*Jointly published by Akadémiai Kiadó, Budapest and Kluwer Academic Publishers, Dordrecht*

*Scientometrics, Vol. 53, No. 1 (2002) 113–121*

# A. H. Zewail: Research collaborator par excellence

B. S. KADEMANI, V. L. KALYANE, VIJAI KUMAR

*Library & Information Services Division, Bhabha Atomic Research Centre, Trombay, Mumbai(India)*

Ahmed Hassan Zewail, the Nobel laureate (1999) in chemistry had collaborated with 103 colleagues and has published 246 papers during 1976 to 1994 in: 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). This authorship pattern included: three authored papers (87) followed by two authored (78), four authored (38), one authored (30), five authored (8), and six authored (5). Highest collaborations were with P. M. Felker (39), M. Dantus (19), and L. R. Khundkar (16). The core journals publishing his papers were*: J.Chem. Phys*. (77), *Chem. Phys. Lett*. (53), *J. Phys. Chem*. (33), and *Nature* (6) out of the 33 journal channels and 32 chapters in books.

## Introduction

The Nobel prize (1999) in Chemistry was awarded to Ahmed Hassan Zewail for developing 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. Simsons was quoted as stating that "Zewail has been marvellously effective in demonstrating the potential of ultrafast laser techniques – of showing quantum behaviour before your eyes".[2]

*0138–9130/2002/US $ 15.00*

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 ultrafast lasers and electrons for studies of dynamics of complex systems with atomic-scale resolution. Time-resolved structures with ultrafast electron diffraction and the dynamics of biological functions are amongst areas of major interest. Detailed descriptive biographical information about A. H. Zewail is already available.[1-7] Hence present attempt is to quantitatively document his research publications productivity.

## Materials and methods

Scientific publications seem to provide the best available basis for measuring the 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.[8] A few scientometric studies on Nobel laureates[9-16] and eminent scientists[17-30] international database analysis,[32-33] national database analysis,[34-36] single research institute productivity analysis[37-40] and single journal analysis[41] have indicated the emergence of an interdisciplinary, multidisciplinary, and extradisciplinary domain.

Present study is limited to the 246 papers by Ahmed Hassan Zewail.[7] The bibliographic fields were analyzed by Normal Count Procedure[31] for domains, authorships, and journals.

## Results and discussion

### *Domainwise contributions*

Ahmed Hassan Zewail had contributed 62 papers in the domain Femtochemistry (1983-1994): out of which 43 papers are in the subdomain ' Real-time molecular dynamics', 14 papers in 'Solvation in clusters', and five papers in 'Ultrafast electron diffraction'. He had contributed 56 papers in the domain Reaction Rates and IVR (1981-1993): out of which 27 papers in 'IVR', 16 papers in 'IVR and reactive dynamics', and 13 papers in 'State-to-state rates' subdomain. He published 49 papers as 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 the domain Molecular Structure from Rotational Coherence (1986-1991). He had seven papers in Solar Energy Concentrators (1977-1991), and six papers grouped as Other Studies during 1981 to 1988.

## Collaboratorship

Domainwise authorship pattern and number of publications and authorships in each domain are presented in Table 1.

Ahmed Hassan Zewail had 30 single authored papers. In multiauthored papers (216) Zewail was first author in 17 papers only.

To measure the collaborative research pattern, a simple indicator called Collaboration Coefficient[42-44] (number of collaborative papers divided by total number of papers) is used. Highest collaboration coefficient was 1.0 in 1986 and 1987. His 87.80 percent of papers were collaborative. Average authourships per paper per domain ranged from 1.63 to 3.83.

Table 1
Number of publications (1976-1994) ofAhmed Hassan Zewail by number of authors and by research domain

| | Domains | | | | | | | | | | Total number of papers | Percen-tage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | | |
| One-authored papers | – | 1 | – | – | 1 | – | – | 1 | – | 27 | 30 | 12.20 |
| Two-authored papers | 15 | 15 | 2 | 15 | 4 | 1 | 7 | 1 | – | 18 | 78 | 31.70 |
| Three-authored papers | 25 | 27 | 4 | 9 | 6 | 6 | 1 | 5 | 2 | 2 | 87 | 35.37 |
| Four-authored papers | 17 | 10 | 2 | 3 | 1 | – | 1 | – | 3 | 1 | 38 | 15.45 |
| Five-authored papers | 3 | 3 | – | – | 1 | – | – | – | 1 | – | 8 | 3.25 |
| Six-authored papers | 2 | – | – | – | – | 2 | – | – | – | 1 | 5 | 2.03 |
| Total | 62 | 56 | 8 | 27 | 13 | 9 | 9 | 7 | 6 | 49 | 246 | 100.00 |
| Collaboration coefficient | 1 | 0.98 | 1 | 1 | 0.92 | 1 | 1 | 0.86 | 1 | 0.45 | 0.878 | |
| Authorships per paper | 3.21 | 2.98 | 3.00 | 2.56 | 2.77 | 3.56 | 2.33 | 2.57 | 3.83 | 1.63 | 2.72 | |

(**A** = Femtochemistry, **B** = Reaction Rates 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)

The Productivity Coefficient[45] (50 percentile age per total productivity age) of Zewail was 0.52 which is a clear indication of his consistent publication productivity behaviour throughout his 19 years of scientific research publishing career (1976-1994) corresponding to his chronological age (30-54). In 1983 he had published 22 papers, out of which 19 were collaborative. Average number of publications per year were 13.

Table 2 shows publication productivity distribution of authors in the research group of Ahmed H. Zewail.

The total number of authors in the research group were 104 including A. H. Zewail.

Table 2
Publication productivity of Ahmed Hassan Zewail and his collaborators (1976-1994)

| No. of papers (p) | No. of authors (n) | Total authorships (pxn) | Prominent collaborators |
|---|---|---|---|
| 1 | 41 | 41 | |
| 2 | 15 | 30 | |
| 3 | 8 | 24 | |
| 4 | 9 | 36 | |
| 5 | 5 | 25 | |
| 6 | 5 | 30 | |
| 7 | 4 | 28 | |
| 8 | 1 | 8 | |
| 9 | 6 | 54 | |
| 10 | 1 | 10 | Jones, K. E. |
| 11 | 2 | 22 | Orlowski, T. E., Bowman, R. M. |
| 13 | 1 | 13 | Baskin, J. S. |
| 14 | 2 | 28 | Lambert, W. R., Perry, J. W. |
| 16 | 1 | 16 | Khundkar, L. R. |
| 19 | 1 | 19 | Dantus, M. |
| 39 | 1 | 39 | Felker, P. M. |
| 246 | 1 | 246 | Zewail, A. H. |
| Total | 104 | 669 | |

## Channels of communication

Distribution of his 246 publications were in 33 journals and 32 chapters in books. Journalwise scattering of publications of Ahmed Hassan Zewail in various journals is provided in Table 3 and depicted in Figure1.

Table 3
Dissemination channels of the publications (1976–1994) of Ahmed Hassan Zewail

| Sl.No. | Channel of communication | Number of papers | Cumulative |
|---|---|---|---|
| 1 | *J. Chem. Phys.* | 77 | 77 |
| 2 | *Chem. Phys. Lett.* | 53 | 130 |
| 3 | *J.Phys. Chem.* | 33 | 163 |
| 4 | *Nature* | 6 | 169 |
| 5 | *Laser Chem.* | 4 | 173 |
| 6 | *Chem. Phys.* | 3 | 176 |
| 7 | *Proc. Natl. Acad. Sci.* | 3 | 179 |
| 8 | *Proc. SPIE* | 3 | 182 |
| 9 | *Appl. Opt.* | 2 | 184 |
| 10 | *Ber. Bunsenges Phys. Chem.* | 2 | 186 |
| 11 | *J. Am. Chem. Soc.* | 2 | 188 |
| 12 | *J. Opt.Soc. Am.* | 2 | 190 |
| 13 | *Phys. Rev. Lett.* | 2 | 192 |
| 14 | *Phys. Today* | 2 | 194 |
| 15 | *Science* | 2 | 196 |
| 16 | *Acc. Chem. Res.* | 1 | 197 |
| 17 | *Ann. Rev. Phys. Chem.* | 1 | 198 |
| 18 | *Can. J. Chem.* | 1 | 199 |
| 19 | *Chem. Eng. News* | 1 | 200 |
| 20 | *Eng. and Science* | 1 | 201 |
| 21 | *Faraday Discuss. Chem. Soc.* | 1 | 202 |
| 22 | *J. Chem. Soc. Faraday Trans.* | 1 | 203 |
| 23 | *J. Luminescence* | 1 | 204 |
| 24 | *J. Photochem.* | 1 | 205 |
| 25 | *J. Photochem. Photobiol. –A* | 1 | 206 |
| 26 | *Kagaku to Kogaya (Chem.Chem. Indus.)* | 1 | 207 |
| 27 | *NASA Tech. Briefs* | 1 | 208 |
| 28 | *Opt. Eng.* | 1 | 209 |
| 29 | *Opt. Lett.* | 1 | 210 |
| 30 | *Philos. Trans. Roy. Soc. Lond.* | 1 | 211 |
| 31 | *Scientific Am.* | 1 | 212 |
| 32 | *Spectroscopy* | 1 | 213 |
| 33 | *Spectroscopy Lett.* | 1 | 214 |
| 34-65 | Chapters in books | 32 | 246 |

