50 Years of Grazing Occultations

2012 August 25, Pescara, Italy

31st European Symposium on Occultation Projects

David W. Dunham, IOTA

Grazing Occultation Geometry

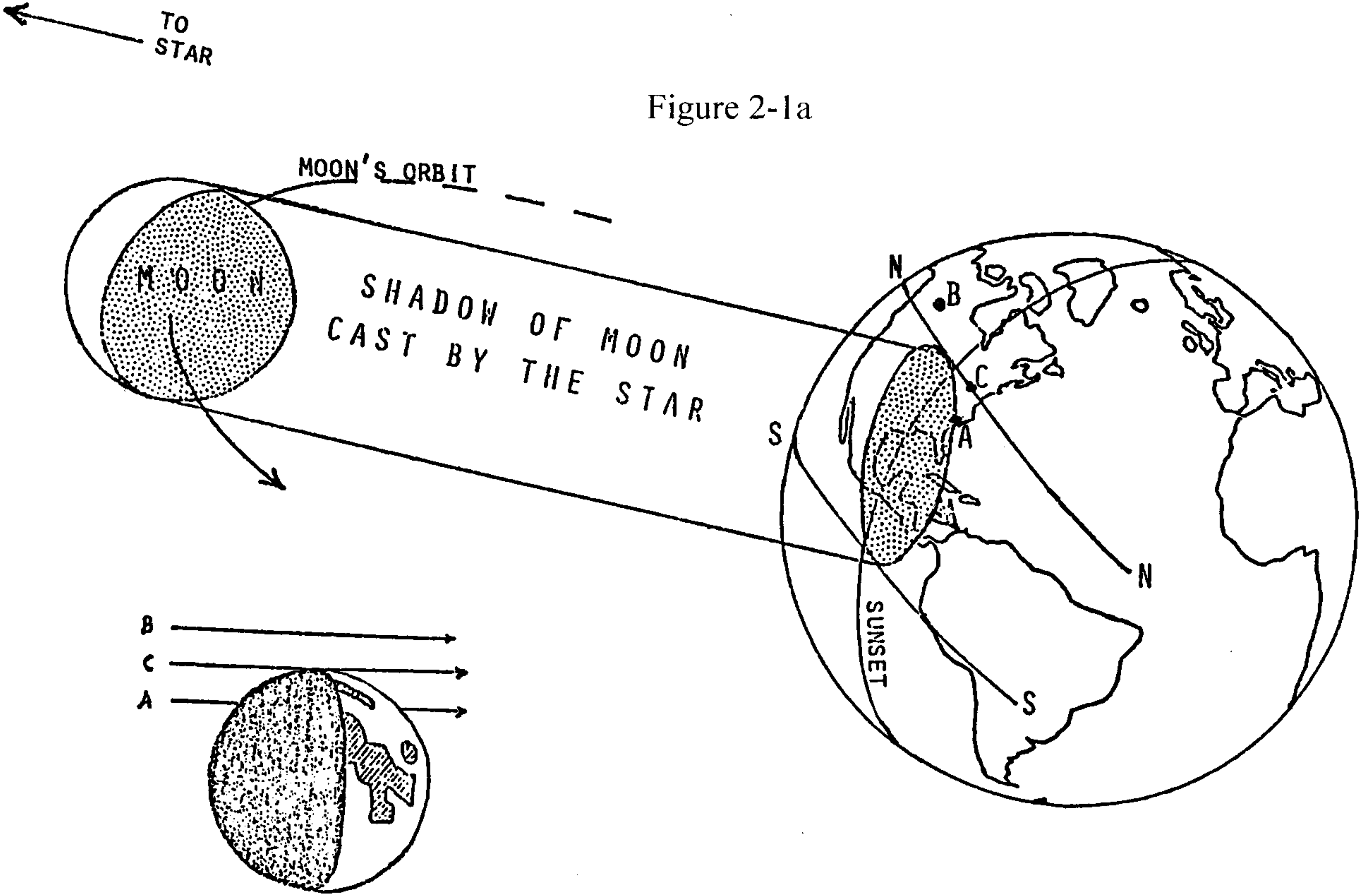


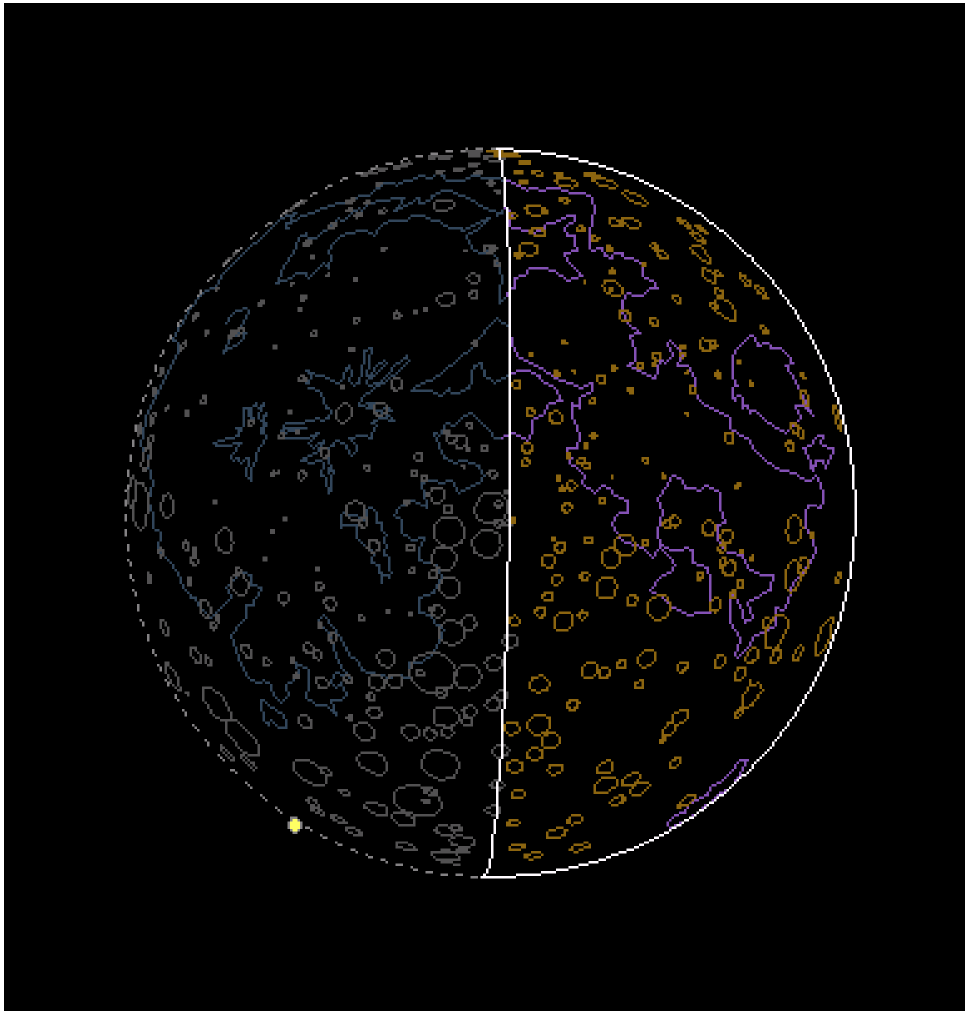
Figure 2-1a

Figure 2-1b

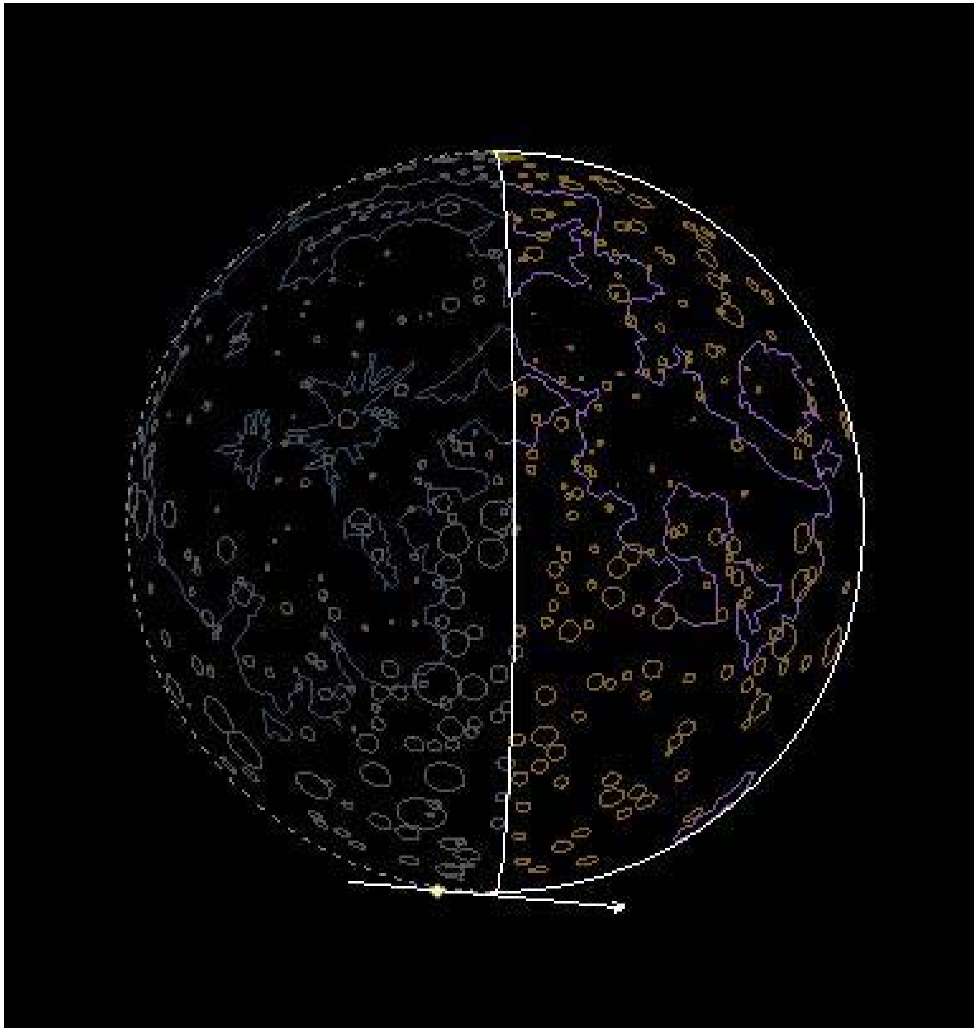
Moscow Institute of Electronics and Mathematics – 50^{th} Anniversary

- I am working at MIEM during 2012 and 2013 with a “megagrant” from the Russian Ministry of Education and Science
- to study optimal trajectories for human space exploration and planetary protection (from hazardous asteroids); that’s another long story
- I was at MIEM in late June when they had their 50^{th} anniversary celebration; I was asked to say a few words
- I thought for a moment, 1962, that was an important year for me, too
- It was the start of my professional career, when I first really did something about grazing occultations,
- making the first computer predictions and mobile expeditions to observe them, and
- reaching out to observers around the world to encourage them to observe these spectacular events
- It was the real start of the International Occultation Timing Association, not yet with that name, but with its intent

The concept of grazing occultations occurred to me earlier, when I was 15 years old. Below is an Occult view of the disappearance of 6.1-mag. β^1 Capricorni from La Cañada, California, October 29, 1957 at 9:25 pm PST; I observed it there from my backyard with a 60mm refractor



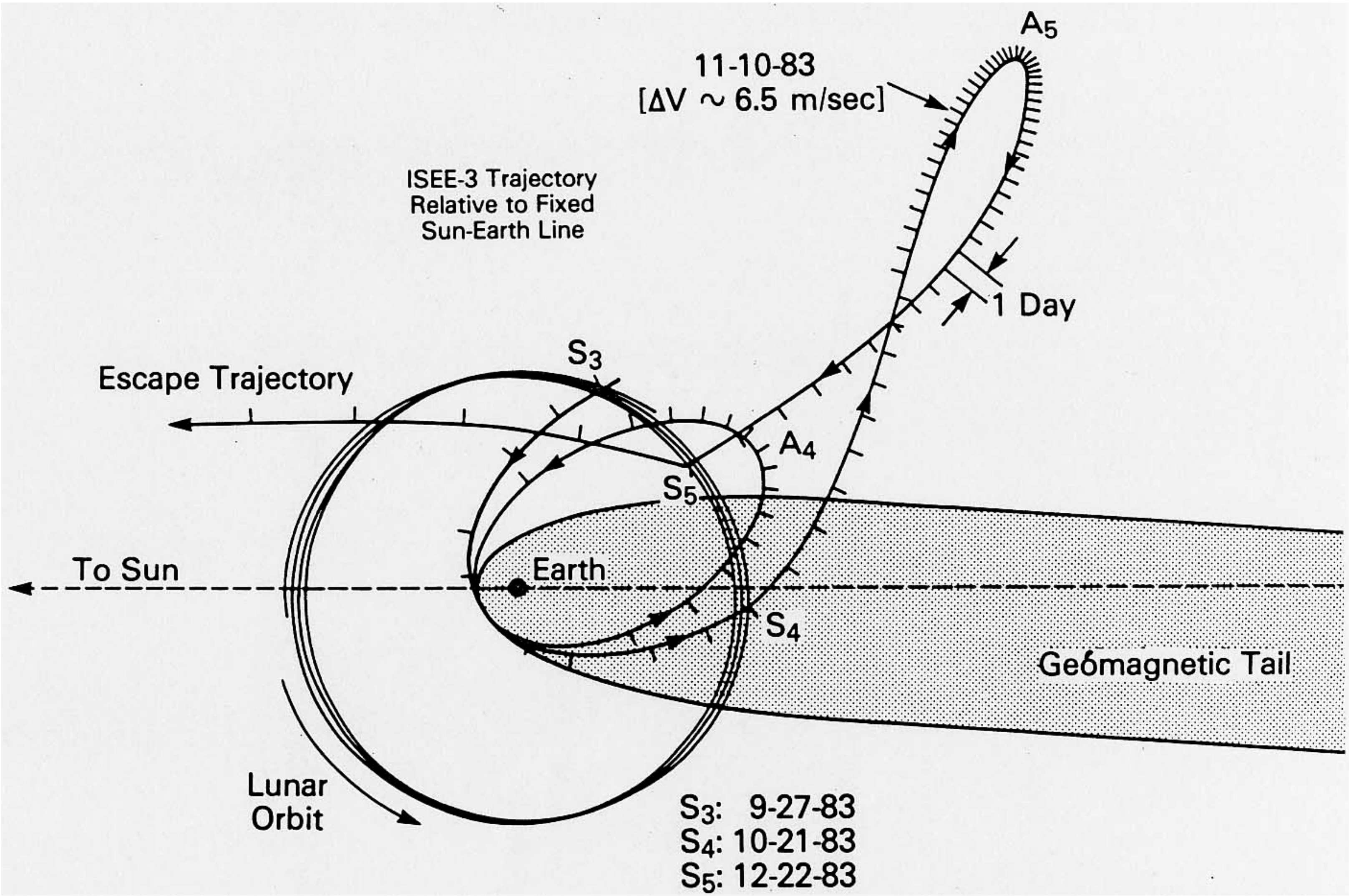
Appulse of 3.1-mag. β^2 Capricorni from La Cañada, California, October 29, 1957, min. dist. 5″ at 9:47 pm PST; I was amazed at that sight, I could see the Moon's motion, the star looked like a spacecraft flying over the Moon. I could see the star's position change from second to second as it passed over the Leibnitz mountains, a real-time view of celestial motion

