Subaru Users Meeting FY2023, 23 - 25 January 2024 (JST) @ NAOJ Mitaka campus.

Astrocomb for HDS precise wavelength calibration

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Abstract

Astrocomb is a laser frequency comb designed for wavelength calibration of high dispersion spectrographs for astronomical observations; an Astrocomb for HDS "HDS comb" is currently under development. The HDS comb will be producing many comb-like emission lines with a precise wavelength in three optical wavelength bands (target wavelength range: 350 nm - 420 nm, 450 nm - 560 nm, 660 nm - 900 nm) with a mode spacing of approximately 30 GHz. The previous version "Okayama comb" was developed for HIDES-F at the Okayama 188 cm telescope and has been in operation since 2019. Compared to other astrocombs in the world, its wide wavelength coverage and long-term durability have advantages for the search for extrasolar planets using Doppler methods with **precise radial velocity (RV) measurements** and for direct measurements of the accelerated expansion of the universe. We plan to install the HDS comb on the Subaru telescope in 2024 and start engineering observations in 2025. In this poster we report on the plan, schedule and status of our project.

Astrocomb（天文コム）

- A laser frequency comb（光周波数コム）for very precise wavelength calibration of high dispersion spectrographs and RV measurements
  - Murphy et al. 2007, Steinmetz et al. 2008, Li et al. 2008 etc.
  - A few hundred MHz (typical comb) → A few ten GHz (astronomy)
- Produce **many comb-like** emission lines with a **precise** wavelength in wide wavelength ranges in optical to infrared.
- Long-term stability with high precisions is required from astronomy.

Science goals of the astrocomb

- Search for (Earth-like) planets around normal stars
  - By using the Doppler method with very precise RV measurements
  - RV precision and stability of **<10cm/s** are required to detect Earth-like planets in the habitable zone around solar-type stars.
  - **Optical** astrocomb is needed for RV monitors of solar-type stars.
- Direct measurements of accelerated expansion of the universe
  - ~10cm/s precision and stability levels are required for a long period.

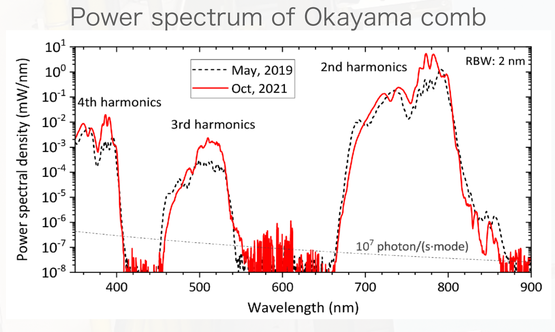
HDS' house at Opt. Nasmyth of the Subaru Telescope

“HDS comb” = Astrocomb for HDS

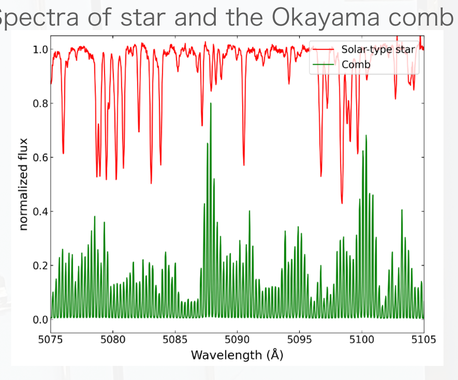
Laser Frequency Comb

- Next version of **Okayama comb**
  - Nakamura et al., Optics Express, 31(12), 20274-20285, 2023
  - Okayama comb has been operated at the Okayama188cm telescope dome since 2019.

Power spectrum of Okayama comb



Spectra of star and the Okayama comb

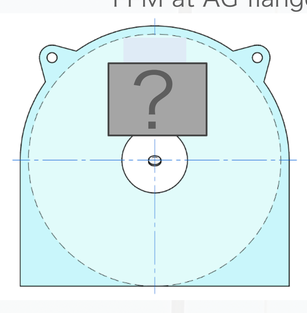


- Mode spacing frequency
  - 30GHz (variable) ~ **0.25** Å@500nm (line spacing)
  - Generates emission lines at suitable uniform frequency intervals
- Target wavelength bands (3 bands)
  - **350 - 420** nm, **453 - 560** nm, **664 - 900** nm (estimates)
- Long term stability : Various innovations (see paper above)
- Manufactured by a Japanese company
  - Easier experimentation and improvement, and **lower cost!**

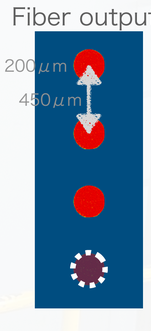
Fiber-Feed Module

- Fiber-Feed module for comb and stellar lights into HDS (3 fibers)
  - Fibers for **object**, **sky(backup)** and **comb** (and more?)
  - Three beams of the lights are injected into HDS simultaneously.
  - Will be installed in front of the HDS slit (not fixed yet)

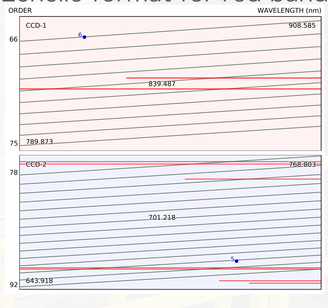
FFM at AG flange of NsOpt



Fiber output



Echelle format for red band



Set-up of HDS

- Radial Velocity precision : **~0.7 m/s = 70 cm/s** (Goal)
- Instrument stability : NOW under investigation
- Resolution : **>30,000 (variable)** # Determined by the slit width
- Wavelength coverages :
  - **390 - 555 nm (recommend)** # Lower limit will be 360 nm.
  - 664 - 900 nm (with strong fringe)

Schedule & Timeline

Operation of previous version comb (Okayama Comb) : **2019-**

Technology transfer to comb manufacturer from AIST team : **2021-2022**

Carry-in proposal : January - April 2024

Pre-ship review : September 2024 (plan)

Engineering review : April - May 2025

Engineering observation start : S25B-

Science review : April-August 2026

Science observation (open-use) : S27A-

Items	2023									2024										2025										2026										2027		
	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Comb order																																														
Comb production																																														
Carry-in Proposal preparation																																														
Carry-in Proposal submission																																														
Pre-ship review																																														
Install to the telecope																																														
Engineering review																																														
Engineering observation																																														
Science review																																														
Science observation (Openuse)																																														

Simulation of 2D data for the HDS comb

(simulation)