

A REVIEW OF 5 MAJOR BRIGHT OUTBURSTS ON SATURN AND A SUGGESTED 57-YEAR PERIOD

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Abstract

Most of the time the observer of Saturn finds little detail beyond the major belts and zones. However, there were very conspicuous temporary brilliant features in the Equatorial Zone in 1876, 1933, and 1990. There were also unusually conspicuous bright features in North Temperate Latitudes in 1903 and in North Polar Latitudes in 1960. The 5 events are briefly described. It may be noted that the second recorded EZ "spot" followed the first one by 57 years and that the third one likewise fell 57 years after the second one. It is also curious that other unusual bright feature activity in the North Hemisphere occurred with a 57-year interval, namely, 1903 to 1960.

There is discussion of whether similar major events may have occurred when Saturn was near its conjunction with the Sun , and hence have gone unrecorded. Other topics considered are the lack of evidence for the presumed sudden appearance of the EZ spots, some evidence for an acceleration in the rotation of the 1933 and 1990 Great White Spots about 25 days after they were discovered, and substantially better evidence for a northward latitude shift of several North Hemisphere belts while the 1990 feature was in its expansion phase.

Introduction

Most of the time observations of Saturn show only a familiar pattern of dark belts and bright zones. Figure 1 shows the standard nomenclature for these features. Occasionally small dark or bright spots are recorded, but they are seldom conspicuous enough or observed long enough to furnish desired periods of rotation. It has been facetiously stated that a photograph of Saturn can be turned upside down after a number of years and will then actually show the planet quite well, with the other pole now tilted toward the Earth. It is surely true that some skillful current observers are giving us much higher resolution CCD images with fine detail that would have gone unrecorded in the past, but their results only reinforce the customary lack of such fine detail.

There have arguably been five periods when unusually conspicuous features on Saturn have been observed:

1. A large and brilliant oval area in the Equatorial Zone in 1876.
2. Many white and dark spots in North Temperate Latitudes in 1903.
3. A large and brilliant oval area in the Equatorial Zone in 1933.
4. Many white spots in North Polar Latitudes in 1960.
5. A large and brilliant oval area in the Equatorial Zone in 1990.

Certainly features have been observed and even photographed at many other times, but I consider that the activity was on a lower level than for the five periods of rare events listed

above. It is curious that the three most recent of these outbursts were all discovered by amateur astronomers.

The Pattern of Behavior of Great White Spots

It is CONJECTURED that these objects appear suddenly. After some days the very bright spot becomes dimmer; and the preceding or east edge moves toward the east. This eastern motion results in a smaller longitude and a shorter period of rotation. The spot, perhaps round when first observed, thus becomes an oval with its long axis often parallel to the equator. The east edge grows diffuse and ill-defined so that observations of the transit of the feature across the central meridian of the planet, intended to determine the period of rotation of the spot, become less accurate, even though the west or following edge is comparatively distinct. The increasingly long spot after some weeks may fill much of the zone in which it lies. The spot can hardly be recognized a month or two after its discovery, although unusual activity in the zone may continue for months.

The feature forms when a huge bubble of ammonia gas rises by convection to the visible surface of the planet. The ammonia ice crystals formed are originally very bright but soon become discolored or sublimate. Dr. Reta Beebe has given us an excellent analysis of the origin and development of "Great White Spots", with especial attention to the one in 1990 (by far the best observed) [6]. She considers three phases of the event: the onset and growth of the original disturbance, the consequent eastward and westward expansion of the bright cloud, and the eventual formation of wave-like structures encircling the whole planet [6,21].

It is interesting to speculate whether a similar mechanism might produce rare brilliant outbursts, whether periodic or random, on the other three gas giant planets in the Solar System. For Uranus and Neptune there are simply no useful observations. On Jupiter we have a history of large changes in brightness of many of the zones but probably nothing as extraordinary as the 3 EZ Great White Spots on Saturn [24]. Might the lower density of Saturn play a role?

The 1876 Equatorial Zone Great White Spot

On 1876 Dec 07 Asaph Hall, who is best remembered as the discoverer of the two satellites of Mars, observed a conspicuous, white, very bright, round spot 2-3 arcseconds, thus 13000 to 20000 kms., in diameter in the Equatorial Zone close to the equator [1]. It was the first definite feature to be recorded on Saturn since the time of William Herschel. Hall and five other American observers followed the spot until 1877 Jan 05. The feature faded and was faint on Dec 30, not distinct on 1877 Jan 02, and barely visible on Jan 05. The observers obtained 18 times of transit of the center of the spot across the central meridian of longitude of Saturn. (This number is given as 19 in the literature, but Boss on Dec 10 did not see the spot until it was past the central meridian.) Hall carried out a mathematical analysis of these positions to find a sidereal rotation period of 10 hours, 14 minutes, and 23.8 seconds, with a probable error of only 2.5 seconds [1,17].