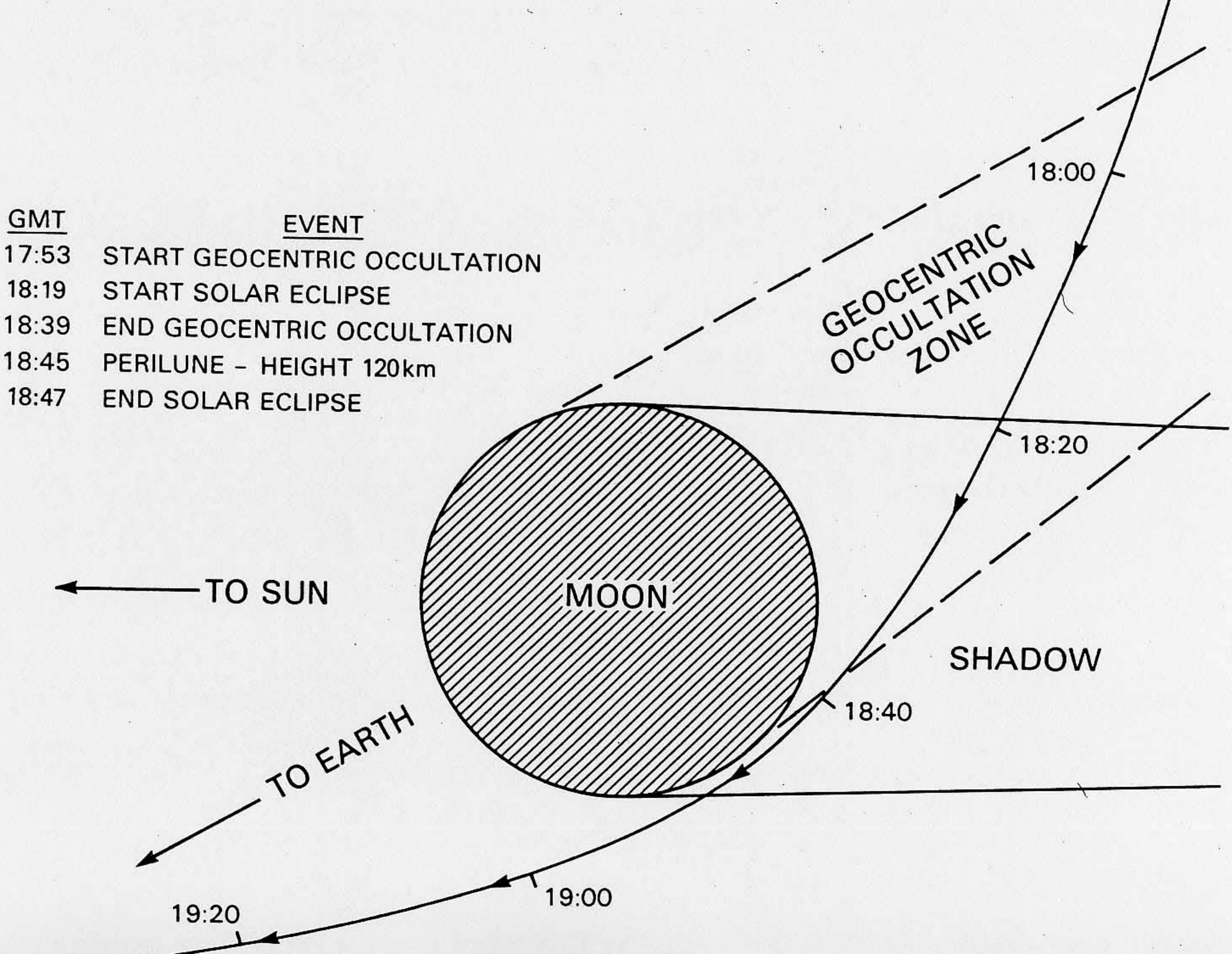


Southern Limit of the β^2 Capricorni Occultation, 1957 October 29

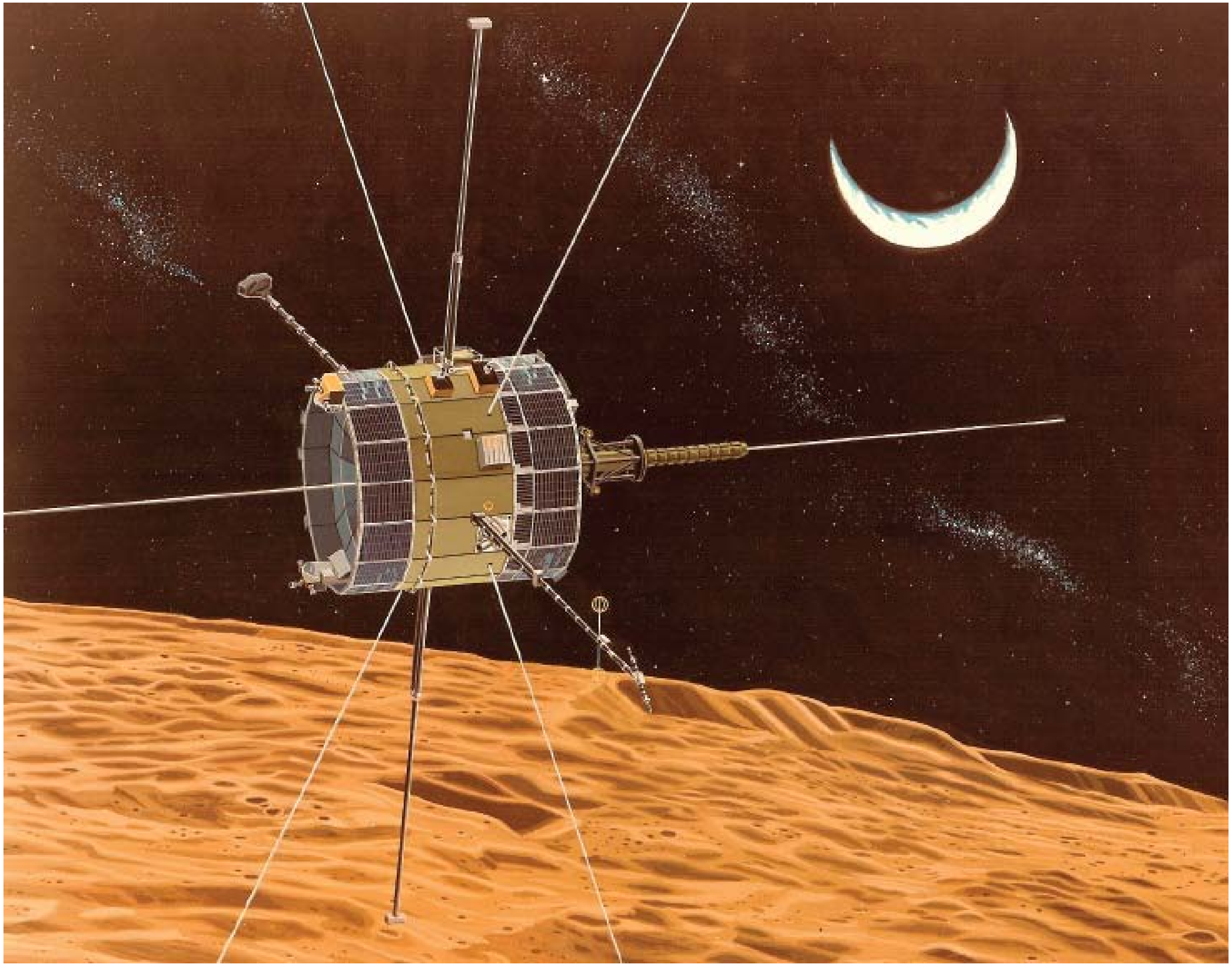
I was puzzled why I did not have an occultation when one was predicted. Then I realized that the prediction was for a station 300 km nw of me, but no event was given for another station 500 km east of me. I had the idea of a grazing occultation, with multiple events of the star by lunar mountains near the southern limit, which must have been just a few km north of me. I thought it would be neat if someone could compute those lines, but I thought I could never do anything that complicated. At that young age, I underestimated my future ability.

26 years later, I computed the trajectory for flying the 3rd International Sun-Earth Explorer (ISEE-3) spacecraft over the Moon, a gravity assist that resulted in the first comet flyby, of Giacobini-Zinner, in Sept. 1985

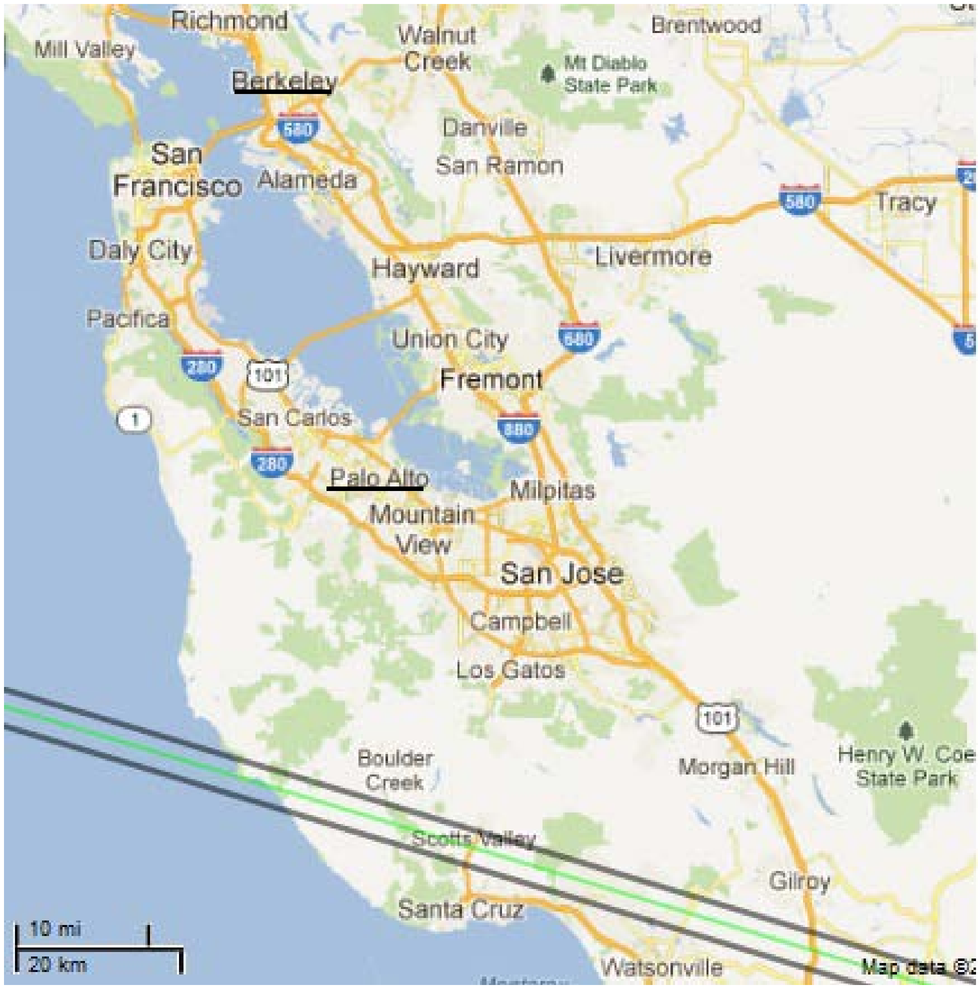



GMT EVENT
17:53 START GEOCENTRIC OCCULTATION
18:19 START SOLAR ECLIPSE
18:39 END GEOCENTRIC OCCULTATION
18:45 PERILUNE - HEIGHT 120km
18:47 END SOLAR ECLIPSE
18:00
GEOCENTRIC OCCULTATION ZONE
18:20
TO SUN
MOON
SHADOW
18:40
TO EARTH
19:00
19:20

My 1957 vision of a spacecraft flying over the Moon was realized, but that's another long story.

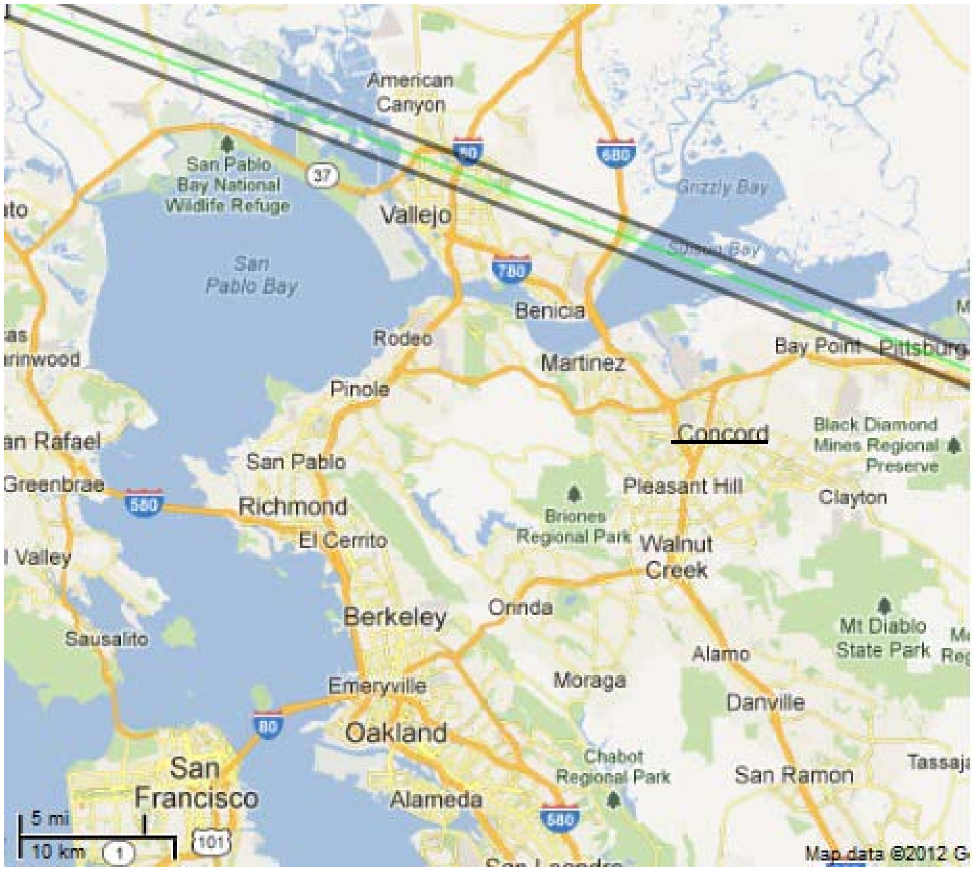


Last Aldebaran Graze of 1959 – 1962 series in California occurred on 1962 March 12



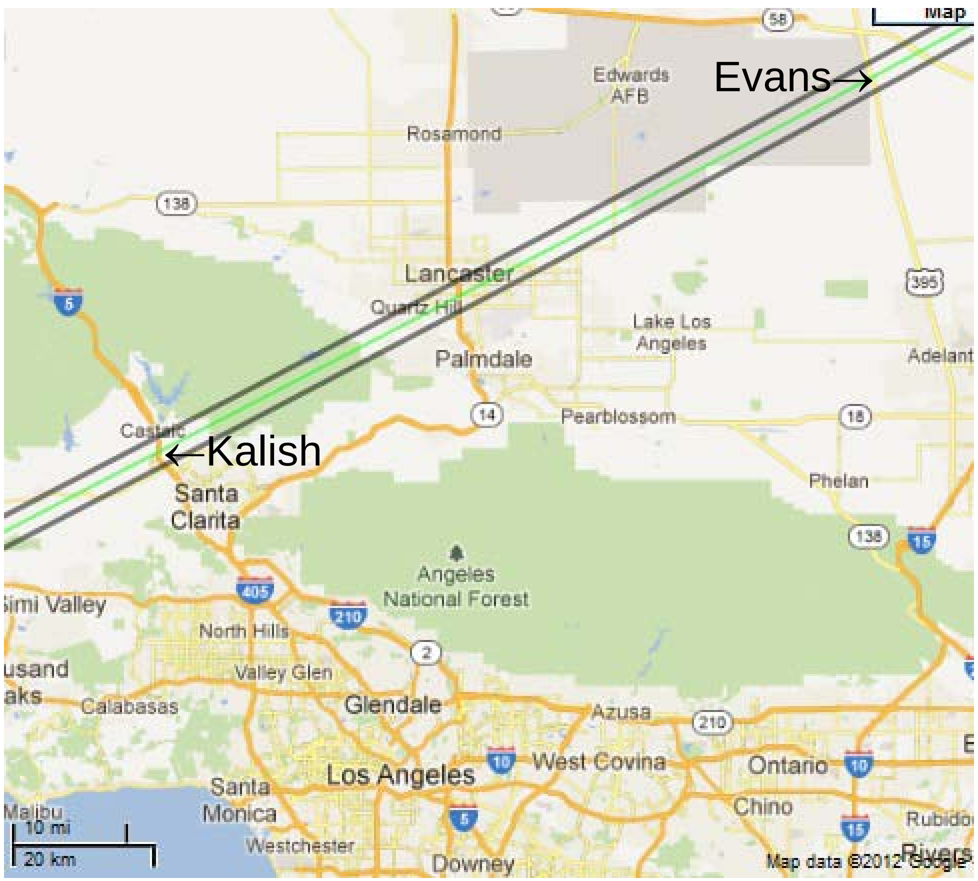
I had completed a course in solid geometry at the Univ. of Calif. At Berkeley shortly before this event, and realized, maybe I could work out the equations and compute it. I started Sat. morning March 10 (event local time was Sun. evening March 11) but the hand calculations using trig function tables and a clunky Marchant calculator were harder than expected; less than 2h before, I had calculated 6 points from Arizona to near Santa Cruz, and convinced a grad student to drive me there. We didn't make it to the limit; while crossing the Bay on the Dumbarton Bridge, using binoculars, I saw the star had disappeared. At Palo Alto, I quickly set up my 60mm refractor and saw Aldebaran reappear on the bright side, coming out like a drop from a faucet; I realized that was close enough to the limit to see the star's angular diameter! The chase for grazes was on!

