# Common questions when planning observations with DKIST Feb 28, 2018

### 1. Can the DKIST instruments work together?

All instruments except Cryo-NIRSP can work together and with Adaptive Optics (AO). All can be operated at once, or only a subset of them can be used (see next question). Note that Cryo-NIRSP will instead work alone, as it requires a relay mirror (M9a) to be inserted in the optical path ahead of the other instruments. The time to switch between the other instruments and Cryo-NIRSP is expected to be of the order of 1 hr.

## 2. How do you split the light when multiple instruments work together?

The light is split using a series of dichroic beamsplitters that transmit longer wavelengths while reflecting shorter wavelengths. Various combinations of such splitters can be used to direct the desired wavelength to any given instrument; it is however important to remember that at any given time, a certain wavelength is directed to one and only one instrument, i.e. no 50/50 split is available. Some small gaps in spectral coverage can also result, depending on the combination of splitters used. More info is available at the page <u>https://dkist.nso.edu/inst/beamsplitter</u>. In the same page, you'll find the socalled DKIST BeamSplitter tool, a GUI that analyzes the proposed light distribution among instruments, and provides possible beamsplitters/mirror configurations.

Finally, an important thing to remember is that the beamsplitters are positioned manually in the beam; given their size and the required precision, changing the light distribution configuration might take up to one day.

## 3. Does the Cryo-NIRSP have image stabilization or support from AO?

If observing near the limb, Cryo-NIRSP can take advantage of the "limb sensor", a system embedded in the limb occulter, that measures and compensates for limb motions. If observing further away from the disk, no stabilization is available. This is true also for the other instruments; no off-limb AO is currently available. On disk, Cryo-NIRSP does not have image stabilization; however, note that seeing-quality improves with wavelength as the Fried parameter scales as  $\lambda^{(6/5)}$ .

### 4. How far off the limb can the DKIST point?

The telescope can point the center of its 5 arcmin FOV out to 1.5 R\_sun. For larger distances, the solar image produced by the primary mirror moves off the heat stop endangering the optical support structure of the telescope.

When observing close to the solar disk, a limb occulter can be used, to minimize scattered disk light. Over/under occulting of  $\pm 5$  arcsec from the limb is possible.

### 5. Can all instruments observe the corona?

Yes. All the instruments can be pointed to the corona, however, scattered light performance and the sensitivity of coronal magnetic field diagnostics both improve in the infrared. Cryo-NIRSP and DL-NIRSP specifically target coronal science. The defining feature of the Cryo-NIRSP is its cryostat that minimizes the thermal IR background for high-dynamic range observations out to 4.6 micron. Still, coverage of visible coronal spectral lines is available with the other instruments as well.

### 6. Can the DKIST observe the corona on the solar disk?

Alas, no. In the visible/IR spectral range accessible with DKIST, coronal structures are too faint to overcome the background (photospheric) continuum.

### 7. How large is the FOV of the DKIST?

The short answer is: the telescope has a hard limit of 5' (round), but each instrument can access only a portion of this without repointing the telescope. For Cryo-NISRP, the FOV is between 2-4 arcminutes; for the other instruments, the FOV is between 1 and 2 arcminutes.

However, there are a lot of details that need to be considered. See next questions.

#### 8. What limits the FOV of the DKIST?

The fixed 5' (diameter) FOV of the DKIST is due to the size of the heat stop at prime focus (the heat stop is hence also a field stop). This is a compromise between the need for a large FOV and the need to limit the amount of light/heat being transmitted further down the optical path.

A second field stop is then used at the Gregorian (secondary) focus. This can be 5' or 2.8' in diameter, and in either case a limb-occulter is available. Limb over/under occulting of up to 5" is possible.

For coronal observations with Cryo-NIRSP the 5' diameter field stop is used; the instrument's optics are designed for a large FOV, and the field stop at the Gregorian focus essentially works to suppress stray light (or the limb, if close enough to the disk). For all the other instruments the 2.8' diameter field stop is used. Indeed, these instruments' optics are designed for a maximum FOV of 2'x 2' (the square inscribed in the 2.8' diameter).

The default field stop for Cryo-NIRSP on disk observations is the 2.8' field stop. In this mode, the narrow disk slit extends across 2' consistent with the area over which the Cryo-NIRSP achieves its highest spatial resolution.

