天文コムを利用した視線速度精密測定のためのデータ取得･解析法の研究

Progress report on the study of data acquisition and analysis method for precise radial velocity measurement using astro-comb

Eiji Kambe[1,5],

H. Izumiura[1,5], H. Tsutsui[1,5], H. Inaba[2,5], K. Nakamura[2,5], M. Schramm[1,2,5], S. Okubo[2,5], H. Yamamoto[2,5], J. Ishikawa[2], K. Hosaka[2,5], F.-L. Hong[2,3,5], A. Onae[2,5], K. Minoshima[4,5], R. Hasegawa[6], K. Helminiak[7]

1. National Astronomical Observatory of Japan,
2. National Institute of Advanced Industrial Science and Technology,
3. Yokohama National University, 4. The University of Electro-Communications,
5. JST ERATO “Minoshima Intelligent Optical Synthesizer Project,
6. Tokyo Institute of Technology, 7. Nicolaus Copernicus Astronomical Center/Poland

outline of my talk

* some backgrounds to start this Koubo-Kenkyu

* purposes and technical approaches of our study

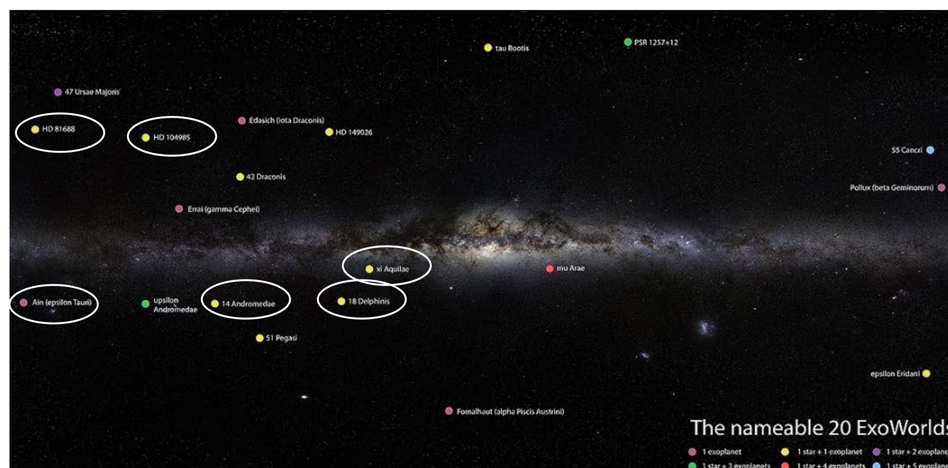
* current status
  preliminary analysis of test observations

* some plans and a comment on Okayama Astrophysical Observatory (OAO)

some more background ….

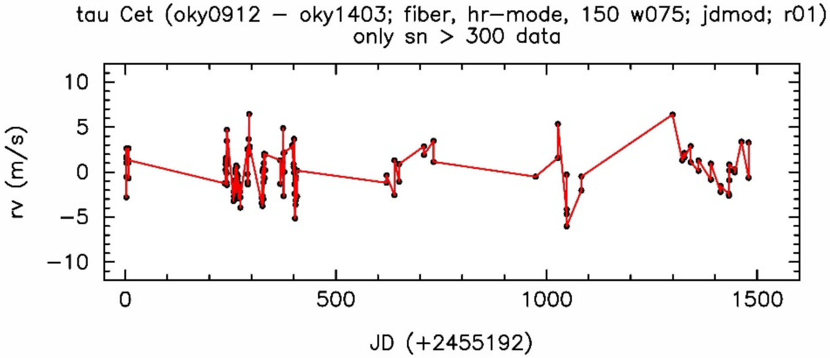
* We have a conventional 1.88m telescope and HIgh Dispersion Echelle Spectrograph (HIDES) at OAO. After installing an iodine cell (gas cell), we have been able to measure stellar radial velocity (rv) with precision of <~ 2 m/s and they are intensively used for exoplanet searches, eclipsing binaries studies, asteroseismology …

six out of 19 exoplanets in the recent NameExoWorlds public event by IAU are found with our telescope



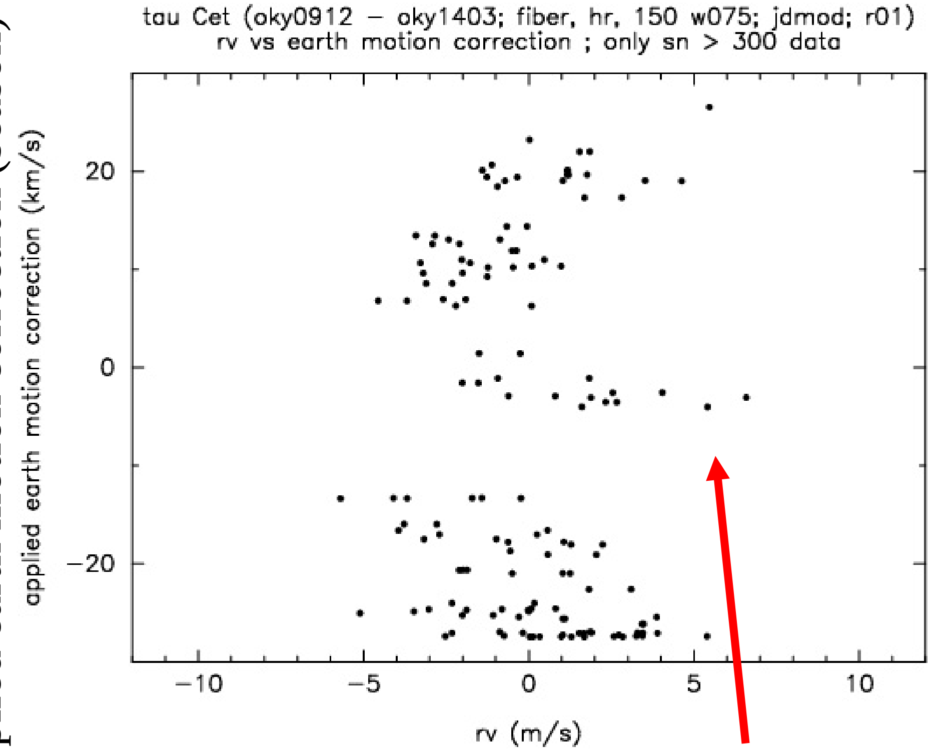
* on the other hand, we have noticed that our precision is apparently not photon noise limited …

τ Cet



σ∼2 m/s

applied earth motion correction (season)



every October …

* in 2014, AIST(+YNU, UEC) was funded to build their astro-comb and suggest us to install it in HIDES. We took it a good opportunity to examine the problem in detail.

purposes and technical approaches of our study

* final goal of our study to find an appropriate data acquisition and analysis method to reach the rv measurement precision of 1 m/s or less

* in its initial phase, we would like to examine causes of the systematic errors in the iodine technic and to find how to cure them using astro-comb spectra.

* currently, we use HIDES as it is, which means that we make various evaluations from short exposure data

typical drift of HIDES is 1 m/s per minutes

how the iodine technic works

• a star spectra is taken through the iodine cell

only 500 nm – 620 nm

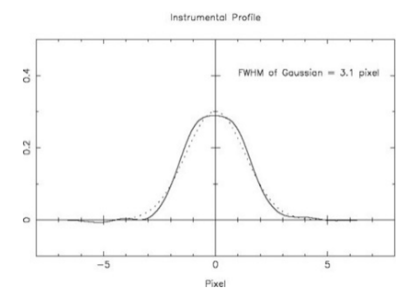
• we estimate stellar rv by modeling the observed spectrum using very high resolution stellar and iodine spectra taking into account a mechanical distortion of spectrograph (instrument profile change)

$$I_{obs}(\lambda(x,t)) \quad = k(t)[I_{star}(\lambda(x)+\delta\lambda_{star}(t))T_{I2}(\lambda(x)+\delta\lambda_{I2}(t)] \otimes IP(t)$$

observed spectrum

stellar template

I2 template



• in this method, wavelength scale (mapping pixel to wavelength), IP, and stellar rv are mutually dependent and not converged to ‘real’ values

