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AN EAST-ASIAN EXTRA-SOLAR PLANET SEARCH NETWORK

HIDEYUKI IZUMIURA
Okayama Astrophysical Observatory, National Astronomical Observatory, National Institute of Natural Sciences, 3037-5 Kamogata, Asakuchi, Okayama 719-0232, Japan
E-mail: izumiura@oao.nao.ac.jp
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ABSTRACT

We are undertaking an extra-solar planet search around G-type giant stars by means of Doppler technique using an iodine absorption cell installed to the high dispersion echelle spectrograph for the 188 cm reflector at Okayama Astrophysical Observatory (Okayama Planet Search Program, OPSP). Having detected the first planet candidate (Sato et al. 2003)the search has been proved very promising. Taking advantage of this success, we are trying to develop OPSP to an international collaborative work. We here report the current status of our efforts for establishing such collaborations, namely, those with Chinese and Korean astronomers. We also propose to establish an East-Asian network to search for extra-solar planets around G-type giant stars with the transit detecting technique as well as the Doppler technique, asking other persons/groups to join us to enjoy the planet search.

Key words : planets: extra-solar — spectra: high resolution — international collaboration — stars: G-type — stars: giants

I. INTRODUCTION

More than 130 planet candidates have been revealed in F, G, and K dwarfs by precise radial velocity measurements (Doppler technique) since the first discovery of a planetary companion to 51 Peg (Mayor & Queloz 1995). Currently, more than 2000 F, G, and K dwarfs are being monitored for further detections, by exploiting all kinds of telescopes from 1-m class up to 10-m's (e.g., Marcy et al. 2003). The accumulated observational results now stimulate development of a deterministic model of planet formation around solar-type stars (e.g. Ida & Lin 2004a,b).

Planets around other types of stars have been less extensively surveyed and theoretically investigated. Those in more massive (>1.5 $M_\odot$), intermediate-mass stars are particularly important for improving the planet formation theory because planets around those stars convey important information on the planet formation mechanism. The evolutionary time scale of those stars is much shorter than solar-like stars, then proto-planetary disks also have shorter life times (<a few Myr; Haisch et al. 2001a,b), which indicates that time allowed for planet formation is also much shorter. Besides, the stronger stellar radiation in those stars should hamper giant planet formation because the ice-forming region required for nuclear formation for giant planets is shifted outward in the proto-planetary disk. Therefore, the existence of gas giant planets around such stars would constrain the timescale of giant planet formation and verify the current planet formation theory (e.g. Pollack et al. 1996). Little is known, however, about planetary systems in intermediate-mass stars because precise radial velocity measurements are difficult when such stars are on the main-sequence (early type stars) due to the lack of appropriate absorption lines in their spectra.

When intermediate-mass stars evolve toward red giant stage, they go through G-type giant phase, where many absorption lines appropriate for high precision radial velocity measurements appear while the stars themselves remain relatively stable against pulsation and surface activities. We initiated an extra-solar planet search in G-type giant stars, which were completely unexplored objects by the Doppler technique, with the high dispersion echelle spectrograph (HIDES) on the 1.88 m reflector at Okayama Astrophysical Observatory (OAO) in 2001 (see section II for details and also the contribution by B. Sato in this issue). We have shown that such stars indeed exhibit only small intrinsic radial velocity dispersions of the order of 20 m s^{-1} (Sato et al. 2005), and this level of stability in radial velocity is small enough to detect massive planets in orbits close to the central stars. In fact we have discovered the first planet candidate (Sato et al. 2003) and we foresees more detections in near future as well. G-type giants seem to be ideal targets for precise radial velocity measurements in the case of planet search in intermediate-mass stars.

However, it is crucially in need of further observing time, which is difficult to solve within the framework of the conventional common use observations at Okayama (OAO), to accelerate the survey. Collaborations with other groups are essential to boost this research program to the utmost limit. We then started to seek for

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opportunities of collaboration with other groups. Here we report the current status of our efforts for establishing such collaborations with people/observatories in East-Asia.

II. OKAYAMA PLANET SEARCH PROGRAM

We briefly describe our current activity, Okayama Planet Search Program (OPSP), at Okayama Astrophysical Observatory (OAO). The readers should see the contribution by Dr. B. Sato in this issue for more details of OPSP. OPSP is a unique program to search G-type giant stars for extra-solar planets, aiming to investigate the presence/absence of planets around intermediate-mass stars, which are more massive than the sun, using the high dispersion echelle spectrograph (HIDES, Izumiura 1999) and iodine gas absorption cell (Kambe et al. 2002) installed at the coude focus of the 188 cm reflector at OAO. OPSP performs precise radial velocity measurements with a precision of about 5 m s^{-1}, which is realized by our own computer code developed for radial velocity analysis (Sato et al. 2002). Targets for OPSP are selected from Hipparcos catalogue by posing the following four constrains: $0.6<B-V<1.0$, $-3<M_V<2$, $\delta > -25°$, and $V<6$. Here B, V, M_v, and δ have the conventional meanings. The color range corresponds to spectral types from G6III to K1III, in which stars are expected to be stable against pulsation and surface activities. The range for M_v corresponds to $1.5<M/M_\odot<5$ for stars in this color range. The third and fourth constraints are necessary for us to observe them from OAO and to obtain a sufficiently high S/N which warrants an accuracy better than 10 m s^{-1} in radial velocity with exposure time less than 30 minutes. Besides, known variables and spectroscopic binaries are excluded. These procedures resulted in a sample of about 300 stars, which mainly consists of late G-type giants while some early-K giants are also found.

OPSP started as a pilot survey of 50 stars in 2001 and turned out to be promising. We have already reported the first discovery of a planet candidate around G9III giant star HD 104985 (V=5.78, D~102 pc) (Sato et al 2003) and have found several candidates more. The HD104985 system is found to have the orbital period of 198 days, velocity amplitude of the star of 163 m s^{-1}, eccentricity of 0.06, the stellar [Fe/H] of -0.15, mass of the primary of 2.3 $M_\odot$, mass of the planet ($m_2 \sin i$) of 8.1 M_J, and semi-major axis of the planet of 0.88 AU. The rate of occurrence of giant planets is roughly estimated to be about 5%. Then we can expect to discover about 15 planets from this OPSP sample. A possible statistical property is beginning to emerge that no stars in the sample show radial velocity variations with periods less than 180 days and with amplitudes larger than 50 m s^{-1}, suggesting that massive and short-period planets may be rare around these types of stars. These observational properties are still in need of confirmation, which can only be accomplished by finding a larger number of planets. However it requires a huge amount of additional observing time, which is difficult to solve within the framework of the conventional common use observations at OAO. Thus, we try to boost the survey to the utmost limit by establishing international collaborations with China and Korea.

III. CURRENT STATUS OF INTERNATIONAL COLLABORATIONS

Since OPSP turned out very promising, we started to look for partners who had an access to similar observing facilities for extra-solar planet search with Doppler technique in 2003. At this moment there are four high resolution echelle spectrographs attached to 2-m class telescopes in the East-Asian region. They are at Okayama and Gunma in Japan, Xinglong in China, and Bohyunsan in Korea. In the following sub-sections we will describe the current status of our efforts for establishing an east-asian planet search network with the Doppler technique.

(a) China-Japan Collaboration

Since 1990's Dr. G. Zhao at the National Astronomical Observatories, Chinese Academy of Sciences (NAOC) and Dr. K. Noguchi at the National Astronomical Observatory of Japan (NAOJ) have been visiting and communicating with each other. They have also been encouraging cooperations between Chinese and Japanese astronomers. Some collaborations were actually carried out so far. We recently joined this activity and became able to take advantage of this warm relationship for further developing the extra-solar planet search around G-giants.

The 2.16 m reflector at Xinglong station of NAOC is equipped with an echelle-type high dispersion spectrograph at its Coudé focus (Coudé Echelle Spectrograph or CES, Zhao and Li 2001). It can provide spectral resolving powers of 44,000 and 37,000 in the blue and red regions, respectively, which are separated at 5500Å by a dichroic filter, for the normal setting with its middle focal length camera each when the slit width is ~1". The CES could be used for the Doppler survey of extra-solar planets around G-type giant stars to extend OPSP (see section II), if an iodine cell were installed.

For this purpose, a small vacuum chamber containing an iodine gas absorption cell wrapped by a flat heater for thermal control was produced particularly for the CES by Dr. E. Kambe, and it was successfully installed in front of the entrance slit of CES in the summer of 2004 (Fig. 1). This iodine cell will allow to perform precise radial velocity measurements to search exo-planets with the Doppler technique.

Another effort has also been made since 2003 for improving the observing capability of CES by an upgrade of its CCD camera, from 1K×1K to 2K×2K or larger, mainly by the people at Xinglong station with

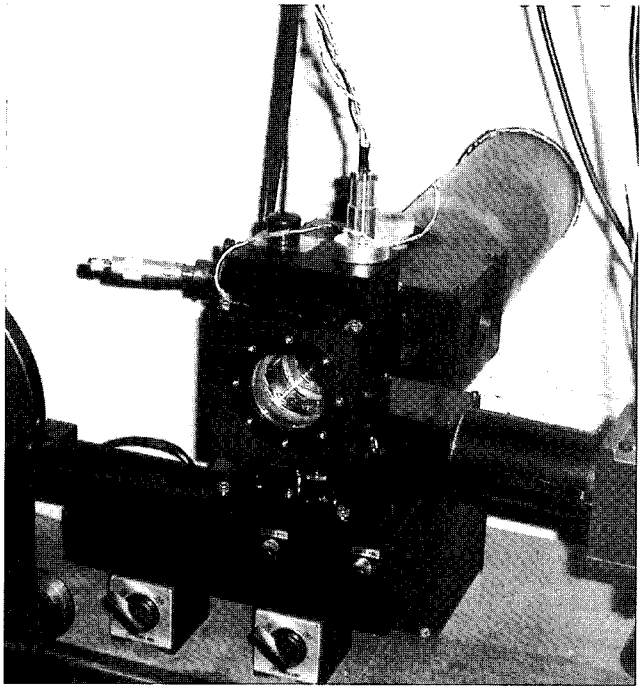

Fig. 1.— Iodine gas absorption cell attached in front of the entrance slit of the Coudé Echelle Spectrograph of the 2.16 m reflector at Xinglong station, NAOC. By courtesy of Dr. E. Kambe

some ingredients from Japan side. This would also help to develop an exo-planets survey of G-type giants at Xinglong.

As to the human exchange (reciprocal visits) both Chinese and Japanese astronomers have been applying observing time to each other's telescope since 2004. In October 2004 Noguchi et al. visited Xinglong for test observations of the newly installed iodine cell to CES at 2.16 m reflector. In November 2004 Chen et al. visited Okayama for observations with HIDES at 188 cm reflector to study abundance differences of young and old metal-rich stars.

The relationship thus has been steadily developing. As a result, we are going to start a search for exo-planets around G-type giants with the iodine cell and CES at the 2.16 m reflector at Xinglong soon in 2005.

(b) Korea-Japan Collaboration

Since 1990's there have been technical exchanges on observatory instrumentations between Bohyunsan Optical Astronomy Observatory (BOAO) of Korea Astronomy Observatory (KAO) and Okayama Astrophysical Observatory of NAOJ. The cooperation was triggered by the first visit of BOAO people headed by Dr. Inwoo Han to OAO (KAO has been transformed to a part of Korea Astronomy & Space Science Institute (KASI) at the submission of this article).