In 1993 Mr. Brent Archinal on the staff of the U. S. Naval Observatory kindly furnished me with copies of those pages of the 1876 and 1877 logbooks for the 26-inch

refractor which relate to observations of the Great White Spot. This information has been incorporated into the text of this paper.

It was decided to reduce the transit data with modern longitude tables. A System I for Saturn has been used by the ALPO and others for the Equatorial Zone, the North Equatorial Belt, and the South Equatorial Belt. It has a sidereal period of rotation of 10 hours, 14 minutes, and 0.0 seconds; the choice of the zero longitude is totally arbitrary. Corrections are applied for phase, light time, and the Saturnicentric longitude of the Earth. John Westfall sent me requested System I tables for 1876 and 1877 central meridian longitudes at 0 hours, Universal Time for all dates, and a small auxiliary table showing the longitude increases for units of hours and minutes.

The System I longitude was then computed for each of the 18 observed transit times. A Least Squares Line was fitted to the data points, employing the weights originally assigned by Hall [17]. The observed changes in longitude give the period of rotation. The standard deviation of the residual of an observed longitude from the fitted line was found to be 10.9 degrees, and 5 of the 18 points had residuals in excess of 10 degrees. It was decided to reject those 5 points. Such a step may seem arbitrary, but 10 degrees corresponds to a transit time error of 18 minutes!. Rather clearly, we have differing identifications of the terminal ends of the spot and/or effects of recorded bad seeing. The observers also had had little experience in making such estimates.

The Least Squares Line was now fitted to the remaining 13 points. There resulted a standard deviation of 3.29 degrees and a System I increase in longitude of 0.564 degrees per day. The corresponding period is 10 hours, 14 minutes, and 24.6 +/- 0.4 seconds (standard deviation), a result in surprisingly good agreement with Hall's determination.

The 1903 North Temperate White and Dark Spots

Many bright and dark spots were reported in low latitudes in the 1890's, but they were inconspicuous and controversial and tended to vanish in bad seeing [2]. Then on 1903 Jun 15 E. E. Barnard, who had been very skeptical about the earlier reports, observed a brilliant white spot at Saturnicentric latitude 36 degrees north in the zone immediately north of the north component of the North Equatorial Belt [3]. It is now called the North Tropical Zone in the standard nomenclature. The new feature faded after two or three weeks but remained visible. It was somewhat oval in shape, often appeared to be double, and was not sharply defined. Different observers made scores of observations of as many as 18 white, or perhaps yellowish, and dark spots, which now developed at about the same latitude, from July to December of 1903. Figure 2 is an example of the observations. The spots were often diffusely bounded. The goal was to determine the period of rotation of Saturn, and different experienced observers obtained somewhat different values, and also different for different spots, but all close to 10 hours and 38 minutes. A major difficulty was correctly identifying the spots, for they lacked individual characteristics. Subsequently a System II of longitudes for features north of the NEB or south of the SEB was created and was employed by many observers; it used a period of 10 hours, 38 minutes, and 25.4 seconds.

The observers thus discovered the equatorial jet stream on Saturn with a velocity of more than 1600 kms. per hour.

The 1933 Equatorial Zone Great White Spot

W.T. Hay or “Will Hay”, a popular British radio comedian, discovered a large white patch in the EZ on 1933 Aug 03 at 22 hrs, 35 mins., Universal Time [4]. A. Weber at Berlin saw the new feature on the same date. The spot became less bright in only a few days but remained brighter than the rest of the EZ, parts of which were surprisingly dark. The spot was originally about 19000 kms. long east-west by 13000 kms. wide north-south. There were marked variations in the aspect of the spot, as indicated on Figure 3; and other bright features appeared in other parts of the EZ. Transit observations by more than a dozen observers from Aug 03 to Sep 16 indicate that the original period of rotation was near 10 hours, 16 minutes but that the period for the hard-to-define center had decreased to about 10 hours, 13 minutes by the middle of September, when the spot could no longer be recognized. E. C. Slipher at the Lowell Observatory found other bright spots in the EZ around almost the whole circumference of the planet. Different observers using different time intervals found periods near 10 hours, 14 minutes. There is evidence of a sudden discontinuity in the period near Aug 23 [4].

Did the 1933 Great White Spot Appear Suddenly?