•so, we would like to restrict some of these parameters with info from astro-comb to estimate more accurate stellar rv

current status of our study

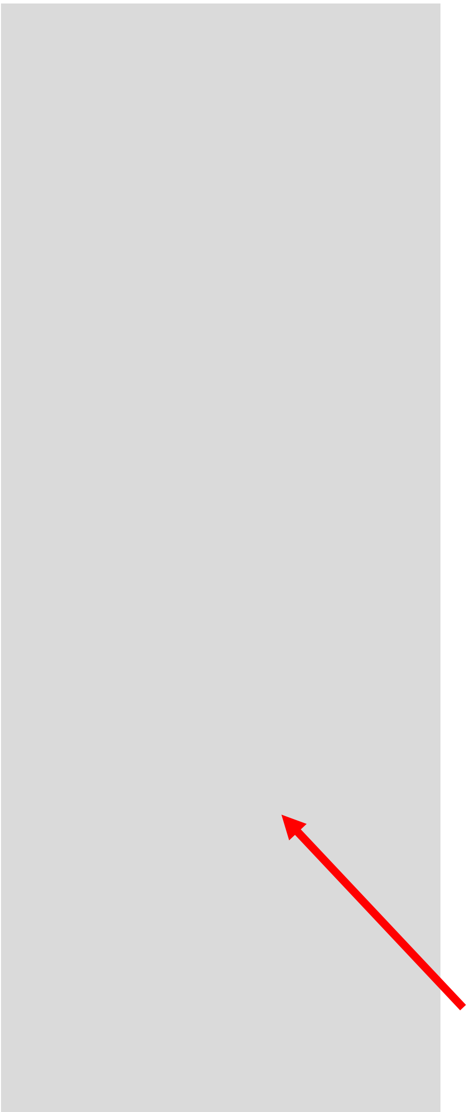
* astro-comb is installed in July 2016 but still under adjustment

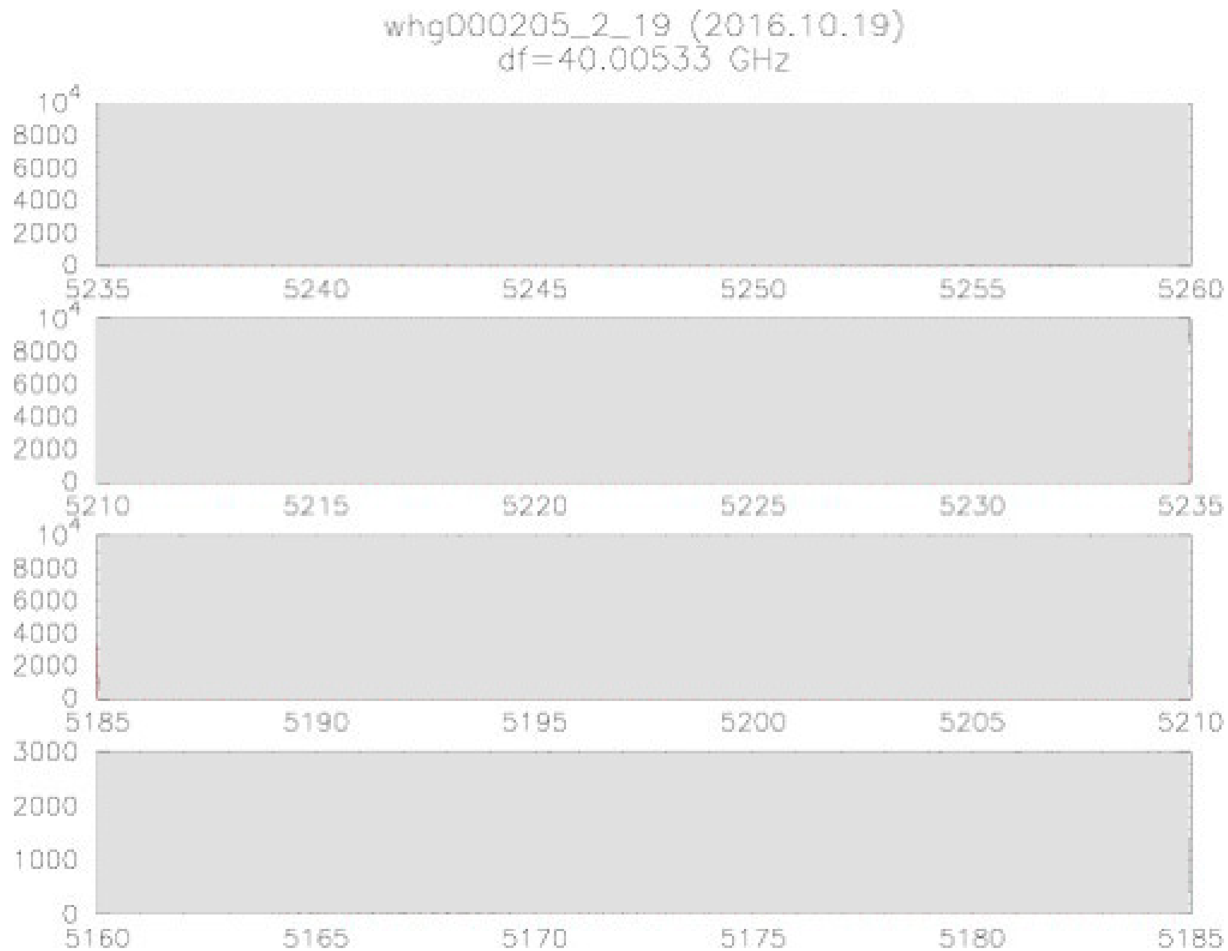
* 40 GHz combs were observed over one order (9 nm) of the echelle spectrograph in October 2016