### 9. What is the FOV of the single instruments? Can you cover a larger FOV?

All the details are provided in the "Instrument Summary Documents" accessible from the web page <a href="https://dkist.nso.edu/CSP/instruments">https://dkist.nso.edu/CSP/instruments</a>. Here a few important points:

The maximum FOV for Cryo-NIRSP in coronal mode is 4' (slit length) x 3' (scan perpendicular to slit). For on-disk mode, this becomes 2'x 2' (the 2.8' field stop is used, and only half of the detector is read).

As mentioned before, the optics of all other instruments are designed for a max. FOV of 2'x 2'. However, none of them can cover such an area at once; some can "field sample", i.e. mechanically move some elements to cover a larger field. For others, it is necessary to repoint the telescope.

- VBI has an instantaneous FOV of 45"x45" (blue), or 69"x69" (red). By physically moving the cameras, it can cover the max. 2'x2' FOV with 9 (blue) or 4 (red) tiles.

- DL-NIRSP has an instantaneous FOV defined by its feed optics configuration and selection of IFU, which together support three modes. By moving a relay mirror, it can cover the 2' x 2' field using field sampling. In middle resolution mode, e.g., this requires a mosaic of 20 x 20 (=400) tiles.

- ViSP has an instantaneous FOV of (50", 60", 75") x slit width, with the three numbers referring to the three different camera arms. The slit can be stepped in an arbitrary number of steps to cover up to 2' in the perpendicular direction.

- VTF has an instantaneous FOV of 60"x60" and no moving imaging hardware. To cover a larger area, the telescope must be repointed.

## 10. How long will it take to build up a particular FOV with rastering instrument?

This depends on a number of variables, including slit size, rastering step size, desired exposure times, S/N values, and so on. Many details are available in the "Instrument Summary Documents" accessible from the web page https://dkist.nso.edu/CSP/instruments. As a general idea,

- the VBI can move from one instantaneous FOV (tile) to another in about 0.5 second;

- the ViSP slit can be stepped between two adjacent positions in less than 200 ms (in the default polarimetric mode);

- the DL-NIRSP can step between field positions in a map in about 50 ms.

The Instrument Teams have released Instrument Performance Calculators (IPC), i.e. software applications that can provide precise answers to such questions. You can find them at https://dkist.nso.edu/CSP/instruments.

### 11. What is the limit in cadence? (I.e. how fast can you go?)

Again, it depends on a number of variables. For the spectrographic instruments, fastest observations will be obtained in spectroscopy-only mode, instead of polarimetry, and for small FOVs. Sit & stare spectroscopy observations with VISP, or single tile for DL-NIRSP, will reach sub-second cadence. Sub-second cadences can be obtained also for imaging instruments, like VBI and VTF, if observing at any single wavelength; remember however that the default mode for VBI is that of reconstructed (speckled) images, with a 3.2 s cadence. For Cryo-NIRSP, sub-second observations should be possible on disk, whereas coronal cases will have a limit of about a second to achieve enough photons.

The Instrument Performance Calculators can provide all these numbers for a variety of input cases.

# 12. How long can the DKIST continuously observe one target or track one position?

Observations are most often limited by degradation of the atmospheric seeing, which might push the spatial resolution to values lower than requested. From the site survey results, we know that the best seeing occurs in the early morning, with a typical duration of 1-2 hours. If lower resolution is sufficient, sequences of several hours could in principle be obtained, but one needs to remember the need for proper calibrations, and the obvious limited number of daylight hours.

#### 13. Is there a fixed orientation of the solar image?

No. Like at the Dunn Solar Telescope, the instruments are positioned on a rotating platform, whose orientation can be changed to satisfy different scientific requests. For example, the vertical axis of the images can coincide with the solar N-S, or a filament's axis, or be perpendicular to the magnetic inversion line in an active region. The orientation can be maintained throughout the duration of the observations, or can be changed rapidly if desired (of the order of minutes). Orientations can also be selected that minimize the effect of terrestrial atmospheric refraction on spectral observations.

### 14. What are the best times to observe with which instruments? (this will become key in connecting up to, e.g. Solar Orbiter orbits).

There is no special, best observing period for any given instrument. The site survey results (Hill et al 2006, SPIE, Volume 6267, id. 62671T) showed that winter is a period with very good seeing, albeit with less observing hours/day, while spring (April-May) might be the worse time of the year with respect to seeing and bad weather days. The Cryo-NIRSP will be operated mostly when sky coronal conditions are optimal, and this can happen throughout the year.

#### 15. