REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
15-06-2001	UU	

4. TITLE AND SUBTITLE
See the abstract below

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
See the abstract below

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Phone.txt

DTICPUB0615.txt

US NAVAL OBSERVATORY COLLECTION

20010705 159

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: UU			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON See the abstract above
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code) See the phone list above*

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Some of the "Astronomical Seeing" Scales

By: Jeff Beish

Association of Lunar and Planetary Observers (A.L.P.O.)

INTRODUCTION

Over the years visual observers have derived many schemes to describe "astronomical seeing" in a quantitative manner. Each has advantages and most are confusing at least. While it is most likely the most subjective chore for the observer, it is never the less assumed by section coordinators to be included in our notes. Discussed will be the several seeing scales this author encounters along the way.

First, the scales used by some of the early observers of the Association of Lunar and Planetary Observers (A.L.P.O.).

Step One (1): One A.L.P.O. Seeing Scale: The first step is to determine the observer's "personal constant" by using several double stars on a "night of exceptional seeing", and with the aperture stopped down to 1 inch. This "personal constant, **r**, is the separation in seconds of arc of the closest pair which can barely be separated.

Step Two (2): This requires that on a night of actual observing the observer find the closest double star which can be resolved using the full aperture and then multiply that separation by the aperture in inches, yielding a value **r'**. This is used along with **r** (as found above) to calculate the telescope efficiency, **e**, as:

$$e = r / r'$$

and the effective aperture, **D'**, can be determined from:

$$D' = (rD) / r'$$

where **D** is the telescope aperture in inches.

Many of the A.L.P.O. Sections use a seeing scale of 0 to 10, with 10 being perfect and descending down from there to 0 as being conditions completely hopeless for someone to observe in. The criteria for each of the above steps have been somewhat subjective and will not be listed here. See the list of reading materials at the end of this article for a more detailed discussions.

Modification of *Step One* above: the observer would perhaps be better served by using the methodology described by *Couteau* in Chapter 4 of **Observing Visual Double Stars.** Couteau explains in detail how to use artificial lighting and small ball bearings to create artificial double stars located some distance away from the observer. In his own words (p. 89):

"You will have a stable stellar image, unaffected by seeing, that can easily be examined comfortably, without twisting your neck. Reflections from two lamps, side by side, will give a beautiful double star. The separation can be varied at will, up to the limit of resolution, and even differences in brightness can be created by moving one lamp with respect to the other."

By using the formula *Couteau* provides, all variables (ball bearing radius, distance between the lamps, distance from lamps to ball bearing, and distance from telescope objective to ball bearing) are used to define the separation of the artificial pair in seconds of arc. In his example, he uses a 4mm ball bearing, lamps separated by **10cm** and located **1m** from the bearing, and an observer **100m** away, to yield a **0.2** seconds of arc separation.

A suitable "test stand" could be built to allow the "personal constant" to be determined without regard to whether or not it was a "night of exceptional seeing." Such a test stand could also be used to compare telescopes of the same aperture to determine which had the better absolute resolution.

In *Texeraux's* **How to make a Telescope**, Willman-Bell, 2nd ed, p309-310) and *Jean Dragesco's* **High Resolution Astrophotography**, CUP, p3-4) and noted the following quantitative scale to estimate seeing based on the work of *Danjon* and *Couder* (1935). It also gets a mention in *Sidgwick's* **Amateur Astronomer's Handbook**, 2nd ed, p454-455). This scale provides an absolute notion of seeing expressed in arcseconds and is not tied to any specific aperture, unlike some of the other scales in common use e.g. *Antoniadi.* We may assume the ***Rayleigh limit*** (140/Dmm) as the baseline measure. In use one simply compares the degree of turbulence in the ***Airy*** pattern with the description, and then reads off the value.

$$a \text{ (in arcsecs)} = 140/D(\text{mm})$$

Table 1. Scale of "Astronomical Seeing" from Amateur Astronomer's Handbook where seeing or (in arcsecs) = 140/D(mm)