1962 April 10th expedition to Concord, Calif., for a graze of 5.1-mag. 64 Orionis by the 33% sunlit Moon



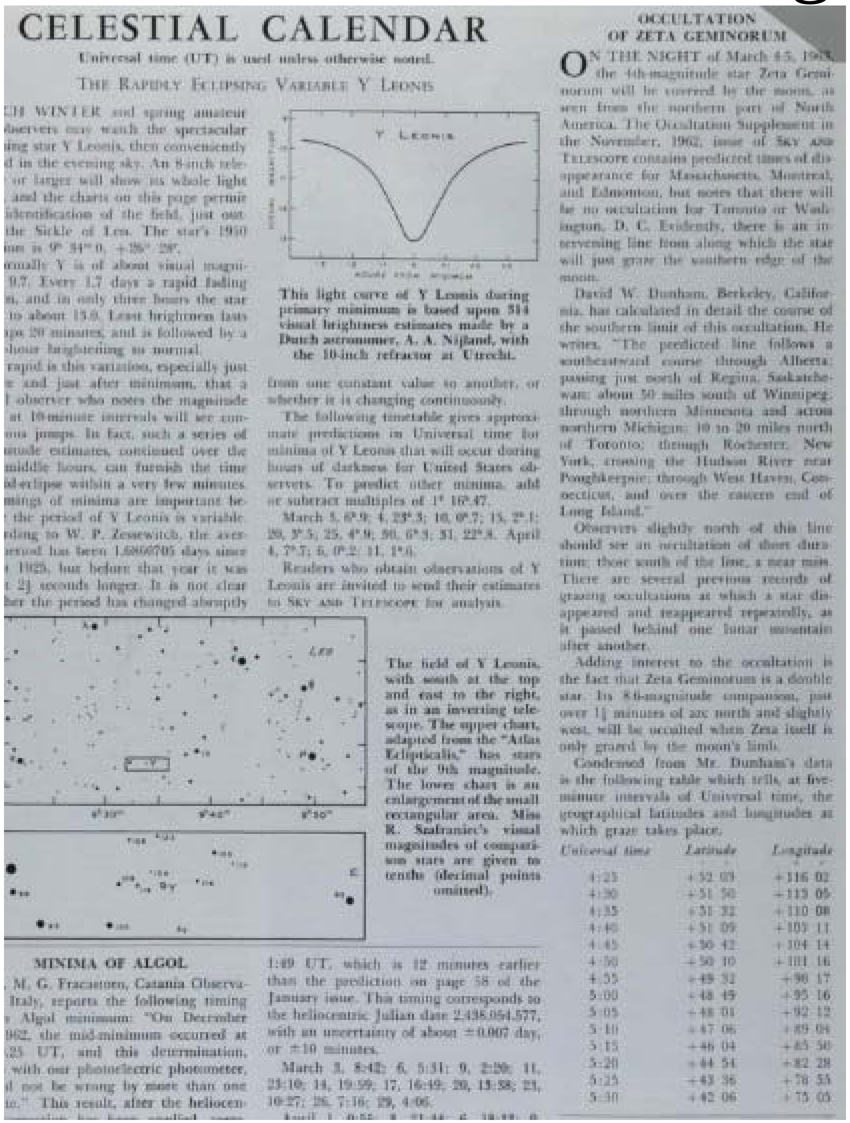
This promised to be a good event, so I computed the path well in advance, and worked with Jack Borde, leader of the Walnut Creek Moonwatch Team, to time the graze from 4 locations across my predicted limit line (I had no lunar profile predictions then). But the prediction was wrong and we all had an 8-min. occultation, with the R at the n. cusp occuring at my predicted time. I discussed my calculations with Prof. Cunningham and he pointed out that I needed to take into account the motion of the observer. This made the calculations harder (needed to iterate) but now accurate enough to locate in the real graze zone.

Len Kalish's 1962 Sept. 18th expedition to Castaic Junction, for a bright-limb graze of 4.1-mag. 5 Tauri



This provided the first confirmation of my predictions, and was the first time that multiple events were seen (but not timed) during a mobile effort. My own next 6 attempts, after the April debacle in Walnut Creek, were all clouded out, remarkably bad luck for California. I could not observe the 5 Tauri graze because it was about 700 km from Berkeley, so I asked Carroll Evans of China Lake to try it, and asked Ronald Royer to announce it at the Sept. meeting of the Los Angeles Astronomical Society. Evans couldn't tell what happened due to desert winds and a low f-number scope, but Kalish responded to Royer's announcement and drove 60 km nw of his LA home to observe the graze.

My 1st prediction published in Sky and Telescope, zeta Geminorum graze of 1963 March 4/5



CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

THE RAPIDLY ECLIPSING VARIABLE Y LEONIS

This light curve of Y Leonis during primary minimum is based upon 514 visual brightness estimates made by a Dutch astronomer, A. A. Nijland, with the 10-inch refractor at Utrecht.

The field of Y Leonis, with south at the top and east to the right, as in an inverting telescope. The upper chart, adapted from the "Atlas Eclipticalis," has stars of the 9th magnitude. The lower chart is an enlargement of the small rectangular area. Miss R. Szafraniec's visual magnitudes of comparison stars are given to tenths (decimal points omitted).

MINIMA OF ALGOL

OCCULTATION OF ZETA GEMINORUM

ON THE NIGHT of March 4-5, 1963, the 4th-magnitude star Zeta Geminorum will be covered by the moon, as seen from the northern part of North America. The Occultation Supplement in the November, 1962, issue of SKY AND TELESCOPE contains predicted times of disappearance for Massachusetts, Montreal, and Edmonton, but notes that there will be no occultation for Toronto or Washington, D. C. Evidently, there is an intervening line from along which the star will just graze the southern edge of the moon.

David W. Dunham, Berkeley, California, has calculated in detail the course of the southern limit of this occultation. He writes, "The predicted line follows a southeastward course through Alberta; passing just north of Regina, Saskatchewan; about 50 miles south of Winnipeg; through northern Minnesota and across northern Michigan; 10 to 20 miles north of Toronto; through Rochester, New York, crossing the Hudson River near Poughkeepsie; through West Haven, Connecticut, and over the eastern end of Long Island."

Observers slightly north of this line should see an occultation of short duration; those south of the line, a near miss. There are several previous records of grazing occultations at which a star disappeared and reappeared repeatedly, as it passed behind one lunar mountain after another.

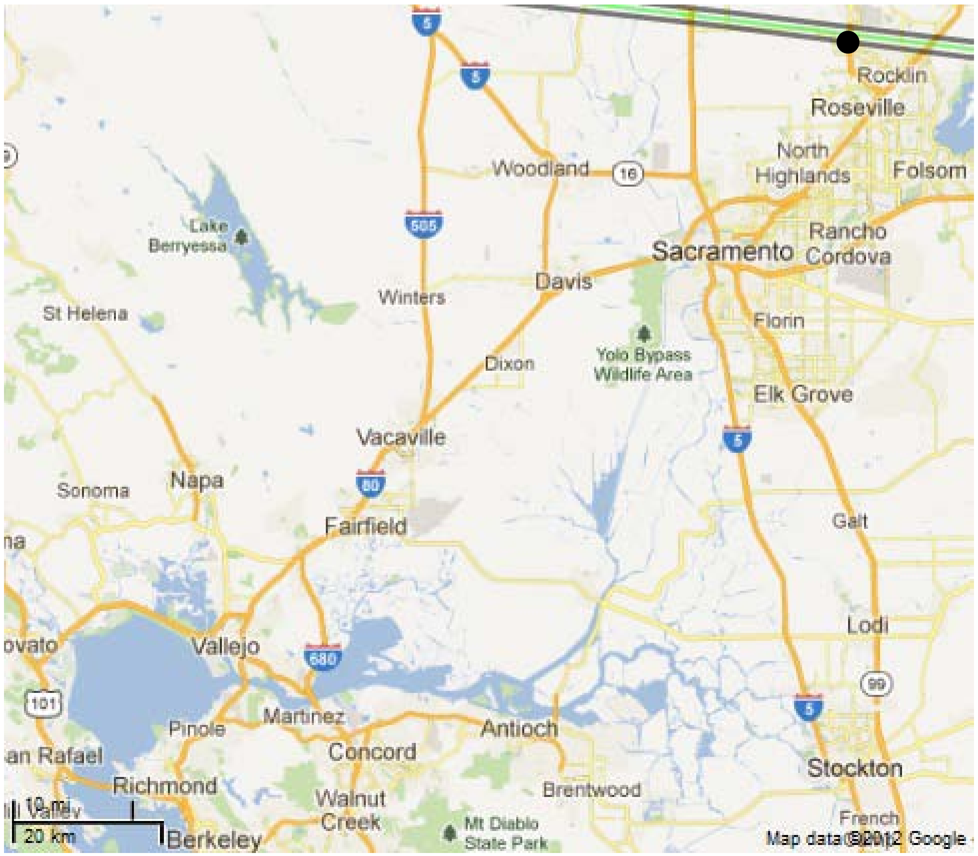
Adding interest to the occultation is the fact that Zeta Geminorum is a double star. Its 8½-magnitude companion, just over 1½ minutes of arc north and slightly west, will be occulted when Zeta itself is only grazed by the moon's limb.

Condensed from Mr. Dunham's data is the following table which tells, at five-minute intervals of Universal time, the geographical latitudes and longitudes at which graze takes place.

Universal time	Latitude	Longitude
4:25	+52 03	+116 02
4:30	+51 50	+113 05
4:35	+51 32	+110 08
4:40	+51 09	+107 11
4:45	+50 42	+104 14
4:50	+50 10	+101 16
4:55	+49 32	+98 17
5:00	+48 49	+95 16
5:05	+48 01	+92 12
5:10	+47 06	+89 04
5:15	+46 04	+85 50
5:20	+44 54	+82 28
5:25	+43 36	+78 55
5:30	+42 06	+75 05

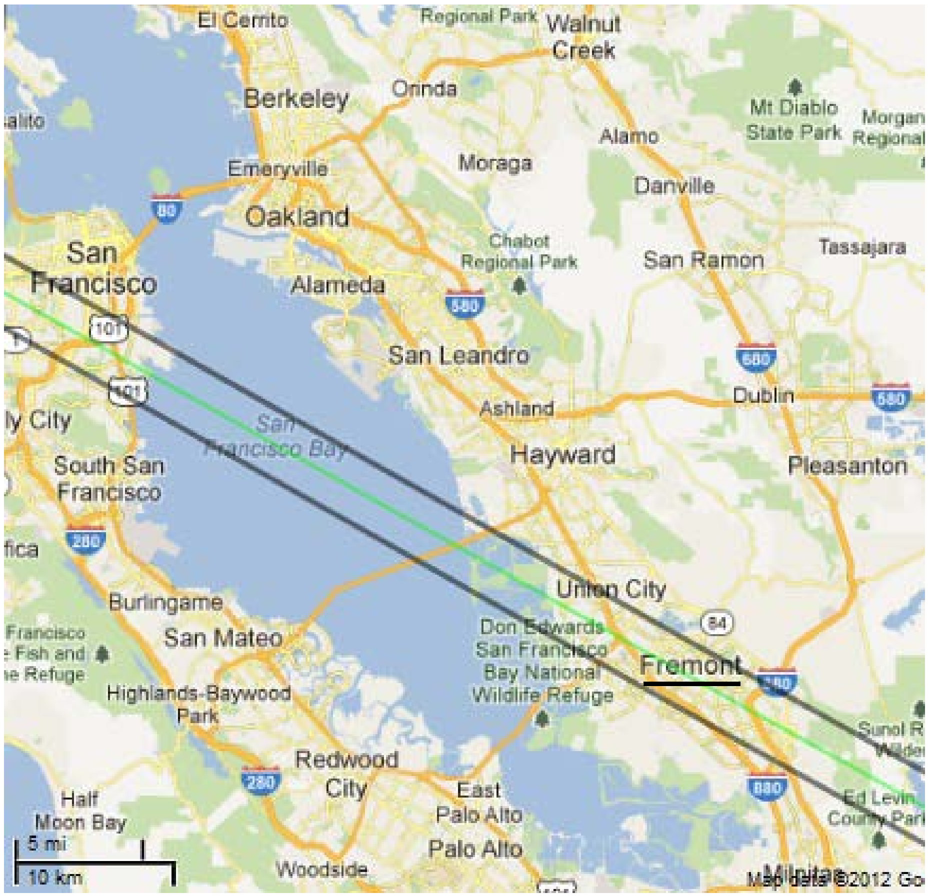
During the last months of 1962, at Prof. Cunningham's suggestion and support, I took a course in the then new Fortran computer programming language, and avidly learned it, applying it immediately to the task of computing grazing occultation paths. This allowed me to compute many more paths and expand my predictions to areas beyond California. I contacted Sky and Telescope about publishing my predictions. They first wanted to be sure my work was legitimate so I documented my procedures. Satisfied, they published a first prediction in March 1963. That graze was not observed, as far as I know. There was still some tedium limiting what could be done as 50 numbers had to be specified to high precision for each event.

My First Observed Graze, north of Roseville, California, 1963 Mar. 31, 6.3-mag. ZC 881, Moon 39%+, CA -3N



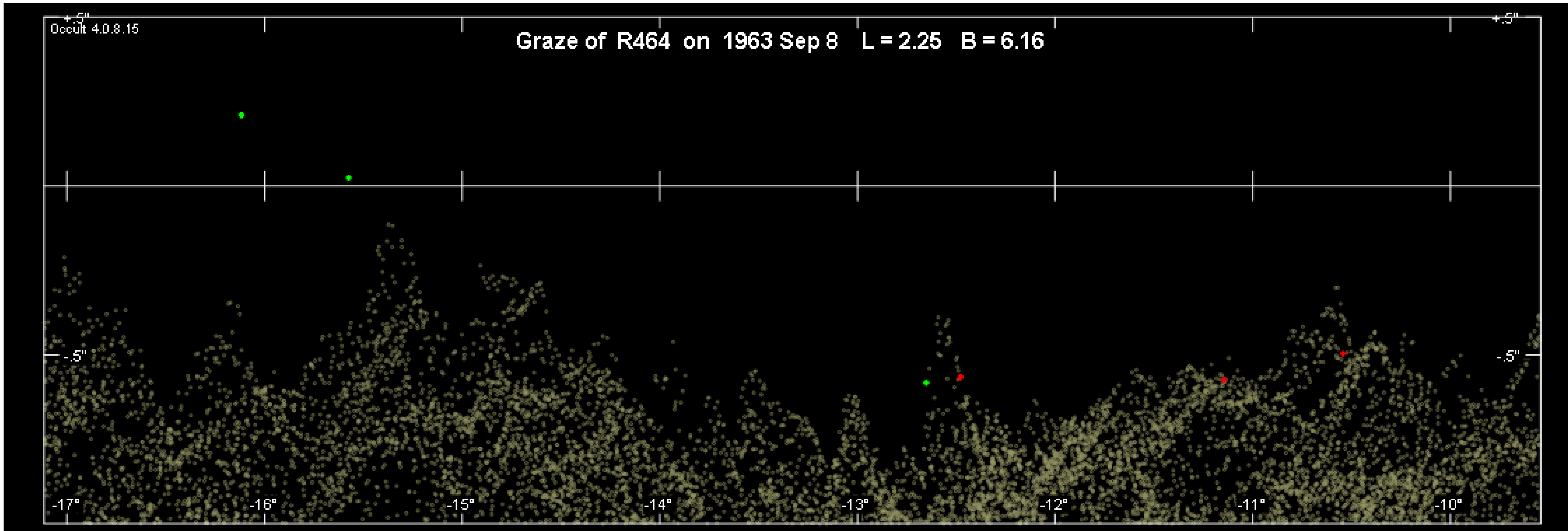
I observed this with my 60mm refractor north of Roseville with Bruce Bowman from the Sacramento Moonwatch Team. Most of the Interstate highways weren't built yet and the town of Rocklin was much smaller then. Although the graze was on the bright limb, I could see the star well enough to know that it grazed among the mountains at the northern cusp, but not well enough to make any definite timings. At least, I saw for myself that my predictions were good.

