IMPORTANCE OF OBSERVATION THAT STARS DON'T TWINKLE OUTSIDE THE EARTH'S ATMOSPHERE

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IMPORTANCE OF OBSERVATION THAT STARS DON'T TWINKLE OUTSIDE THE EARTH'S ATMOSPHERE*

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Stars observed by the human eye outside the earth's atmosphere show no obvious time variations of their visible light intensity for time lapses from tenths of seconds up to several minutes as observed on Apollo 7 (and 8 also[1]). We discuss here two aspects of the importance of this observation.

First, the lack of star twinkling is of prime importance to the lunar astronomical observatory. The effect of moving electron density irregularities in the interstellar plasma is shown by this observation to be small. The tenth-of-a-second twinkling of Jovian decametric (10^7 c/sec) radio noise is believed[2] to result from inhomogeneities in the solar wind in the path of ~ 4 a.u. between Jupiter and the earth. In analogy one might have expected twinkling of visible light to result from inhomogeneities due to interstellar winds. By direct observation of thousands of stars this does not appear to be the case.[3]

Search for and study of twinkling from the advantaged position of the moon based astronomical observatory then offers a new method to determine distances to stars, and in particular may give new information on the curious problem of quasars, now said to be the most distant of all objects. In principle random motions of interstellar plasma would become amenable to study throughout the galaxy.

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Secondly, lack of visible star twinkling rules out random laser action in stellar atmospheres and gaseous nebulosities for time variations from tenths of seconds up to several minutes. Radio emission from galactic concentrations of hydroxyl radicals at $\lambda \sim 18$ cm is believed to drive from laser action.[4] If this hypothesis is correct then there must exist natural ways to create inverted atomic and molecular populations, so that one might expect both maser and laser action to be a probable phenomenon. Non-observation of visible twinkling in thousands of stars from first down to fourth plus magnitude (with eye aided by 28 power telescope) and in nebulous formations, and in one other galaxy, the Magellanics, is thus of major importance to set upper limits on probability of naturally occurring laser action.

The stars used by the astronauts for navigation, and which together with their neighbors were studied the most carefully are listed in Table 1.

Table 1

STARS USED FOR ASTRONAUT NAVIGATION

Star No.	Greek Letter	Name	Right Ascension	Declination	Magnitude
1	α	Andromedae	0:06:40.6	+28:54:30	2.1
2	β	Ceti	0:41:56.0	-18:10:03	2.2
3	γ	Cassiopeiae	0:54:42.1	+60:32:19	Var.
4	α	(Archernar) Eri	1:36:29.2	-57:24:15	0.6
5	α	Polaris (U Mu)	2:00:56.6	+89:06:43	2.1
6	θ	Eridani	2:57:00.5	-40:26:10	3.4
7	α	Ceti	3:00:33.1	+ 3:57:41	2.8
8	α	Per(Mirfak)	3:21:57.4	+49:44:43	1.9
9	α	(Alderbaran) Tau	4:34:01.5	+16:26:40	1.1
10	β	Ori (Rigel)	5:12:57.1	- 8:14:19	0.3
11	α	Aur(Capella)	5:14:14.9	+45:57:59	0.2
12	α	Car(Canopus)	6:23:13.1	-52:40:38	- 0.9
13	α	C Ma(Sirius)	6:43:41.7	-16:40:10	- 1.6
14	α	CMi(Procyon)	7:37:34.5	+5:18:39	0.5
15	γ^2	Velorum	8:08:30.9	-47:14:19	1.9
16		Ursae Majoris	8:56:57.4	+48:10:21	3.1
17	α	Hydrae	9:25:57.9	- 8:30:53	2.2
18	α	Leo(Regulus)	10:06:37.0	+12:07:45	1.3
19	β	Leo (Denebola)	11:47:22.6	+14:45:23	2.2
20	γ	Corvi	12:14:06.3	-17:21:32	2.8
21	α^1	Cru (Acrux)	12:24:44.9	-62:54:59	1.0
22	α	Vir (Spica)	13:23:27.1	-10:59:23	1.2

Table 1--continued

Star No.	Greek Letter	Name	Right Ascension	Declination	Magnitude
23	η	UMa(Alkaid)	13:46:14.5	+49:28:39	1.9
24	θ	Centauri	14:04:44.0	-36:12:30	2.3
25	α	Boo(Arcturus)	14:14:09.3	+19:21:12	0.2
26	α	Coronae Bor	15:33:17:4	+26:49:29	2.3
27	α	SCO(Antares)	16:27:22.8	-26:21:38	1.2
28	α	TR A (Atria)	16:45:09.2	-68:58:11	1.3
29	α	Ophiuchi	17:33:24.1	-12:34:58	2.1
30	α	Lyr (Vega)	18:35:49.2	+38:45:27	0.1
31	σ	Sagittarii	18:53:13.1	-26:20:22	2.1
32	α	AQL(Altair)	19:49:10.3	+ 8:46:18	0.9
33	β	Capricorni	20:19:09.5	-14:58:13	3.2
34	α	Pavonis	20:23:02.8	-56:50:33	2.1
35	α	CYG (Deneb)	20:40:18.3	+45:09:42	1.3
36	ϵ	Pegasi	21:42:33.8	+ 9:43:22	2.5
37	α	P sa(Formal-haut)	22:55:49.8	-29:47:51	1.3

REFERENCES

1. Time (magazine) January 17, 1969, page 45.
2. "Interplanetary Scintillation of Jupiter's Radio Emission" by D. L. Thompson, Bull. Am. Phys. Soc. 13, No. 12, 1714 (1968).
3. At electron densities $N_e \sim 1/cm^3$, the characteristic plasma frequency is $\sim 10^4$ c/sec, much smaller than the frequency of decametric radio emission $\sim 3 \times 10^7$ c/sec, or of visible light, $\sim 10^{14}$ c/sec, so that the cross section of electron scattering reduces to the classical electron cross section, $\sigma_e \sim (8\pi/3)\,(e^2/ma^2)^2 \sim 0.5 \times 10^{-24} cm^2$. However in the case of radio waves, of $\lambda \sim 10$ m, clumps of electrons in volumes $\sim \lambda^3$, can act coherently to scatter, with cross section $(N_e\,\lambda^3)^2\,\sigma_e \sim 10^{-6}\ cm^2$. Between earth and Jupiter, separated by distance L, there are approximately $L/\lambda^3 \sim 10^4$ clumps per cm^2 so that the change of intensity of a radio wave traveling the path is $\Delta I \sim N_e^2\,\lambda^3\,L \sim 1\%$, a measurable effect. For visible light however, $\lambda \sim 10^{-4}$ cm, coherent effects are nil at $N_e \sim 1/cm^3$ so that $\Delta I \sim N_e\,L\,\sigma_e$ and visible light arriving from stars at kiloparsec distances, $\gtrsim 10^{22}$ cm, may still feel a variable diminution of $\Delta I \sim 1\%$, a measureable effect.
4. See, for example, a recent review by A.H. Barrett, Science 157, 881 (1967).

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