

UNIVERSITY OF MICHIGAN

NO.	DATE.	INST. COMP.	P	S	L	M	F	A	Δ
	1914		h m	h m	h m	h m	h m	mm.	mgm.
140	Oct. 23	B-EW	.. .. .	.. .. .	.. .. .	7 24	.. .. .	0.2	..
		B-NS	.. .. .	.. .. .	.. .. .	24	.. .. .	0.2	..
141	Nov. 10	B-EW	.. .. .	11 22.7	11 25.8?	.. .. .	.. .. .	0.6	..
		B-NS	11 19.0	23.0	25.8	11 26.1	.. .. .	0.5	2.4
		W-EW	.. .. .	23.0	?	.. .. .	.. .. .	0.8	..
142	Nov. 18	B-EW	9 52.1	micros.	?	9 58.9	? micros.	0.8	..
		W-EW	52.2	9 55.9	9 57.3	58.8	10 8	0.4	2.
143	Nov. 24	B-EW	.. .. .	12 17.4	.. .. .	.. .. .	13.21	(2.5)	..
		B-NS	.. .. .	17.2	.. .. .	.. .. .	24	(4.5)	..
		W-EW	.. .. .	17.2	.. .. .	.. .. .	12 55	(1.5)	..
		W-NS	.. .. .	17.2	.. .. .	.. .. .	13 15	(1.1)	..
144	Dec. 4	B-EW	.. .. .	22 43.9	22 46.6†	22 46.8	? micros.	0.15	..
		B-NS	.. .. .	44.3	46.4	47.2	.. .. .	0.1	..
145	Dec. 20	B-EW	.. .. .	.. .. .	.. .. .	} 15 0±	.. .. .	..	..
		B-NS	.. .. .	.. .. .	.. .. .		.. .. .	..	..
		W-NS	.. .. .	.. .. .	.. .. .		.. .. .	..	..
146	Dec. 25	B-EW	.. .. .	3 51.4	3 53.8	3 54.3	.. .. .	1.3	..
		B-NS	.. .. .	54.2	56.7	57.4	.. .. .	0.3	..
		W-EW	.. .. .	.. .. .	.. .. .	54.9	.. .. .	0.6	..
		W-NS	.. .. .	.. .. .	.. .. .	55.2	.. .. .	0.2	..
	1915								
147	Jan. 13	B-EW	.. .. .	.. .. .	7 28	7 39.6	7 46	0.2	..
		B-NS	.. .. .	.. .. .	7 24	7 30.3	>8 0	0.5	..
		W-EW	.. .. .	.. .. .	7 25	7 33	7 44	..	..
148	Mar. 5	B-EW	.. .. .	.. .. .	4 32.8	.. .. .	.. .. .	0.7	..
		B-NS	.. .. .	.. .. .	4 32.9	.. .. .	.. .. .	0.6	..
		W-EW	.. .. .	.. .. .	4 32.9	.. .. .	.. .. .	0.4	..
		W-NS	.. .. .	.. .. .	4 33.0	.. .. .	.. .. .	0.4	..
149	April 23	B-EW	15 37.5*	15 43.9*	.. .. .	.. .. .	16 3+	..	..
		B-NS	15 37.4*	15 44.0*	.. .. .	.. .. .	16 0+	..	4.8
		W-EW	15 37.5*	15 44.0*	.. .. .	.. .. .	16 2	..	..
		W-NS	15 37.5*	15 44.0	.. .. .	.. .. .	? micros.	..	..
150	May 1	B-EW	5 12.0*	5 21.6*	5 43.3	5 43.7	8 6	9.5	..
		B-NS	5 12.1*	5 22.1	5 42.4	5 46.3	7 24	13.6	7.8
		W-EW	5 12.0*	5 21.6	5 43.2	5 43.6	8 6	1.6	..
		W-NS	5 12.0*	5 21.7	5 42†	5 46.3	8 6	3.5	..
151	May 3	B-EW	.. .. .	.. .. .	.. .. .	5 11†	.. .. .	..	..
		B-NS	.. .. .	.. .. .	.. .. .	5 11	.. .. .	..	..
		W-EW	.. .. .	.. .. .	.. .. .	5 12	.. .. .	..	..
		W-NS	.. .. .	.. .. .	.. .. .	5 11+	.. .. .	..	..
152	May 6	B-EW	.. .. .	12 15.6?	.. .. .	12 29.1	13 0±	0.9	..
		B-NS	.. .. .	.. .. .	12 25.8	12 28.0	13 0±	1.2	7.1?
		W-EW	.. .. .	12 15.5?	12 28	12 29.0	13 0+	0.5	..
		W-NS	.. .. .	12 15.5?	12 27.7	12 30.5	13 0+	1.8	..

PUBLICATIONS OF THE OBSERVATORY

NO.	DATE.	INST. COMP.	P	S	L	M	F	A	Δ
	1915		h m	h m	h m	h m	h m	mm.	mgm.
153	June 1	B—EW	14 59.8?	15 3.3	15 9.7	15 11.0	15 40+	5.4	...
		B—NS	14 53.6?	15 3.3	15 10.3	15 13.5	15 42	3.3	4.9
		W—EW	.. .. .	15 2.9	15 9†	15 11.3	15 45	1.4	...
		W—NS	.. .. .	.. .. .	15 9.9	15 13.5	15 47	1.8	...
154	June 6	B—EW	21 39.7	21 47.8*	.. .. .	21 54	22 45+	1.8	...
		B—NS	21 39.6*	21 47.9*	.. .. .	22 10	22 35	0.9	6.7
		W—EW	21 39.8	21 48.0*	.. .. .	.. .. .	23 0±	0.7	...
		W—NS	21 39.8	21.47.9	.. .. .	22 10	22 50	0.7	...
155	June 23	B—EW	.. .. .†	.. .. .	4 14.7	4 15.6	.. .. .	1.1	...
		B—NS	.. .. .	.. .. .	4 12.9	13.7	.. .. .	3.0	3.
		W—EW	.. .. .	4 12.5?	4 14.7	15.6	.. .. .	0.7	...
		W—NS	.. .. .	.. .. .	4 13.0	14.7	.. .. .	2.0	...
156	June 23	B—EW	.. .. .†	.. .. .	5 11.6	5 12.0	.. .. .	1.9	...
		B—NS	.. .. .	.. .. .	5 9.7	5 11.0	.. .. .	2.8	3.
		W—EW	.. .. .	5 9.?	5 11.4	5 11.9	.. .. .	0.8	...
		W—NS	.. .. .	5 6.1?	5 9.4*	5 10.9	.. .. .	2.6	...
157	July 31	B—EW	1 42.6	1 51.8	2 6.6	2 11	3 7	1.6	...
		B—NS	1 42.6	1 51.8	2 6.2	2 13.4	3 8	1.5	8.0
		W—EW	1 42.2	1 51.7	2 6	2 12	3 30	0.5	...
		W—NS	.. .. .	.. .. .	.. .. .	2 13.7	.. .. .	0.2	...
		W—V	.. .. .	.. .. .	.. .. .	2 13.7	.. .. .	0.1	...
158	Aug. 3	B—EW	.. .. .	.. .. .	.. .. .	14 13	.. .. .	...	...
		B—NS	.. .. .	.. .. .	.. .. .	14 13	.. .. .	...	...
		W—EW	.. .. .	.. .. .	.. .. .	14 15	.. .. .	0.1	...
159	Aug. 7	B—EW	.. .. .	.. .. .	.. .. .	Traces	.. .. .	...	...
		B—NS	.. .. .	.. .. .	.. .. .	15 42†	.. .. .	...	...
		W—EW	.. .. .	.. .. .	.. .. .	15 49±	.. .. .	...	...
160	Sept. 7	B—EW	1 26.8	1 31.7	.. .. .	.. .. .	3 39	>40	...
		B—NS	1 26.9	1 31.6	1 35.8	.. .. .	3 9	>50	...
		W—EW	1 26.9	1.31.6±	.. .. .	1 37	3 27	21.4	3
		W—NS	1 26.9	1 31.6±	.. .. .	.. .. .	3 21	11.6	...
		W—V	.. .. .	.. .. .	1 36.1	1 39	1 43.3	4.4	...
161	Sept. 7	B—EW	.. .. .	.. .. .	4 22.0	4 24.0	.. .. .	...	...
		B—NS	.. .. .	.. .. .	.. .. .	Trace	.. .. .	...	4.?
		W—EW	.. .. .	.. .. .	4 22	4 23.1	.. .. .	...	...
		W—NS	.. .. .	4 17.3?	4 21.6	4 26	.. .. .	...	...
162	Sept. 7	B—EW	4 33.9†	.. .. .	4 45†	4 45.3	5 1	0.4	...
		B—NS	4 34.2?	4 39.8?	4 44.7	4 45.1	4 59	0.4	4.0
		W—EW	4 34.3?	.. .. .	4 44.9	4 45.1	4 58	0.1	...
		W—NS	4 34.1	4 39.9?	4 44.6	4 45.0	5 1	0.2	...
163	Sept. 7	B—EW	5 8.8?	5 13.2?	5 18.7	.. .. .	.. .. .	...	...
		B—NS	.. .. .	5 13.8†	5 19.7	5 21	.. .. .	0.1—	...
		W—EW	.. .. .	5 14.9†	.. .. .	Trace	.. .. .	...	3.8
		W—NS	5 9.4	5 14.7?	5 19.9	5 20.1	5 30	0.1	...

NO.	DATE.	INST. COMP.	P	S <sub>1</sub>	L	M	F	A	Δ
	1915		h m	h m	h m	h m	h m	mm.	mgm.
164	Sept. 7	B-EW	.. .. .	.. .. .	.. .. .	13 9	.. .. .	..	..
		B-NS	.. .. .	.. .. .	.. .. .	13 6-II	.. .. .	..	..
		W-EW	.. .. .	.. .. .	.. .. .	13 10	.. .. .	..	..
		W-NS	.. .. .	.. .. .	.. .. .	13 9	.. .. .	..	..
165	Sept. 7	B-EW	.. .. .	20 50.6	.. .. .	20 58.3	21 13	0.1	..
		B-NS	20 46.6	20 50.4	20 56.7†	21 1.1	21 14	0.1	4
		W-EW	.. .. .	20 52.0?	.. .. .	.. .. .	21 11	0.1	..
		W-NS	20 45.6?	.. .. .	.. .. .	21 1	21 12	0.1	..
166	Sept. 12	B-EW	20 50.5?	20 53.1?	21 10±	21 13	.. .. .	0.2	..
		B-NS	.. .. .	.. .. .	.. .. .	21 1-4	.. .. .	..	..
167	Oct. 2	B-EW	23 52.6	23 55.2?	.. .. .	.. .. .	.. .. .	..	..
		B-NS	23 53.4	.. .. .	.. .. .	.. .. .	.. .. .	0.5	..
		W-EW	23 53.4†	23 56.3	.. .. .	.. .. .	.. .. .	0.2	1.8
		W-NS	23 53.5	23 56.9	.. .. .	.. .. .	.. .. .	0.9	..
168	Oct. 3	B-EW	.. .. .	.. .. .	2 4.6	2 4.9	2 22	0.8	..
		B-NS	.. .. .	.. .. .	2 3.3?	2 3.5	2 21	0.7	4.5?
		W-EW	.. .. .	1 57.8	2 4.3	2 4.6	.. .. .	0.3	..
		W-NS	.. .. .	.. .. .	2 3.6±	2 4.6	.. .. .	0.6	..
169	Oct. 3	B-NS	6 59.0	7 3.7	7 5.1	Off sheet	9 0	>67	..
		W-EW	6 59.0	7 3.8±	7 8.?	Double	9 2	28	3.0
		W-NS	6 59.0	7 3.7	7 7.2±	?	9 7	17.0	..
170	Oct. 11	B-EW	19 39.1	19 43.2	19 49.2	19 54.5	.. .. .	1.3	..
		B-NS	19 39.3	19 43.5	19 49.5	19 52.1	.. .. .	1.0	..
		W-EW	19 39.2	19 43.1?	19 50±	19 53.2	.. .. .	0.2	..
		W-NS	19 39.1	19 43.3	19 50±	19 54.1	.. .. .	0.3	..
171	Nov. 1	B-EW	.. .. .	7 47.5	.. .. .	8 23	.. .. .	0.8	..
		B-NS	.. .. .	7 48	.. .. .†	8 22	.. .. .	0.8	..
		W-EW	.. .. .	7 48	.. .. .	8 23	.. .. .	0.5	..
		W-NS	.. .. .	7 49 ±	.. .. .	8 23	.. .. .	0.8	..
172	Nov. 21	B-EW	0 23†	0 26.7	0 30.4	0 35	1 35	55.0	..
		B-NS	.. .. .	0 27.1	29.8	Off sheet	1 25	>35.0	..
		W-EW	0 23†	0 27.4	31.0	34	1 35	8.5	2.7
		W-NS	.. .. .	.. .. .	30.7	32	1 10	15.9	..
		W-V	.. .. .	.. .. .	33.5	32.0	1 36.4	7.8	..
173	Nov. 26	B-EW	.. .. .	.. .. .	.. .. .	Visible	.. .. .	..	..
		B-NS	.. .. .	.. .. .	.. .. .†	19 37	.. .. .	0.1	..
		W-EW	.. .. .	.. .. .	19 31	?	.. .. .	0.05	..
		W-NS	.. .. .	.. .. .	.. .. .	Trace	.. .. .	..	..
174	Dec. 12	B-EW	.. .. .	.. .. .	21 16.3	21 16.8	.. .. .	1.4	..
		W-NS	21 9.1	21 13.6?	.. .. .	21 19.3	21 27?	0.1	2.9
175	Dec. 29	B-NS	.. .. .	.. .. .	0 10.9	0 13.7	.. .. .	0.15	..
176	Dec. 31	B-EW	12 26.4	12 31.6	12 39.4	12 39.8	13 16?	3.8	..
		B-NS	.. .. .	.. .. .†	12 36.4	12 40.0	13 20?	2.4	3.6?
		W-EW	12 26.3	12 31.6	12 39.1	12 39.7	13 19?	0.9	..
		W-NS	.. .. .	.. .. .	.. .. .	12 39.8	.. .. .	..	..

126 and 127. The recorded L is the beginning of the disturbance, but later portions, if present, are very weak. However, since the period of the waves is short, 6-7 seconds, in both cases, it is possible that these times should be identified as S in both shocks.

July 13. W-NS shows a slight disturbance at 3<sup>h</sup>17<sup>m</sup>; possibly artificial.

129. Probably one or more phases have been misidentified since the values of  $\Delta$  from different forms of the Laska formulae are very discordant.

130. The Jamaica earthquake.

131. B-NS record poor.

133. No record of shock on W-NS. Values of  $\Delta$  discordant.

134. Some microseisms and probably a small shock.

136. Long waves from about 17<sup>h</sup>34<sup>m</sup> to 18<sup>h</sup>. Trace on B-EW.

137. Ecuador earthquake?

138. B-EW shows short vibrations superposed on the first few long waves of the main portion; on W-EW they continue throughout the main portion.

139. A small disturbance, perhaps not a true earthquake. A trace on W-NS; a weaker trace on W-EW; and probably a trace on W-V.

140. Some flat slow waves, period 28 sec., visible on W horizontal.

141. Phases not well marked. Nothing seen on W-NS.

142. On B-NS microseisms are too strong to distinguish earthquake. Very small record on W-NS, the tail being strong, however, and apparently extending to 10<sup>h</sup>16<sup>m</sup>, though this is uncertain on account of microseisms.

143. Curious record; no well marked phases. A refers to initial throw of pen, which is large compared with the disturbances which follow.

146. Small irregular waves superposed on the large ones. Phases very uncertain.

Jan. 6, 1915. Slow flat waves on B-EW having a maximum at 0 hrs., period about 20 sec.

147. Slow flat waves lasting over 20 min. W-NS shows only a very slight trace. Preliminaries are not distinguishable among microseisms.

Feb. 25. A slight disturbance at 9<sup>h</sup>25<sup>m</sup> in the midst of sinusoidal waves.

Feb. 28. Some flat waves at 20 hrs., period about 20 sec.

148. An irregular disturbance beginning abruptly at times given as L, and lasting a few minutes.

March 28. A small disturbance at 20<sup>h</sup>29<sup>m</sup> lasting for several minutes in midst of microseisms. Period 10-12 sec.

April 7. Some slight disturbances about 16<sup>h</sup>14<sup>m</sup>.

149. If P and S are correctly identified the long waves (L) are not plain being apparently very feeble with short period vibrations superposed. On W-V P is markedly a single sudden small displacement.

April 25. A small disturbance (perhaps artificial) on W-V from 21<sup>h</sup>29<sup>m</sup>.8 to 21<sup>h</sup>30<sup>m</sup>.4. Nothing notable on other records.

150. No appreciable record on W-V.

151. Flat waves, period about 20 sec. Also some very weak waves about one hour earlier.

152. P may be wrongly identified as S.

153. Shock in the midst of slight microseisms on W. W shows short waves superposed on the long ones of the main portion.

154. Amplitudes of S.

B-EW	12.0
B-NS	2.5
W-EW	4.7

June 14. At 22<sup>h</sup>6<sup>m</sup> there is a small disturbance on W with a trace on B—perhaps artificial.

June 15. W-V shows a small irregular disturbance at 0<sup>h</sup>59<sup>m</sup>.6 probably artificial.

156. In both shocks the long waves die away gradually disappearing in about 15 min.

July 22. B-NS shows a small shock at 4<sup>h</sup>33<sup>m</sup>.

July 25. B-NS and W-EW some very flat slow waves for several minutes beginning 21<sup>h</sup>17-18<sup>m</sup>. Amplitudes not over 0.1 mm. No well defined maxima.

Aug. 6. Probably some long waves, in the midst of microseisms, about 14<sup>h</sup>6<sup>m</sup> on W-EW; trace on B-EW; better shown on B-NS; continue feebly for 10-12 min.

Aug. 16. B-EW shows some very feeble waves for 15 minutes, beginning at 1<sup>h</sup>30<sup>m</sup>. Trace on B-NS and W-EW.

Sept. 6. B instruments show a very slight disturbance at 18<sup>h</sup>51<sup>m</sup>.

160. The W pens exhibit a peculiar jerky motion.

164. A very slight disturbance.

165. Phases are very poorly marked and indistinguishable in many cases.

166. Phases poorly marked. Possibly S at 21<sup>h</sup> 0<sup>m</sup>.7. Traces on horizontal W. Record poor.

167. B—NS shows a peculiar disturbance beginning at 23<sup>h</sup> 53<sup>m</sup>.4 (= P?) visible for about 10 minutes having its maximum at 23<sup>h</sup> 55<sup>m</sup>.6. S is doubtful and L very weak if present.

169. B—EW not running. No action on W—V.

170. Phases misidentified?

171. F in microseisms.

Nov. 4. B—NS a few slow waves in the midst of microseisms at 19<sup>h</sup> 56<sup>m</sup>, period 18-20 sec., amplitude 0.2 mm.

172. F runs into microseisms. W—NS not very sensitive.

173. Slow flat shock in weak microseisms.

Dec. 7. A peculiar disturbance at 18<sup>h</sup> 45<sup>m</sup> lasting a minute or two, consisting of very short vibrations superposed on longer rather irregular waves. Amplitudes:

B—EW	0.6
B—NS	0.7
W—EW	1.4
W—NS	0.5

174. B—NS trace but microseisms too strong. W—EW out of order.

Dec. 17. B—NS shows a few slow flat waves with M at 8<sup>h</sup> 5<sup>m</sup>.

175. B—EW microseisms mask. W—EW pen behaves badly.

176. W—NS insensitive. Time of L not accurate?

### MICROSEISMS, 1914 AND 1915

1914.

Jan. 1-9.

Sinusoidal microseisms coming to a maximum on 3-4<sup>d</sup>. Best shown on EW components where they have a maximum amplitude of 0.2 mm. and a period of 5-6 seconds.

Jan. 9-11.

Waves slower and more irregular.

Jan. 11-12.

Tremors stronger.

INST.—COMP.	MAX. AMPLITUDE.	PERIOD.
	mm.	sec.
B—EW	0.25	5-6½
B—NS	0.3	5-6
W—EW	0.1	6
W—NS	?	...

Jan. 12-13.

Same. Period 5 seconds.

Jan. 13-15.

Weaker.

Jan. 16-18.

Tremors faint.

Jan. 18-19.

Stronger.

Jan. 19-20.

Considerably stronger.

INST.—COMP.	MAX. AMPLITUDE.	PERIOD.
	mm.	sec.
B—EW	0.4	6
B—NS	0.3	6
W—EW	0.1	6
W—NS	Very small.	

Jan. 20-21.

Tremors continue. Some well marked groups.

Jan. 21-23.

Weaker.

Jan. 23-24.

A few small tremors. Nearly continuous on B—EW.

Jan. 24-25.

Some slow irregular waves.

Jan. 25-26.

Weak, regular, sinusoidal waves, with occasional stronger groups on W—EW. Period 4 sec.

Jan. 26-29.

Tremors die away gradually.

Jan. 31-Feb. 5.

Slight irregular tremors.

Feb. 5-9.

Growing stronger, particularly on EW instruments where they are perfectly continuous on 7-9.

Feb. 9-11.  
Tremors grow weaker.

Feb. 11-13.  
Irregular tremors stronger, particularly toward last of 12-13<sup>d</sup>, being then very irregular and peculiar. Stronger on NS than before.

Feb. 13-14.  
Much weaker, dying down during the day.

Feb. 14-15.  
Weak tremors visible. Some regular sinusoidal waves.

Feb. 15-17.  
Same, weaker.

Feb. 17-18.  
Irregular tremors extremely feeble. Some regular sinusoidal waves on B—NS and more faintly on B—EW. Period about 6 seconds.

Feb. 18-19.  
Slightly stronger. Visible on W—EW.

Feb. 19-20.  
Weaker.

Feb. 20-21.  
Regular sinusoidal waves in groups but usually connected by small tremors. Amplitude small, about 0.1 mm. Period about 6 seconds.

Feb. 21-25.  
Weak sinusoidal waves which are more prominent on EW components.

Feb. 26-27.  
Numerous small sinusoidal waves on all horizontal instruments.

March 1-3.  
Regular sinusoidal waves nearly continuous. Best shown on NS records.

INST.—COMP.	MAX. AMPLITUDE.	PERIOD.
	mm.	sec.
B—NS	0.2	5
W—NS	0.05	5

March 3-5.  
Traces of above.

March 9-15.  
Very slight tremors, some being irregular.

March 16-20.  
Irregular tremors, stronger during first part of day.

March 20-23.  
Some feeble regular sinusoidal microseisms.

March 25-26.  
Irregular tremors; stronger during the day than at night.

March 31-April 1.  
Some slight regular sinusoidal waves on NS records.

April 1-2.  
Same; stronger.

April 2-3.  
Microseisms weaker and somewhat irregular.

April 4-5.  
Some slow irregularities on NS records.

April 7-8.  
Slight irregular motion toward latter part of record on B—NS.

April 8-12.  
Same; visible also on B—EW.

April 19-20.  
Fairly strong irregular microseisms on B—NS.

April 20-21.  
Same; weaker.

April 24-25.  
Many regular sinusoidal waves, period about 5½ sec.

April 25-26.  
Some feeble tremors, slightly slower.

April 29-30.  
Slight irregular tremors on B—EW.

May 13-14.  
B—NS very slight irregular tremors, stronger toward morning of 14th.

May 22-23.  
B—NS some slight microseisms.

May 29-30.  
B—NS some slight microseisms occasionally.

June 5-6.  
B—NS some very slight slow irregular tremors.

June 10-11.  
B—NS very slight tremors.

June 13-16.  
Same.

June 18-19.  
Same.

June 29-July 2.  
B—NS a few weak tremors.

July 7-10.  
B—NS numerous very small tremors decrease in strength to 10th.

- July 11-12.  
B—NS some very small tremors of short period.
- July 13-16.  
Minute slow tremors.
- July 16-18.  
Small tremors on B—NS.
- July 24-25.  
Some faint tremors on B—NS. It is not certain whether they continue after this day since the records of this instrument are poor during the next few days.
- Aug. 11-12.  
B—NS weak tremors.
- Aug. 12-14.  
Stronger; seen also on B—EW.
- Aug. 14-16.  
Weaker.
- Aug. 17-18.  
Some small tremors.
- Aug. 25-27.  
B—NS shows small tremors which are nearly continuous on 26-27.
- Aug. 27-28.  
Weaker.
- Sept. 2-4.  
Slight sinusoidal waves on B instruments.
- Sept. 4-5.  
Very slight tremors.
- Sept. 5-6.  
Stronger. ?
- Sept. 6-8.  
Stronger, particularly on EW. Trace on W.
- Sept. 8-11.  
Tremors die away gradually.
- Sept. 15-26.  
Weak regular sinusoidal waves; strongest on 17-18.
- Sept. 26-27.  
Very regular sinusoidal waves practically continuous.
- Sept. 27-29.  
Stronger. Traces on W.
- Sept. 29-30.  
Much weaker.
- Sept. 30-Oct. 3.  
Small sinusoidal waves.
- Oct. 3-4.  
Microseisms present but weaker.
- Oct. 4-7.  
Slight sinusoidal waves.
- Oct. 11-12.  
B—NS slow flat microseisms?
- Oct. 12-13.  
Slight regular sinusoidal waves.
- Oct. 13-14.  
Apparently some slight slow irregular oscillations on B—NS, but B—EW shows only regular sinusoidal waves.
- Oct. 14-15.  
Very weak regular sinusoidal waves.
- Oct. 15-16.  
The motion very feeble.
- Oct. 16-21.  
Rather strong sinusoidal pulsations on 16-17, and 18-19; die away slowly.
- Oct. 23-28.  
Sinusoidal.
- Oct. 28-30.  
Much stronger.
- Oct. 30-31.  
Not so strong.
- Oct. 31-Nov. 8.  
Sinusoidal, strongest on 1-3.
- Nov. 8-9.  
Numerous groups of sinusoidal waves,—trains?
- Nov. 9-10.  
Irregular tremors.
- Nov. 10-11.  
Same. Small sinusoidal waves on B—EW.
- Nov. 11-12.  
Regular sinusoidal waves, stronger.
- Nov. 12-13.  
Weaker, dying away.
- Nov. 13.  
B—NS irregular waves in the morning.
- Nov. 15-16.  
B—NS irregular waves stronger toward end of record. Very much smaller ones on B—EW.
- Nov. 16-18.  
Very strong irregular waves on B—NS; smaller ones on B—EW.
- Nov. 18-24.  
Microseisms, stronger on 20-21.
- Nov. 24-25.  
Slight irregular tremors.

- Dec. 2-7.  
B—NS irregular microseisms, slightly stronger on 5-6.
- Dec. 7-30.  
Numerous microseisms every day.
- Dec. 13-14.  
Microseisms become considerably stronger during latter part of record.
- Dec. 14-15.  
B—NS very strong irregular tremors all day. Weaker and more regular on B—EW. Scarcely visible on W.
- Dec. 15-21.  
Above die down to weak tremors.
- Dec. 21-22.  
Tremors stronger on latter portion of B records.
- Dec. 22-23.  
Continued throughout record.
- Dec. 23-25.  
Weaker.
- Dec. 25-27.  
Tremors grow stronger.
- Dec. 27-30.  
Grow weaker.
- 1915**
- Dec. 31-Jan. 3.  
Rather strong irregular microseisms, being weaker on 2-3.
- Jan. 3-4.  
Microseisms stronger and more regular.
- Jan. 4-5.  
Same; a few large slow irregular motions in first part of day.
- Jan. 5-6.  
Microseisms weaker.
- Jan. 6-8.  
Irregular tremors increase and die away.
- Jan. 8-11.  
Small tremors stronger on 10-11.
- Jan. 11-13.  
Sinusoidal waves in groups; better marked on EW.
- Jan. 13-14.  
All records, including W—V exhibit very striking sinusoidal waves, showing the group structure. The period on all instruments is about  $5\frac{1}{2}$  seconds.
- Jan. 14-16.  
Fade away.
- Jan. 17-23.  
Small microseisms, partly of sinusoidal nature on B—EW, more irregular on B—NS.
- Jan. 23-24.  
Tremors stronger, continuous B—NS.
- Jan. 24-25.  
W—EW some short sinusoidal waves, period 3-4 seconds.
- Jan. 28-31.  
Tremors as before, being more regular on EW.
- Jan. 31-Feb. 1.  
A few weak tremors.
- Feb. 1-2.  
Stronger toward latter part of day, sinusoidal.
- Feb. 2-10.  
Continue.
- Feb. 14-17.  
Few weak and slow tremors.
- Feb. 17-18.  
Slight quick sinusoidal waves, 15-20 per minute.
- Feb. 18-20.  
Grow less.
- Feb. 24-25.  
Some small sinusoidal waves.
- Feb. 25-28.  
Fairly strong irregular tremors, especially on EW; grow weaker.
- Mar. 1-2.  
Slight disturbances throughout day.
- Mar. 3-5.  
Slight microseisms.
- Mar. 6-7.  
Slight tremors.
- Mar. 10-11.  
Die down but become considerably stronger toward latter part of record.
- Mar. 11-12.  
Marked sinusoidal waves with strong groups.
- Mar. 12-17.  
Decrease in intensity.
- Mar. 17-19.  
Stronger and more continuous.
- Mar. 19-24.  
Decrease.
- Mar. 24-25.  
Somewhat stronger.



- Mar. 25-31.  
Tremors much weaker at end of the period.
- Mar. 31-Apr. 1.  
Faint tremors most pronounced on W—NS where they appear as groups of sinusoidal waves.
- Apr. 1-2.  
Weaker.
- Apr. 2-4.  
Increase.
- Apr. 4-8.  
Die away.
- Apr. 8-10.  
Sinusoidal waves stronger again, especially on W.
- Apr. 10-11.  
Much weaker and in detached groups.
- Apr. 11-12.  
Slow irregular disturbances throughout day on B—NS; occasional groups of sinusoidal waves on W. Trains?
- Apr. 12-17.  
Microseisms, being strongest on 14-15.
- Apr. 18-19.  
Microseisms, more prominent on W.
- Apr. 21-23.  
Sinusoidal waves, stronger on 21-22.
- Apr. 25-26.  
Some sinusoidal waves.
- Apr. 29-30.  
Some irregular disturbances on B—NS.
- May 6-7.  
Traces of microseisms on W.
- May 7-8.  
Some sinusoidal waves, in groups.
- May 14-15.  
Some feeble sinusoidal waves.
- May 27-31.  
Same.
- June.  
First few days of month slight traces of sinusoidal waves almost continually on both components of EW, accentuated by trains.
- July 1-2.  
Some very slight sinusoidal waves.
- July 6-7.  
Slight and rather irregular microseisms.
- July 15-16.  
Slight microseisms.
- July 20-21.  
Slight sinusoidal waves.
- July 23-24.  
Occasional sinusoidal waves on W—EW.
- July 26-27.  
Sinusoidal waves on early part of W—EW record.
- Aug. 5-6.  
Microseisms, stronger toward end of record
- Aug. 16-18.  
Some very slight tremors on EW.
- Aug. 18-20.  
Stronger.
- Aug. 20-22.  
Die away.
- Aug. 23-25.  
Tremors as above.
- Aug. 26-29.  
Feeble tremors.
- Sept. 1-5.  
Slight sinusoidal waves, strongest on 3-4.
- Sept. 8-9.  
Slight traces of microseisms.
- Sept. 13.  
Weak microseisms, nearly continuous throughout remainder of the month, being stronger on Sept. 23-24, 27-29, and weak on Sept. 18-19, 25-27, 29-30.
- Sept. 30-Oct. 2.  
Slight microseisms.
- Oct. 6-8.  
Microseisms increase and wane.
- Oct. 8-10.  
Microseisms just visible.
- Oct. 10-14.  
Weak microseisms.
- Oct. 15-22.  
Very feeble microseisms.
- Oct. 22-24.  
Much stronger sinusoidal waves.
- Oct. 24-27.  
Weaker.
- Oct. 27-28.  
Practically disappear.
- Oct. 28-29.  
Some slight rather irregular motion.
- Oct. 31-Nov. 1.  
Fairly strong irregular microseisms all day, with an earthquake superposed on them.

PUBLICATIONS OF THE OBSERVATORY

177

- Nov. 1-2.  
Fairly strong sinusoidal microseisms.
- Nov. 2-4.  
Continue, weaker.
- Nov. 4-5.  
Slightly stronger.
- Nov. 5-7.  
Much less prominent.
- Nov. 7-9.  
Somewhat stronger.
- Nov. 9-11.  
Feeble.
- Nov. 11-13.  
Somewhat stronger.
- Nov. 13-14.  
Weaker, not continuous.
- Nov. 14-16.  
Grow considerably stronger.
- Nov. 16-17.  
Slightly less.
- Nov. 17-20.  
Sinusoidal microseisms. Principally in groups.
- Nov. 20-22.  
Nearly continuous, rather irregular.
- Nov. 22-26.  
Grow weaker.
- Nov. 28-29.  
Irregular. Grow quite strong toward end of record, especially on B—NS.
- Nov. 29-30.  
Slow microseisms, with occasional groups of stronger waves. Best shown on B—NS.
- Nov. 30-Dec. 1.  
Microseisms visible.
- Dec. 1-4.  
More sinusoidal in character.
- Dec. 4-10.  
Weak microseisms.
- Dec. 10-13.  
Strong sinusoidal microseisms, slacking toward end.
- Dec. 13-15.  
Weaker but still conspicuous on B, especially B—NS.
- Dec. 15-19.  
Weaker.
- Dec. 19-21.  
Rather slow and irregular.
- Dec. 21-24.  
Sinusoidal microseisms, with emphasized groups.
- Dec. 24-25.  
Practically no microseisms.
- Dec. 25-26.  
Feeble microseisms toward end of record.
- Dec. 26-27.  
Sinusoidal microseisms mostly in groups.
- Dec. 27-31.  
Sinusoidal waves stronger.