Two nights later (1963 April 2), Fremont, Calif., I saw a graze of 5.4-mag. 85 Geminorum, Moon 63%+, CA -2S

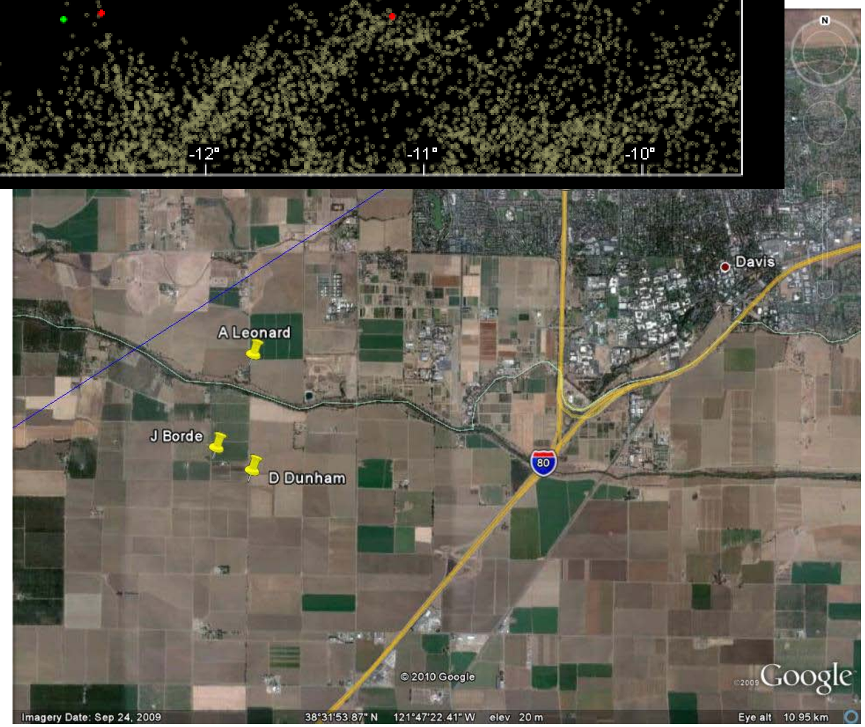


Remarkably, two nights later, Jack Borde, a few other members of the Walnut Creek Moonwatch Team, and I observed another graze from Fremont. Again it was on the sunlit limb near the southern cusp, but we were able to make crude timings of a few of this brighter star’s graze events.

The first successful dark limb graze where the observers travelled to their sites - 1963 Sept. 8 Graze of 6.1-mag. ZC 464, Davis, Calif.



Finally, good timings were made of this graze with CA 15N and Moon 72%- sunlit. This is adopted from Dave Gault's presentation on the current graze archive given at the 2010 IOTA meeting.



My 1st graze map published in Sky and Telescope, for the 1963 Oct. 8 graze of 3.0-mag. zeta Tauri, CA 13N, Moon 67%-

GRAZING OCCULTATION OF ZETA TAURI

ON THE NIGHT of October 7-8 at about 11 p.m. Central standard time, a 20-day-old moon will occult the 3rd-magnitude star Zeta Tauri. This event should prove interesting for observers in the central and eastern United States and in eastern Canada. Predictions for several American and Canadian stations are given in the "Occultation Supplement" of SKY AND TELESCOPE last November.

Not everyone will see the star pass behind the moon's disk. For some it will just graze the dark limb, for others it will miss the moon altogether. I have computed the northern geographical limit of this occultation; its approximate course is plotted on the map. Along this line, Zeta Tauri should appear at the mean limb of the moon; south of the line, the star will be occulted; north of it, Zeta will miss the moon.

Within a few miles of the line, however, observers may see a grazing occultation in which the star moves almost tangent to the moon's edge, possibly vanishing abruptly behind dark lunar mountains and flashing out again several times. Zeta Tauri will touch the moon's northwest limb at position angle 345° (this angle is counted around the moon's edge from north through east). This is on the dark side of the disk, giving a fine view in small telescopes.

Observers about 20 miles northwest of Fort Worth, Texas, will be among the first to see the graze. The moon's altitude above the horizon, however, will be only 11° at the time Zeta is nearest the moon, about 4:59 UT. About 20 miles southeast of Montreal, Canada, toward the opposite end of the track, the graze will occur at about 5:23 UT. There the moon's altitude will be 37°.

Other points along the approximate line lie some 35 miles northwest of Little Rock, Arkansas; southeast of the Mississippi and Ohio river junction; about eight miles southeast of Evansville, Indiana; about 15 miles northwest of Columbus, Ohio; in Akron, Ohio; a few miles southeast of Erie, Pennsylvania; and some five miles southeast of Rochester, New York.

DAVID DUNHAM
1519 Arch St.
Berkeley 8, Calif.

Universal times are marked along the northern-limit line of the occultation of Zeta Tauri on October 7-8. They indicate approximately when the moon will graze the star.

This map helped generate interest among new observers across the eastern USA

Observations of the 1963 October 8th graze of zeta Tauri were the first published in Sky and Telescope, in the Dec. 1963 issue

A Well-Observed Grazing Occultation

N THE evening of October 7-8, 1963, Zeta Tauri grazed the moon's dark for observers along a narrow strip passed near Fort Worth, Texas; mbus, Ohio; and Montreal, Quebec. ctions by David Dunham were pub- l in Sky and Telescope for October, page 218.

orably located amateurs saw the 3rd- itude star wink on and off as eleva- on the lunar limb moved through ar's line of sight.

a watcher was well south of the g-occultation path, he saw a normal ation, the star disappearing only North of the line, Zeta passed just of the moon and no occultation ed.

Garland, Texas, the moon was quite he horizon when James E. Smith ta Tauri disappear at 4:58:40 Uni- time. The occultation was brief, er, and the star reappeared at), as timed with a 6-inch reflector. mary Pierson, at May, Texas, saw sappear at 4:54 UT. She missed it out, however, while consulting a chart two minutes later.

g a 6-inch reflector, John Brannen nearly 13-minute occultation from Rock, Arkansas. He reports, "Zeta entered a small valley located est of a group of craters near ib. It disappeared at 4:55:04.4 UT and reappeared at 5:08:02.3. My latitude is 34° 43′ 55″ north, and longitude 92° 13′ 58″ west."

The following reports are from amateur groups with more extensive programs:

Dayton, Ohio

My physics students at the Washington Township High School in Dayton responded enthusiastically to news of the predicted grazing occultation of Zeta Tauri. On the night of October 7th, about 30 of them reported, with all the telescopes and binoculars they could find.

We separated into eight groups along the predicted graze path. Timing the event was made easy by the local radio station WONE, which broadcast voice time signals every 15 seconds. The time and observations were tape recorded at each station. All observers reported seeing the occultation, except two who remained at our school, about 1½ miles north of the northern limit.

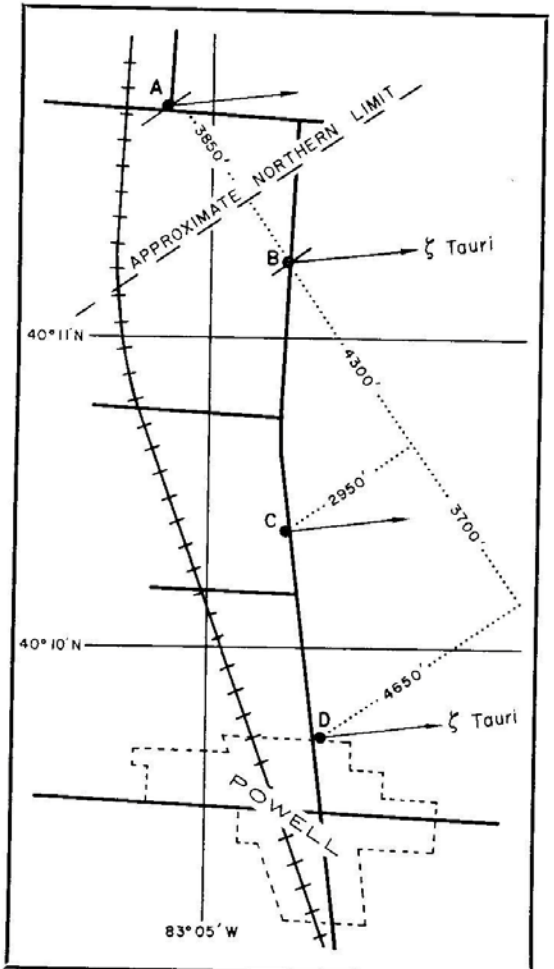
Observer Freedman probably had one of the most spectacular views. He watched with a 60-power 3-inch reflector at west longitude 84° 12′ 08″, north latitude 39° 35′ 13″, altitude above sea level 975 feet. Zeta disappeared and reappeared at the following Universal times: **D,** 5:07:35; **R,** 5:07:52; **D,** 5:07:57; **R,** 5:08:05; **D,** 5:08:15; **R,** 5:08:55; **D,** 5:09:00; **R,** 5:09:05; **D,** 5:09:15; **R,** 5:09:30.

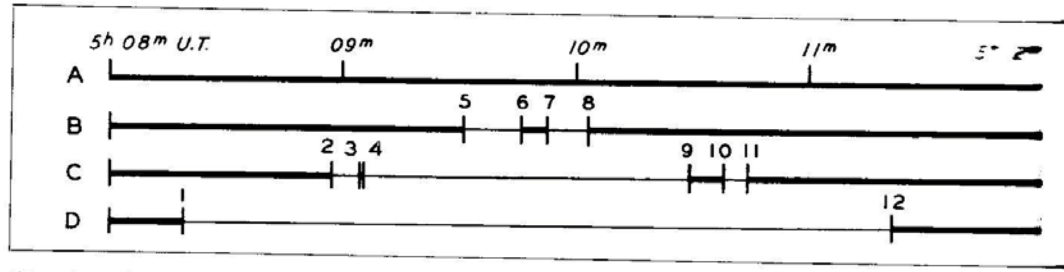
At four other stations the star disappeared at least twice, making our program so successful that almost everyone offered to travel a hundred miles to see future grazes. One boy even got his Christmas telescope early for the October event!

DAVID E. LAIRD
99 Virginia Ave.
Dayton 59, Ohio

Columbus, Ohio

Members of the Columbus Astronomical Society observed the occultation of Zeta Tauri at the four sites shown on the map. Each was located at roughly ¾-mile intervals along a nearly north-south line about 15 miles northwest of Columbus, This is the 2nd page (page 370) of the 2-page article about the 1963 October 8th zeta Tauri graze in S&T's Dec. 1963 issue





near the predicted geographical limit.

Early on the evening of October 7th, the following members of the Columbus society gathered with telescopes and other equipment: Barnett Golding, John Kissel, Charles Legg, Larry Ochs, Mike Peugh, Dan Sagstetter, and Steve Yanochek. Allen Austin, Butch Hall, and John Morris of the Worthington High School Astronomy Club, and Dan McGrath of Bishop Watterson High School in Columbus, also joined our group.

We observed with a 6-inch refractor and two 6-inch and one 4-inch reflectors. A two-man team recorded CHU time signals on tape, while the other groups had

OBSERVED CONTACT TIMES

Contact (see chart)	*Universal time**	*Station on Map*
1	*5h 08m 19s.5*	D
2	*5 08 57.2*	C
3	5 09 04.5	C
4	*5 09 05.0*	C
5	*5 09 31.1*	B
6	5 09 45.8	B
7	*5 09 52.8*	B
8	5 10 03.1	B
9	5 10 29.0	C
10	*5 10 38.0*	C
11	5 10 44.0	C
12	5 11 21.5	D

*Italics denote disappearances, all others are reappearances.

a timekeeper, observation recorde[r] ... observer.

As the predicted time of conta[ct] ... one observer thought the moon ... miss Zeta, for the illuminated por[tion] ... its disk had already passed the sta[r] ... ing the illusion that the dark part ... also miss. However, the star had ... reached the predicted contact ... angle, and his location eventually ... to be a proper one.

The southernmost station, D, had ... simple occultation lasting 3m ... shown in the accompanying diagra[m] ... table. There was a deep graze at C, ... Zeta Tauri was hidden three tim[es] ... 1m 47s. The observer at B, near the ... ern limit, saw two disappearances ... seconds. Zeta was not occulted at A, ... of the predicted limit.

Our society has additional inform[ation] available to interested persons. We ... also like to hear from other successfu[l] ... servers of this occultation.

BARNETT GOLDI[NG]
111 Richar[ds] ...
Columbus, ...

High school students open the eyes of USNO

19631008_ZC847-DunhamComments.txt - Notepad

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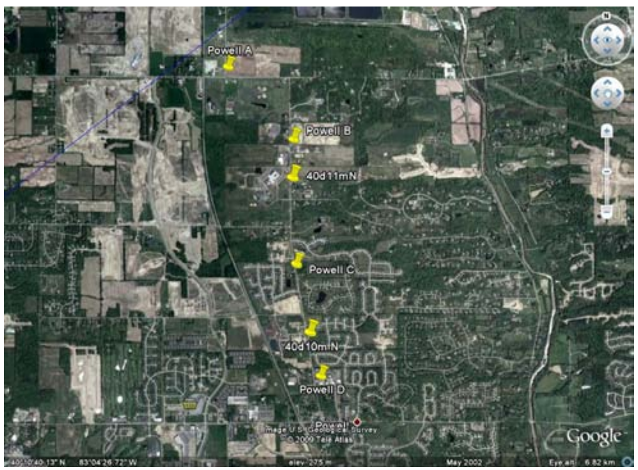
The 1963 Oct. graze is important since it was the first one for which details of observation expeditions were published. Tom Van Flandern was just starting work at the US Naval Observatory at the time; when he saw the article in Sky and Telescope, he got the US topographic map that showed the sites north of Columbus, scaled the positions, and analyzed the timings that he was able to measure from the time diagram.

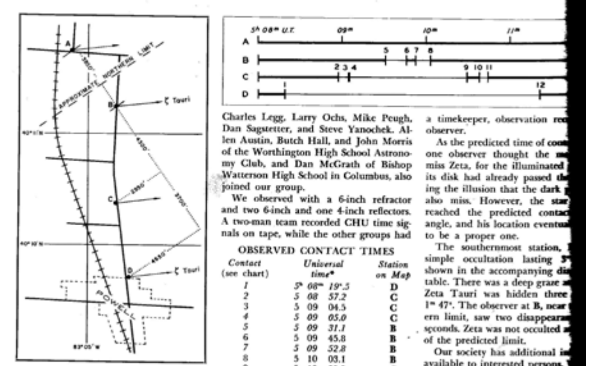
Tom found a mismatch (shift) of 0.4" or so; at the time, it was assumed that the FK3 star positions and Watts data were more accurate than that, so Raynor Duncombe, director of the Nautical Almanac Office, was incredulous when Tom showed him the results.

This sparked USNO's interest in grazes at the time.

David

From Dave Gault's 2010 IOTA meeting presentation





near the predicted geographical limit.

