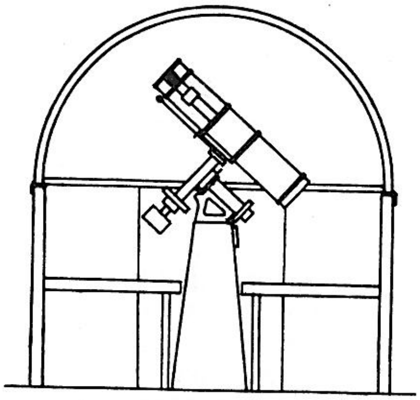

THE SPECTRUM

BUFFALO ASTRONOMICAL ASSOCIATION INC.
BUFFALO MUSEUM OF SCIENCE
HUMBOLDT PARKWAY
BUFFALO NEW YORK 14211

APRIL 1970

APRIL MEETING: For our meeting of April 11, 1970 (8:00 PM, EST, at the Museum) we have arranged a very colorful program entitled TOTAL SOLAR ECLIPSE 1970, to be presented by a number of our members, including Dale Hankin, Larry Hazel, Walter Semerau, Walter Whyman and others. We invite anyone and everyone who observed the recent eclipse and who took photographs to participate in this program. Please be prepared to give a short talk (5-10 minutes) and bring your slides. See Ernst Both before the meeting to arrange your presentation. Talks should be informal. The main idea is to let your fellow members share in your experiences. Refreshments will be served. This is your chance to find out what others did during this memorable eclipse.

* * *

All members who submitted photographs for the recent Astrophotography Exhibit may pick them up at the April Meeting. We are making plans for a second exhibit to take place sometime in the fall or winter of 1970 - please plan to submit new photographs.

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* TRANSITS OF MERCURY * By Dr. Frederick R. West

On May 9, 1970, the Sun will rise above the Buffalo horizon with Mercury visible in front of the Sun's disk. When the disk of an inferior planet like Mercury appears to cross the Sun's disk, the planet is said to transit the Sun. The transit of May 9, 1970 is predicted to end at 7h 13m EST, approximately two hours after sunrise (see the RASC's OBSERVER'S HANDBOOK FOR 1970, p. 63). Transits of the inferior planets occur at some aspects of inferior conjunction, when the planet passes between the Earth and the Sun. The average time interval between successive aspects of inferior conjunction for a given planet (Mercury or Venus) is the synodic period of the planet.

To determine if an inferior planet will transit the Sun at a given aspect of inferior conjunction, we have to consider the five orbital elements which determine the size, shape, and space orientation of the planet's orbit. These are: a = the mean Sun-planet distance in astronomical units; e = the orbital eccentricity; i = the inclination of the planet's orbit to the ecliptic; Ω = the celestial longitude of the ascending node of the planet's orbit (=the intersection of the orbit with the ecliptic where the planet goes from south to north of the ecliptic); and $\tilde{\omega}$ = the celestial longitude of the planet's perihelion point. These elements are listed in Table I for Mercury and the Earth, along with Mercury's synodic period. The space geometry of the Sun (S), planet (P), and the Earth (E) is shown in Figure A. If a planet is to transit the Sun at any given inferior conjunction, its space distance (z) from the plane of the ecliptic must then subtend an angle at the Earth ($\lambda_{\oplus}$) that is less than the apparent radius of the Sun; otherwise the planet will cross to the north or south of the Sun at inferior conjunction. Figure B shows the relationship between the ecliptic, the planet's orbit, with the angle i between the ecliptic and orbit at the nodes, and the planet's arc distance λ_p from the ecliptic as seen from the Sun. By trigonometry we can show that from the orbital elements and Figures A and B for a transit to occur, the arc distance NP of the planet from a node of its orbit must be only a few degrees at most. Therefore, transits do not occur at most aspects of inferior conjunction.

