COMMISSION No. 9

INSTRUMENTS AND TECHNIQUES (INSTRUMENTS ET TECHNIQUES)

PRESIDENT: C.M. Humphries VICE PRESIDENT: J. Davis

Given here are reports on the scientific and business meetings held in Baltimore involving Commission 9 only. Reports on the following Joint Commission Meetings co-sponsored by Commission 9 (JCM 3 and JCM 6), and on three additional meetings organised jointly with other Commissions, will be found elsewhere in this Volume or in Highlights of Astronomy (Volume 8):

- High Angular Resolution Imaging from the Ground (JCM 3)
- Stellar Photometry with Array Detectors (JCM 6)
- Problems of IR Extinction and Standardization (with Commission 25)
- Future Space Programs (with Commission 44)
- Gamma-ray, X-ray, Extreme and Far UV, IR and Radio Astronomy from Space (with Commissions 40 and 44)

BUSINESS SESSION: 9 August 1988

Reporting on the period 1985-88, the President said that the areas of interest of Commission 9 had been enlarged by including infrared and sub-millimetre wave telescope technology and instrumentation. Although no specialist symposia had been organised by the Commission in the period under review (since these had been catered for by a wide range of topical meetings arranged by other bodies), it was felt that an important function of the Commission should continue to be the provision of a full programme of scientific sessions at each General Assembly. To this end, at the present General Assembly in Baltimore, Commission 9 had arranged or co-sponsored thirteen such sessions. Attendances at these (audiences of 75 - 200 were obtained consistently, and at one session - the Saturday morning tutorial on adaptive optics - only standing room remained) suggested that this policy was a fruitful one. The active Working Groups of the Commission continued to be those on Photoelectronic Detectors, Astronomical Photography, and High Angular Resolution Interferometry.

The following officers of the Commission were nominated and elected for the period 1988-91: President: J. Davis; Vice-President: J.C. Bhattacharyya; Organising Committee: E. Becklin (subject to confirmation), M. Cullum, J.-L. Heudier (Chairman, Astronomical Photography W.G.), C.M. Humphries, G. Lelièvre (Chairman, Photoelectronic Detector W.G.), E.H. Richardson, L.I. Snezhko, W.J. Tango (Chairman, High Angular Resolution Interferometry W.G.), R.G. Tull.

The names of the following new members were presented to the meeting and accepted: Guoxiang Ai, N.M. Ashok, M.T. Bridgeland, J. Guibert, B.W. Hadley, P.V. Kulkarni, I.S. McLean, M.C. Morris, G. Pizzichini, M. Pucillo, J. Rowntree, M. Valtonen, W.W. Weiss, R.A. Windhorst.

A discussion followed on the role of IAU symposia or colloquia on astronomical optics and instrumentation, particularly in view of the increasing tendency for such meetings to be held regularly and frequently (at least in the U.S.A. and Europe) by The Society of Photo-Optical Instrumentation Engineers (SPIE) and by some of the larger observatories. The view was expressed that contact between the Commission and SPIE on the scheduling of meetings and their content could be beneficial to each side; it was agreed that this should be pursued further by the incoming President and his organising committee.

SCIENTIFIC SESSIONS AND WORKING GROUP MEETINGS

Progress on Telescopes (Visible, IR And Sub-mm): 3 August 1988

Chairman: C.M. Humphries

J. Nelson (U. California, Berkeley) opened the session by describing the recent history and current status of the 10 metre (f/1.75 Ritchey-Chrétien) Keck telescope project. With the enclosure for the telescope already erected at Mauna Kea, the telescope itself is scheduled for installation there in 1989, with the testing phase starting in 1990. In the current programme of stress-polishing the optics, the focal lengths of individual segments are required to be matched to within 300 microns.

SEST, the only large sub-millimetre telescope in the southern hemisphere, was constructed as a collaborative venture by Sweden and by ESO, and has already begun operation at La Silla (first light in March 1987; scheduled observations started in April 1988). Described in a presentation by R.S. Booth (Onsala Space Observatory), SEST is an open-air telescope making extensive use of carbon fibre in its construction. The low temperature coefficient of this material, combined with its high tensile strength, reduces thermal distortion and allows the telescope to operate under wind loads of 14 m s^{-1}. The reflector profile has been set to 65 microns rms from the best-fit paraboloid and further improvements will be made in the next few months to reach the specified accuracy of 50 microns rms. At present it has dual polarization receivers covering the frequency ranges 80 - 117 GHz and 220 - 240 GHz, and a 350 GHz system is under construction.

A new infrared telescope has been completed and is now in operation at the Rothney Astrophysical Observatory in the Canadian Rockies (E.F. Milone and T.A. Clark, U. Calgary). The telescope has an alt-alt mounting and is driven in two axes by computer controlled friction disc drives. Present instrumentation includes broadband and CVF photometry. A contract between the University of Calgary and the Astrophysical Research Consortium for the polishing of a 1.8m honeycomb mirror will enable the current 1.5m metal mirror to be replaced.

