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JUPITER
and How to Observe It

Springer

John W. McAnally
USA
cpajohnm@aol.com

Series Editor
Dr. Mike Inglis BSc, MSc, PhD.
Fellow of the Royal Astronomical Society
Suffolk County Community College, New York, USA
inglism@sunysuffolk.edu

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In memory of my father and mother, John R. McAnally, Jr., and Margaret McAnally. I am eternally grateful for their love and encouragement.

And in memory of my mother-in-law, Mary Dicorte, who always asked how the book was coming along. I will miss her prayers, love, and kind ways.

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Author contact information:
By e-mail: cpajohnm@aol.com
or
through the Web site of
The Association of Lunar and Planetary Observers

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Introduction

Jupiter and How to Observe It

Welcome to a wonderful pastime! Observing the planets and learning something about them is an activity that anyone can do. I often liken amateur astronomy to the game of golf. Anyone can take up the sport. You can spend lots of money for equipment or you can be more frugal. You can participate at any level you wish and you can start when you are young and continue until you are old, all of your life at any age! However, amateur astronomers have one great advantage; we don't have to complain about our golf scores! My interest in astronomy began in the 1960s, not in science class but in reading class. We read a story in the eighth grade about the Hale 200-in. telescope on Mount Palomar, and how George Hale raised the money so it could be built. I am not sure what happened, but something in me just clicked and I knew that somehow I had to get into astronomy. My parents were poor, so my first telescope was inexpensive, small and hopelessly inadequate; yet, I remember going out with it every clear night. Later in high school I purchased a telescope that was still small but much better optically, and my views became much more clear. The planets especially have always fascinated me with their bright appearance and motion against the background stars. Whether observing visually or taking images through a telescope, I continue to be intrigued by what can be seen on their surfaces, by what changes and what stays the same!

In writing this book it is my hope that after reading it the beginner, who is just starting out, will acquire enough knowledge from it to be able to go to the telescope and make a meaningful observation the very first time. The methods and procedures described are not, for the most part, overwhelming or difficult; they simply require patience, care, and attention to detail. I believe the advanced amateur will also find enough here to be challenging, especially the more advanced procedures of imaging and reducing and reporting real data that is scientifically valuable. I have tried to follow a logical approach. As with any new endeavor, it is important to understand terminology and scientific notation about the subject to be studied, before the study is undertaken. Speaking the language is important and I have tried to make 'Jupiter speak' a little less daunting. It can also be helpful to have an understanding of the subject's past history and to think about what might occur in the future.

Section I of this book will discuss much of what we already know about Jupiter, and will hopefully provide a good grounding in the planet in preparation for Sect. II. Section II will discuss in some detail how to observe the planet, record data in a meaningful way, and report it. There is so much about Jupiter to know and understand. My own lifetime journey through this learning process has been a most enjoyable experience. I hope you enjoy yours. Every night can be a new adventure!

John W. McAnally
Assistant Coordinator for Transit Timings
Jupiter Section
Association of Lunar and Planetary Observers
2124 Wooded Acres
Waco, Texas 76710
cpajohnm@aol.com

Section I

Chapter 1

The Earliest Observations

1.1 Known to the Ancients

Jupiter is so bright in the night sky that it can easily be seen with the naked eye; in fact, among the planets, only Venus can shine brighter. Being so bright it was known to man long before the invention of the telescope. Ancient civilizations around the world knew of its wanderings and made attempts to predict its behavior against the stars. In mythology, Jupiter was the chief god of the Romans. The Greeks referred to Jupiter as Zeus. I can imagine that even prehistoric man would have noticed Jupiter, shining so bright against the other star-like bodies. We can think of Jupiter as our chief planet in the solar system. As we'll see, we might not even exist without this giant planet!

1.2 Galileo Galilei and Discovery of the Galilean Moons

Galileo Galilei was perhaps the first person to effectively use a telescope to explore the heavens, and is credited with being the first person to use a telescope to look at Jupiter. In January 1610 he noticed three star-like objects lined up in a row in Jupiter's equatorial plane (he eventually discovered a forth one). This alignment apparently aroused his deep curiosity and he eventually came to the conclusion that they must be in orbit around Jupiter! What a discovery! Seeing that another planet had bodies in orbit about itself, and knowing of the problems with the orbital theories of the time, Galileo came to the further conclusion that the Earth must not be the center of the motions that were observed in the universe. Having previously been encouraged in his other scientific studies by the Church in Rome, Galileo made his findings known to the Pope. Much to his disappointment, the Church soon took exception to his assertions that Earth was not the center of the universe and forbade him to continue his research or to even discuss it openly. He was subsequently placed under house arrest. Of course, we now know that Galileo was correct, but at the time Jupiter presented him with what was truly a life-threatening situation! These four moons are now known as the 'Galilean moons'.

