Measurement of 461 GHz Atmospheric Opacity at Delingha

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Abstract—**POST (POrtable Submillimeter Telescope), mostly used for astronomical site evaluation and experimental observation, is a 30-cm transportable submillimeter telescope worked around 500 GHz. After an upgrade in 2014, POST was deployed at Delingha, a western city in China. Atmospheric opacity at 461 GHz was mainly measured there during the winters of 2015 and 2016. Total time of the measurements was more than 1000 hours. Statistical results show the quartiles of atmospheric opacity was 1.07, 1.51 and 1.95 during the observing season. ^{12}CO (J = 4-3) line of Orion A and M17SW were successfully detected and we also made a full mapping towards the Moon at some transparent days. Detailed results will be presented in this paper.**

I. Introduction

The 30-cm POST telescope was an old product of the age of 2000s [1]. Now it is mostly used for astronomical site evaluation and experimental observation at submillimeter wave lengths. Measurements of atmospheric opacity between 460 and 500 GHz have been made at some sites in western China [2][3]. Also, The first astronomical observation ever made with NbN superconducting tunnel junctions was realized on this telescope [4]. We upgraded its servo control system of antenna and some other modules of the receiver in 2014 [5]. Then, POST was shipped to Delingha (3200 m), a western city in China, for atmospheric opacity testing at 461 GHz. Non-consecutive measurements were made from Jan. to Apr. 2015 and in Jan. 2016 due to POST is not an unattended telescope yet and could not work under bad weather like rainy or snowy days. During the atmospheric opacity measurements, we took some time and successfully observed the ^{12}CO (J = 4-3) spectral line of two different source. A full mapping of the Moon at 461 GHz was also made while atmospheric transmission at this frequency was good.

II. Instrument and Measurement Methods

Before the newly upgrade in 2014, two other times of great upgrade was made on POST [6][7]. This time the upgrade involved SIS junction, detector bias, low temperature LNA, backend and antenna servo control system. Receiver noise temperature at 461 GHz was 230 K measured in field of Delingha.

The telescope operated as a tipper while measuring the atmospheric opacity. We digitalized the outputs of IF total power corresponding 14 different angles from zenith to near horizontal. Calibrator temperature was acquired twice at the start and end of each tip cycle. Then average was used as ambient temperature. When assuming a plane parallel uniform atmosphere, the zenith atmospheric opacity τ_0 could be fitted by the following equation. Here an approximation of $T_{atm} = T_{amb}$ was used. It took nearly four minutes of a measurement cycle to fit one τ_0.

$$T_{obs}(z) = T_{rx} + T_{amb}\left(1 - e^{-\tau_0 \sec(z)}\right)$$

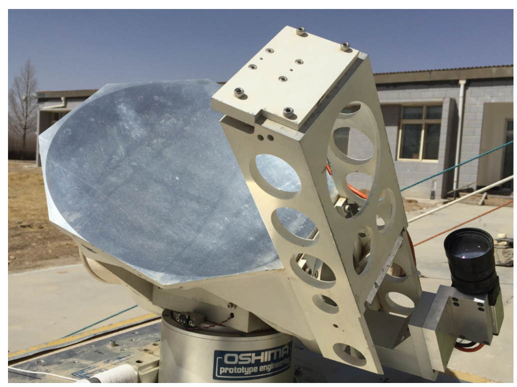

Fig. 1 The 30-cm antenna of POST on site

III. Statistical Results

The measurements lasted more than 1000 hours in total and, removing one-third untrusted data, we got 10684 valid τ_0 data. These untrusted data almost obtained in bad weather with poor dynamic range which resulting in an incredible fitted τ_0 with large uncertainty. It could be determined that these time periods were unable to carry out astronomical observations. Consequently, the below statistical results should be better than the actual situation. More should be noticed is that the measurements were carried out mostly in the winter, so they could only reflect atmospheric transmission of the site to a certain extent.

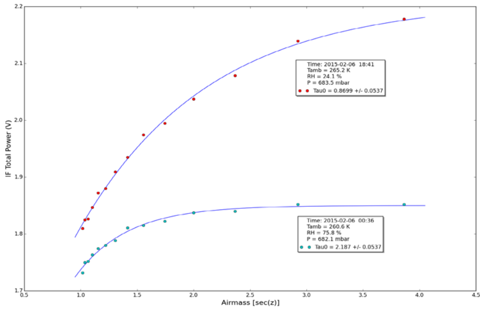

Fig. 2 Two fitted τ_0 at different time periods

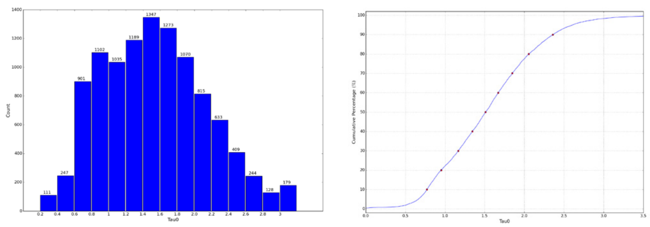
Fig. 3 Histogram distribution (left) and cumulative percentage (right) of measured τ_0 in the winter time

TABLE I
QUARTILES OF THE MEASURED τ_0

Quartile	Zenith pacity
25 %	1.07
50 %	1.51
75 %	1.95

IV. ^{12}CO (J = 4-3) LINE OBSERVATIONS

During the long time atmospheric opacity measurements, we made spectral line observations towards the standard sources of Orion A and M17SW when atmospheric transmission was tested good at 461 GHz (τ_0 around 1).

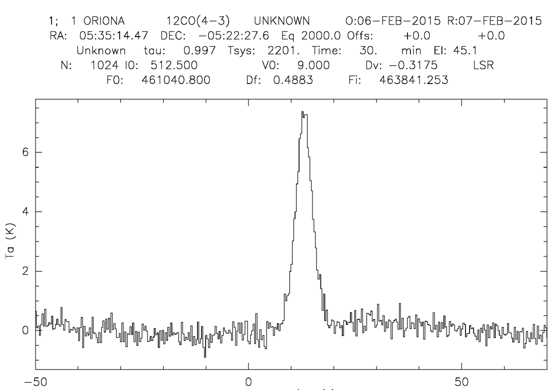

Fig. 4 ^{12}CO (J = 4-3) of Orion A observed in Feb. 6, 2015 (Total integration time was 30 mintues)

Also, we made a full mapping of the Moon by using the total power observation mode in Jan. 24, 2016. The observation was a 51 x 51 points 2D mapping with space interval of 1' in both AZ and EL directions. During the mapping, atmospheric opacity was around 0.7 indicating an transmission rate about 50 %. Fig. 5 shows the diameter of the Moon is about 30'.

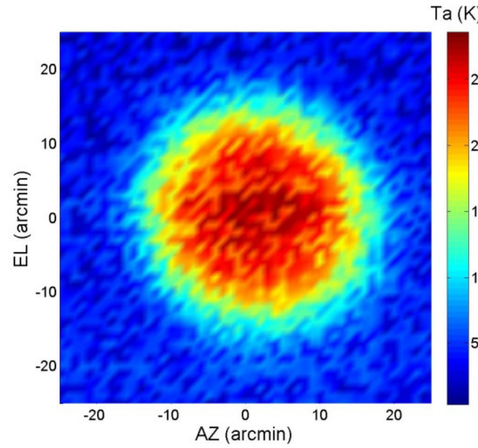

Fig. 5 The Moon mapping at 461 GHz, τ_0 was about 0.7 while observing

V. SUMMARY

POST telescope was transported to Delingha for atmospheric opacity evaluation at 461 GHz after a system upgrade. Inconsecutive measurements were made from Jan. to Apr. 2015 and in Jan. 2016. Statistical results show that quartiles are 1.07, 1.51 and 1.95 of the observing season. The real atmospheric transmission at this frequency should be worse for some bad data have not been counted in when standard errors of the fitting parameters are large. Moreover, POST was not working under some severe weather. These times were not suitable for astronomical observation and were not included in the statistics.

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