L.P. Bautz of the National Science Foundation gave a review of recent developments and plans for new observing facilities in the U.S.A. Included in these are: the Caltech 10 metre sub-millimetre dish being commissioned at Mauna Kea; the 10 antenna x 25 metre VLBA network due for completion in 1992; the 3.5m Apache Point telescope at Sacramento Peak, New Mexico being built by the Astrophysical Research Consortium, the honeycomb mirror for which has already been manufactured; the Keck telescope (referred to above); the conversion of the MMT to use a 6.5m monolithic primary mirror; the Magellan 8m telescope project; the 2 x 8m Columbus project with a single mount but equivalent to an aperture of 11.3m; proposed NOAO projects for 8m telescopes; and the segmented Spectroscopic Survey Telescope (see below).

A status report on the 6m SAO telescope in the USSR was provided by L.I. Snezhko. Replacement of the primary mirror in 1983-5 improved imaging quality to give 90 per cent encircled energy diameters of 0.9 arcsec on-axis at the prime focus and 1.1 arcsec at 4.5 arcmin off-axis. Improvements have also been made to the setting accuracy (+/- 3 arcsec) of the telescope and to the environment in the dome (by installing an air ventilation system). Most observations at present fall into the following categories: extragalactic spectroscopy using a TV scanner; high and moderate resolution stellar spectroscopy; speckle interferometry; superhigh time resolution photometric studies; stellar magnetic field measurements. A 2-dimensional detection system with digital storage and processing (the QUANT system) has been installed recently and this is used in an echelle spectrograph operated with a long slit, in direct imaging, and in multi-object spectroscopy. Approximately 30% of the observational time is allocated to the Special Astrophysical Observatory by the Time Allocation Committee (Chairman: Dr. V.Yu. Terebizh), and the remaining time goes to external programs including 15% to foreign users.

Harlan Smith (U. Texas, Austin) described the Spectroscopic Survey Telescope project (at a session on 9 August). This is a joint program between the Universities of Texas and Penn State, with the former responsible for the mechanical design and development and the latter for the optical work. The telescope has a constant elevation tilt (altitude 60 degrees), and thus behaves like a zenith telescope, but rotates on an azimuth bearing so that most of the northern hemisphere becomes accessible except for a small cap overhead. The primary mirror is segmented and uses 85 separate 1 metre diameter spherical mirrors on a common mount to give a total surface area larger than that of a 9m mirror, though an average of about 8m is normally used. When the telescope is in operation at fixed azimuth, the object being observed will move through the 12° field of view in approx. 1 hour and this is tracked by a moving (x-y-z) spherical aberration corrector and detector system. The focal surface is linked to one of several spectrographs in the basement of the building by an optical fibre link. Work on manufacturing the mirror segments (using 5cm thick Pyrex, with students providing the manpower) and the invar tetrahedral support structure, is well under way.

Additional presentations were given by: K. Kodaira "The Japanese National Large Telescope"; F. Merkle "Recent Developments at ESO"; P.V. Kulkarni "The Mt. Abu Telescope"; Li Depei "8-Metre Mirror Fabrication"; D. Downes "IRAM"; A. Boksenberg "Recent Developments at RGO and La Palma".

Active and Adaptive Optics: 3 August and 6 August 1988

Chairmen: F. Merkle, 3 August
L. Goad, 6 August

J. Hardy (Itek Corp.) reviewed methods of wavefront sensing and proceeded to consider the properties of (1) the atmospheric structure function as a function of projected actuator spacing for an adaptive mirror, and (2) the combined optical transfer function of the telescope and atmosphere in terms of the fitting errors when the actuator spacing (L) is not matched with r_0. In the latter case when photon noise, subaperture averaging, timing and other experimental errors are included, the SNR falls off rapidly as $L > r_0$ and partial compensation soon becomes less effective than full compensation (though still capable of yielding improved imaging). The conclusion was that, since full compensation is the better prospect, the need is to reduce the cost of adaptive mirror actuator systems (currently approx. $1000 - 2000 per actuator channel including drive electronics).

A status report on the 37 element adaptive system being developed and tested at Kitt Peak for infrared use was given by L. Goad (NOAO, Tucson). Wavefront sensing is accomplished with Hartmann-Shack optics feeding a GaAs image intensifier and Reticon detector, and the servo loop is operated at a frequency of 100Hz with a correction bandwidth of approx. 30Hz. For completing the loop,

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Goad distinguished between modal control (in which Nth order Zernike polynomials are calculated) and zonal control (which is slower than modal control).

Fred Forbes (NOAO, Tucson) described the piezoelectric bimorph mirrors that are being developed by NOAO. Two thin piezoelectric wafers are cemented together with a metal electrode in between. One of the faces is chosen as the reflecting surface and is polished flat, while the other face, also polished, has a pattern of hexagonal electrodes deposited on it. Voltages applied to the electrodes produce bending moments that give local curvature on the mirror. These mirrors are small and lightweight and have excellent frequency response (up to about 10kHz).

The status of the ESO 19-element adaptive system for infrared applications and the future goals for adaptive optics with the VLT were described by F. Merkle (ESO). A system in which three adaptive mirrors would be used sequentially was considered for visible wavelengths: the first of these would be a standard tip-tilt mirror, whereas the other two would be optimally designed so that separate corrections could be made for low and high spatial frequency components. The low frequency one would have fewer than 50 sub-aperture elements, large amplitude (10 microns) and slow response (30 ms); the high frequency one would have up to 1000 elements, relatively small amplitude (1 micron) but fast response (3 ms). Also mentioned by Merkle was the group at Chengdu in China (Institute of Optics and Electronics, Academica Sinica) that has developed a prototype adaptive system and has achieved closed-loop operation in laser applications.