1.3 Cassini and the Great Red Spot

After Galileo, as the quality of lenses and telescopes improved, observers began to detect markings on Jupiter's surface. In 1665, Giovanni Dominico Cassini discovered a "permanent spot" on Jupiter and followed it on and off for several years. Cassini also discovered Jupiter's equatorial current, the flattening of its poles, and its limb darkening. Later, when the Great Red Spot was recognized in 1879, it was suggested that this was a rediscovery of Cassini's spot. However, there is really no empirical evidence to support this, and we must be careful not to state this as fact [1].

As the years went by and telescopes and lenses continued to improve, more and more discoveries were made regarding Jupiter. Many of the people making these discoveries would be considered amateurs today. However, these amateurs were serious, dedicated, careful observers. And as we will see, there continues to be room in astronomy for amateurs today, and perhaps more so than ever!

1.4 In Good Company

The amateurs of today are in very good company with many notable observers who have led the way before us such as Bertrand Peek, Hargreaves, Phillips, Molesworth, and Elmer Reese; and with contemporaries of today such as Miyazaki, Don Parker, Phillip Budine, John Rogers, Walter Haas, Olivarez, and many, many others. If not for these observers, the visual record of Jupiter would be sparse indeed. We can take pride in helping to continue the works of so many wonderful amateurs.

The telescopes and related equipment are better than ever. I can only imagine what Bertrand Peek would have given for a good web cam or CCD camera! How much easier our work is compared to theirs; yet, we can only hope to measure up to their discipline, their persistence, and their attention to detail!

So, from Galileo to today many years have gone by and yet, Jupiter still begs to be observed! What will we discover next year, and the next, and the next?

Chapter 2

Jupiter's Place in the Solar System

Whether our study of Jupiter is casual or serious, it will be helpful to understand some basic facts about the planet, including simple nomenclature. This knowledge will help us in our own study, and it will allow us to understand what others say and write about the planet. As I have found over the years, there is always something new and exciting to learn, something new to be discovered and revealed, but we must understand the language.

So, where does Jupiter stand in the scheme of things? Our solar system is comprised of many bodies, large and small. We were taught about the nine planets in school, and their order in distance from the Sun. Recently, the International Astronomical Union changed the classification of Pluto, and it is no longer officially classified as a planet in the simple sense. Now we have eight planets and all manner of other bodies.

2.1 Physical Characteristics

Jupiter displays a series of bright zones and darker belts, generally running parallel to its equator. Figure 2.1 illustrates the globe of Jupiter with the belts and zones that are usually visible. Not all features will be visible at all times, as belts and zones are prone to brighten, darken, become larger or smaller, or even disappear from time to time.

Jupiter is the fifth planet from the Sun. It is a gas giant, having no surface as we think of on Earth. Its volume is so large, that if it were a hollow sphere, all the other planets would fit easily inside with room to spare. Even mighty Saturn is only about one-third its mass. However, Jupiter's density is so low that if there were a water ocean large enough, Jupiter would float on its surface!

Jupiter's large mass is of extreme importance to the solar system and especially to Earth. Jupiter's mass perturbs the orbit of nearly every planet in our solar system. It also influences the orbits of smaller bodies that come into the inner solar system from the Kuiper Belt and the Ort Cloud. Jupiter's mass and strong gravitational influence has a tendency to either sweep up small bodies that cross its orbit, or to eject them from the solar system entirely. This solar system 'vacuum cleaner' made it possible for Earth to survive long enough for life to form and evolve. Without this protection, the bombardment of Earth would occur too frequently by bodies

