Observations of Saturn’s Ring at the time of its Disappearance in 1907, made with the 40-in. Refractor of the Yerkes Observatory. By E. E. Barnard. (Plates 9, 10.)

The position of Saturn for observation of the phenomena connected with the disappearance of the ring has been unusually favourable this year, though the south declination (5°) of the planet was somewhat unfortunate for northern observers.

At the reappearance of the ring in October 1891, Saturn rose only about two hours before the Sun, and the resulting low position and the approach of daylight made it very unfavourable for the observation of such a delicate thing as the ring when it is placed edge on towards us. At that time, with the 36-in. and 12-in. refractors of the Lick Observatory, and under such conditions, I was unable to see the ring (M.N. for April 1892, vol. iii. p. 419).

According to Professor Hermann Struve, the following table represents the dates of the present disappearances and reappearances of the ring of Saturn.*

1907. Apr. 17. Disappearance. The Earth in the plane of the rings.
   ,, Oct. 4. Disappearance. The Earth in the plane of the rings.

On account of the position of Saturn in the direction of the Sun, the disappearance of the ring in April was invisible from the Earth. The reappearance in January next will be favourable for observation.

The present paper deals with the reappearance and disappearance of the ring in July and October of this year (1907). The times are central standard time, 6th slow of G.M.T.

The unusually bad spring weather prevented early observations with the 40-in. telescope. The planet was observed, however, as frequently as the weather and other circumstances would permit. It was supposed the "reappearance" of the ring, when the Sun passed through its plane on or about July 26, would be a definite phenomenon, and that the time of this reappearance could be determined with some sort of precision. But the reappearance was a remarkably gradual phenomenon, and there was no possible means of telling when it occurred. The ring simply very slowly and gradually got brighter, and for several days it was impossible to tell that any change had taken place; and then it became bright and almost linear. It was not, however, at this time that the greatest interest lay. It was sometime previous to the reappearance of the ring that the most important phenomena were visible.

When the planet was examined on July 2 the entire surface of the ring was easily seen, though the Sun was not then shining on its visible surface. Where it was projected on the sky, the ring

Mar. 1908. Ring at the time of disappearance in 1907.

appeared as a greyish hazy or nebulosus strip, which was not well defined under the best conditions. It was about 1.5 times as broad as the trace of the ring on the ball. Nothing could be seen of the sunlit edge of the ring, which must have been too thin to be visible. There were two nebulous condensations of greater brightness on the ring at each side of the planet. These were quite conspicuous, but were ill defined and nebulosus, and of a pale grey colour. The ring and condensations were so pronounced that they were strongly visible at 15° 50′ (36′ before sunrise), when the approaching daylight was very bright. They were still visible as late as 16° 2′ (24′ before sunrse), and, though faint, could have been followed a little later yet. Rough measures were made of the distances of these condensations on the preceding side of the planet from the preceding limb.

The Centre of the most Distant Spot from the Preceding Limb.
7°7′(1)[7°6′]

The Centre of the Nearer Spot from the Preceding Limb.
2°9′(1)[2°8′]

One setting was made for the extreme diameter of the ring, and this gave 40°·9 [40°·0]* while two settings gave 18°·85 for the equatorial diameter of the planet.

At 15° 4′ a faint satellite (Eneladus) following was visible on the south side of the ring, close to the second condensation on that side. The satellite and condensation were of the same brightness, which will give some idea of the brightness of the ring and condensations. The trace of the ring across the ball was not black. The seeing was not good enough to tell whether part of this trace was due to the shadow of the ring, which in all probability at that time did not reach to the ball. The width of this trace was measured by setting the wires so that their outer edges were separated by the width of the trace—a correction afterwards being applied for the thickness of the wires = 0°·10. The width was 0°·62(1) at 14° 50′. The ring, as projected on the sky, seemed to be a little south of the trace.

Position of the trace of the ring on the ball at 15° 30′:
From South Limb.
8°·83(3)[8°·63]
From North Limb.
7°·84(3)[7°·66]

This trace was without any visible irregularities.

July 5. 15° cm. The condensations were again visible. The nearer condensations were estimated to be 1.5 times as bright as the distant ones. One setting gave for the width of the trace of the ring on the ball 0°·70. I could see nothing of the sunlit edge of the ring.

