

51. BIOASTRONOMY - SEARCH FOR EXTRATERRESTRIAL LIFE
BIOASTRONOMIE - RECHERCHE DE LA VIE DANS L'UNIVERS

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INTRODUCTION

The past three years have seen not only a growth in the activities of our commission, but an extension of its activities into important areas which have heretofore motivated too little activity. Of particular interest have been the many activities directed towards elucidating the question of the abundance of extrasolar planetary systems. There have been a number of observations showing the presence of disks of dust around nearby stars, disks which fit the idea that stars are often formed with an accompanying disk of dust which may in many or perhaps all cases produce a planetary system. Infra-red evidence for dust disks exists for something like twenty stars. The disk of Beta Pictoris has even been clearly imaged at optical wavelengths, showing without a doubt that such disk structures exist. One very impressive detection of an apparent brown dwarf object has also been made; should this be confirmed by other observations, it would be clear evidence for the existence of planet-like bodies in the systems of other stars.

The development and pursuit of radio searches for extraterrestrial intelligent radio signals has proceeded at an impressive rate. Of special interest has been the development of systems which can monitor more than 8 million radio frequency channels at once. One of these has been placed into operation in a continuous search with a high sensitivity radio telescope. Even more powerful systems, using specially designed VLSI chips, are under construction. These will bring to our work the most sophisticated equipment permitted by modern technology.

Over the past few years, programs in bioastronomy have received increased support both from within the scientific community and from governmental and private funding agencies. As a result, the programs of all kinds now underway or under development are more stable, better organized, and far more powerful than the programs of the past. It is realistically expected that the future searches for extraterrestrial radio signals, now being organized, will be millions of times more powerful than past searches.

ACTIVITIES OF COMMISSION 51

Through the good offices of our secretary, M. Papagiannis, a newsletter concerning Commission 51 activities, "Bioastronomy News" was distributed as warranted to the members of the Commission.

The major activity of the commission since its last report was IAU Colloquium 99, which was held at Balatonfured, Lake Balaton, Hungary from June 21 through June 27, 1987. The title of the Colloquium was "Bioastronomy: The Next Steps". This Colloquium was very ably organized by our Vice-President, George Marx, and a number of his colleagues from Hungarian scientific

institutions. The Chairperson of the Scientific Organizing Committee was Jill Tarter. Approximately 120 scientists participated in the Colloquium, including many who were new to the activities of our Commission; we applaud this spread of interest in our subject.

The subjects discussed at the colloquium covered the usual broad range which is characteristic of our meetings. They included new results on prebiotic chemistry on earth-like planets; the possible nature of and evidence for the existence of organic molecules in comets, particularly Halley's Comet; ideas about the origins of chirality in biological systems; and some proposed exotic theories of the origin of life. Also discussed were specialized optical systems for the detection of planets or spectral evidence for life; the cognitive systems of non-human large brained creatures, such as dolphins; and some speculations on the social structures of other civilizations. There was a special meeting to discuss protocols for the handling of the report of an actual detection of another civilization; a number of very helpful suggestions were made to those actually conducting searches. Some hypotheses regarding the galactic distribution of life were presented, as well as some ideas as to the location of possible biological habitats within the solar system, such as in the hypothetical ocean of Europa.

A very interesting group of papers was presented describing the efforts of a number of groups to measure very accurate stellar radial velocities. The goal of these projects is to detect small periodic deviations in the radial velocity caused by the gravitational effects of companions, particularly those of planetary mass. Several groups reported success in measuring radial velocities to an accuracy of about 10 meters per second, an accuracy adequate to detect the presence of planets of Jupiter mass with many stars. Some tantalizing early results were given in which radial velocity variations consistent with the presence of planet appear in the data, but not yet with very high statistical significance.

Papers were given describing the observations of circumstellar disks at infra-red wavelengths, and the observation of the Beta Pictoris disk at optical wavelengths by two groups. The optical photographs of the Beta Pictoris disk are of much better quality than the earlier ones, and show the disk to be an extremely thin structure.

There were a number of papers describing ongoing attempts to detect extrasolar radio signals. There were a group of related papers dealing with the data analysis aspects of such searches; it was clear that considerable effort must be devoted to optimizing data analysis procedures when millions of channels are being monitored, and when a large variety of signal types need to be searched for in the data.

The living and working accommodations at this Colloquium were excellent. In addition, the organizers provided a host of excellent social occasions which, as always, contributed to the transfer of ideas and results, and built a spirit of international cooperation.

SOME SCIENTIFIC HIGHLIGHTS OF RECENT YEARS

Considering the many topics which are dealt with by Commission 51, it is not possible to write a comprehensive summary of all the research relevant to the work of the Commission. However, certain areas are of particular relevance, and we give here some of the highlights of work in these areas.

The Detection of Circumstellar Disks

D. E. Backman and F. C. Gillett of the Kitt Peak National Observatory have examined the observations of IRAS for evidence of excess infra-red radiation from stars, excess radiation which is indicative of the presence of a circumstellar disk. 136 stars have been studied from a group of A, F, G, and K stars lying within 20 pc. of the earth. Of this sample, 24 have very significant infra-red excesses. The largest excesses are exhibited by Alpha Lyrae, Alpha Pisces Austrinus, Beta Pictoris, and Epsilon Eridani. Three of these, Beta Pictoris, Alpha Pisces Austrinus, and Alpha Lyrae have disks which are actually resolved in the IRAS data. Typical disk temperatures are 80K. Estimates of total dust mass range from 0,2 to 4 earth masses. The disks seem to have central voids.

Bradford Smith of the University of Arizona and Richard Terrile of the Jet Propulsion Laboratory have obtained improved optical images of the Beta Pictoris disk. These images show that the disk has a diameter of about 2500 A. U. and a width which may be as small as 50 A. U.; the disk is very thin, and is evidently being seen almost edge-on. They have searched for similar disks in more than 28 other nearby stars and have found none. As a result of their experience with such searches, they have designed improved instrumentation which should make it possible to detect much fainter examples of such disks. Observations of much higher sensitivity will be very important for they may reveal whether the disks are truly absent in other stars, or whether the disk material is being consumed by the process of planetary formation.

Searches for Other Planetary Systems

In a remarkable development, at least three groups have been attempting to detect the existence of planets through very accurate measurements of stellar radial velocities. The group with the most extensive data is probably B. Campbell, U. of Victoria, G. Walker, U. of British Columbia, and S. Yang of the U. of British Columbia. They have made frequent observations of 16 solar type stars over a period of six years using the Canada-France-Hawaii telescope. The errors in their measurements are 13 meters/second. Seven of their stars exhibit long term velocity variations in the range 25 to 65 m/sec., with implied companion orbital periods of more than about ten years. These perturbations can not be caused by brown dwarf companions, since conventional astrometry would have detected them. Companions of a few Jupiter masses are implied. They suggest that these companions are the tip of the planetary mass spectrum. The stars in their sample showing the most significant variations are Epsilon Eridani and Gamma Cephei.

Similar accuracies are being obtained by R. McMillan of the Lunar and Planetary Laboratory of the University of Arizona. The observations have not continued long enough to give good evidence of companions. Similar observations are being made by G. Marcy and V. Lindsay of San Francisco State University. Again, accuracies of the order of ten meters/second are being obtained, but the observations have not continued long enough to give definitive results.

Several groups, including in particular a group led by G. Gatewood at the Allegheny Observatory, are attempting to detect planets through the detection of small perturbations in proper motion. All of these groups are using modern photometric devices to obtain very accurate differential measurements of stellar positions. The accuracies obtained in these instruments are of the order of 0,001 arcsecond, which is sufficient to detect the presence of planets of the mass of Jupiter accompanying nearby solar type and less massive stars.

Late in 1987, B. Zuckerman, University of California, Los Angeles, and E. Becklin, University of Hawaii, reported the remarkable discovery of excess infra-red radiation from the location of the white dwarf star Giclas 29-38. The infra-red color temperature of the excess radiation is 1200K, with an estimated uncertainty of 200K. If the radiation is emitted by a single spherical black body of 1200K, then its radius equals 0.15 solar radius. These parameters are very similar to the theoretical values of the substellar objects called brown dwarfs. After testing a number of alternative explanations, Zuckerman and Becklin have concluded that the object is almost certainly a brown dwarf in orbit around G29-38. This is a very notable discovery. In previous searches of white dwarf stars for evidence of cool companions, the authors did not find evidence for such objects (Zuckerman, B. and Becklin, E. E., 1987, Ap. J.), thus indicating that they are rare. A previous report of the detection of a similar object in orbit around the M dwarf Van Biesbroeck 8 was not confirmed by subsequent searches for the object.

Considering the large amount of activity directed towards the detection of extrasolar planets, and the prospects for more powerful instruments, such as the Hubble Space Telescope and the Keck 10-meter telescope, it is possible to be optimistic that the question of the abundance of planetary systems will be answered in the near future.