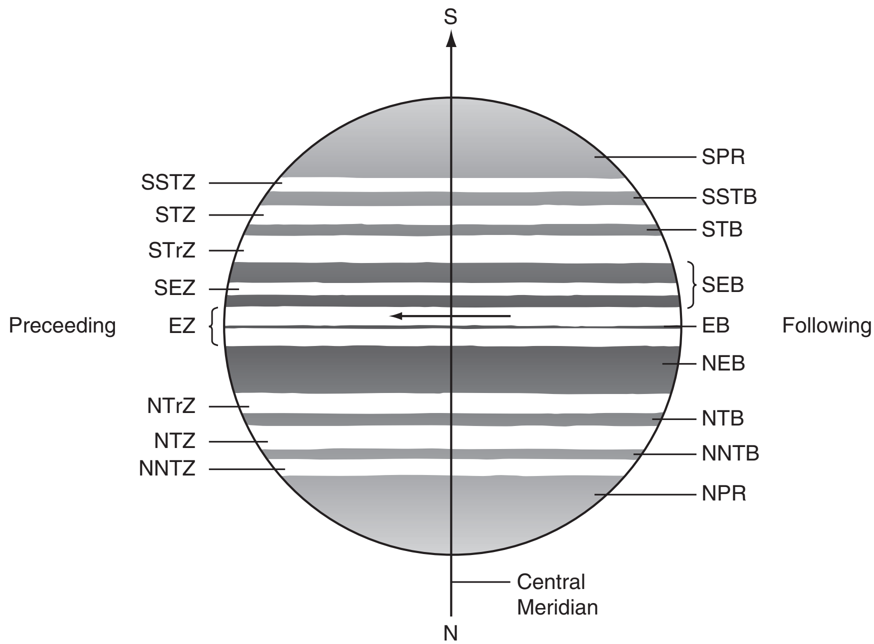


Fig. 2.1. The belts and zones of Jupiter (Credit: John W. McAnally).

Table 2.1. Jupiter's physical and orbital characteristics compared to Earth

	Jupiter	Earth
Equatorial diameter (km)	143,082	12,756
Polar diameter (km)	133,792	12,714
Rotation periods		
		23h 56m 4s
System I	9h 50m 30.003s (877.90°/day)	
System II	9h 55m 40.632s (870.27°/day)	
System III	9h 55m 29.711s	
Axial tilt	3.12°	23.44°
Mass	1.899×10^{27} kg	5.974×10^{27} kg
Density	1.32 g cm^{-3}	5.52 g cm^{-3}
Surface gravity	2.69 g	1.00 g
Mean distance from Sun	5.20280 AU	1.00000 AU
Orbital eccentricity	0.04849	0.01671
Period (sidereal)	4,332.59 days	365.26 days

1 astronomical unit (AU) = 149,597,870 km [2]

too large for Earth to survive as we see it today. The recent 1994 collision of Comet Shoemaker-Levy 9 with Jupiter is a great example of Jupiter as protector of the solar system.

Jupiter exhibits differential rotation; that is, different latitudes of the planet have different rotation rates. Generally, System I includes the latitudes from the north edge of the south equatorial belt, all of the equatorial zone, to the south edge of the north equatorial belt. System I also includes the south edge of the north temperate belt. System II includes the rest of the planet. Since amateurs in the past have observed Jupiter in visible wavelengths, it has been common practice for them to refer to System I and II. Professional astronomers have generally used a third rotation system, System III. The System III rotation rate is related to a radio source on Jupiter that rotates with the planet at a specific rate. Since these three rotation rates are different, we must designate which system we are referring to when we speak of longitudinal positions on Jupiter. Depending upon the latitude at which a feature appears on Jupiter, amateurs refer to System I or II longitude. This usage will become more apparent in the section of this book dealing with transit timings. Table 2.1 summarizes Jupiter's physical data and orbital characteristics.

2.2 A System of Basic Terminology and Nomenclature

Like most sciences, planetary astronomy comprises a language of special terms and nomenclature. Understanding those associated with Jupiter will facilitate our discussions and explanations, since this scientific shorthand can actually help to keep our discussions simple and unambiguous. Years ago, A.L.P.O. Jupiter Section Coordinator Phil Budine suggested a simple, straightforward system that we can still use today. There are abbreviations for the terms and nomenclature of dark and bright features, and for the belts and zones; so, some of the more common terms and abbreviations are shown in Tables 2.2 and 2.3. Various dark and bright features can be seen in the belts and zones at any given time. Some of the features most often seen are illustrated in Table 2.4. These illustrations are modeled after illustrations used by past A.L.P.O. Jupiter Recorder Phillip Budine.