The seeing was very poor, and the sky clouded a few minutes later and did not again clear.

* The square brackets throughout this paper mean that the enclosed values have been reduced to the mean distance of Saturn from the Sun. The numbers in parentheses are the number of settings of the micrometer wires. The times are central standard times, 6° cm slow of Greenwich.
July 6. 14h 30m. The ring was rather faint—very much fainter, apparently, than on July 2, and perhaps somewhat narrower.

Width of trace on ball 0".62(2).

Position of the trace:

From South Limb.
8".79(3) [8".53]

From North Limb.
8".02(3) [7".79]

There was a faint dark belt south of the trace of the ring, 6".6(1) from the south limb. The condensations on the ring were visible as before. Nothing could be seen of the sunlit edge of the ring.

July 12. 14h 10m. The feebly luminous ring was visible as a thin nebulous strip on each side of the planet. Seeing very bad. There was a satellite preceding and another (Enceladus) following the ring. When best seen, the ring was about midway in brightness between these satellites. It was very thin and of a pale nebulus colour. The sunlit edge could not be seen. As late as 15h 35m (57m before sunrise) the ring was still distinctly visible.

July 23. 13h 50m. Sky thick. Seeing very bad. The ring was dimly visible as a faint thin line. The sunlit edge could not be seen.

July 24. Full moon. Seeing poor. 14h 20m. The full extent of the ring was visible as a narrow, almost thread-like strip. It was faint and nebulus, without any irregularities. A faint satellite (Enceladus) was close following the following edge of the ring; when best seen, the ring was perhaps one magnitude less bright than this satellite. There was no appearance of direct sunlight falling on the ring or its edge. The following ansa seemed to be the most distinct—perhaps a little brighter.

July 25. Full moon. 15h 10m. The ring fairly well seen as a faint nebulus strip. 15h 15m. There was a small satellite (Enceladus) preceding the preceding end of the ring; it was 1½ magnitude brighter than the ring, which was of a faint grey colour. Seeing fair. With an occultor in the eyepiece the ring was quite easily visible. There was no appearance of direct sunlight, however, but the same pale illumination seen previously. There did not seem to be any irregularities on the ring, which was very narrow, and quite distinct when best seen. The trace of the ring on the ball was not black. At 15h 45m (1h 0m before sunrise) the ring could still be fairly well seen.

July 26. 15h 0m. Seeing fair. Slight haze. Bright moonlight. The ring was a little brighter, but whether due to less moonlight or not, it was not possible to tell. A small satellite (Enceladus) near and preceding the preceding end of the ring was but little brighter than the ring, perhaps as much as half a magnitude.

15h 15m. The ring was decidedly brighter than on the 25th. This was perhaps due to the direct sunlight shining on it. It was very thin. A faint satellite (Tethys) followed the ball, and
was a little south of the ring. It was but a little brighter than the ring near it.

Width of trace of ring on ball = $0''45(4)$.  

$15^h\ 30^m$. The small satellite (Tethys) following was much brighter than the ring near it—perhaps one magnitude brighter. The ring on the sky was broader than the trace.

A power of 700 was then applied. With this the ring was pale and nebulous. The illumination did not then look like direct sunlight.

Position of trace of ring on ball at $15^h\ 45^m$—

<table>
<thead>
<tr>
<th>From South Limb</th>
<th>From North Limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8''77(2)\ [8''22]$</td>
<td>$8''23(2)\ [7''72]$</td>
</tr>
</tbody>
</table>

The thickness of the trace was $0''52(4)$.  

$16^h\ 0^m\ (45^m$ before sunrise). The ring was still easily seen. It was but little less bright than the satellite (Enceladus) preceding.  

$16^h\ 2^m$. The ring was still faintly visible. The sky was white from daylight.

July 28. $11^h\ 40^m$. The ring was bright, but much less bright than the ball of the planet. The illumination looked like true sunlight. The projection of the ring on the sky was south of the projection on the ball.  

$14^h\ 30^m$. Thickness of trace on ball $0''44(4)$. The illumination of the ring did not look like direct sunlight. It was a pale grey nebulous light.  

$15^h\ 35^m$. The ring could not be traced up to the ball, but was discontinuous for some few seconds.  