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3	5 09 04.5	C
4	5 09 05.0	C
5	5 09 31.1	B
6	5 09 45.8	B
7	5 09 52.8	B
8	5 10 03.1	B
9	5 10 29.0	C
10	5 10 38.0	C
11	5 10 44.0	C
12	5 11 21.5	D

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BARNETT G[...]
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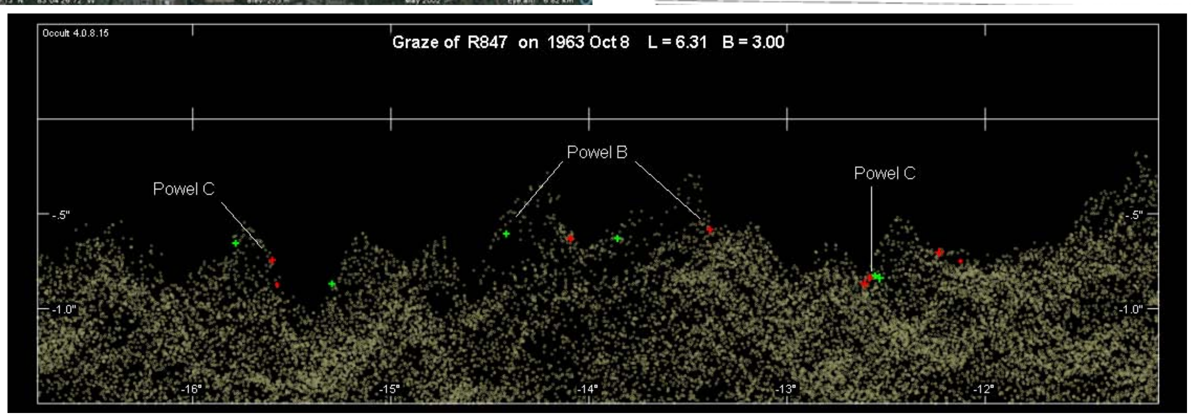
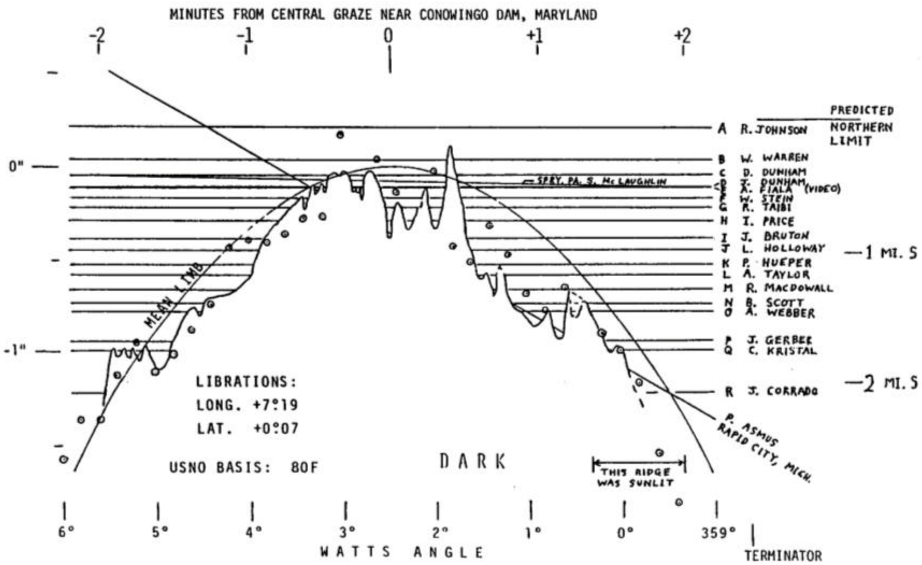
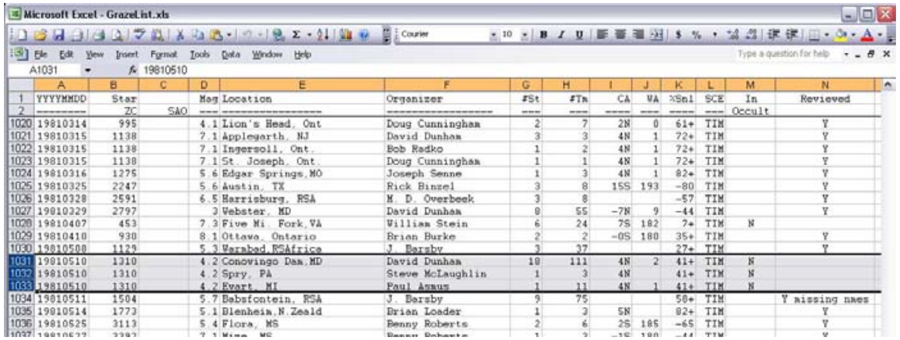


Dave Gault declared, the illegitimate delta Cancri graze now legitimate!

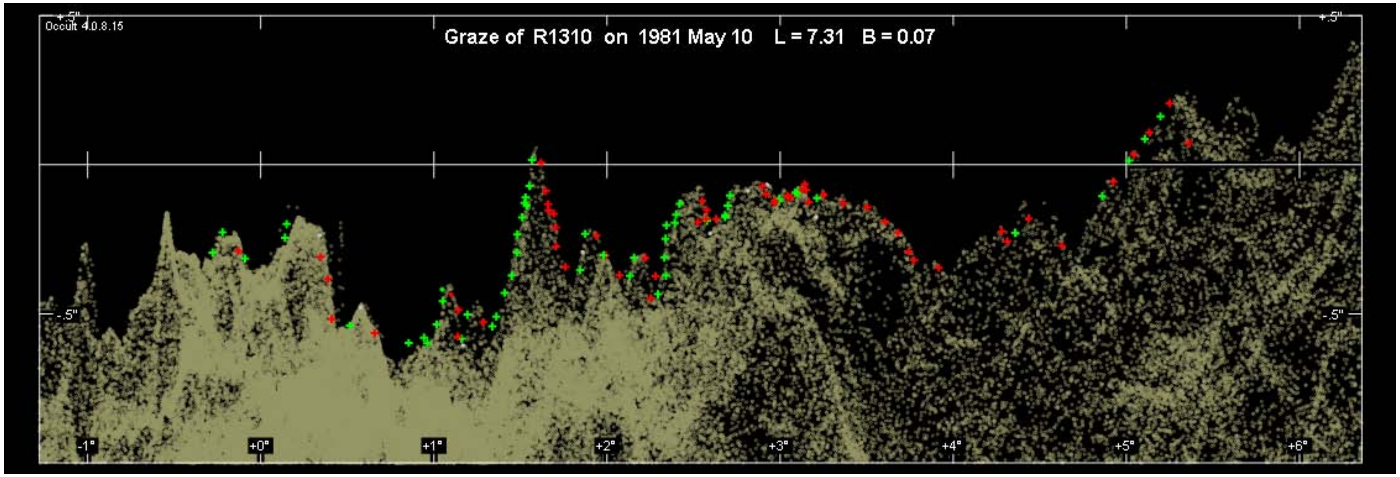
Lunar Profile from Graze of delta Cancri – 1981 May 9-10



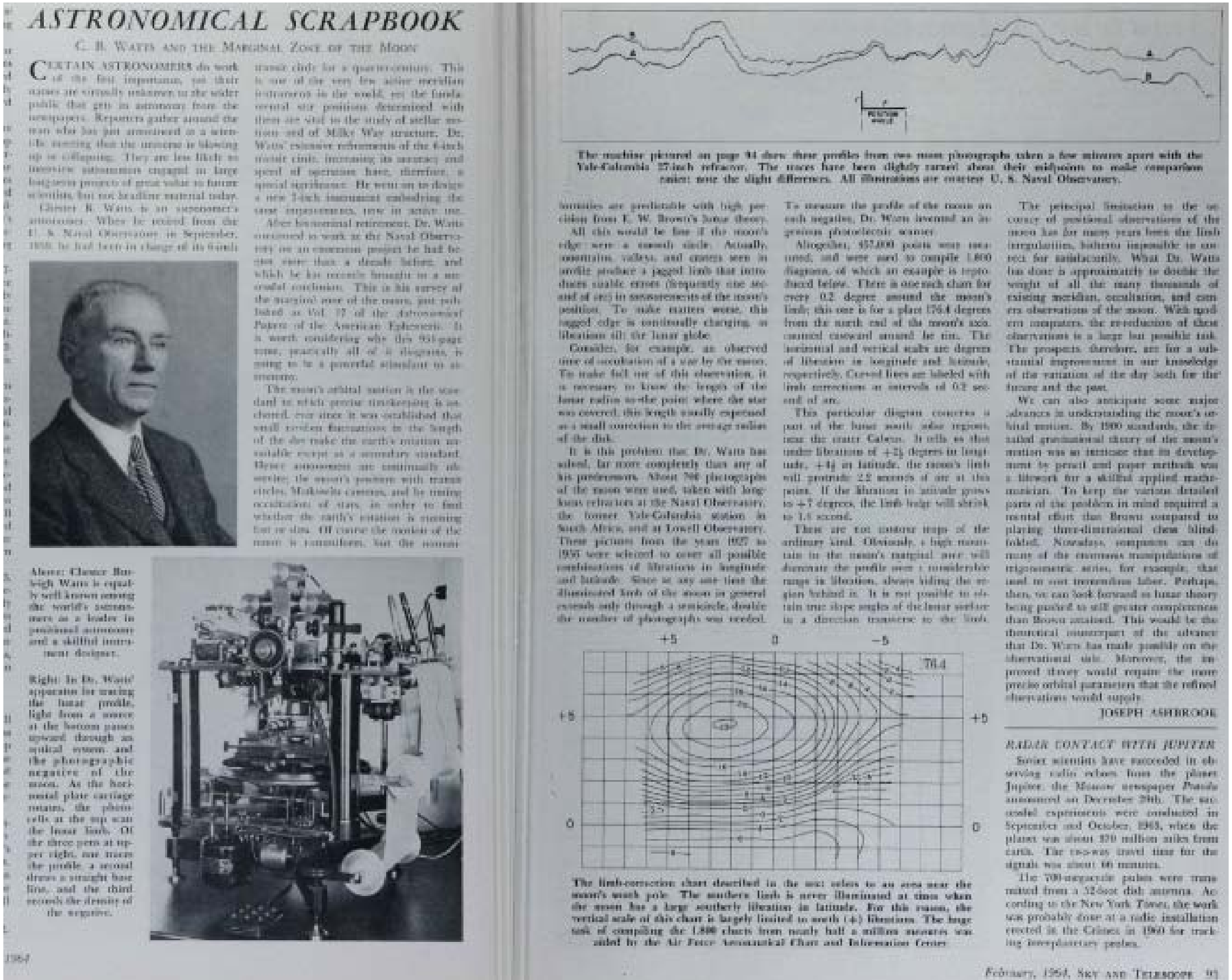
Circled dots are Watts' predicted limb corrections



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	YYYYMMDD	Star		Mag	Location	Organizer	#St	#Tm	CA	WA	%Snl	SCE	In	Reviewed
2	--------	ZC	SAO	---	----------------	----------------	---	---	----	---	----	---	Occult	
1020	19810314	995		4.1	Lion's Head, Ont	Doug Cunningham	2	7	2N	0	61+	TIM		Y
1021	19810315	1138		7.1	Applegarth, NJ	David Dunham	3	3	4N	1	72+	TIM		Y
1022	19810315	1138		7.1	Ingersoll, Ont.	Bob Radko	1	2	4N	1	72+	TIM		Y
1023	19810315	1138		7.1	St. Joseph, Ont.	Doug Cunningham	1	1	4N	1	72+	TIM		Y
1024	19810316	1275		5.6	Edgar Springs, MO	Joseph Senne	1	3	4N	1	82+	TIM		Y
1025	19810325	2247		5.6	Austin, TX	Rick Binzel	3	8	15S	193	-80	TIM		Y
1026	19810328	2591		6.5	Harrisburg, RSA	M. D. Overbeek	3	8			-57	TIM		Y
1027	19810329	2797		3	Webster, MD	David Dunham	8	55	-7N	9	-44	TIM		Y
1028	19810407	453		7.3	Five Mi. Fork, VA	William Stein	6	24	7S	182	7+	TIM	N	
1029	19810410	930		8.1	Ottawa, Ontario	Brian Burke	2	2	-0S	180	35+	TIM		Y
1030	19810508	1129		5.3	Warmbad, RSAfrica	J. Barsby	3	37			27+	TIM		Y
1031	19810510	1310		4.2	Conowingo Dam, MD	David Dunham	10	111	4N	2	41+	TIM	N	
1032	19810510	1310		4.2	Spry, PA	Steve McLaughlin	1	3	4N		41+	TIM	N	
1033	19810510	1310		4.2	Evart, MI	Paul Asmus	1	11	4N	1	41+	TIM	N	
1034	19810511	1504		5.7	Babsfontein, RSA	J. Barsby	9	75			58+	TIM		Y missing nmes
1035	19810514	1773		5.1	Blenheim, N.Zeald	Brian Loader	1	3	5N		82+	TIM		Y
1036	19810525	3113		5.4	Flora, MS	Benny Roberts	2	6	2S	185	-65	TIM		Y



The 1964 publication of Watts' charts gave us the possibility to predict the lunar profile for grazing occultations


ASTRONOMICAL SCRAPBOOK

C. B. Watts and the Marginal Zone of the Moon

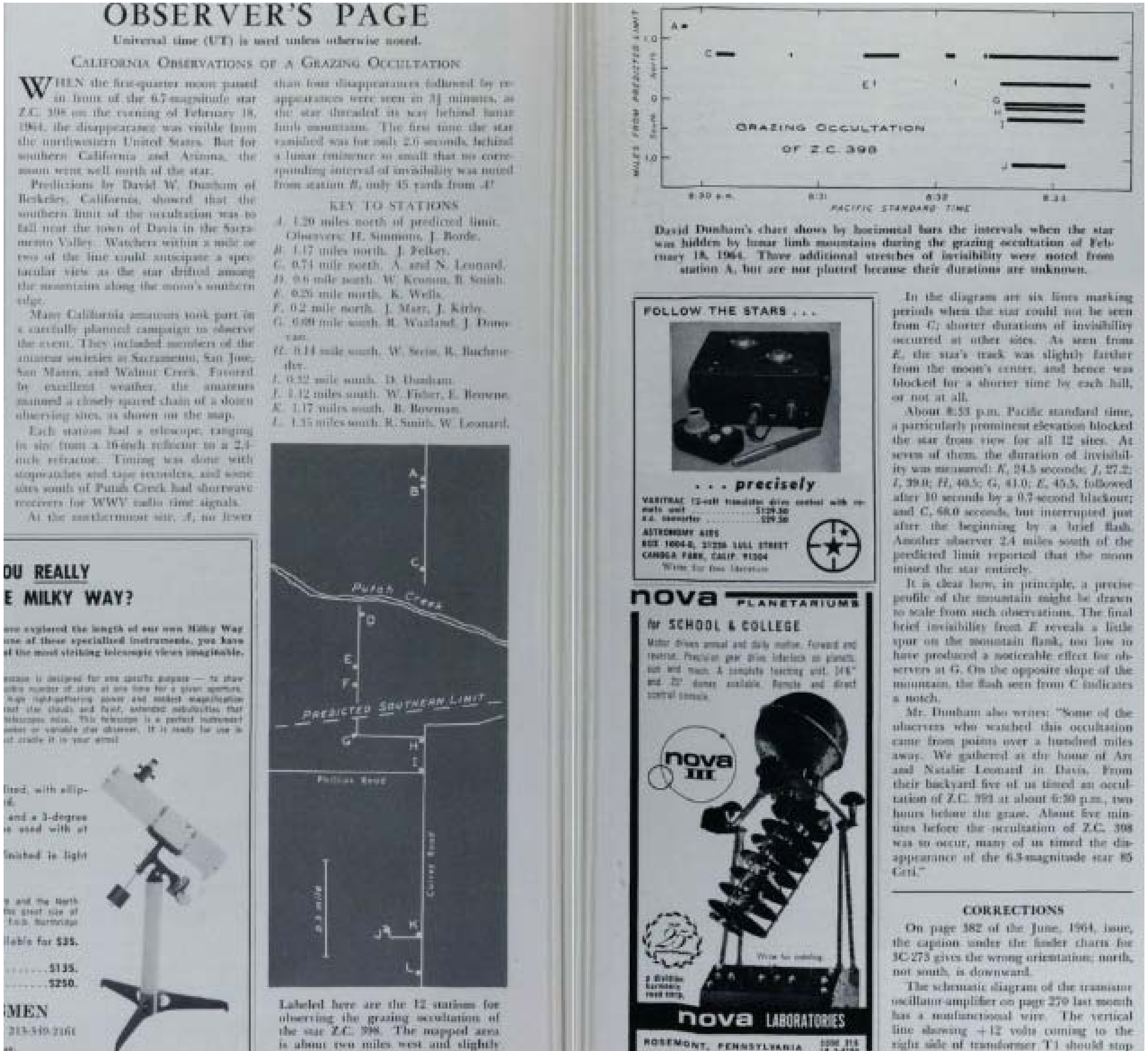
JOSEPH ASHBROOK

RADAR CONTACT WITH JUPITER

February, 1964, Sky and Telescope 93

This was published in the 1964 Feb. issue of Sky and Telescope.
The figure at the bottom for WA 176.4° was in the range for a graze we observed that month, so I knew from it that a high mountain would dominate our profile.