A simple example can help us understand how we put this terminology into use. Figure 2.2 shows a large condensation, or barge, on the north edge of the north equatorial belt. This feature would be described as, 'Dc L cond N edge NEB'; which literally means 'dark center, large condensation, north edge, north equatorial belt.' So, you see how in simple, straightforward notation we have completely described the feature and where it resides. If we were describing a bright feature we would use the designation 'W', instead of 'D'. Later, when we discuss central meridian transit timings, you will see how we combine this description with the longitudinal position of the feature to turn this kind of observation into real, meaningful data.

As we will see in Sect. II of this book, your observations are only valuable if they are properly recorded and notated. The system of nomenclature presented here should allow anyone to accomplish this task. Organizations such as The Association of Lunar and Planetary Observers (A.L.P.O.) and the British Astronomical Association (BAA) have standard observing forms that the observer can use to record observations. Many other organizations around the world also have standardized forms. Standardized observations greatly facilitate the gathering

Table 2.2. The basic nomenclature and abbreviations for Jupiter's belts and zones

SPR	South Polar Region
SSTB	South South Temperate Belt
STZ	South Temperate Zone
STB	South Temperate Belt
STrZ	South Tropical Zone
SEB	South Equatorial Belt
SEZ	South Equatorial Zone
EZ	Equatorial Zone
EB	Equatorial Band
NEB	North Equatorial Belt
NTrZ	No rth Tropical Zone
NTB	North Temperate Belt
NTZ	North Temperate Zone
NNTB	North North Temperate Belt
NPR	North Polar Region

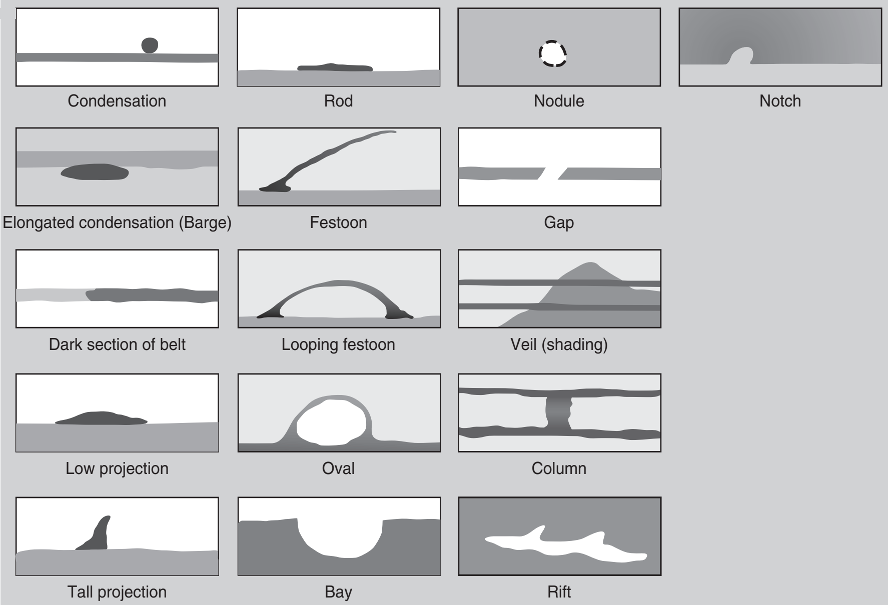
Table 2.3. Basic nomenclature used for transit timing observations

Dark marking	D
White or bright marking	W
Center	C
Preceding	P
Following	F
North	N
South	S
Large	L
Small	Sm
Projection	Proj
Condensation	Cond
Central Meridian	CM
System I	(I) or CM1 or L1
System II	(II) or CM2 or L2
System III	(III) or CM3 or L3

and recording of data and its subsequent use by the professional community and other amateurs.

I strongly encourage you to use this standard system of notation. Not only will its use make you a better planetary astronomer, it can even add some anticipation and excitement to your endeavors. What features are you going to be able to record tonight? Will they be the same tomorrow night, or next week? I think you will find it fascinating to learn that some features are long-lived and some are not! You are going to learn so much about Jupiter, and you will be amazed at how easily you retain what you have learned when you observe in this fashion!

Table 2.4. Basic nomenclature for dark and bright features commonly seen on Jupiter (Credit: John W. McAnally)



From standard nomenclature proposed by Phillip W. Budine.