Mainly because of its orbital eccentricity, conditions of a transit of Mercury differ considerably for transits occurring near the ascending node (shown in Figure B) and those that occur near the descending node. For a transit of Mercury to occur, inferior conjunction must take place when Mercury is closer than 4° 46' to the ascending node (those inferior conjunctions that now occur between November 6 and November 16), or is closer than 2° 40' to the descending node (inferior conjunctions now occurring between May 6 and May 11). Thus transits can happen only for inferior conjunctions that occur over a total arc length of 14° 52' out of Mercury's 360° orbital arc around the celestial sphere, or on an average of at one inferior con= junction in 24, that is, only once every 7.7 years. Also an average of nearly twice as many transits will take place in November than in May. Transits that have or are predicted to occur between 1950 and 2000 are listed in Table II. A total of 8 transits will occur, with two in May and six in November. The author observed the last transit of Mercury on November 7, 1960 at Indiana University's Kirkwood Observatory as a member of a 4-man observing team under the direction of Dr. James Cuffey.

Mercury's orbital eccentricity also causes considerable variation in the time interval between successive aspects of inferior conjunction. Although Mercury's synodic period is 115.88 mean solar days, the actual interval between inferior con= junctions can range from 106 mean solar days (if the inferior conjunctions occur 52° on either side of perihelion) to 129 mean solar days (for inferior conjunctions 62° on either side of aphelion). For example, the interval between the last inferior conjunction on January 13, 1970 and the one which will occur May 9, 1970 will be 116 days, while the interval between that and the one of September 13, 1970 will be 126.4 days. Also because of its orbital eccentricity, Mercury moves much more slowly in its orbit at the descending node in May ($2^\circ.95$ per day) than at the ascending node ($6^\circ.07$ per day). At inferior conjunction, Mercury appears to us to move retrograde (from east to west) on the celestial sphere; from geometry, the apparent westward rate of motion of its disk across the Sun is about 1° 36' per day near the descending node (May), and about 2° 21' per day near the ascending node (November). Therefore the maximum possible duration of a transit at the descending node is considerably longer (7h 55m) than one at the ascending node (5h 31m). The transit of May 9, 1970 will last 7h 53m, close to the maximum possible. For observatories in Europe and the western half of the Soviet Union, the Sun will be above the horizon for the entire transit.

Like eclipses of the Sun, transits of Mercury are not random events, but instead tend to recur at definite intervals, as an inspection of Table II shows. The condition necessary for a series of transits to recur at a definite interval of time is that the time interval must be an integral number of synodic periods of Mercury that nearly equals an integral or half-integral number of sidereal periods of Mercury and an integral or half-integral number of sidereal (Earth-) years. Six of these intervals of less than 50 years between successive transits in the series are listed in Table III, with the lengths of the integral number of synodic periods, the integral or half-integral number of sidereal periods, and the integral or half-integral number of sidereal years in mean solar days listed for each interval; this alllows comparison of differences between the three periods for ech interval. The best intervals (where the differences between the three periods are least) are the ones of 46 and 16.5 sidereal years.

The May 9, 1970 transit is one of a series of transits separated by 16.5 years; we see in Table II that the transits of November 14, 1953 and November 13, 1986 are some of the other transits in this series. Although they are not listed, it is very likely that transits of Mercury will occur in May 2003 and November 2019 in this series. As many as 7 transits can occur in such a series, which would require 99 years to complete. In a series of transits separated by intervals of 46 years, as many as 23 transits spanning a total of 1012 years can occur. The transits of November 14, 1953 and November 15, 1999 form part of such a series. * * /To be concluded in the May issue/. * *

TABLE I: Orbital Elements - (Mercury's Synodic Period = 115.88 days)

	a	e	i	Ω	ϖ
Mercury	a= 0.3871	e= 0.20563	i= 7°00'15"	Ω = 47°59'	ϖ = 77°00'
Earth	1.0000	0.0169	0°00'00"	------	102°18'

