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SEEING MEASUREMENTS AT SAN PEDRO MÁRTIR OBSERVATORY USING THE DIMM METHOD

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RESUMEN

Hemos llevado a cabo una nueva campaña para medir el *seeing* en el sitio del Observatorio Astronómico Nacional en San Pedro Mártir, esta vez empleando un DIMM. Los resultados obtenidos durante 123 noches, distribuidas en un lapso de casi tres años, arrojan una mediana de 0.60 segundos de arco con un primer cuartil de 0.48 segundos de arco. Estos valores se midieron a 8.3 m del suelo y con un tiempo de exposición de 6 ms. Mostramos que el *seeing* puede ser excelente y muy estable durante noches enteras; las mejores medidas dan una mediana de 0.37 segundos de arco, y un primer cuartil de 0.32 segundos de arco, en observaciones obtenidas durante más de ocho horas continuas. Los presentes resultados concuerdan muy bien con nuestro estudio previo del sitio. El valor esperado de la mediana del *seeing* a una altura de 15 m y extrapolando a tiempo nulo de exposición es de 0.61 segundos de arco. Por último, comparamos San Pedro Mártir con los principales sitios del mundo donde se ha medido el *seeing* con instrumentos DIMM. De esta comparación concluimos que San Pedro Mártir es uno de los mejores sitios astronómicos en el mundo.

ABSTRACT

We have conducted a new campaign to measure the seeing at the site of the Observatorio Astronómico Nacional at San Pedro Mártir, this time with a DIMM instrument. The results obtained during 123 nights, over a period of almost three years, yield a median seeing of 0.60 arcsec and a first quartile of 0.48 arcsec. These measurements were made 8.3 m above the ground and with exposure times of 6 ms. We show that the seeing can be excellent and very stable for whole nights, with the best measurements yielding a median of 0.37 arcsec and a first quartile of 0.32 arcsec during more than eight hours of continuous observations. The current results are in very good agreement with our previous study of the site. The expected value of the median seeing 15 m above the ground and extrapolated to null integration time is 0.61 arcsec. Finally, San Pedro Mártir is compared with those major astronomical sites in the world where seeing has been measured with DIMM instruments. This comparison allow us to conclude that San Pedro Mártir is one of the best astronomical sites in the world.

Key Words: **SITE TESTING: SEEING**

1. INTRODUCTION

Studies to evaluate the site at the Observatorio Astronómico Nacional in San Pedro Mártir, Baja California, México, have been made by several authors. Meteorological analyses of the site have been published by Mendoza (1973), Alvarez & Maisterrena (1977), Walter (1984), Tapia (1992), Michel et al. (2001), and Hiriart, Ochoa, & García (2001). Water vapor content has been measured by Hiriart et al. (1997) and a thorough study of near-ground atmospheric turbulence and meteorological conditions was conducted by Echevarría et al. (1998). Further studies of the atmospheric turbulence profile above the Observatory site were done by Avila, Vernin, &

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TABLE 1

LOG OF OBSERVATIONS WITH THE DIMM

Date yymmdd	N_{hours}	N_{meas}	1^{st} Qrt.	Median	3^{rd} Qrt.	Mean	σ
000819	2.9	106	0.65	0.73	0.96	0.81	0.20
000820	7.5	389	0.50	0.58	0.74	0.63	0.16
000821	6.4	499	0.59	0.81	1.04	0.89	0.39
010322	6.2	236	0.69	0.82	0.95	0.83	0.16
010804	3.4	305	0.37	0.40	0.45	0.42	0.08
010806	6.8	399	0.62	0.69	0.77	0.70	0.11
010807	8.0	415	0.58	0.68	0.83	0.73	0.20
010808	5.2	268	0.44	0.48	0.54	0.52	0.14
010809	1.2	124	0.67	0.72	0.80	0.76	0.13
010819	2.9	106	0.65	0.73	0.96	0.81	0.20
010820	7.5	389	0.50	0.58	0.74	0.63	0.16
010821	6.4	499	0.59	0.81	1.04	0.89	0.39
010828	8.0	715	0.69	0.79	0.93	0.82	0.19
010829	8.2	628	0.61	0.70	0.80	0.71	0.16
011029	6.6	211	0.34	0.37	0.43	0.39	0.08
011117	9.6	344	0.76	0.95	1.37	1.09	0.49
011118	9.9	319	0.47	0.58	0.68	0.60	0.16
011119	7.8	433	0.60	0.80	1.19	0.98	0.59
020114	6.9	535	0.40	0.49	0.57	0.50	0.11
020117	2.3	153	0.94	1.09	1.25	1.10	0.23
020119	5.8	176	0.54	0.64	0.72	0.64	0.12
020122	10.3	781	0.59	0.70	0.89	0.77	0.24
020123	8.9	774	0.80	0.91	1.05	0.94	0.21
020205	8.5	778	0.79	0.95	1.22	1.04	0.36
020206	10.1	1336	0.63	0.78	0.91	0.79	0.20
020207	10.8	1494	0.62	0.75	0.89	0.77	0.23
020208	11.2	1153	0.48	0.57	0.67	0.59	0.14
020214	8.0	1468	0.61	0.70	0.80	0.71	0.14
020215	4.2	604	0.38	0.45	0.51	0.45	0.09
020216	6.0	1178	0.78	0.88	1.01	0.90	0.17
020217	5.6	923	1.19	1.50	1.94	1.63	0.61
020218	5.5	742	1.32	1.48	1.67	1.52	0.29
020301	2.3	301	1.04	1.17	1.32	1.20	0.21
020309	7.7	770	0.55	0.64	0.77	0.67	0.16
020310	4.9	315	0.45	0.50	0.58	0.52	0.10
020311	10.1	816	0.65	0.74	0.85	0.76	0.15
020312	8.6	1129	0.32	0.37	0.45	0.39	0.10
020313	8.2	704	0.57	0.66	0.74	0.66	0.12
020314	4.5	519	1.03	1.37	1.70	1.42	0.46
020315	8.9	990	0.79	1.01	1.43	1.14	0.45
020408	9.0	1005	0.43	0.56	0.81	0.68	0.37
020409	9.2	1225	0.36	0.43	0.55	0.46	0.13
020410	9.0	1203	0.43	0.52	0.63	0.54	0.16
020411	9.5	995	0.32	0.40	0.48	0.41	0.10

TABLE 1 (CONTINUED)

Date yymmdd	N_{hours}	N_{meas}	1^{st} Qrt.	Median	3^{rd} Qrt.	Mean	σ
020412	9.2	1230	0.40	0.50	0.61	0.51	0.15
020603	7.3	160	0.58	0.66	0.80	0.70	0.18
020604	8.1	1344	0.59	0.71	1.15	0.96	0.56
020605	6.9	980	0.45	0.50	0.57	0.52	0.09
020615	7.0	915	0.82	1.18	1.47	1.19	0.43
020616	8.2	1131	0.40	0.47	0.56	0.49	0.12
020617	8.6	510	0.41	0.48	0.55	0.48	0.10
020618	6.7	285	0.79	0.90	1.04	0.93	0.22
020619	8.5	324	0.51	0.58	0.77	0.68	0.25
020620	8.5	1315	0.45	0.53	0.61	0.54	0.13
020621	7.7	945	0.52	0.59	0.67	0.60	0.11
020704	4.5	691	0.55	0.66	0.82	0.75	0.30
020705	8.1	1388	0.46	0.55	0.71	0.62	0.25
020706	7.3	1115	0.37	0.45	0.50	0.44	0.09
020707	8.3	1372	0.45	0.57	0.70	0.61	0.23
020708	8.0	1203	0.39	0.45	0.54	0.48	0.13
020709	5.6	687	0.50	0.63	0.84	0.70	0.27
020727	2.5	371	0.58	0.64	0.74	0.66	0.12
020728	3.8	477	0.55	0.65	0.81	0.71	0.22
020729	9.3	1402	0.42	0.53	0.60	0.51	0.12
020730	8.7	1264	0.46	0.50	0.56	0.51	0.09
020801	8.6	1329	0.45	0.53	0.60	0.53	0.11
020802	10.0	1713	0.44	0.50	0.57	0.51	0.11
020803	9.4	1668	0.41	0.50	0.60	0.52	0.13
020804	9.5	1594	0.42	0.51	0.69	0.62	0.30
020805	9.5	1586	0.52	0.62	0.81	0.76	0.43
020806	9.5	1439	0.54	0.68	1.00	0.81	0.37
020807	9.4	1481	0.38	0.47	0.54	0.47	0.12
020808	9.9	1806	0.60	0.72	0.86	0.77	0.26
020809	9.4	693	0.53	0.65	0.81	0.69	0.19
020810	9.6	1064	0.40	0.47	0.56	0.50	0.16
020811	1.1	115	0.37	0.40	0.44	0.41	0.06
020812	9.9	1507	0.40	0.45	0.51	0.46	0.09
020813	9.7	1323	0.45	0.50	0.56	0.51	0.09
020814	10.0	1724	0.39	0.43	0.48	0.44	0.07
020815	9.8	1370	0.53	0.62	0.75	0.66	0.18
020816	9.2	383	0.52	0.58	0.69	0.62	0.13
020817	9.6	1463	0.42	0.51	0.62	0.53	0.16
020818	10.0	1556	0.48	0.52	0.57	0.53	0.08
020819	10.0	1007	0.50	0.70	0.91	0.72	0.24
020918	8.6	627	0.43	0.50	0.60	0.52	0.12
020919	8.5	697	0.63	1.08	1.71	1.22	0.71
021008	5.3	765	0.51	0.57	0.64	0.59	0.11
021009	9.6	1268	0.38	0.52	0.63	0.53	0.20
021010	10.8	1754	0.41	0.56	0.96	0.73	0.44
021011	3.8	459	0.46	0.49	0.54	0.51	0.07

TABLE 1 (CONTINUED)

Date yymmdd	N_{hours}	N_{meas}	1^{st} Qrt.	Median	3^{rd} Qrt.	Mean	σ
021014	10.1	1018	0.32	0.38	0.45	0.41	0.16
030319	7.5	962	1.16	1.51	2.01	1.63	0.59
030516	8.8	633	0.48	0.53	0.60	0.55	0.09
030519	1.9	296	0.61	0.69	0.86	0.75	0.20
030520	2.1	300	0.61	0.68	0.85	0.75	0.20
030521	7.1	1043	0.79	0.99	1.25	1.05	0.33
030522	5.4	544	0.67	0.76	0.95	0.84	0.25
030523	3.5	468	0.66	0.75	0.86	0.78	0.17
030524	8.4	1136	0.60	0.67	0.76	0.69	0.12
030525	7.9	966	0.69	0.95	1.26	1.00	0.37
030526	6.1	720	0.37	0.43	0.53	0.46	0.11
030527	5.9	678	0.60	0.76	0.94	0.79	0.23
030528	8.5	1091	0.54	0.61	0.67	0.62	0.12
030529	4.7	492	0.72	0.85	0.96	0.86	0.18
030530	8.7	1712	0.57	0.64	0.73	0.66	0.13
030531	3.2	625	0.55	0.64	0.74	0.66	0.15
030606	4.7	914	0.63	0.84	1.05	0.86	0.25
030622	5.5	722	0.75	0.87	1.00	0.89	0.18
030623	4.7	789	0.50	0.64	0.84	0.70	0.26
All	799.0	93061	0.47	0.60	0.79	0.69	0.35

TABLE 2

LOG OF OBSERVATIONS OF CONAN ET AL.

Date yymmdd	N_{hours}	N_{meas}	1^{st} Qrt.	Median	3^{rd} Qrt.	Mean	σ
001201	3.2	176	0.51	0.56	0.61	0.56	0.09
001203	8.4	782	0.54	0.62	0.71	0.63	0.13
001204	9.6	1000	0.77	0.89	1.05	0.93	0.24
001207	4.7	153	0.66	0.76	0.83	0.75	0.12
001208	9.7	784	0.72	0.94	1.15	0.96	0.33
001209	9.6	728	0.51	0.64	0.86	0.71	0.25
001211	9.1	662	0.63	0.76	0.95	0.81	0.23
001212	3.5	307	1.27	1.38	1.58	1.44	0.25
001213	8.7	791	1.91	2.43	3.00	2.55	0.82
011006	7.8	505	0.42	0.49	0.64	0.53	0.14
011007	8.4	371	0.49	0.63	0.71	0.61	0.15
011009	7.9	845	0.53	0.60	0.71	0.63	0.13
011010	7.2	389	0.46	0.53	0.60	0.54	0.10
011011	5.4	387	0.77	0.91	1.09	0.96	0.28
All	103.3	7880	0.58	0.74	1.04	0.95	0.66

TABLE 3

COMPARISON WITH SIMILAR DIMM STUDIES IN OTHER SITES

Site	Site Elev. (m)	DIMM Height (m)	Exp. Time (ms)	1^{st} Qrt. (arcsec)	Median (arcsec)	3^{rd} Qrt. (arcsec)	Mean (arcsec)	N_{nights}	Start	End	Ref.
Paranal, Chile	2636	6	5	0.64	0.82	1.08	0.91	$\sim$ 1700	03/98	11/02	(1)
La Silla, Chile	2335	6	5	0.70	0.89	1.15	0.97	$\sim$ 1400	03/99	11/02	(1)
Maidanak, Uzbekistan	2580	6	0	0.55	0.69	0.90	0.76	725	08/96	11/00	(2)
Apache Point, USA	2788	···	20	0.83	1.03	1.30	1.17	261	02/99	06/03	(3)
Kunming, China	1940	4	20	···	1.09	···	0.95	256	05/95	12/96	(4)
Gaomeigu, China	3193	4	20	···	0.78	···	0.70	234	05/95	12/96	(4)
La Palma, Spain	2400	5	10	$\sim$ 0.52	0.69	$\sim$ 0.90	···	233	10/94	08/98	(5)
Mount Fowlkes, USA	2027	1.8	10	$\sim$ 0.88	1.03	$\sim$ 1.28	···	186	07/01	07/02	(6)
San Pedro Mártir, México	2800	8.3	6	0.48	0.60	0.81	0.71	123	08/00	06/03	(7)
Sierra Negra, México	4580	5	10,20	0.62	0.78	1.05	0.90	85	02/00	04/03	(8)
Siding Springs, Australia	1130	2	10	···	···	···	1.20	64	06/93	12/93	(9)
Cerro Tololo, Chile	2200	6	0	0.79	0.96	1.17	···	48	05/02	07/02	(10)
Cerro Chico, Chile	5150	2.5	0	0.55	0.71	0.87	···	38	07/98	10/00	(11)
Devasthal, India	2540	2	10	···	1.07	···	1.20	37	10/98	12/98	(12)
South Pole	3200	12	33	$\sim$ 1.20	1.70	$\sim$ 2.20	···	28	05/95	09/95	(13)
Mauna Kea, USA	4123	···	0	···	0.88	···	0.92	13	05/02	06/02	(14)
Cananea, México	2480	2	20	0.78	0.91	1.08	···	···	02/99	10/99	(15)
Karoo Plateau, S. Africa	1760	···	···	0.74	0.92	1.16	···	···	04/94	02/98	(16)

References: (1) ESO (2002); (1) ESO (2002); (2) Ilyasov (2002); (3) Rest (2002); (4) Qian et a. (2001); (4) Qian et a. (2001); (5) Wilson et al. (1999); (6) Barker et al. (2003); (7) this work; (8) Carrasco et al. (2003); (9) Wood et al. (1995); (10) Tokovinin et al. (2003); (11) Giovanelli et al. (2001); (12) Stalin et al. (2001); (13) Loewenstein et al. (1998); (14) Chun et al. (2002); (15) INAOE (2002); (16) Erasmus (2000).

Cuevas (1998) and by Conan et al. (2002), and a study of the horizontal optical turbulence layers was done by Masciadri, Avila, & Sánchez (2002). A compilation of most of these, and other works, is being prepared by Cruz-González, Tapia, & Avila (2003).

In this contribution we present the results of a new campaign to evaluate the site, this time using a Differential Image Motion Monitor (DIMM). Our previous campaign (Echevarría et al. 1998) was mostly devoted to measuring the seeing by means of the *Carnegie Monitor* and the University of Arizona *Site Testing Telescope* (STT) which were based on different methodological techniques. Although this time we have accumulated fewer data, the results of both campaigns may shed some light on the consequences of diverse instrumental characteristics upon seeing evaluation. One of the purposes of this work is to compare the San Pedro Mártir site with those sites for which DIMM-based seeing estimates have been obtained.

2. INSTRUMENTATION AND OBSERVATIONS

We used a two-aperture DIMM from LHESA Electronique. This instrument, described by Vernin & Muñoz-Tuñon (1995), is very similar to those employed at La Palma (Wilson et al. 1999) and at Sierra Negra (Carrasco et al. 2003). It consists of a 20 cm Schmidth-Cassegrain telescope (Celestron) on an equatorial mount with automatic guiding capabilities, a diaphragm with two 60 mm diameter apertures whose centers are separated by 140 mm, an optical wedge in one of these apertures, an intensified CCD camera (LHESA's LH750EIA), and a PC-compatible computer equipped with a frame grabber.

The resulting double image of the same star is captured by the camera and sent to the computer via the frame grabber. By computing the variance of the differential motion of the double image, in both the parallel and perpendicular directions with respect to the apertures, two independent values of seeing are obtained. The advantage of this differential technique is that the erratic motion of the image, produced by the instrument (due to tracking errors, wind shaking and bad focusing among other things) is canceled out.

The DIMM telescope and part of the electronics were located at the top of a concrete pedestal, the same place where the Carnegie Monitor was installed during our previous campaign (Echevarría et al. 1998); the diaphragm of the telescope was placed 8.3 m above the ground. The computer and the rest of the electronics were located inside a small hut, well detached from the pedestal.

Each data point originated from the processing of a sequence of 200, 6 ms exposure time frames. By including the associated processing time, we obtained a pair of airmass corrected seeing measurement every 14 seconds. In all cases, each data point was calculated as the average of the simultaneous seeing measurements. When these values differed by more than 12% —the expected relative error for the DIMM (Muñoz-Tuñon, Vernin, & Varela 1997)— the data point was discarded. Measurements with zenith distances larger than 60° were also discarded. Nights with less than 100 measurements or with fewer than one hour of observations (eight) were not considered in this analysis.

Data from a total of 109 observation nights were collected from August 18, 2000 through June 23, 2003. Most of them were obtained simultaneously with our ongoing astronomical observing runs, which explains their non-uniform time-distribution. In addition, and in order to improve our seasonal coverage in Autumn, we have included —with their kind permission— 14 nights observed in December 2000 and October 2001 by Conan et al. (2002). These measurements were obtained with the same DIMM used for this work and at the same height. However, their December measurements were done with an integration time of 10 ms, not 6 ms —the time used in all our observing runs and in their October 2001 one. Consequently, each of the December 2000 seeing values was multiplied by 1.06, in order to convert it into its approximate 6 ms equivalent. This factor was estimated from our results with the interlaced exposures method described in § 8, and from the null exposure time corrections reported in Giovanelli et al. (2001) and Ilyasov (2002). The log of the observations, together with the seeing statistics for each night, are shown in Tables 1 and 2.

3. THE SEEING DISTRIBUTION

The median seeing values for each of the 123 individual nights, folded with the orbital period of the Earth, are shown in Figure 1. Twenty-eight nights (23%) had median seeing of 0.50 arcsec or smaller, while only eleven nights (9%) had median seeing larger than 1.0 arcsec (almost all in the months of December through March). The sample is not evenly distributed. Though there is a noticeable clustering in August while some other months are poorly sampled, we do not expect large deviations in the overall results. A discussion on the seasonal behavior of the seeing distribution will be given in § 5.

The seeing distribution for the overall set of observations, comprising 100,941 measurements accumulated during a total of 902 hours, is shown in

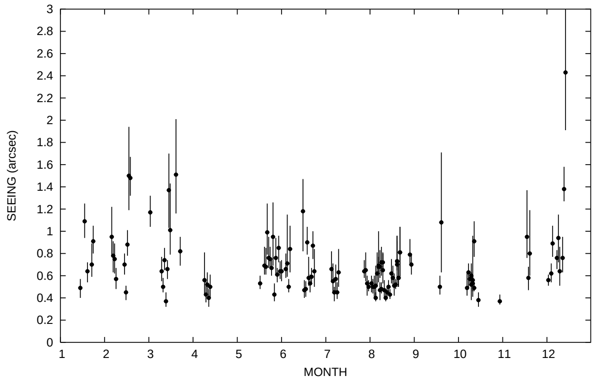

Fig. 1. Nightly seeing statistics. The dots represent the median values while the bars represent the first and third quartiles.

Figure 2. The distribution of the data is of log-normal type, as expected for a positive random variable (Muñoz-Tuñon et al. 1997). The median is 0.60 arcsec and the first quartile value is 0.48 arcsec.

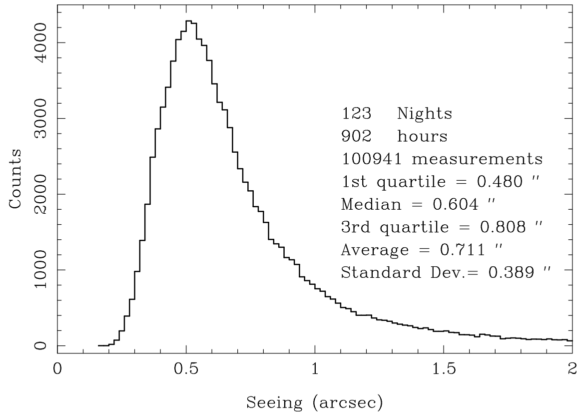

Fig. 2. Seeing distribution from all the measurements.

4. NIGHTLY SEEING STABILITY

In order to illustrate the seeing stability during any given night, in Figure 3 we have plotted the data points as a function of time for three nights with excellent, good and bad seeing, each one together with its corresponding histogram. The upper pair of graphs corresponds to observations made during the March 12, 2002 night, which lasted 8.6 hours. The median value is 0.37 arcsec, with measurements as low as 0.2 arcsec. The middle graphs correspond to the night of July 7, 2002, with 8.3 hours of data. Here the median seeing is 0.59 arcsec. At the bottom of the figure we show an example of bad seeing observed in March 19, 2003. This run lasted 7.5 hours and yielded a median value of 1.51 arcsec. In this last example, the seeing started out with a value of ~ 1 arcsec and then degraded throughout the night, reaching values greater than 3 arcsec.

These examples are not unique. In particular, many other nights with excellent and very good seeing were measured, as shown in Tables 1 and 2, where nights with a large number of data points, and excellent median and sigma values can be cross-selected. These results are comparable to previous ones obtained for single nights, as is the case of the examples shown by Echevarría et al. (1998) in their Fig. 10, using simultaneous STT and Carnegie Monitor observations.

5. SEASONAL DISTRIBUTION OF SEEING

Figure 4 shows the seeing distribution as a function of season. Although the number of nights available is not well distributed for good seasonal statistics, we can point out the following: (1) Summer, with median seeing around 0.55 arcsec, is an excellent observing season. (2) Spring and Autumn, with median seeing values around 0.62 arcsec, are very good. (3) Winter, with median seeing of 0.78 arcsec, is not as good. (4) The average of the median values of the four seasons is 0.64 arcsec, slightly larger than the overall median. This is probably due to the above mentioned poor seasonal distribution in our sample.

In spite of the many differences (number of observed nights, number of observations during a given night, methods of observation and reduction, heights of the instruments, etc.) if we compare these seasonal results with those obtained by Echevarría et al. (1998) using the Arizona STT (see their Fig. 19), some general trends stand out.

Very similar values are obtained for Spring and Summer, confirming them as the best seasons for this site. In the present work we obtain better results for Autumn and worse for Winter (by 0.05 and 0.09 arcsec, respectively). It should be noticed that, in both works, these are the worst-sampled seasons, a deficiency that should be corrected in the future. However, it seems that these are worse seasons than Spring and Summer, with Winter being probably the worst.

