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SCIENTOMETRIC PORTRAIT OF NOBEL LAUREATE AHMED HASSAN ZEWAIL

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ABSTRACT

Scientometric analysis of 246 papers by Ahmed Hassan Zewail, the Nobel laureate in chemistry (1999), published between 1976 and 1994 in diverse fields: femtochemistry (62), reaction rates and IVR (56), general reviews (49), coherence and optical dephasing phenomena (27), solids: magnetic resonance and optical studies (13), liquids and biological systems(9), local modes in large molecules (9), molecular structure from rotational coherence (8), solar energy concentrators(7), and other studies(6). Data was analyzed for authorship pattern with his 103 collaborators. Highest collaborations were with P. M. Felker (39), M.Dantus (19), and L.R.Khundkar (16). The highest number of collaborators (38) were during 1986 – 90, followed by 30 during 1981 – 1985. His productivity coefficient was 0.52 which is a clear indication of consistent publication productivity behaviour throughout his 19 years of research.

Keywords: Scientometrics; Bibliometrics; Bio-bibliometrics; History of science; Sociology of science; Scientometric portrait; Role model scientists; Science of science; Individual scientist.

INTRODUCTION

Scientific publications seem to provide the best available basis for measuring research output. One of the first writers to suggest number of research papers as a scientific measure of research productivity was Nobel laureate William Shockley (1957). Lehman(1958) discussed scientific creativity and the ages at which the productivity peaks for scientists in different fields and different countries. He obtained data by counting the publications of scientists at a given age and found chemists' maximum production rate at ages 30 through 34. A few scientometric studies on Nobel laureates (Cawkell and Garfield, 1980; Gupta, 1983; Kragh,1990; Kademani, Kalyane and Kademani,1994; Kademani, Kalyane and Kademani, 1996a; Kalyane and Sen, 1996; Kalyane and Kademani, 1997; Kademani, Kalyane and Jange, 1999; Kademani, Kalyane and Vijai Kumar (in press); and eminent scientists (Dieks and Slooten, 1986; Lancaster, Zeter and Metzler, 1992; Kalyane and Kalyane, 1993; Kalyane and Devarai, 1994; Kalyane and Kalyane, 1994; Kademani, Kalyane and

Balakrishnan, 1994; Peters and Van Raan, 1994; Plomp, 1994; Kalyane, 1995; Kalyane and Kademani, 1995; Kalyane and Munnolli, 1995; Kalyane and Samanta, 1995; Kademani and Kalyane, 1996a; Kademani and Kalyane, 1996b; Kademani, Kalyane and Kademani,1996b; Kalyane and Sen, 1998; Tiew, 1999; Brittain, 2000) have indicated the emergence of an interdisciplinary, multidisciplinary, and extra disciplinary domain specializing in studies on individual scientists. Recently a reference curve is standardized for an Indian role model scientist (Kalyane, Madan and Vijai Kumar, 2001). This pilot study has indicated that it is possible to develop a model on the performance of a role model scientist of a country that has a direct bearing on the identification of promising scientists and human resource development in developing countries.

Individual scientist, including Nobel laureates, is the current focus of scientometric studies. An ever-growing stress is recently being laid on individual scientist rather than gross statistical macro data (Schubert and Glanzel, 1992). The Nobel Prize is regarded as the most honorific recognition of scientific achievement. The prestige of the Nobel prize is so great that it enhances the standing of nations and institutions as well as the reputation of its laureates (Zuckerman, 1967a; Zuckerman, 1967b; Zuckerman, 1977).

Nobel Prize (1999) in Chemistry

The 1999 Nobel prize in Chemistry was awarded to Ahmed Hassan Zewail for his development of a highly sophisticated form of flash photography. Zewail has demonstrated that by using ultra-short lasers, it is possible to see in *slow motion,* the behaviour of atoms and molecules in chemical reactions. In a series of experiments, he developed the world's fastest camera, a device that provides a laser flash measured in femtoseconds. This is the time scale on which the reactions actually occur. One femtosecond (fs) is 10^{-15} seconds. No chemical reaction takes place faster than this. Zewail's work led to the birth of a new field called femtochemistry, which deals with the use of high-speed cameras to monitor chemical reactions at a scale of femtoseconds. With this new technique of femtosecond laser spectroscopy, he made it possible to follow how atoms move in a molecule during a reaction so that the eye can see it by a slow motion replay. "Zewail has been marvelously effective in demonstrating the potential of ultra fast laser techniques - of showing quantum behaviour before your eyes" (Ball, 1999).

Femtosecond spectroscopy has developed rapidly during 1990s to become a widely used research technique. Groups around the world are using it not only to study reactions in molecular beams but also on surfaces, in clusters, and in solutions, looking at the processes such as catalysis, surface activation and dissolution. Femtochemistry is shedding new light on energy conversion process in chlorophyll and retinal. Zewail's current research is devoted to developments of ultra fast lasers and electrons for studies of dynamics of complex systems with atomic-scale resolution. Time-resolved structures with ultra fast electron diffraction and the dynamics of biological functions are amongst areas of major interest.

Biographical details (Zewail, 1994; Bakshi, 1999; Ball, 1999; Service, 1999; Stevenson, 1999; Das, 2000; Palit, 2000) and a brief resume of Zewail (Appendix 1) are recommended reading.

OBJECTIVES

The present attempt is to quantitatively document research productivity of Ahmed Hassan Zewail differentiating his:

1. contributions,
2. authorship pattern ,
3. most active researchers,
4. collaborator dynamics,
5. title keyword tomography, and
6. reprinting and translations.

METHODS

This study is limited to the analysis of 246 papers (1976 – 1994) included in volumes I - II of, *Femtochemistry : Ultra fast dynamics of the chemical bond* by Ahmed Hassan Zewail (1994). Authors could not obtain an up-to-date and complete list of Zewail's publications. The same classification used by Zewail (1994) is used here to categorize his papers for the analysis.

The bibliographic fields were analyzed by normal count procedure (Kalyane and Vidyasagar Rao, 1995) for domains, authorships, and keywords in the titles of the articles. To measure the collaborative research pattern, a simple indicator called Collaboration Coefficient defined by Subramanyam (1983) as the number of collaborative papers divided by total number of papers is used. To calculate the Productivity Coefficient (Sen and Gan, 1990) the indicator, that is, 50-percentile age per total productivity age is used.

