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A NEW ACTIVITY INDEX FOR COMETS

by Fred L. Whipple
Smithsonian Astrophysical Observatory

Summary

An activity index, AI, is derived from observational data to measure the increase of activity in magnitudes for comets when brightest near perihelion as compared to their inactive reflective brightnesses at great solar distances. Because the observational data are still instrumentally limited in the latter case and because many comets carry particulate clouds about them at great solar distances, the application of the activity index is still limited. A tentative application is made for the comets observed by Max Beyer over a period of nearly 40 years, providing a uniform magnitude system for the near-perihelion observations.

In all, 32 determinations are made for long-period (L-P) comets and 15 for short-period (S-P). Although the correlations are scarcely definitive, the data suggest that the faintest comets are just as active as the brightest and that the S-P comets are almost as active as those with periods (P) exceeding 10^4 years or those with orbital inclinations of $i < 120°$. Comets in the range $10^2 < P < 10^4$ yr. or with $i > 120°$ appear to be somewhat more active than the others.

There is no evidence to suggest aging among the L-P comets or to suggest other than a common nature for comets generally.

Introduction

The physical characteristics of comets have been measured in many ways, including integrated or nuclear magnitudes and colors, coma and tail dimensions, polarizations and orientations, spectral characteristics of the various components and variations of all of these measured quantities. Few of these measures, however, provide classification criteria comparable to or correlated strongly with the criteria of orbital period and orientation. For example, the dust-to-gas ratio (D/G) in the coma spectra of comets is highly dependent upon solar distance, r. In a thorough statistical study, Donn (1977) could find no significant difference between "new" and "evolved" comets as measured by the D/G ratio, although comets show a wide diversity in this ratio at relatively small solar distances. By "evolved" comets, Donn refers, of course, to short-period comets as compared to "new" comets, defined by Oort (1950) as having extremely long periods, or extremely small values of the inverse semimajor axis, a.

Kresák (1973) used the extreme solar distances, r_o, to which short-period comets had been observed as a criterion for the state of activity of their nuclei. Again (1977) he compared properties of old and new comets, finding few correlations. Rickman et al. (1987), in estimating the masses, volumes and densities of short-period comet nuclei, introduce a quantity, Sf, to represent the active area of a comet (in km^2) at the time of maximum brightness.

Meech (1990) has made a most valuable summation of evidence and criteria for differentiating old from new comets and for the aging of comets. A major effect is that many new comets are brighter and relatively more active before perihelion than after, as compared to short-period (S-P) comets where the reverse is frequently true. Meech's comparison, showing that new comets are systematically observed to greater solar distances than S-P comets, includes a number with very large values of the perihelion distance. Clearly for this criterion to be more significant, intrinsic brightness (physical dimensions?) should be allowed for in the comparisons.

As a consequence of such considerations, I have attempted to devise an observational measure for the comparative activity of a comet between maximum near perihelion, q, and minimum at great solar distances. Clearly such a criterion or activity index, AI, must be highly dependent upon the value of q so that the characteristics of an individual comet will depend on the deviation of its AI from the average at the individual comet's perihelion distance.

The Activity Index

The classical absolute magnitude of a comet, $H - y$, is defined (*e.g.* Vsekhsvyatskii, 1964) by

$$H - y = m - 5\log\Delta - y\log r \qquad (1)$$

where m is the observed magnitude, Δ and r the geocentric and heliocentric distances, respectively, measured in AU, and $y = 2.5n$, with n being the inverse power of r in the luminosity equation.

For typical comets, $n \sim 4$ ($y \sim 10$) when they are active near perihelion, ideally decreasing to $n = 2$ ($y = 5$) at large r when, theoretically, the comets are reflecting sunlight as inert bodies. Thus H_{10} is often found to be appropriate near perihelion although y may be found to assume a wide range of values.

The basic objective of the activity index is to evaluate the absolute magnitude change of a comet from near perihelion to the extreme observed value of r_o and H_5. The extreme value of H_5 should be corrected to its opposition value by the addition of the term $-2.5 \log \phi(\alpha)$ where $\phi(\alpha)$ is a function of the phase angle, α, measured at the comet between the Earth and the Sun. The phase-angle correction is yet to be well measured for comets so the correction here will be approximated by $-0^m.03\alpha$, where α is measured in degrees and is generally small (see *e.g.* Kresak, 1973). Hence the extreme absolute magnitude is here defined as

$$h_o = H_5 - 0.03\alpha, \qquad 2$$

evaluated near the maximum observed solar distance, r_o.

For comparison, the perihelion (q) value of the magnitude is taken as Hy, the absolute magnitude near perihelion later corrected to $r = q$ with ($y = 2.5n$), the correction term $+y \log q$, where q is measured in AU.

The Activity Index, AI, is then determined by the difference between these two magnitudes, h_o and H_y, both evaluated at $r = q$ as:

$$\mathrm{AI} = h_o - H_y + (5 - y) \log q. \qquad 3$$

The activity index is thus ideally the magnitude difference between the comet as seen when inactive and when most active. In fact, of course, this ideal is not always reached because few comets are observed to great enough distances for their light curves to follow a simple $1/r^2$ law and because, as Meech's (1990) Table 1 testifies, most comets have still remained diffuse when last observed. In addition minor corrections to h_o may be needed because of magnitude variations caused by rotation of the nucleus while, h_o and Hy may not be exactly comparable because of unknown phase-angle effects.

The probable differences between the faint and bright magnitude systems may not seriously denigrate the AI values because their absolute values are not their principle merit. They are most valuable in comparing different classes of comets. The vital consideration in such studies is thus to assure consistency within each magnitude system.

A Tentative Application of the Activity Index

A very serious problem in making practical use of the activity index is simply illustrated by comparing two extensive tables of H_{10} for periodic comets by Kresák and Kresáková (1987) and Hughes (1987). For 48 comets the mean difference in the tabulated values is $3^m.06$ with $\sigma = 1^m.34$, for a single difference, the Hughes' values being the larger (*i.e.*, fainter in luminosity). In spite of such a systematic difference, the two studies agree that the comets of intermediate period (15 or 20 to 200 years) differ significantly in their logarithmic cumulative H_{10} distributions from the S-P and L-P groups. On the other hand, Hughes finds that the S-P and L-P comets have similar distribution slopes in the H_{10} log(number) cumulative diagram while Kresák and Kresàková conclude that the three groups are all different in this respect.

Because of such magnitude calibration problems, this tentative study with the activity index is limited to brighter comets observed by Max Beyer over more than four decades and listed in some 42 articles (see Beyer, 1969, for these references) including 17 major compilations of physical observations of comets. This remarkable observation set is unparalleled and can provide a test base leading to further studies with more recent observations, particularly those involving fainter limiting magnitudes for extreme values of r_o.

During the period of Beyer's observations, the limiting magnitudes increased a bit as observing techniques improved. Major contributors were Hamilton M. Jeffers and Elizabeth Roemer with their associates, and the perennial George Van Biesbroeck, though the latter tended to be less meticulous in his magnitude system than the former. Also Jeffers and Roemer frequently evaluated the nuclear magnitude, a practice that is important in this study because a majority of comets maintain a particulate coma at great solar distances, as mentioned earlier.

The basic data for long-period comets are listed in Table Ia and for short-period comets in Table Ib. The successive columns contain:

1. Comet name to 14 spaces.
2. The comet's Roman numeral designation.
3. q: Perihelion distance in AU.

4. i: Orbital inclination to the ecliptic.
5. Orbital $1/a(\mathrm{AU})^{-1}$ original (Marsden, 1989, Tab. 3) or Period in years.
6. H_y: the absolute magnitude ($\Delta = 1$) derived by M. Beyer (1969 references).
7. $y = 2.5n$, where n is Beyer's value.
8. Obs: Observer of comet (m_o) at great $r = r_o$; VB: van Biesbroeck; J: Jeffers; H: Hirose; C: L. Cunningham; JVR: Jeffers, S. Vasilevskis and Roemer; JK: Jeffers and Klemola; JS: Jeffers and Stephenson; R: Roemer; RTL: Roemer, Thomas and Lloyd; WP: West and Pedersen.
9. m_o: observed magnitude at $r = r_o$.
10. r_o: great solar distance.
11. h_o: H_5 at r_o corrected by -0.3α (Eq. 2).
12. AI: Activity Index (see Eq. 3, above).
13. ΔAI: Mean residual Eq. 4 and Eq. 5 plus corr. Eq. 6 below.
14. (In Table Ib only) year of m_o measure.

Table Ia: Data for Long-Period Comets

Name	No.	q	i	1/a orig	H_y	y	Obs	m_o [a]	r_o [a]	h_o	AI	ΔAI
Pelt.-Whip.	1932 V	1.037	71°.7	22945	7.42	32.0	VB	17	1.59	13.7	5.8	-0.2
Dod.-Forb.	1932 X	1.131	24.5	24562	7.7	16.4	J	17.5	2.02	13.5	5.2	-0.5
Fri.-Ree.-Hon.	1941 II	0.942	26.3	19938	10.9	5.4	H	>17[b]	1.36	17.0	(6.2)	(-0.8)
deKock-Paraskev.	1941 IV	0.790	168.2	2029	5.77	5.0	J	17	3.54	12.0	6.2	-0.5
Whip.-Fedt.-Tev.	1943 I	1.354	19.7	7352	4.17	10.3	VB	16.5	2.74	11.6	6.7	+1.4
Bester	1947 I	2.408	108.2	-1	3.12	14.3	J	18.7	5.8	10.9	4.2	+0.3
Bester	1948 I	0.748	140.6	24	6.31	7.4	J	17.7	4.0	11.2	5.2	-1.7
Pa.-Mrkos	1948 V	2.107	92.9	34	4.37	11.1	J	19.2	6.6	10.8	4.4	+0.1
Bap.-Bok-New.	1949 IV	2.058	105.8	735	5.59	13.8	C	19.0	5.5	11.6	3.3	-1.2
Minkowski	1951 I	2.572	144.2	37	7.15	3.8	C	19.0	6.4	10.6	4.0	+0.2
Mrkos	1952 V	1.283	112.0	14220	5.81	29.3	B	>17.5	1.9	13.8	>5.4	>-0.7
Peltier	1952 VI	1.202	45.6	+2	8.87	14.2	JVR	18	2.2	14.4	4.8	-1.5
Mrkos-Honda	1953 III	1.022	93.9	2983	7.48	30.5	R	19.3	3.3	14.6	7.1	+0.3
Abell	1954 X	0.970	53.2	70	5.86	9.1	R	>18	5.0	11.0	>5.2	>-1.2
Mrkos	1955 III	0.534	86.5	20013	6.85	13.0	J	18[c]	2.0	13.9	9.2	+0.8
Bak.-Mac.-Kri.	1955 IV	1.427	50.0	4353	4.79	18.1	R	18	2.4	13.8	7.0	+1.1
Honda[d]	1955 V	0.885	107.5	-727	6.85	11.7	VB	16[d]	1.9	12.1	(5.6)	(-1.3)
Baade	1955 VI	3.870	100.4	+42	3.05	10.8	JK	19.5	7.7	10.6	4.1	+1.1
Mrkos	1956 III	0.842	147.5	Par.	10.8[d]	5	VB	18	0.9	16.1	(5.3)	(-2.3)
Arend-Roland	1957 III	0.316	119.9	-98	5.15	10.9	R	18.8	5.4	13.4	11.1	+1.5
Mrkos	1957 V	0.355	93.9	2001	3.63	5.5	R	19.0	5.0	12.0	8.6	-0.5
Burnham	1958 III	1.323	15.8	256	6.75	18.1	RTL	19.0	2.5	14.2	5.8	-0.4
Burn.-Slau.	1959 I	1.628	61.3	76	7.10	12.2	RTL	19.6	4.1	13.6[c]	5.0	-0.7
Burnham	1960 II	0.504	159.6	-135	7.78	9.5	RTL	17.5[c]	1.5	14.9[c]	8.4	-0.4
Seki-Lines	1962 III	0.03138	65.0	25	5.12[f]	8.9	R	20.4	4.9	14.0	(14.7)	(-0.8)
Honda	1962 IV	0.653	72.9	Par.	10.47	13.0	R	20.5[g]	1.5	19.2	(10.2)	(-1.4)
Humason	1962 VIII	2.133	153.3	4935	2.14	8.7	R	17.8	5.7	17.8	6.8	+1.1
Ikeya	1963 I	0.632	160.6	11389	5.18	12.0	R	19.2	3.4	13.4	9.6	+1.5
Everhart	1964 IX	1.259	68,0	2721	6.39	15.1	R	19.5	2.9	14.2	6.8	+0.2
Ikeya-Seki	1968 I	1.697	129.3	842	3.12	14.6	R	21.5	6.7	13.4	8.0	+2.2
Tago-Hon.-Yam.	1968 IV	0.680	102.2	6492	10.28	13.9	R	>20	!.6	>16.5	>7.7	>-0.8
Bally-Clay.	1968 VII	1.771	93.2	Par.	8.08	6.8	R	17	1.9	13.1	4.6	(-1.1)
Tag.-Sat.-Kos.	1969 IX	0.473	75.8	507	6.39	7.6	R	18.1	2.5	13.2	7.7	-1.3
Bennett	1970 II	0.538	90.0	7334	3.45	11.1	R	18.9	4.5	12.0	10.2	+1.7
Abe	1970 XV	1.113	126.7	283	5.56	6.5	R	16.9	2.6	13.6	7.9	+0.9

Table Ib: Data for Short-Period Comets

Name	No.	q	i	Per.	H_y	y	Obs	m_o [a]	r_o [a]	h_o	AI	ΔAI	yr.
Arend-Rigaux	1957 VII	1.386	$17^{\circ}.2$	$6^{y}.7$	$8^{m}.87$	21.5	R	$20^{m}.5$	3.0	$16^{m}.4$	$5^{m}.3$	$-1^{m}.5$	70
Ash.-Jack.	1956 II	2.325	12.5	7.5	8.73	5.0	R	20.0	3.8	14.9	6.1	+0.9	64
Encke	1953[h]	0.338	12.4	3.3	10.14[h]	11.7[h]	R	20.2	3.3	16.0	9.0	-1.0	63
Faye	1969 VI	1.616	9.1	7.4	10.20	6.4	R	20.9	3.4	15.6	5.1	-1.0	63
Giac.-Zinn.	1959 VIII	0.936	30.9	6.4	10.18	23.6	WP	25.0	4.8	17.8	8.3	-0.2	84
Hon.-MrK.-Paj.	1954 III	0.556	13.2	5.2	12.78	15.2	JS	19.5	1.6	17.6	7.4	-2.5	90
Kearns Kwee	1963 VIII	2.213	9.0	9.0	9.23	5.0	RL	20.1	4.0	14.6	5.4	+0.1	65
Olbers	1956 IV	1.178	44.6	69.6	5.02	9.8	R	18.8	4.3	12.8	7.4	+1.1	57
Pons-Brook	1954 VII	0.774	74.2	70.9	4.66	10.8	J	18.0	4.3	11.5	7.5	+0.5	53
Pons-Win.	1951 VI	1.160	21.7	6.2	11.4	5.0	R	18.1	1.5	16.8	5.4	-1.9	70
Reinmuth2	1954 VI	1.686	7.1	6.6	10.82	7.6	R	20.5	3.2	16.2	4.6	-1.8	73
Schajn-Schad.	1971 IX	2.227	6.2	7.3	9.5	5.0	R	19.8	1.8	17.0	7.5	+1.7	71
Schw-Wach.2	1961 VII	2.157	3.7	6.5	8.47	10.0	R	>20.0	3.0	14.8	4.7	-0.6	62
Schaumasse	1960 III	1.196	12.0	8.2	7.6[i]	21.4[i]	RTL	19.0	2.1	16.5	7.7	+0.8	59
Tut.-Gia.-Kre.	1962 V	1.123	13.8	5.5	10.77[i]	26.8[i]	RL	21.0	2.0	19.1	7.3	-0.6	73

