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Joint Institute for Laboratory Astrophysics of the National Bureau of Standards and University of Colorado, Boulder, Colorado

BACKGROUND AND PERSONNEL

In July 1962, the Joint Institute for Laboratory Astrophysics was formed through collaboration of the National Bureau of Standards and the University of Colorado. Two groups from the National Bureau of Standards combined to form the NBS Laboratory Astrophysics Group. From the Atomic Physics Division of the Washington Laboratories came E. C. Beaty, P. L. Bender, L. M. Branscomb, S. Geltman, S. J. Smith, G. H. Dunn, J. L. Hall, and L. J. Kieffer; from the theoretical astrophysics group at the Boulder Laboratories came J. T. Jefferies and R. N. Thomas. This Group forms one of four components of JILA. A second component consists of several members of the Department of Physics and Astrophysics of the University of Colorado: W. Brittin, J. P. Cox, R. H. Garstang, and W. A. Rense. Cox joined JILA in March 1963; Garstang will arrive in the fall of 1964. A third component consists of several members of the Department of Aerospace Engineering Sciences in the Engineering College of the University. The first of these, the new Chairman of the Department, M. Uberoi, arrived in February 1963; other appointments will follow. The fourth component of JILA consists of some ten positions to be filled with Visiting Fellows each year, each membership being effectively equivalent to a sabbatical year for the recipient. The Visiting Fellows are chosen from applicants interested in the broad area summarized as laboratory astrophysics. In the year 1962–63, these Visiting Fellows have been J. P. Cox, Cornell University; P. McWhirter, Culham Laboratories, England; Y. Nakagawa, Institut d'Astrophysique, Paris; M. Rudge, University College, London; and E. Smith, Sacramento Peak Observatory.

JILA will concentrate on research and academic training in the broad field of laboratory astrophysics—more specifically, the application of detailed laboratory and theoretical studies in the areas of low-energy atomic physics to the interpretation of astrophysical problems. The atomic physics group has over the last decade produced much information on the cross sections of interest in astrophysical studies—the work on negative ions is a well-known example. The astrophysics program has specialized in the study of stellar atmospheres, particularly in connection with the study of nonequilibrium thermodynamics and problems of aerodynamics and astrophysics. With the addition of Cox and Garstang, the areas of principal interest branch out into problems of stellar stability and more detailed problems of atomic physics in astrophysics. The aerodynamics group of Uberoi will add emphasis to the astrophysics-aerodynamics collaboration. The Laboratory for Atmospheric and Space Physics of the Department of Physics and Astrophysics is closely linked to JILA through its Director, W. Rense.

During the year 1962–63, George Chamberlain and James Faller have been NBS Postdoctoral Fellows within JILA. Charlotte Pecker, from the Institut d'Astrophysique, and Ray Weymann, from UCLA, have been visiting Research Associates for some months.

Two special sets of lectures are perhaps noteworthy: Dr. M. R. C. McDowell of Royal Holloway College, London, gave six lectures on the theory of ion–atom collisions. Professor E. A. Hylleraas, Director of the Institute for Theoretical Physics of the University of Oslo, delivered five lectures on scattering theory and the structure and stability of doubly excited negative ions. Both sets of lectures will be published as *Technical Notes* by the NBS [1], [2].

WORK CARRIED OUT DURING THE PAST YEAR

A. Physics of Atomic Collisions. E. Beaty and P. Patterson made high-precision measurements of the mobilities and diffusion coefficients of three species of helium ions and measured the rate coefficient for the formation of helium molecular ions in three-body collisions. This work is particularly interesting because it appears in conflict with conventional theoretical limits on the molecular helium mobility. Similar measurements have been made in neon [3].

L. Kieffer and G. Dunn have completed a detailed experimental study of dissociative ionization of hydrogen molecules by electron impact [4]. Specifically, they measured the kinetic energy distribution of protons from the dissociating ions and—for the first time—obtained agreement with theoretical prediction. More importantly, they measured the angular distribution of the protons with respect to the ionizing electron beam direction and showed this distribution to be highly anisotropic, as predicted by Dunn. A student is continuing studies on angular distributions in oxygen and nitrogen.

G. Dunn has under study the photodissociation of the H_2^+ ion in a crossed beam experiment. The integrated cross section appears in disagreement with approximate theoretical calculations [5].

S. J. Smith and G. Chamberlain have in progress an experimental study of the elastic scattering of monoenergetic electrons from atomic hydrogen in crossed beams.

L. Branscomb and Bruce Steiner (NBS Washington) completed the analysis of data taken earlier on the photodetachment cross section of the negative iodine ion, with the result that the binding energy of this ion is now known to an accuracy of three millivolts. Concurrently, T. O'Malley (Visiting Fellow of JILA) has developed the theory for the threshold behavior of negative ion photodetachment including the effect of polarization and quadrupole moments as part of a general study of electro-scattering phase shifts at low energies.

S. Geltman completed a very accurate calculation of the cross section for the H^- bound–free absorption coefficient, and it is in excellent agreement (within a few percent) of the precise experiments of Smith and Burch [6]. S. Geltman and M. Rudge (Visiting Fellow of JILA) have under way detailed calculations of the free–free absorption coefficient using these accurate wave functions. Geltman and Rudge, with M. J. Seaton (University College, London), published this year a paper on the theory of ionization [7]. Rudge has completed a new calculation of the cross section for ionization of H^- by electron and positron impact. L. M. Branscomb is planning to attempt a measurement of this cross section.

Rudge also has in progress a calculation of the cross section for ionization of atomic hydrogen by proton impact, and, in collaboration with Zirin (High Altitude Observatory) and Schwartz (Martin Company), a study of the ionization of *Fe* XIV by electron impact.