RESULTS AND DISCUSSION

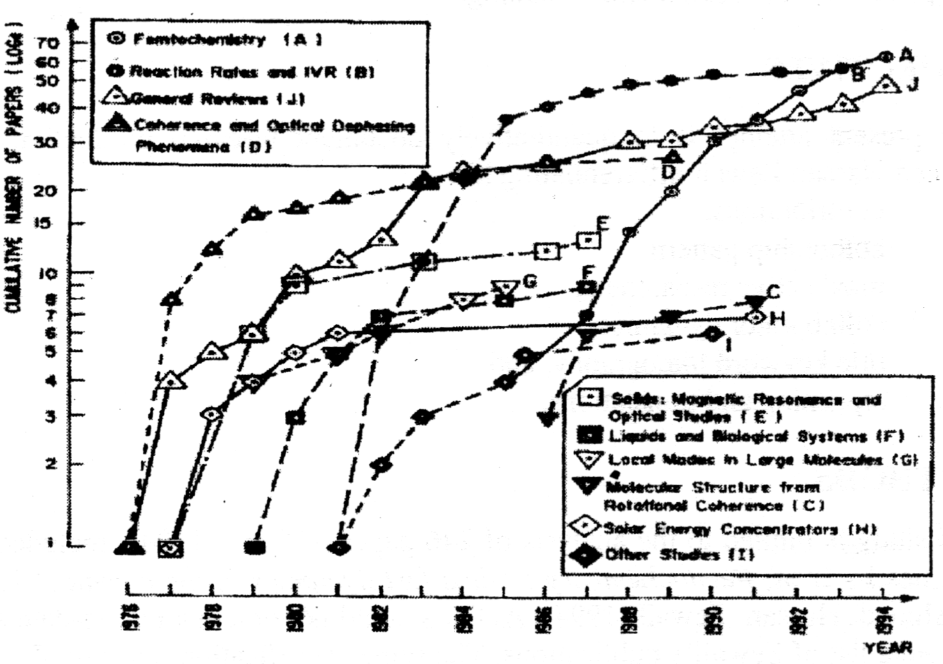
Contributions

Zewail had research communications as categorized below:
A = Femtochemistry (Real-time molecular dynamics, Ultrafast electron diffraction, and Solvation in clusters at high pressures); B = Reaction rates and intramolecular vibrational energy redistribution (IVR) (State-to-state rates,

IVR and reactive dynamics and IVR); C = Molecular structure from rotational coherence; D = Coherence and optical dephasing phenomena; E = Solids: magnetic resonance and optical studies; F = Liquids and biological systems; G = Local modes in large molecules; H = Solar energy concentrators; I = Other studies; and J = General reviews.

Cumulative publication productivity during 1976–1994 is depicted in Figure

Figure Domainwise Publication Productivity of Ahmed Hassan Zewail



Zewail had contributed 62 papers in the domain of Femtochemistry (1983–1994): out of which 43 papers are in the sub–domains Real – time molecular dynamics, 14 papers in Solvation in clusters and five papers in Ultra fast electron diffraction. He had contributed 56 papers in the domain Reaction rates and IVR (1981-1993): out of which 27 papers were in IVR, 16 papers in IVR and reactive dynamics, and 13 papers are in State-to-state rates sub–domains. He had 49 papers in General reviews (1976-1994) followed by 27 papers in Coherence and optical dephasing phenomena (1976–1987). Nine papers each were in Liquids and biological systems (1979–1987), and Local modes in large molecules (1979–1985). He had eight papers in domain Molecular structure from rotational coherence (1986–1991). He had seven papers in Solar energy concentrators (1977-1991), and six papers in Other studies during 1981 to 1988.