Graze of 6.4-mag. ZC 398 observed 1964 February 19, again near Davis, Calif., Moon 34%+ sunlit, Cusp Angle 6S



OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

CALIFORNIA OBSERVATIONS OF A GRAZING OCCULTATION

WHEN the first-quarter moon passed in front of the 6.7-magnitude star Z.C. 398 on the evening of February 18, 1964, the disappearance was visible from the northwestern United States. But for southern California and Arizona, the moon went well north of the star.

Predictions by David W. Dunham of Berkeley, California, showed that the southern limit of the occultation was to fall near the town of Davis in the Sacramento Valley. Watchers within a mile or two of the line could anticipate a spectacular view as the star drifted among the mountains along the moon's southern edge.

Many California amateurs took part in a carefully planned campaign to observe the event. They included members of the amateur societies at Sacramento, San Jose, San Mateo, and Walnut Creek. Favored by excellent weather, the amateurs manned a closely spaced chain of a dozen observing sites, as shown on the map.

Each station had a telescope, ranging in size from a 16-inch reflector to a 2.4-inch refractor. Timing was done with stopwatches and tape recorders, and some sites south of Putah Creek had shortwave receivers for WWV radio time signals.

At the northernmost site, A, no fewer than four disappearances followed by reappearances were seen in 3½ minutes, as the star threaded its way behind lunar limb mountains. The first time the star vanished was for only 2.6 seconds, behind a lunar eminence so small that no corresponding interval of invisibility was noted from station B, only 45 yards from A!

KEY TO STATIONS

A. 1.20 miles north of predicted limit. Observers: H. Simmons, J. Borde.
B. 1.17 miles north. J. Felker.
C. 0.74 mile north. A. and N. Leonard.
D. 0.6 mile north. W. Kronum, B. Smith.
E. 0.26 mile north. K. Wells.
F. 0.2 mile north. J. Marr, J. Kirby.
G. 0.09 mile south. R. Wazland, J. Donovan.
H. 0.14 mile south. W. Stein, R. Buchroeder.
I. 0.32 mile south. D. Dunham.
J. 1.12 miles south. W. Fisher, E. Browne.
K. 1.17 miles south. B. Bowman.
L. 1.35 miles south. R. Smith, W. Leonard.

Labeled here are the 12 stations for observing the grazing occultation of the star Z.C. 398. The mapped area is about two miles west and slightly south of Davis, California.

David Dunham's chart shows by horizontal bars the intervals when the star was hidden by lunar limb mountains during the grazing occultation of February 18, 1964. Three additional stretches of invisibility were noted from station A, but are not plotted because their durations are unknown.

In the diagram are six lines marking periods when the star could not be seen from C; shorter durations of invisibility occurred at other sites. As seen from E, the star's track was slightly farther from the moon's center, and hence was blocked for a shorter time by each hill, or not at all.

About 8:33 p.m. Pacific standard time, a particularly prominent elevation blocked the star from view for all 12 sites. At seven of them, the duration of invisibility was measured: K, 24.5 seconds; J, 27.2; I, 39.0; H, 40.5; G, 41.0; E, 45.5, followed after 10 seconds by a 0.7-second blackout; and C, 68.0 seconds, but interrupted just after the beginning by a brief flash. Another observer 2.4 miles south of the predicted limit reported that the moon missed the star entirely.

It is clear how, in principle, a precise profile of the mountain might be drawn to scale from such observations. The final brief invisibility from E reveals a little spur on the mountain flank, too low to have produced a noticeable effect for observers at G. On the opposite slope of the mountain, the flash seen from C indicates a notch.

Mr. Dunham also writes: "Some of the observers who watched this occultation came from points over a hundred miles away. We gathered at the home of Art and Natalie Leonard in Davis. From their backyard five of us timed an occultation of Z.C. 393 at about 6:30 p.m., two hours before the graze. About five minutes before the occultation of Z.C. 398 was to occur, many of us timed the disappearance of the 6.3-magnitude star 85 Ceti."

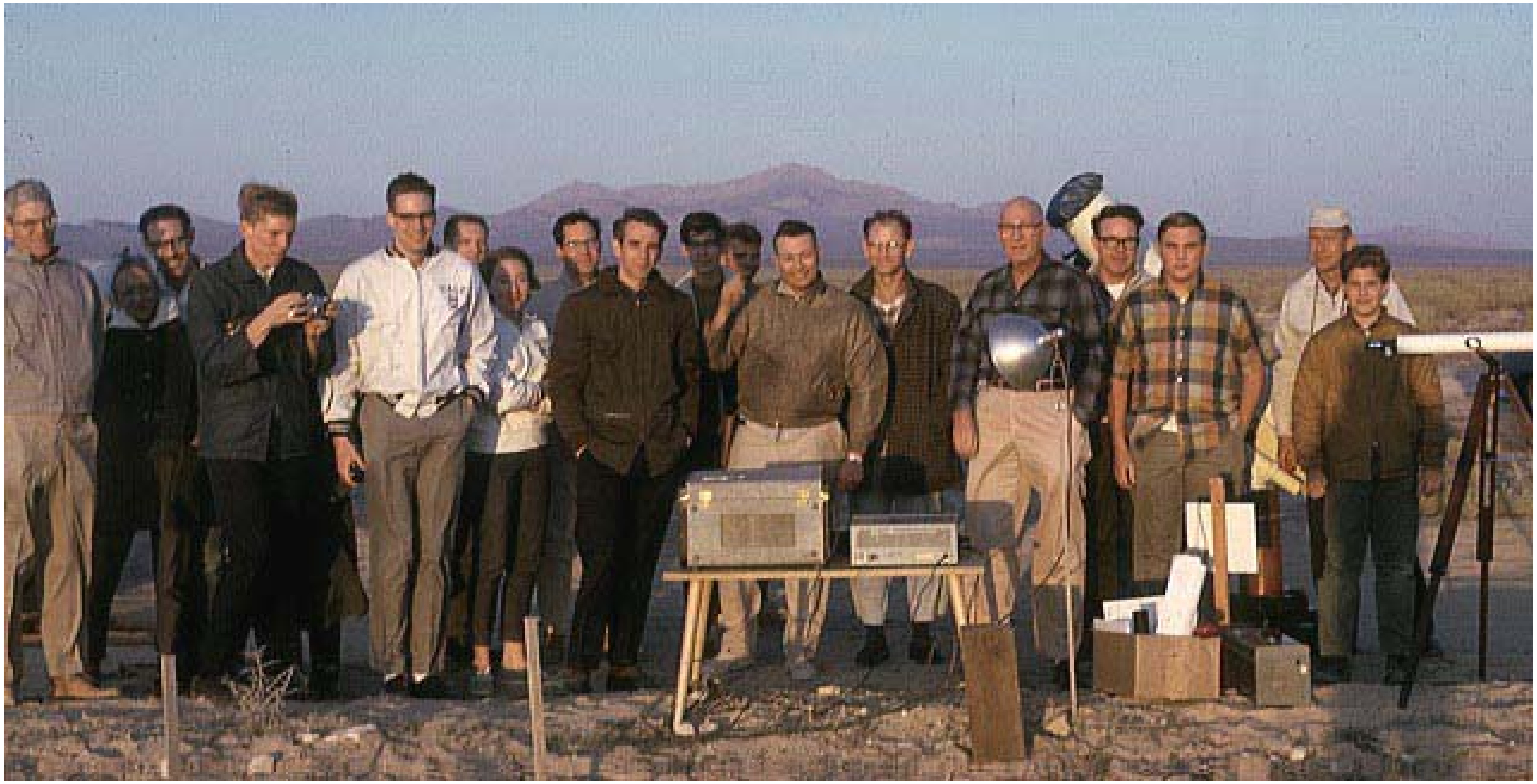
CORRECTIONS

On page 382 of the June, 1964, issue, the caption under the finder charts for 3C 273 gives the wrong orientation; north, not south, is downward.

The schematic diagram of the transistor oscillator-amplifier on page 279 last month has a nonfunctional wire. The vertical line showing +12 volts coming to the right side of transformer T1 should stop at the center dot.

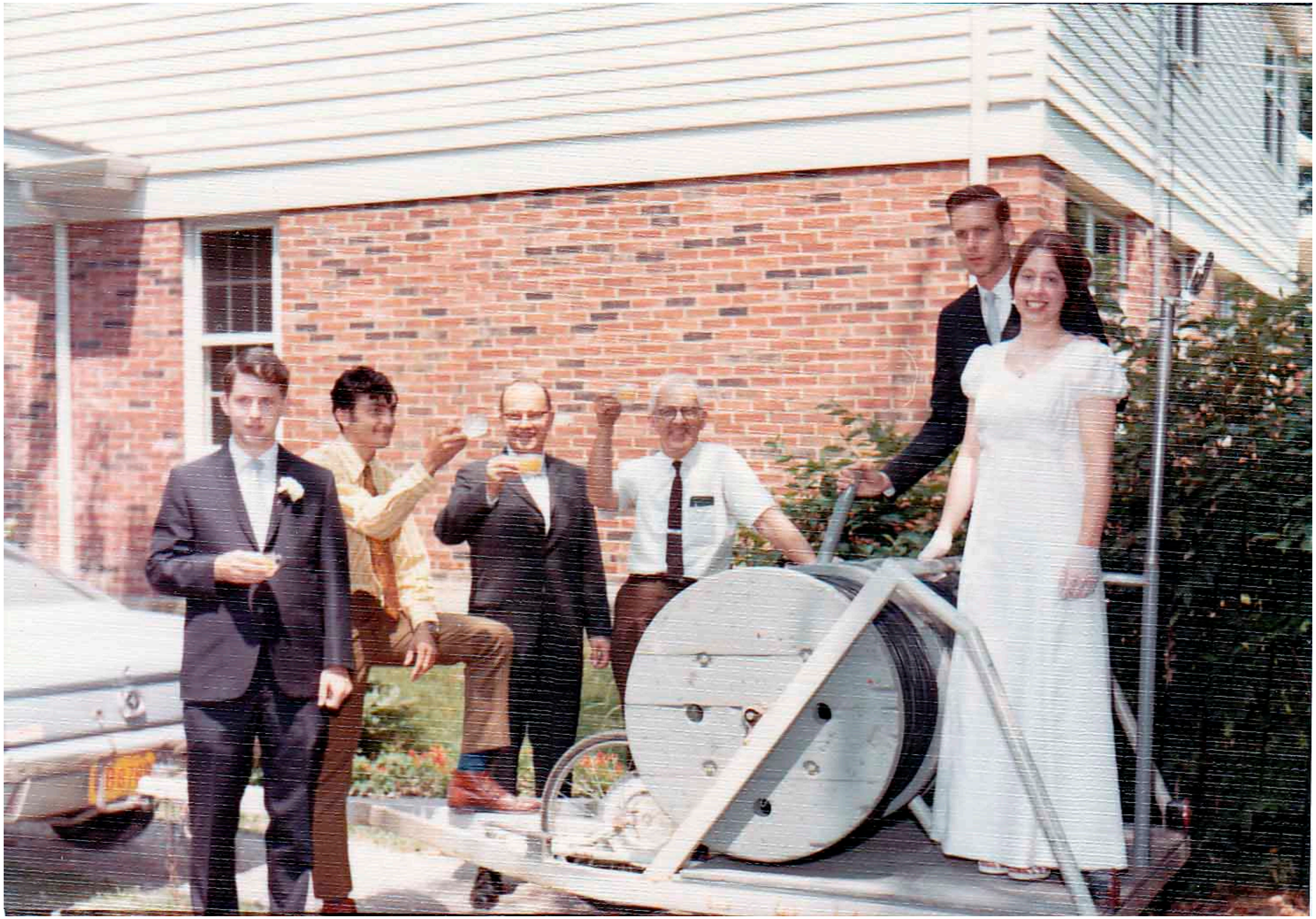
I led this expedition (I believe some sites from 1963 Sept. 8th were reused) with members of the Walnut Creek and Sacramento Moonwatch Teams, and from as far away as San Jose. Most observers had one occultation by the high mountain since I didn't know then about the rest of the profile. Others and I obtained Watts' charts and started plotting (by hand!) profiles for future grazes.

Starting in 1965, cable systems were developed for observing grazing occultations, first at USNO, then by 3 clubs in California (Riverside, Santa Barbara, and Mount Diablo Astronomical Society), and Milwaukee, Wisconsin



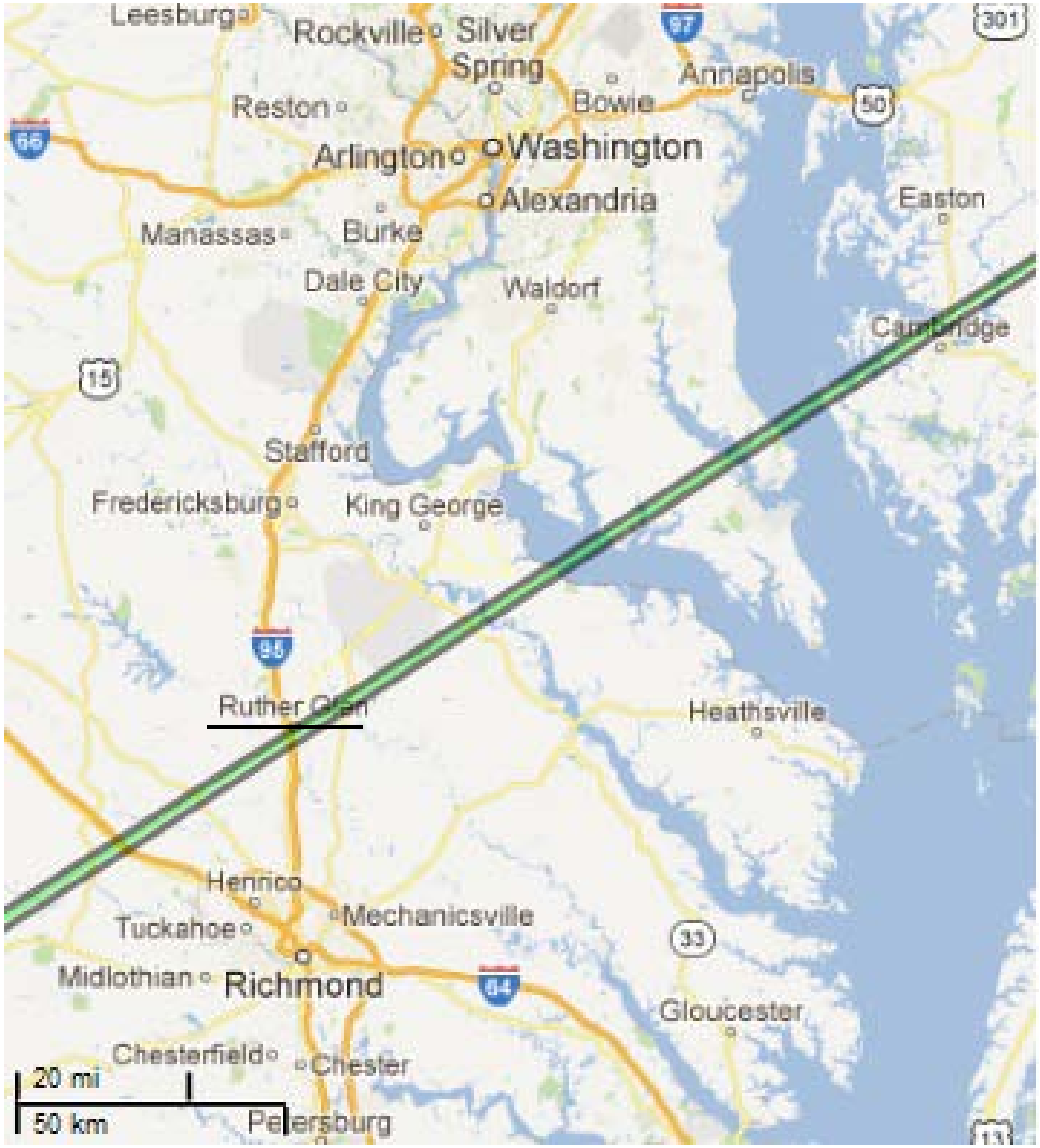
This is a Riverside A.S. expedition to the desert in 1966; I'm wearing a white jacket. Observations were visual, with audio tones recorded at the central station.

1970 July 11, standing on the Milwaukee cable trailer at our wedding in Highland Park, Illinois



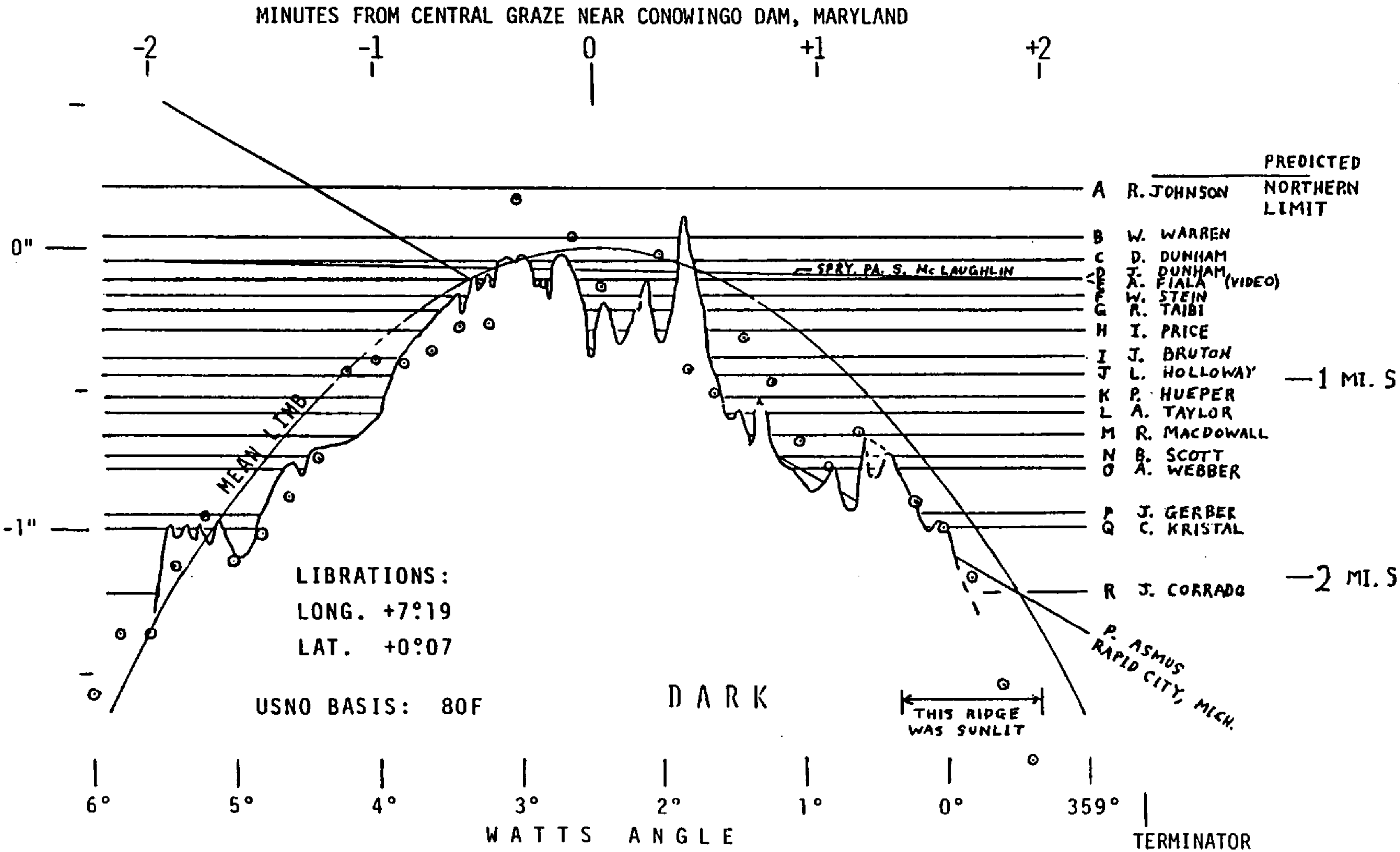
From left to right, Tom Van Flandern, Ronald Abileah,
Homer DaBoll, Edward Halbach, David Dunham, and Joan Dunham

Finally, I observed a graze of β^2 Capricorni with 12 others near Ruther Glen, VA on 1977 June 5, Moon 83%-, CA 3N, Sun alt. -2°



In spite of the conditions, the events were easily seen with the star's 3.1-mag. brilliance. In the meantime, the International Occultation Timing Association (IOTA) had been formally established as a dues-paying organization in July 1975, primarily to promote the observation and analysis of lunar grazing occultations.

Lunar Profile from Graze of delta Cancri – 1981 May 9-10
Alan Fiala, USNO, obtained the first video recording of multiple events during this graze, with 7 D's and 7 R's



Circled dots are Watts' predicted limb corrections

Video of 1990 April Aldebaran Grazing Occultation from Poland

The First Multiple Stations were Deployed for Grazing Occultations

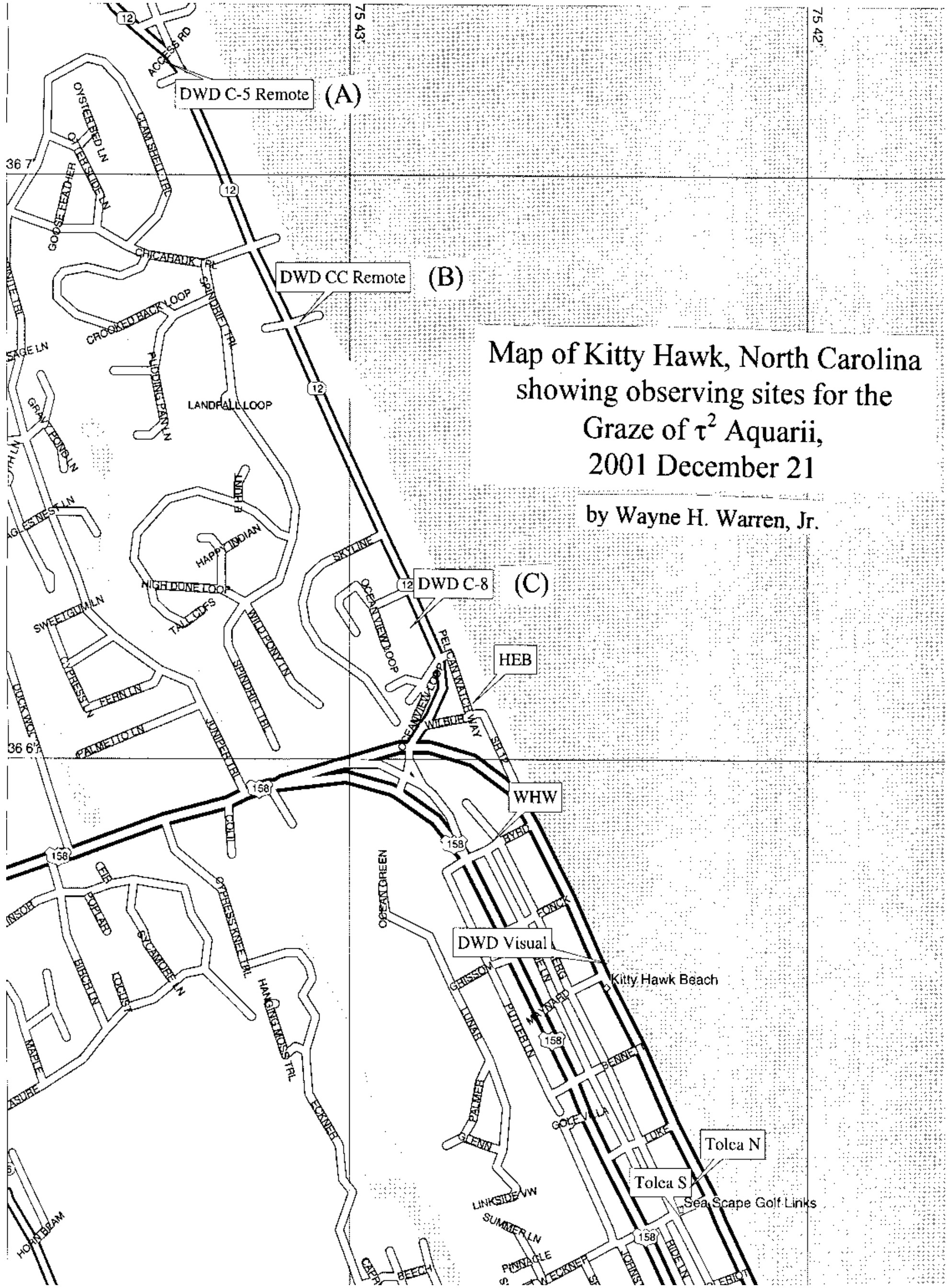
- In the 1990’s, I often thought, the equipment is doing all the work, maybe I should be somewhere else making another observation.
- For a graze of omicron Leonis the morning of 1998 November 12, I set up a 5-in. clock-driven SCT at Delta, Pennsylvania, near York
- I left a student there after showing him how to make adjustments to keep the star in the field of view, and set up another telescope about 0.5 km away to record the event
- When I came back, he was excited to see the multiple occultations of the star. “Did you make any adjustments?” “No”. “At least, you were there to protect the equipment”.
- “Actually, it was the other way around. Whenever a car drove by, I hid behind the telescope box.”

Remote Stations Successfully Run Two Weeks Later

- On 1998 Nov. 26, after Thanksgiving dinner, I drove about 10 miles south and set up a 20-cm SCT with video to record a marginal grazing occultation
- Then I set up another telescope 200 m north and observed the graze visually there. The video station recorded three events, the first unattended mobile video occultation observation, as far as I know.
- Two nights later, I had another success with a better graze, of 4th-mag. χ Piscium at Assateague Island, Maryland

2001 Dec. 21 Grazing Occultation of 4.0-mag. τ^2 Aqr

- Moon 32%+, Cusp Angle 12S
- Observed from 8 stations at Kitty Hawk, North Carolina, by only **4** observers. Kitty Hawk has many summer homes, unoccupied on a December weekday, so we had many safe places to set up telescopes 1 to 2 hours before the graze.
- 4 of the video stations were unattended
- Also observed from 6 stations in Georgia


Map of Kitty Hawk, North Carolina
showing observing sites for the
Graze of τ^2 Aquarii,
2001 December 21
by Wayne H. Warren, Jr.
DWD C-5 Remote
(A)
DWD CC Remote
(B)
DWD C-8
(C)
HEB
WHW
DWD Visual
Tolca N
Tolca S
Kitty Hawk Beach
Sea Scape Golf Links
75 43'
75 42'
36 7'
36 6'
ACCESS RD
CHICAHAUK TRL
CROOKED BACK LOOP
LANDFALL LOOP
HAPPY INDIAN
HIGH DUNE LOOP
SKYLINE
OCEAN VIEW LOOP
WILBUR
SWEETGUM LN
PALMETTO LN
JUNIPER TRL
HANGING MOSS TRL
LINKSIDE VW
SUMMER LN
PINNACLE
LUNAR
PALMER
GLENN
12
158

My Telescopes for Remote Observation

Station “A”, C-5 & PC23C,
& f/6.4 focal reducing lens from Orion

Station “B”, Sony Digital Camcorder

No Telescope, just an undriven good camcorder! I set the Moon just outside the field, above and left, 8 min. before the graze. This station had 5 D’s and 5 R’s, more than any other; although it had less than 1000^{th} the aperture of the 1m telescope on Hokkaido, it was more successful!

Station "C", C-8 & Watec 902H

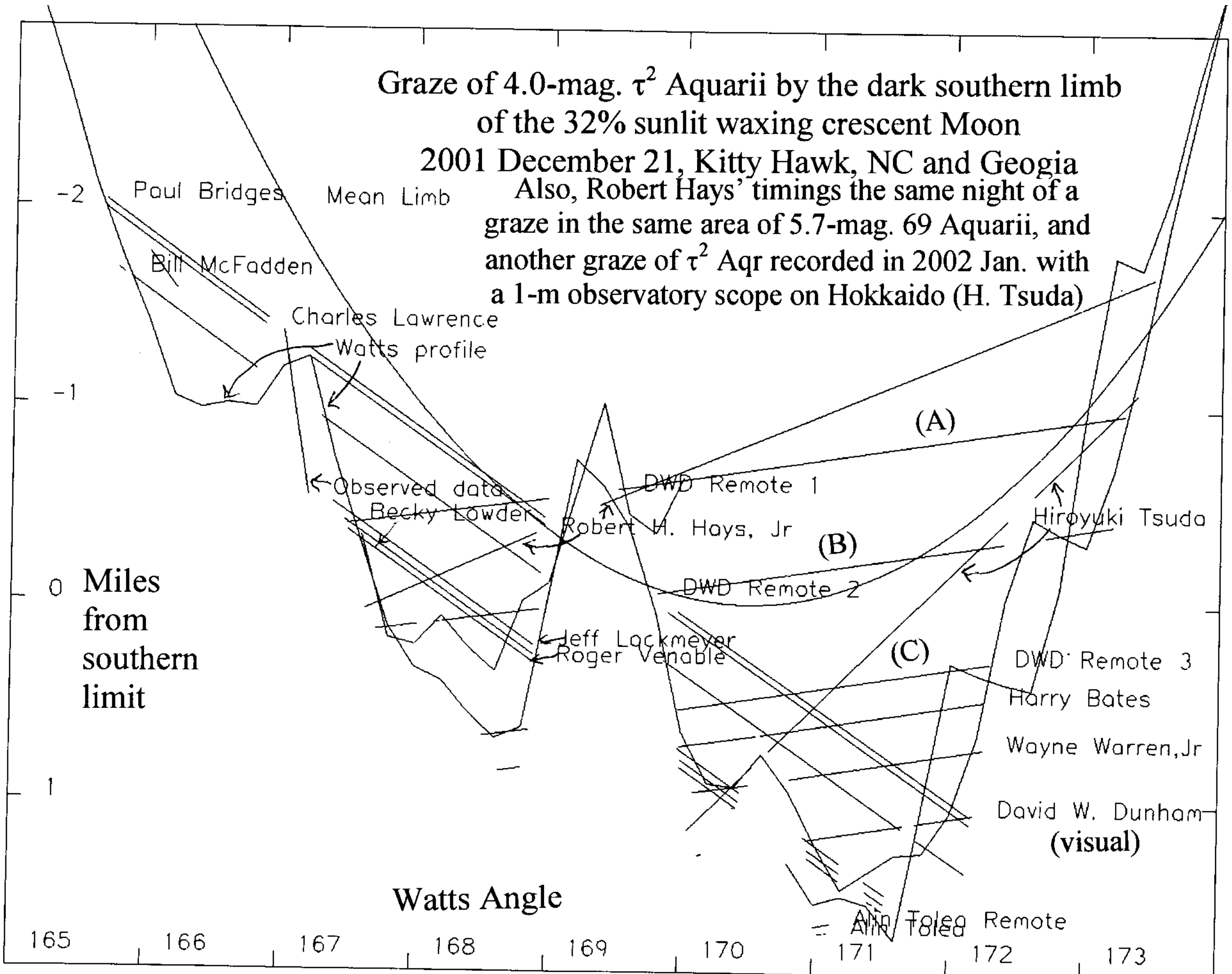
and Meade f/3.3 focal reducing lens ($150 from Focus Camera). A cat jiggled the video a little after the graze.

My Visual Observation

I only had a couple of minutes before the graze when I arrived here. I discovered that I had left the last eyepiece holder (visual back) at another station, so I watched the graze with the 50mm finder scope.