TABLE II: Dates of Mercury Transits; A= ascending node, B= descending node

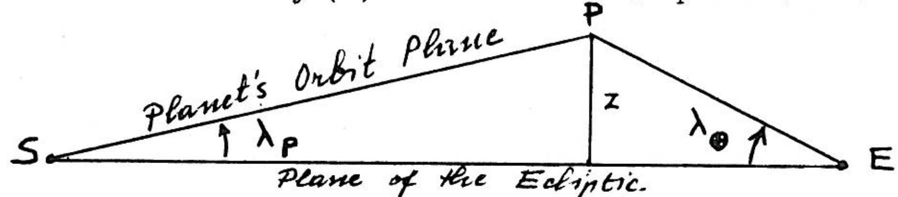
November 14,	1953	A	November 10,	1973	A
May 6,	1957	D	November 13,	1986	A
November 7,	1960	A	November 6,	1993	A
May 9,	1970	D	November 15,	1999	A

TABLE III: Intervals at which series of Mercury Transits recur

1)	3.5	sidereal years	=	1,278.396	mean solar days
	11	synodic periods of Mercury	=	1,274.68	"
	14.5	sidereal " "	=	1,275.54	"
2)	9.5	sidereal years	=	3,469.932	"
	30	synodic periods of Mercury	=	3,476.32	"
	39.5	sidereal " "	=	3,474.76	"
3)	13	sidereal years	=	4,748.332	"
	41	synodic periods of Mercury	=	4,750.98	"
	54	sidereal " "	=	4,750.30	"
4)	16.5	sidereal years	=	6,026.73	"
	52	synodic periods of Mercury	=	6,025.63	"
	68.5	sidereal " "	=	6,025.89	"
5)	20	sidereal years	=	7,305.127	"
	63	synodic periods of Mercury	=	7,300.31	"
	83	sidereal " "	=	7,301.43	"
6)	46	sidereal years	=	16,801.793	"
	145	synodic periods of Mercury	=	16,802.237	"
	191	sidereal " "	=	16,802.09	"

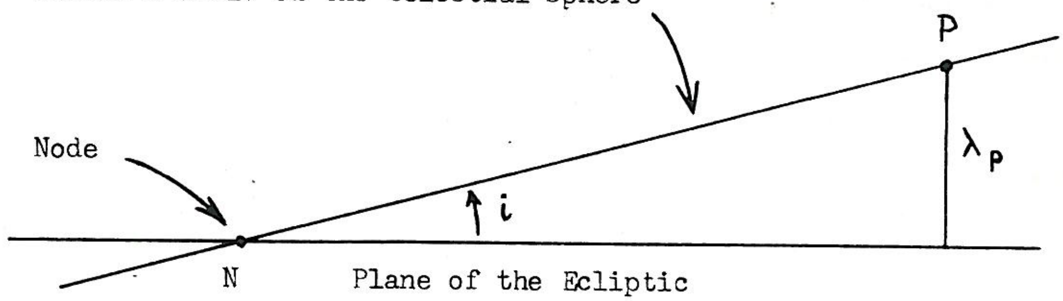
FIGURE A: Geometry of the positions of the Sun (S), an inferior planet (P) and the Earth (E) relative to plane of the ecliptic at the aspect of inferior conjunction. (z) is the distance of the planet from the plane of the ecliptic and λ_P and $\lambda_\oplus$ are the arc distances subtended by (z) on the celestial sphere at the Sun and Earth respectively.

FIGURE A:



The geometry of the ecliptic, the planet's orbital path on the celestial sphere, the inclination (i) of the orbital path to the ecliptic at the ascending node (N) and the arc subtended by (z) at the Sun for an arc distance NP of the planet from the node.

FIGURE B:



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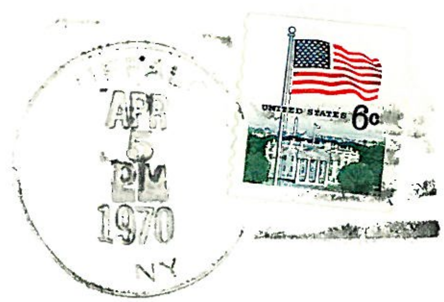

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