A. H. Zewail's 63.63 percent publications were in journals published from US and 12.12 percent from UK. Average Bradford Multiplier was 2.2, Publication Density was 3.84, Publication Concentration was 8.97.

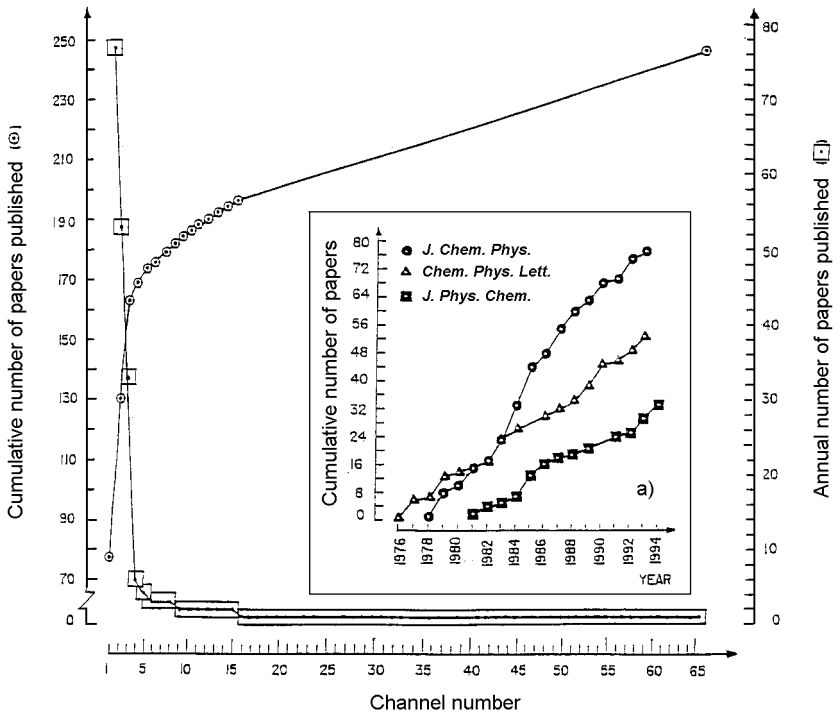


Figure 1. Bradford–Zipf bibliograph on publications of Ahmed Hassan Zewail and a) annual cumulative growth of publications in the core journals

## Conclusion

Publication productivity of the Nobel laureate Ahmed Hassan Zewail was found to be consistent throughout his scientific career under study. He organised research team consisting of 104 collaborators (including himself) documented in authorships to papers in a short span of 19 years only.. His papers were published in 33 journals. He received innumerable awards and honors including the Nobel prize in 1999 at the age of 53. This pattern suggest that honours and awards a scientist receives may attract more collaborators resulting in increase in publication productivity.

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Received July 9, 2001.

*Address for correspondence:*
B. S. KADEMANI
Library & Information Services Division
Bhabha Atomic Research Centre, Trombay, Mumbai-4000 085, India
E-mail: