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FACILITY FORM 608	N 66 13081	
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	61	1
	(PAGES)	(CODE)
CR 68407	06	
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)	

28 June 1965

National Aeronautics and Space Administration  
Washington, D. C. 20546

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THE CHEMISTRY OF COMETS  
An Annotated Bibliography

THE CHEMISTRY OF COMETS  
An Annotated Bibliography

by

J. B. Evans  
and  
V. J. DeCarlo

Melpar, Incorporated  
3000 Arlington Boulevard  
Falls Church, Virginia

March 1965

NOTE: This work was performed on Contracts NASw-589 and NASw-890 with the National Aeronautics and Space Administration, Washington, D. C.

## FOREWORD

All investigations of cometary phenomena are directed toward the elucidation of the origin, formation, and evolution of comets which will, in turn, lead to a better understanding of the origin, formation, and evolution of the Solar System. Such investigations have encompassed many disciplines and recent advances in the fields of low-temperature physics and chemistry, photochemistry, magnetohydrodynamics, charge-transfer reactions, and scattering phenomena may hasten the ultimate explanation of cometary phenomena.

The multitude of astronomical observations made in the past have allowed the analysis of the observed cometary spectra and the tabulation of the physical properties and behavior of comets. From this data, notable experimental and theoretical studies have evolved.

The experimental studies have been pointed primarily toward an explanation of the occurrence of the observed emissions. Many preliminary assignments of cometary spectra have been verified by definite identification of the emitting species through laboratory investigation. With this done, the experimental studies have been aimed toward an explanation of the chemical processes and mechanisms responsible for the formation of the emitting species.

Various theoretical studies of cometary phenomena have been advanced to explain the existence of the nucleus, the mechanisms which produce the coma, and the properties of the tail. Such theories have described the nucleus, coma, and tail in terms of structure, composition, temperature, evaporation, photo-decomposition, and interaction with protons, electrons, and radiowaves. However, these theories must remain speculative as they have not, as yet, been wholly verified by experimental data.

In this respect, continued investigations in the chemistry of comets will be an invaluable tool in determining (1) the nature, concentration, ionization, and dissociation of the parent molecules of the emitting species in the coma and tail, (2) the release mechanisms responsible for the existence of the parent molecules, and (3) the composition of the nucleus.

The references included in this bibliography were accumulated at Melpar, Inc. during the course of Contracts NASw-589 and NASw-890, a program in comet chemistry directed toward the determination of the parent compounds responsible for the emissions observed in cometary spectra. Thus, all references reflect these investigations in their subject matter or represent the necessary background knowledge.

For convenience, the references are divided into three areas - (1) those which report the results of land-based observations and the theoretical interpretations resulting from these observations, (2) those which report data obtained in the laboratory as a direct result of experimentation, and (3) those which may indicate the trend of our future space investigations.

The availability of the Government contract reports is indicated when practical or necessary by the "N", "OTS", or "AD" numbers given after the reference. These numbers refer to the library indexes of the National Aeronautics and Space Administration, The Office of Technical Services, and the Defense Documentation Center, respectively.

Both an author index and a chemical index have been added to the bibliography for the user's convenience. The chemical index includes those chemical species cited in the abstracts and titles of the publications. The authors feel that, while no bibliography can claim to be complete, this compilation will provide a good basis for anyone interested in undertaking a study in the chemistry of comets.

The Chemistry of Comets -- An Annotated Bibliography

J. B. Evans and V. J. DeCarlo

OBSERVATIONS AND INTERPRETATION

1. B. M. Middlehurst and G. P. Kuiper (Editors)  
THE SOLAR SYSTEM. VOL. IV. THE MOON, METEORITES, AND COMETS  
The University of Chicago Press, Chicago, Ill., 1963

A comprehensive survey of information is contained in the six chapters devoted to comets and authored by noted authorities. Chapter 15 is authored by E. Roemer and deals with the discovery, orbits, and observation of comets; Chapter 16, by J. G. Porter, with orbital statistics; Chapter 17, by K. Wurm, with the physical and chemical properties and includes discussions of the form, spectra, excitation, densities, polarization, and mechanical theory; Chapter 18, by L. Biermann and Rh. Lust, with the structure and dynamics of cometary tails; Chapter 19, by F. L. Whipple, with the structure of the nucleus; and Chapter 20, by J. H. Oort, with empirical data on the origin of comets.

2. R. A. Lyttleton  
THE COMETS AND THEIR ORIGIN  
Cambridge University Press, New York, N. Y., 1953

The properties and formation of comets are described in an effort to elucidate the origin of comets.

3. N. B. Richter  
THE NATURE OF COMETS  
Methuen and Company, Ltd., London, England, 1963

A translation of the original "Statistik und Physik der Kometen," the book provides a review of information concerning the history, statistics, theoretical models, structure, origin, formation, and decay of comets. Recent data obtained from the observations of Comets Arend-Roland and Mrkos and a chapter discussing future cometary investigations are also included.

4. P. W. Merrill  
SPACE CHEMISTRY  
The University of Michigan Press, Ann Arbor, Michigan, 1963

The chemistry of the solar system, stars, and nebulae is discussed and includes a short treatment of the chemistry of comets.

5. P. Swings  
CONSIDERATIONS REGARDING COMETARY AND INTERSTELLAR MOLECULES  
Astrophysical Journal 95, 270 (1942)

A comparative study is made of the possible mechanisms of formation, dissociation, and ionization in comets and in interstellar space. The additional identification work necessary to an explanation of these processes is set forth, while the identification, ionization, dissociation, and abundance of  $\text{CH}^+$ ,  $\text{CN}$ , and  $\text{C}_2$  are treated at length.

6. P. Swings  
MOLECULAR BANDS IN COMETARY SPECTRA. IDENTIFICATIONS  
Rev. Mod. Phys. 14, 190 (1942)

A discussion summarizes the identification of the molecules OH, NH, CN, CH, C<sub>2</sub>, CH<sup>+</sup>, CO<sup>+</sup>, and N<sub>2</sub>. The source of these molecules and the problems associated with their identification are treated.

7. P. Swings  
COMETARY SPECTRA, REPORTS ON THE PROGRESS OF ASTRONOMY  
Monthly Notices of the Royal Astronomical Society 103, 86 (1943)

A review of cometary astronomy discusses the visible, ultraviolet, astronomical, and laboratory observation of the diatomic molecules OH, NH, and CH<sup>+</sup>; the triatomic CH<sub>2</sub>; and the less definite OH<sup>+</sup> and NH<sub>2</sub>. The previously identified molecules CN, C<sub>2</sub>, CH, CO<sup>+</sup>, and N<sub>2</sub> are also treated in a concluding discussion of the excitation mechanism and rotational structure of cometary bands, and of the physical form and stability of cometary materials.

8. P. Swings and T. Page  
THE SPECTRUM OF COMET BESTER (1947k)  
Astrophysical Journal 111, 530 (1950)

An analysis of the ultraviolet, visible, and near infrared spectra of comet Bester (1947k) is presented with a summary of identifications for CN, C<sub>2</sub>, OH, NH, CO<sup>+</sup>, N<sub>2</sub><sup>+</sup>, OH<sup>+</sup>, NH<sub>2</sub>, and the  $\lambda$  4050 band system. Molecules identified in the tail include CO<sup>+</sup>, and CO<sub>2</sub><sup>+</sup>, and the tentatively assigned NO and O<sub>2</sub>. Slit spectrograms of the tail cover the ultraviolet region, while spectrograms of the head cover the visible and near infrared region. A comparison of this spectra with those of other comets is given, and the transitions and origin of the specific emissions are postulated.

9. T. Page  
RECENT STATISTICAL STUDIES IN ASTRONOMY  
Science 132, 1870 (1960)

Statistical studies reveal information about the mass, expansion, and radio emission of galaxies and the origin and loss of comets.

10. P. Swings and L. Haser  
ATLAS OF REPRESENTATIVE COMETARY SPECTRA  
The University of Liege, Institute of Astrophysics, Cointe-Schlessin,  
Belgium, 1956  
AD 119 234

A compilation of 350 representative spectra is presented with description, notes, and references given as necessary. A foreword describes the

meaningful aspects of cometary spectroscopy and includes definitions; instrumental influences; principles for the identification of emissions; wavelength tables; the cometary bands, continuum, molecules, etc; and the interrelation between cometary spectra and that observed in the atmosphere and stars.

11. P. Swings and L. Haser  
NOTES ON COMETARY SPECTRA  
The University of Liege, Institute of Astrophysics, Cointe-Schlessin,  
Belgium, 1956  
AD 119 235

Notes published in addendum to Swing's Atlas explain the limitations effected by instrumental and observational errors and by the choice of comet model.

12. L. Haser  
LA CONSERVATION DES RADICAUX LIBRES A' BASSE TEMPERATURE ET THE STRUCTURE  
DES NOYAUX DE COMETES  
Comptes Rendus 241, 742 (1955)

It is theorized that the observed radicals are formed by photodissociation of the parent molecules produced by sublimation of the ices in the nucleus.

13. L. Haser  
SUR LA PRODUCTION DES RADICAUX LIBRES DANS LES COMETES  
Bull. Acad. R. Belg. 42, 80, 813 (1956)

A new process for the production of radicals by comets is proposed.

14. P. Swings  
THE SPECTRA OF THE COMETS  
Vistas in Astronomy 2, 958-981, Pergamon Press (1956)

A presentation of the general characteristics of comets is followed by a description of the ultraviolet, visible, and near infrared spectrum of the coma and tail. The assignment of the emissions is discussed along with the possible causes of excitation and the mechanisms.

15. P. Swings et al  
NOTES ON COMETARY PHYSICS  
The University of Liege, Institute of Astrophysics, Cointe-Schlessin,  
Belgium, 1957  
AD 117 169

Notes prepared preliminary to "Research on Relations between Cometary, Solar, and Atmospheric Physics," discuss the identification of emissions



in cometary spectra, the possibility of fluorescence excitation in comets, the chemical reactions in comets, and the monochromatic intensity distribution in a comet's head.

16. P. Swings  
RESEARCH ON RELATIONS BETWEEN COMETARY, SOLAR, AND UPPER ATMOSPHERIC PHYSICS  
The University of Liege, Institute of Astrophysics, Cointe-Schlessin,  
Belgium, 1958  
AD 152 525

An attempt to discover an interrelationship between cometary, solar, and atmospheric processes is presented in three sections. The section on cometary physics includes a number of studies: the assignment of the infrared system of CN, the identification of the forbidden lines of O(I) in comets and a comparison with that of the upper atmosphere, assignment of accurate wavelengths in the visible region and in particular for NH<sub>2</sub>, a comparison of Comet Encke in 1957 and 1947-1937, the origin of the continuous spectrum of comets, the intensity and polarization of light scattered by cometary particles, trapped radicals and their possible reactions, and the theoretical distribution of the molecules in the head.

17. P. Swings et al  
ON THE ORIGIN OF THE CONTINUOUS SPECTRUM OF COMETS  
The University of Liege, Institute of Astrophysics, Cointe-Schlessin,  
Belgium, 1959  
AD 243 271

The possible causes of the continuous spectrum of comets are examined. Four mechanisms are considered -- diffuse reflection by the solid nucleus, scattering by molecules, scattering by solid particles, and scattering by free electrons. It is concluded that the solar continuum of comets is due primarily to scattering by solid particles.

18. P. Swings et al  
RELATIONS BETWEEN COMETARY AND SOLAR ACTIVITY  
The University of Liege, Institute of Astrophysics, Cointe-Schlessin,  
Belgium, 1960  
AD 243 274

The behavior of dust and gaseous cometary heads is compared to solar activity to indicate that the brightness of a dust head is not related appreciably to solar activity while a gaseous head may be.