Authorship Pattern

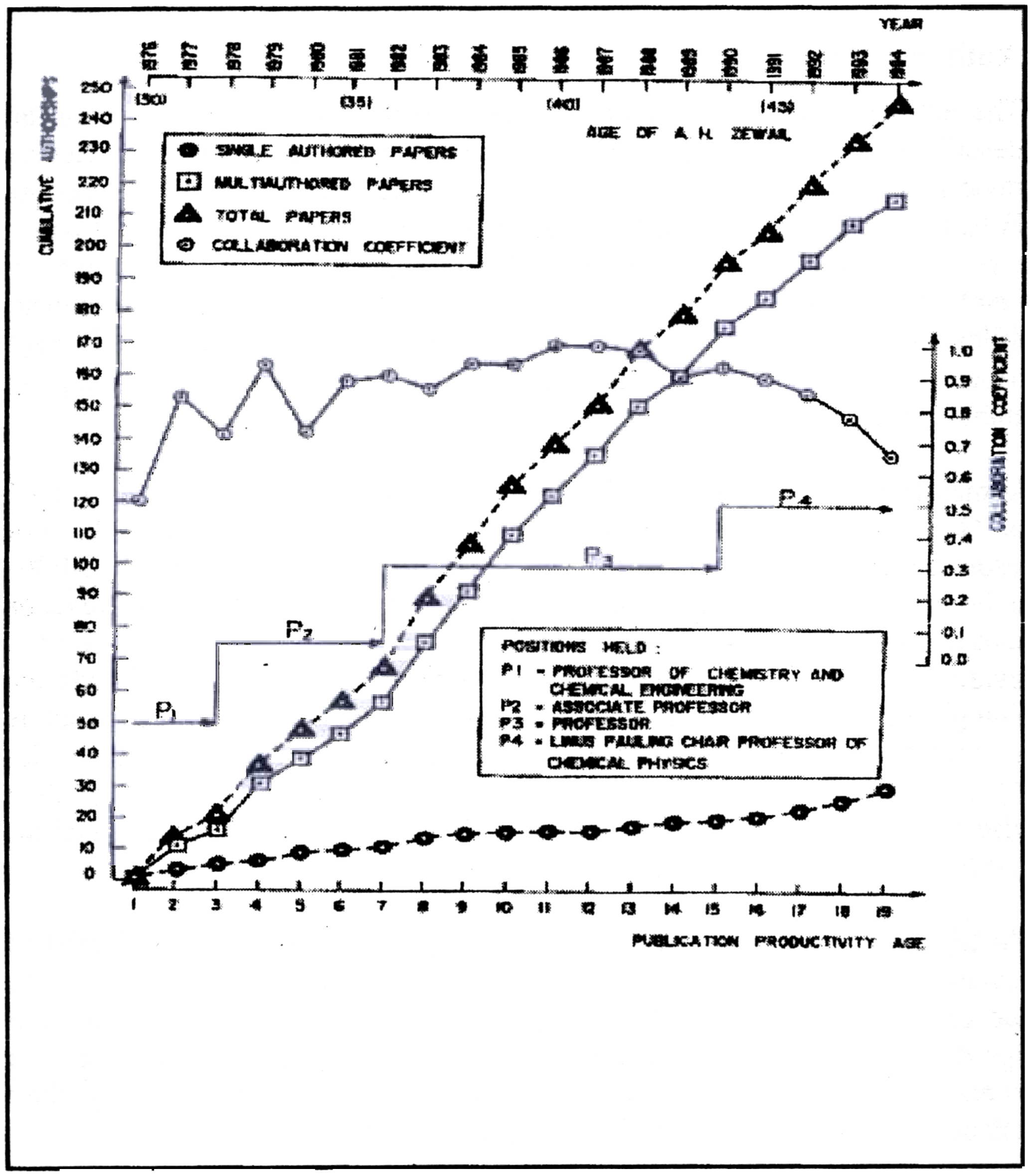
The authorship pattern and the number of publications in each domain are described here. Two authored papers were 18 in the domain of General reviews, followed by 15 papers each in Femtochemistry, Reaction Rates and IVR, and Coherence and Optical Dephasing Phenomena. A total of 27 papers were three-authored in Reaction Rates and IVR and 25 papers in Femtochemistry. There were 17 four-authored papers in Femtochemistry followed by 10 papers in Reaction Rates and IVR. There were only eight papers having five authors each followed by only five papers having six authors each.

Ahmed Hassan Zewail had 30 single authored papers in various domains such as General reviews (27), Reaction rates and IVR (1), Solids: Magnetic resonance and optical studies (1) and Solar energy concentrators (1). Multi–authored (216) papers in various domains as Femtochemistry (62), Reaction rates and IVR (55), Coherence and optical dephasing phenomena (27), General reviews (22), Solids: Magnetic resonance and optical studies (12), Liquids and biological systems (9), Local modes in large molecules (9), Molecular structure from rotational coherence (8), Solar energy concentrators (6), and Other studies (6). In multi-authored papers Zewail, was first author in 17 papers only. Year wise productivity of Ahmed H. Zewail is shown in Figure 2. He published his first two papers in 1976 at the age of 30 years.

The highest collaboration coefficient was 1.0 in 1986 and 1987 and 87.80% of Zewail's papers were published collaboratively. This result agree with Zuckerman (1976b) who studied 41 Nobel laureates, and found that they have high degree of collaboration and productivity. Zuckerman found that laureates generally published more and that might be the reason for is why they collaborated more than the matched sample of scientists.