E. C. Slipher is quoted as reporting “The surface of the planet was closely examined at Lowell Observatory less than 48 hours before the discovery of the spot, and no indication of its presence was then found [22].” Antoinette Beiser, the Librarian at the Lowell Observatory, kindly examined the E. C. Slipher archives at my request. The vague “less than 48 hours” would mean an observation after 22 hrs., 35 mins., UT on Aug 01. Beiser found nothing at all about such observations so that Dr. Slipher apparently spoke from memory only. The earliest 1933 Saturn Lowell photograph which she found was on Aug 09, days after the announced discovery. Thus it is pure guesswork as to whether Slipher on Aug 01 or 02 was observing that portion of the planet where the famous spot very soon erupted. The outbreak MAY have been very sudden, but empirical evidence is lacking.

The 1960 White Spots in North Polar Latitudes

J. H. Botham, an amateur astronomer in South Africa, discovered an intensely white spot on 1960 Mar 31 [5]. It lay in the North North Temperate Zone at latitude 60 degrees north and was almost as bright as the brightest part of Ring B. There was a bright zone stretching from limb to limb by May 05. Dr. Audouin Dollfus independently discovered the spot on Apr 27 and later determined a rotation period of 10 hours, 40.5 minutes. Other observers found brighter spots in a very active and unusually bright North North Temperate Zone from April to September of 1960. See Figure 4. For example, Cragg found an average period of 10 hours, 39 minutes, and 52 seconds for 5 spots [13]. Robinson determined a slightly varying period of 10 hours, 40.1 minutes for a spot followed from Jul 23 to Sep 06; it was brighter and larger than the original Botham-Dollfus Spot on or about Aug 25 [23]. There is some evidence that this NNTeZ activity had begun in the summer of 1959 [5,13].

The 1990 Equatorial Zone Great White Spot

On 1990 Sep 25 (Universal Time date) Stuart Wilber, an amateur astronomer in Las Cruces, NM was surprised to see a conspicuous if small bright spot in the EZ [14,18,21]. He quickly informed Dr. Clyde Tombaugh, who in turn alerted the New Mexico State University astronomers; and Scott Murrell secured a photograph on Sep 25 as the feature was rotating off the disc. Alberto Montalvo and Michael Sweetman also observed the new spot on the discovery date but made no immediate reports. The discovery longitude in System I was about 335 degrees. I had observed this region on Sep 13 and found nothing unusual. No observations of these longitudes of Saturn after Sep 13 and before Sep 25 are known to me.

By Sep 28 the spot was a large and brilliant oval, brighter than the brightest parts of Ring B. It was actually off the bright end of a visual intensity scale employed by many experienced observers! Its behavior was much as already described for its predecessors. The Saturnigraphic latitude of its center on Oct 04 was 4 degrees north [6], and its major axis was oriented in a southeast-northwest direction, as shown on Figure 6.. By Oct 07 the spot had developed both eastward and westward extensions. By Oct 10 other bright spots had appeared in the EZ. See Figure 5. It soon became difficult to estimate the position of the terminal ends of the original spot when attempting central meridian transits. By the middle of October the length of the "spot" was more than 80000 kms., and on Oct 23 it girdled the whole globe. On Nov 09 and later dates the Hubble Space Telescope was turned to Saturn and gave us uniquely detailed and amazing images of the very active atmospheric disturbance. A complex pattern of wave-like structures encircled the whole EZ.[6,21].

Beebe fitted a Least Squares Line to weighted observations over the interval from Sep 25 to Nov 18; these included visual transits, ground-based CCD images, and Hubble Space Telescope CCD images. The resulting period of rotation found was 10 hrs., 14 mins., and 28.2 +/- 2.66 secs.[6]. Heath and McKim from BAA data determined the period for the center of the "storm" from Oct 01 to Nov 11 to be 10 hrs., 13 mins., and 45 secs. [18]. The difference is 43 seconds! It is clearly a matter of great difficulty to make consistent choices of the terminal ends (which determine the center) of a Great White Spot., except in its very early stages.

An Apparent Acceleration of the 1990 GWS and a Northward Shift of the NEB

I found a period of 10 hrs., 13 mins., and 45.2 +/- 3.1 secs. from 9 visual transits over the interval from Oct 04 to Nov 11[16]. However, there is evidence of a sudden acceleration on or near Oct 24 (much as near 1933 Aug 23 for another Great White Spot); and if we fit SEPARATE lines before and after that date for the observed center of the spot, we get:

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Oct 04 to Oct 24	10 hrs.	14 mins.	2.4 +/- 1.8 secs.	(5 transits)
Oct 24 to Nov 11	10	13	27.7 +/- 3.8	(5 transits)

The BAA data confirm that after Oct 24 the GWS as a whole began to move in decreasing longitude[18]. However, most of these later observations are mine.

Many drawings and photographs in October show the north edge of the GWS extending into the south part of the NEB, much as the oval Great Red Spot on Jupiter appears to depress the south edge of the South Equatorial Belt toward the north on that planet. Now look at Figure 7, which plots observed Saturnographic latitudes against date. The latitudes come from my careful visual estimates. It is interesting that the north and south NEB components appear to shift to the north by, say, 10 or 12 degrees of latitude over an approximate time interval of Oct 05 to Oct 30. It appears uncertain on the plot whether the delicate North Temperate Belt shared this northward shift. It should be remembered that after Sep 25 most of the observations are in the longitudes of the GWS. Latitudes estimated from drawings by Marc A. Gelinis in Quebec confirm that the three belts under discussion were farther north on Oct 16 and Oct 30 by at least 5 degrees of latitude than from Jun 02 to Aug. 15[15]. Hollis in an extensive study found these Saturncentric average latitudes for the centers of several belts: S component NEB +13.7 degrees, N component NEB +20.9 degrees, and North Temperate Belt +41.4 degrees, where + means north [19].

A Suggested 57-Year Period for Major Outbreaks

In 1989 Frank J Melillo noted that conspicuous white ovals had been observed in the North Hemisphere of Saturn in 1876, 1903, 1933, and 1960[20]. These numbers suggested to him a period of 27-30 years; he further pointed out that the outbreaks had all occurred when the ecliptical longitude of Saturn was in the range of 290-315 degrees. (Saturn would be in this interval from May of 1990 to July of 1992.) He urged careful watches for an imminent future similar event. Augustin Sanchez-Lavega pointed out that the 4 outbreaks had all occurred near the time when the north pole was tilted toward the Sun by the maximum attained amount[25]. It may appear unlikely that this tilt could have affected solar heating much near the equator in 1876 and 1933. But - what happened in 1990?

It is certainly hard to quarrel with successful predictions! Saturn has thus had a major outbreak in each of its last 5 passages through the ecliptical longitudes cited above. In this small sample there has been an alternation between "Great White Spots" in the EZ and brilliant spots in middle or high north latitudes. The latter are much smaller and also are not influenced by the very strong jet stream near the equator. A few authors have noticed that the second observed Great White Spot in the EZ followed the first one by 57 years and that the third one followed the second also by 57 years [18]. It is further curious that the higher latitude activity in 1960 is 57 years after that in 1903. One might prefer to find evidence for a period of 59 years, which is twice the sidereal period of revolution of Saturn. Any period of 57 years would after a few cycles be out of step with the (nominal) seasons on Saturn.

We might look into the past for any earlier activity at 57 year intervals. The critical years for the EZ would be 1819 and 1762. For the North Tropical and North North Temperate Zone events we might look at 1846 and 1789. In A. F. O'D Alexander's excellent book, "The Planet Saturn. A History of Observation, Theory and Discovery", there are no reports of unusual surface events in any of the four years cited above.

How Much has Gone Unobserved?

It must be appreciated that Saturn is not under constant observation. For several months it is too close to conjunction with the Sun. One might like to think that there is a major EZ outbreak every Saturnian year at the proper ecliptical longitude and that those intermediate between the recorded ones have gone unobserved near conjunction. Table 1 lists these periods of no observations in the records of the ALPO for several perhaps typical apparitions soon before the 1990 EZ outburst. It will be noted that the average unobserved interval is 116 days. It appears clear from the discussion above that the recognizable parts of the 5 outbreaks could all have run their course in 116 days or less.

The synodic period of the planet is 378 days so that the empirical probability that an outburst like the 5 described here will go unobserved is $116/378 = 0.31$. The probability that it will be observed is then $1 - 0.31$ or 0.69. The probability that 5 bright spot outbreaks will ALL be recorded becomes $(0.69)^5 = 0.16$, or about 1 chance in 6. There is thus a very good chance that some exciting events did go unobserved.

Table 1. Sample Time Intervals When Saturn not Observed.
Dates by Universal Time.

Conjunction With Sun	Last Observation Before Conjunction	First Observation After Conjunction	Interval In Days
1985 Nov 23	1985 Sep 13[7]	1986 Jan 25[8]	134
1986 Dec 04	1986 Oct 05 [8]	1987 Feb 07 [9]	125
1987 Dec 16	1987 Oct 18 [9]	1988 Feb14 [10]	119
1988 Dec 26	1988 Nov 28 [10]	1989 Feb 20 [11]	84

Average Unobserved Interval = 116 days

Predictions and Acknowledgments

Perhaps nothing is more subject to major blunders than predicting the future. Nevertheless, let me suggest that future observers watch for an outbreak of conspicuous white spots in some zone north of the North Equatorial Belt in 2017 (1960 + 57) and for an extraordinary Great White Spot in the Equatorial Zone in 2047 (1990 + 57). Or perhaps that intriguing number 57 is just a coincidence, and the chief purpose of this paper should be to encourage close and time-extensive coverage of Saturn.

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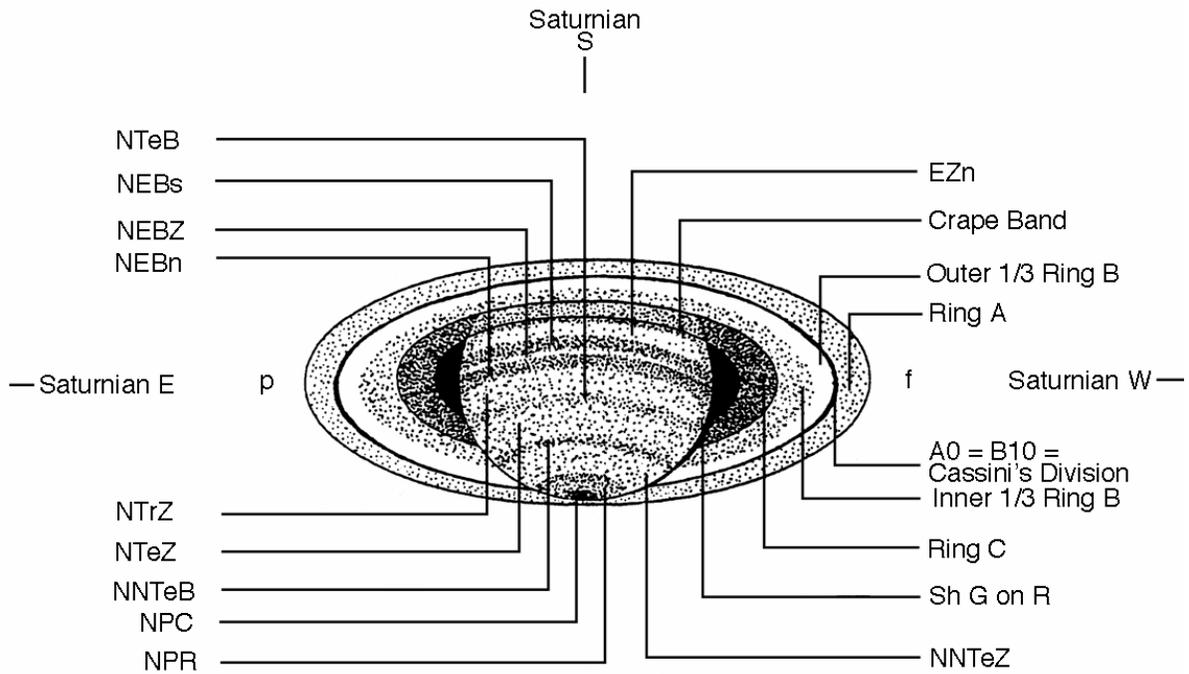


Figure 1. Nomenclature of Saturn's Globe and Rings, with the planet tilted to Earth as it was at the time of the visibility of the 1990 White Spot. South is at the top to approximate the view in an inverting telescope without image reversal, located in the Northern Hemisphere. "p" indicates preceding and "f" following directions. "E" and "W" apply to planetary directions (the opposite of celestial directions), following International Astronomical Union usage. Globe features are abbreviated as follows: B, Belt; C, Cap; E, Equatorial; N, North; n, north component; R, Region; S, South; s, south component; Te, Temperate; Tr, Tropical; and Z, Zone.

