circular polarization) and linear polarization in the Balmer lines of 3 X-ray sources: HD 77581, θ^2Ori and HD 153919 as well as in Beta Lyrae and HD 226868 (Cyg X-1). Variations of circular polarization in phase with the orbital period were found. This is to be expected if the magnetic field of the visible component is locked to the neutron star for avoiding entanglement of the lines of force of both the stars. Variation of linear polarization was also noted, indicating alternate clockwise and anti-clockwise rotation as one or the other pole is pointed toward the observer.

Vidal discussed optical observations of three stars. Fortythree visual observations of HD 77581 on 34 nights showed a total variation of 0.1 mag with a period of 8.95 days (same as X-ray period); radial velocity data indicated gas streams near conjunction. The secondary may be a black hole as its mass appears to lie between 2 and 3.5 $M_\odot$. No star of $m_V < 14$ is a possible candidate for Cen X-3; this leads to a mass greater than 3 $M_\odot$ for the invisible component, making it a possible candidate for a black hole.

Rees gave a brilliant review of the theoretical aspects of X-ray binaries. The X-ray source in the binary is a compact object which could be a white dwarf, a neutron star or a black hole. If the mass is transferred from the larger star through the inner Lagrangian point L_1 and falls on the neutron star, then 1-10 per cent of its rest mass energy can be released. The energy released by accretion onto a black hole can be as high as 40 per cent if the black hole is rotating. The energy ($\sim 10^{38}$ ergs will be radiated largely in the X-ray region.

If the central object is a spinning magnetic neutron star like a pulsar, we need 10^6 times more energy than a pulsar, which in this case comes from the accreted matter. If we assume an oblique rotator, its magnetic field will be limited by the Alfven radius inside which the matter will flow along magnetic lines of force and thus get funnelled towards the poles. Radiation can be produced either by Bremsstrahlung or by cyclotron process. The spin of the neutron star will produce pulses, their shape and polarization being determined by the beam pattern. The 35 day period of Her X-1 can be explained if we could find a mechanism for switching off the X-rays. Possible mechanisms are: (*i*) Switching off of mass transfer by the pulsation of the primary causing a filling of the Roche lobe at certain times only; (*ii*) A negative feed-back in which X-ray radiation pressure obstructs mass flow; (*iii*) A positive feed-back in which strong overflow of matter stops X-rays by increasing optical depth; (*iv*) Precession of the neutron star with a solid core. The theoretical upper limit of neutron star masses is about 2 $M_\odot$, which is satisfied by most X-ray binaries.

If the compact object is a black hole, it can still accrete material, but it has no hard surface and no magnetic field. The limit of the black hole is determined by the circular orbit of the least angular momentum. The binding energy for this orbit can be as high as 42 per cent of the rest mass energy for Kerr metric describing a rotating black hole. Most of the energy is released within a few Schwarzschild radii ($R_s = 3 \times 10^5$ $M/M_\odot$ cm). The characteristic signature of X-ray produced in this case would be the absence of a definite period and irregular flickering of time scales upto milli-second. For real identification, the mass should be high. This seems to be the case for Cyg X-1 and perhaps for SMC X-1.

Some of the outstanding questions are: Why is the 35-day cycle of Her X-1 not seen in the optical region? How do these systems evolve? How did the accompanying supernova explosion go unnoticed? What about sources like Sco X-1?

Rees' paper was followed by several short discussions. Meyer observed that the Roche lobe of the primary of Her X-1 is not filled because the observed mass transfer rate of $10^{-9} M_\odot$/yr is much smaller than the estimated rate of $10^{-6} M_\odot$/yr for a filled Roche lobe. Wade described the interferometric observations of radio binaries made by Hjellming at 8085 MHz and 2695 MHz. For the novae HR Del (1967), FH Ser (1970) and V 365 Sct (1970), the radiation is found to be consistent with an expanding plasma. In the ordinary radio binaries: α Sco B, β Per, β Lyr, b Per and AR Lac, the periods are found to change slowly or in jumps. These stars also show flare activity. The strongest radio emission is found in β Per in which the major flare has no correlation with optical variation. It can be interpreted as plasma radiation of 10^6 °K. Miley observed Sco X-1 at 6 cm and 50 cm; he found that it varies in the radio region as in X-ray and optical regions.

