo L G & Riley S J.** Gas phase reactions of iron clusters with hydrogen. I. Kinetics. *J. Chem. Phys.* 82:3659-65, 1985.
17	41	58	**Rosen M D, Hagelstein P L, Matthews D L, Campbell E M, Hazi A U, Whitten B L, MacGowan B, Turner R E, Lee R W, Charatis G, Busch G E, Shepard C L & Rockett P D.** Exploding-foil technique for achieving a soft x-ray laser. *Phys. Rev. Lett.* 54:106-9, 1985. 86-1717
9	23	32	**Shah J, Pinczuk A, Gossard A C & Wiegmann W.** Energy-loss rates for hot electrons and holes in GaAs quantum wells. *Phys. Rev. Lett.* 54:2045-8, 1985. 86-0923
1	42	43	**Shechtman D & Blech I A.** The microstructure of rapidly solidified Al_6Mn. *Met. Trans. A—Phys. Met. Mater. Sc.* 16:1005-12, 1985. 86-0523
5	82	87	**Siegel W.** Covariantly second quantized string II. *Phys. Lett. B* 151:391-5, 1985. 86-1690
4	68	72	**Siegel W.** Covariantly second quantized string III. *Phys. Lett. B* 151:396-400, 1985. 86-1690
25	21	46	**Simpson J J.** Evidence of heavy-neutrino emission in beta decay. *Phys. Rev. Lett.* 54:1891-3, 1985. 85-1527, 86-1214
12	21	33	**Skriver H L.** Crystal structure from one-electron theory. *Phys. Rev. B—Condensed Matter* 31:1909-23, 1985. 86-5081
0	41	41	**Slusher R E, Hollberg L W, Yurke B, Mertz J C & Valley J F.** Observation of squeezed states generated by four-wave mixing in an optical cavity. *Phys. Rev. Lett.* 55:2409-12, 1985. 86-3094
6	31	37	**Stone A D.** Magnetoresistance fluctuations in mesoscopic wires and rings. *Phys. Rev. Lett.* 54:2692-5, 1985. 86-0097
6	26	32	**Takayanagi K, Tanishiro Y, Takahashi M & Takahashi S.** Structural analysis of Si(111)-7X7 by UHV-transmission electron diffraction and microscopy. *J. Vac. Sci. Technol. A* 3:1502-6, 1985. 86-1229
2	30	32	**Turkevich L A & Scher H.** Occupancy-probability scaling in diffusion-limited aggregation. *Phys. Rev. Lett.* 55:1026-9, 1985. 86-1385
8	38	46	**Valdmanis J A, Fork R L & Gordon J P.** Generation of optical pulses as short as 27 femtoseconds directly from a laser balancing self-phase modulation, group-velocity dispersion, saturable absorption, and saturable gain. *Optics Letters* 10:131-3, 1985. 86-0527
2	37	39	**Vilenkin A.** Cosmic strings and domain walls. *Phys. Rep.—Rev. Sect. Phys. Lett.* 121:263-315, 1985. 86-1182
26	67	93	**Wapstra A H & Audi G.** The 1983 atomic mass evaluation. (I). Atomic mass table. *Nucl. Phys. A* 432:1-54, 1985. 86-8430
10	35	45	**Webb R A, Washburn S, Umbach C P & Laibowitz R B.** Observation of *h/e* Aharonov-Bohm oscillations in normal-metal rings. *Phys. Rev. Lett.* 54:2696-9, 1985. 86-0097
14	20	34	**Weiner J S, Chemla D S, Miller D A B, Wood T H, Sivco D & Cho A Y.** Room-temperature excitons in 1.6-μm band-gap GaInAs/AlInAs quantum wells. *Appl. Phys. Lett.* 46:619-21, 1985. 86-1937
13	25	38	**Wills B J, Netzer H & Wills D.** Broad emission features in QSO_S and active galactic nuclei. II. New observations and theory of FeII and HI emission. *Astrophys. J.* 288:94-116, 1985. 86-0971
18	60	78	**Witten E.** Dimensional reduction of superstring models. *Phys. Lett. B* 155:151-5, 1985. 86-0706
3	110	113	**Witten E.** Symmetry breaking patterns in superstring models. *Nucl. Phys. B* 258:75-100, 1985. 86-0706
6	46	52	**Zwiebach B.** Curvature squared terms and string theories. *Phys. Lett. B* 156:315-7, 1985. 86-0706