Notes to Table Ia and Ib:

a) Many of the references to these observations are contained in the tabulations by Svoren (1984 and 1985) and by Kamél (1991).
b) Based in "not seen" observation.
c) Became brighter later.
d) Split.
e) Poorly observed.
f) Not observed near q.
g) Faded rapidly and may have disappeared. No nucleus seen.
h) Mean of 5 dates and measures.
i) Mean of 2 measures.

Discussion: L-P Comets

Table I shows, as expected, a strong dependence of AI on the perihelion distance. From the data for the L-P comets in Table Ia, two least-square solutions for this dependence were calaculated. The first included a term proportional to the date, $\Delta t = (19xx - 1900)/100$, yielding:

$$(3.19 \pm 1.15) + (6.41 \pm 2.04)\Delta t - (5.41 \pm 0.78)\log q = \mathrm{AI} \qquad (4)$$

where values of standard deviations are included.

A second solution was made, not including a time variation viz.:

$$(6.76 \pm 0.23) - (5.88 \pm 0.88)\log q = \mathrm{AI}. \qquad (5)$$

The solution with Δt (Eq. 4) represents the observations slightly better than that with only the $\log q$−term, $\sigma = 1^{m}.06$ vs. $1^{m}.26$ for a single AI. The dependence q in AI is $1/q^{2.2}$ for Eq. 4 and $1/q^{2.4}$ for Eq. 5, perhaps not as high a power as might have been expected.

There appeared to be some dependence of the AI residuals on h_o, the absolute magnitude at great distance. A solution shows that AI residuals systemmatically increased with the value of h_o, leading to a correction to the AI residuals of

$$\text{Correction } (\Delta\mathrm{AI}) = 0^{m}.145(13^{m}.43 - h_o). \qquad (6)$$

The question as to whether Eq. 4 or Eq. 5 is superior in seeking correlations with other physical or orbital characteristics of comets has no clearcut answer. The residuals from Eq. 4 shows a rather large dependence

Table II
Values of ΔAI for L-P Comets (Table Ia)

$\frac{1}{a} \times 10^6 AU^{-1}$ Per.(yr.)	< 22 $> 10^7$	22-100 $10^6 - 10^7$	100-464 $10^5 - 10^6$	464-2154 $10^4 - 10^5$	2154-10^4 $10^3 - 10^4$	10^4-46416 $10^2 - 10^3$
	m	m	m	m	m	m
ΔAI	+0.3	-1.7	-0.4	-0.5	+1.4	-0.2
ΔAI	-1.5	+0.1	+0.9	-1.2	+0.3	-0.5
ΔAI	(-1.3)	+0.2		-0.5	+1.1	(-0.8)
ΔAI	+1.5	-1.2		+2.2	+1.1	-0.7
ΔAI	-0.4	+1.1		-1.3	+0.2	+0.8
ΔAI		-0.7			-0.8	+1.5
ΔAI		(-0.8)			+1.7	
Mean	-0.28	-0.43	+0.25	-0.26	+0.71	+0.02

Table III
Gas/Dust Ratios (L-P Comets)

High			Low-Medium		
Comet	q AU	ΔAI m	Comet	q AU	ΔAI m
1957III	0.32	+1.5	1948I	0.75	-1.7
1957V	0.36	-0.5	1955V	0.88	-1.3
1962III	0.03	-0.8	1960II	0.50	-0.4
1970II	0.54	+1.7	1969IX	0.47	-1.3

on date while Eq. 5 clearly errs for the earliest comets. To avoid a possible fruitless discussion, I will list the mean residual of Eq. 4 and Eq. 5 corrected by Eq. 6 for such comparisons (ΔAI). The residuals in parenthesis will be included because they seem to be consistent with the others and because the data sample is so small. Thus, Table II lists these mean residuals for the orbital classes grouped in decades of periods.