R. E. Wilson considered the possibility whether the invisible component of β Lyr is a black hole. It is definitely more massive with Q=4 to 6. But it is a composite source consisting of high and low temperature regions. If we assume a thick flattened disk as postulated by Huang, it could be approximated by a highly elongated ellipsoid with the axes ratio of 1 : 3. Then the poles will be 2500° to 3000° K hotter than the equatorial regions; since we do not see the poles, the star will appear underluminous by as much as 1 magnitude. Further, the lines will be washed out by rotation. Hence the secondary appears underluminous and it may not be a black hole.

The discussion ended with a paper by Kondo in which he considered the problem of mass determination of close binary stars, particularly X-ray sources. He drew attention to the effect of radiation pressure on the size of the Roche lobes and mass-luminosity law for evolved stars in binaries.

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NEXT DECADE IN THE STUDY OF SOLAR AND STELLAR ATMOSPHERES

(Joint meeting of Commissions 10, 12 and 36)

The joint meeting was held in the afternoon of 27th August. Only two invited speakers, Kuhi and Delache, spoke respectively on the observational and theoretical approaches to the problems of stellar atmospheres in the coming decade. It was made clear in the beginning itself that stellar atmospheres would include extended atmospheres and envelopes in future.

Kuhi considered the instrumental and observational aspects separately. In the last few years, instrumental developments have increased the spectral range and sensitivity. The spectral range is increased by space observations in UV and X-ray regions, by use of image tubes in the near infrared and by radio observations. Increase in sensitivity is obtained by the use of TV and image tube techniques with which one can observe quasars of 10^m to 22^m (Westphal, Warfer, Robertson, etc.) and obtain spectra at 2Å/mm with a resolution of 0.1Å and a speed gain of 100 (McNally et al). There are calibration problems, but we can use extremely high resolution for lines with 1 per cent accuracy. Hence accurate line profiles of brighter objects and low resolution spectra of fainter objects can be obtained, thus converting small telescopes of 1 metre size into larger instruments. It was pointed out that Fourier Transform spectroscopy in the visible region will be possible shortly.

Intensity interferometer of Brown and Twiss is being supplemented by the speckle interferometer of Labeyrie. The latter can reach fainter magnitudes, but it uses image tubes and requires large telescope scale because photographs are obtained at high rate and then they are analysed by producing 2-dimensional Fourier transforms of the image and adding them together. With these techniques, we can measure stellar diameters accurate to 0″.002, limb darkening with a resolution of 0″.01 for a 9^m star and surface brightness variation. For example, binary separation of α Ori (0″.04) and 8 per cent variation of the radius of o Cet due to pulsation have been detected.