Alin Tolea's Remote Setup

He also observed about 100m away visually with binoculars held steady against a trash dumpster. Alin is a grad student at Johns Hopkins U. in Baltimore; he's from Romania, where he has organized graze expeditions by e-mail and telephone.



by Marshall Stapko, Mitsuru Sôma, and David Dunham


Multi-Station Occultation Observing with Galileo Sized Optical Systems
Scott Degenhardt, IOTA
Galileo's Legacy 2009
Waianae, Hawaii

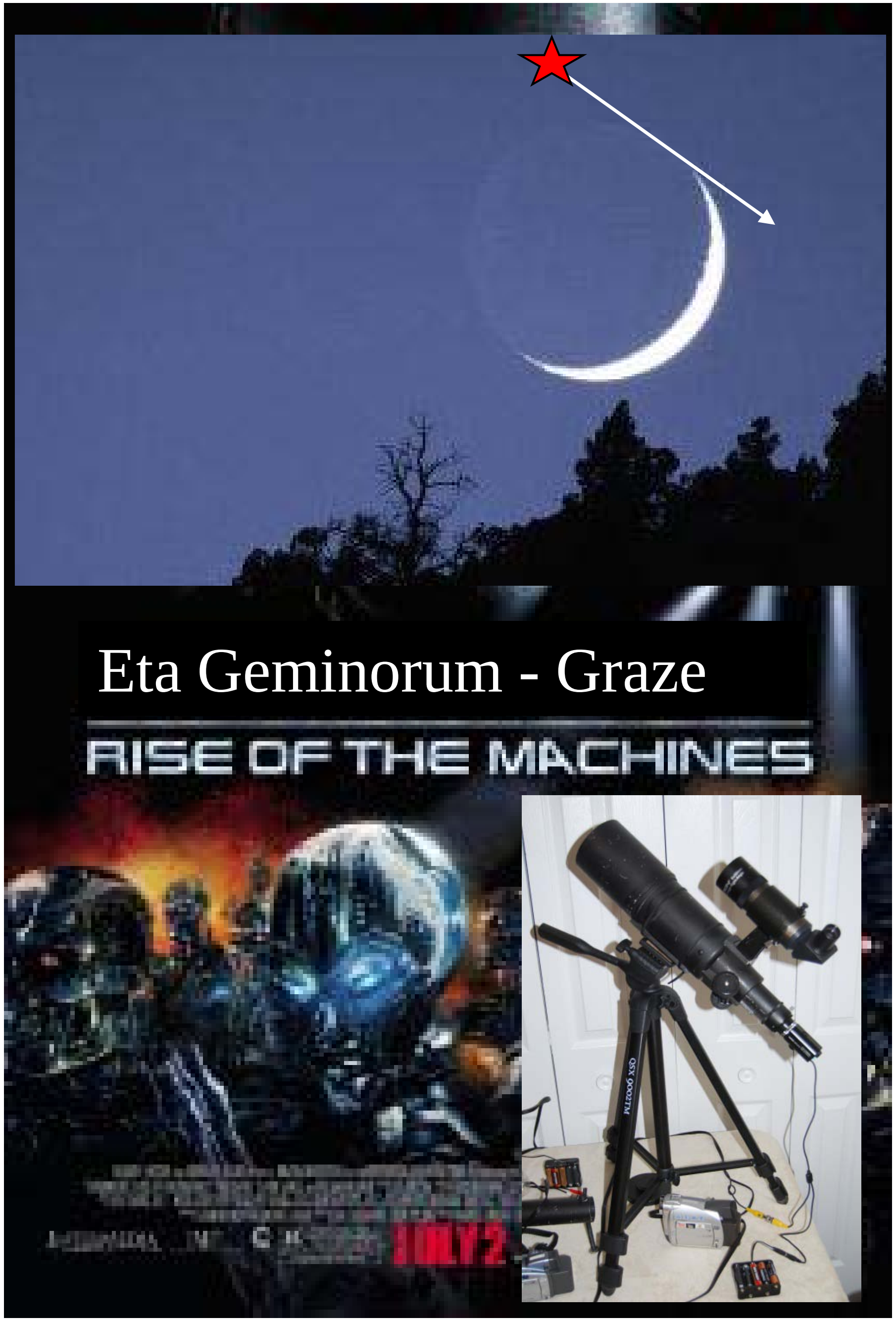
Mighty Mini

Can record occultations of stars to mag. 9.5, even mag. 10.0 under good conditions. These are fine for asteroidal occultations, but how about lunar grazes? Glare from the Moon and their low power cause problems

Mighty Midi – Orion 80mm short tube

Can record occultations of stars to mag. 11.0, even mag. 11.3 under good conditions; these work better for grazes

I use visual finder scope and $60 Quantanray tripod while scotty uses a mighty mini video as the finder and MX-350 tripod (not as sturdy as the Quantanray)



Grazing Occultation of 3.5-mag. eta Geminorum in Arizona, 2011 April 10, my first success with remote stations (a humiliating defeat, it was machines, 3; humans, 0)

Moon 36%+

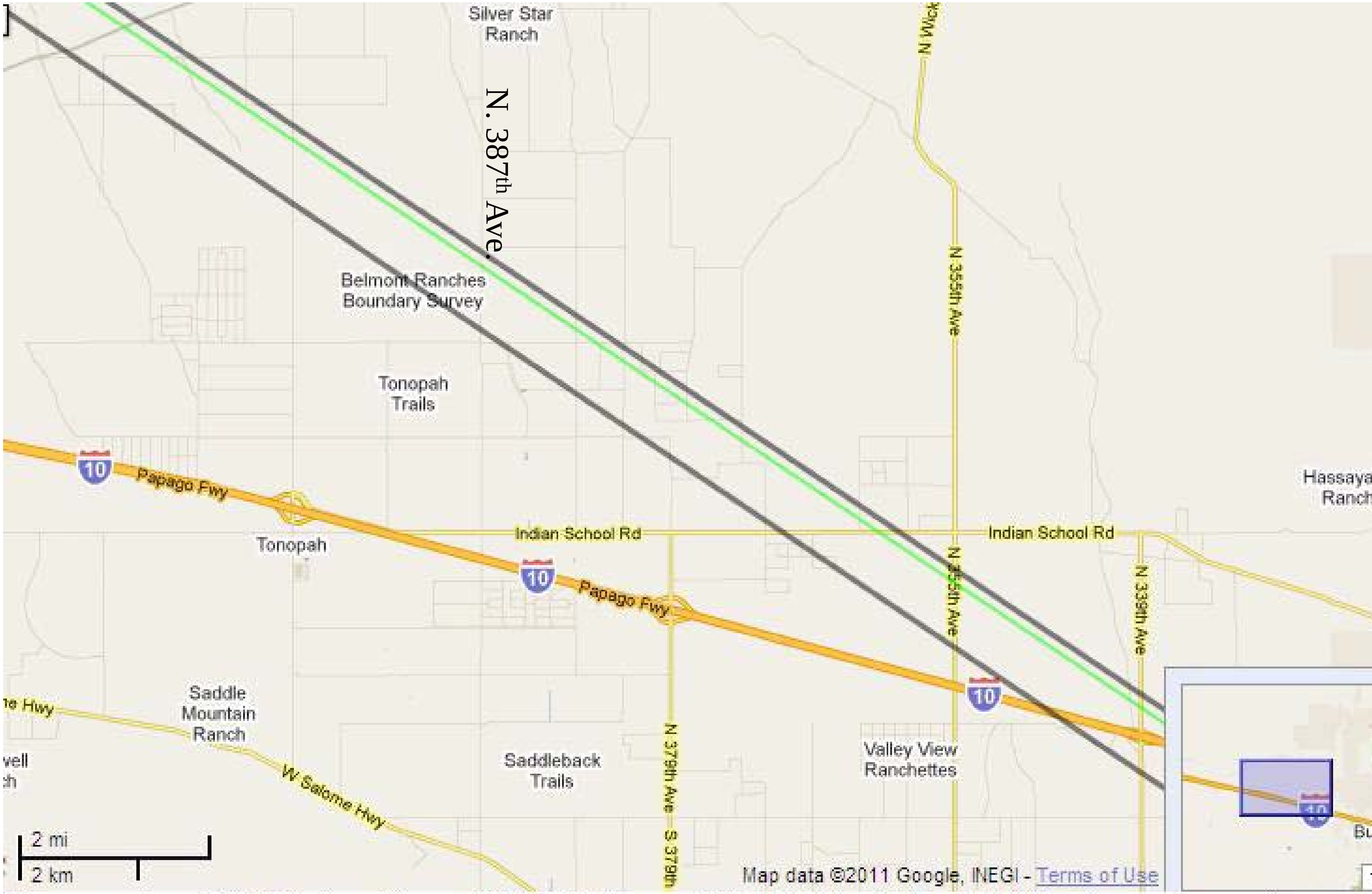
Cusp Angle 15N

Graze path in central Arizona

2011 April 10 (UT; April 9 MST)

Map center is at (WGS84 datum) Lat = 33.335117, Lon = -112.483521, which is 3.327 Km from path center.)

Graze path in Tonopah, AZ area

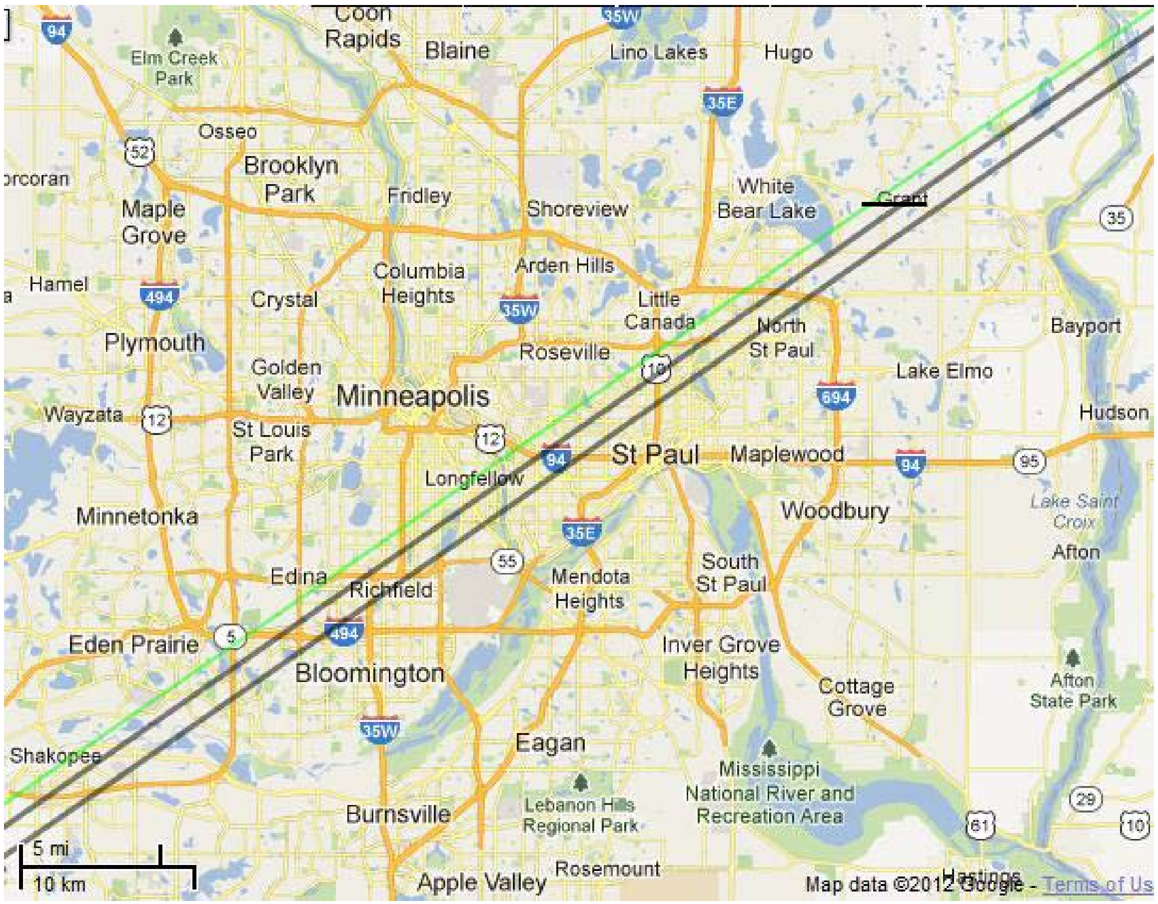


(Map center is at (WGS84 datum) Lat = 33.510484, Lon = -112.873536, which is 0.712 Km from path center.)

Stations on N. 387th Ave.

(Map center is at (WGS84 datum) Lat = 33.520538, Lon = -112.884222, which is 0.335 Km from path center.)

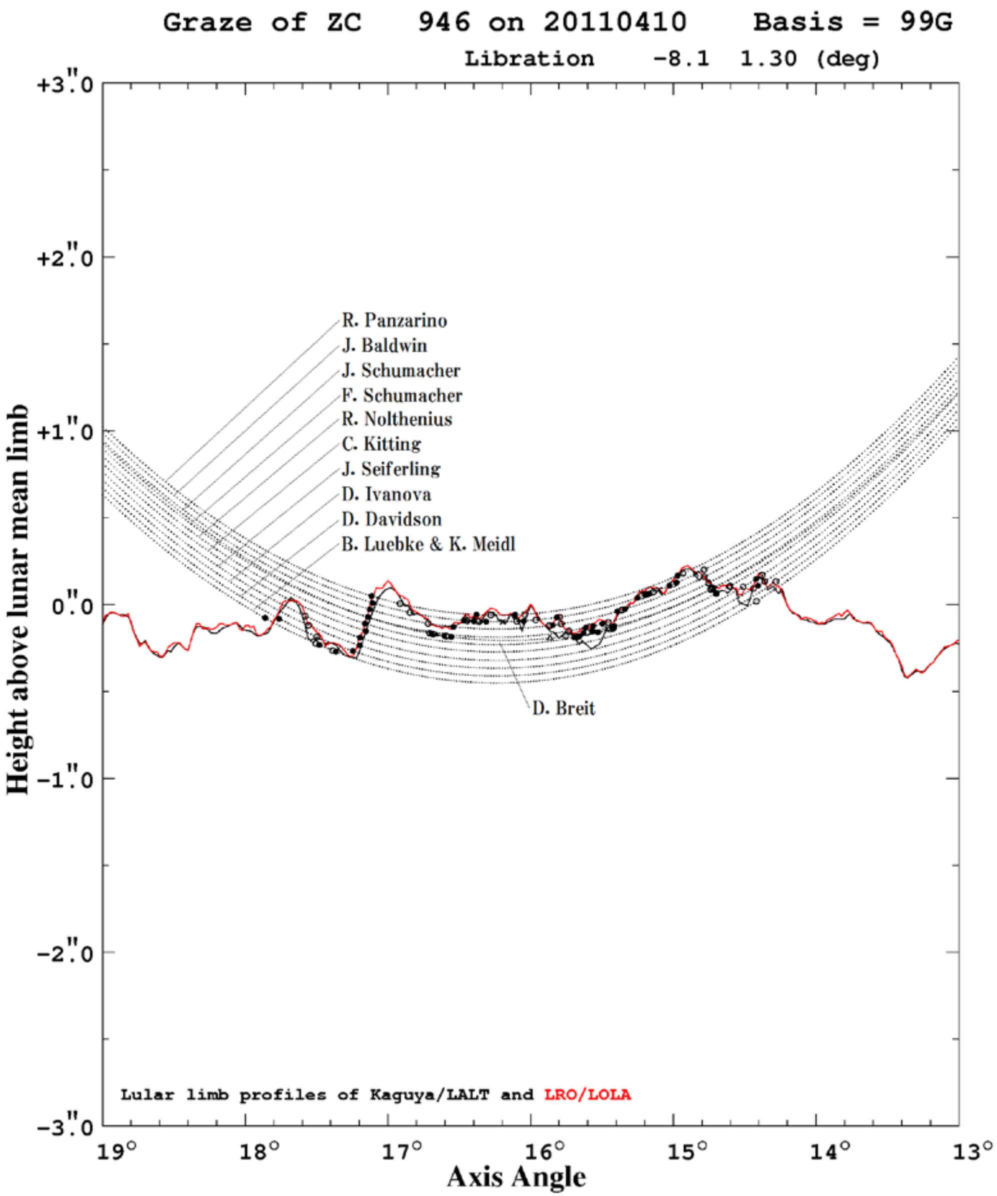
Graze of 4.9-mag. ω^2 Tauri (ZC 628) over Minneapolis, Minn. on 2012 Aug. 11, Moon 35%-, CA 2N



Station 4's single R indicates a south shift of about 200m; we can still determine corrections to stellar proper motions from graze observations

I attended an astrodynamics conference in Minneapolis, Minnesota Aug. 12-16. I went there early because I noticed that this graze occurred 2 days before; I made plans to observe it from near Grant. With the small cusp angle, I thought that there would be too much glare to record with midi systems, but I took 2 of them, to try, and 2 4-inch SCT's for attended stations that Joan and I ran. But like in Arizona, the machines triumphed; it was machines, 2, humans, 0. Station 3 recorded 6 D's and 6 R's; I'll play the video.

Comparison of Kaguya & LRO profiles



Here is a recent reduction of observations of the 2011 April 10th eta Geminorum graze by Dr. Mitsuru Sôma at the Japanese National Observatory. The profiles are close, but LRO's, with more orbits and points than Kaguya, is more accurate near Axis Angles 14.3 and 15.4.

With multiple stations and LRO data, there are still new things that can be done with grazing occultations!