$15^h\ 45^m$. The following ansa seemed to be a little thicker than the preceding. A very faint belt on the ball was seen north. The ring on the sky was about twice as thick as its trace on the ball.

August 6. $13^h\ 45^m$. Trace of ring on ball:—

<table>
<thead>
<tr>
<th>From South Limb</th>
<th>From North Limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8''68(3)\ [8''04]$</td>
<td>$8''37(3)\ [7''89]$</td>
</tr>
</tbody>
</table>

Measures were very poor—seeing very bad.

August 11. $12^h\ 40^m$. Position of trace:—

<table>
<thead>
<tr>
<th>From North Limb</th>
<th>From South Limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8''25(3)\ [7''59]$</td>
<td>$9''37(3)\ [8''63]$</td>
</tr>
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</table>

$15^h\ 0^m$. The ring was much less bright than the ball. It looked like a bar of light on each side of the planet. Seeing very poor.

September 1. $11^h\ 5^m$. A faint belt was visible on each side of the trace of the ring.

September 3. $13^h\ 0^m$. The trace on ball seemed to be thinner than usual, and did not seem very distinct. When best seen the ring was clean cut, like a bar sharply pointed at the ends. The thickness of the ring on the sky was roughly $0''67(1)$.

September 8. $10^h\ 45^m$. The trace of the ring on the ball was
occasionally seen. It was very narrow. The ring was bright and narrow.

September 10. 12h 5m. The trace of the ring was very faint and narrow. The planet was occasionally well seen, but the trace on the ball could scarcely be made out.

October 1. 11h 6m. Seeing bad. The ring was of a pale ashy colour and comparatively faint. It was not very thin, and looked like a nebulous strip.

October 4. 8h 30m. The ring was entirely invisible, with magnifying powers of 460 and 700.

8h 40m. Feeble traces of the ring following the planet were suspected, but not certain. The presence of Titan near interfered. A satellite preceding the planet prevented any chance of seeing the ring on that side. There was a faint satellite (Mimas) following, which seemed to be on the ring. Seeing poor.

9h 10m. With an occluder in the field, in the moments of best seeing, feeble traces of the ring were visible following.

9h 25m. With occluder, the following part of the ring was feebly glimpsed, but it was very difficult.

At 9h 45m a hexagonal diaphragm was put on over the O G. This collected the stray light into six rays, leaving clearer sky between. An occluder was used in the eyepiece. With this, very feeble traces of the ring could be seen following, but not near the planet. It could also be seen feebly once in a while preceding. In moments of steadiness, the trace of the ring or shadow of the ring on the globe could be seen. But this would have been easy if the seeing had been good.

10h 0m. The seeing had got too bad to do anything with the planet.

11h 40m. The diaphragm removed, occluder on. The seeing very bad; could see nothing of the ring in the steadiest moments.

October 5. 10h 0m. A few minutes' opportunity was offered to observe Saturn with the 40-in. The seeing was fair, and I think better than on the 4th. The ring was faintly visible with the occluder. It seemed to be decidedly brighter than on the 4th. It was very slender and faint. A satellite was close preceding the planet. The shadow of the ring on the ball was sharply marked, but the seeing was not good enough to show it black. The ring was much fainter than a faint satellite (Mimas) near its following end.

October 6. 9h 25m. The seeing was extremely bad, with a very high wind.

10h 30m. Seeing very bad, but by glimpses with the occluder the ring could be seen occasionally very feebly. Even with good seeing the ring would have been faint.

10h 50m. In moments of steadiness, fairly good glimpses of the ring were had. It was certainly brighter than on the 4th, and perhaps somewhat brighter than on the 5th. The shadow on the ball could also be seen.

The planet was examined later, but the seeing was too bad for any observations of value.
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October 8. 9h 0m. The ring could only be seen by occultation of the planet. It was very faint and narrow. The south belt across the planet was far more conspicuous than the north one, which was rather difficult.

Position of the shadow on the ball. 9h 10m:

From South Limb. From North Limb.
8°'92(3) [8°'08] 8°'98(3) [8°'14]

Very uncertain—the planet very faint in haze.

11h 0m. I could not see anything of the ring with Saturn uncovered in the field, but with occluder I could see it at both sides of the planet very easily, though it was faint. It was straight and very narrow, with no irregularities. A faint satellite at the following side interfered. The ring was easier than at the previous observations since its disappearance. The south belt was very diffused to the south, while the north belt was diffused to the north. The equatorial space between these two belts was the brightest region of the planet.

11h 25m. Thickness of shadow on ball was 0°'69(2). Distance of south belt from shadow = 2°'29(2). A satellite following half way to end of ring was very much brighter than the ring.

October 13. 8h 25m. The ring could be seen with Saturn uncovered in the field. It was thin and rather faint. A satellite following and another preceding.

Micrometer positions on the ball:—

South belt from south limb 6°'77(2) South belt from north limb 10°'94(2)
Shadow from south limb 8°'81(2) Shadow from north limb 8°'25(2)
North belt from south limb 10°'64(2) North belt from north limb 7°'30(2)

There was a faint broad shading parallel to the equator in the northern hemisphere. The southern edge of this was 13°'9(2) from the S. limb, and 3°'8(2) from the N. limb. The seeing was very bad. This last marking was a very faint and diffused belt. Though the ring was faint, it could be distinctly seen with 460 diameters, with Saturn uncovered in the field, while with the occluder it was seen quite easily on both sides.

11h 0m. The ring was easily visible without occultation of the planet. It was very thin, but by occultation it was quite conspicuous. There were two regions of greater brightness on both the preceding and following ansa [the condensations]. The seeing was good.

Thickness of the shadow 0°'28(2). The equatorial region was brighter than any other part of the planet. The north belt was fainter than the south one.

October 28. 6h 30m. The ring was distinctly visible. The two luminous spots were quite conspicuous on each ansa.

November 3. 6h 30m. The ring and condensations were easily seen. The outer condensations were the brighter. These were so distinct that they looked almost as definite as an ill-
Prof. E. E. Barnard, Observations of Saturn's

defined satellite would be if projected on the ring. Measures were made at 7h 10m.

From the following limb:

The distant one.  
7' 88(7) [7' 34]
3' 04(6) [2' 84].

The near one.

From the preceding limb:

The distant one.  
8' 14(5) [7' 59]
2' 68(5) [2' 50]

The near one.

Distance between the centres of the two following condensations:

4' 40(4) [4' 10]

Thickness of the trace of ring on the ball:

0' 71(4) [0' 66]

The position of the centre of the trace was measured, but the seeing was so poor that the result was uncertain.

From North Limb.  
9' 21(2) [8' 59]
8' 82(2) [8' 23]

7h 50m. The inner condensation was a little the brighter in each case. It looked as if it might be double, but the seeing was not good enough to decide. Between the two condensations the ring was almost discontinuous. From the inner condensation to the ball the ring was easily seen to join up to the ball, and was but little less bright than the adjacent condensation. The outer ones seemed to be more brightly condensed, or like very small blurred stars. The inner condensations were about as bright as the faint satellite (Tethys) preceding, and somewhat brighter than the distant ones (condensations).

Assuming that these luminous places were symmetrical with respect to the ball, and taking the means of the measures, we find the distance of the nearest condensations from the limb was

2' 86 [2' 67]

Distance of the outer condensations from limb was

8' 01 [7' 46]

November 5. Very bad sky—thick, with misty clouds.

10h 17m. In moments of steadiness and clearness the distant condensation in the preceding ansa looked like a small, ill-defined satellite. There was a faint satellite (Enceladus) close to it, and it was not possible from their appearance to tell which was the satellite. They were the same size, same form, and same brightness—small hazy spots. The nearer condensation was the brighter, and at times it seemed to be double. The space between it and the ball was nearly as bright as the condensation. The ring between the distant and near condensations was faint and almost discontinuous. The full extent of the ring was seen with difficulty because of the poor sky.
Mar. 1908. *Ring at the time of disappearance in 1907.*

At 10 h 12 m the following measures were made between the preceding limb and the condensations:

<table>
<thead>
<tr>
<th>Distant condensation</th>
<th>Near condensation</th>
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<tr>
<td>5&quot;.17(3) [7&quot;.63]</td>
<td>2&quot;.82(2) [2&quot;.63]</td>
</tr>
</tbody>
</table>

At 10 h 31 m the distant condensation and the faint satellite appeared as one. On the following side the nearer condensation was decidedly brighter than the distant one, say by half a magnitude or more. The inner condensation was certainly double. Perhaps a faint satellite was close to it. The trace of the ring on the ball did not appear black, but the seeing was too poor to be sure.