Interpretation of observations can give routine results as well as surprises. The following important results and problems were discussed: (i) Growth of non-LTE calculations for extended atmospheres is imminent. For example, N III lines (λ 4630, 4640, 4641 Å) in Of stars cannot be explained by the Bowen mechanism, because the O lines which give rise to them are in absorption. Non-LTE calculations with 2-electron transistions have been successful. (ii) Infrared excesses in stars need to be explained in terms of extended circumstellar envelopes. Observations in the radio regions are very useful for fixing the mechanism; e.g., dust seems to be important. Interaction of the star, circumstellar material and interstellar medium must be taken into account. (iii) Polarization measurements of late-type and Be stars would also give clues to the nature of circumstellar material, e.g., electron scattering in the nonspherical atmosphere around Be stars is important. (iv) In the study of stellar chromospheres by Ca II emission, it is found that H and K emission increases with luminosity and decreases with age as pointed out by Skumanich, although T-Tauri stars do not appear to obey the age correlation. λ 10830Å line may be useful, but it is erratic. (v) Revision of f-values is necessary; new f-values for Fe have changed the iron abundance by factors ranging from 5 to 10. (vi) Non-LTE versus LTE controversy can be settled by further work. Although the LTE approach is easier to work, it gives wrong abundances and turbulent velocities. The non-LTE approach is more realistic. Recent work of Mihalas and coworkers has shown that: (a) In the case of Of stars, where He and H line widths require $Y = 0.15$ to 0.12 and $V_\sigma = 15$ to 20 km/sec, the difficulties disappear with non-LTE calculations which give $Y=0.10$ and $V_\sigma = 0$; (b) In B stars, Mg lines give normal abundance, but $V_\sigma = 4$ km/sec for $T=15{,}000$ to $20{,}000$ K; with non-LTE calculations both abundance and V_σ are reduced and the temperature dependence is properly understood. Thus departures from LTE are important for weak lines also; (c) Situation for late-type stars is more complicated due to line blanketing, but curve of growth studies cannot be realistic and non-LTE methods must be used. (vii) Velocity fields in stellar atmospheres are of two kinds: (a) Microturbulence parameter V_σ was introduced by Struve to account for the increase in the width of medium strong lines. What is it really ? We must know the answer because its effect on abundance analysis is quite large. Even in the case of the sun, it is contoversial whether microturbulence is the small scale turbulence associated with convection. It is perhaps the effect of departure from LTE. Study of A stars by Smith shows that f-values, a-values, magnetic field, dispersion and line blanketing parameter can affect V_σ. It is imperative that the highest possible dispersion should be used. It is found that the more detailed the model atmosphere, the smaller is the value of V_σ. Atmopsheres of Ap stars must also be studied for this purpose. (b) Expanding atmospheres and mass loss in supergiants give rise to gradients in V_r and V_σ which appear to be correlated. V_σ increases with luminosity and decreases with later spectral type. While expansion produces asymmetry in line profile, microturbulence washes it out. In cepheids it is possible to distinguish between V_r and V_σ gradients, both of which change with phase; further study should explain the difference. (viii) High dispersion spectra and high speed microdensitometers could give digital data which will be very useful to workers who do not have these facilities.

Delache considered in detail the historical background of the classical or 'restricted' theory in which the stellar atmosphere is identified with the boundary of the star. He also gave the outline of an 'extended' theory of the future in which the stellar atmosphere is considered as a multiregion where the stellar interior slowly passes into the interstellar medium.

Before 1950 one used the LTE approach. It is based on the physics of atomic spectroscopy and thermodynamics, equation of transfer of radiation and the geometry of plane parellel stratified atmosphere. The solution consists in obtaining the source function as a function of the optical depth. Before 1950 it was customary to assume LTE characterised by statistical equilibrium and conservation of mass and momentum giving a static atmosphere with $V=0$. Mathematically, it was then easy to construct an LTE model for the stellar atmosphere as a function of T_{eff} and g. Turbulence and inhomogeneities were introduced as adjustable parameters. Velocity gradients are easier to treat and if they can be treated stochastically, a parameter like V_σ can be added to the transfer equation.

In 1950's it was realised that LTE is not applicable to solar and stellar chromospheres. Hence quasiempirical non LTE models of chromospheres and their effect on the disk spectrum were considered. In 1960's the non-LTE treatment was extended to photospheres also, which gave improved line profiles and abundances. Now the departure from LTE requires no new physics, we only need better computational techniques as provided by the modern fast electronic computers. The usual procedure is to obtain improved observational data and fit them to computed models. First we try the LTE approach and if it fails we go to non-LTE methods. In these we put all the necessary physics (such as spectroscopy, thermodynamics, hydrodynamics, magnetic fields, etc.) and the complexities (like inhomogeneities, turbulence, velocity gradients, etc.) into large computers and obtain a model which fits all the data. By this procedure, we get better values of abundances and turbulence parameters as well as predictions concerning polarization, molecular species, etc. The questions to be considered in the coming decade are : Can the simpler curve of growth method be extended to non-LTE situations ? Is it possible to find a new theorem which will enable individuals, who do not have large computers, to make non-LTE computations on a 'do-it-yourself-kit' basis ?

As far as the 'extended' stellar atmosphere's therory is concerned, we must use the fluxes from the 'interior' storage models and obtain a model atmosphere which smoothly merges into the interstellar medium. Here we have to consider not only the radiative flux but also the flux of mass which is evident from observations. The mass motions must be related to the photon transport. Inside the star we have an LTE screen which leaks radiation and matter at the boundary. Hence radiative transfer must be studied along with the hydrodynamic transfer of energy by mass outflow. Some of the interesting problems which the 'extended' theory will have to tackle are : Abundence variations in stars ; Circumstellar envelopes and their relation to the interstellar mediun ; Protostars in which shock wave serves as a photosphere; Inhomogeneities involving time dependent radiative transfer ; Chemistry of molecules ; Study of complex objects like ϵ Aur ; and Thermodynamics of stellar atmospheres.

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A REPORT ON COLLOQUIA COPERNICANA

The Colloquia Copernicana, to mark the quincentenary birth anniversary of Nicholas Copernicus were held at Toruń (Poland) between September 5-12, 1973. The colloquia were organised by the Polish Academy of Sciences in cooperation with the International Union of History and Philosophy of Science, UNESCO and the International Astronomical Union. The scientific programme of the Colloquia was organised in the form of four symposia, each consisting of about two sessions, namely:

- I The Astronomy of Copernicus and its Background.
- II Man and Cosmos.
- III The Reception of the Heliocentric Theory.
- IV Copernicus and the Development of Exact and Social Sciences.

The first Symposium, which was historically the highlight of the Colloquia, was initiated by W. Hartner (Frankfurt) with an introductory review paper on the Astronomical Background, i.e., the Islamic antecedents of Copernicus. Hartner began his talk by a quotation from Abū-Naṣr Ali (Al-Birūni's teacher, 11th century) about the planetary "elliptical" orbits. According to Hartner, Abū-Naṣr refuted the two natural motions of Aristotles, i.e., the rectilinear (finite) and circular (infinite), and he talked about some kind of ellipses although in ambiguous terms. Hartner wondered why Ibn Al-Haithan and Al-Birūnī could not notice the inconsistency of the Ptolemic lunar theory, since lunar evection could not be explained by the hypothesis of perfect uniformity. He also mentioned similarities of Peuerbach's and Azakael's elliptical motion. According to him there were many Islamic astronomers who were interested in the idea of elliptical motion, although they did not wish to renounce Aristotle altogether. Hartner then discussed especially the works of Qutbuddīn, Ibn Shātir, and Naṣīruddīn Tūsī. Finally he projected two diagrams, one from Copernicus' and the other from Naṣīr Al-Tūsī's work, which everyone saw to be identical even in the lettering. Hartner propounded the thesis that there should be some mode of transmission of Islamic astronomy to Copernicus, which has yet to be discovered.

The next paper of Miss G. Rosińska (Cracow) on the Islamic Tradition in Cracow was therefore very appropriate. Miss Rosińska is collecting a bibliography of Arab astronomical works which could be extant at that time at the Cracow University and she is also studying the work of Cracow astronomers to look for the reception of Arab astronomy. She is of the opinion that most probably Cracowian (models of) astronomy could be thought of as the link between the Arab and Copernicus' astronomy. A preliminary investigation indicates the hypothesis to be true for the Lunar Theory

David A. King (Cairo) presented a short survey of the Islamic Astronomical Tables, which, in his opinion are based on complicated trigonometrical formulae. Besides that, King said, that the Muslim astronomers also tried to simplify the use of the planetary equation table based on the Ptolemic model. Such tables have in fact many thousand entries. He suggested that the accuracy of these tables should now be worked out and the achievement of the Arabs should be re-estimated in the light of the new findings.

The last two papers in this session were read by W. Petri (Munich) : Earth's Rotation in the Aryabhatas and by S. N. Sen (Calcutta) : Indian Planetary Theories of Ancient and Medieval Times. Prof. Petri pointed out that whereas Aryabhata's rotation of the earth was a