87417

## OBSERVATORY NOTES

### ON A METHOD ADOPTED FOR THE DETERMINATION OF THE ELEMENTS OF SPECTROSCOPIC BINARIES WITH AN ABBREVIATION OF THE LEAST-SQUARES SOLUTION

By RALPH H. CURTISS

For several years the writer has presented in a course on spectroscopic binary orbits the various formulæ which have been proposed for the determination of the elements of these stellar systems from measures of radial velocity. In connection with this course all the geometrical methods, beginning with that of Lehmann-Filhés, have been tested and compared many times. Taking these tests and comparisons into account, a method has been adopted at this Observatory, which is short, determinate, and quite satisfactory in practice. The formulæ, which are obtained easily from those derived by H. C. Plummer on pages 214 and 215 of Volume 28 of the *Astrophysical Journal*, are given below.

In addition to the symbols more frequently employed in this connection, we define:

$\gamma'$ , the algebraic mean of the maximum and minimum ordinates of the velocity curve, referred to the zero axis.

$t_1, t_2, t_3, t_4$ , the abscissæ of the points of the velocity curve corresponding to the ends of chords of the orbit making angles of  $45^\circ$  with the line of apsides. (The ordinates of these points, beginning on the descending branch of the velocity curve are  $\gamma' + 0.7071 K$ ,  $\gamma' - 0.7071 K$ ,  $\gamma' + 0.7071 K$ , and  $\gamma' - 0.7071 K$  respectively.)

$\eta$ , the quantity,  $\frac{1}{2} (E_2 - E_1)$ ,

$\eta'$ , the quantity,  $\frac{1}{2} (E_1 - E_2)$ ,

$\tau$ , the quantity,  $\frac{t_2 - t_1}{P}$ ,

$\tau'$ , the quantity,  $\frac{t_4 - t_3}{P}$ ,

The formulae are:

$$2\pi\tau = 2\eta - \sin 2\eta, \quad (1)$$

$$2\pi\tau' = 2\eta' - \sin 2\eta', \quad (2)$$

$$\tan (45^\circ - \omega) = + \frac{\cot \eta}{\cot \eta'} \quad (3)$$

$$\tan \phi = - \frac{\cot \eta}{\sin (45^\circ - \omega)} = - \frac{\cot \eta'}{\cos (45^\circ - \omega)} \quad (4)$$

$$v_1 = 45^\circ - \omega, \quad (5)$$

$$v_3 = 90^\circ + v_1, \quad (6)$$

$$T = t_1 - M_1/\mu = t_3 - M_2/\mu. \quad (7)$$

In applying this method the quantities,  $\gamma' \pm 0.7071 K$ , are first computed and the corresponding abscissæ are read off the preliminary curve. The values of  $\tau$  and  $\tau'$  are formed and equations (1) and (2) are then solved by Table I below.  $\omega$  and  $e$  follow from equations (3) and (4) and may be checked roughly by Tables II and III.  $v_1$  and  $v_3$  may then be written down from relations (5) and (6),  $M_1$  and  $M_2$ , corresponding to  $v_1$  and  $v_3$ , are taken from the *Tables for the True Anomaly*, given in the *Publications of the Allegheny Observatory*, Vol. 2, No. 17. Two values of  $T$  follow from formula (7), and a third more briefly by noting the value of  $t$  whose ordinate is  $\gamma' + K \cos \omega$ . The differences among these values will give some indication of the departure from ellipticity of the preliminary curve. The adopted value of  $T$  may be a straight mean of these values or a compromise suggested by a consideration of the conditions of the case.

An ephemeris is then computed at convenient intervals with the formula,

$$V = \gamma' + K \cos u,$$

using again the *Tables for the True Anomaly*, referred to above, to proceed from  $M$  to  $v$ . With the curve given by this ephemeris as a guide, it is a few minutes work to make a second, and usually final, determination of the elements if the first set is not satisfactory.

To facilitate the use of this method Table I is published below. This table contains values of  $\eta$  (or  $\eta'$ ) tabulated with  $\tau$  (or  $\tau'$ ) as argument and also first differences of the tabulated quantity. In form this table is a reversal of Schwarzschild's arrangement (*Astronomische Nachrichten*, Vol. 152, pages 69 to 72) of a tabulation of the same quantities. The values in Table I have all been computed and checked by the present writer. They correct certain discrepancies in