The use of adaptive optics in long baseline interferometry was discussed by P. Léna (Observatoire de Paris) including SNR considerations at infrared wavelengths, partial atmospheric compensation and deconvolution techniques.

O. von der Lühe (NOAO, Sacramento Peak) described the 19 hexagon segment system developed by Lockheed Palo Alto and tested jointly with NOAO on a 1m solar telescope at Sacramento Peak. Results shown on a video recording demonstrated the improved resolution that had been obtained for imaging solar granulation.

An example of a 512 element segmented adaptive system that can be purchased commercially was given by Bill Hulburd (Thermo Electron Technology Corp., formerly Western Research Corp.). The gaps between the segments occupy less than 2% of the area. For 3-axis control of the segments and piston movements up to 10 microns such a system would cost approx. $300 per segment, i.e. $100 per degree of freedom.

A. Wirth (Adaptive Optics Associates) reported on the lenslet arrays for Hartmann-Shack wavefront sensors, and processor boards with parallel 10MHz channels, currently available from AOA for adaptive systems. The parent company, United Technologies, also supplies adaptive mirrors using electrostrictive actuators.

At the Adaptive Optics 'tutorial' on August 6, the design of systems and their realisation was considered in more detail and from a practical point of view. Presentations were given by Larry Goad, Allan Wirth, Fritz Merkle and Renaud Foy; among the topics covered were wavefront sensors and sampling, types of adaptive mirror, signal processing, loop control, and laser-generated artificial guide stars.

CCD and Array Imagers for the Visible and Infrared: 8 August 1988

Chairman: M. Cullum

This session was concerned principally with the status of various array detector development projects, and with the experience of some of the groups that have been testing and using them.

Optical Detectors

Martin Cullum (ESO) reviewed the situation regarding the two major European manufacturers of optical CCDs: EEV(GEC) in England and Thomson-CSF in France. Both of these firms have been actively working in the last year towards achieving CCDs that are larger in area than those that have been widely available in the past, as well as the manufacture of thinned devices.

Thomson have recently completed a development contract, funded jointly by ESO and INSU, to produce a modified version of their standard TH7882 CCD that can be butted on three sides. The individual chips have 400 x 579 pixels of 23 microns across. This project has yielded CCDs of excellent cosmetic quality, $6e^-$ readout noise and an improved CTE compared to some previous Thomson CCDs. To complement this work, ESO and the Toulouse Observatory have developed a machine to align and mount a 2 x N array of individual CCDs on a common substrate with a precision of 2 microns for any pixel on the combined array. This machine is currently undergoing final tests in Toulouse and will shortly be installed at ESO in Garching.

Thomson have also started to deliver samples of their new 1024 x 1024 CCD with 19 micron pixels, and some of the first test results from this chip are described below.

With support from CNES, the French Space Agency, Thomson have also produced some thinned versions of their 576 x 384 pixel CCD. These have been evaluated by Thomson and by Laurent Vigroux and his colleagues at CEN-Saclay. Although the prototype versions are still not fully optimized and exhibit a few problems such as non-uniform annealing, the RQE in the visible and especially in the soft X-ray and UV region shortward of about 280nm is significantly better than the standard CCDs. In the visible, a peak RQE of about 53% has been measured, going down to about 10% at 320nm.

EEV have also produced the first wafers for their new family of 'large' CCDs. These will all have 22.5 micron pixels with the formats: 298 x 1152, 770 x 1152 and 1242 x 1152. The first tests of these devices at EEV are expected in October 1988.

Under contract from the Royal Greenwich Observatory and the Anglo-Australian Observatory, EEV have also recently delivered the first batch of thinned P8603 CCDs for evaluation. These have been tested by David Thorne at the RGO who has measured peak quantum efficiencies at 650nm of between 65 and 75%. The sensitivity of these devices at 340nm was somewhat lower than expected, with RQE figures averaging about 5%, probably again due to non-optimized backside surface treatment. The prototype chips were of an unsupported pellicle design that exhibited flatness deviations of up to 150 microns peak-to-peak for some chips. Future thinned chips will be mounted on a glass supporting plate on the electrode side to overcome this problem.

One of the prototype thinned EEV CCDs from the RGO has been given a fluorescent coating at ESO to see whether it is mechanically feasible to coat an unsupported pellicle using a spinning technique, and to see whether any significant improvement in the UV RQE could be realised. The results of this experiment were encouraging, yielding an efficiency in excess of 35% right through the atmospheric UV region, and peaking at about 80% in the visible.

Patrick Waddell (CFHT) reported on aspects of the CCD implementation at the CFHT. One aspect felt to be of considerable importance for an observatory like the CFH, where instrument change-overs occur frequently, was that of the adoption of observatory and international standards for the mechanical and optical design of dewars, and for the electrical and data transfer interfaces. This was necessary to assure maximum versatility and reliability of the different systems installed.

Considerable attention has also been paid to the 'observer interface' between the observer and the instrument and host computer. To a large extent, modern visual interaction methods with the control computer have been employed to avoid the need for visiting astronomers having to remember command strings. The data acquisition system at the CFHT currently employs an HP9000 series computer with a Sun pre-processing workstation and IRAF software.

