Report No. 7

on

Contract AF 19(604)-41

J. Allen Hynek July 25, 1953

THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION

Report No. 7
RF Project 430

REPORT

By

THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION

COLUMBUS 10, OHIO

Cooperator AF CAMBRIDGE RESEARCH LABORATORIES
230 Albany Street, Cambridge 39, Mass.
Contract AF 19(604)-41

Investigation of FLUCTUATIONS OF STARLIGHT AND SKYLIGHT

Subject of Report Progress for the Period

April 1, 1953 - June 30, 1953

Submitted by J. Allen Hynek

Date July 25, 1953

ABSTRACT

Scintillation studies with the photoelectric photometer were continued but with some diversion of effort into motion picture photography of image motion and image pulsation.

Successful movies of bright stars in noontime daylight were obtained, revealing a wealth of information on image form and motion in the daytime stellar image.

Photoelectric studies were extended to a close double star (Castor) and it was shown that the images of this close double (2.6 seconds of arc) scintillated independently of each other, whereas the motions and sizes of the individual components varied synchronously.

Studies of artificial sources 1000 feet from the telescope were begun.

PERSONNEL AND ADMINISTRATION

The only change in personnel was the addition of a computing assistant, Miss Ann Smith, on April 15, 1953. The addition was made because of the lengthy computations involved in the reduction of magnetic tape stellar scintillation records.

Facilities at the University continue to be adequate and all equipment is in reasonably good operating condition.

COMMUNICATIONS

Two additional scientific reports were prepared for publication during this period. Scientific Report No. 2 in the series on fluctuation of starlight, entitled "An Experiment at the Telescope on Three Criteria of Astronomical Seeing: Image Motion, Definition, Photoelectric Scintillation," by Roger Hosfeld, was printed in a limited edition during May, 1953 preparatory to a larger issue expected to be made at Cambridge.

Scientific Report No. 3 entitled "Experimental Verification of a Recently Proposed Theory of Astronomical Seeing," by Geoffrey Keller and Robert Hardie, now awaits only instructions from Cambridge as to the preferred method of reproduction.

It is planned that both scientific reports will also be published in recognized astronomical journals.

Dr. Hynek gave talks on "Stellar Scintillation" at Vanderbilt University on May 14 and at the Barnard Astronomical Society in Chattanooga on May 15.*

A visit to Dr. Hall and his associates at the Naval Observatory was made by Dr. Hynek on June 1 in order to exchange progress notes on the cooperative program in stellar scintillation being carried out by that observatory and the McMillin Observatory. The mutual exchange of ideas in this and past conferences has been heartening, and has led to a tentative plan for a general conference on stellar scintillation and astronomical seeing to be held at Columbus in the autumn of 1953.

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* An interesting sidelight at Chattanooga was the first radio broadcast, over WAPO, of a tape recording of stellar scintillation, prepared by Mr. Protheroe, of this project. Since the frequencies of scintillation are in the audio range, the listeners heard a low-pitched rumble.

STATEMENT OF THE PROBLEM AND METHOD OF ATTACK

A full statement of the problem and the approaches being used was given in the previous progress report (No. 6), to which reference is made. Further development of the mode of attack can be gathered from the following summary of significant results obtained during the present report period.

SUMMARY OF SIGNIFICANT RESULTS OBTAINED DURING REPORT PERIOD

Some diversion of effort from straight scintillation measures in the direction of image motion study was made, as planned. These new measures corroborated previous project results on the basic independence of scintillation and image motion. Five observational items are worthy of note during this period:

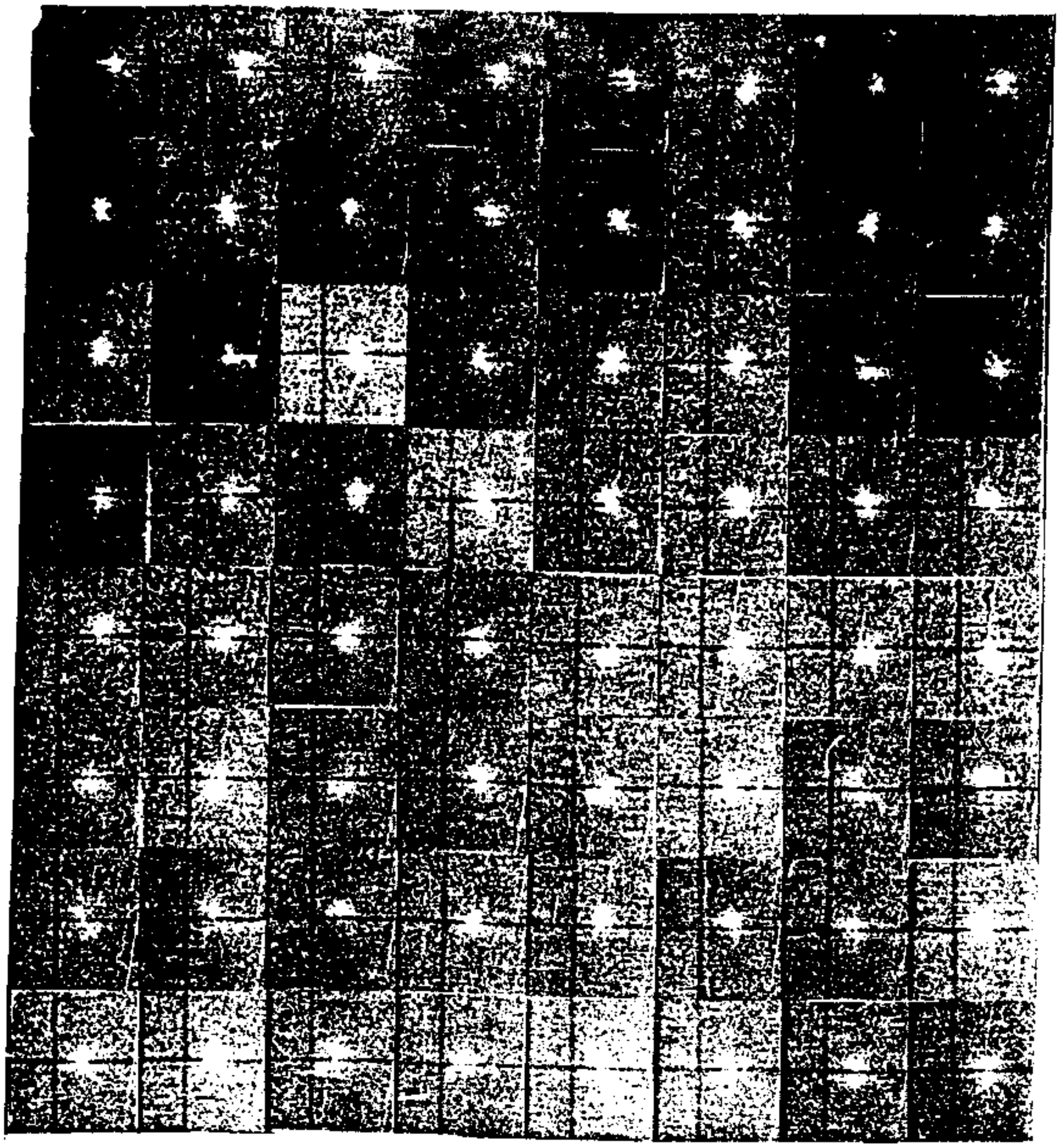
1) Daytime motion pictures of the star Capella were taken from which initial measurements of image motion and changes in image size were made.

The image motion, from measures on 64 frames (2 seconds running time), at 1:30 P.M. on April 21, 1953, was 3 seconds of arc radially from the mean position. Actual measures were made in the N-S and E-W directions. Some tendency for correlation between the North and West excursions was evident; i.e., a preferential motion of the entire image in the NW-SE line appeared to exist in so far as the 64 frames under consideration were concerned.

The size of the image, on the other hand, fluctuated between five and ten seconds of arc.

The accompanying photograph shows all 64 frames (actually only 63, as No. 2 and No. 3 from the left in the top row were inadvertently made identical) used in the preliminary measures. The successive frames are arranged in rows, with frame No. 1 at the upper left corner, Nos. 2, 3, etc. aligned to the right along the top row. It will be noted that no two images are alike except the two inadvertently identical prints. Note expecially frames 49, 50, 51 (second row from bottom, 1, 2, 3 from left) which illustrate the large changes in image shape which can occur in 0.1 second elapsed time. It should be remembered that these movies were taken in bright daylight.

2) The question had frequently arisen as to whether the components of a close double star scintillated together or



0" 25" 30"
Scale, Seconds Arc

Capella: 21 April 1953 1:30 PM
32 Frames per Second

Variations in the Size and Position of the Daytime Image of Capella

separately; i.e., whether or not scintillation was coherent. To answer this, the integrated scintillation (below 10 cps with the Brown recorder) of the close double star Castor was compared with the scintillation of the neighboring single star Pollux (same elevation angle). If the components of Castor (magnetudes 2.0 and 2.8, separation 2.6 seconds of arc) scintillate in phase, the recorder trace pattern should be indistinguishable from that of a single star; if, however, the intensity variations of the two stars were out of phase, the scintillation should be reduced, as it is in the case of extended sources like the planets, and for the same reason.