Geltman has calculated the two-quantum photodetachment probability for I^- and other ions [8], following the suggestion of John Hall, whose giant-pulse ruby laser makes possible an experimental measurement of this probability using the photodetachment apparatus.

B. Astrophysics. John Cox has continued collaboration with A. N. Cox of Los Alamos on the problem of *He* II instability of Cepheids. Detailed calculations on the evolution of a small perturbation on the static configuration of "normal" and *He* II-unstable stellar models have succeeded in reproducing Cepheid-like behavior in the latter case, with the oscillations damping rapidly in the former case [9]. Work is in progress to delineate the area of this type of instability.

Cox has also continued work on *He*-rich, semi-degenerate stars in collaboration with E. Salpeter of Cornell [10].

J. Jefferies, in collaboration with astrophysicists from the High Altitude and Sacramento Peak Observatories, has been engaged in the analysis of the chromospheric spectra from the very successful 1962 solar eclipse expedition to New Guinea. With Orrall of Sacramento Peak, he has explained a serious discrepancy in the literature concerning the temperature of solar prominences [11]. A review of theoretical problems in the solution of transfer equations for atomic spectral lines was presented by Jefferies [12].

Two other investigations by Jefferies are nearly complete: a study of the excitation of helium lines in the solar chromosphere leading to a determination of the helium abundance, and a study of proton kinetic energy distributions in coronal-loop solar prominences.

Jefferies and Ray Weymann (temporary JILA staff member) completed a set of observations of line profiles of the calcium H and K lines in spectra of G, K, and M type stars at Mt. Wilson Observatory. These data will be interpreted in an attempt to discern the chromospheric structure of such stars.

Elske Smith (Visiting Member of JILA) has continued her work on solar flares. An analysis of the spectrum of the 2 September 1960 flare was published during the year [13], and she has also been engaged in the reduction of the 1962 eclipse data.

Richard Thomas has continued investigations of non-ITE effects in stellar atmospheres, and their relation to aerodynamic phenomena in such atmospheres. Collaboration with Charlotte Pecker of the Institut d'Astrophysique has continued on the problem of the solar corona and rocket ultraviolet spectrum [14]. An investigation of the effect of levels out of the ground configuration on the observed red and green coronal line intensities has been followed by a more general investigation of the effect of coronal self-emission upon the statistical equilibrium of coronal ions [15]. The application of these results on coronal opacity to the analysis of the rocket ultraviolet spectrum, and to the coronal model, is in progress.

James Faller developed an unusual photoelectric instrument for the purpose of measuring the relative strength of the solor chromospheric continuum on both sides of the Balmer discontinuity, with improved accuracy and height resolution. The equipment was used in Alaska during the 20 July 1963 solar eclipse.

William Rense successfully obtained high-resolution line profiles of the solar Lyman-α radiation in July 1962 using a rocket-borne Echelle spectrograph. This work was carried out in the University's Laboratory for Atmospheric and Space Physics, under his direction. The vacuum ultraviolet rocket spectra of the chromosphere and corona obtained by Rense and collaborators were interpreted in an extended paper by Fritz Rohrlich and Charlotte Pecker [16].

C. Resonance Physics. P. L. Bender has investigated the possibility that optical pumping by sunlight occurs naturally in the sodium of the earth's upper atmosphere, with the result that the effect appears negligible except in the case of artificial sodium releases from rockets at the higher altitudes [17]. Bender also made a theoretical investigation of hydrogen atom spin exchange collisions, with applications to the operation of a hydrogen maser [18].

Optical pumping of rubidium vapor in the presence of a high-pressure buffer gas was observed using natural sunlight.

J. Hall developed a giant-pulse ruby laser, producing about 1 J and up to 50 MW of monochromatic light, for the purpose of studying nonlinear interactions of atoms and matter with radiation. The feasibility of measuring the two-quantum photodetachment of I^- negative ions has been studied. A fluorescence experiment on anthracene has been carried out with Jennings of NBS, in which two photon processes give a fast fluorescence as well as the previously observed delayed fluorescence due to exciton-excitor collisional recombinations. Preliminary work on detection of high frequency beats from two closely spaced gas laser lines in the infrared has been started.

James Faller began work to measure the acceleration of gravity using an interferometer (one plate of which is the falling object) together with a gas laser light source. In addition to the importance of this measurement of the field of standards, possible variations in the gravitational field strength (which could be of cosmological origin) might be detected with the high precision obtainable with this new technique [19].

D. Plasma Physics, Statistical Physics, and Aerodynamics. Wesley Brittin continued investigations of the quantum statistics of plasmas, and with Willard Chappell of Harvard, published an extensive discussion of the Wigner distribution function and second quantization in phase space [20].

Yoshinari Nakagawa (Visiting Fellow of JILA) made an experimental study, in collaboration with K. Earnshaw of Roger Gallet's laboratory at NBS, of the structure of self-ionizing hydromagnetic shock waves in a magnetic field [21]. Experiments are planned to apply hydromagnetic shocks to the study of solar flares.

Mahinder Uberoi has studied several forms of hydromagnetic instabilities of the type reported by Chapman, and has found three additional solutions.

E. Data Center of Atomic Collision Cross Sections. The Data Center has completed its survey of all literature reporting cross sections for two-body collisions involving a free electron, and is currently providing bibliographic searches for the general scientific community. The material is coded by subject matter as well as by normal reference to author, journal, etc. Preparation for the publication of the complete bibliography by subject classification is in progress, under the direction of L. J. Kieffer. Reasonable requests for printouts from this bibliography will be honored without charge.

LEWIS M. BRANSCOMB, *Chairman*

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