* we made test observations for two nights, in Dec, 2016 and Feb, 2017

➔ I will shows some preliminary results with Th-Ar spectra

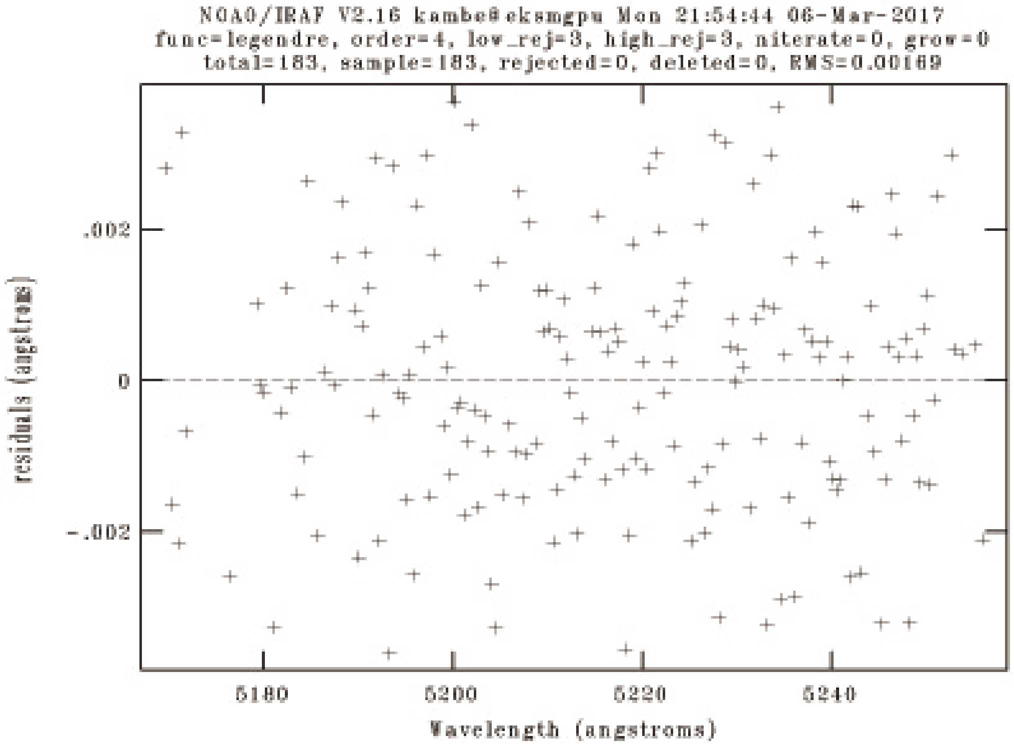
an astro-comb spectra in October 2016





250+ lines per order

we tried to make pixel-to-wavelength mapping with standard IRAF routine assuming equidistant comb peaks