The recorder traces clearly showed less percentage scintillation from Castor, the double star, than from Pollux, the single star. Thus, the scintillation of double stars whose components are as close as 2.6 seconds of arc is not coherent, and the limiting separation below which scintillation is coherent must be below 2.6 seconds of arc. Looked at physically, this observation, made by Mr. Hosfeld, made with the 12.5-inch refracting telescope of the McMillin Observatory, means that two 12.5-inch cylindrical light paths through the earth's atmosphere, coincident at the telescope and diverging by only 2.6 seconds of arc, undergo independent intensity variations.

It should be noted that the comparison star, Pollux, does not have the same color as the double star, Castor, but this cannot account for the difference in scintillation since it has not yet been possible to establish any difference in scintillation with color using the full aperture of the telescope.

3) Next, it was of interest to determine whether the motions of the component images of the same double star were also incoherent. Motion pictures of Castor were taken for this purpose. A frame by frame examination of the photographs (taken at 8 frames per second) showed the two images moving as a unit with a relatively fixed spacing.

The sizes of each image of the components of this close double star also appeared to vary synchronously. When the image of the brighter component expanded, the fainter component (a threshold image) would disappear; when the bright component became condensed, the fainter reappeared.

These observations showed that image size and motion are largely coherent for closely spaced double stars, whereas scintillation is primarily incoherent.

In a previous report (Progress report No. 6) it was demonstrated that image motion could be affected independently of scintillation (by introducing a stream of warm air

near the telescope); here we find an actual difference of character in these two parameters of a stellar image under normal conditions.

4) An experiment demonstrating further that scintillation is not produced near the telescope was performed by measuring the integrated scintillation of a flashlight bulb on a building 1000 feet from the telescope. The scintillation of this effectively "point" source was found to be 1 per cent of the total signal whereas the value for a star at the zenith (where stellar scintillation is a minimum) is about 10 per cent. Placing a heated coil from a hot plate under the flashlight bulb increased the scintillation to about 3 or 4 per cent of the total signal. Even this marked thermal disturbance, therefore, failed to produce scintillation equal to the minimum observed in stars.

5) The out-of-focus image of a star shows the familiar shadow patterns frequently mentioned in the literature. These can be recorded by motion pictures. It was of interest to determine whether similar patterns could be observed in an out-of-focus image of a nearby artificial light.

A 60-watt lamp was placed on the building 1000 feet from the telescope and motion pictures of the out-of-focus images were taken. Exposures at 64 frames per second showed shadow patterns having continuity across the image and moving with the direction of the wind. The size, spacing, and velocity of the pattern elements have not yet been determined.

The experiment demonstrates that the existence of well-marked shadow patterns does not necessarily imply the presence of scintillation of the image.

The program of harmonic analysis of stellar scintillation, the other major branch of the present project work, was seriously retarded by circuit troubles and the presence of spurious noise.

The instrumental noise associated with the tape recorder, an integral part of the apparatus for this program, was finally found to be located primarily in the tape transport mechanism. Since the present recorder used a frequency modulation system rather than the more customary amplitude modulation technique, variations in tape speed set the lower limit on the signal-to-noise ratio.

A new transport mechanism (Magnecorder PT6-AH) was incorporated into the recording system after long, discouraging attempts to use the original mechanism showed that it had to be abandoned. Slight circuit additions were made to match the new recording head to the basic circuitry. This change has resulted in a greatly improved signal-to-noise ratio as well as an increased permissible amplitude variation in recording.

The new equipment is still under test. A preliminary star recording indicates that the recorder and associated circuitry is now showing a more normal behavior.

FUTURE WORK

Emphasis during the coming period will undoubtedly be on the harmonic analysis of daytime stellar scintillation, if the promise of proper functioning of the electronic apparatus is fulfilled. Stars at various zenith distances will be run to delineate further the occurrence of variations in the frequency-amplitude curve. It is also anticipated that square and rectangular as well as the usual circular apertures will be used, in various orientations, to check preferential motion of shadow patterns across the objective.

Work on integrated scintillation studies and its correlation with image motion and pulsation will be continued by Mr. Hosfeld. In particular, Mr. Hosfeld will complete the measures on the motion pictures already taken.

NOTE: In submitting this report it is understood that all provisions of the contract between The Foundation and the Cooperator and pertaining to publicity of subject matter will be rigidly observed.

Investigator Ruben H. Hosfeld Date 28 July 1953

W. M. Scotten 28 July 1953

Supervisor J. A. Hynek / RH Date 28 July 1953

For The Ohio State University Research Foundation

Executive Director Oram C. Woolpert / RH Date 7/29/53