Remote observing environment using a KVM-over-IP for the OAO 188 cm telescope

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ABSTRACT

We have prepared remote observing environment for the 188 cm telescope at Okayama Astrophysical Observatory. A KVM-over-IP and a VPN gateway are employed as core devices, which offer reliable, secure and fast link between on site and remote sites. We have confirmed the KVM-over-IP has ideal characteristics for serving the remote observing environment; the use is simple for both users and maintainer; access from any platform is available; multiple and simultaneous access is possible; and maintenance load is small. We also demonstrated that the degradation of observing efficiency specific to the remote observing is negligibly small. The remote observing environment has fully opened since the semester 2016A, about 30% of the total observing time in the last semester was occupied by remote observing.

Keywords: remote observing, KVM-over-IP

1. INTRODUCTION

Okayama Astrophysical Observatory, a branch of National Astronomical Observatory of Japan, serves as the observing and research base of optical and infrared astronomy in Japan. The observatory has a 188 cm telescope

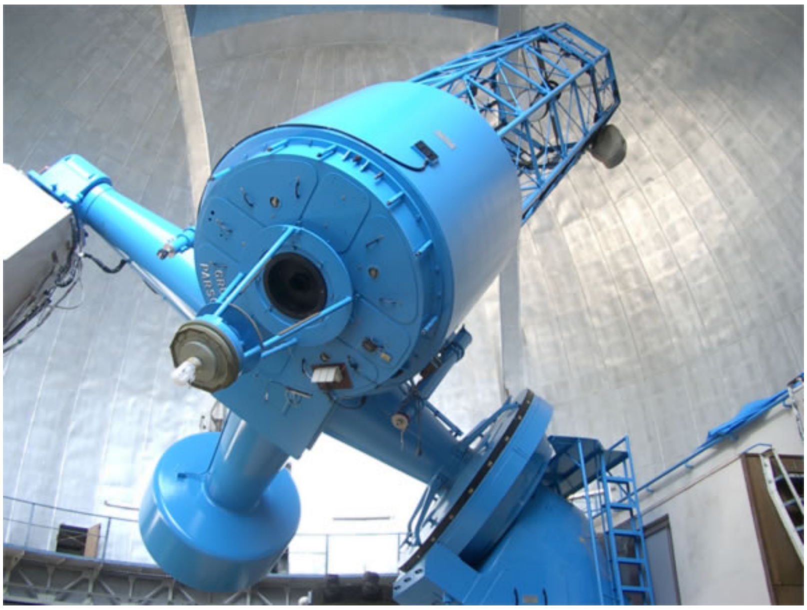

Figure 1. The 188 cm telescope at Okayama Astrophysical Observatory.

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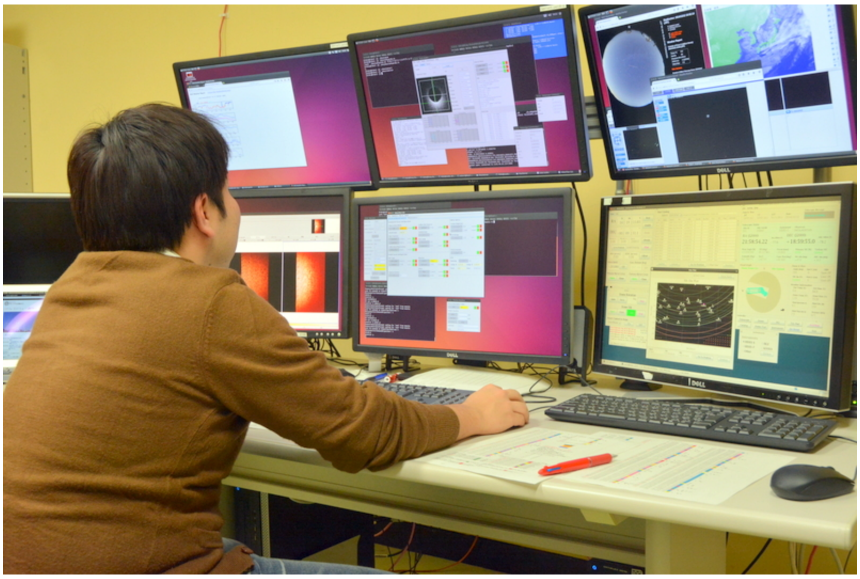

Figure 2. Observing console for the 188 cm telescope and instruments at Okayama Astrophysical Observatory.