The productivity coefficient of Zewail, was 0.52, which is a clear indication of his consistent publication productivity behaviour throughout his 19 years of scientific research. He had the highest number of collaborative papers (19) in 1983 and published the highest number of (22) papers in that year. He published 19 papers in 1985, and 17 papers each in 1984 and 1988. The average number of publications per year is 13. The nature of the effect on productivity depends on the type of links.

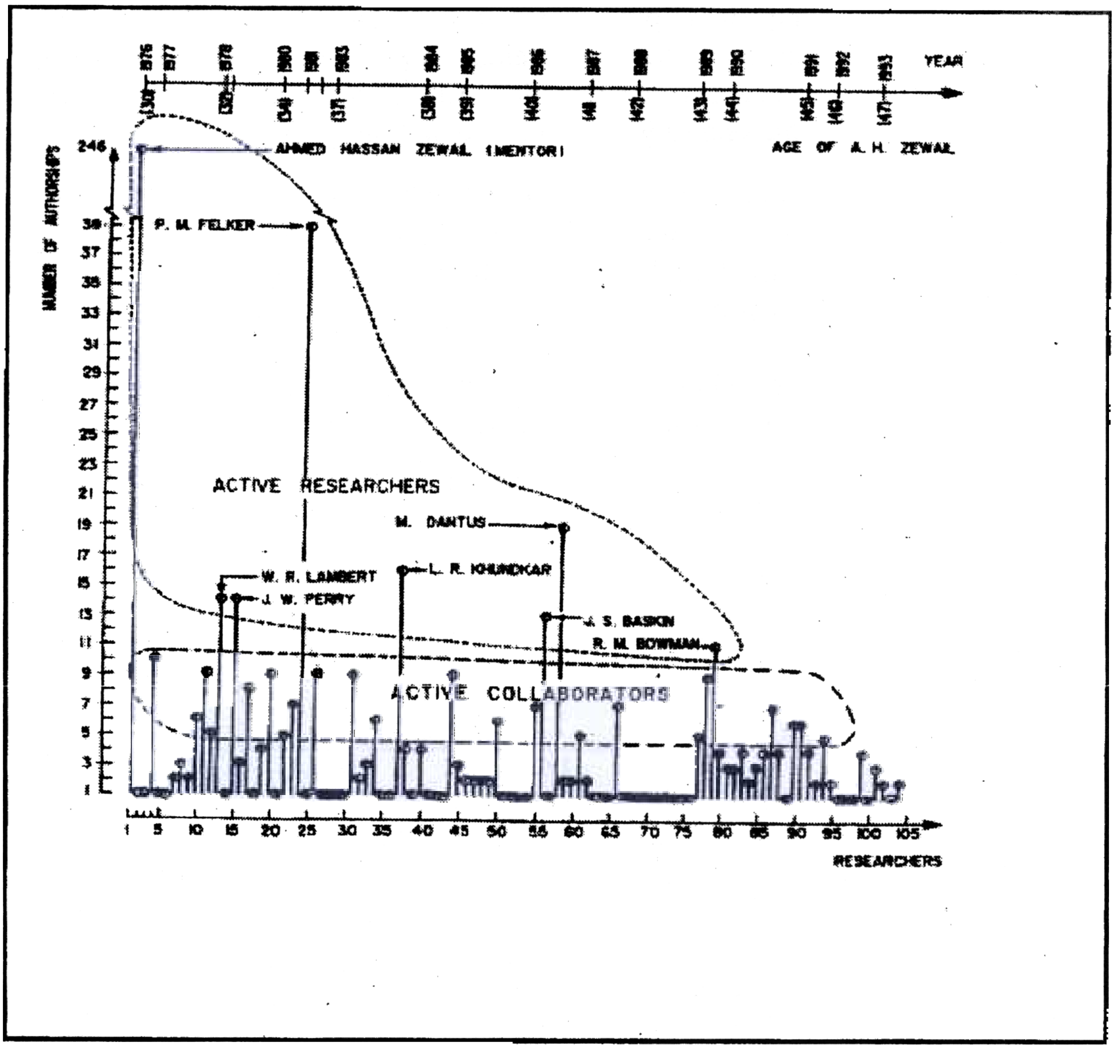
Figure 2: Authorship Pattern of Zewail's Published Works



While collaboration with highly productive scientists tends to increase personal productivity, collaboration with low productive scientists on the other hand generally decreases it. Further, the most prolific authors seem to collaborate more frequently, and authors at all levels of productivity tend to collaborate with higher productive authors than with low productive authors.