As well as RCA and Thomson CCDs, one of the new Ford/Photometrics 512 x 512 CCDs has also recently been tested. This was of very good cosmetic quality and had an excellent CTE even at very low signal levels. The readout noise has been measured to be about 7 e^-.

Lloyd Robinson (Lick Observatory) presented information about the status of the new Reticon 1200 x 400 CCD. This project, funded jointly by EG&G-Reticon and the National Science Foundation, aimed at producing a large area CCD of good quality suitable, in particular, for spectrometric applications.

The project was started by Reticon in July 1987, and the first sample CCDs, at present unthinned and front illuminated, were received at the Lick Observatory in April 1988. The initial tests have revealed that the chip is, indeed, very good: almost perfect cosmetically with virtually no charge pockets, a full-well capacity of about 450,000 electrons, and a readout noise of 4 e^-. The CTE, revealed by cosmic-ray events, is also excellent. Another interesting characteristic of the device is the possibility of being able to hold the clock levels low during an integration without charge spreading along the columns. This 'multi-phase-pinned' mode of operation gives a significantly reduced dark current level compared to conventional CCDs, thus enabling the detector to be operated at a higher temperature. The dark signal measured in this mode of operation was less than 20 electrons pixel^{-1} hour^{-1} at -110 C.

Reticon will deliver the first thinned versions of the chip, with hopefully a good UV response, before the end of 1988. One final, but important, point made was that the unthinned version of the chip is already available for sale !

Bill Schempp (Photometrics Ltd.) gave some brief results from the first tests of the new 1024 x 1024 pixel CCD from Thomson which had recently been received by Photometrics. Although this was a low grade prototype device with a number of cosmetic defects, the performance was encouragingly good. The readout noise was 8 e^- and the full-well capacity about 250,000 electrons. At a temperature of -37 C, at which all the initial tests were carried out, the dark current was 13 e^- pixel^{-1} sec^{-1}. Further tests at lower temperatures were under way.

In a general discussion on the progress of the Tektronix 512 x 512 and 2048 x 2048 CCDs, several participants were able to support the rumours that Tektronix has, at last, managed to produce CCDs which, although not perfect, were virtually free of the charge pocket problem that has long plagued them.

Altogether, the scene for optical CCDs looked much more rosy at this IAU General Assembly than at the last one. It is clear from the data presented during the session that excellent chips have been produced with characteristics that were only dreamed of several years ago, not only by the traditional manufacturers of these devices but also by 'silicon foundries' having little or no previous CCD experience. It is also interesting to note how many of the recent CCD development projects have been funded by astronomical institutes or produced primarily for astronomical applications. This is probably indicative of the maturity of CCD technology that such developments have become a realistic and affordable possibilty for the astronomical community.

Infrared Array Detectors

Zoran Ninkov (U. of Rochester) gave a review of infrared array detectors that are currently available from commercial vendors, and described both the technological differences as well as the achieved or anticipated performance figures. The IR detectors that are generally preferred for astronomy at the present time are those of a hybrid construction, where the detective element and readout stage are fabricated from different materials. The detector materials traditionally used at infrared wavelengths have been either intrinsic or extrinsic semi-conductors. A newer class of very heavily doped materials - 'Impurity Band Conductors' (or IBC) - have recently become available that show considerable promise. The potential advantages of IBC detectors include a more uniform response and radiation hardness. To control the potentially large dark current with such detectors, a blocking layer of undoped material is grown between the active layer and the electrode, whence the acronym BIB detectors (blocked impurity band).

The method of manufacturing the chip and the internal architecture also have an important effect on the eventual performance of the detector. Epitaxially grown detector materials, although not yet so widely available as the bulk materials commonly used at the present time, as well as the use of Mesa architectures, hold the promise of improvements in the response uniformity and dark current as these become available.

Of the three most common technologies employed to read out infrared arrays - CCD, Reticon and Direct Readout or DRO - it was pointed out that DRO arrays have several advantages. They are usable at liquid Helium temperatures and allow selective and non-destructive readout modes, although with the possible disadvantage of non-linearity. There would also appear to be advantages in changing from the N-MOS FETs, found in many of today's DRO arrays, to P-MOS because of their lower ultimate 1/f noise at low temperatures.

IR arrays with pixel formats up to about 60 x 60 pixels are already in use at most of the world's major observatories. Devices with 128 x 128 and 256 x 256 already are on the horizon with a readout noise of less than 100 e^- and very low dark current levels.

Photoelectronic Detectors Other than CCDs: 9 August 1988

Chairman: G. Lelièvre

The session started with a rescheduled presentation of the Spectroscopic Survey Telescope by Harlan J. Smith (University of Texas). A summary of this contribution can be found in the session devoted to telescopes. The rest of the session dealt with detectors other than CCDs, mostly photon-counting detectors. The status of various development projects was described as well as some experience in using them.

Mark Clampin (STScI) discussed the design and development of Ranicon detectors for optical photon-counting imaging with ground-based telescopes. The significant factors that determine the performance of these detectors are found to be the proximity focussing stage, the microchannel plate stack (MCP) and the signal processing electronics. The low photon-counting efficiency typically found with optical MCP-based detectors (due to ion barrier films) presents an additional consideration. A new approach to the signal processing electronics reduces non-linearity, while achieving increased processing speeds and a position error corresponding to less than 21 microns FWHM.

An advanced Ranicon incorporating a reduced proximity-focussing gap and an unfilmed input plate in the MCP stack shows significiant improvement in detector performance. For the advanced Ranicon, the spatial resolution is shown to be typically 40 microns FWHM at 650nm and the point spread function to be stationary over the active imaging area, principally due to the removal of non-linearities and noise sources from the signal processing electronics.

Gerard Wlérick (Observatoire de Paris) presented the results of deep soundings using the Lallemand electronographic camera at the Canada-France-Hawaii Telescope. With its 81mm diameter photocathode and a resolution better than 70 lp/mm, the equivalent number of pixels is 2×10^7, making it particularly suitable for large field photometry. Special care is devoted to high accuracy photometry using fiducial marks engraved on the photocathode for registration, flat fielding at twilight, and screens to evaluate the background noise. The data handling, after digitization, is similar to the procedure used for CCD data. At the CFHT Cassegrain focus (F/8), the sampling (camera + PDS) is about 0.12 arcsec over a field of 9.5 arcmin; this large field is essential for large surveys requiring photoelectric standards in the field. It also provides a better knowledge of telescope imperfections (such as scattered light) which are important for a correct data reduction. Many results were presented including a UBV Catalogue of all objects in a selected field of SA 57, up to B=25.5.

Martin Cullum (ESO) in the absence of J Gethyn Timothy, presented the development status of projects related to the Multi-Anode Microchannel Array (MAMA) as well as results from evaluations at ESO (point spread function, linearity, count rates). Large format cameras (2048 x 2048) are being developed for use in the Hubble Space Telescope and are scheduled to be built by early 1989. Other MAMA applications include rocket flights, speckle imaging and astrometry. The flat field response of the bialkali detector is found to vary with exposure time, attributable solely to problems with the photocathode. Measurements show that centroid positions may be computed from MAMA data to an accuracy of at least 0.01 pixel. The DQE is 0.22 of the cathode RQE. With an unfilmed MCP, the DQE would be expected to be significantly higher.

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Renaud Foy (Observatoire de Paris and CERGA) presented CP40, the Photon-Counting Camera developed at CERGA and Observatoire d'Haute Provence under Alain Blazit's supervision (CERGA). Four Thomson CCDs are fed through a fibre optics reducer and splitter, with a common stack of 40mm diameter Varo image tubes coupled with a RTC microchannel plate intensifier. The hardware photon-centroiding processor gives an accuracy of 1/4 pixel, providing 3072 x 2304 logical pixels. Due to the Varo first stage, the quantum efficiency remains satisfactory (about 12%) and does not lose primary photo-events, unlike MCP intensifiers which lose about half of the photon-events. The CCDs are used in video mode. Further developments include duplications of the CP40 at Paris Observatory, an improvement of the Direct Memory Access board and an increase of the readout speed. Many applications are already supported by the CP40 prototype: speckle imaging, multi-telescope interferometry, multi-slit spectroscopy, segmented pupil imaging etc.

As an application of the large format of the CP40, Gérard Lelièvre (Observatoire de Paris) showed the recent results of the Segmented Pupil Imagers at CFHT and Pic du Midi. As a result of recording the data at video rate, the eight sub-pupil images can be recentered, selected and recombined by computer at the site immediately after the observations are made. Sub-pupil images with resolution between 0.25" and 0.4" were presented while the full pupil images were typically between 0.6" and 0.8".

Alex Boksenberg (RGO) gave an update on IPCS developments and presented some new ideas related to detectors for the Herschel telescope. During the discussion. Trung Hua (Laboratoire d'Astronomie Spatiale) demonstrated that old photon-counting cameras are well alive and can still produce good quality science.

Clearly photon-counting detectors play a dominant role in key fields such as low-light level spectroscopy; in recording fast events to achieve very high time resolution; in diffraction limited applications (speckle interferometry); in high spectral resolution; and in atmospheric turbulence limited cases (direct imaging with a-posteriori fast guiding). Electronography remains a unique method for deep surveys in large and crowded fields as long as large format CCDs or arrays of CCDs are not available. All contributors emphasised the necessity of having large-area detectors, particularly for large telescopes under design or forseen within five to ten years. At the present time, it may be better to consider using photon-counting detectors than to anticipate rapid developments in CCD technology.

Photographic Working Group (PWG): 4 August 1988

Chairmen: D. Malin/J.-L. Heudier

The following scientific and technical papers were presented:

Performance of 2 New Image Processing Algorithms to Improve the Image Visibility of Astronomical Photographic Pictures (S. Koutchmy).

Astronomical Results from Electronography at the CFH Telescope (G. Wlérick).

An Ultradeep Photographic Survey with the 100" DuPont Direct Camera (R.A. Windhorst).

Hypersensitization of Infrared Plates and Vacuum Hypersensitization (A. Maury).

Plate Addition and Batch-to-batch Variation in Hypering Properties (D. Malin).

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Review of Plate Manufacturing Facilities of Eastman Kodak Co. (J. Burdsall) - open discussion on Burdsall's paper and on the future availability of astronomical emulsions.
Review of poster papers (J.-L. Heudier).

Poster papers exhibited were:

Astronomical application of Konica SRV 3200 Film (K. Tomita).
A new tuning fork? (D. Block and B. Tully).
Detection of new Herbig-Haro objects on deep Schmidt plates (B. Reipurth and C. Madsen).
Total eclipse of the sun of 18 March, 1988 (F.J. Heyden).
Report on hypersensitization at the Bosscha Observatory (Hidayat, Wiramihardja, Raharto and Kogure).
Second Palomar Sky Survey: First Results (A. Maury).
The light echo of SN 1987A (D. Malin).
Hypersensitization of Kodak IV-N photoemulsions (V. Tsintsarov, M. Panov and Ts. Georgiev).
Semi-automated identification of IRAS point sources using UKST plates and the Cosmos measuring machine (A. Savage et al).
Hypersensitization Facilities at the Indian Insitute of Astrophysics (A. Rajamohan, J.C. Bhattacharyya and K.R. Sivaraman).

Apart from a brief description of plate addition by Malin, the second session consisted mainly of topics in photographic technology, especially concerning plate production. Malin had provided a list of IIIa J and F emulsion batch numbers extending over 10 years to David Jeanmarie (Al Millikan's successor) and John Burdsall of the Eastman Kodak Company with an indication of the response of these batches to nitrogen hydrogen hypersensitization. The practical response of these emulsions agreed well with the sensitometric tests conducted after manufacture and it was agreed that plate speeds could generally be increased somewhat, perhaps on average by 30% without affecting those sensitometric properties that are essential for astronomy. Burdsall agreed to produce, and Malin agreed to test, experimental batches of a variety of emulsion types with improved response to hypersensitization and ultimate long-exposure speed.

The presentation by Burdsall of the Eastman Kodak Company was a particularly valuable contribution. It gave details of plate manufacture that were not previously available and the talk was frequently interrupted by pressing questions. Mr. Burdsall was very forthcoming in his answers and discussion was continued for a considerable time after the conclusion of his paper. This was joined by Gordon Brown, Product Planner for Scientific Photography at Eastman Kodak who explained that the spectroscopic plates used by astronomers represented only a small fraction (less than 10%) of total plate production by the Company. The largest users of plates are in the graphic arts field.

Mr Brown explained that plate production was extremely labour-intensive (a point amply confirmed by Burdsall's pictures of the plant) and that economic factors had forced a major review of product lines during the previous 12 months. Many emulsion types coated on glass had been discontinued, including types IIaD and 098-04. However, as a result of strong representations from members of the Working Group, these had now been reinstated though with some special ordering conditions that were established during later discussion in a subsequent meeting of the Organising Committee of the PWG. The scientific meeting closed after two extremely useful and productive sessions.

Business Meeting of the PWG

Committee members present were: D. Malin (Chairman); J.-L. Heudier (Chairman-elect); J. Davis; B. Hidayat; C. Humphries; K. Ishida; R. Sivaraman; M Tsvetkov; R. West (present for first part only) and as observers: G. Brown and J. Burdsall (Eastman Kodak); C. Madsen; A. Maury.

1. Relations with Eastman Kodak

Several incidents had contributed to a deterioration of relationships between the PWG and the Eastman Kodak Company. Almost all of these could be traced to communication problems and all have now been very satisfactorily rectified. We were impressed with the enthusiasm with which new ideas for collaboration between the astronomical community and the Company were discussed.

Emulsion types IIaD and 098-04 will continue to be manufactured, but with 100 ft^2 (about 9.5 m^2) minimum order quantities. These will now have special order numbers (to be advised) and will be manufactured when accumulated orders approach 100 ft^2 or twice a year, the ordering windows closing at the end of December and end of June each year. While orders will be accumulated by Eastman Kodak it is strongly recommended that small users of these products use the services of the officers of the PWG to consolidate and share orders with other observatories.

2. A Journal for Astronomical Photography

The meeting expressed its regret and disappointment at the sudden demise of the AAS Photobulletin, formerly the official organ of the PWG and the American Astronomical Society. It was felt that there was still a need for such a journal and two alternatives were discussed. The Chairman had received a letter from the editor of the Journal of Photographic Science, published in England by the Royal Photographic Society (RPS), offering that journal as an alternative for Working Group publications. Although this Journal does not levy page charges, few if any participants in the PWG were members of the RPS and most of the other papers in the journal would not be of direct interest.

After considerable discussion, which revealed that Eastman Kodak Company were prepared to donate $10,000 a year to the project, it was decided to consider further an offer from the Sky Publishing Corporation to produce a new journal, under the editorial control of a panel selected by the PWG, to publish refereed papers on astronomical photography. The journal would be quite separate and distinct from Sky and Telescope magazine and would be of a quality similar to that of the AAS Photobulletin. Approval for this course of action has been given by Commission 9 and requested from the IAU Executive Committee.

3. Election of New Officers and Consultants

The meeting considered that while the Organising Committee gave good international representation, the custom of having only one delegate from each country restricted the availability of experts in our speciality. It was decided therefore to appoint initially three prominent specialists as consultants to the Committee. The new committee and its consultants are listed below. An asterisk indicates new members.

4. Future of the Working Group

Despite the steady decline in users of photography, it was the opinion of the meeting that the Group should continue as an independent part of IAU Commission 9 and not be absorbed into the Working Group that covers electronic 2-dimensional detectors (as has occurred with the AAS Photographic Working Group). It is our belief that photography will continue as a technique for the specialist in the forseeable future; general practitioners are now using CCD's with great success for many problems that were previously investigated photographically. To stay competitive in the areas where it is especially valuable (sky surveys, panoramic detection of faint objects), more sophisticated techniques and a greater level of specialist skills are required. The Working Group is an important repository of those skills. This point has been discussed more fully in 'The Age of the Specialist' in the procedings of the Working Group meeting held in Jena in April, 1987 (published as Astrophotography 87, ed. S. Marx, Springer-Verlag, February 1987).

5. Election of Organising Committee

The following agreed to serve on the Organising Committee for 1988-1991:

Chairman: Jean-Louis Heudier (France); Secretary: Jorge Schumann (FRG).

Members: John Davis (ex-officio, Australia); Olga Dokuchaeva (USSR); Brian Hadley (UK); Bambang Hidayat (Indonesia); Kei-ishi Ishida (Japan); Hideo Maehara (Japan); David Malin (Australia); Siegfried Marx (DDR); R. Rajamohan (India); William Schoening (USA); Alex Smith (to be confirmed, USA); Milcho Tsvetkov (Bulgaria); Richard West (Denmark); Olga Zichova (Czechoslovakia).

Consultants: John Burdsall (Eastman Kodak Co., USA); Claus Madsen (ESO, Germany FRG); Alain Maury (France).

<u>WG on High Angular Resolution Interferometry</u>: 10 August 1988

Chairman: J Davis

A total of 12 reports were presented followed by a short business session.

<u>J. Davis</u> (University of Sydney), "SUSI - A Progress Report". Construction of the Sydney University Stellar Interferometer (SUSI) commenced in 1987 at the Paul Wild Observatory in northern New South Wales. Initially the new instrument will have a North-South array of siderostat stations to give baselines covering the range 5-640m. Starlight will be directed by the 0.20m diameter siderostats via fixed mirrors and an evacuated pipe system to a central laboratory containing a T 420m path equalisation system and beam combining optics. The design is based on a successful prototype instrument and features active wavefront tilt correction and a fringe-tracking optical path equalisation system. The limiting magnitude is expected to be +8 and first light is planned for early 1990.

<u>William J. Tango</u> (University of Sydney), "Dispersion in Long Baseline Stellar Interferometry". The path compensating system used to match the paths in a long baseline interferometer should strictly be in vacuo, but for practical reasons it may be convenient to operate the compensator in a stable air-conditioned environment. This arrangement introduces a large differential air path and the resulting dispersion will seriously affect the measurement of fringe visibility, particularly when wide optical bandwidths are used. Dispersion compensators consisting of variable thicknesses of one or more glasses can be used to correct

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for the air dispersion. A single glass is not sufficient if the excess air path exceeds ~10m, but two glasses can correct the dispersion for air paths up to 500m when the optical bandwidth is less than ~100nm.

J. A. Hughes (USNO), "The USNO Astrometric Optical Interferometer". Preliminary planning for the USNO astrometric, optical interferometer continues. The instrument will operate as a multi-r_0 system using a dispersed fringe technique. Large (1 to 1.5 meters) siderostats will feed one-meter beam compressors in the present plan. Evacuated pipes will carry the light to the central beam combiners. The possibility of using air-bearings for the siderostats is under investigation. As much of the beam combining optics and delay lines as possible will be underground. The layout of the baselines is under discussion, but two independent baselines approximately twenty meters long will be used. At least two passbands will be utilized to reduce atmospheric effects. Preliminary simulations indicate that it should be possible to reach the brighter quasars and thus provide an inertial reference system. The goal is to have a working instrument installed by 1993.

Yves Rabbia (CERGA), "Michelson Interferometry with "small" Telescopes at CERGA". "Small" implies "working with few speckles" and includes observations at 2.2 and 10 microns with the 2 x 1m telescopes and at 0.4 to 0.7 microns with the 2 x 26cm telescopes of the I2T. The 2 x 1m telescopes lie on an E-W baseline providing a 3.5m to 15m continuously varying separation. Observations are made in wide band (~ K and N filters). A double cat's eye device on a step-by-step moving carriage forms a discrete delay-line. At each station of the carriage, a Fourier interferogram is recorded when fringes pass the zero path difference. A signal to noise ratio of ~100 has been obtained for Alpha Orionis at 10 microns. Programs in astrophysics and astrometry are under way and improvements are planned for optimized operation and increased sensitivity.

The N-S baseline of the I2T has been extended to 140m. Fringes are observed in dispersed light in a spectral window of 30nm. The limiting magnitude is V ~ 4.5. Efforts are in progress to increase sensitivity and accuracy through upgrading of hardware and software (telescope mechanics, automatic pointing, image tracking, 2 dim. detector, fringe detection, data acquisition and reduction). Future plans include the development of the I2T into InT (n telescopes) for imaging using phase closure etc. A third telescope is under construction.

