schleier. Ich beobachtete durch farbige Glasscheiben, ich hatte eine grüne und eine rote Scheibe, welche ich übereinander legte. Gegen 9 Uhr konnte ich mit noch einigen Mitgliedern meiner Familie die ganze Mondscheibe erkennen, welche scheinbar unten an der Sonne hing, jedoch nur für einige Sekunden, nachher war sie nicht mehr sichtbar. Der Himmelsgrund sah durch die Scheiben immer schwarz aus, die Mondscheibe erschien dunkelgrau«.

In Santiago sind keinerlei besondere Phänomene beobachtet worden.

Santiago de Chile, Observatorio Astronómico, 1913 Jan. 29. *R. Prager.*

The Faint Equatorial Belts on the Planet Neptune

discovered with the 26-inch Refractor of the U. S. Naval Observatory at Washington. By *T. J. J. See.*

[With a plate by way of illustration.]

As far back as 1902, while occupied with the measurement of the planetary diameters and the determination of the constants of irradiation for the different planets and satellites of the Solar System, with the 26-inch telescope of the Naval Observatory at Washington, I prepared a paper on the faint belts discovered on the planet Neptune in 1899. This has now remained unpublished for more than ten years, and as I recently found it among my manuscript papers, I deem it well to give it to the public without further delay, merely remarking that during the winter of 1899–1900 the belts on Neptune were distinctly recognized by Mr. *W. W. Dinwiddie* and Mr. *G. H. Peters,* both of whom saw the markings substantially as drawn by the writer, in the sketches now published.

In the drawing of the belts on Neptune here reproduced, the markings are perhaps a little too distinct, but this somewhat too great definiteness seems to be inherent in the nature of any sketch on a sensible scale, while on the very small disc of Neptune it is difficult to make out more than a general resemblance to the outlines here traced. But the separate sketches were made on different nights and I believe the series to give a faithful representation of the appearance of the planet.

At the end of the account of the Belts on Neptune I have added a notice of the discovery of the belts on the other major planets, which will I trust not prove to be wholly devoid of interest to students of this subject.

Soon after beginning observations of the Satellite of Neptune on October 6^{th}, 1899, a period of good seeing commenced which lasted for about six weeks. The air was very steady, and on many nights, about three o'clock in the morning, a bank of fog beginning over the Potomac river would stretch over the city and at length envelop the Observatory. During this period the most difficult double stars were measured, and on many nights the disc of the planet Neptune came out with unusual sharpness. While occupied with the measure of the Satellite on October the 10^{th}, a mottled appearance on the disc of the planet accidentally attracted attention.

The first drawing is taken from a sketch made on that night, and the others have been added since. As the observer had not contemplated studying the planet for surface markings, little further thought was given to the matter, till attention was again arrested by the unexpected appearance of beaded bands on the still and foggy night of Oct. 24^{th}, when the disc of the planet came out with unexpected sharpness. The ball of Neptune seemed small, very sharply defined, perfectly motionless, and of a greenish or greyish color.

The stillness of the night may be judged by the fact that the great telescope clearly resolved the components of 95 Ceti, the most difficult of known double stars, which had never before been measured at Washington. 85 Pegasi, τ Cygni and ϰ Pegasi are some of the other difficult stars measured on the best nights, when the belts on Neptune came out faintly against the brighter body of the planet.

In general the bands on Neptune were found to be extremely faint, but on a few occasions they came out with more distinctness. The plate gives the bands as noted at the time, and from these sketches it is easy to infer their general character. Assuming that they are parallel to the equator of the planet, it appears that the inclination of this plane to the plane of the Satellite's orbit does not surpass 20°. Professor *S. J. Brown* was led from theoretical considerations to conclude that this inclination is about 18°.

The uncertainty in the direction of faint belts seen on so small a disc is of course too great to enable us to fix the ascending node of Neptun's Equator on the plane of the Satellite's orbit. Whether future observations will furnish more definite information on this point remains to be seen. But I think it proper to point out that these phenomena are probably the most difficult yet disclosed in the Solar System; and observers who recognize them even with good telescopes under the best possible conditions will have to be very keen sighted and patient in waiting for the best moments of the night and the best nights of the year.

Not a moment of the season of 1899–1900 which gave promise of results was allowed to pass unimproved, and it only seems proper for the writer to say that he passed many long nights in the study of Neptune, when once the existence of the bands became known. A fair perquisite of steadiness is ability to separate the companion of 95 Ceti, of which an orbit is given in A. N. 3629. This star precedes Neptune by $2^h 30^m$ in right ascension, but in the present position the planet is sufficiently close by to serve as a test of steadiness.

On several occasions during his use of the 26-inch telescope at Washington, Prof. *Asaph Hall* suspected mottlings on the surface of Neptune, but he could never make out the details with sufficient clearness to obtain results worth publishing. Subsequently Prof. *S. J. Brown* noticed an unsymmetrical appearance of the planet's disc.

The chief interest attaching to the discovery of equatorial belts on the planet Neptune arises from the circumstance that phenomena depending on planetary rotation first noticed on Jupiter, and then on Saturn, and finally on Uranus are now seen to be common also to the most remote member of the Solar System.

Notice of the Discovery of Belts on the other Major Planets.

It is of some interest to recall the progress of our knowledge of the belts on the great planets of the Solar System.

Galileo's toy-like telescopes had shown Jupiter as a disc uniformly brilliant and devoid of details; but on May 17, 1630 *Zucchi* observed that there were two parallel bands across the planet analogous to the zones of spots on the Sun. At first he was inclined to make a map of the surface, but his efforts to form a Joviography soon convinced him that the position, extent, and coloring were variable, and thus altogether different from the fixed phenomena presented on the surface of the Moon.

It appears probable that *Torricelli, Fontana, Zupus* and other Italian philosophers of the early part of the 17^{th} century saw the belts on Jupiter, but it is not probably that they anticipated *Zucchi,* who may therefore be considered the first discoverer of equatorial bands on the planets. The only similar phenomenon previously noticed was *Galileo*'s detection of the zones in which the Sun-spots occur. Since the belts and spots have something in common, and appear to depend on the internal circulation and rotation of the masses, modern research tends to increase, more and more, the analogy between Jupiter and the Sun; yet the planetary belts are so different in appearance from the Sun-spot zones, that they must be considered separately.

It is reported that from the time Campani's telescopes began to be directed on Saturn, about 1664, the existence of belts on the planet's globe was noticed; but the earliest record of such markings which we have been able to trace down is that made by *J. D. Cassini,* at Paris in 1675 (Phil. Trans., 1676, p. 589). It was noticed from the first that the belts appear curved, like the zones of the planet's surface, and of different colors.

The exploration of Saturn's surface since the time of *Herschel* has established the general character of its detail, which is found to be complicated and so changeable as to give the impression that the planet is an early stage of development. Though some of the spots which have appeared on the disc have furnished the period of the planet's rotation with considerable accuracy, it is to be anticipated that much valuable work remains to be done before we shall have a good knowledge of the rotation of the different zones of Saturn's surface.

On January 29, 1862, *Lassell* wrote of Uranus:

»I received an impression which I am unable to render certain of an equatorial dark belt and of an ellipticity of form.« (Monthly Notices, 1872, p. 164, paper by *W. Buffham*).

This is the first record of belts afterwards seen with more certainty by *Buffham,* in 1871 and in 1872; and confirmed more amply by the observations of Professors *Young* and *Schiaparelli* and the *Henry* Brothers from 1878 to 1884. Using a silver on glass reflector of perfect achromatism the *Henry* Brothers have shown that Uranus has at least two faint equatorial belts, one on either side of the equator, and thus fixed the general character of the planet's surface markings. The similarity between the belts on Neptune and Uranus is sufficiently remarkable to be deserving of attention.

Mare Island, California, 1913 Febr. 19. *T. J. J. See.*

The Variation of the Sun. By *C. G. Abbot, F. E. Fowle* and *L. B. Aldrich.* [1]

In the year 1902 preliminary experiments were begun at Washington to determine the solar constant of radiation. About 700 determinations of it have now been obtained, depending on observations at altitudes ranging from sea-level to 4420 meters. As originally devised by *Langley* we determine spectral energy intensities and atmospheric transmission coefficients for numerous wave-lengths between about 0.30 μ in the ultra-violet and 2.5 μ in the infra-red, by spectrobolometric observations at high and low sun. The indications of the spectrobolometer are reduced to the standard scale of calories per sq. cm. per minute by means of the readings of the pyrheliometer.

At the time when the observations were begun in 1902 there was no satisfactory establishment of the standard scale of pyrheliometry, nor indeed any pyrheliometer which was invariable relatively to itself from year to year. We at first made use of a modification of *Tyndall*'s mercury pyrheliometer. This was improved in 1906 as the copper disk pyrheliometer, which has been in use on Mount Wilson ever since, and which is described in Volume II of the Annals of the Astrophysical Observatory. A still later improvement took place in 1910 with the introduction of the so-called »Silver-Disk Pyrheliometer« which has attained considerable favor, and which is now in use in numerous countries. Neither of these instruments is capable of yielding independently the standard scale of radiation, but they possess the valuable qualities of simplicity and of being constant from year to year. Beginning with the year 1903 and extending until the end of the year 1912 we have repeatedly devised and experimented with instruments to fix the standard scale of radiation. Three of these instruments (called Water-flow Pyrheliometers Nos. 2 and 3, and Water-stir Pyrheliometer No. 4) have been tested with satisfactory results which are stated in a publication by two of us [2]. We are now satisfied that the measurements made since 1903 can be reduced to the standard scale of radiation to within 1 per cent.

Measurements of the solar constant of radiation were begun at Washington, practically at sea-level, and were continued when favorable opportunities presented themselves from October 1902 until May 1907. Measurements were

[1]) Published by permission of the Secretary of the Smithsonian Institution.

[2]) See »Smithsonian Pyrheliometry Revised«; Smithsonian Miscellaneous Collections, Vol. 60, No. 18, 1913.