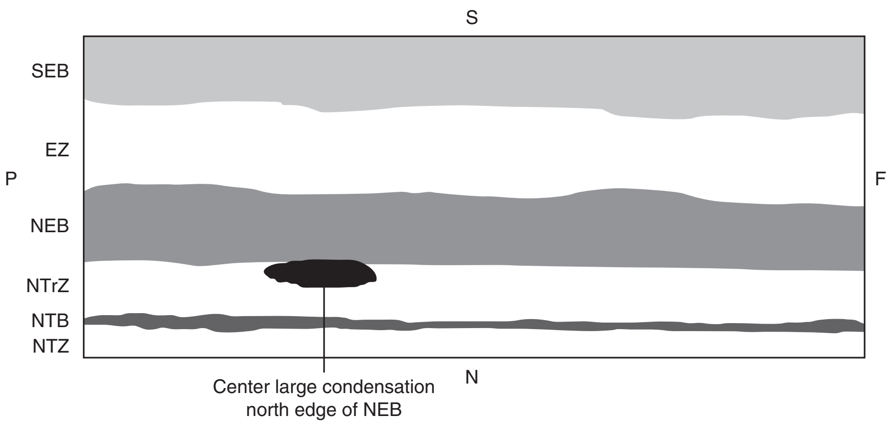


Fig. 2.2. Example of a large condensation depicted on the northern edge of Jupiter's North Equatorial Belt (Credit: John W. McAnally).

Chapter 3

The Physical Appearance of the Planet

The disk of Jupiter presents a variety of features that can be observed by an amateur astronomer with modest equipment. Features both obvious and subtle await the eager observer. Indeed, Jupiter is often referred to as "the amateurs' planet", due in part to its enormous size and angular diameter that makes it easy to observe. The use of CCD cameras and web cams by many amateurs today is becoming more commonplace, with excellent images being obtained showing great detail. It is the physical appearance of the planet and ease of observation that first attracts most of us. In this chapter we will deal with the physical structure, characteristics, and phenomenon that can be observed visually and by imaging; in other words, those things that anyone, including an amateur with a telescope, can see. Specifically, we will examine non-vertical structure in Jupiter's clouds, winds, jet streams, and color.

The observation of features on the surface of Jupiter, or rather in its cloud tops, and the observation of changes in the longitudinal and latitudinal positions of features, and the determination of the movement of features with regard to the speed of various currents and the appearance and reappearance of other phenomena, has been a mainstay of amateur observations since the beginning of recorded observations more than 150 years ago. While there is much to Jupiter amateurs cannot observe directly, these things we can see. Amateurs today continue this wonderful tradition of observational astronomy.

3.1 Common Visual Markings

Although we should never approach the observation of Jupiter with any preconceived notion of what may be seen, it can be useful to have an understanding of the type of features that may be present at any given time. The bright ovals, eddies, and condensations are evidence of great turmoil and chaos in the visible atmosphere of Jupiter. Features seen in Jupiter's cloud tops are not stationary, and may be short or long lived. Knowing this, I think the observation of these features is all the more tantalizing. You may wish to review the figures and tables in Chap. 2 again while studying this chapter.

Generally, the planet is made up of clouds that have organized themselves into dark belts and bright zones, due mainly to the rapid rotation of the planet. The belts and zones are defined by powerful jet streams that are permanent winds blowing eastward or westward. Dark spots and bright ovals are storms that drift eastward or westward at slower rates. The rapid rotation of the planet causes all motions to be channeled along lines of latitude; thus the belts and zones run east and west. See Fig. 2.1 in Chap 2, which depicts the placement of belts and zones and nomenclature.