Studies of Biologically Relevant Molecules

The "Astrochemistry" group at the University of Massachusetts continued studies of comparative molecular abundances in different types of interstellar clouds; the investigation of reaction pathways; mapping of physical, chemical, and dynamical properties of cloud regions which may be sites of solar-type star formation; and searches for new molecular constituents of dense interstellar clouds. Phosphorus nitride, the first interstellar molecule to contain phosphorus, a biologically important element, was discovered (Ziurys, 1987). Other detections have been made of HCNH^+ , SO^+ , C_3H , HC_2CHO . A study of C_3H_2 , the first interstellar hydrocarbon ring, has been carried out.

An important question for bioastronomy is whether the molecules of the interstellar clouds survive the stellar and planetary formation processes. An additional question is whether there is some mechanism which delivers the molecules to the surfaces of planets after they are cool enough that the molecules will not be destroyed. A possible storage place and means of delivery is provided by comets. Thus there has been considerable interest in determining the content of large molecules in comets. An important goal has been to find formaldehyde in comets. Formaldehyde is one of the prime intermediaries in the production of the basic molecules of terrestrial biology. Its presence would suggest that the other intermediaries are present, and that planets will be commonly seeded with the materials which produce an earth-like biochemistry.

Radio emission from OH in Comet Halley has been mapped with high resolution by de Pater, Palmer, and Snyder (1986). This work showed that the Very Large Array was an excellent instrument for detecting molecules in resolved comets. The work on OH was followed by similar observations in the 6-cm formaldehyde line. This search yielded a weak formaldehyde emission line. Model fitting to the observational results suggests that the formaldehyde abundance in the cometary gas is about 5%. This supports the idea that the molecular precursors of biologically relevant molecules exist in interstellar and cometary material in substantial abundances. This suggests strongly that comets could have provided much prebiological material to planetary surfaces.

Radio Searches for Extraterrestrial Intelligent Radio Emissions

Very encouraging major advances have been made in the instrumentation for the search for extraterrestrial intelligent radio signals. As has long been recognized, there have been two obstacles to the pursuit of extensive radio searches: 1) lack of substantial observing time on large radio telescopes; and 2) the inability to observe very large numbers of frequency channels simultaneously. Two programs are addressing these problems very successfully.

The first program is that of P. Horowitz of Harvard University, who has acquired the dedicated use of the 84-foot radio telescope at the Oak Ridge Station. Horowitz constructed a signal processor, based on conventional computer integrated circuit technology, which could act as a radio spectrum analyzer for more than 100,000 channels simultaneously. This signal processor was used for several years in a project named "Project Sentinel" to search the entire sky visible to the radio telescope for signals at the 21-cm wavelength of neutral hydrogen. The channel bandwidth used was of the order of 0.01 Hz, so that the total bandwidth covered in this search was very small. Success in the search would have required the extraterrestrial transmitter to transmit at a frequency which was corrected for Doppler effects both at the transmitters location and for the motion of the solar system. A small number of candidate signals were detected in this search at frequencies whose use on earth is not permitted by international convention. Subsequent efforts to recover these signals from the same celestial location and on the same frequency did not succeed. With only this evidence, the assumption must be made that these signals were of terrestrial origin and were the product of improperly tuned transmitters or were harmonic radiations from transmitters.

This original system has now been replaced with a new system which can analyze over 8 million channels simultaneously. This system is being used in a new search of the entire sky called "Project Meta". This search will be carried out at the 21-cm frequency again, harmonics of the 21-cm line frequency, and also at frequencies associated with the OH line and possibly others. The increased frequency coverage provided by the new spectrum analyzer allows signals to be detected even if the frequency has not been corrected for the Doppler effects imposed by the transmitter's motion and the motion of the solar system.

A more ambitious program is the SETI (Search for Extraterrestrial Intelligence) program of NASA. This program is based at the NASA Ames Research Center and the Jet Propulsion Laboratory. The Program Manager is B. Oliver. The key instrument in this program is a Multi-Channel Spectrum Analyzer, or "MCSA", which will be able to analyze at least 8 million frequency channels simultaneously. This analyzer will use customized VLSI technology to achieve high speed, therefore large overall frequency coverage, at low cost. It will have the ability to observe several bandwidths simultaneously, and will have minimum bandwidths of the order of one Hertz, allowing it to achieve very high sensitivities for narrow-band signals, and yet allowing it to cover a large fraction of the low-noise radio window in reasonable observing times.

A very important feature of this program will be the sophisticated computer analysis system which will operate in real-time with the MCSA. At present, it is planned that the output of all frequency channels will be read out at one second intervals. The computer analysis system will then search this ensemble for a large variety of signals, including narrow band continuous wave signals, broadband signals, and narrow band signals which drift in frequency, as could be the result of Doppler effects or intentional signal protocols. The system will also search for pulsed signals, where the pulses may come at uniform intervals

or irregular intervals, and pulses which drift in frequency. To accomplish all of this with so many data points and at reasonable expense has been the greatest challenge to this project. However, many of the demanding computer algorithms required to accomplish all of this have been developed.