Almost 2/3 of the data corresponding to Autumn were measured by Conan et al. (2002). The median value for those 14 nights, 0.74 arcsec (see Table 2 above), is undoubtedly influenced by only one night (December 14), the worst of all those reported here or, to our knowledge, elsewhere. In addition, Conan et al. (2002) find bimodal distributions both in their whole data for December, 2000 and for isolated intervals of several nights, an anomaly they consider

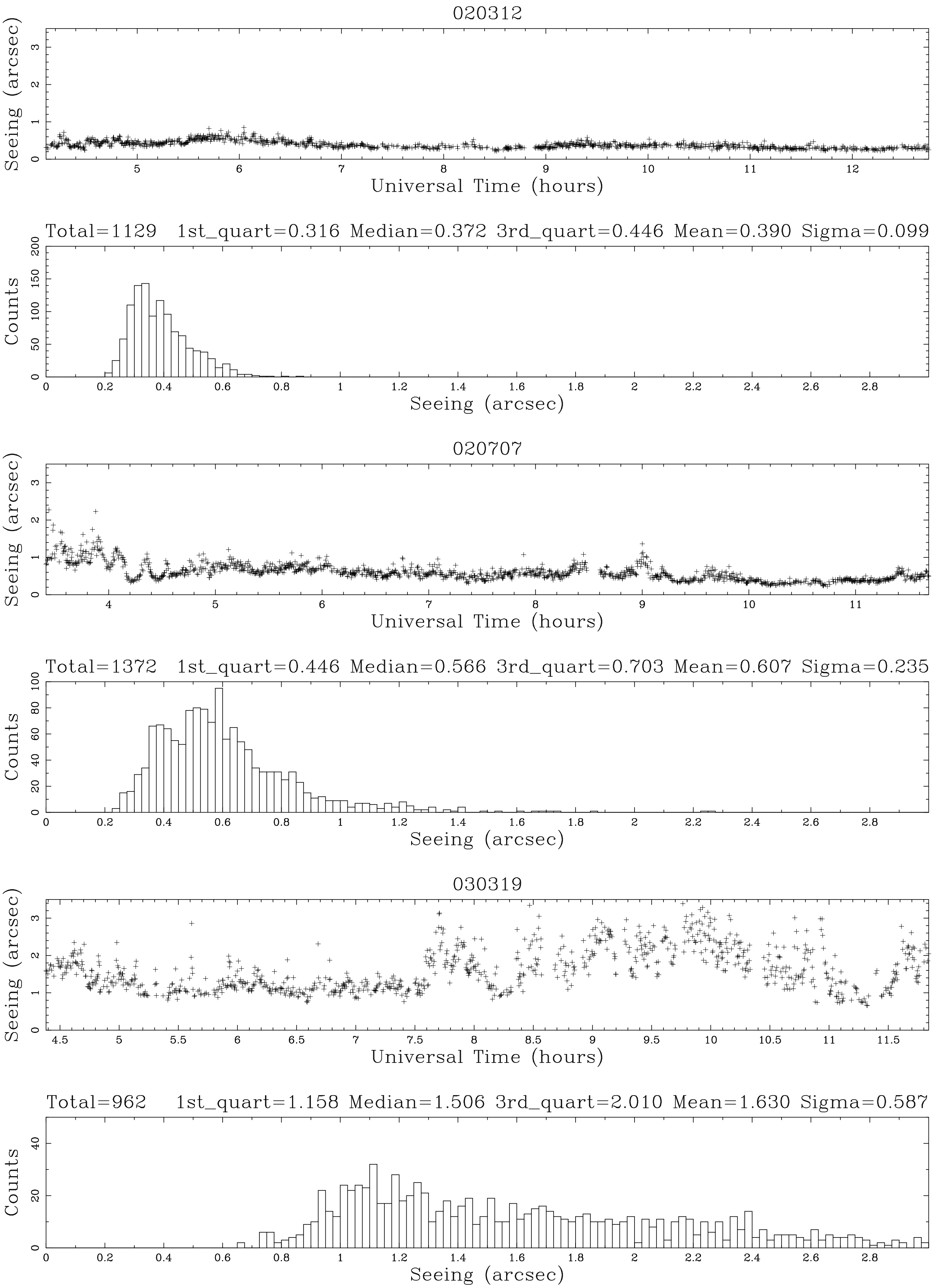

Fig. 3. Examples of good, average and bad observing nights.

as possibly due to two turbulent regimes that may occur during the same night. In fact, the last part of that observing run took place under clearly unstable and deteriorating weather conditions (see their Fig. 9). Some of those nights are comparable to the one we show in the two bottom panels of Fig. 3, as an example of a night with bad seeing.

6. COMPARISON WITH PREVIOUS MEASUREMENTS AT THE SITE

The median and first quartile for the seeing distribution obtained from 123 nights in this paper (0.60 and 0.48 arcsec, respectively), are in very good agreement with the corresponding values found by Echevarría et al. (1998) during 383 nights (0.61 and 0.50 arcsec) with the Arizona STT. Although the number of nights involved, the methodologies and instrumentation techniques are significantly different, it is apparent that seeing evaluations yield similar results when made with the DIMM, the STT or the Carnegie Monitor, as long as a well-sampled, reasonably large number of nights is measured.