19. P. Swings  
EXCITATION AND ABUNDANCES IN COMETS  
University of Liege, Institute of Astrophysics, Cointe-Schlessin, Belgium, 1960  
AD 243 275

Cometary spectra is analyzed in studies of a fluorescence excitation

mechanism for the C<sub>2</sub> Swan bands, the radii of the nuclei of the periodic Comets 1957c and 1959b, and the relative abundances of CO<sup>+</sup> in the tail and CN in the head of Comet Bester 1947k.

20. P. Swings, D. Bosman-Crespin and C. Arpigny  
THEORETICAL CONSIDERATIONS ON THE PREDICTED FAR ULTRAVIOLET SPECTRA OF  
COMETS AND OF POLAR AURORAE  
University of Liege, Institute of Astrophysics, Cointe-Schlessin, Belgium,  
1960  
AD 257 098

The expected far ultraviolet spectra of comets and aurorae is discussed and specific predictions are tabulated for application to planned rocket and space probe investigation.

21. P. Swings  
RECENT PROGRESS IN COMETARY SPECTROSCOPY  
University of Liege, Department of Astrophysics, Cointe-Schlessin, Belgium,  
1963  
AD 430 639

The report discusses recent progress in cometary observations and spectroscopy as well as in the understanding of the excitation mechanism of the diatomic and triatomic radicals and ions.

22. A. H. Delsemme and P. Swings  
HYDRATES DE GAZ DANS LES NOYAUX COMETAIRES ET LES GRAINS INTERSTELLAR  
Ann. d'Astrophys. 15, 1 (1952)

The presence of solid hydrates of CH<sub>4</sub>, CO<sub>2</sub>,... in cometary nuclei and interstellar grains is assumed and substantiated by noting that the vapor pressures of the various hydrates are of the same order of magnitude, while the vapor pressures of solid CH<sub>4</sub>, H<sub>2</sub>O etc. differ by very large factors.

23. P. D. Jose and P. Swings  
THE SPECTRUM OF COMET 19481  
Astrophysical Journal 111, 41 (1950)

From an analysis of eight spectrograms of Comet 19481, sodium emission is identified at  $r = 0.73$  and  $r = 0.79$  AU, and CN and the  $\lambda 4050$  group at  $r = 2.21$  AU. The usual complex structure of the CN bands is attributed to the fluorescence excitation by solar radiation. The behavior of CH and "CH<sub>2</sub>" are compared, and unidentified features observed within and between the Swan bands and in the yellow-red region are discussed.

24. P. Swings et al  
RESEARCH ON RELATIONS BETWEEN COMETARY, SOLAR AND UPPER ATMOSPHERIC PROCESSES  
University of Liege, Department of Astrophysics, Cointe-Schlessin, Belgium,  
March 31, 1964  
AD 601 136

This report presents a discussion of the progress achieved in a program for the laboratory production of molecules of astronomical interest; study of the physical mechanisms of comets and the upper atmosphere; and investigations related to space experiments, which include far ultraviolet spectra of stars, comets and aurorae, and artificial comets.

25. L. Houziaux  
DENSITY OF  $C_2$  MOLECULES IN THE HEAD OF COMET MRKOS 1955e  
The University of Liege, Institute of Astrophysics, Cointe-Schlessin,  
Belgium, 1961  
AD 269 914

The energy emitted in the (1,0) band of the Swan system for  $C_2$ , as derived from photoelectric observations, is used to calculate the variation between the density of the  $C_2$  molecule in regions close to the nucleus and that in external regions of the head.

26. P. Swings and J. L. Greenstein  
PRESENCE DES RAIES INTERDITES DE L'OXYGEN DANS LES SPECTRA COMETAIRES  
Comptes Rendus 246, 511 (1958)

The identification of O(I) in cometary spectra is presented.

27. J. L. Greenstein and C. Arpigny  
THE VISUAL REGION OF THE SPECTRUM OF COMET MRKOS (1957d) AT HIGH RESOLUTION  
Astrophysical Journal 135, 392 (1962)

The emission line and band spectrum of the head of Comet 1957d are analyzed and presented in a table of identifications. The  $C_2$  and  $NH_2$  bands produced by resonance fluorescence were nearly completely resolved, while the Na(I) lines were found to be asymmetric with respect to the nucleus.

28. J. L. Greenstein  
THE SPECTRUM OF COMET HUMASON (1961e)  
Astrophysical Journal 136, 688 (1962)

Spectroscopic observations of Comet 1961e are analyzed and presented in a table of identifications.

29. J. L. Greenstein  
HIGH-RESOLUTION SPECTRA OF COMET MRKOS (1957d)  
Astrophysical Journal 128, 106 (1958)

A new second-order effect observed in high-dispersion Coude' spectra of Comet Mrkos is presented in a detailed study of Swings' resonance-fluorescence mechanism. Intensity ratios between individual rotational cyanogen lines were found to change within 4000km on opposite sides of the nucleus and are reportedly caused by motions.

30. P. Swings, G. T. Elvey and H. W. Babcock  
THE SPECTRUM OF COMET CUNNINGHAM, 1940c  
Astrophysical Journal 94, 320 (1941)

The identification of well-resolved ultraviolet bands due to OH and NH in slit spectrograms of Comet Cunningham is reported along with a description of the observed CH bands, the abundances of the OH and NH molecules, the absence of CN bands in the tail, and bands observed between  $\lambda$  4000 and 4130.

31. P. Swings et al  
RESEARCH ON RELATIONS BETWEEN COMETARY, SOLAR AND UPPER ATMOSPHERIC PROCESSES  
University of Liege, Department of Astrophysics, Cointe-Schlessin, Belgium,  
March 31, 1963  
N63-17540

Progress is reported for investigations in time-resolved spectroscopy in the far ultraviolet, the absorption spectra of H<sub>2</sub>, D<sub>2</sub>, HD, C<sub>3</sub>, SO<sub>2</sub><sup>18</sup>, SO<sub>2</sub><sup>18</sup>, and H<sub>2</sub>O, and applicable efforts in instrumentation. The physical mechanisms responsible for cometary phenomena and related space investigations are discussed.

32. L. Remy-Battiau  
THE LUMINOSITY VARIATIONS OF COMET HEADS  
University of Liege, Department of Astrophysics, Cointe-Schlessin, Belgium,  
August 20, 1964  
AD 606 655

A study directed toward the elucidation of the relation between solar activity and cometary brightness re-examines Whitney's work on cometary outbursts under the assumption that the light emitted at the time of an outburst is due to scattering of solar radiation by small solid particles. The study considers the masses and required energies and concludes that solar particles are not likely to be responsible for cometary outbursts.

33. B. Donn and H. C. Urey  
ON THE MECHANISM OF COMET OUTBURSTS AND THE CHEMICAL COMPOSITION OF COMETS  
Astrophysical Journal 123, 339 (1956)

Prominent comet activity is proposed to arise from explosive chemical reactions involving free radical and unstable molecules.

34. B. Donn and H. C. Urey  
CHEMICAL HEATING PROCESSES IN ASTRONOMICAL OBJECTS  
Mem. Soc. Roy. Sci. Liege, 4<sup>o</sup>, 18, 124 (1957)

Chemical heating by recombination of atoms, free radicals, or energetic molecules is considered as an explanation of the cause of comet outbursts.

35. B. Donn  
COMETS AND THE CHEMISTRY OF MATTER IN SPACE  
Astronomical Journal 64, 126 (1959)

A brief note points out that comets may be looked upon as the initial stages of accumulation from the solar nebula which could have ultimately developed into asteroidal and planetary objects and, thus, that the investigation of comets is a valid approach to cosmic chemistry.

36. B. Donn  
FORMATION AND TRAPPING OF FREE RADICALS (A. M. BASS AND H. P. BROIDA, EDITORS)  
Chap. 11, pp. 347-363, Academic Press, Inc., New York, N. Y., 1960

A brief description of comets is given in a review of the low-temperature chemistry of cometary constituents, comet models, cometary spectra, and postulated mechanisms or causes of cometary phenomena.

37. B. Donn  
THE CHARACTERISTICS OF DISTANT COMETS  
Ann. d'Astrophys. 25, 319 (1962)

The spectroscopic observations and colors of comets are analyzed and indicate that only sunlight scattered from solid grains can explain the data. The use of previous comet-tail models as set forth by Brandt, Osterbrock, Chamberlain, and Parker to explain interplanetary medium or as a solar-system probe is refuted.

38. H. C. Urey  
COMETARY COLLISIONS AND TEKTITES  
Nature 197, 228 (1963)

The proposed formation of tektites by cometary collision with the earth is supported.

39. B. Donn  
THE ORIGIN AND NATURE OF SOLID PARTICLES IN SPACE  
Presented at the New York Academy of Sciences Conference on Cosmic Dust,  
Goddard Space Flight Center, Greenbelt, Md., November 21-22, 1963

An analysis of the types of particles that exist in interplanetary space is concerned with the collection and detection of such particles and with the identification of their primary source. Possible sources of such material are considered to be primary grains, cometary dust, asteroidal dust, meteorite ablation products, meteoric residue, and interstellar grains.

40. B. Donn and G. W. Sears  
PLANETS AND COMETS: ROLE OF CRYSTAL GROWTH IN THEIR FORMATION  
Science 140, 1208 (1963)

Crystal growth theory is applied to the formation of smoke particles from the primordial solar nebula to indicate that solid particles with filamentary structures will form and thus facilitate successive aggregation into planets, comets, and asteroids.

41. B. Donn  
THE ORIGIN AND STRUCTURE OF ICY COMETARY NUCLEI  
Icarus 2, 396 (1963)

The origin and structure of the nuclei is examined within the boundaries of presently accepted models. The analysis considers the distance from the sun, velocity, temperature, cloud of comets, and the formation of planets. The structure of the nuclei is considered in terms of an H<sub>2</sub>O ice, density, pressure, and temperature.

42. L. S. Marochnik  
THE FORM OF COMETARY ENVELOPES  
Sov. Astron. 4, 480 (1960) - Astron Zh. 37, 508 (1960)

Alfven's hypothesis relating to the interaction between cometary gas and a stream of particles carrying a magnetic field is used to show that the form of a cometary envelope is described by a catenary, in accord with observations. The parabolic relationship flowing from the mechanical theory of cometary forms is only a rough approximation. The transverse motions observed in the tails of comets are accounted for in terms of Alfven waves. The upper limit of the magnetic field is estimated. (Author)

43. L. S. Marochnik  
SOME MECHANISMS OF THE RADIO EMISSION OF COMETS  
Byul. Komis. po. Kometam i Meteoram Astron. Soveta AN SSSR, No. 5, 21-27  
(1961): Ref. Zh., Fizika, No. 1, 49 (1963), Abstract 1Zh294  
AD 412 130

An investigation is carried out of the transformation of cometary gas plasma oscillations into radio emission. The effective temperature of the plasma waves and the intensity of the arising radio emission are calculated. The latter corresponds to the observed values. It is shown that the reflection of the solar radio emission by the comet plasma is inessential. The effect of the comet's proper magnetic field is also inessential. (LM)

44. L. S. Marochnik  
ON THE PLASMA NATURE OF A COMETS' HEAD  
Sov. Astron. 6, 532 (1963) - Astron. Zh. 39, 678 (1962)

The gas in a comet's head is considered to be a plasma with a high degree of ionization. The shape of the comet's head and the origin of the ionization are also treated.

45. L. S. Marochnik  
INTERACTION OF SOLAR CORPUSCULAR STREAMS WITH COMETARY ATMOSPHERES.  
I. SHOCK WAVES IN COMETS  
Sov. Astron. 6, 823 (1963) - Astron. Zh. 39, 1067 (1962)

An attempt is made to develop the theory of shock waves in application to comets. The possibility of considering the process of collision of a cometary head with a solar corpuscular stream in terms of magnetohydrodynamics is shown. The parameters of shock waves originating during this process are computed. The results obtained are used to analyze some phenomena in comets. (Author)

46. L. S. Marochnik  
WAVE MOTIONS IN COMET TAILS  
Sov. Astron. 7, 218 (1963) - Astron. Zh. 40, 284 (1963)

The causes for wave motions in ionized cometary tails are discussed. It is shown that these motions are related to magnetohydrodynamic waves. The increase in amplitude and wavelength with distance from the head to the tail is accounted for as an increment in the local Alfvén velocity.

47. L. S. Marochnik  
INTERACTION BETWEEN SOLAR CORPUSCULAR STREAMS AND COMETARY ATMOSPHERES.  
II. "COLLAPSING" ENVELOPES. RADIO-FREQUENCY EMISSION  
Sov. Astron. 7, 334 (1963) - Astron. Zh. 40, 504 (1963)

The collapsing envelopes observed in Comet Morehouse 1908 III and other

comets are analyzed and correlated with the occurrence of ionization and radio-frequency emission.

48. L. S. Marochnik  
CAUSE OF IONIZATION OF COMETARY MOLECULES  
Sov. Astron. 7, 544 (1964) - Astron. Zh. 40, 714 (1963)

In this paper it is shown that the focussing of the magnetic field of the solar corpuscular stream leads to an increase in the concentration of protons in the stream. Even if the corpuscular stream was extremely rarified before collision with the comet, the increase of proton concentration is sufficient for explaining the observed lifetime of parent molecules before ionization by recharging  $H^+ + M \longrightarrow M^+ + H$  ( $M$  = a parent molecule). The focussing of the field to the nucleus also makes it possible to understand the location of ions near the cometary nucleus. (Author)

49. V. I. Cherednichenko  
THE DISSOCIATION AND IONIZATION OF COMETARY MOLECULES IN THE PHOTON AND CORPUSCULAR FIELD OF SOLAR RADIATION  
Astron. Zh. 36, 254 (1959)

An attempt is made to determine the lifetimes of prechosen cometary molecules under bombardment by photon and corpuscular solar radiation.

50. V. I. Cherednichenko  
LIFETIME OF COMETARY ICES IN THE FIELD OF PHOTON AND CORPUSCULAR SOLAR RADIATION  
Meteoritika, Akad. Nauk. SSSR, Komitet Meteorit. No. 19, 143-54 (1960)

A more complete description is given for the calculation of the lifetimes of assumed cometary molecules under the influence of photon and corpuscular radiation.

51. Yu. V. Evdokimov  
MOTION OF THE JACOBINI-ZINNER COMET FROM 1933 TO 1946  
Sov. Astron. 7, 415 (1963) - Astron. Zh. 40, 544 (1963)

The orbital elements of the Jacobini-Zinner comet are computed from observations made of the 1933 and 1939 apparitions and the 1939 and 1946 apparitions.



52. Y. V. Yevdokimov  
MASSES OF COMET GIACOBINI-ZINNER AND THE DRACONID METEOR STREAM  
Smithsonian Contributions to Astrophysics, Vol. 7, pp. 297-299, Smithsonian  
Institution Astrophysical Observatory, Washington, D. C., 1963  
N63-16664

The change in the mass and motion of Comet Giacobini-Zinner is assessed and related to the Draconid meteor stream.

53. V. Fessenkov  
A NOTE ON THE COMETARY NATURE OF THE TUNGUS METEORITES  
Smithsonian Contributions to Astrophysics, Vol. 7, pp. 305-308, Smithsonian  
Institution Astrophysical Observatory, Washington, D. C., 1963  
N63-16664

The fall of the Tungus meteorite is analyzed with evidence given to support the theory that it was a small comet.

54. S. K. Vsekhsvyatskiy  
THE PROBLEMS ABOUT COMETS AND THE SOLAR SYSTEM  
Transactions of the Congress of the All-Union Astronomic-Geodetic Society,  
Moscow, 1960, pp. 107-119 (1962)  
OTS/SLA 63-19537

The theories for the origin of comets and the mechanism of their formation are reviewed. It is concluded that comets and other small bodies permit an estimation of the amount of matter ejected from planets and thus, the study of comets will allow the history of the planetary system to be elucidated.

55. S. K. Vsekhsvyatski  
ABSOLUTE MAGNITUDES OF 1954-1960 COMETS  
Sov. Astron. 6, 349 (1963) - Astron. Zh. 39, 1094 (1962)

The absolute magnitudes and photometric parameters of 62 comets observed during 1954-1960 are compiled from available photometric and brightness data.

56. S. K. Vsekhsvyatskii  
OBSERVATIONS AT KIEV OF COMET SEKI-LINES 1962  
Sov. Astron. 7, 133 (1963) - Astron. Zh. 40, 176 (1963)

The brightness of the head of Comet Seki-Lines 1962 covering the entire apparition from April 3 to May 6, 1962 is presented.

57. B. Yu. Levin  
THE STRUCTURE OF ICY COMET NUCLEI  
Sov. Astron. 6, 593 (1963) - Astron. Zh. 39, 763 (1962)

A hypothesis is proposed that the substances of the icy cometary nuclei are present in the form of separate atoms and molecules embedded in an amorphous noncoherent condensate of different volatile substances, and secondly, that the evaporation of volatile substances from the nucleus leaves a porous matrix, the fragments of which are meteoric particles.

58. V. M. Yuzhakov  
REMARKS ON THE MAGNETIC FIELD IN THE TAIL OF THE COMET 1957d  
Sov. Astron. 7, 591 (1964) - Astron. Zh. 40, 779 (1963)

The induction of the magnetic field in the tail of the Comet Mrkos 1957d is determined from the helical structure of the field, and the value found was  $5 \cdot 10^{-6}$  G, which is less than the interplanetary field by a factor of approximately ten. (Author)

59. D. O. Mokhnach  
EFFECT OF PHOTODISSOCIATION ON THE DISTRIBUTION OF SURFACE BRIGHTNESS IN THE CARBON ATMOSPHERE OF COMETS  
Dokl. AN SSSR, Astronomiya, Tom 157, No. 2, 309-312, Izdatel'stvo "Nauka", 1964  
ST-OA-10195 (NASA)

An attempt is made to construct a simple model of a carbon coma, considering the deviation in the distribution of surface brightness ( $1/r$  and  $1/r^2$ ) as observed in Comet Burnham (1959k).

60. K. A. Shteins and S. Ya. Sture  
THE DIFFUSION OF COMETS  
Sov. Astron. 6, 398 (1962) - Astron. Zh. 39, 506 (1962)

As Part IV, the problem of new comets is assessed in terms of diffusion processes. The study concludes that the stabilization of the diffusion process involves several million years.

61. E. A. Dibai  
ORIGIN OF COMETARY NEBULAE II  
Sov. Astron. 7, 606 (1964) - Astron. Zh. 40, 795 (1963)

It is shown that the principal morphological characteristics of cometary nebulae may be represented as the result of focusing of shock waves originating at the interface between a cold, dense neutral gas and an ionized gas in the Stromgren zone. (Author)

62. O. V. Dobrovolskiy  
RADIO EMISSION FROM COMETS  
Byul. in-ta Astrofiz. AN Tadzh SSR, No. 26, pp. 3-11 (1958)  
AD 264 497

A review of the reported radio emissions observed from comets and the theoretical mechanism or cause of such emission is given.

63. A. D. Dubyago  
STRUCTURE OF COMET NUCLEI AND FORMATION OF METEOR STREAMS  
Astron. Zh. 27, 5 (1950)  
AD 120 694

The structure of comet nuclei is considered as consisting of many separate solid bodies of a quite large size. It is shown that the density of the nuclei can be estimated from the periodic processes observed in comets. The velocity with which meteors leave the comet head is estimated. It is concluded that the meteor swarms associated with periodic comets must originally have a small extent perpendicular to the plane of the orbit, and that the rate of propagation of the swarm may be evaluated.

64. V. G. Fesenkov  
ON THE NATURE AND ORIGIN OF COMETS  
Sov. Astron. 6, 459 (1963) - Astron. Zh. 39, 583 (1962)

In an attempt to discover the origin of comets, it is postulated that short-period comets are generated from aperiodic comets, that cometary nuclei consist of compact agglomerations of fairly unstable particles, that the total mass of a comet can be estimated from the brightness of the comets head and from reaction effects attendant upon the rotation of the head about the comets axis, and that the distance between the component parts of the nucleus is quite short. In conclusion, it is stated that such compact clusters of unstable species could not possibly originate in volcanic eruptions from the interior of a planet.

65. B. A. Vorontsov-Vel'yaminov  
PARTIAL GAS DENSITIES IN COMET 1942g WHIPPLE  
Sov. Astron. p. 674 - Astron. Zh. 37, 709 (1960)

The partial gas densities in Comet Whipple are computed from the absolute monochromatic emission spectra of the CN 3883, C<sub>2</sub> 4730, and C<sub>3</sub> 4050 bands as determined by reference to stellar spectra.

66. S. M. Poloskov  
THE INFRARED SPECTRUM OF COMETS  
ca 1951  
N64-23179

A study of the infrared spectra of comets refutes Swings identification of the (red) system of the CN molecule and assigns this emission to  $A^2\Pi-2\Sigma$  system of the  $N_2^+$  molecule.

67. S. V. Orlov and S. M. Poloskov  
COMETS  
?  
N64-24654

A summary of Soviet studies of comets covers comet models, cometary physics, and the origin and evolution of comets.

68. L. Biermann  
COMET TAILS AND SOLAR CORPUSCULAR RAYS  
Zeitschrift fur Astrophysik 28-29, 274 (1950-51)

The acceleration of long comet tails, consisting of  $CO^+$  and other ions, to that which exceeds the gravitational acceleration of the sun is theorized to be produced by the solar corpuscular radiation of the sun.

69. L. Bierman and E. Trefftz  
UBER DIE MECHANISMEN DER IONISATION  
Zeitschrift fur Astrophysik 59, 1 (1964)

The possible mechanisms for the excitation of the forbidden oxygen lines in comets are discussed along with the production by ionization of suitable parent molecules which can account for the observed emissions of  $C_2$ , CN, and  $CO^+$ .

70. D. Antrack, L. Bierman and Rh. Lust  
SOME STATISTICAL PROPERTIES OF COMETS WITH PLASMA TAILS  
Annual Review of Astronomy and Astrophysics, Vol. 2, p. 327, Annual Reviews, Inc., Palo Alto, California, 1964

The report surveys the results obtained from the observations of comets in a study of the solar plasma through its effects on the plasma-tail comets.

71. N. T. Bobrovnikoff  
PHYSICAL THEORY OF COMETS IN THE LIGHT OF SPECTROSCOPIC DATA  
Rev. Mod. Phys. 14, 164 (1942)

A brief summary of the general problems raised by new spectral data is presented in order to point out certain unacceptable physical theories and to outline observational procedure which may serve to provide better understanding of cometary phenomena.

72. N. T. Bobrovnikoff  
ON THE SPECTRA OF COMETS  
Astrophysical Journal 66, 439 (1927)

The spectra of 22 comets obtained between 1908 and 1927 are analyzed. A correlation is drawn between the heliocentric distance and the type of continuous spectra and between the phase-angle and the type of spectra. Sudden changes in the spectra are discussed and reasons in support of a fluorescence origin of cometary spectra are given.

73. J. A. Bruwer  
PHOTOGRAPHIC OBSERVATIONS OF COMETS  
Circulars 7, 20 (1963)

The photographic observation of Comets Seki-Lines 1962c, Temple 2, and Humason 1961e is tabulated, listing date of observation, magnitude, and position.

74. A. J. Cohen  
ASTEROID- OR COMET-IMPACT HYPOTHESIS OF TEKTITE ORIGIN: THE MOLDAVITE  
STREW-FIELDS  
Tektites, pp. 189-212, The University of Chicago Press, Chicago, Ill.,  
1963  
N64-14934

Arguments are presented in support of the comet-impact terrestrial origin of tektites.

75. R. Coutrez, J. Hunaerts and A. Koeckelenbergh  
RADIO EMISSION FROM COMET 1956h ON 600 MC  
Proc. IRE 46, 274 (1958)

An attempt is made to identify the emission as due to a  $\Lambda$ -type doubling of the level  $J = 3/2$  for the  $^2\Pi_{3/2}$  state of the CH molecule.

76. J. Dufay and A. Baranne  
LE SPECTRE DE LA COMETE WILSON-HUBBARD (1961d)  
Ann d' Astrophys. 25, 301 (1962)

The spectra of Na, NH<sub>2</sub>, C<sub>2</sub>, and CN as recorded photographically ~~are~~ discussed and explained.

77. W. C. Erickson and P. Brissenden  
A SEARCH FOR DECAMETRIC RADIATION FROM THE COMET WILSON 1961d  
Astrophysical Journal 136, 1138 (1962)

A search for decametric radio emission from Comet Wilson made by Clark Lake radio astronomy station reports definite negative results.

78. F. H. Flynn  
INTENSE FAR-RED EMISSION FROM COMET CANDY (1960n)  
Observatory 81, 247 (1961)

The observation of red emission near 7900 and 3100<sup>0</sup>Å is tentatively assigned to CN.

79. C. C. Kiess  
RECENT ADVANCES IN ASTRO-GEOPHYSICS  
Georgetown College Observatory, Georgetown University, Washington, D. C.,  
1964  
N64-15286

A brief lecture presents a general description of comets and the role they play in the study of the formation of the solar system.

80. W. Liller  
THE NATURE OF THE GRAINS IN THE TAILS OF COMETS 1956h AND 1957d  
Astrophysical Journal 132, 867 (1960)

Continuous spectra between  $\lambda$  3400 and  $\lambda$  6400 obtained from observations of the tails of Comets Arend-Roland (1956h) and Mrkos (1957d) are compared with theoretical light scattering curves. Results indicate that iron spherules of an average diameter of 0.6 $\mu$  and masses of  $8 \times 10^{-13}$ g produced the radiation. Considerations of the brightnesses of the tails allow estimates to be made of the total masses of the particles.

81. W. Liller  
PHOTOELECTRIC PHOTOMETRY OF COMETS  
Astronomical Journal 66, 372 (1961)

A description is given of narrow-band photoelectric photometry of Comets

Arend-Roland (1956h), Mrkos (1957d), Encke, and Burnham (1959k). The observations are summarized in three parts dealing with head spectra, tail spectra, and monochromatic isophotal contours of Comet Burnham.

82. R. A. Lyttleton  
A COMETARY MECHANISM FOR THE FORMATION OF TEKTITES  
Proc. Roy. Soc. A 272, 467 (1963)

The formation of tektites is theorized to be caused by short-period comets which have an eccentricity small enough to allow the accretion of cometary material to occur during the passage of the earth through the comet and thus, produce a narrow jet of material falling vertically downward through the atmosphere.

83. R. A. Lyttleton and J. M. Hammersley  
THE LOSS OF LONG-PERIOD COMETS FROM THE SOLAR SYSTEM  
Monthly Notices of the Royal Astronomical Society 127, 257 (1964)

The loss of long-period comets from the solar system by planetary action is estimated statistically.

84. B. G. Marsden and G. van Biesbroeck  
THE ORBIT OF COMET 1944I (van GENT-PELTIER-DAIMACA)  
Astronomical Journal 68, 235 (1963)

A hyperbolic orbit of the Comet 1944I, first observed in 1943 by Gent, is determined from positions covering a 57-day arc.

85. G. van Biesbroeck and B. G. Marsden  
ORBIT OF COMET 1954V (ABELL)  
Astronomical Journal 68, 212 (1963)

From 34 observations made a year after the comet had attained its perihelion, it is calculated that the hyperbolic excess of the osculating orbit is 19 times its mean error, but that the "original" orbit was elliptical.

86. A. McKellar  
SOME TOPICS IN MOLECULAR ASTRONOMY  
J. Roy. Astron. Soc. Canada 54, 97 (1960)

Spectroscopic studies of molecules in various astronomical bodies are reviewed.

87. A. McKellar  
INTENSITY MEASUREMENTS ON EMISSION BANDS IN COMETARY SPECTRA  
Rev. Mod. Phys. 14, 179 (1942)

Intensity measurements on the bands in the spectra of Comet Jurlof-Achmarof-Hassel (1939d) and Comet Cunningham (1940c) are presented in one of the first reports on the quantitative spectrophotometry of comets. The mechanism of the excitation of the CN, C<sub>2</sub>, and CH cometary bands is considered in the light of such measurements. The resonance-fluorescence mechanism apparently accounts for the production of CN emission bands.

88. A. McKellar  
COMPARISON OF THE  $\lambda$  3883 CN BAND IN THE SPECTRA OF COMETS 1940c AND 1942g  
Astrophysical Journal 100, 69 (1944)

Differences in the structure of the  $\lambda$  3883 (0,0) CN band as observed in the spectra of Comet Cunningham (1940c) and Comet Whipple-Fedtke-Tevzadze (1942g) are noted and discussed in terms of the resonance production of the bands and the effects of the different heliocentric distances and radical velocities of the comets.

89. A. McKellar  
ROTATIONAL DISTRIBUTION OF CH MOLECULES IN THE NUCLEUS OF COMET CUNNINGHAM (1940c)  
Astrophysical Journal 98, 1 (1943)

From the observed profile of the  $\lambda$  4315  $^2\Delta$ ,  $^2\Pi$  CH band in the comet, the distribution of the rotational levels of the upper  $^2\Delta$  state is found. Assuming the resonance mechanism for the production of the band, the distribution among the rotational levels of the normal  $^2\Pi$  state is derived. The results indicate that all the molecules exist in the two lowest rotational levels, K = 1 and K = 2.

90. F. D. Miller  
FILTERS FOR COMET PHOTOGRAPHY  
Pub. Astron. Soc. Pac. 70, 279 (1958)

The analysis of several components of the structure of a comet by means of direct photography with suitable emulsion/filter combinations is illustrated with results obtained from the observation of Comet Mrkos 1957d.

91. F. D. Miller  
THE TYPE I TAIL OF COMET 1955e  
Pub. Astron. Soc. Pac. 74, 60 (1962)

Extended analysis of observations made of Comet Mrkos (1955e) presents two previously unobserved bands of CO<sup>+</sup> at  $\lambda$  6139 and 6239 and an unidentified emission near  $\lambda$  6600. The existence of the comet's well-developed Type-I tail observed at a high heliographic latitude in a period of comparative solar calm is brought forth as noteworthy.



92. F. D. Miller  
OBJECTIVE-PRISM SPECTROGRAMS OF COMET HUMASON (1961e)  
Pub. Astron. Soc. Pac. 74, 523 (1962)

Analysis of four objective-prism spectrograms of Comet Humason (1961e) is given. Bands of neutral molecules such as CN and C<sub>2</sub> were not found in the spectra. The (1,0), (2,0), and (3,0) CO<sup>+</sup> tail bands appeared superimposed on a continuum.

93. F. D. Miller  
NOTE ON THE SPECTRUM OF COMET IKEYA (1963a)  
Astrophysical Journal 139, 766 (1964)

Unidentified emission at  $\lambda$  6158, 6199, 6542, and 6562 observed in the spectra of Comet Ikeya (1963a) is reported and postulated to be due to ions.

94. M. F. Walker  
OBSERVATIONS OF COMETS BAKHAREV-MacFARLAND-KRIENKE, 1955f, AND BAADE, 1954h  
Pub. Astron. Soc. Pac. 70, 191 (1958)

The results of three-color photoelectric observations obtained in 1955 at the Mount Wilson and Palomar Observatories are reported.

95. F. L. Whipple  
A COMET MODEL. I. THE ACCELERATION OF COMET ENCKE  
Astrophysical Journal 111, 375 (1950)

A comet model is proposed, in which the nucleus is visualized as a conglomerate of ices, "volatiles," and meteoric materials combined at extremely low temperatures. The model resolves the chief problems of cometary motions and accounts for a number of other cometary phenomena.

96. F. L. Whipple  
A COMET MODEL. II. PHYSICAL RELATIONS FOR COMETS AND METEORS  
Astrophysical Journal 113, 464 (1951)

The loss of gaseous and meteoric materials from the nucleus is considered in terms of the comet's structure and compared with previous observations.

97. F. L. Whipple  
A COMET MODEL. III. THE ZODIACAL LIGHT  
Astrophysical Journal 121, 750 (1955)

An attempt is made to explain the occurrence of the zodiacal light, which

arises from the scattering and diffraction of sunlight by small particles, by the postulation of a comet model which can account for the replenishment of these particles by ejection or disintegration by comets.

98. F. L. Whipple  
PROBLEMS OF THE COMETARY NUCLEUS  
Astronomical Journal 66, 375 (1961)

The icy model is examined critically through a presentation of the relevant observational and theoretical evidence of its existence and nature.

99. F. Whipple  
REMARKS ON COMETS, METEORS, AND PLANETARY EVOLUTION  
Smithsonian Astrophysical Observatory, Harvard College Observatory,  
Cambridge, Mass.  
N64-24771

A discussion of comet accumulation in the outer parts of the solar system is presented.

100. C. Whitney  
COMET OUTBURSTS  
Astrophysical Journal 122, 190 (1955)

Several comet outbursts accompanied by the ejection of spherical halos are investigated. Special attention is paid to the mass and energy ejected in a typical halo. On the basis of the results, it is suggested that the energy of an outburst may be derived from normal insolation. The activity can possibly be explained in terms of the icy-conglomerate comet nucleus. (Author)

101. A. A. Wyller  
C<sub>2</sub> PHILLIPS BANDS IN EMISSION FROM COMET CANDY (1960n)?  
Observatory 82, 73-5 (1962)

It is suggested that the  $\lambda$  7906 and  $\lambda$  8106 emission observed from Comet Candy may be due to the infrared C<sub>2</sub> Phillips system ( ${}^1\Pi_u = {}^1\Sigma_g^+$ ).

102. H. Zanstra  
THE EXCITATION OF LINE AND BAND SPECTRA IN COMETS BY SUNLIGHT  
Monthly Notices of the Royal Astronomical Society 89, 178 (1928)

The line and band spectra observed in the head of a comet are theorized to be produced by the absorption of sunlight and subsequent resonance or fluorescence re-emission.

103. COMETARY TAILS  
Defense Documentation Center, Cameron Station, Alexandria, Va., July 1962  
ARB No. 10857

A bibliography of 29 reports dealing with observational and laboratory investigations of comets is offered.

104. H. Alfvén  
ON THE THEORY OF COMET TAILS  
Tellus IX, 92 (1957)

It is shown that some of the difficulties of Biermann's theory, which postulates that the repulsive force in comet tails is due to a corpuscular radiation from the sun, can be overcome if the assumed radiation consists of beams with a frozen-in magnetic field of the same type as required in the electric field theory of magnetic storms and aurorae. The interaction of such a beam with the head of a comet could produce an amplified magnetic field which determines the shape of the tail. The high accelerations observed in tails may be due to electromagnetic forces.

105. D. B. Beard and M. P. Nakada  
INTERPLANETARY MAGNETIC FIELDS AS A CAUSE OF COMET TAILS  
Nature 199, 580 (1963)

In explanation of the formation of cometary tails, it is pointed out that the gases in cometary comae can be efficiently ionized by a solar wind of ionized hydrogen embedded in a magnetic field, and that an interplanetary magnetic field can couple the cometary gas to the solar wind.

106. T. Carrington  
FLUORESCENCE IN COMETS AS A MARKOV PROCESS  
Astrophysical Journal 135, 883 (1962)

The fluorescence mechanism for the emission of electronic spectra of diatomic radicals in comet heads, as proposed by Swings and Hunaerts, is treated statistically and compared with previous less-rigorous calculations.

107. F. Hoyle and M. Harwit  
PLASMA DYNAMICS IN COMETS. I. PLASMA INSTABILITY  
Astrophysical Journal 135, 867 (1962)

An attempt is made to find a mechanism consistent with Bierman's theory that tail ions are accelerated through interaction with streams of solar particles. The field-free case is examined in an effort to establish conditions for which cometary plasma acceleration may be enhanced by plasma instability. From this it is concluded that plasma instability does not appreciably contribute to tail plasma acceleration.

108. M. Harwit and F. Hoyle  
PLASMA DYNAMICS IN COMETS. II. INFLUENCE OF MAGNETIC FIELDS  
Astrophysical Journal 135, 875 (1962)

In an attempt to find a mechanism consistent with Bierman's theory, it is shown that, if predominantly transverse magnetic fields are imbedded in the solar stream, the observed accelerations can be readily imparted to tail ions. The  $10 \text{ km sec}^{-1}$  ejection velocities from comet heads and the filamentary structure of many comet features are accounted for. Observational tests for the transverse field hypothesis are suggested.

109. C. R. O'Dell  
EMISSION-BAND AND CONTINUUM PHOTOMETRY OF COMET BURNHAM, 1959k  
Pub. Astron. Soc. Pac. 73, 35 (1961)

Two interference filters were used to observe the continuum around  $\lambda 4470$  and the  $\text{C}_2$  Swan band sequence near  $\lambda 4700$ . The data obtained includes information on the variation of surface brightness with distance from the nucleus, on changes in the comet with time and heliocentric distance, and the distribution of the material responsible for the band or continuum emission.

110. D. E. Osterbrock  
A STUDY OF TWO COMET TAILS  
Astrophysical Journal 128, 95 (1958)

Photographic observations of the directions of the tails of Comet Baade (1954h) and Comet Haro-Chaviro (1954k) indicate that the tail lies in the orbital plane roughly midway between the radial and tangential directions. Analysis of the observations indicate that the material in the tail must be subjected to a resisting force roughly equal to the radial repulsive force of the sun, that this resisting force can be caused by the interplanetary gas if the tail contains a large fraction of hydride molecules, and that the possibility the tail consists of solid particles small in comparison with the wavelength of light can not be ruled out.

111. C. R. O'Dell and D. E. Osterbrock  
EMISSION-BAND AND CONTINUUM PHOTOMETRY OF COMET SEKI (1961f)  
Astrophysical Journal 136, 559 (1962)

$\text{C}_2$  densities are obtained from photoelectric measurements of the continuum and  $\text{C}_2$  emission-band fluxes from Comet Seki (1961f) and Comet Burnham (1959k).

112. J. A. O'Keefe and B. N. Shute  
ORIGIN OF TEKTITES  
Science 139, 1288 (1963)

It is shown from the observed distribution of tektites that they can not be the result of cometary or meteoritic impact but, rather, can be accounted for as a result of fusion stripping of a satellite.

113. E. J. Öpik  
PHOTOMETRY, DIMENSIONS, AND ABLATION RATE OF COMETS  
The Irish Astronomical Journal 6, 93 (1963)

Considering the peculiarities of light distribution in the coma, it is estimated that the brightness of comets varies inversely as the first power of distance from the observer instead of the traditionally-used second power. This is postulated to be of major importance for artificial comets, making their construction prohibitive. The sudden appearance of radicals and ions in cometary envelopes is said to point to an active shell or radiation belt surrounding the nucleus. Formulae for absolute magnitudes and photometric radii of comets are given and confirmed by recoil radii. These are seen to be much smaller than the dimensions of "false nuclei" observed telescopically. The total evaporation rate of the nuclear ices is estimated, and the luminescent radicals ( $C_2$ , CN) and ions ( $CO^+$ ) are reported to account for almost one percent of the total gaseous mass. The layered mechanism of simultaneous evaporation of constituents of different volatility is discussed. From molecular weight and cosmogonic considerations, it is theorized that solid hydrogen is an important constituent of the nuclei. The mechanism of outbursts is said to be a sudden increase of the evaporation area caused by shake-off of clouds or fragments. The revision of the photometric parameters of comets, based on new formulae, is suggested.

114. E. J. Öpik  
SURVIVAL OF COMET NUCLEI AND THE ASTEROIDS  
University of Maryland Mimeo, 59 pp., 1961

The article considers the dynamic survival of comets and other stray bodies in encounters with planets in an effort to uncover by statistics any possible genetic link between comets and asteroids.

115. E. J. Öpik  
NOTE ON STELLAR PERTURBATIONS OF NEARLY PARABOLIC ORBITS  
Proc. Amer. Acad. Arts and Sciences 67, 169 (1932)

The effect of passing stars on the stability of the orbits of meteors and comets in the solar system is assessed in a statistical consideration.

116. E. J. Öpik  
THE SPIKE OF COMET AREND-ROLAND 1956h  
The Irish Astronomical Journal 5, 37-50 (1958)

The spike of Comet Arend-Roland is discussed and interpreted to be a "synchrotron" consisting of dust particles of different radii released in an outburst which left the nucleus instantaneously devoid of all volatile material.

117. E. J. Öpik  
THE MOTION OF THE CONDENSATION IN THE TAIL OF HALLEY'S COMET JUNE 5-8, 1910  
Zeitschrift für Astrophysik 58, 192 (1964)

The observed motions of the condensation in Halley's comet are found to agree with that of hypothetical rays calculated from the observed behavior of rays in Type-I plasma tails. It is suggested that this analogy may offer a clue to the understanding of the evolution and metamorphosis of the observed ray emission in comet tails.

118. D. H. Robey  
A NEW MODEL FOR COMETS--THE COLD, PARTIALLY CONDENSED, MAGNETIZED PLASMA  
J. Astronautical Sciences 9, 41 (1962)

A study of the general properties of comets presents those characteristics which suggest that a comet's nucleus may be surrounded by and attached to a magnetized plasma. This theory is used to postulate a formula for coma contraction and is also applied to comet outbursts. The contraction is believed to be caused by the solar wind which may, during periods of solar flare, cause a sudden contraction to effect a comet outburst.

119. G. J. Szasz and S. F. Singer  
SYMPOSIUM ON THE PHYSICS OF COMETS AND METEORS  
Office of Naval Research, London, November 18, 1952  
AD 382

An account of a recent Liege symposium includes discussions of the spectroscopy of comets, the structure of the head and tail, and the origin and evolution of comets.

120. K. Wurm  
THE ULTRAVIOLET SOLAR SPECTRUM AND COMETS  
Proceedings of the Tenth International Astrophysical Symposium, Liege,  
July 11-14, 1960  
AD 269 781

The importance of the interaction of solar ultraviolet radiation with cometary atmospheres is assessed, concluding that its action may be weak in comparison with the role of corpuscular radiation.

121. K. Wurm  
STRUCTURE AND DEVELOPMENT OF COMETARY TAIL  
Hamburger Sternwarte, Hamburg-Bergedorf, Germany, March 31, 1964  
AD 602 048

A final report on contract AF61(052)-583 presents five separate papers which deal with the study of the structure and development of ion-type cometary tails.

122. K. Wurm  
DIE IONISIERUNG IN DEN KOMETEN  
Icarus 1, 144 (1962)

New support is given to the theory that the ionization of cometary molecules is intrinsic to the cometary atmospheres themselves. It is argued that the ionization occurs in a limited region in front of the nucleus and that the ions are expelled in narrow rays within a small cone which is directed toward the sun. Apparently, outbursts lead to the formation of a shrinking parabolic envelope around the nucleus, which is accompanied by a closing-in of the tail rays to the tail axis. The true mechanism of ionization is still obscure.

123. K. Wurm and B. Balazs  
THE HEADS OF COMETS AND THE LIFETIMES OF THEIR MOLECULES  
Icarus 2, 334 (1963)

From the extension and spherical shape of the CN and C<sub>2</sub> heads, an average lifetime of these molecules until ionization of the order 10<sup>6</sup> seconds for unit heliocentric distance is derived. This long lifetime excludes densities of protons in the "solar wind," which exceed  $n_p = 10 \text{ cm}^{-3}$ . (Author)

124. K. Wurm  
BRIGHTNESS AND STRUCTURE OF THE NA-EMISSION IN COMETS  
Hamburger Sternwarte, Hamburg-Bergedorf, Germany, March 31, 1964  
AD 604 048

The structure of a Na-coma is investigated. In consequence of a relatively high repulsive force originating from light pressure and a relatively high average lifetime of the atoms, a typical parabolic shape to the coma is expected.

125. A. Mammano and K. Wurm  
THE AXES OF THE TYPE-I TAILS OF COMETS  
Hamburger Sternwarte, Hamburg-Bergedorf, Germany, March 31, 1964  
AD 604 048

The axes of the Type-I tails of comets are defined by the directions (position angles at the nucleus) to which the tail rays are "closing in."

The axes are always lagging behind the prolonged radius vector. It is shown that the directions of the tail axes are determined by the forces which regulate the outflow of the tail material from its source in the head. A direct influence of the "solar wind" on the position of the tail axes is not apparent. (Author)

126. K. Wurm  
AN EXPANDING HALO OF COMET ALCOCK (1963b)  
Hamburger Sternwarte, Hamburg-Bergedorf, Germany, March 31, 1964  
AD 604 048

On May 27/28, 1963 Comet Alcock showed an increase in light of about three magnitudes accompanied by an outbreak of gas and dust. The gas halo expanded with a velocity of one kilometer per second. The expansion of the dust material was much smaller amounting only to 50 to 100 meters per second. (Author)

127. M. J. S. Belton, J. C. Brandt and P. W. Hodge  
ON THE CHARACTERISTICS OF DISTANT COMETS  
Space Science Laboratory, University of California, Berkeley, California  
AD 299 839

Donn's article on the characteristics of distant comets is criticized. It is shown that his arguments concerning the composition of the tails and their curvature and orientation are mutually contradictory. Brandt's use of these tails to probe the interplanetary medium is strengthened and his arguments for a transition region between the solar wind and the solar breeze at 2 AU are reinforced.

128. J. C. Brandt  
ON THE STUDY OF COMET TAILS AND MODELS OF THE INTERPLANETARY MEDIUM  
Astrophysical Journal 133, 1091 (1961)

The theories of Bierman, Parker, and Chamberlain are applied to Osterbrock's observations of Comets Baade 1954h and Haro-Chavira 1954k.

129. J. C. Brandt  
INTERPLANETARY MEDIUM PHYSICS AND COMET TAILS  
California University, Berkeley, 1964  
AD 603 780

The programs, results, and reports resulting from research on interplanetary medium physics and comet tails are summarized.



130. S. Grundzinska  
THE ABUNDANCE OF CO<sup>+</sup> IONS IN THE TAILS OF COMETS  
Ann. d'Astrophy. 23, 797 (1960)

The abundance of CO<sup>+</sup> in the tail of Comet Bester (1947k) is found to be 30 to 40 times greater than that of CN in the head. Assuming that the abundance for CN is taken equal to that suggested for C<sub>2</sub> by Wurm, the abundance of CO<sup>+</sup> ions in the tail around the region of the head is estimated to be on the order of 10<sup>6</sup> per cm<sup>3</sup>.

131. S. L. Miller  
THE OCCURRENCE OF GAS HYDRATES IN THE SOLAR SYSTEM  
Proc. Nat. Acad. Sci. 47, 1798 (1961)

The occurrence and properties of the hydrates in planetary, interplanetary, and cometary environment is discussed. A mixed hydrate of methane, carbon dioxide, ethane, etc. is postulated to be a likely constituent of comets.

132. K. Watson, B. C. Murray and H. Brown  
THE STABILITY OF VOLATILES IN THE SOLAR SYSTEM  
Icarus 1, 317 (1963)

A study of the stability of the ices of water, ammonia, carbon dioxide, and methane is extended to the rings of Saturn, the surfaces of the smaller satellites of Jupiter and Saturn, and bodies in orbits similar to those of short-period comets.

133. D. E. Blackwell and R. V. Willstrop  
A STUDY OF THE MONOCHROMATIC POLARIZATION OF COMET AREND-ROLAND (1956h)  
Monthly Notices of the Royal Astronomical Society 117, 590 (1957)

Polarization measurements obtained with glass and gelatin filters are reported to have isolated the continuum near 4530Å and the (0,0) CN emission band near 3850Å. The polarization curve of the continuum was found to agree reasonably with that of a metallic meteorite, and the amount of polarization in the CN measurements was consistent with a fluorescence mechanism.

134. J. D. Kraus  
OBSERVATIONS AT A WAVELENGTH OF 11 METERS DURING THE CLOSE APPROACH OF  
COMET AREND-ROLAND  
Astronomical Journal 53, 55 (1958)

The observation of a radio source which may have been related to Comet Arend-Roland is reported.

135. J. W. Shaw  
NATURAL ENVIRONMENT OF INTERPLANETARY SPACE  
The Ohio State University Research Foundation, Columbus, Ohio, 1960  
AD 250 230

Chapter IV of this report is devoted to solid particles in interplanetary space and includes a short description of the form and composition of comets, their orbits, and the number of observed and unobserved comets.

LABORATORY STUDIES

136. G. Herzberg, A. Monfils and B. Rosen  
MOLECULAR SPECTRA IN THE REMOTE ULTRAVIOLET. INTRODUCTORY REPORT  
Mem. Soc. Roy. Sci. Liege 4, 146 (1961)  
OTS/SLA 63-10245

Recent progress made in vacuum ultraviolet spectroscopy is reviewed as it applies to astrophysics and theoretical molecular spectroscopy. Individual molecular spectra of the gaseous state and recent improvements in vacuum spectrographs are discussed.

137. G. Herzberg  
RECENT LABORATORY INVESTIGATIONS OF MOLECULES OF ASTRONOMICAL INTEREST  
Mem. Soc. Roy. Sci. Liege 28, 397 (1956)  
AD 132 241

Laboratory investigations of molecules of importance to stellar atmospheres, planetary atmospheres, and comets are summarized. The discussion includes the SiC<sub>2</sub> molecule in carbon stars, possible detection of polyatomic molecules in stellar atmospheres, the dissociation of diatomic molecules, methods for band spectroscopy to determine temperature, the mechanism of OH production in the upper atmosphere, molecular hydrogen in planetary atmospheres, and the formation of molecules in comets.

138. G. Herzberg  
LABORATORY INVESTIGATIONS OF THE SPECTRA OF INTERSTELLAR AND COMETARY MOLECULES  
Mem. Soc. Roy. Sci. Liege, Ser. 4, 15, 291 (1955)

The identification and formation of diatomic molecules in interstellar, planetary, and cometary medium is summarized. Laboratory data are presented for CN<sup>+</sup> and NH<sup>+</sup> and for the triatomic radicals C<sub>3</sub> and NH<sub>2</sub> of comets. The possible presence of HCO in interstellar medium and planetary atmospheres is discussed.

139. J. Oro  
COMETS AND THE FORMATION OF BIOCHEMICAL COMPOUNDS ON THE PRIMITIVE EARTH  
Nature 190, 389 (1961)

It is suggested that one important consequence of the interactions of comets with the earth is the accumulation of relatively large amounts of carbon compounds which are known to be transformed spontaneously into amino acids, purines, and other biochemical compounds. Laboratory experiments are described in verification of this theory.

140. A. E. Potter and B. Del Duca  
LIFETIME IN SPACE OF POSSIBLE PARENT MOLECULES OF COMETARY RADICALS  
Icarus 3, 103 (1964)

The space lifetimes of some possible parent molecules of radicals are estimated from laboratory measurements of absorption cross sections and the solar ultraviolet flux. The parent molecules include ethylene, acetylene, methane, cyanogen, hydrazine, ammonia, water, etc.

141. P. Wilkinson  
DIATOMIC MOLECULES OF ASTROPHYSICAL INTEREST: IONIZATION POTENTIALS AND DISSOCIATION ENERGIES  
Astrophysical Journal 138, 778 (1963)

A critical analysis is made of the ionization potentials and dissociation energies of 143 diatomic molecules and molecular ions of astrophysical importance. The data are summarized in a table and includes values and references for  $C_2$ , CH, CN,  $CO^+$ , NH,  $N_2^+$ ,  $CH^+$ ,  $O_2^+$ , as well as others.

142. G. J. Pontrelli  
THE FORMATION AND PROPERTIES OF CERTAIN COMETARY SPECIES  
Final Report on NASA Contract NASw 707, E. I. DuPont de Nemours and Company, Wilmington, Delaware, January 1965

$C_2$ ,  $C_3$ , and CH radical-radical reactions and properties observed in the continuous and flash photolysis of diacetylene are related to the postulated mechanisms of radical formation at or near the nucleus of comets.

143. G. Herzberg  
THE SPECTRA AND STRUCTURES OF FREE METHYL AND FREE METHYLENE RADICALS  
Proc. Roy. Soc. A 262, 291 (1961)

Vacuum ultraviolet photolysis of dimethyl mercury and diazomethane is reported to produce the spectra of the two astrophysically important radicals,  $CH_3$  and  $CH_2$ . Analysis of the spectra results in the determination of the electronic and geometric structure of the radicals, which can be applied to future analysis of cometary spectra.

144. G. Herzberg and J. Shoosmith  
ABSORPTION SPECTRUM OF FREE  $CH_3$  AND  $CD_3$  RADICALS  
Can. J. Phys. 34, 523 (1956)

A preliminary study presents the absorption spectrum of  $CH_3$  as produced by the vacuum ultraviolet flash photolysis of dimethyl mercury.

145. G. Herzberg and P. A. Warsop  
SPECTRUM AND STRUCTURE OF THE FREE HNCN RADICAL  
Can. J. Phys. 41, 236 (1963)

The spectra and structure of HNCN produced in the flash photolysis of diazomethane are investigated. The  $3440\text{\AA}$  band is assigned to this free radical, and its ground and first-excited state are determined.

146. G. Herzberg  
LABORATORY PRODUCTION OF THE  $\lambda$  4050 GROUP OCCURRING IN COMETARY SPECTRA;  
FURTHER EVIDENCE FOR THE PRESENCE OF  $\text{CH}_2$  MOLECULES IN COMETS  
Astrophysical Journal 96, 314 (1942)

The  $\lambda$  4050 system occurring in cometary spectra is assigned to  $\text{CH}_2$  (which is later refuted by Herzberg and others and assigned to  $\text{C}_3$ ).

147. G. Herzberg and J. Shoosmith  
SPECTRUM AND STRUCTURE OF THE FREE METHYLENE RADICAL  
Nature 183, 1801 (1959)

An explanation for the previous misidentification of the  $\lambda$  4050 as due to  $\text{CH}_2$  is presented through more recent identification of the vacuum ultraviolet spectrum ( $\lambda$  1400) of  $\text{CH}_2$  produced by the photolysis of diazomethane.

148. G. W. Robinson and M. McCarty  
THE PRODUCTION AND SUBSEQUENT PHOTOLYSIS OF TRANSIENT PRODUCTS FROM THE  
PHOTODECOMPOSITION OF DIAZOMETHANE AT  $4.2^\circ\text{K}$   
J. Am. Chem. Soc. 82, 1859 (1960)

Experiments on the photolysis of solid diazomethane and its isotopic modifications present evidence for the assignment of part of the observed spectra to an electronic transition of methylene in the near ultraviolet. Other products of the photolysis were trapped, and their nature is described.

149. N. Sreedhara Murthy  
A LABORATORY STUDY OF THE 'ROTATIONAL TEMPERATURE' OF  $\text{CH}^+$  ( $^1\Pi - ^1\Sigma$ )  
COMETARY BAND  
Proc. Phys. Soc. 81, 1141 (1963)

The determination of the intensities of five rotational lines of the (0,0) band of the  $\text{CH}^+$  ( $^1\Pi - ^1\Sigma$ ) cometary system is reported as the result of an analysis of spectra produced through excitation by a high-frequency electrodeless discharge.

150. A. E. Douglas  
LABORATORY STUDIES OF THE  $\lambda$  4050 GROUP OF COMETARY SPECTRA  
Astrophysical Journal 114, 466 (1951)

Study of the spectra obtained from laboratory production of the  $\lambda$  4050 group previously observed in cometary spectra indicates that it is due to the  $C_3$  molecule. Isotope effects and the fine structure show that hydrogen is not present and therefore, the emission can not be due to  $CH_2$  as postulated by Herzberg.

151. R. G. Bennett and F. W. Dalby  
EXPERIMENTAL OSCILLATOR STRENGTHS OF CH AND NH  
J. Chem. Phys. 32, 1716 (1960)

The oscillator strengths of the  $A^2\Delta$  and  $B^2\Sigma$  states of CH and the  $A^2\Pi$  state of NH are calculated from the determination of the radiative lifetimes of the emitting species as produced by electron bombardment of methane and ammonia.

152. K. Clusius and A. E. Douglas  
THE  $\lambda$  4050 BANDS OF THE  $C_3^{13}$  MOLECULE  
Can. J. Phys. 32, 319 (1954)

Excitation of the  $\lambda$  4050 cometary bands with  $C^{13}$  provide very good evidence that the  $C_3$  molecule is responsible for this emission in comets.

153. G. V. Marr and R. W. Nicholls  
THE EMISSION OF THE ' $\lambda$  4050Å' BANDS AND AN ASSOCIATED VIOLET CONTINUUM IN OXYACETYLENE FLAMES  
Can. J. Phys. 33, 394 (1955)

A strong violet continuum is reported to appear with the  $C_3$  bands excited in the luminous region of a fuel-rich oxyacetylene flame. Preliminary photographic intensity measurements on the spectra of the different regions of the flame show strong correlation between the  $C_3$  bands and the continuum.

154. G. V. Marr  
COMBUSTION STUDIES OF ASTROPHYSICAL SIGNIFICANCE. III.  
The University of Western Ontario, London, Ontario, Canada, March 1, 1957  
AD 152 611

Spectroscopic investigation of the luminous mantle of fuel-rich oxyacetylene flames encompasses band-head intensity measurements for the radicals  $C_2$ , CH,  $C_3$ , and CN; rotational plots for  $C_2$ , CH, and OH; and determination of vibrational temperatures and the mechanisms of product formation. The experimental observations of  $C_3$  are considered in relation to previous laboratory and astrophysical investigations. The formation of  $C_3$  in comets is discussed, and the fluorescence mechanism by solar radiation is shown to account for the cometary band emission occurring in the absence of continuum emission.

155. P. S. Skell and L. D. Wescott  
CHEMICAL PROPERTIES OF  $C_3$ , A DICARBENE  
J. Am. Chem. Soc. 85, 1023 (1963)

The chemical reactions of carbon vapor, produced in vacuo, with olefins at liquid-nitrogen cooled surfaces are reported. The conditions of reaction have been controlled to simulate cometary ambient conditions.

156. B. Rosen  
NEW INVESTIGATIONS ON THE  $C_3$  SPECTRUM AT  $4050\text{\AA}$   
Astronomical Journal 66, 383 (1961)

A brief summary of laboratory investigation of the  $\lambda$  4050 system for  $C_3$  and its importance to cometary physics is presented.

157. G. V. Marr  
COMBUSTION STUDIES OF ASTROPHYSICAL SIGNIFICANCE. 1. A SURVEY OF THE  
GENERAL MECHANICS OF FLAME PROPAGATION, AND OF RELEVANT EXPERIMENTAL  
TECHNIQUES  
The University of Western Ontario, London, Ontario, Canada, May 1, 1956  
AD 101 687

The general mechanics and experimental techniques for flame propagation are presented and directed toward an effort to provide information on excitation conditions in astrophysical sources. Hydrocarbon/oxygen premixed flames are considered and it is suggested that  $C_2H_2/O_2$  flame be used as a source of the  $C_3$  radical which occurs in cool stars and comets.

158. G. Herzberg and D. A. Ramsay  
ABSORPTION SPECTRUM OF FREE  $NH_2$  RADICALS  
J. Chem. Phys. 20, 347 (1952)

The  $\alpha$ -bands observed in comets is assigned to  $NH_2$  through preliminary investigations of the absorption spectra produced in the flash photolysis of  $NH_3$ .

159. G. Herzberg and D. A. Ramsay  
THE ABSORPTION SPECTRUM OF FREE  $NH_2$  RADICALS  
Discussions of the Faraday Society 14, 11 (1953)

A thorough laboratory investigation of the absorption spectra of  $NH_2$  as produced from the flash photolysis of  $NH_3$ , is presented. The structure of the spectrum and isotope shifts obtained with deuterated  $NH_3$  confirm that  $NH_2$  is responsible for the  $\alpha$ -bands observed in cometary spectra.

160. D. A. Ramsay  
THE ABSORPTION SPECTRA OF FREE NH AND NH<sub>2</sub> RADICALS PRODUCED BY THE FLASH  
PHOTOLYSIS OF HYDRAZINE  
J. Phys. Chem. 57, 415 (1953)

Some preliminary results from the flash photolysis of hydrazine include the determination of the critical flash intensity above which thermal explosion occurs and the observation of the absorption spectra of the NH and NH<sub>2</sub> products of the explosion reaction.

161. D. A. Ramsay  
ELECTRONIC SPECTRUM AND STRUCTURE OF THE FREE NH<sub>2</sub> RADICAL  
J. Chem. Phys. 25, 188 (1956)

Rotational and vibrational analysis of the NH<sub>2</sub> bands, produced by the flash photolysis of ammonia and hydrazine, is reported to verify the assignment of the  $\alpha$ -bands of ammonia to the NH<sub>2</sub> radical.

162. M. W. Feast  
AN EMISSION BAND SYSTEM ATTRIBUTED TO THE MOLECULE NH<sup>+</sup>  
Astrophysical Journal 114, 344 (1951)

Emission bands produced from the excitation of flowing ammonia in a hollow-cathode discharge tube are identified as NH<sup>+</sup>. The postulated importance of this molecule is based on previous observations of NH in cometary spectra and the dual presence of both CH and CH<sup>+</sup> in cometary spectra.

163. J. A. Glasel  
STABILIZATION OF NH IN HYDROCARBON MATRICES AND ITS RELATION TO COMETARY  
PHENOMENA  
Proc. Nat. Acad. Sci. 47, 174 (1961)

The ultraviolet spectra of NH resulting from RF discharge through the low-temperature solids CH<sub>4</sub>-N<sub>2</sub>-A, CH<sub>4</sub>-N<sub>2</sub>, and NH<sub>3</sub>-A is shown in an attempt to substantiate that free radicals such as NH can be trapped in the frozen solids which exist in comets.

164. F. O. Rice and M. Frearno  
THE FORMATION OF THE IMINE RADICAL IN THE ELECTRICAL DISCHARGE  
J. Am. Chem. Soc. 75, 543 (1953)

The formation of the NH radical from electrical discharge in hydrazoic acid is described. Allied experiments with electrical discharge in ammonia, hydrazine, cyanic acid, and nitrogen-hydrogen mixtures failed to produce the radical.



165. L. J. Stief and V. J. DeCarlo  
ORIGIN OF  $\text{NH}(A^3\Pi) \longrightarrow \text{NH}(X^3\Sigma^-)$  EMISSION IN COMETS  
Nature 205, 889 (1965)

The photolysis of hydrazine at the krypton resonance lines and at low pressures is reported to produce the  $\lambda$  3360 emission spectra of NH. The spectra are that of the triplet system which has been previously observed in cometary spectra. From this, hydrazine-type compounds are postulated to be responsible for the NH emission in comets.

166. H. Schuler and A. Michel  
ON NEW EMISSION BANDS FROM ELECTRIC EXCITATION OF AMMONIA  
Z. Naturforsch. 10a, 1 (1955)

Two band systems appearing between 5200 and 8500 $\text{\AA}$  are reported to occur upon electrical excitation of  $\text{NH}_3$  at one atmosphere.

167. W. Groth and K. H. Welge  
BLITZLICHT PHOTOLYSE UND PHOTOCHEMISCHE ZERSETZUNG DES AMMONIAKS  
Bull. Soc. Chim. Belg. 71, 705 (1962)

The ultraviolet flash photolysis of  $\text{NH}_3$  to produce the NH and  $\text{NH}_2$  radicals is described.

168. K. D. Bayes, K. H. Becker and K. H. Welge  
FLASH PHOTOLYSIS OF  $\text{NH}_3$  IN THE VACUUM ULTRAVIOLET  
Z. Naturforsch. 17a, 676 (1962)

The production of  $\text{NH}_2$  and NH radicals from the vacuum ultraviolet photolysis of gas-phase  $\text{NH}_3$  at wavelengths between 2200 and 1650 $\text{\AA}$  is reported.

169. K. H. Becker, F. Stuhl and K. H. Welge  
FLASH PHOTOLYSIS AND FLUORESCENCE OF  $\text{NH}_3$  IN THE VACUUM ULTRAVIOLET  
Bonn University, Germany, 1962  
AD 438 411

The production, kinetics, and electronic states of the  $\text{NH}_2$  and NH radical in the vacuum ultraviolet flash photolysis of  $\text{NH}_3$  is described. In fluorescence studies of the primary product NH, the  $c^1\Pi \longrightarrow a^1\Sigma$  transition, is observed, but not the  $3\Pi \longrightarrow 3\Sigma^-$  transition.

170. H. J. Rommel  
PHOTOLYSIS OF AMMONIA IN THE FAR ULTRAVIOLET  
Bonn University, Germany, 1963  
AD 438 494

The influence of the NH radical on the overall mechanism of the ammonia photolysis is assessed.

171. F. Stuhl and K. H. Welge  
FLASH PHOTOLYSIS OF  $\text{NH}_3$  IN THE VACUUM ULTRAVIOLET. II.  
Z. Naturforsch. 18a, 900 (1963)

An analysis is made of the formation of NH in the vacuum ultraviolet photolysis of  $\text{NH}_3$ . It is reported that NH radicals appear directly in the  $3\Sigma^-$  state.

172. W. E. Groth  
PHOTOCHEMICAL INVESTIGATIONS IN THE FAR ULTRAVIOLET  
Bonn University, Germany, 1963  
AD 416 366

The report summarizes present progress made in a series of investigations on the far ultraviolet photochemical behavior of  $\text{NH}_3$ .

173. W. Groth, H. Okabe and H. J. Rommel  
PRIMARY PROCESSES OF  $\text{NH}_3$  PHOTOLYSIS AT  $1470\text{\AA}$   
Z. Naturforsch. 19a, 507 (1964)

The photolysis of  $\text{NH}_3$  at  $1470\text{\AA}$  is investigated and found to proceed to 12 percent by reaction to NH radicals and to 88 percent by reaction to  $\text{NH}_2$  radicals.

174. K. H. Becker and K. H. Welge  
THE INVESTIGATION OF THE FLUORESCENCE AND PHOTOCHEMICAL PRIMARY PROCESSES  
IN THE VACUUM UV BY  $\text{NH}_3$ ,  $\text{N}_2\text{H}_4$ ,  $\text{PH}_3$  AND THE REACTIONS OF THE ELECTRONICALLY  
EXCITED RADICALS  $\text{NH}^*(1\Pi)$ ,  $\text{NH}^*(3\Pi)$ ,  $\text{PH}^*(3\Pi)$   
Z. Naturforsch. 19a, 1006 (1964)

(In German)

175. E. Fink and K. H. Welge  
LIFETIME OF THE ELECTRONIC STATES  $\text{N}_2(\text{C}^3\Pi_u)$ ,  $\text{N}_2^+(\text{B}^2\Sigma^+_u)$ ,  $\text{NH}(\text{A}^3\Pi)$ ,  $\text{NH}(\text{c}^1\Pi)$ ,  
 $\text{PH}(\text{C}^3\Pi)$   
Z. Naturforsch. 19a, 1193 (1964)

(In German)

176. K. D. Beyer and K. H. Welge  
PHOTODISSOCIATION OF  $\text{H}_2$ ,  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{NO}$ ,  $\text{CO}$ ,  $\text{H}_2\text{O}$ ,  $\text{CO}_2$  AND  $\text{NH}_3$  IN EXTREME VACUUM  
ULTRAVIOLET  
Z. Naturforsch. 19a, 19-28 (1964)

(In German)

177. K. H. Becker and K. H. Welge  
FLUORESCENCE OF NH RADICALS DURING THE PHOTODISSOCIATION OF NH<sub>3</sub> IN THE  
VACUUM ULTRAVIOLET  
Z. Naturforsch 18a, 600-3 (1963)

(In German)

178. A. E. Douglas and P. M. Routly  
THE SPECTRUM OF THE CN<sup>+</sup> MOLECULE  
Astrophysical Journal 119, 303 (1954)

It is reported that two band systems due to two  $1\Sigma - 1\Sigma$  rotational transitions of the astrophysically-important CN<sup>+</sup> molecule have been produced from a discharge through helium mixed with a trace of C<sub>2</sub>N<sub>2</sub>. Four other unidentified bands are also reported.

179. R. G. Bennett and F. W. Dalby  
EXPERIMENTAL OSCILLATOR STRENGTH OF THE VIOLET SYSTEM OF CN  
J. Chem. Phys. 36, 399 (1962)

The electron bombardment of HCN to produce the emission spectrum of CN is described. The oscillator strength of the B<sup>2</sup> $\Sigma$  state is determined from a direct measurement of the spontaneous radiative lifetime.

180. D. E. Paul and F. W. Dalby  
KINETICS OF DISAPPEARANCE OF THE CN RADICAL FORMED FROM C<sub>2</sub>N<sub>2</sub>  
J. Chem. Phys. 37, 592 (1962)

The flash photolysis of C<sub>2</sub>N<sub>2</sub> to produce CN radicals is utilized in a kinetic study of the rate of disappearance of CN radical in cyanogen, cyanogen chloride, hydrogen, and hydrocarbons. The emission spectrum of the CN radical is found to arise from a fluorescence of the CN radical and not from formation of radical in its excited state.

181. A. E. Douglas and P. M. Routley  
ON THE SPECTRA OF THE CN<sup>+</sup> AND CN MOLECULES  
Astrophysical Journal 117, 461 (1953)

The spectra of CN<sup>+</sup> and CN observed from C<sub>2</sub>N<sub>2</sub> in a helium discharge tube are reported. The band origins and rotational constants of  $1\Sigma - 1\Sigma$  transition of CN<sup>+</sup> are listed and two new band systems of neutral CN, occurring in the same region as the CN<sup>+</sup>, are identified.

182. R. L. Brown and H. P. Broida  
SPECTRAL STUDY OF ACTIVE NITROGEN FLAMES EXHIBITING CN "TAIL" BANDS  
J. Chem. Phys. 41, 2053 (1964)

Flames of active nitrogen and simple chlorinated hydrocarbons are reported to exhibit several zones which can be defined by their differences in intensity and spectra. One zone has been found to exhibit that emission which arises from the  $B^2\Sigma$  state of CN. The mechanism of its occurrence is postulated.

183. R. N. Dixon and R. W. Nicholls  
AN EXPERIMENTAL STUDY OF THE BAND INTENSITIES IN THE CN RED SYSTEM  
Can. J. Phys. 36, 127 (1958)

Experimental band intensities are reported for the CN red system obtained from an active nitrogen - carbon tetrachloride source.

184. E. A. Ballik and D. A. Ramsay  
GROUND STATE OF THE  $C_2$  MOLECULE  
J. Chem. Phys. 31, 1123 (1959)

The rotational and vibrational analysis of  $C_2$  band system as observed in the near infrared spectrum of the emission from a carbon furnace indicate that the  $3\Sigma_g^-$  state is the ground state of  $C_2$  in the gas phase.

185. E. A. Ballik and D. A. Ramsay  
THE  $A' 3\Sigma_g^- - X' 3\Pi_u$  BAND SYSTEM OF THE  $C_2$  MOLECULE  
Astrophysical Journal 137, 1 (1963)

The detail of the vibrational and rotational lines of the infrared band system of the  $C_2$  molecule is presented and a possible mechanism is advanced to explain the presence of the  $C_2$  Swan bands and absence of the  $C_2$  Phillips bands in cometary spectra.

186. E. A. Ballik and D. A. Ramsay  
AN EXTENSION OF THE PHILLIPS SYSTEM OF  $C_2$  AND A SURVEY OF  $C_2$  STATES  
Astrophysical Journal 137, 34 (1963)

Nine new bands of the Phillips system of  $C_2$  are presented and measurements on three other bands are extended to higher J values, with new molecular constants evaluated for both states. A general summary of molecular constants for all known states of  $C_2$  and a diagram of the potential curves are given also.

187. V. J. DeCarlo  
STUDY IN COMETARY ASTROPHYSICS  
NASA Contractor Report, National Aeronautics and Space Administration,  
Washington, D. C., July 1964

C<sub>2</sub> emission observed from the vacuum ultraviolet photolysis of low-pressure methane and acetylene is reported to coincide with the Swan bands observed in cometary spectra. A second investigation of the ultraviolet photolysis of ice (H<sub>2</sub>O) produced unidentified and unreproducible emission bands and continuum, each occurring between  $\sim \lambda$  4000-4700.

188. L. J. Stief, V. J. DeCarlo and R. J. Mataloni  
VACUUM ULTRAVIOLET PHOTOLYSIS OF ACETYLENE  
Melpar, Inc., Falls Church, Va., November 1964, (submitted to J. Chem. Phys. for publication)

In a study initiated by a program in cometary astrophysics, the photolysis of acetylene at the krypton and xenon resonance lines is described. Evidence is presented for the production of a long-lived excited state of acetylene which at low pressure leads to the formation of the excited C<sub>2</sub>. The spectra of the C<sub>2</sub> emission at the krypton and xenon lines are consistent with the Swan bands previously observed in cometary spectra. An excited-molecule mechanism for the photolytic reactions is postulated.

189. L. J. Stief and V. J. DeCarlo  
ORIGIN OF THE C<sub>2</sub>(A<sup>3</sup>Π<sub>g</sub>) → C<sub>2</sub>(X<sup>3</sup>Π<sub>u</sub>) EMISSION IN COMETS  
Melpar, Inc., Falls Church, Va., November 1964 (submitted to Nature for publication)

From the results of laboratory investigation, it is postulated that the C<sub>2</sub> Swan bands observed in cometary spectra are due to the photodissociation of acetylene or an acetylene-type molecule.

190. G. V. Marr  
COMBUSTION STUDIES OF ASTROPHYSICAL SIGNIFICANCE. II. A SURVEY OF  
CHEMICAL KINETICS FOR PREMIXED HYDROCARBON/OXYGEN FLAMES  
The University of Western Ontario, London, Ontario, Canada, July 1, 1956  
AD 110 208

The trend of possible reaction processes thought to be occurring in premixed hydrocarbon/oxygen flames is outlined as an aid in the study of reaction processes occurring in astrophysical sources such as comets, etc. The collision processes involved in conventional kinetics are applied to combustion processes. The relevant parameters are defined and an example of the analysis of the steady state departure from thermal equilibrium is given for an idealized flame. The available techniques for the analysis of the reactions occurring are outlined and considered in the postulation of probable reaction mechanisms which are capable of forming the excited C<sub>2</sub>, CH, HCO, and OH free radicals in premixed hydrocarbon flames.

191. R. G. Bennett and F. W. Dalby  
EXPERIMENTAL OSCILLATOR STRENGTH OF COMET-TAIL SYSTEM OF  $\text{CO}^+$   
J. Chem. Phys. 32, 1111 (1960)

The electron bombardment of CO is utilized to produce the emission spectra of the comet-tail system of  $\text{CO}^+$  and to measure the radiative lifetimes of its upper electronic state.

192. D. Robinson and R. W. Nicholls  
INTENSITY MEASUREMENTS ON THE  $\text{CO}^+$  COMET TAIL, AND THE BO  $\alpha$  AND  $\beta$   
MOLECULAR BAND SYSTEMS  
Proc. Phys. Soc. 75, 817 (1960)

The photoelectric measurement of the relative band intensities of the comet tail system ( $A^2\Pi - X^2\Pi$ ) of  $\text{CO}^+$  and the BO  $\alpha$  and  $\beta$  molecular band systems is reported. The study is a part of a program for the establishment of intensity and transition probability data for molecular band systems of astrophysical, aeronautical, and combustion interest.

193. R. W. Nicholls  
TRANSITION PROBABILITIES OF MOLECULAR BAND SYSTEMS  
The University of Western Ontario, Department of Physics, London, Canada,  
June 1962  
N63-18009

Franck-Condon factors calculated to high vibrational quantum numbers are presented for vacuum ultraviolet transitions in  $\text{N}_2$ ,  $\text{N}_2^+$ ,  $\text{O}_2$ , CO, and  $\text{CO}^+$ .

194. H. I. S. Ferguson, R. W. Nicholls and L. Herman  
EXCITATION OF THE FIRST NEGATIVE SYSTEM OF  $\text{O}_2^+$  BY PROTON BEAM IN AIR AND  
OXYGEN  
Colloq. Spectros. Intern. 9th, Lyons, 1961 2, 60-83 (1962)

An account is given of the excitation of the bands of the first positive system of  $\text{O}_2^+$  by a beam of 40KeV protons. Experiments with nitrogen, acetylene, and water vapor are also reported. The experiments indicate that a direct excitation occurs with charge transfer.

195. D. Robinson and R. W. Nicholls  
INTENSITY MEASUREMENTS ON THE  $\text{O}_2^+$  SECOND NEGATIVE, CO ÅNGSTRÖM AND THIRD  
POSITIVE, AND NO  $\gamma$  AND  $\beta$  MOLECULAR BAND SYSTEMS  
Proc. Phys. Soc. 71, 957 (1958)

In an effort to obtain intensity measurements for band systems of astrophysical interest, the relative band intensities are reported for the second negative system of  $\text{O}_2^+$ , the Ångström and third positive systems of CO, and the  $\gamma$  and  $\beta$  systems of NO.

196. R. G. Turner and R. W. Nicholls  
AN EXPERIMENTAL STUDY OF BAND INTENSITIES IN THE FIRST POSITIVE SYSTEM OF  $N_2$   
Can. J. Phys. 32, 468 (1954)

Vibrational transition probabilities are interpreted from the integrated intensities of 52 bands of the  $N_2$  first positive system.

197. R. G. Turner and R. W. Nicholls  
AN EXPERIMENTAL STUDY OF BAND INTENSITIES IN THE FIRST POSITIVE SYSTEM OF  $N_2$   
Can. J. Phys. 32, 475 (1954)

Band intensities of the first positive system of nitrogen are used together with theoretical transition probabilities to determine the dependence of the electronic transition moment on the internuclear separation.

198. L. V. Wallace and R. W. Nicholls  
THE INTERPRETATION OF INTENSITY DISTRIBUTIONS IN THE  $N_2$  SECOND POSITIVE  
AND  $N_2^+$  FIRST NEGATIVE BAND SYSTEMS  
J. Atm. Terr. Phys. 7, 101 (1955)

The variation of the electronic transition moments is compared with the observed internuclear separations, and the effect of this variation upon the array of vibrational transition probabilities is assessed.

199. R. G. Bennett and F. W. Dalby  
EXPERIMENTAL DETERMINATION OF THE OSCILLATOR STRENGTH OF THE FIRST NEGATIVE  
BANDS OF  $N_2^+$   
J. Chem. Phys. 31, 434 (1959)

Investigation of the electron bombardment of  $N_2$  has led to the determination of the radiative lifetime of the upper state of the  $\lambda$  3914 transition of  $N_2^+$  and its corresponding oscillator strength. The radiative lifetime of the upper state of the  $\lambda$  3371 transition of the second positive system of  $N_2$  is found to depend on the conditions of excitation.

200. J. A. Glasel  
THE BOMBARDMENT OF SOLID  $D_2O$  BY LOW-ENERGY ELECTRONS UNDER ASTRONOMICAL  
CONDITIONS  
Proc. Nat. Acad. Sci. 48, 491 (1962)

The rate of production of  $D_2$  from the electron bombardment of solid  $D_2O$  is measured with a helium mass spectrometer leak detector in an attempt to assess the effect of astronomical conditions on simple molecules in condensed forms.

201. R. Berger  
THE PROTON IRRADIATION OF METHANE, AMMONIA, AND WATER AT 77°K  
Proc. Nat. Acad. Sci. 47, 1434 (1961)

The bombardment of low-temperature mixtures with 12-MeV protons to produce acetone, urea, and acetamide is described. The significance of this reaction is presented through postulated processes to explain the presence of NH<sub>3</sub> and CO<sub>2</sub> in comets.

202. R. G. Bennett and F. W. Dalby  
EXPERIMENTAL DETERMINATION OF THE OSCILLATOR STRENGTH OF THE VIOLET SYSTEM OF OH  
J. Chem. Phys. 40, 1414 (1964)

The electron bombardment of CH<sub>3</sub>OH and H<sub>2</sub>O to produce the violet emission system of OH is used in the determination of the radiative lifetime of the  $A^2\Pi \longrightarrow X^2\Sigma$  transition of OH and the corresponding oscillator strength.



PLANNED SPACE INVESTIGATION

203. P. Swings  
POSSIBLE CONTRIBUTIONS OF SPACE EXPERIMENTS TO COMETARY PHYSICS  
Smithsonian Institution Astrophysical Observatory, Cambridge, Mass., 1962  
N63-14253

Suggested plans for space investigations of comets are presented and include discussions of proposed far ultraviolet observations, artificial comets, an orbiting artificial cometary nucleus, and a comet probe. A review of the physical characteristics and past astronomical observations of the spectra of comets is also discussed.

204. D. L. Roberts  
THE SCIENTIFIC OBJECTIVES OF DEEP SPACE INVESTIGATIONS. COMETS  
IIT Research Institute, 10 West 35th Street, Chicago, Ill., March 9, 1964  
N64-19569

Deep space measurements which can provide useful data on comets are discussed along with a description of the comets of interest and the planned space missions.

205. H. C. Corben  
REMARKS ON A COMET PROBE  
Space Age Astronomy, p. 330, Academic Press, New York, N. Y., 1962

The requirements for launching a comet probe are given in a brief and preliminary assessment.

206. COMET INTERCEPT STUDY  
Space Technology Laboratories, Inc., Redondo Beach, California  
N63-16229

The study of the requirements and feasibility of a comet intercept mission includes a compilation of the properties of 31 short-term comets, the determination of the injection energies for each of the comets at a suitable launch period, the calculation of the distance of the comet from the earth at intercept, computation of the transit and flight times, determination of necessary guidance requirements, suggestions of possible scientific instruments, and an assessment of the capabilities of available boosters.

207. FAR INTERPLANETARY AND INTERSTELLAR PROBES  
Space/Aeronautics, January 1964, p. 98

The programs and probes planned for interplanetary and interstellar investigation are discussed. A Mariner-type craft is stated to be intended for cometary missions, which will probably not be possible before the late 60's or during the 70's. The primary obstacle to a cometary probe is reportedly more precise guidance equipment.

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