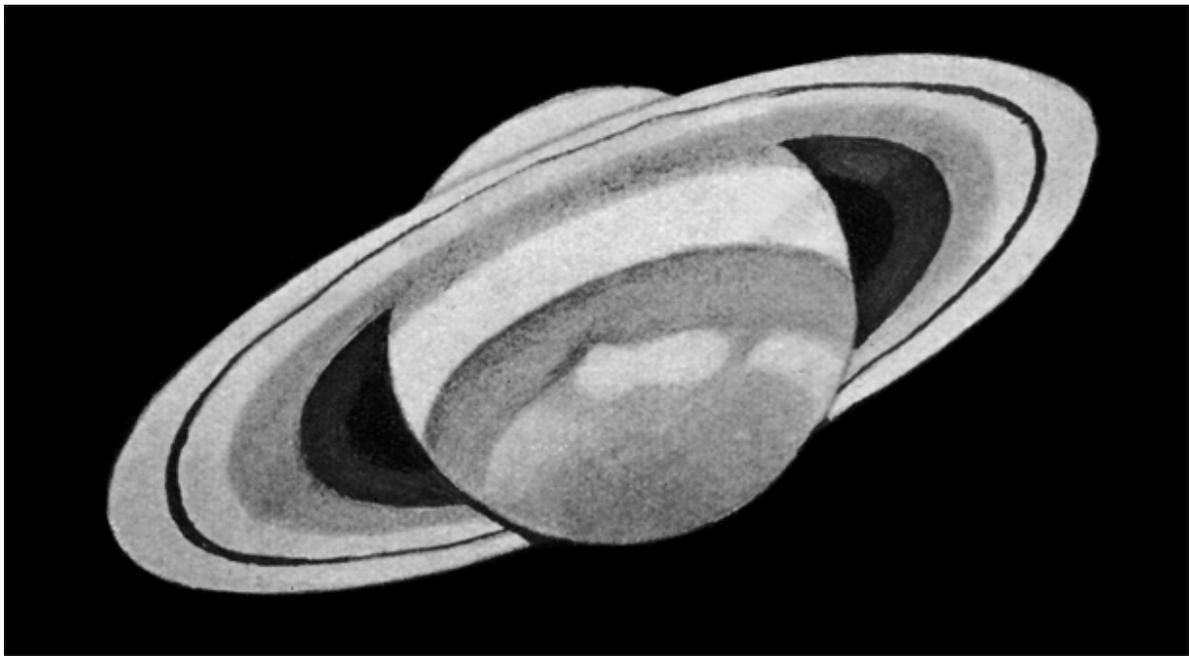


Figure 2. The 1903 NTrZ White Spot, drawn by W.F. Denning of Bristol, England, with a 10-in (25-cm) reflector at 312X. 1903 July 15, 23h 52m UT. South at top. From *Splendour of the Heavens* (1925), p. 374.