With the limited data set of Table II, the comets with periods $> 10^4$ yr. appear to be slightly less active than those in the range $10^4 > P > 10^2$ yr. The difference is $-0^m.27 \pm 0.25$ (19 comets), compared to $0^m.39 \pm 0.26$ (13 comets) or $0^m.66$ in total at roughly the 2σ level. The difference is even stronger between the comets in the group $10^4 > P > 10^3$ yr. and the remainder, both of longer and shorter period. Because the difference in activity level of comets with periods exceeding 10^4 yr. is only about half that of the shorter-period L-P comets, there seems to be little cause to attach much importance to the result. If it is later sustained by much more data, it may become of real physical interest.

Table II, however, definitely does not support any theory of decreasing activity with aging among L-P comets. Highly retrograde L-P comets with $i > 110°$ do, on the other hand, appear to be more active than those with $i < 110°$: Mean ΔAI= $+0^m.41 \pm 0^m.39$ for 10 comets ($i > 110°$) vs. $-0^m.19 \pm 0^m.20$ for 22 comets ($i < 110°$), neglecting the three poorly observed parabolic comets. This difference, in each case at the 1σ level, is scarcely definitive, but is suggestive.

Similarly an increase in the Dust/Gas (D/G) ratio with ΔAI is suggested by eight comets with $q < 1$AU in Table III, where the ratio is taken from the compilation by Donn (1977). The mean ΔAI for four comets with high D/G is +0.5 and -1.2 for the four with low and medium values of D/G. It seem quite logical that dusty comets should appear to brighten more than "gassy" comets, simply because the dust is ejected through the coma more slowly than the gas.

No other suggestive correlations of ΔIA with observed characteristics of L-P comets were found. Gener-

Table IV
Comparison of AI with Sf

Comet	h_o−AI	$2.5 \log Sf$	Δ
A-J	$8^m.7$	$2^m.07$	$+0^m.52$
E	7.0	0.25	(-2.88)
F	10.5	0.41	+0.36
GZ	9.6	0.94	+0.01
HMP	10.2	0.11	-0.20
KK	9.2	0.10	-1.09
O	5.6	4.92	+0.56
PB	4.0	5.11	-0.66
SW2	10.1	1.02	+0.62
Sch	8.8	2.15	+0.60
TGK	12.4	-1.80	-0.70

ally, through the comets with large values of ΔIA seemed to include the more interesting or individualistic ones.

As a concluding remark about the L-P comets, the scatter in ΔIA seems remarkably small ($\sigma = \pm 1^m.06$) implying a mean range of only a factor of 7.0, or only a factor of 2.7 from the mean for the variations in brightness increase from "inactively" to maximum, evaluated near the proper perihelion for each comet. The total range derived is $3^m.9$ or a factor of 36. On the other hand, the range in h_o, presumably a measure of cometary area (for a fixed albedo), is $7.^m2$ or a factor of 759. This implies a range of 28 in radius or 2×10^4 in volumn (or mass, if of constant density). In other words, the smallest comet nuclei appear to behave remarkedly like the largest over four orders of magnitude in volume. Equation 6, relating ΔIA to h_o, suggests that small nuclei may, indeed, be relatively more active than larger ones. The effect, however, may be only a magnitude-system defect.

Discussion: S-P Comets

For the short-period comets, Beyer's data are rather limited, including only 15 good cases (Table Ia). This scatter in activity is only slightly larger than for the L-P comets ($\pm 1^m.24$ in σ of ΔIA vs. $\pm 1^m.06$). The S-P comets are systematically less active than the S-P comets by $0^m.40 \pm 0^m.37$ or 1σ, making them almost as active as the comets with $P > 10^4$ yr. (Table II) and the L-P comets of $i < 110°$. No correlation indicating an increase of ΔIA with high vs. low-medium dust appears among the 7 S-P comets of Table Ia included in Donn's (1977) list.