W.A. Traub (CFA), "Current Status of IOTA". The Infrared-Optical Telescope Array (IOTA) is a collaborative project, involving the SAO, Harvard, the Universities of Massachusetts and Wyoming, and Lincoln Laboratories (MIT), to build an interferometer on Mt Hopkins, Arizona. Two 0.45m diameter siderostats are being built with a third planned for the near future. IOTA will have two arms, one north-east ~40m long and one south-east ~20m long. Two long discrete delay lines, and two short continuous delay lines will be housed in a vacuum. Dispersed fringe detection will be used in the visible, with a matched-filter fringe pattern recognition technique. Delay line control will be fine-tuned using the measured fringe pattern. Phase closure and multi-wavelength-baseline information will be used in a hybrid mapping scheme for bright objects, but amplitude measurements only will be possible for faint objects. The system is intended to serve as a test bed and prototype for a larger system.

John Baldwin (Cavendish laboratories), "COAST - A Progress Report". COAST is planned to be a four-telescope interferometer using measurements of 6 visibilities and 3 closure phases for reconstructing images in the red and near infrared. The instrument, with maximum baselines of ~100m, is to be sited at Cambridge (UK). Two telescopes have been funded and construction of the first siderostat is nearing completion using a 50cm flat followed by fixed horizontal 40cm Cassegrain optics. The housing for the path compensators, combining optics and detectors, now half completed, is a 30m long corrugated steel tunnel with a 1m covering of earth. Work on avalanche photodiodes for photon counting detectors is progressing; counting rates up to 350 kHz have been achieved and 2-4 MHz can be expected. We hope to have first fringes in about a year.

H.A. McAlister (Georgia State University), "The CHARA Interferometer Project". The CHARA interferometer array is envisioned as consisting of seven 1m telescopes in a Y-configuration contained within a circle of 400 meters diameter. The limiting resolution of 0.1 mas would be applied to fundamental problems in stellar astrophysics. Simultaneous access to all seven beams is planned with delay lines for each arm, to allow the development and use of imaging algorithms. Correcting only for overall tilt is expected to provide a limiting magnitude of V = +11 while higher order wavefront conditioning may extend this to V = +14. Anderson Mesa, near Flagstaff, Arizona, is being tested as the site for the array.

G.P. di Benedetto (IFC Milan), "Saturation of the Variance of Optical Path Fluctuations in a Long Baseline Michelson Interferometer". The prototype I2T interferometer at CERGA was operated at 2.2 microns to measure optical path difference fluctuations as a function of the baselength. Data for the star Arcturus at 8.8m, 13.8m and 17.3m, in good seeing conditions (: 1 arcsec), show saturation of the RMS phase errors at a level smaller (up to a factor 4) than that expected from the Kolmogorov model. By assuming that such discrepancy is due to outer-scale effects, an external length of turbulence of a few tens of meters may be derived.

R. Foy (CERGA) "The VISIR Project". VISIR is a 3 x 1.50m telescope interferometer project intended for astrophysical programs and for preparation of the interferometric mode of the VLT. A Phase-A study of a dedicated telescope, funded by INSU/CNRS and carried out at IRAM, has resulted in the very compact skew-axis mount proposed by Plathner. This design could be useful for the VLT's Auxiliary Telescopes. A study of a transporter, to allow 2D continuous telescope movement for path matching or for hypersynthesis, will start in the fall. It is suggested that VISIR should be an international facility and that linked operation with the VLT's Auxiliary Telescopes would be productive.

R.V. Stachnik (NASA), "Interferometry and NASA". As a consequence of a series of ESA and NASA-sponsored conferences on space optical interferometry, NASA Headquarters requested its JPL center to undertake a study of supporting Space-Specific Technologies. The aim was to assist the Astrophysics Division in guiding development of needed technologies by the technololgy development arm of NASA. At present, limited "astrophysics" funding is being put into optical interferometry, but signfiicant long term "technology" funding is possible. Factors influencing NASA interest in space interferometry are the appearance of several very highly rated optical interferometers in the recent "explorer" scientific satellite evaluation and the recent release of a National Academy of Sciences/Space Science Board document recommending optical interferometers as part of NASA's long-range plan.

L. Mertz "Optical Beam Combining". An inexpensive lenticular receiver provides complex visibility information from individual photons. The information can be averaged directly in polar coordinates with digital low-pass filters for improving the precision while tracking fringes. These instruments could function with a pair of telescopes to provide single-baseline stellar interferometry, or with more telescopes to get multiple baselines for phase closure renditions of

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optical aperture synthesis.

F. Merkle (ESO), "NOAO-ESO Workshops". Two workshops on ground-based interferometric imaging have been held, one at Oracle, Arizona, USA, in January 1987 and the other at Garching, FRG, in March 1988. The proceedings of the first meeting were published by NOAO and publication by ESO of the proceedings of the second is imminent.

Business: It was agreed to continue the annual publication list and to circulate the WG mailing list with electronic mail addresses. A WG newsletter was proposed and will be investigated by the incoming chairman of the WG. Future meetings were discussed and it was agreed that an international symposium should be organized for circa 1990. The WG Organizing Committee for 1988-1991 is J Baldwin, Y Balega, R Foy, J Gay, F Merkle, M Shao, R V Stachnik, W J Tango (Chairman), C H Townes and P Venkatakrishnan.

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