Upon completion of the instrumentation, it is planned to use this equipment on dedicated radio telescopes, and the world's largest radio telescopes to the extent observing time is available on them. Two distinct searches will be made. One, the "All Sky Survey", will survey the entire sky for signals over a wide overall band of frequencies covering about 10 Ghz of the radio spectrum. Smaller antennas will be used in this search, as well as limited integration time, leading to a good but not ultimate sensitivity for signals. The other "Targetted Search" will use large antennas and long integration times to search for signals from about 800 nearby stars and other promising objects. The sensitivity will be several orders of magnitude higher than with the All Sky Survey. It is expected that these searches will be commenced several years from now.

A search for signals from 78 stars is being made with a 30-meter telescope at the Instituto Argentino de Radioastronomia by F. Colomb, M. Martin, and G. Lemarchand. So far 34 stars have been examined in the frequency range 1415.4 to 1425.4 Mhz. A spectrometer providing 74 channels of 2.5 Khz width each was employed. With the observing parameters employed, the minimum detectable flux was $5 \cdot 10^{-23}$ watts/m². The search will be completed for the entire sample of 78 stars, and then will be repeated at the OH line. In the search a number of signals were detected; however, in every case observational tests revealed that the sources of the signals was terrestrial interference.

I. Mirabel of the Instituto de Astronomia Y Fisica del Espacio, of the University of Buenos Aires, has conducted a search at the 4829 Mhz frequency of formaldehyde using the 140-foot radio telescope of the NRAO. A spectrum analyzer providing 1024 channels of 76.2 Hz each was used. The galactic center was observed for four hours. Thirty-three stars were also observed for about two hours each. For one hour the system was tuned to the formaldehyde frequency tuned to rest in the reference system of the star, and the other hour had the system tuned to the rest frequency relative to the sun. No evidence for signals was found. The typical noise after one hour of integration was 1.27 Jy.

An ongoing search has been carried out for many years at the Ohio State University under the direction of R. Dixon. Recent activities there have been directed towards upgrading the instrumentation. A new computer is being installed which will allow the observatory to search a very wide frequency range near the H and OH lines continuously. An automatic "frequency zoom" is being implemented which will be triggered by a signal detection, and will lead to the automatic detailed recording of the signal. Telescope tracking is being increased to one to two hours, and will be automatically activated upon detection of a signal. In addition to these developments, a phased array is being developed to produce many observing beams simultaneously. The goal is to be able to observe the entire sky with large collecting area at any given time.

At the University of California, Berkeley, S. Bowyer, D. Wertheimer, and V. Lindsay have developed an instrument which searches for extraterrestrial radio transmissions by utilizing the cosmic radio power collected in the course of other radio astronomy observations. The instrument searches approximately 65,000 contiguous radio channels, each about one Hertz in bandwidth, for signals. The observing project, called "Serendip II" has operated about 2000 hours at the NRAO 300-foot telescope. When a narrow peak in the radio spectrum is detected, the instrument automatically records power, telescope direction,

and the time and frequency of the event for further study. So far about 37 signals have been detected by the system, and these will be reobserved to identify, if possible, their source. In addition, a real-time scheme to reject terrestrial radio interference has been completed.

At the Nancy Observatory of the Paris Observatory, a search is being conducted by F. Biraud and J. Tarter for narrow band signals in the bands at 21-cm and 18-cm wavelength. The resolution is 50 Hz, and a large number of nearby solar-type stars are being searched for evidence of intelligent radio transmissions.

At the Algonquin Radio Observatory, a search has been made at 10.6 Ghz., (2.8-cm wavelength) by J. Vallee and M. Simard-Normandin of the Herzberg Institute of Astrophysics. In this special search, a special arrangement of the telescope is used such that only signals with a very high percentage of linear polarization are accepted by the system. The hypothesis is that intelligent signals will be very highly polarized, in contrast to most natural cosmic emissions. A single channel of about 200 Mhz bandwidth is used. The region of the galactic center has been observed with this system. No highly linearly polarized source of flux density greater than about 30 mJy was found.

PLANS FOR THE FUTURE

There will be an international symposium on bioastronomy in Toronto in the summer of 1988. Commission 51 expects to hold its next Symposium or Colloquium in the summer of 1990 in a location yet to be decided. We look forward to the important results to be obtained from projects now in progress.

Frank D. Drake
President of the Commission

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