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Patterns of Astronomical Seeing at KSA SEM Observatory

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한국과학영재학교 천지인 천문대의 천문학적 시상 패턴

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Abstract: We report patterns of astronomical seeing at KSA SEMO (Korea Science Academy Space Earth and Man Observatory). Though the data of the seeing measured at the local observatory is essential in identifying the seeing of the observatory, systematic measurement of seeing has not been made in Pusan yet. For this reason, KSA SEMO adopted the Santa Barbara Instrument Group (SBIG) Seeing Monitor to constantly record the seeing. The seeing monitoring was done through an elaborate procedure involving direct CCD images in the focal plane which were subsequently analyzed for the full width at half maximum (FWHM) Gaussian widths. Based on the seeing monitoring for 8 months, we classified five patterns of the seeing at KSA SEMO: 'Sunset/Sunrise Effect', 'Extreme Fluctuation', 'Sudden Increment', 'Daily Variation' and 'Stable Condition'. Seeing was generally good from 1:00 am to 3:00 am than other times, and it was also better in Winter than in Summer.

Keywords: Astronomical Seeing. Seeing. KSA SEMO. Seeing Monitor

요 약: 한국과학영재학교 천지인 천문대의 천문학적 시상 패턴에 관한 연구를 수행하였다. 관측지의 시상 상황을 결정하기 위해서는 그 관측지에서 시상을 측정하여 데이터를 얻는 것이 가장 중요함에도 불구하고, 부산 지역에서 시상에 관한 체계적인 측정이 이루어지지 못하였다. 이러한 이유에서 본 천문대에서는 2008년 5월부터 SBIG사의 시상 모니터를 도입, 매일 시간별 시상을 꾸준히 측정하고 있다. 시상 측정은 CCD로 직접 천체 이미지를 촬영하여 FWHM 지수를 추정하는 방식으로 이루어진다. 우리는 지난 8개월 동안 시상 모니터를 운영하면서 얻어진 한국과학영재학교 천지인 천문대에서의 시상 자료를 바탕으로 KSA SEMO에서의 시상 패턴을 'Sunset/Sunrise Effect', 'Extreme Fluctuation', 'Sudden Increment', 'Daily Variation', 'Stable Condition' 등으로 분류하였다. 시상은 전반적으로 오전 1시에서 3시까지가 다른 시간대에 비하여 좋은 것으로 나타났으며, 여름의 시상이 겨울보다 좋았다.

주요어: 천문학적 시상, 시상, 한국과학영재학교 천지인 천문대, 시상모니터

Introduction

Astronomical seeing, often abbreviated to "seeing", refers to the blurring and twinkling of astronomical objects such as stars caused by turbulence in the Earth's atmosphere. In a small-sized telescope, images of stars can show continual shifting and scintillation due to local seeing conditions, while the images of stars in a large-sized telescope can produce a seeing disk (Birney, 1998). These effects of seeing put a limit on the quality and accuracy of all ground-based astronomical observations. For example, the Hale Telescope at Palomar Observatory, California can only detect a star's image larger than 1.2'', even though the theoretical expectation of the star's image through the telescope is about 1/40'', due to effect of seeing

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(Babcock, 1953). For this reason, seeing is an important factor in determining a location for a new astronomical facility (Lawrence et al., 2004, Loewenstein et al., 1998).

Astronomical seeing is affected by the state of the atmosphere surrounding the telescope. According to earlier research, the effect of seeing is mostly due to the random distortion of straight light from a star (Keller, 1953). When the starlight penetrates the atmosphere, the beam of light causes resonance with the suspended particles in the atmosphere such as water vapor, aerosols and cloud particles. In addition, the fluctuation in the local atmosphere changes the intensity, spatial-temporal phase and angle of arrival of the starlight (Coulman, 1985). No matter how precisely the optical system is structured, images obtained by the telescope are very different from theoretical images. In order to compare several seeing values, quantitative measurement of the effect of seeing is indispensable. Among the several ways of quantitative measurement of seeing, measuring the full width at half maximum (FWHM) of the image is the most common way. As mentioned earlier, starlight incident upon a point light source produces a seeing disk due to the effect of seeing. The diameter of the seeing disk within the range of the FWHM is a measure of the astronomical seeing conditions. In other words, the FWHM becomes larger when the distortion of the starlight gets more intense, making a larger seeing disk. When the local atmosphere is stable, the FWHM is small since the distortion in the wave front of the starlight gets smaller. In Korea, average seeing is about 2''. At observatories located at the top of a mountain or on a small island such as Mauna Kea Observatory or La Palma Observatory, seeing conditions can be as good as 0.4'' (Vernin and Munoz-Tunon, 1991). According to a seeing model by Benkhaldoun et al. (1996) and Peach (2006), the following meterological conditions should be met in order to maintain good seeing; (a) short zenith distance, (b) small air temperature variation, (c) low ground heat, (d) slow wind speed, (e) weak jet stream, (f) wide isobar interval.