(see Figure 1) manufactured by Grubb and Parsons in 1960, and four open-use instruments: HIDES[1],[2] ISLE[3],[4] KOOLS, and MuSCAT.[5] These instruments offers both imaging and low to high resolution spectroscopic capabilities. Okayama Astrophysical Observatory provides with the telescope and four instruments for the astronomical community of the world. To make a better use of the telescope and further achievements, we have prepared remote observing environment based on KVM-over-IP, and opened the remote mode[6] since the semester 2015A. This would be the first attempt to utilize the KVM-over-IP or remote observing. In this paper, we report the structure, performance and initial use results of our remote observing environment.

2. REMOTE OBSERVING ENVIRONMENT BASED ON KVM-over-IP

2.1 Design concept

A design concept of our remote observing environment is replication of the on site console to remote sites.

Okayama Astrophysical Observatory has been operated in a classical mode: a principal investigator and/or team members come to the observatory, operate the telescope and instruments by themselves, and collect data of objects of their interest. Figure 2 shows our on site observing console. It consists of three PCs, keyboards, mice, speakers and six Full-HD (1920 × 1080) monitors with vertical dual display configuration. All the information associated with the ongoing observation are aggregated on these displays: telescope GUI is appeared on the lower right, the latest sky image over the observatory, weather information, images from monitoring cameras on the upper right, auto guider GUI on the upper center, instrument GUI on the lower center, and quick look image of the latest Echelle spectra on the lower left. Sounds are also useful information for observers to judge whether major instruments work properly, and to know the status change of the instruments such as the end of telescope pointing or that of exposure. In addintion to the alarm, speakers play streaming sounds collected inside the dome: the sound sources are dome rotation, changes in telescope transmission gear systems, or compressor of the mechanical coolers.

2.2 KVM-over-IP meets our design concept

We investigated the way to realize the concept and found that employing the KVM-over-IP is simple, secure and hassle-free solution.

A KVM switch is a hardware device which enables a user to access multiple PCs from a set of keyboard, video device and mouse; the switch and target PCs are connected with dedicated cables. There is another type

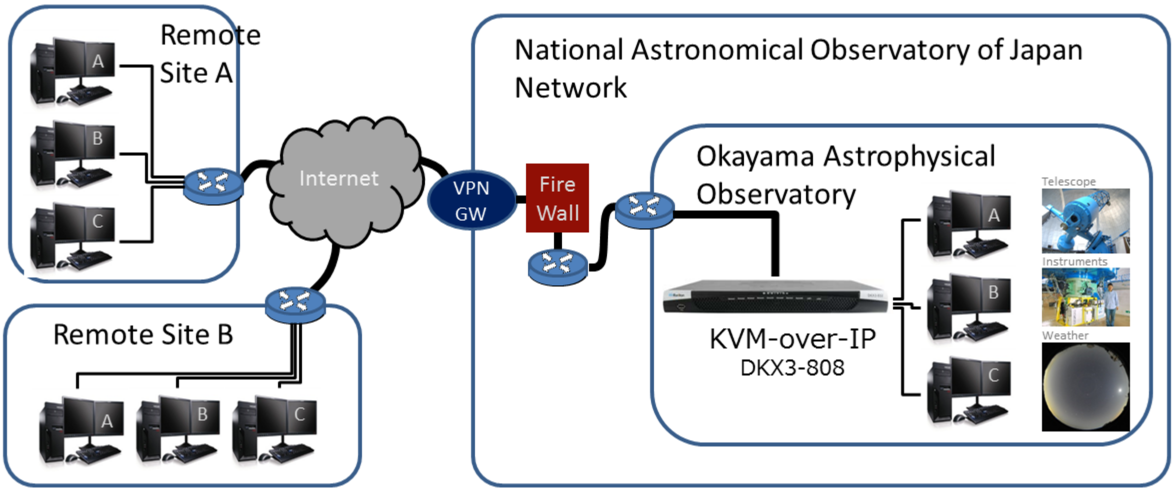

Figure 3. on site console at Okayama composed of 3 PCs with dual diaplays can be replicated by a KVM-over-IP to multiple remote sites. KVM-over-IP offers a simple solution to construct remote observing environment.

of KVM that enables to access target PCs over internet. This sub-type is called as KVM-over-IP. It is exactly what we need and it realizes our design concept without any difficulty. Eventually, we employed a KVM-over-IP, DKX3-808 from Dominion KX III series, manufactured by Raritan Inc. as a core device. Dominion KX III series* is a linux based hardware appliance which comes with standard features such as 1920×1080 HD analog and digital video, up to 30 FPS HD video, DVI, HDMI, DisplayPort and VGA, high (24-bit) color palette support, dual monitor, digital audio, fast (gigabit) ethernet ports, dual-stack networking IPv4 and IPv6, FIPS 140-2 cryptographic module, 256-bit AES encryption, browser-based BIOS level access and control, etc.

2.3 Benefits of Dominion KX III

The built-in functions of DKX3-808 offers many advantages for both service side and user side. Major advantages are listed below.

- All the things that remote observers have to do is to just connect the DKX3-808 via Web browser and select a target to operate from a menu list. Then Raritan's KVM client software starts and the target appears on the client desktop. The KVM client software is downloaded automatically if it is for the first time for a client PC to access the DKX3-808. The feature is very convenient for remote observers since it eliminates the need to install client software on each user desktop by themselves.
- Multi-platform access is available. Remote observers can access the DKX3-808 from Windows, Linux, Sun/Solaris or Macintosh, since two types of KVM client software based on Windows .NET or Java are available. A Java free client software works on Windows platforms.
- Up to eight† remote user can access the same targets simultaneously (see Figure 3). This feature is useful for remote observers. Team members can join the observation from anywhere on earth as long as fast network connectivity is available. Trouble shooting of open-use instruments by observatory staff from home or trip destinations is also possible, which greatly reduces the waste of time and improves satisfaction of observers.

*http://www.raritan.com/products/kvm-switches/dominion-kxiii

†The total number of simultaneous access to the same target depends on the model. Dominion KX III series provides users 1,2,4 and 8 simultaneos access to the same target.

- If there arises security issues or major version up of operating system, the vender fixes it and prepares a new BIOS. The only thing the observatory staff have to do is to replace old BIOS to the new one. Putting the maintenance issues by vendor's hand significantly reduces a burden of observatory support staff.
- DKX3-808 is a hardware switch physically connected with KVM ports of targets. Therefore it does not add any load on the targets unlike RDP or VNC software technology. Moreover targets operated by legacy OS can be controlled remotely; any instrument, less frequently required but unsubstitutable, hosted by a PC operated by legacy OS, can be used on active service.

2.4 Security and safety measures

It is important to take measures about security and safety for a long time operation of our remote observing environment.

2.4.1 Network security

The KVM-over-IP is connected to a subnet, called visitor subnet, inside the NAOJ network which prohibits any access from outside the NAOJ network. To assure the access to the visitor subnet for authorized observers, we have prepared a VPN gateway, ASA5512-X from CISCO systems Inc. The VPN gateway is accessible from major platforms, Windows, Linux and Macintosh, with a dedicated software prepared by CISCO. The software can be download automatically when we access to the URL, assigned for the VPN gateway, for the first time. Authorized observers first establish a VPN connection to the visitor subnet prior to access the DKX3-808. To avoid possible cracking, any access from the visitor subnet toward the other NAOJ subnets is prohibited by NAOJ's router. The opposite access from visitor subnet toward outside is not restricted, so that remote observers can transfer the observed data to their home institute.

2.4.2 Information security

Authorized observers can access the visitor subnet anytime unless their account has expired. Therefore it is possible for hostile users to steal a glance at displays on observation of their interest, unless we do not take any measure. Such information leakage can be prevented by proper setting of the user account. The DKX3-808 has three kind of built-in access levels: `deny`, `view`, and `control`. `View` enables users to show whole target display information but prohibits to control whole targets. So we set the access level `control` or `view` to the observers of the night and set `deny` to the observers of the other night. Currently we manage the account access level by hand, but we hope to automate the task in the near future with open-LDAP in conjunction with a dedicated database which holds schedule of remote observing.

2.4.3 Safety of on site workers

We have prepared a selector switch that alters the access to the KVM-over-IP by authorized observers from permit to prohibit or vice versa. This is to assure the safety of observatory staff at work during maintenance or inspection. Tragic accident might happen when remote observers operate the telescope or dome without knowing the existence of staff at work. The remotely operate mode is called as remote mode, and locally operate one is called as local mode. The observatory staff are to turn the selector switch to local mode prior to any work inside the dome. A switch status monitoring daemon is prepared to check a return failure by workers. Alert mail is issued when the daemon find the return failure.

2.4.4 Rain measure

We have to care about changes in weather to protect telescope and instruments against rain fall. We have prepared autonomous system to protect the facilities inside the dome cooperate a dedicated software with rain sensors in our observatory campus. The dome shutter begins to close when at least two rain sensors detect rain drops. These sensor status is recorded in a database every ten seconds and the database can be accessed by any clients inside the observatory.

Figure 4. Remote observing console in Mitaka campus, Tokyo. This picture was taken on the first night of commissioning on December 2, 2014.

2.4.5 Network connection loss

Although the remote observing is based on the network, we know the connectivity is not always assured. The loss of connectivity occurs mostly by planed works, but partly by unanticipated incidents such as emergency reboot of network devices commenced by a maintainer or automatic reboot by the device itself in response to the momentary stop of electricity, etc.

We have prepared a daemon process to monitor the connectivity loss. A server in Okayama Astrophysical Observatory issues ping command every 15 seconds toward a core network device that is located at the other end of the network in Tokyo to monitor the network status. Once connection loss is found and the condition has last more than 30 minutes, a termination process automatically starts : the telescope is pointed toward rest attitude, and the dome shutter is closed. In additoin, we have also prepared backdoor access to the visitor subnet to ensure a continuous connection. The bandwidth of the network is 100Mbps, it is enough to issue security commands toward telescope, dome and instruments.

2.5 Remote observing consoles prepared

Two kind of remote consoles have prepared to enhance the convenience of observers.

2.5.1 Fixed console in Mitaka campus

We have prepared a remote observing center[6] in Mitaka campus, headquarters of NAOJ in Tokyo, for observers in Tokyo and around. Figure 4 shows the remote observing console installed at a corner of Subaru Telescope remote observing room. The remote console is composed of three Windows PCs, keyboards and mouse, and six Full-HD displays, that is same configuration with that of on site. The frame rate of 30 FPS, identical to the maximum rate attained by KVM-over-IP, is always available on the Mitaka console. Incidentally, the network bandwidth was evaluated with iperf[‡] as following: the bandwidth from Mitaka to OAO was 50 Mbps, while OAO to Mitaka was 30 Mbps. Observers does not need to establish a VPN connection since the console is connected to visitor subnet of NAOJ network.

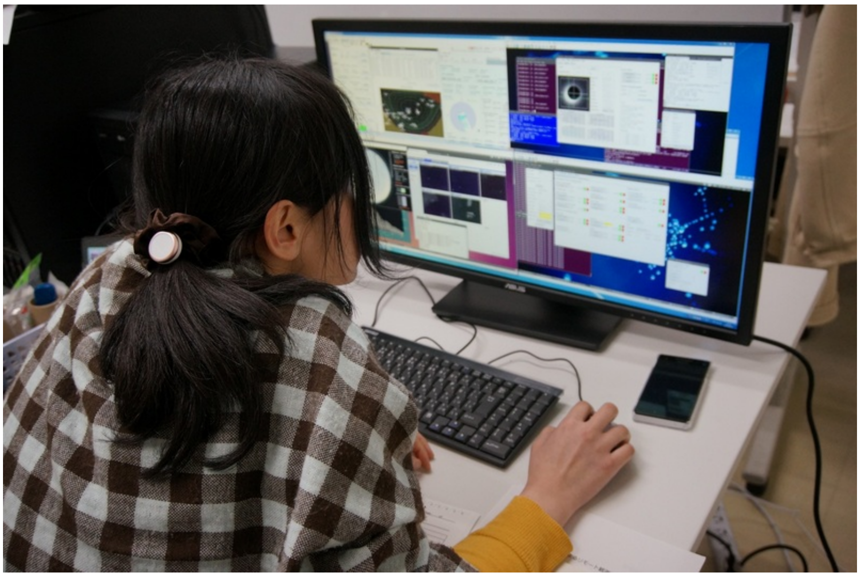

Figure 5. Remote observing at Hiroshima University. The 4K-display, PB287Q from ASUS, allows to play sound and aggregate four Full-HD video information of the on site console, offers cost effective solution to realize distributed remote observing. This picture was taken on the first night of the commissioning of distributed remote observing on Feb. 4, 2015.