3.1.1 The Polar Regions

To the visual observer, the polar-regions most often present a gray, dusky appearance, absent specific features. Indeed, during the apparitions of 2000–2001 and 2001–2002, most visual observers reported no features at all. A few observers using large instruments with exceptional image contrast reported an occasional small, bright oval near the latitude of the NNTB or SSTB. However, these sightings were never widely observed and thus, difficult to confirm. Occasionally there is an exception to the inactivity usually noted in the polar-regions, as reported during October 1997. During that apparition, several independent observers observed faint dusky markings, slightly more intense than the surrounding region. Among those observers, I was able to observe one feature well enough to make one set of transit timings. This occurred on the night of October 26, 1997 U.T. (Fig. 3.1). Quoting from my own observing log, "The NPR is also exceedingly

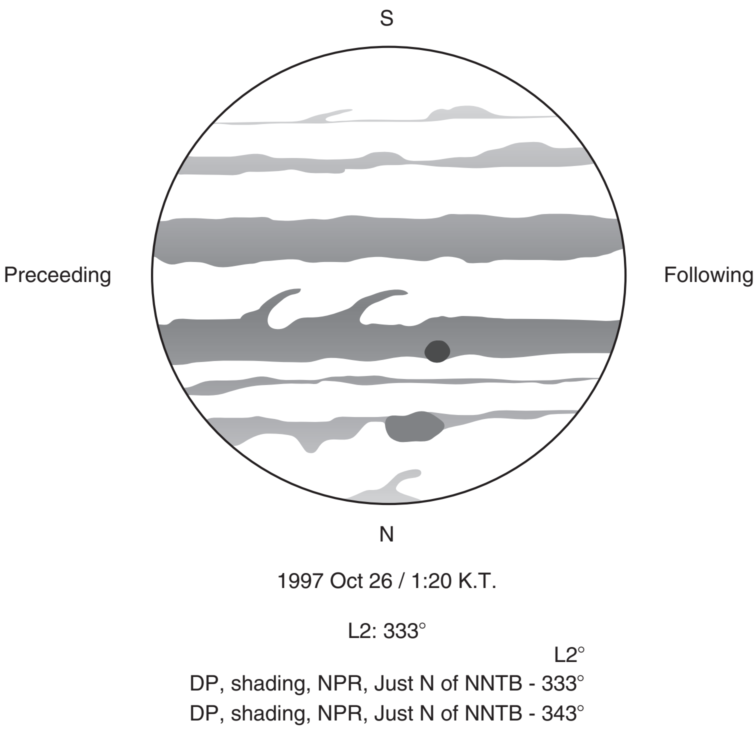


Fig. 3.1. A full disk drawing of Jupiter showing the shading or veil in the north polar region of Jupiter on October 26, 1997 (Credit: John W. McAnally).

faint. A dusky patch or mottling is seen by me for the first time at the southern edge of the NPR (these had previously [recently] been reported by others). This mottling was very distinct and unmistakable! It was fairly extended in longitude. It was seen clearly enough that I was able to make a CM transit timing of the preceding and following edge. This may be the first measurement (CM transit timing of such a feature, at least during this apparition) reported to A.L.P.O. (this observation was made in integrated light). The mottling was also seen in green (W56) light. Not seen in yellow (W12) light." Alas, the feature disappeared and was not observed again. However, their existence was confirmed beyond doubt when these dusky markings were captured in a few CCD images, coinciding with the longitudinal position observed by me and several other observers. These dusky markings were first seen visually and later also confirmed by CCD imaging. A fine example that visual observations are still of value.

Often, the polar-regions seem to spread their gray appearance all the way to the NTZ or the STZ. Occasionally, however, subtle, lighter zones can be made out, divided by thin, grayish belts barely seen. Observing the often too subtle NNNTB and NNTB, their southern counterparts, and intervening zones, is extremely difficult. Consequently it is very difficult to collect current, useful data on the drift rates and wind currents in these regions. Occasions have been rare in which any useful transit timings have been obtained from the polar-regions. However, when bright or dark features present themselves in these belts and zones for long enough, the observations that can be obtained are of great importance. As recent as July 2006, CCD and webcam images continued to reveal a north polar region that was mostly unremarkable (Figs. 3.2 and 3.3). However, the improved camera technology consistently revealed light and dark dusky markings in the region. With advances in CCD and webcam technology, we can expect amateurs to obtain images with such high resolution that features in the polar regions will be captured consistently with enough resolution that measurements of currents and drift rates in this region will not only become possible but routine.