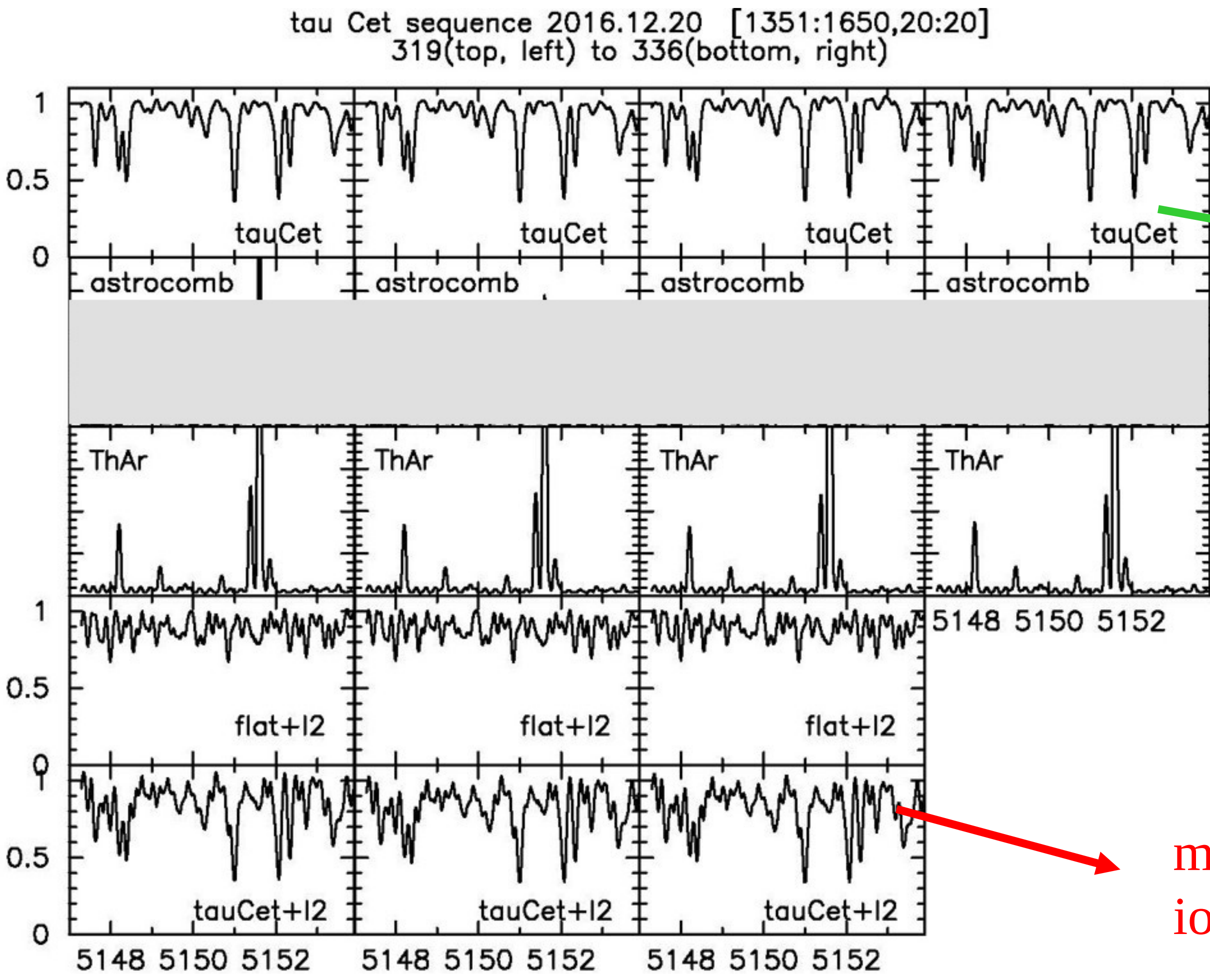


100 m/s

rv precision is 100 m/s per line ➔ 2 m/s per 2,500 lines

it is good as a first trial, but at least twice as bad as the one photon noise predicts test observations in 20 Dec, 2016 and in 9 Feb, 2017