BOAO recently completed a new high dispersion spectrograph, namely, Bohyunsan Observatory Echelle Spectrograph (BOES, http: //www.boao.re.kr /BOES /boes.html) for their 1.8 m reflector. BOES is a very efficient spectrograph having optical fibers with different diameters for the light feeding and more powerful than HIDES at OAO. One of the input fibers has the core size of 200μm which subtends 2.9" on the sky provides a spectral resolving power of 44,000. BOES is already equipped with an iodine gas absorption cell as well. BOES is, thus, one of the best instruments for planet search with the Doppler technique in the East-Asia. They finished the commissioning in 2003 and opened it to the astronomical community in 2004.

Dr. Han and the author have been discussing to find an opportunity to start a collaboration, if possible, on a planet search around G-type giants since the author's first visit to BOAO in 2003. And fortunately enough, we have indeed reached a researcher-based agreement during this EAMA6 period to initiate an actual collaborative extra-solar planet search around G-type giant stars, with BOES at BOAO and HIDES at OAO: both the Korea team at BOAO and the Japan team at OAO make best efforts to get observing time, and, if possible, invest on average 1.5 nights per month from 2005. With BOES at BOAO 1.8 m reflector and HIDES at OAO 1.88 m reflector we will perform a high precision survey of radial velocity variations in G-type giants. The accuracy of 3–6 m s^{-1} in radial velocity measurements achieved by BOES is comparable to that with HIDES at OAO. This collaboration will produce a large, homogeneous radial velocity data set of G-type giants.

In this collaboration we will first make a common target list of G-type giants. Then we share the target list and observing time. On average we will allocate 1.5 nights per month observing time at each site from own resources and survey about 150 stars each. At OAO this collaboration is carried out as a new program in addition to the current OPSP (section II). Several new planetary candidates would be detected from the sample of ~300 stars in total. We will start observations as soon as possible in 2005. With this collaboration we will be able to obtain a statistical picture of planetary systems in intermediate-mass stars and to verify the validity of current planet formation theory.

IV. PROPOSAL TOWARD AN EAST-ASIAN PLANET SEARCH NETWORK (EAPSNET)

To summarize, we have been making efforts for establishing two two-country collaborations for Doppler survey of G-type giants for extra-solar planets as the first step toward an East-Asain Extra-Solar Planet Search Network. In the year 2005, both collaborations probably start with actual observations at Xinglong (China), Bohyunsan (Korea), and Okayama (Japan). As far as we know, this is the first network of 2-m class optical telescopes in East-Asia.

Since we have managed to start Doppler surveys,

we then would like to extend our activities to other directions of extra-solar planet searches with further persons or observatories in the two or other countries involved.

First of all, we would like to initiate a transit monitoring of G-type giant stars, although it is obviously a very tough (and challenging) task to obtain significant results. The relative photometric accuracy to be achieved is about 0.0001 mag, which is hundred times as accurate as those of currently available techniques and is similar to those necessary for detecting earth-size planets around G-dwarf stars. One advantage of detecting a transit of a giant planet in front of a G-type giant against an earth-like planet in front of a G-type dwarf is the longer transiting time for the former case. This may relax the requested accuracy of photometry by a factor of 3 because the duration in G-giants should be 10 times longer than in the dwarfs.

There are a couple of groups which are specialized in massive, high accuracy photometry of numerous stars over a long period of time. Namely, TAOS project at Lulin Observatory in Taiwan and YSTAR project conducted by Yonsei University in Korea are the most promising and attractive groups. We would like to talk with those people, to look for opportunities of collaborations, to learn their techniques, and so on. In addition the 2.4 m and 1 m reflectors at the brand new GMG observatory in Yunnan Province of China could be an important contributor.

We finally would like to propose a comprehensive co-operation among East-Asian 2-m class telescopes, starting from the exo-planets survey of G-giants discussed here. It should eventually be developed to regular (annual or biannual) meetings on astronomy and astronomical instrumentations in East-Asia.

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