November 12. 5 h 45 m. The condensations were readily visible. There were two considerable satellites of equal brightness, one near the preceding and the other near the following end of the ring.

5 h 50 m. The condensations were bright and nearly equal. The inner ones were bright up to the ball. The space between them was almost discontinuous.

6 h 30 m. Seeing very poor. At this time there was a faint satellite (Mimas) between the bright satellite on the following side and the end of the ring. The outer condensations seemed to be perhaps a little brighter than the inner ones, and possibly a little larger. They were all very conspicuous. The outer one, following, was at least two times as bright as Mimas. The small satellite itself (Mimas) was about the same brightness as the ring between the two condensations. There was a faint satellite (Enceladus) close to the preceding end of the ring, which was nearly as bright as the outer condensation on that side. It was a little north, following the condensation. Occasionally the full extent of the ring was seen up to near Mimas.

7 h 0 m. The faint satellite (Enceladus) preceding and the outer condensations were together at this time, and made quite a large spot. Distance between the two condensations on the following ansa:

\[ 5".04(4) [4".76] \]

Roughly, the length of the outer condensation was:

\[ 2".10(4) [1".98] \]

It was perhaps 2 1/2 times as long as broad, and diffused rather abruptly on each side. I should say that the outer condensation was 1 1/2 as bright as the bright satellite following.

7 h 20 m. The faint satellite (Mimas) following was going back at this time, and was making a double bright spot with the outer condensation. The faint satellite (Enceladus) preceding was then between the two preceding condensations and very slightly north of the line between them. Could not make out anything on the ball except the trace which was seen only once in a while, though it was conspicuous enough when seen. The inner condensation seemed to go up to the ball without much if any loss of light.
The seeing did not permit any accurate measures from the limbs, but the following results were obtained.

Distance of preceding condensation from preceding limb—

\[7''66(6)[7''23]\]

The limb was only a blur, from bad seeing. With the planet unobscured in the field, the condensations were quite conspicuous, \(7^h 40^m\). At this time the faint satellite (Mimas) was between the two condensations following, but nearer the distant one.

Distance from following limb to outer condensation—

\[7''72(8)[7''29]\]

At the time of these measures the faint satellite (Mimas) following was close preceding the outer condensation.

The outer and the inner condensations seemed to be of the same brightness. It looked as if the preceding condensation on the preceding ansa was not quite as bright as the one on the following ansa, but the presence of the faint satellite (Mimas) near the following one may have been the cause of this. A half moon, with bad seeing, made the sky very bright.

The Condensations.

The following table contains the measures of the distances of these condensations from the preceding and following limbs of Saturn. They are reduced to the mean distance (9'5389) of Saturn from the Sun, and are therefore comparable.

<table>
<thead>
<tr>
<th></th>
<th>Preceding.</th>
<th></th>
<th>Following.</th>
</tr>
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<tbody>
<tr>
<td>Nov. 5</td>
<td>2'85</td>
<td>7'56</td>
<td>...</td>
</tr>
<tr>
<td>Nov. 12</td>
<td>3'50</td>
<td>7'59</td>
<td>2'84</td>
</tr>
<tr>
<td>Nov. 12</td>
<td>...</td>
<td>...</td>
<td>2'64</td>
</tr>
<tr>
<td>Nov. 12</td>
<td>7'23</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Mean</td>
<td>2'68</td>
<td>7'46</td>
<td>2'74</td>
</tr>
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</table>

It is evident that the condensations are symmetrical with respect to the centre of Saturn. The individual differences are not large when we take account of the indefinite character of the phenomenon.