The median seeing we obtain here is not in good agreement with the one derived by Avila et al. (2003), as a by-product of their investigation of atmospheric turbulence parameters in San Pedro Mártir. Using the Generalized Scidar mounted on the 1.5 and 2.1 m telescopes (located at about 1 and 20 m above ground level, respectively) they obtain a median seeing of 0.71 arcsec for the whole atmosphere, as measured during eight and three nights from the respective telescopes. This number does not include the dome seeing, and has been corrected to the 2.1 m telescope height.

In their abstract, Conan et al. (2002) quote a median seeing value of 0.92 arcsec for the four campaigns they undertook (31 nights). We believe this figure is erroneous since elsewhere in the same paper they report 0.77 arcsec. Even so, this value is 0.17 arcsec higher than the one obtained in the present work. We believe this, and the smaller disagreement between our result and that of Avila et al. (2003), might arise from both small sample statistics and the fact that a large fraction of their observations were carried out at near ground level, where the neighboring ground-turbulence possibly alters the measurements by larger amounts than the estimated corrections. In particular, we note that during two of their campaigns Conan et al. (2002) mounted the DIMM in the same place where the GSM was located for their December campaign (Avila, R., personal communication). That places the DIMM aperture barely above zero level (see their Fig. 2) with respect to the microthermal instrumented mast used to correct the seeing values to the 8.3 m level. Anyway, Conan et al. (2002) show (see their Figs. 6 and 7), height corrections are not always needed, nor are they sometimes enough. The authors attribute the latter underestimations to the finite (10 ms) DIMM integration time that, according to them, should be corrected by a factor calculated from simultaneously measured turbulence and wind profiles, data they obtained from Generalized Scidar measurements during their May, 2000 campaign (8 nights). From these data, they estimated null-time correction factors between 1.01 and 1.85 for the 10 ms exposures used for the December 2000 DIMM campaign. Apparently, this and other DIMM-inherent peculiarities of seeing evaluation deserve further careful studies (Tokovinin 2002).

7. COMPARISON WITH OTHER SITES

Table 3 shows a comparison of seeing measured in several astronomical sites, listed by decreasing number of observed nights. Since many variables are involved in measuring local seeing, we have restricted the comparison of our results to those obtained in other sites for which DIMM-based evaluations have been reported. Still, there are three aspects that make the comparison not straightforward: (1) Some site campaigns are of very short duration and do not cover the variations over a full year; (2) The heights above ground at which the measurements were done are generally different from one site to the other, and (3) The exposure times employed are not the same. Special attention should be paid to the corresponding columns in Table 3. We also note that not all the data in the table have been journal-published; many can only be found in web sites.

When compared with other DIMM-surveyed sites, San Pedro Mártir is of excellent quality. Our DIMM was placed higher above ground level than almost all the other sites listed. This is somehow compensated by the shorter exposure time we employed, which deteriorates the measured seeing [see e.g., Tokovinin (2002)]. Our result for the first quartile also compares excellently with those measured in other sites, a fact consistent with our finding that seeing can be very small and stable during whole nights.

8. NULL EXPOSURE TIME CORRECTION

In order to obtain an estimate of the seeing at null exposure time, as reported in other sites, we have conducted a series of experiments by implementing the interlaced-exposure technique proposed by Tokovinin (2002) for DIMM observations.