There have been many attempts to compensate for the effect of astronomical seeing such as the Adaptive Optics system (Hardy et al., 1998). However, the most effective way to overcome seeing is to observe on a night when the overall seeing is good. In order to find the best time and location for an observation, the seeing forecast designed for the local site is essential and many observatories such as around the world have conducted researches on conditions of local astronomical seeing (Shcheglov and Guryanov, 1991, Neimeier et al., 2003, Wilson et al, 1999). However, any systematic measurement of Korean astronomical seeing which is necessary for building an effective seeing forecast service has not been done yet (Yook et al., 2003).

Since the limit on the improvement in seeing with a large telescope, depends on the local atmospheric turbulence mostly set by the local atmospheric turbulence, measuring the seeing is required for identifying the overall seeing of the local site. For this reason, KSA SEMO (Korea Science Academy Space Earth and Man Observatory) adopted the SBIG Seeing Monitor to constantly record seeing. We analyzed some specific characteristics of astronomical seeing at the local site by comparing the seeing of each day. With more accumulation of seeing data, we expect to use the data in many ways such as predicting astronomical seeing (Khetselius and Tertitskii, 1976, Murtagh and Sarazin, 1993). Astronomical studies, i.e., the photometric or spectroscopic nvetigations (Yoo et al., 2005; Lee et al., 2008), the seeing is most important in securing the astronomical data.

Experimental Setup

We introduced and set up the SBIG Seeing Monitor for the first time in Korea to constantly measure astronomical seeing every night. Fig. 1 and Fig. 2 are the pictures of the Seeing Monitor installed in KSA SEM Observatory. As seen in the pictures, the Seeing Monitor is fixed on the ground pointing to the direction of Polaris. Field of View is large enough to capture the Polaris all night. In Fig. 2, a small-sized

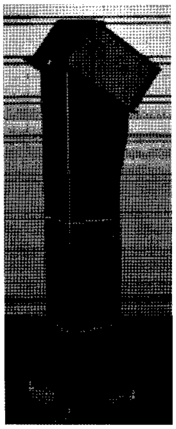

Fig. 1. Seeing Monitor at KSA.

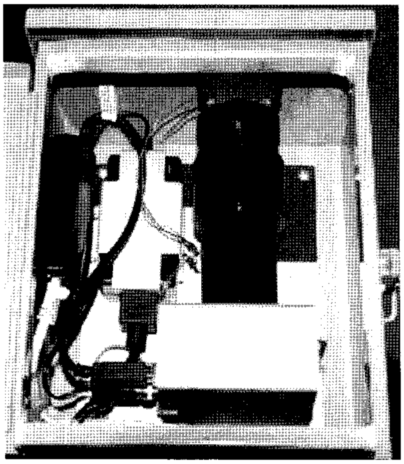

Fig. 2. The Inside of Seeing Monitor.

telescope is directly joined with the CCD plane which is connected to the power source and the computer.

Table 1 and Table 2 represent major specifications of Seeing Monitor (http://www.sbig.com).

The Seeing Monitor system measures the horizontal jitter in the position of Polaris at high speed. A set of equations then can be used to calculate the FWHM that one will obtain in a long exposure image from the rms jitter. The jitter is measured by reading out the CCD while it is being exposed by the light from Polaris in Time Delay and Integration (TDI) mode. An example of the resulting image is shown in Fig. 3.