Researchers and their authorship pattern of collaborative works with Ahmed H. Zewail in chronological order of their association (starting with first paper publication year) are shown in Figure 3 and Table 1 (See Appendix 2).

Figure 3: The Authorship Pattern of Researchers Collaborating with Zewail



The Most Active Researchers

The most active researchers with Zewail were: P.M. Felker (39), M. Dantus (19), L.R. Khundkar (16), W.R. Lambert (14), J.W. Perry (14), J.S. Baskin (13), T.E. Orlowski (11), R.M. Bowman (11), and K.E. Jones (10). Table 1 (Appendix 2) indicates the collaboration status clearly. Forty-one authors have collaborated only once with Zewail. Total number of authors in the research group was 104.

Collaborator Dynamics

During any research activity, many researchers may join and leave their mentor (Sindermann, 1985; Long and McGinnis, 1985) periodically. Collaboration flux would continue whatever may be the reasons. Pivotal activity of the mentor continues through out with new collaborators between the periods. Table 2 differentiates the quinquennial periods and in the matrix, each cell is divided into two parts wherein relational tuple values are given for those who are common during two adjacent quinquennia (in bold) and those who are new collaborators during the same adjacent quinquennia (in normal).

In the first quinquennium (QI), there were 22 collaborators, out of which 10 collaborators continued to appear in authorships in (QII). Out of 10 collaborators in QII only 3 continued in QIII and QIV. Hence, from 1976 – 1980 in the horizontal matrix there was no appearance of new collaborators.

Table 2: Number of Common and New Collaborators in the Publication Productivity of Ahmed Hassan Zewail (1976 – 1994)

Years	QI	Q II	Q III	Q IV
QI (1976-1980)	**22** 22	**10** 0	**3** 0	**3** 0
Q II (1981-1985)	**1z** 1	**1z** 29	**14** 0	**4** 0
Q III (1986-1990)	**1z** 0	**1z** 0	**1z** 38	**13** 0
Q IV (1991-1994)	**1z** 0	**1z** 0	**1z** 0	**18** 14

(Tuple: bold for number of common collaborators cohort and normal for number of new collaborators cohort; 1z indicates A.H. Zewail, the pivot author around whom all other 103 collaborators revolve; the asterisk (*) representation in Table 1, columns QI to QIV was transformed into the collaborator dynamics)

In the second quinquennium (QII–QI), Zewail continued his activity alone and W.S. Warren collaborated with him only in 1981. During QII–QII, 29 new collaborators joined Zewail, (30 including Zewail) and only 14 continued. During QII–QIV only 4 collaborators appeared in the authorship. No new collaborator joined between QII–QIII and QII–QIV. During QIII–QII, Zewail continued his publication activity alone. However, during QIII–QIII period, 38 new collaborators appeared with Zewail. Out of these 39 (including Zewail) only 13 continued from QIII to QIV. The QIV period (1991–1994) was interesting as 14 new collaborators appeared and 18 old collaborators continued in contributions with Zewail. Table 2 clearly indicates the input (in human resource), output (in authorship) and the migration flow of the human resource in relation to the mentor.

Title Keyword Tomography

A recent study on the database tomography (Kostoff et al., 1997) for Research Impact Assessment is adopted for this analysis. Titles of the papers are one of the best indicators to understand and to grasp instantaneously the thought content of the papers. The titles contain important keywords. The keyword frequencies that appeared in the titles of the papers are provided in Tables 3.

Table 3: Most Prolific Keywords in the Titles of Zewails Papers (1976 –1994)

Keyword	**Frequency**
Picosecond	47
Femtosecond	45
Reactions	24
Dynamics	21
Real – time probing	18
Intramolecular vibrational energy redistribution (IVR)	15
Large molecules	12
Observation	11
Femtochemistry	10
Molecules	10
Applications	9
Dephasing	9
Vibrational energy redistribution	9
Chemical reactions	8
Coherence	8
Molecular beam	8
Excitation	7
Intramolecular	7
Luminescencee solar concentrators (LSC)	7
Isolated molecules	6
Jet-cooled	6
Laser	6
Measurements	6
Photofragment spectroscopy	6
Supersonic beams	6
Time – resolved	6
Direct observation	5
Dissociation	5
High – energy	5
ODMR	5
Optical dephasing	5
Quantum beats	5
Suprsonic molecular beams	5
Transition states	5
Unimolecular reaction rates	5

Table 4 indicates the formulae that appear once in the titles of Zewail's papers, giving a glimpse of the wide spectrum of his research activity and applications of the techniques.

Table 4: Formulae Used Once in the Titles of the Publications of A.H. Zewail (1976 –1994)

Br + I_2 ; $C_2F_4I_2 \rightarrow C_2F_4 + 2I$; CH_3I ; CaO ; CHD_3; CHT_3 ; H_2O_2 (vOH = 5)2OH ; ICl ; ICN ; ICN $\rightarrow$ CN + I; I_2Nen (n = 2-4) ; I_2Xn (n = 1) ; I_2Xn (n = 1 ; X = He, Ne and H_2) ; IHgI* $\rightarrow$ [IHg…] ‡ $\rightarrow$HgI + I ; NaI ; NCNO $\rightarrow$ CN + NO ; R – I $\rightarrow$ R‡ + I.

Reprinting/Translations

Two of Zewail's papers have been translated and reproduced in many scientific periodicals (Table 6).

Table 6: The Number of Translations Achieved by Two of Zewail's Articles

A. H. Zewail. **The Birth of Molecules.** *Scientific American,* 262, 76 (1990).

Translated and reproduced in *Le Scienze* 46 (270), 52 (1991) **(Italian)**; *Saiensu* **(Japanese)**; *Pour la Science*, 160, 92 , (1991) **(French)**; *Investgacion y CIENCIA* 173, 42 (1991) **(Spanish)**; *Spectrum der Wissenschaft* , p.100 (February ,1991) **(German)**; *B MNPE HAYKN* 2, 30 (1991) **(Russian)**; *Ke Xue* 152, 22 (1991) **(Chinese)**; *Majallat Al OLOOM* 8, No. 9, 60 (September, 1992) **(Arabic)**; *Tudomany*, p.28 (February, (1991) **(Hungarian)**; *Vigyan (Hindi)* (Indian); *Al Khairia* **(English)**; and *Proceedings of the Royal Institution* 63, 269 (1990) (**United Kingdom).**

2. M.Gruebele and A.H.Zewail. **Ultrafast Reaction Dynamics.** *Physics Today* 43, 24 (1990).

Translated and published in *Ber. Bunsenges. Phys. Chem.* 94, 1210 (1990) **(German)**; *Parity* 5, No. 12, 8 (1990) **(Japanese)**; *Sov, Phys. Uspekhi* 161, No.3, 69 (1991) **(Russian).**

CONCLUSION

Publication productivity of Nobel laureate Ahmed Hassan Zewail was found to be consistent throughout his scientific career under study. Such examples are very rare to find. Percentage of collaborative work of the scientist was found to be very high as he had as many as 103 collaborators within a short span of 19 years only. He pioneered and specialized in the domain of Femtochemistry. He received innumerable awards and honors including the Nobel prize in 1999 at the age of 53. This pattern suggests that honours and awards a scientist receives may attract more collaborators resulting in accelerating publication productivity. It will be interesting to study synchronous self-citation rate, diachronous self-citation rate (Lawani, 1982), citer motivation (Brooks, 1985;