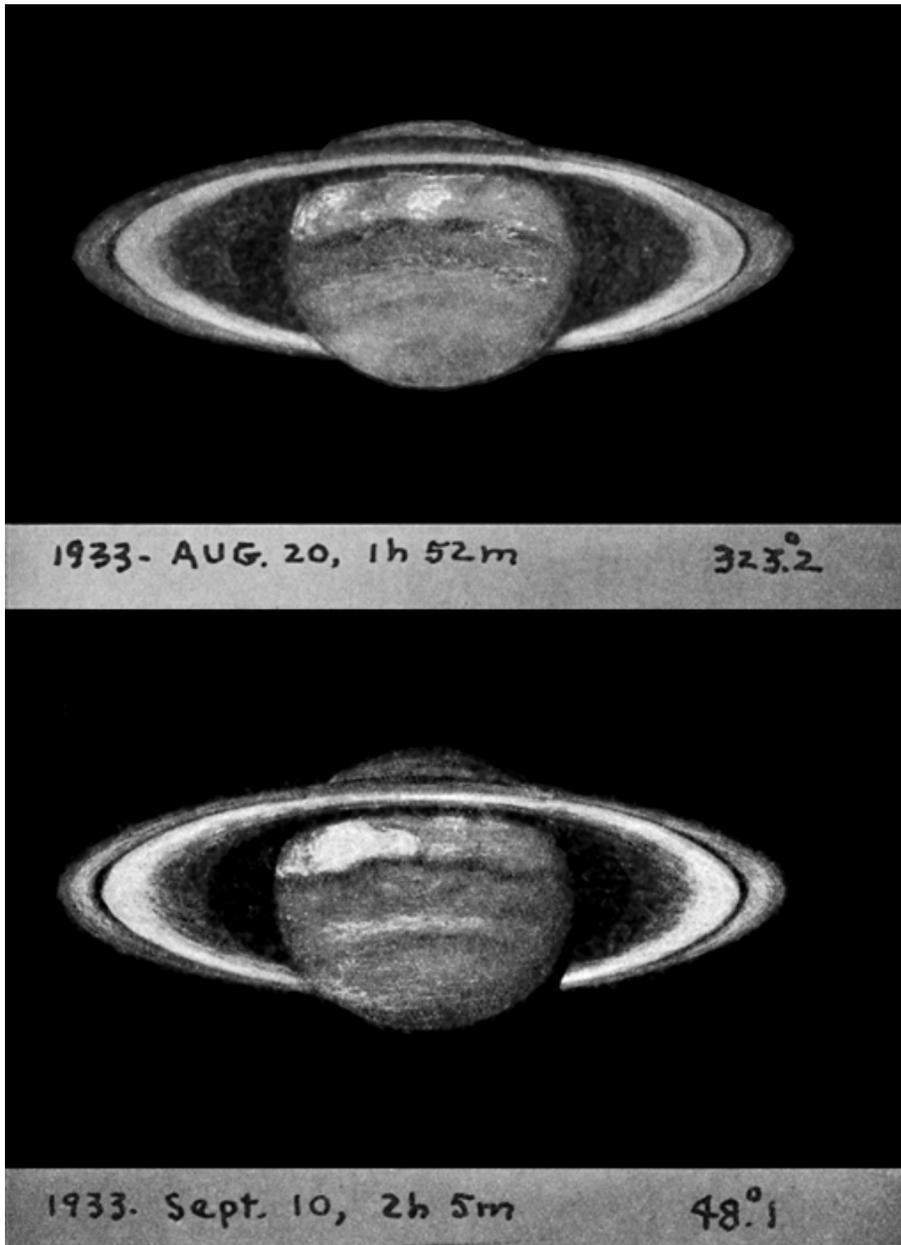


Figure 3. Two drawings by Latimer J. Wilson of Franklin, Kentucky with an 11-in (28-cm) reflector showing the 1933 EZ White Spot. The captions below each drawing give the Universal Time and the System I central meridian longitude. South at top. From *Popular Astronomy*, Nov. 1933, p.437.

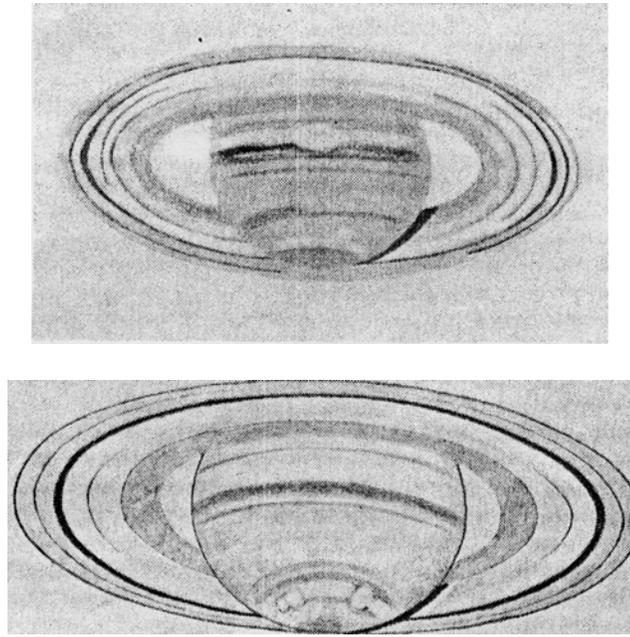


Figure 4. Two drawings of Saturn in 1960 showing the very rare North North Temperate Zone bright features, near bottom of globe. Upper drawing by Leif J Robinson on July 23 at 7 hrs., 17 mins., UT, .25-cm reflector at 250X and 500X.. Lower drawing by Thomas A Cragg on August 9 at 5 hrs, 25 mins., UT,. 30-cm refractor at 160X.. Copied from "Journal ALPO", Vol. 15, 1961, pg. 97. South at top.