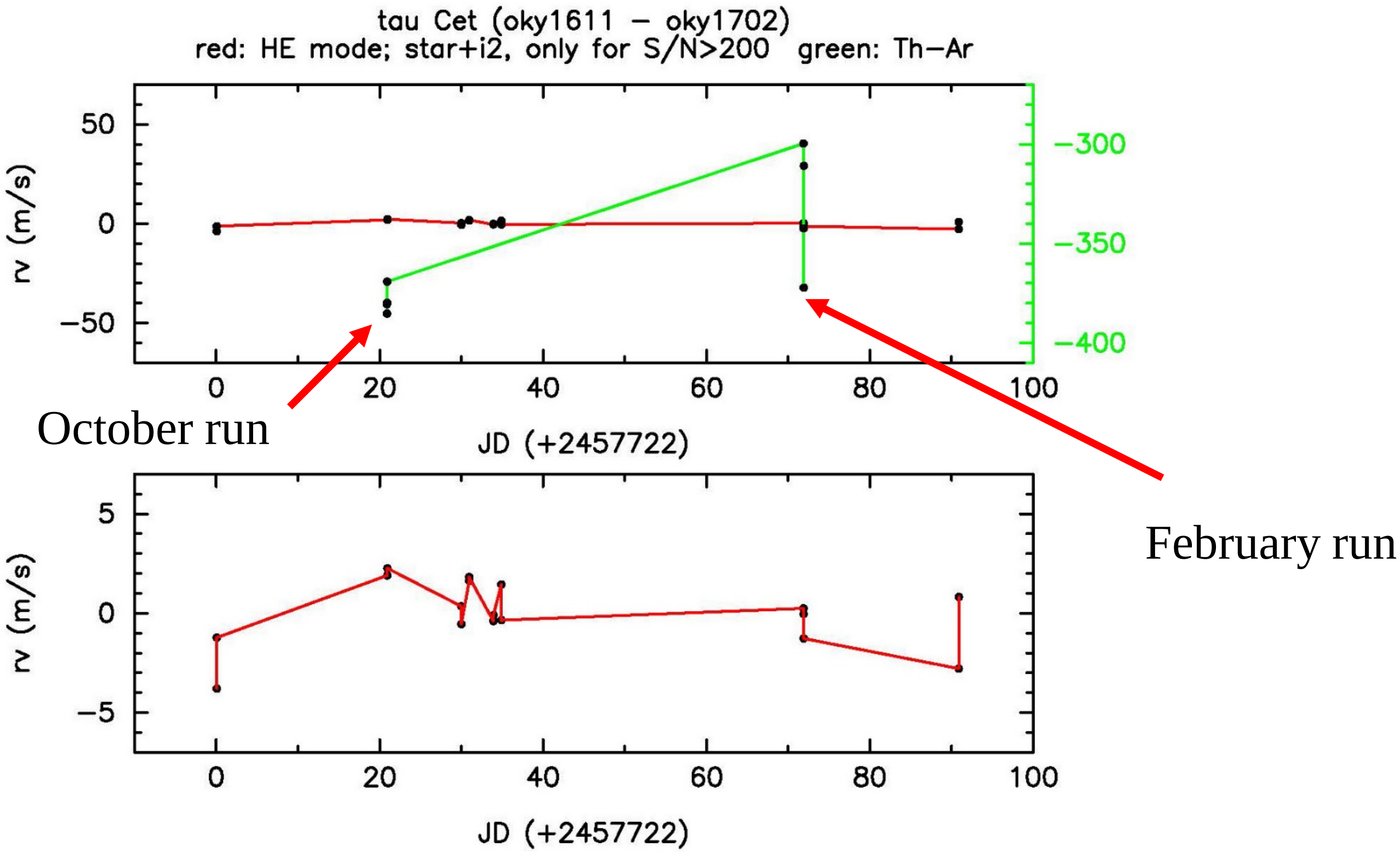
in these observations, we took stellar (tau Cet and Procyon) and reference spectra repetitively.