2.5.2 Transportable console

There are some monitoring programs which requires many observing epochs with intervals from some days to some week, but requires small amount of exposure time for each night. For such programs, traveling to Okayama or Mitaka sometimes becomes a problem even though the traveling distance is short. We have prepared two sets of transportable consoles to be rent out upon request. This is to support distributed remote observing[6] which means an observation from observer's office. The entity is a Windows PC with a 4K display (Quad Full-HD, 3,840 × 2,160). Figure 5 is a picture of distributed remote observing held at Hiroshima University, 70 km westward of Okayama Astrophysical Observatory. The 4K display, aggregates four windows which reflects each Full-HD video of on site, is useful and cost-effective to prepare transportable consoles. Moderate frame refresh rate of 17 FPS was obtained at the observation, although the network distance between Hiroshima University and Okayama Astrophysical Observatory is quite long, more than 1,500 km. We have experienced, to date, the distributed observing from four sites: Hiroshima University, Kyoto University, Tokyo Institute of Technology, and Kavli IPMU of the University of Tokyo (see Figure 6).

3. PERFORMANCE

3.1 Frame rate

Frame rate can be measured by a built-in function provided by the DKX3-808 client software.

Table 1 summarizes the measured frame rate at various remote sites. It ranges 17 to 30 FPS in all the domestic sites. These frame rates exceeds 10 FPS, the refresh rate of telescope GUI, it is expected that significant degradation will not appear on the client's screen. According to the remote observer at Kyoto University, where the frame rate of 23 is available, about 0.2 seconds latency is recognized. He noticed the delay by means of mouse operations; there appears two mouse pointers on the client screen; one is of local mouse and the other is of target's which reflects the local mouse inputs. He found the target's mouse pointer always begins to move 0.2 seconds after the local mouse operation. He also reported us that the latency does not degrade the total operability.

[‡]https://iperf.fr/

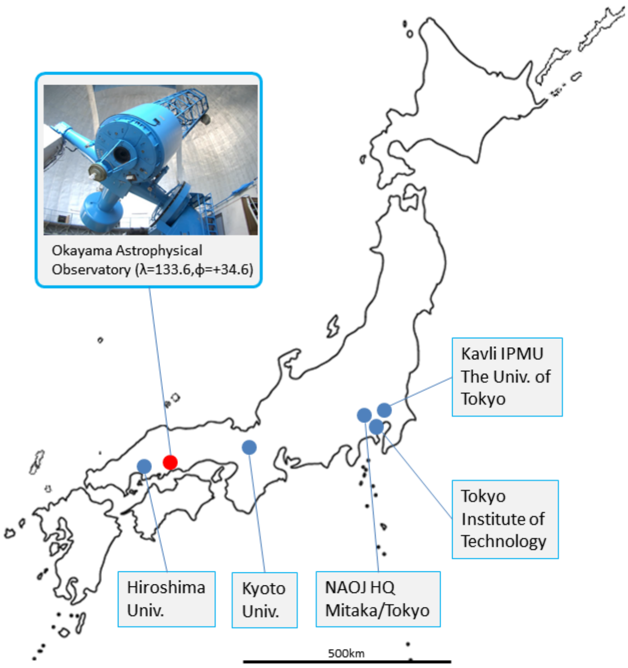

Figure 6. Location of Okayama Astrophysical Observatory and remote observing sites.

Table 1. Frame rate measured at various sites.

Site	FPS	VPN
Mitaka, NAOJ Headquarters	30	w/o
Hiroshima University	17	w/
Kyoto University	23	w/
Tokyo Institute of Technology	21	w/
Kavli IPMU, The University of Tokyo	23	w/
In the Shinkan-sen train with tethering by NTT-docomo	9	w/
Subaru Telescope (Hawaii, USA)	7	w/o

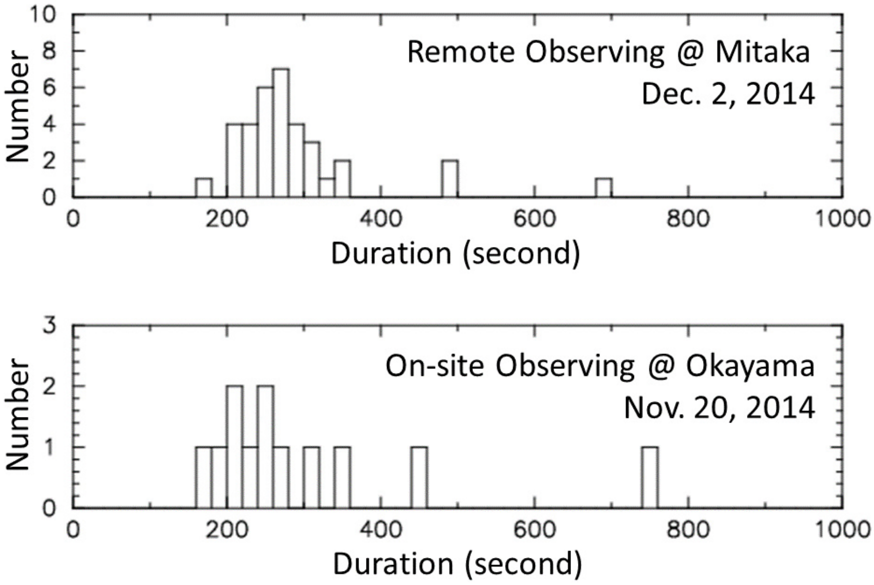

Figure 7. Comparison of observing efficiencies between observations made in Okayama and in Mitaka.

The overseas frame rate is somewhat small as expected; the rate of 7 FPS was obtained at Subaru Telescope, Hawaii, USA where is at the distance larger than 6,000 km. Closer frame rate was experienced by one of the author who was on the way to Tokyo in the Shinkan-sen train, connected to DKX3-808 from a note PC via tethering provided by NTT-DoCoMo. Under the frame rate of 9, a recognizable latency was present and distorted sound was sometimes heard, but it was operable with a slight patience.

3.2 Observing efficiency

Observing efficiency was compared through the observation from on site and a remote site. A series of spectroscoic observations of nearby cool stars were carried out with infrared instrument, ISLE, at both in Okayama and Mitaka. The observation required frequent manual operation, since our objects were too bright (K$\sim$6) in general, almost all the science exposure was enough with the shortest exposure of 4 seconds. The observing procedure was a repeat of the following; telescope pointing, object identification, guide the object on the slit, and science exposures with 4 noddings. Such observation with a lot of manual operation is appropriate to compare the observing efficiency, since the difference in efficiency becomes evident if there are any latency specific to the remote observation. Figure 7 shows histograms of duration spent for each object. The duration is defined as the time between the beginning of telescope pointing to the end of exposure. The lower panel shows a result of on site observations and the upper panel shows that of remote observations. We can see there are no significant difference in efficiencies between on site and remote observations.

4. USE RECORDS

We started the commissioning of the remote observing environment in December 2014 and fully opened it since the semester 2016A. We have served 53 distinct remote observing to date and the amount of time is up to 413 hours. Total of 7 remote users have experienced the remote observing.

4.1 User number and cumulative time by month

The remote observing environment seems to be establishing among users. Figure 8 shows a history of remote observing. The horizontal axis is calendar month and the vertical axis is number of distinct remote observations by month. The figure shows that the use number begins to increase soon after the full open of the environment. The average use number is 7 from January to May 2016. Figure 9 shows growth of cumulative use time of our remote observing environment. After the full open in January 2016, the use records begins to grow rapidly, the

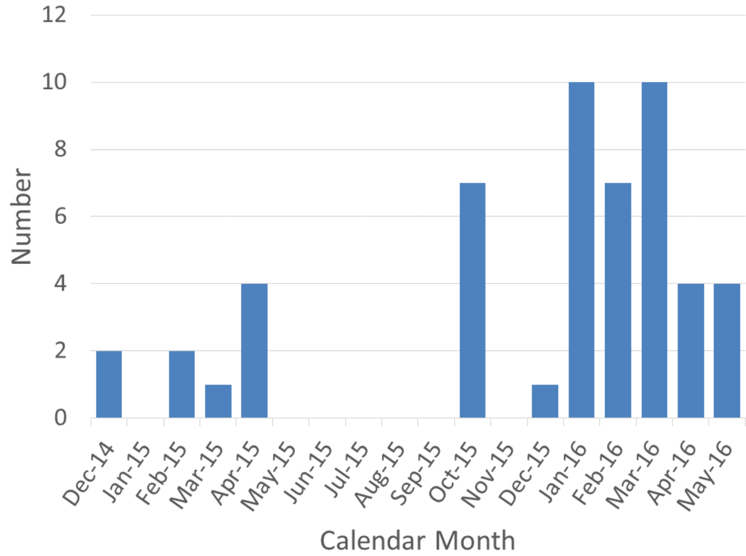

Figure 8. Histogram of distinct remote observing by calendar month.