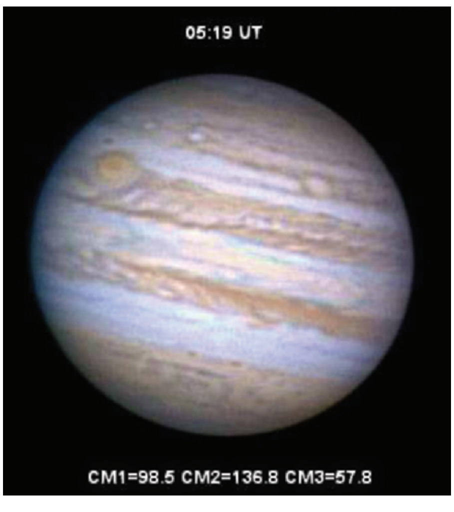


Fig. 3.2. A webcam image of Jupiter demonstrating the lack of detail in Jupiter's north polar region on February 11, 2004. South is to the top right of image. (Credit: Donald C. Parker).

Fig. 3.3. A webcam image showing a little more activity in Jupiter's north polar region, although the region is still unremarkable, on April 12, 2006. South is to the top right of image. (Credit: Donald C. Parker).

3.1.2 The North–North Temperate Region

The North–North Temperate Region generally extends from 57° North to 35° North latitude. As mentioned, the North–North Temperate belt (NNTB) can be difficult to observe and is not always present (Fig. 3.4). However, when the belt is present, it is important to note its width and intensity. There may also be seen the occasional projection on its southern edge. Although these are rare, if present, careful observations and transit timings can yield valuable data concerning drift rates and wind currents. During the 2000–2001 apparition, a remarkable, dark segment appeared in the NNTB (Fig. 3.5). In fact, a disk drawing of Jupiter on August 2, 2000 shows this dark segment quite well. Similarly, CCD images by David Moore, I. Ikemura, Peach, Maurizio Di Sciullo, Antonio Cidadao, and others around the world also captured this dark segment. Observers continued to detect this segment in CCD images in early 2002, although the segment was fading and not near the intensity of 2000–2001. By April 2002, images by Don Parker revealed a NNTB segment that was broken and spread out. Thus, the feature was long-lived and yielded very useful data concerning the drift rate and wind speeds in this belt. It measured 10–15° in longitudinal length when first seen. Features such as this are very rare in the NNTB. This one presented a wonderful opportunity to check recent data about currents against that collected in prior years with Earth based telescopes and against wind speed data collected during the Voyager series. Often, the NNTB goes wanting for such data! This feature was extensively imaged by amateurs using CCD cameras but was also widely observed visually. The feature lasted for over 14 months. The NNTB was unremarkable from June 2002 to May 2004 (Fig. 3.6). However, in April 2006 imagers detected a bright oval and a little red spot (LRS) in the NNTZ. Portions of the NNTB were also seen, reddish-brown in color.

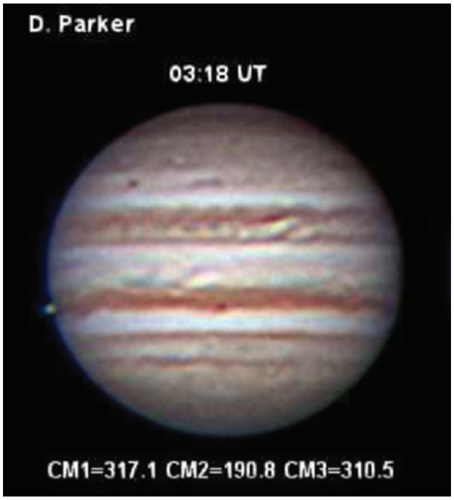


Fig. 3.4. An image of Jupiter showing a fairly dark NTB, and a discontinuous NNTB on September 30, 1998. Note the narrow NEB and bright Mid-SEB Outbreak running down the middle of the SEB. South is up. (Credit: Donald C. Parker).

Fig. 3.5. Jupiter on August 30, 2000. Note the dark segment of the NNTB and that the remainder of the NNTB is discontinuous or absent. South is up. (Credit: Donald C. Parker).

3.1.3 The North Temperate Region

The North Temperate Region extends from latitude 35° North to 23° North. While the polar-regions are often disappointing, the North Temperate Belt (NTB) contains a class of feature all its own. To the casual observer, the NTB usually presents the appearance of an otherwise featureless, thin, grayish or reddish-gray belt slightly more intense than the neighboring polar region. However, closer scrutiny reveals otherwise. The belt can be continuous, fragmented, or completely absent. During the 2000–2001 and 2001–2002 apparitions, the NTB was reported by most observers to have a reddish-brown coloration mixed in with the gray tone (Fig. 3.7). I have