Scale	t-value	Description
I	t > 1.5a	Image tending towards a planetary appearance
II	t = a	Strong turbulence; rings weak or absent
III	t = 0.5a	Medium turbulence, diffraction rings broken, central spot having undulating edges
IV	t = 0.25a	Complete rings crossed by moving ripples
V	t =< 0.25a	Perfect images without visible distortion and little agitated

Yet another scale: Harvard Observatory's *William H. Pickering* (1858-1938). Pickering used a 5-inch refractor. His comments about diffraction disks and rings will have to be modified for larger or smaller instruments, but they're a starting point:

Table 2. Scale of "Astronomical Seeing" using **William H. Pickering Scale.**

SCALE	REMARKS
1	Star image is usually about twice the diameter of the third diffraction ring if the ring could be seen; star image 13" in diameter.
2	Image occasionally twice the diameter of the third ring (13").
3	Image about the same diameter as the third ring (6.7"), and brighter at the center.

4	The central Airy diffraction disk often visible; arcs of diffraction rings sometimes seen on brighter stars.
5	Airy disk always visible; arcs frequently seen on brighter stars.
6	Airy disk always visible; short arcs constantly seen.
7	Disk sometimes sharply defined; diffraction rings seen as long arcs or complete circles.
8	Disk always sharply defined; rings seen as long arcs or complete circles, but always in motion.
9	The inner diffraction ring is stationary. Outer rings momentarily stationary.
10	The complete diffraction pattern is stationary.

NOTE: On this scale 1 to 3 is considered very bad, 4 to 5 poor, 6 to 7 good, and 8 to 10 excellent.

After surveying many astronomical books surfing the Net looking for reports on "astronomical seeing" it is obvious the subject lacks credible description. These is a paper trail talking points on the subject, however, a detail description is limited to what amateur astronomers have to say. One may wish to use modern photometers, electronics and computers to record intensities variations of stars, but that would be too much like work. Someday it would be nice if someone would describe in empirical terms "astronomical seeing."

This author has used a Bi-filar micrometer on many occasions to measure the blurring and slow expansion and contraction of Mars to convert to angles and compare those results with well known seeing scales. By calculating the linear or plate scale of the telescope (using the focal length and eyepiece apparent angles) one can then measure the amount of displacement in the image in seconds of arc. This can then be applied to the definitions of the various seeing scales. My personal seeing scale is a number between 0 and 10 that is defined as follows:

Table 3. Scale of "Astronomical Seeing" using the Beish Seeing Scale (My name in lights!).

SCALE	BLUR	REMARKS
	(+/- arcsec)	
10	0.0	**Perfect**, no high frequency blur or scintillation. The complete diffraction (Airy disk) stationary.
9	0.2	**Near perfect**, no high frequency blur, very slight scintillation. Airy disk always visible; arcs frequently seen on brighter stars.
8	0.5	**Excellent**, no high frequency blur, 1-PPS scintillation barely noticeable. Airy disk visible; rings beginning to be in motion.

7	0.7	**Good**, no high frequency blur, 2-PPS scintillation barely noticeable. Airy disk beginning to blur; rings in motion.
6	0.9	**Good**, no high frequency blur, 5-PPS scintillation increasingly noticeable.
5	1.1	**Fair**, beginning high frequency blur, planet details unstable.
4	1.4	**Fair**, high frequency blur, planet details unstable and fuzzy.
3	1.6	**Poor**, high frequency blur increasingly noticeable, planet details unstable and fuzzy.
2	1,8	**Poor**, high frequency blur increasingly noticeable, planet details washed out.
1	2.1	**Poor**, high frequency blur renders planet details completely washed out.
0	-	**Obviously out of the question to observe.**

So, the above demonstrates just how subjective the published and unpublished "astronomical seeing" scales can be. The time and effort to make our personal reference to astronomical seeing more scientific is worth while for an observer to do occasionally. But, it is not necessary to conduct testing at each observation period. Experienced planetary observers will on occasion test his or her "personal equation." That includes some measure of what they perceive the "seeing" to be.

Subjectivity is just a human perception. Remember, after all the high tech- machines record minute data points and statistical curves and tables, it is the human eye that renders science a subjective art for the human mind.

More seeing scales have been published over the years and if anyone else can add to this list please do. Maybe reduce the confusion of the seeing scales to one everyone can understand.

Reading Material

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