Table 1. CCD Specifications

CCD	
CCD	Kodak KAF-0402ME
Pixel Array	765×510 pixels
CCD Size	6.9×4.3 mm
Total Pixels	390,000
Pixel Size	9×9 microns
Full Well Capacity	~100,000 e-
Dark Current	~1epixel/sec at 0°C
Dark Current Doubling Temp	~6 deg. C

Table 2. Optical Specifications

Optical Specifications	
Lens Focal Length	150 mm
Lens Focal Ratio	f/5.6
Field of View	2.6×1.7 deg

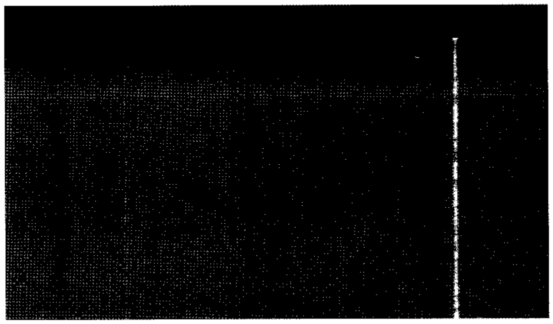

Fig. 3. TDI readout Image of Polaris.

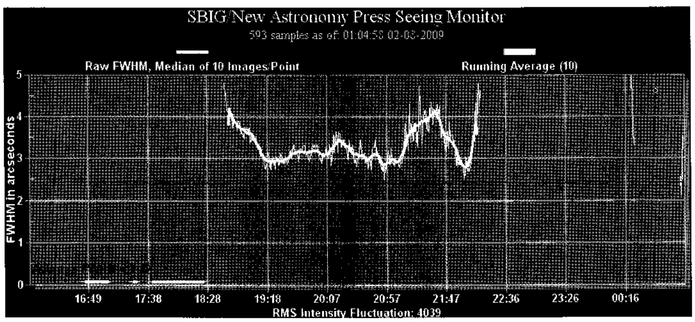

Fig. 4. Seeing Monitor Output Log Image.

Table 3. A Sample of Seeing Monitor Output Log File

20:10:26	04-19-2008	4422	4904	3.25	9	3.44;	3.58;	3.61;	3.38;	3.25;	3.12;	2.96;	2.71;	2.61;
20:11:22	04-19-2008	4747	5233	2.61	9	2.61;	3.24;	3.02;	2.73;	2.66;	2.36;	2.36;	2.31;	2.17;
20:12:19	04-19-2008	4436	4865	2.22	9	2.08;	2.02;	2.26;	2.24;	2.22;	2.23;	2.35;	2.09;	2.1;
20:13:15	04-19-2008	3981	4454	2.62	9	2.33;	2.62;	2.93;	3.04;	2.69;	2.46;	2.61;	2.39;	2.89;
20:14:11	04-19-2008	4749	5280	2.56	9	2.59;	2.58;	2.42;	2.56;	2.39;	2.38;	2.42;	2.58;	2.72;
20:15:08	04-19-2008	4533	5176	2.64	9	2.75;	2.98;	2.64;	2.6;	2.67;	2.61;	2.53;	2.61;	2.73;
20:16:04	04-19-2008	4942	5560	2.34	9	2.71;	2.48;	2.22;	2.67;	2.18;	2.34;	2.21;	2.35;	2.21;
20:17:01	04-19-2008	4727	5242	2.06	9	2.12;	1.96;	1.97;	1.96;	2.06;	2.33;	1.95;	2.2;	2.49;
20:17:57	04-19-2008	4450	5025	2.61	9	2.39;	2.28;	2.52;	2.23;	2.61;	2.73;	2.93;	2.61;	2.84;

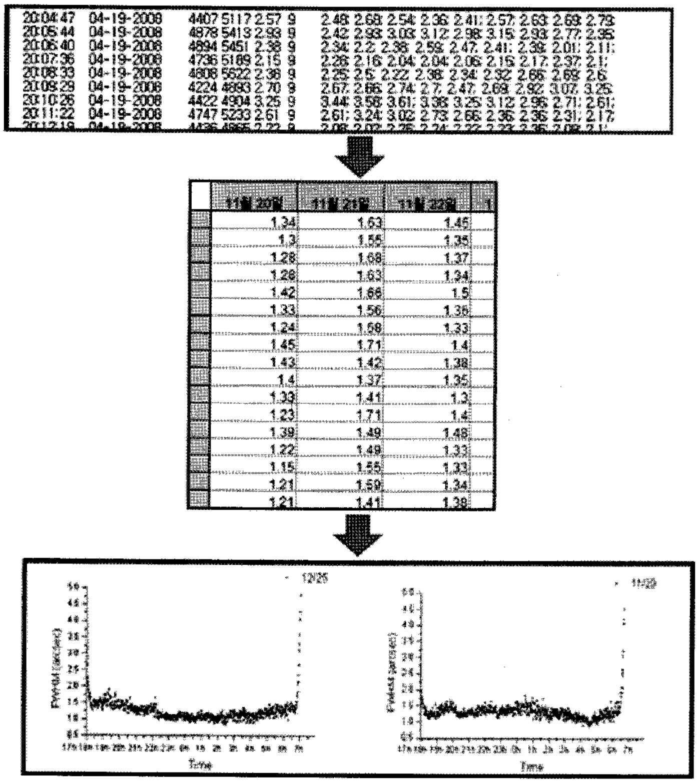

Fig. 5. Procedures of data reduction.

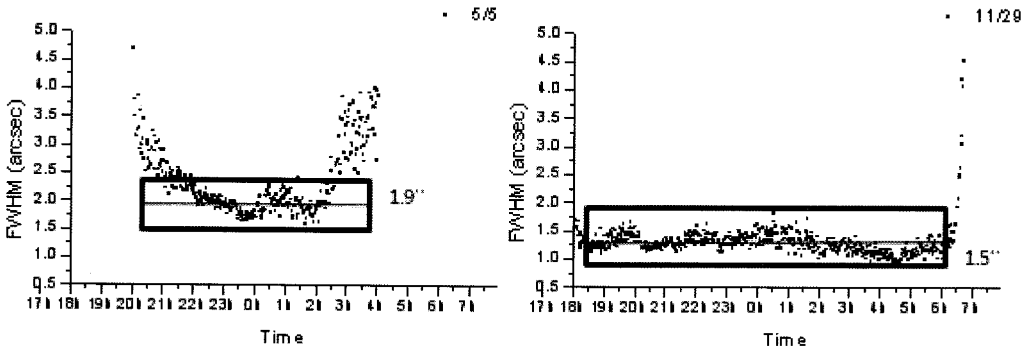

Fig. 6. Samples of determining the average value of the seeing.

A sample of an output image of the Seeing Monitor is given on Fig. 4. The variation in FWHM is represented as a simple graph at the middle. The average FWHM at the left bottom and root mean square (RMS) Intensity Fluctuation which is converted to FWHM later at the bottom are also presented.

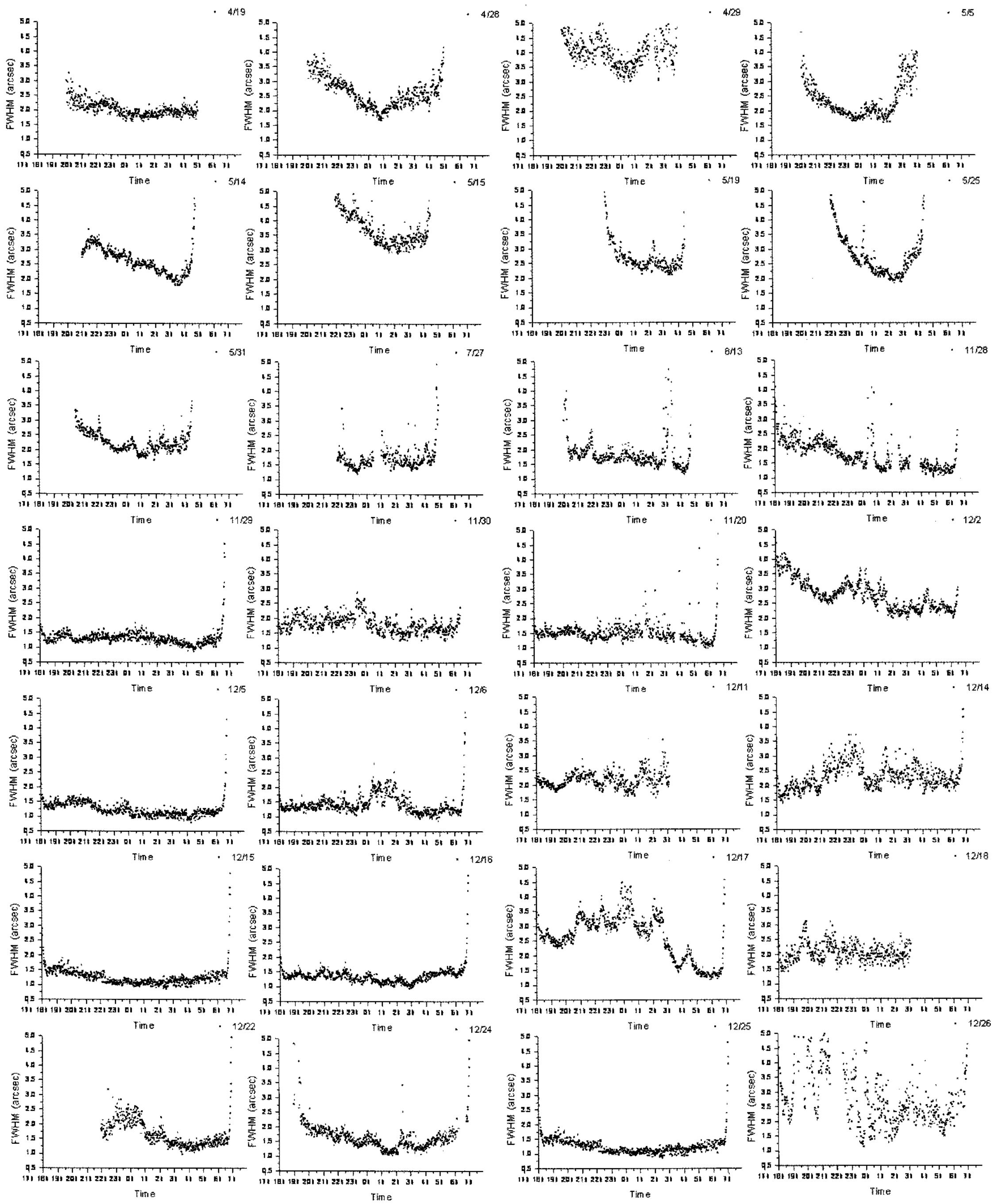

Fig. 7. Samples of seeing conditions at KSA SEMO.

The seeing log is recorded in a text format as in Table 3. From the left, 'time', 'date', 'average analog-to-digital (ADU) unit of Polaris', 'RMS of Intensity', 'mean of FWHM', 'number of available raw FWHM' and 'raw FWHM data' are saved continually.

Analysis Procedures

In order to compare the daily seeing condition, we extracted the seeing log data and converted them into graphs with the same format.

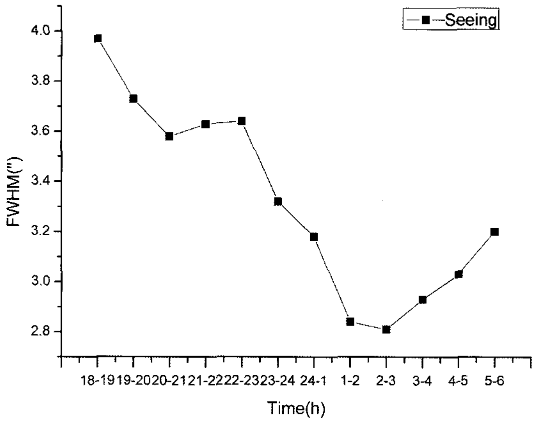

Fig. 8. Average values of seeing of an 1 hour interval.

We determined the mean seeing of each day by calculating the average seeing value among stabilized values of the seeing.

Results and Discussions

Fig. 7 shows some of the seeing variations for different nights at KSA SEM Observatory.

In Fig. 7 and Fig. 8, the seeing is shown to be best between 1 AM to 3 AM regardless of the date.

In a recent research on the astronomical seeing in UK (Peach, 2006), the seeing was reported to be better in Summer compared to other seasons in UK because of low velocity of jet stream in Summer. However, from Table. 4, we can conclude that seeing at KSA SEMO is better in Winter than those in other seasons. Possible causes of this phenomenon are a seasonal rain front and high humidity during the Summer. More accumulations of seeing data and meteorological observations with radiosonde are needed to identify the specific cause of seasonal seeing variation (Barletti et al., 1977).

We also classified some patterns of seeing at KSA SEM Observatory from the data we accumulated for about one year:

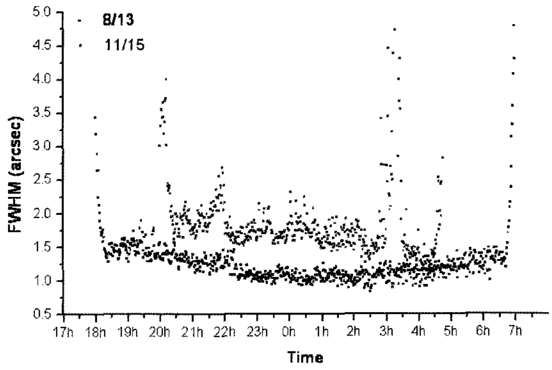

Fig. 9. Effects of sunset and sunrise on Seeing.

A. Sunset/Sunrise Effect: In all seeing data, the FWHM reaches its peak around sunset and sunrise. This is mainly due to the atmospheric turbulence due to the heat produced by the Sun near the ground. Compared to the sunrise/sunset time (8/13 sunrise 04:08:43, sunset 20:48:45, 11/15 sunrise 05:53:56, sunset 18:43:56), Fig. 8 shows that it needs at least one hour for the atmosphere to stabilize.

B. Extreme Fluctuation: When the atmospheric pressure around KSA SEMO is low and the amount of water vapor in the atmosphere was high, a pattern of extreme fluctuation throughout the nighttime was observed. We compared the average cloud cover of days showing extreme fluctuation with the others: the average cloud cover of days with extreme fluctuation was 5.4 while the other value was 2.5. This indicates that extreme fluctuation pattern is related to the cloud cover in the local sky.

C. Sudden Increment: Sudden increments of FWHM were observed when there was a small amount of clouds covering the sky. We tried to find out what causes the sudden increment but there was no clear relation between meteorological factors and the time of increments. We are planning to set up all-sky camera in order to confirm whether clouds covering the Polaris are causing sudden increments in seeing.

D. Daily Variation: Some graphs of seeing showed a

Table 4. Seasonal average of seeing values

Season	Spring (3-5)	Summer (6-8)	Fall (9-11)	Winter (12-2)
FWHM (")	2.93	3.82	3.62	2.78

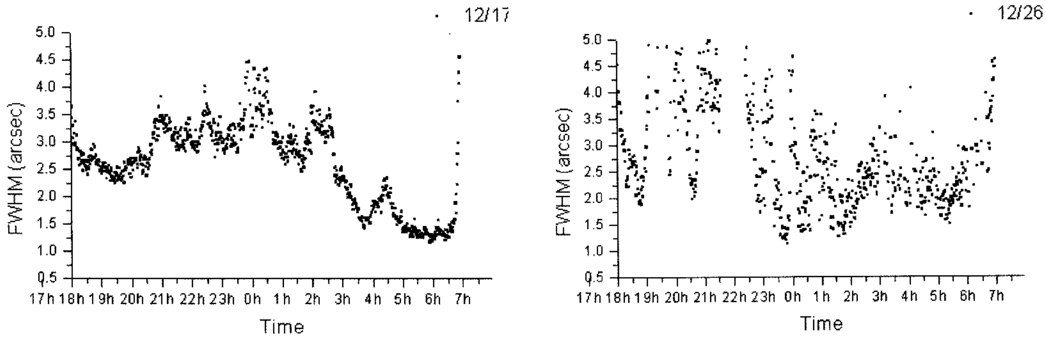

Fig. 10. Extreme Fluctuation examples.

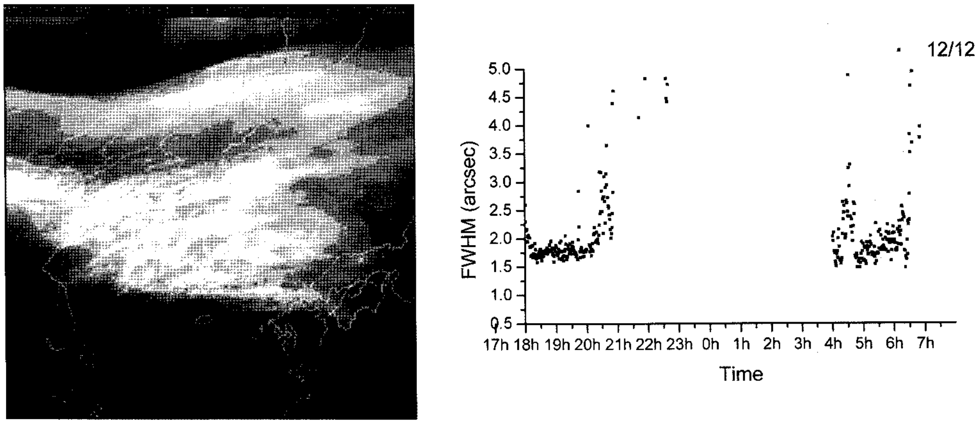

Fig. 11. Satellite image of wide cloud covers in Korea when the seeing of the day showed extreme fluctuation.

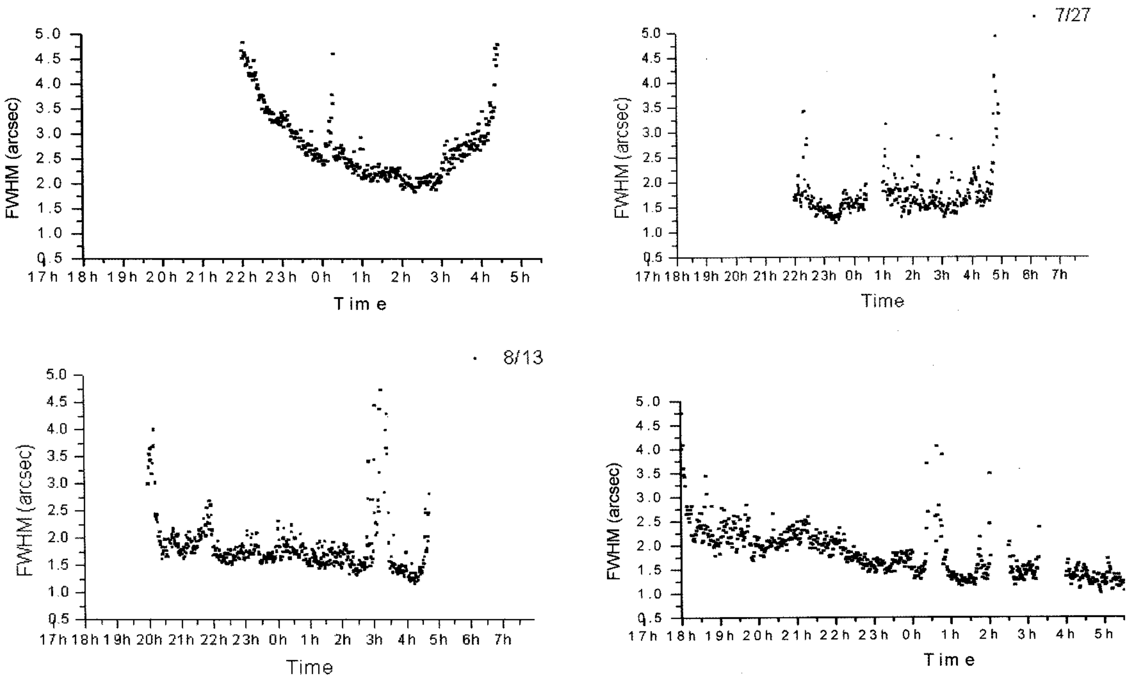

Fig. 12. Sudden Increment examples.

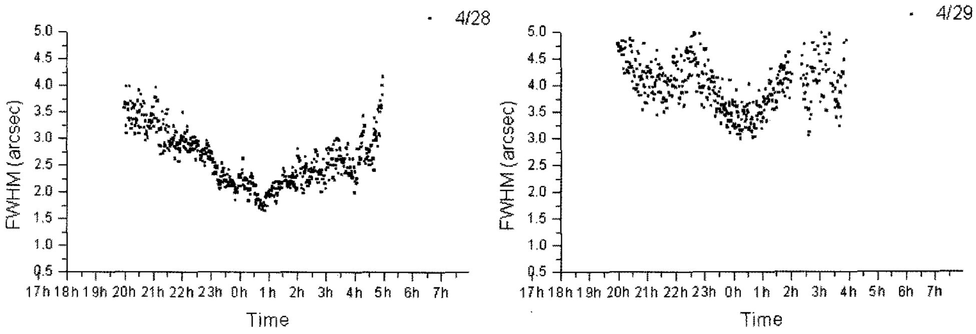

Fig. 13. Daily Variation example.

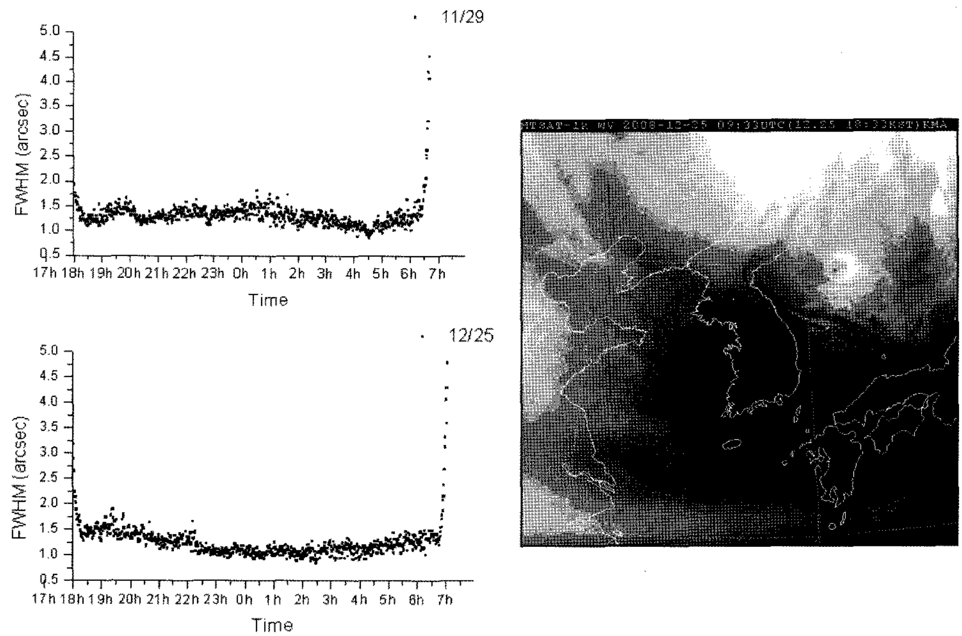

Fig. 14. Graphs and satellite image of examples showing Stable Conditions.

slight difference between consecutive days. These samples are subject to revision to clarify the meterological factors that affect local seeing conditions most.

E. Stable Conditions: We categorized some days with the average FWHM lower than 1.5'' and we will find the meterological factors commonly found during these days after more accumulation of the data. The average cloud cover of days showing Stable Conditions is 0.5 which is relatively low compared to the value of 3.2, average cloud cover of all days measured. Other local meteorological values such as water vapor contents and temperature didn't show clear relations with the seeing.

We compared the FWHM data of each day with meteorological factors indicating the status of upper air, but no other clear evidence of relations was confirmed yet. We will measure the primary meteorological factors of ground atmosphere at local site and collect the seeing data continually in order to find specific relations between the local atmospheric turbulence and the seeing.

Conclusions

We conducted research on patterns of astronomical seeing at KSA SEM Observatory by the means of recording seeing condition with the Seeing Monitor. The following is a summary of our research.

(1) Seeing conditions are better in Winter than those in other seasons.

(2) Seeing is best from 1:00am to 3:00am regardless of season or date.

(3) At least one hour is needed for the atmosphere to stabilize around the Astronomical Twilight.

We classified five patterns of astronomical seeing at KSA SEM observatory. We tried to confirm the relations between meteorological conditions and seeing by comparing wind speed and temperature gradient in upper atmosphere with seeing. However, no clear evidence is yet found. We also compared the local meteorological factors and seeing but we were only able to describe the relations between extreme fluctuation pattern and the cloud cover. We will conduct in-depth research of relations between seeing and meteorlogical factors after more accumulation of seeing data and local meterological factors measured inside the KSA SEM Observatory.

We hope observatories located near the ground such as observatories at science high schools or public observatories would benefit from the seeing patterns greatly since the effect of seeing is more intense at those facilities. Finding characteristics of the local seeing can help astronomers conduct the observation in more efficient ways (Wilson et al., 1999). After more accumulation of data, we expect to explain seasonal, annual patterns of astronomical seeing.

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