I have at various times compared the brightness of these condensations with that of Mimas, Enceladus, and Tethys. The following approximate values of the magnitudes of these satellites reduced, to the mean distance of Saturn have been supplied me
by Mr. Parkhurst from his unreduced measures of the magnitudes of the satellites of Saturn:

- Mimas . . . . 12'3 magnitude.
- Enceladus . . . . 11'7 "
- Tethys . . . . 10'2 "

Taking the positions of the condensations from the measures, and comparing them with the dimensions of the ring system (from my own measures in M.N., lvi. p. 171), it is seen at once (Plate 10, fig. 2) that the outer condensations are located on the outer part of the inner bright ring, in a region that is the brightest of the entire Saturnian system. The inner ones apparently fall on the crape ring. These condensations, therefore, would seem to be on the brightest and the faintest parts of the system. As this light is unquestionably transmitted through the material of the rings, it is evident that the above facts are opposed to each other if we assume that the condensations are caused by the crape ring and the outer part of the inner bright ring, or the thinnest and densest portions of the ring system. It is improbable that the two similar phenomena are produced by exactly opposite conditions. In the crape ring there are so few particles that the sunlight would readily pass through with little or no scattering effect or augmentation by additional reflection. It is known that a narrow portion of the inner bright ring is very much brighter than any other part of the rings or ball. The explanation of this is doubtless due to a denser collection in this zone of the small bodies that form the rings—just as the scarcity of them produces the dustiness of the crape ring for the want of material to reflect light. It is probable, therefore, if they are not too densely crowded to let the sunlight shine through among them, that when seen from the under side they will appear brighter than the other portions of the ring by repeatedly reflecting and scattering the transmitted light. Looking at the diagram, it would seem that the outer condensations are due to the inner bright ring alone. It would appear most probable that the outer bright part of the inner bright ring is responsible for both condensations. On this supposition, the inner condensations are due to the two brighter portions of the inner bright ring seen in perspective. Just why there should be a loss of illumination between the condensations is not quite clear at present, unless it is that the greater depth of the rings in perspective in some way militates against either the transmission or reflection—or both—of the solar rays in that direction.

In the description, I have used the word 'condensation' for these luminous appearances, although I believe it to be misleading. Though these bright places look decidedly broader than the thin trace of the ring on the sky, and appear to be condensations on the ring, I think it is simply a matter of contrast or irradiation, and that they are not any broader in reality than the trace of the ring where they occur. I have come to this conclusion from the drawings that I have made, and which are communicated with this.
paper, where the ring has simply been darkened between the points of greater brightness without changing its original outline. The result is that, when looked at from a distance, the bright places appear broader than the ring, and look like the 'condensations' as seen in the sky. I think, if the definition were perfect, it would be at once evident that this explanation is the true one. That they are not material condensations is shown by the fact that they entirely disappear when the ring is edge on toward us, at which time they should be most conspicuous if they were masses on the ring.

There is one fact that seems to have been brought out strongly at this disappearance of the rings. The sunlight can sift through them just as it does in the case of the crape ring, only to a very much less degree. The rings were visible when there was no direct sunlight shining upon the surface presented to us—the Sun being on the opposite side to that of the Earth. This phenomenon might be explained by either of two suppositions: that the rings are self-luminous, or that the sunlight sifts through among the particles composing them and thus makes them visible. Inasmuch as the rings have been proved to consist of discrete particles, their temperature cannot be high, and they are therefore not likely to be self-luminous. The second supposition seems to be a simple and sufficient explanation. This is not improbable, for the rings are extremely thin, as no trace of the illuminated edge could be seen at any time while they were supposed to be invisible. Notwithstanding the fact that the sunlight may thus penetrate entirely through even the bright rings, it does not do so with sufficient intensity to illuminate a satellite when in their shadow; for although Japetus was visible at the eclipse of November 1, 1889 (M.N., vol. 1, pp. 107-110), through the entire shadow of the crape ring, it was wholly invisible in a 12-in. telescope when it was in the shadow of the bright rings. In fact, though the rings are translucent, they are not transparent.

I have excluded the idea that the illumination is due to reflection of the sunlight from the ball of Saturn, for the further part of the ring was visible—the entire surface—which could not be so by reflection from Saturn.

P.S.—1908 March 3.—In looking over my observations of 1907 July 2, I find a note which has a bearing on Professor Aitken's measures of two condensations at the place of the inner ones. The note, which is attached to the sketch of the inner condensation preceding, says: “Possibly here there are two condensations.” It will be seen, in my later notes, I also suspect the inner condensation of being double; but the seeing was never so good that I would be sure enough of it to make measures.

Previous Disappearances of the Rings.

I have gathered the following facts from the American Ephemeris and elsewhere about some previous disappearances of the rings:—
In 1848 the Earth passed the plane of the ring in April, going south. On September 3 the Sun passed the plane, going south. On September 13 the Earth passed back north, and on January 19, 1849, the Earth once more went south with the Sun. Therefore between April 12 or 13 and September 3 the Earth and Sun were on opposite sides of the ring. This was again the case between September 13 and January 19.

1861 November 22. The ring disappeared by the Earth passing through its plane to the north—the Sun being some 2° south.

In 1862 it reappeared on January 31, the Earth passing through the plane of the ring to the south. On May 17 it disappeared by the Sun passing through the plane to the north. It reappeared on August 12, the Earth passing to the north.

1878. The ring disappeared on February 6, the Sun passing to the south. It reappeared March 1 by the Earth passing to the south.

In 1891 the ring disappeared, September 22, by the Earth passing to the north. It reappeared, October 30, by the Sun passing to the north.

1892, about May 20, the Earth was less than 3° north of the plane of the rings, but it did not come any nearer, and the ring did not disappear.

1907. The American Ephemeris does not give the times of disappearance and reappearance, but one can deduce them from the “Apparent Elements of Saturn’s Ring,” p. 515. I have already given Professor Struve values of these quantities for the present apparition of the planet. For completeness of this list I will repeat them here.

1907 April 17. The ring disappeared by the Earth going south. July 26. It reappeared by the Sun passing south.

October 4. The ring disappeared by the Earth passing north.

1908 January 7. It reappears, the Earth passing south.

The following table, containing the mean times of meridian transit and the declinations of Saturn at the critical times for the phenomena of the disappearance and reappearance of the ring, may be of interest in connection with the present and for comparison in future disappearances of the ring. The last column indicates the cause of the disappearance or reappearance.

<table>
<thead>
<tr>
<th>Date</th>
<th>M.T. of Transit h m</th>
<th>Declination</th>
<th>With reference to Plane of Ring</th>
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<tr>
<td>1848 Apr. 22</td>
<td>21 24</td>
<td>-5 17</td>
<td>☄ going S.</td>
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<tr>
<td>Sept. 3</td>
<td>12 44</td>
<td>-5 5</td>
<td>☄  &quot;  S.</td>
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<td>&quot; 12-13*</td>
<td>12 6</td>
<td>-5 22</td>
<td>☄  &quot;  N.</td>
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<tr>
<td>1849 Jan. 19</td>
<td>3 36</td>
<td>-5 20</td>
<td>☄  &quot;  S.</td>
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<tr>
<td>1861 Nov. 22</td>
<td>19 20</td>
<td>+5 15</td>
<td>☄  &quot;  N.</td>
</tr>
<tr>
<td>1862 Jan. 31</td>
<td>14 48</td>
<td>+5 15</td>
<td>☄  &quot;  S.</td>
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</table>

* The meridian passage and declination are given for the 12th.
Date. | M.T. of Transit | Declination | With reference to Plane of Ring |
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<td>1862 May 17</td>
<td>7 30</td>
<td>+7 38°</td>
<td>○ N.</td>
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<tr>
<td>Aug. 12</td>
<td>2 8</td>
<td>+5 17°</td>
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<td>1878 Feb. 6</td>
<td>2 15</td>
<td>-6 14°</td>
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<td>0 54</td>
<td>-5 9°</td>
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<td>1891 Sept. 22</td>
<td>23 24</td>
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<td>○ N.</td>
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<tr>
<td>Oct. 30</td>
<td>21 11</td>
<td>+3 25°</td>
<td>○ N.</td>
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<td>1907 April 17</td>
<td>21 54</td>
<td>-4 48°</td>
<td>○ S.</td>
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<tr>
<td>July 26</td>
<td>15 40</td>
<td>-3 12°</td>
<td>○ S.</td>
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<tr>
<td>Oct. 4</td>
<td>10 47</td>
<td>-5 6°</td>
<td>○ N.</td>
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<tr>
<td>1908 Jan. 7</td>
<td>4 30</td>
<td>-5 3°</td>
<td>○ S.</td>
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From an inspection of this table it will be seen that the present disappearance of Saturn's ring has been an extremely favourable one—the most favourable in forty-five years—comparing in this respect with the disappearances of 1848–9.