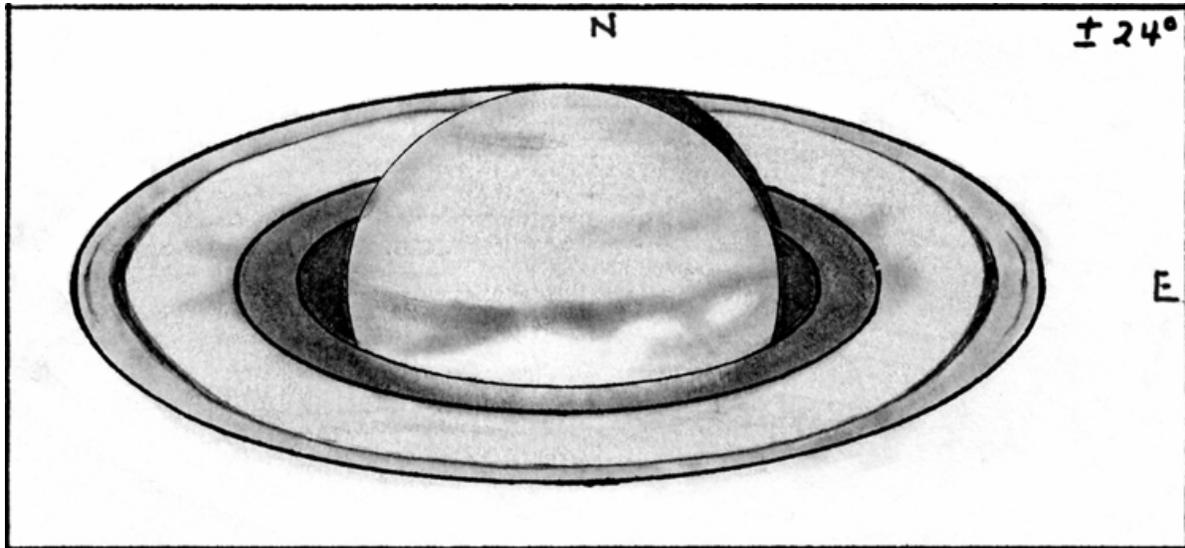


Figure 5. The 1990 EZ Great White Spot, drawn by Richard Hill of Tucson, Arizona, on 1990 October 10, 01h 09m UT. 14-in (36-cm) Schmidt-Cassegrain, 308X. Seeing = 2 arcseconds, twilight conditions. North at top.



Figure 6. Photograph of Saturn by Donald C Parker on 1990 October 04 at 2 hrs., 21 mins., UT. 16-in (41-cm) . F:76 (eyepiece projection) reflector, TP 2415 film, hydrogen hypered, exposure 3.5 seconds. Note the southeast-northwest tilt of the long axis of the Great White Spot in the EZ. South at top.

Observed Saturnigraphic North Latitude of Selected Belts on Saturn

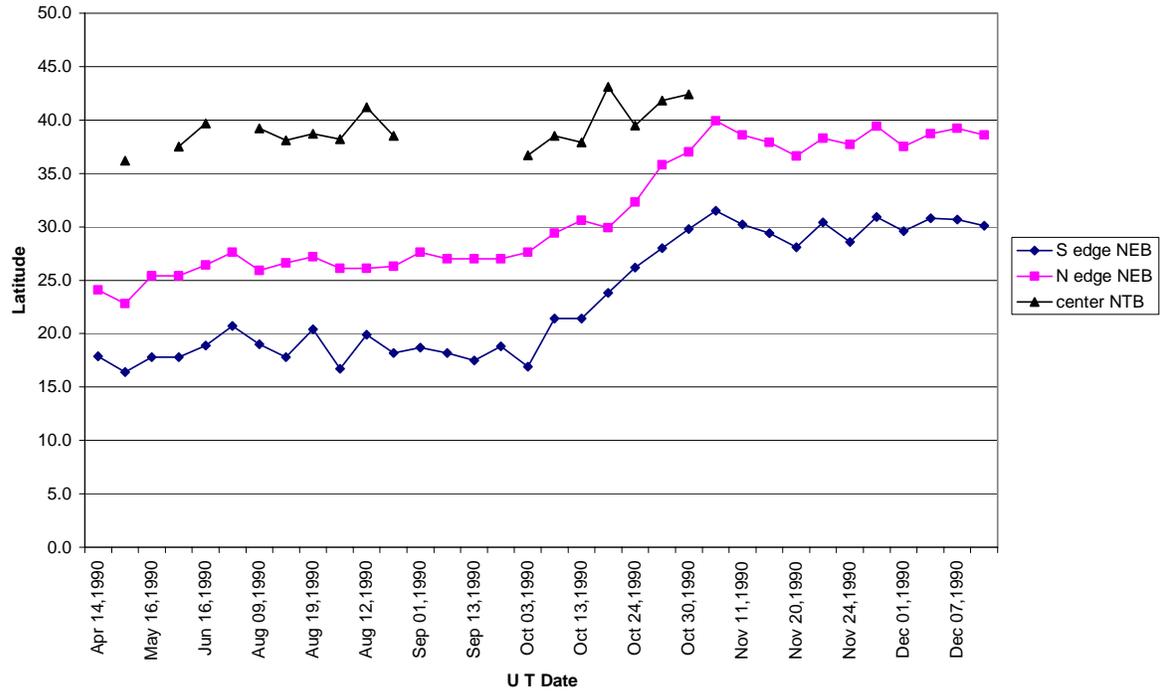


Figure 7. Observed Latitudes vs. U. T. Date.

Note that time intervals on the horizontal axis are not equal.