If the present calculations of cometary activity are valid, they should demonstrate a positive correlation with the active areas calculated by Rickman et al. (1987) designated as Sf. Such values are listed for the 11 common comets in Table IV. Activity near perihelion is indicated in magnitudes by h_o−AI (Col. 2 of Table IV) and should correlate with $2.5 \log Sf$ (Col. 3), where Sf is the active area in km, for the comets identified by 1 to 3 letters in Col. 1 of Table IV. A least-squares solution yields the result, omitting P/Encke which fits poorly:

$$(9^m.30 \pm 0.88) - (0^m.88 \pm 0.10)(h_o - \mathrm{AI}) = 2.5 \log Sf \tag{6}$$

The residuals from Eq. 6 are listed (O-C) in the fourth column of Table IV, in magnitudes, with $\sigma = \pm 0^m.62$. Considering the differences in methodology between the analysis by Rickman et al. and that of the present paper, a mean error of only $\pm 0^m.62$ over a range of 7^m to 8^m indicates reasonable consistency between the two and implies that both have physical significance.

In the present study, values of h_o for S-P comets were obtained from data similar to those for h_o in Tables Ia and b, but for which H_{10} or similar near-perihelion data were not available from observations by Beyer. From 14 comparisons of H_{10} by Kresák and Kresáková (KK, 1987) with Beyer's results, a correction of $-1^m.1 \pm 0^m.2$ to KK's H_{10} leads to a mean agreement with Beyer's values at perihelion. In all, values of

AI and ΔAI have been obtained for 36 S-P comets in this fashion. The value of ΔAI averages $0^m.07$ smaller than for the 15 S-P comets of Table Ib. The comparison of 13 in common with the Sf values of Rickmann et al. lead to results much like those of Eq. 6 and Table IV although the scatter is much larger ($\sigma = 1^m.73$ vs. $\pm 0^m.62$). For that reason no listing of these calculations are included. The mean value of h_o for these 36 S-P comets is $2^m.6$ fainter than for the 15 represented by Beyer magnitudes. The difference in the mean value of ΔAI from that of Beyer S-P comets is more than explained by the corrections of Eq. 5 for h_o magnitudes. No conclusion about the mean relative activity of these fainter comets appears valid.

Discussion: General Comments

In recent years observers have directed much effort in an attempt to distinguish significant systematic differences in the spectra and other properties of L-P and S-P comets. After several studies of cometary spectra including Cochran (1987), Cochran et al. (1989) state "Overall, however, we must now conclude that there is no obvious differences between low activity comets and the "normal" comets and that all of the studied comets appear fairly homogeneous." From IUE observations of faint comets, Weaver et al. (1981) reach the same conclusion: "All of the cometary spectra are remarkably similar which suggests that these comets may have a common composition and origin." These statements seem also to represent the results of the present paper concerning the activity level of L-P and S-P comets.

Some differences in the spectra of individual comets are, however, evident, such as noted in the review of comets observed by the IUE satellite by A'Hearn (1989), from spectra of seventeen comets by Newburn and Spinrad (1984,1985,1989) and earlier from abundance measures by A'Hearn and Millis (1980). In a summary of calculations and estimates of cometary albedos, Hartmann et al. (1987) find a considerable range; the lower values, incidentally, correlate somewhat with negative values of ΔAI. Dust-to-gas ratios also vary greatly from comet to comet. To what extent these differences were induced by different environments and aging, and to what extent they represent localized differences in the nuclei induced by the falling together of components of somewhat different properties produced in a common original environment is difficult to ascertain.

In general, however, the accumulating evidence does little to suggest a drastically different environment for the origin of L-P vs. S-P comets, or for large subgroups among them.

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