In 1848–9 and 1861–2 there were two disappearances and two reappearances each of the ring. In 1878 there was only one disappearance, and the corresponding reappearance, both very unfavourably situated. The ring was invisible for about twenty-two days.

In 1891 there was only one disappearance and reappearance. The conditions were likewise very unfavourable. The ring was invisible some thirty-eight days.

At the present apparition of the planet there were two disappearances and two reappearances.

There is an important series of observations of Saturn made with the 15-inch refractor of the Harvard College Observatory by the Bonds at the disappearance of the ring in 1848. These observations form part of volume ii. of the Harvard College Observatory Annals.

Some of the drawings of Saturn given in the above volume show the ring and condensations essentially as they have appeared here in the past six months.

The conditions of the disappearances and reappearances of the ring in 1848 were almost identical with those we have just witnessed.

In all his observations Bond assumed that what he saw was the sunlit edge of the ring. The explanation of its visibility was therefore an easy one. The observations of the present disappearances have shown, however, that it was not the edge which we saw, but the very oblique unilluminated surface of the ring. The minor axis of the ring about the 1st of July was some 2°.

Bond's explanation of the bright markings, condensations, or knots seen on the ring during its "invisibility" was very ingenious, but it depended upon the edge of the ring being seen through the Cassini division. The extreme thinness of the ring and the largeness of the condensations make this explanation unsatisfactory.
Fig. 2.

Diagram of the ball and ring system of Saturn, showing the projected positions and limits of the condensations.

The lines A, B, B, A show where the centres of the condensations fall. The dotted lines a, a, b, b, b, b, a, a show the limits of the condensations.
Mar. 1908. Ring at the time of disappearance in 1907.

In *Monthly Notices* for November 14, 1862, vol. xxiii, pp. 87–88, there are some observations of Saturn at the time of the disappearance of the ring in that year made at Greenwich and Pulkowa. In both these there are distinct references to luminous appendages, which seem roughly to be the same seen at the observations of this year—1907. The descriptions are not quite in satisfactory accord with their appearance as seen to-day. The ring was supposed to have disappeared on May 17, 1862, by the Sun going north, and to have remained invisible until August 12. At Pulkowa the descriptions seem to indicate only two appendages, one on the preceding, the other on the following ansa. They did not seem to have been perfectly symmetrical.

The Pulkowa observations are:

"1862 May 20. The aspect of the luminous appendages has not varied since last night, with this difference only—that I estimated the length of the preceding side as 0.65 and the following as 0.5 of the planet's diameter.

"1862 May 21. Images good. Estimated extent of luminous appendages:—Preceding side 0.6, following side 0.4, of the planet's diameter; also the intensity of the light appears much more feeble on the following side. The size of these appendages increased in the neighbourhood of the planet, giving them the form of sharp wedges.

"1862 May 22. Images less favourable than yesterday. Extent of luminous appendages on preceding side 0.6 and on following side 0.5 of the planet's diameter.

"1862 June 3. Image very bad, yet the luminous appendages are still distinctly visible. It appears that the length of the following ansa is a little the greater, but this is not certain."

The Greenwich observations are:

"1862 May 17. The ring beyond the planet at times just visible on the left of the disk, but on the right only a small faint spot could be seen in the plane of the ring, about 1/3 the diameter of the disk from the planet's limb. I should have suspected this was a satellite but for its elongated shape. Sky very hazy.

"1862 May 19. Saturn very well seen. The ring distinctly visible on the left of the disk, and fairly but not so distinctly visible on the right. Where it crosses the disk, the under edge is much sharper and better defined than the upper edge.

"1862 May 20. Saturn very well seen; the ring distinctly visible, appearing brighter than it did last night. The Greenwich observations were made by Mr. Carpenter."

There are also some observations by Mr. Wray in the same number of the *Monthly Notices*, in which he saw something of the kind in December of 1861 and January of 1862 with a 7-in. refractor.

*Yerkes Observatory,*
*Williams Bay, Wis.:
1907 November 25.*