measuring rv from adjacent Th-Ar spectra

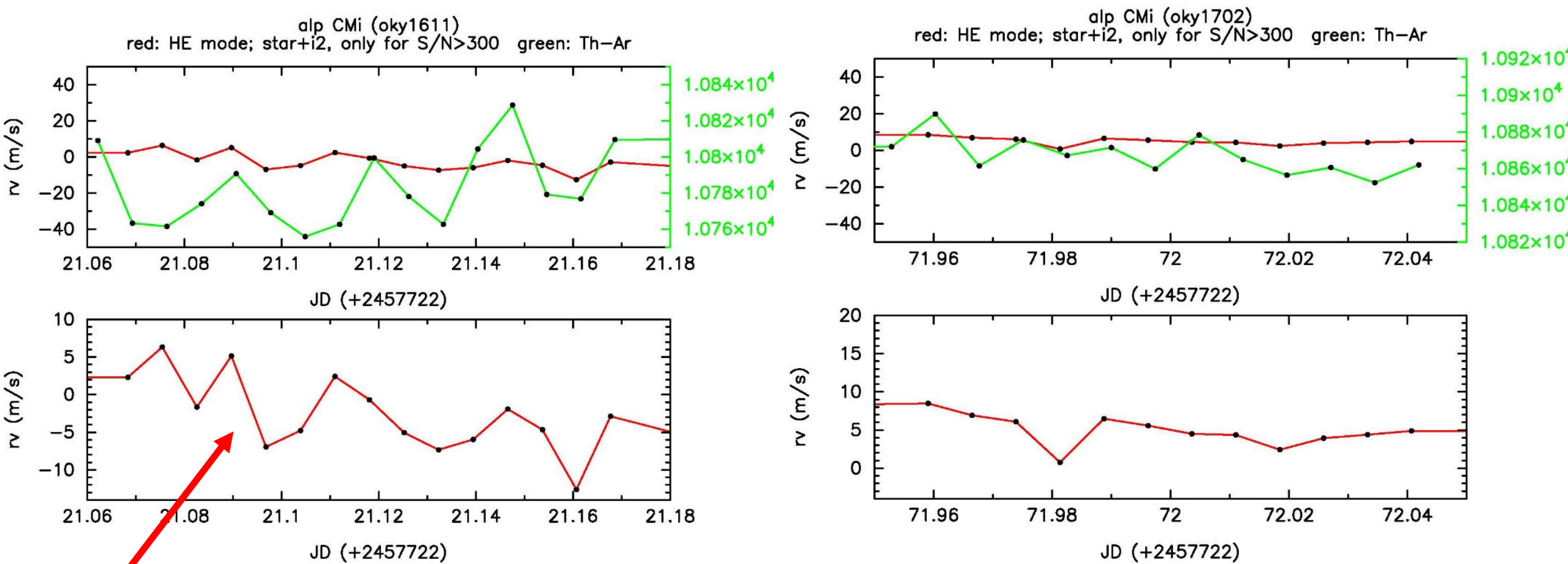
measuring rv by the iodine technique

τ Cet



scatter is about 30 m/s for Th-Ar method
< 2 m/s for the iodine technique

Procyon



due to stellar pulsations

large modulation (~50 m/s) of rv from Th-Ar calibration
➔ probably due to non-uniform illumination of HIDES entrance slit

some plans and a comment on OAO

* we have installed astrocomb and just started experiments

* hardware improvements

on astro-comb itself ➔ Inaba-san's talk

on HIDES

➔ to add a fiber agitator and/or polygon fiber to homogenize science fiber illuminations

➔ stabilize HIDES itself (our director has already got some fund)

* software improvements

- using wavelength information from astro-comb spectra in the iodine technique
- give some restrictions on the shape of instrumental profile from astrocomb lines with very narrow slit (as point spread function) ?

* continue collaborations with other groups

- Univ. of Munich, Xinglong/NAOC are about to start operating their astro-combs and we intend to form a network of exoplanet search telescopes

* a comment on OAO

the operation style of 1.88m (and even that of the observatory itself) will drastically change from 2018

➔ we will terminate the open-use of 1.88 m telescope at the end of this year. Most of the manpower and budget will be used to start up the new Kyoto 3.8 m telescope on the same site.

➔ 1.88 m telescope is likely to be kept maintained by a consortium consisting of current intensive users and the local city government.

this may be a good chance to obtain test observing time for this kind of experimental researches.