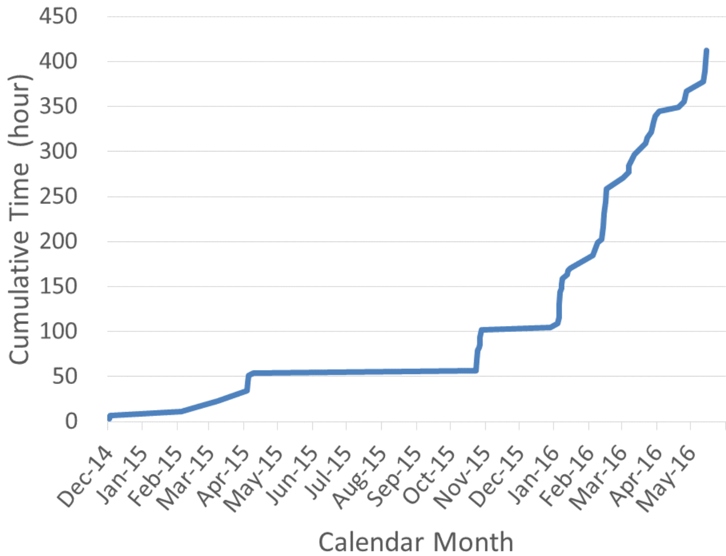

Figure 9. Cumulative time of remote observing.

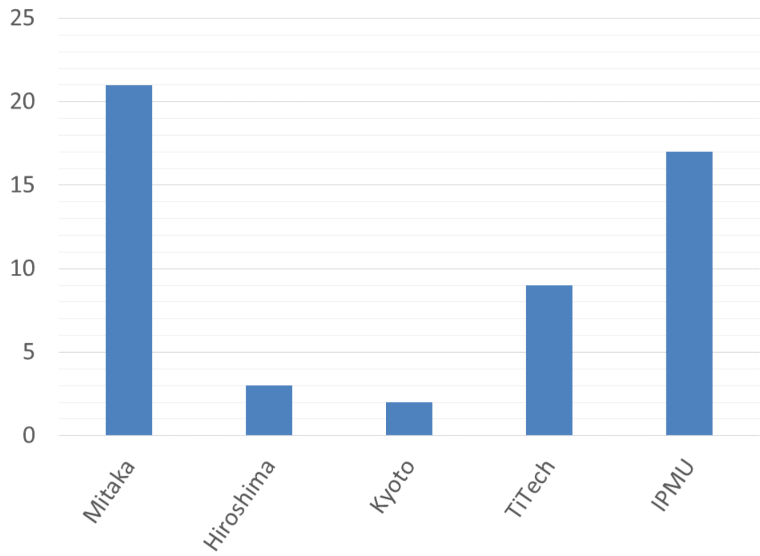

Figure 10. Histogram of distinct remote observing by remote site.

amount of use exceeds 300 hours in the last 5 months. Since the total observing time served for observation in the semester is 1,100 hours, the fraction of observation with remote observing is 27%.

4.2 Remote observing by site

Figure 8 shows the number of distinct remote observing by site. The figure shows that more than half of the remote observing has carried out in a form of distributed observing. The number of remote observing from Mitaka is 21, it occupies 40% of the total remote observing. On the other hand, the rest of 60% is carried out with the portable consoles from users in Hiroshima University, Kyoto University, Tokyo Institute of Technology and Kavli IPMU.

5. CONCLUSION

We have prepared remote observing environment, based on a KVM-over-IP and a VPN gateway, for the 188 cm telescope at Okayama Astrophysical Observatory. The environment has fully opened for the community since last January, about 30% of the total open-use time in the last semester has carried out with remote observing. We have successfully demonstrated the usefulness of the KVM-over-IP for the remote observing; the use is simple; maintenance load is small; the frame rate is enough fast; no significant degradation of observing efficiency was found.

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