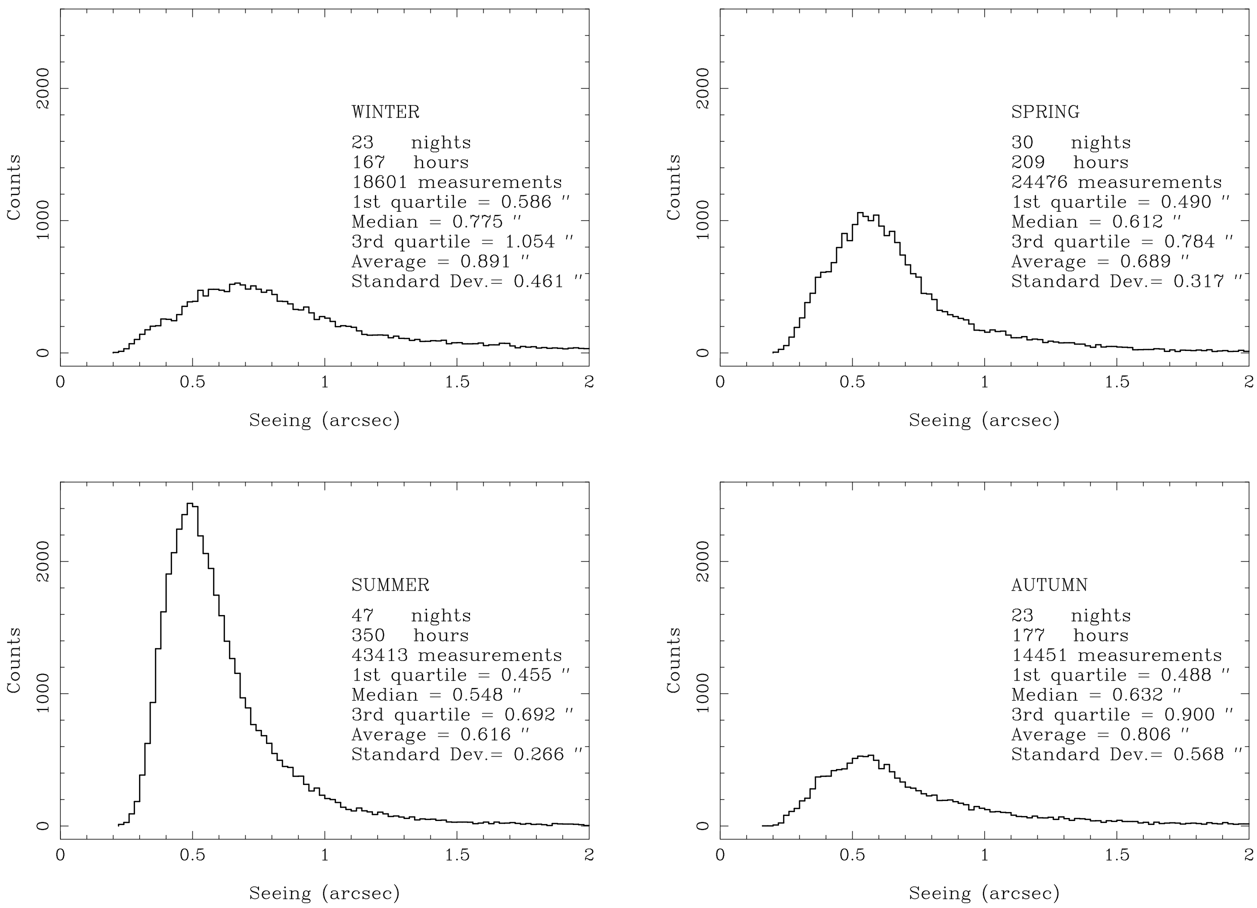

Fig. 4. Seasonal distribution of the seeing measurements.

This technique consists of alternated seeing measurements with a given exposure time, τ, and with twice that time, 2τ. With these two values it is possible to extrapolate the seeing to null exposure time $\epsilon_0 = \epsilon_\tau \epsilon_{corr}$, where $\epsilon_{corr} = (\epsilon_\tau/\epsilon_{2\tau})^k$. For the values listed in Table 3, Ilyasov (2002) and Giovanelli et al. (2001) used $k = 1$, while Tokovinin et al. (2003) employed $k = 0.75$, as suggested by Tokovinin (2002).

Given the limitations imposed by the fact that our instrument integration time is fixed by a mechanical switch not controlled by the computer, we manually alternated the integration-time between 6 and 12 ms after each measuring cycle (200 frames). During seven nights we obtained ten sets of such alternated measurements each one lasting between two and three hours. From the pair of median seeing values for each set, ϵ_{corr} was calculated. By averaging these results we get $\epsilon_{corr} = 1.10 \pm 0.03$ for $k = 1$ and $\epsilon_{corr} = 1.08 \pm 0.03$ for $k = 0.75$. If we apply these corrections to our reported median seeing we get a null exposure time seeing of ~ 0.66 arcsec.

In addition, from the long-term microthermal campaign of Echevarría et al. (1998) (see their Fig. 12), we estimate that the seeing in this site would improve by ~ 0.05 arcsec should the DIMM be risen from 8.3 to 15 m above ground level. In all, we estimate a yearly median seeing —at 15 m and null exposure time— of ~ 0.61 arcsec.

9. CONCLUSIONS

From an almost three-year long program, consisting of 123 nights of unevenly distributed DIMM measurements at the site of the Observatorio Astronómico Nacional in San Pedro Mártir, we conclude:

(a) The overall median seeing and first quartile at 8.3 m and with 6 ms integration-time have values of 0.60 and 0.48 arcsec, respectively.

(b) It is not uncommon for the seeing to remain very stable for whole nights, the best results yielding a median of 0.37 arcsec for more than eight hours of continuous observations.

(c) We found a substantial seasonal variation of seeing, in general accord with the Echevarría et al.

(1998) results: Summer, with a median of 0.55 arcsec, is excellent; Spring and Autumn, with median values around 0.62 arcsec, are very good, the latter slightly better than previously reported; Winter, with a median of 0.78, is not as good, and even worse than previously reported. These results might be influenced by low-number statistics, specially those for Autumn and Winter, seasons that should be better sampled.

(d) Extrapolating our result for the yearly median seeing, we estimate a null exposure time value of 0.61 arcsec at 15 m above ground level.

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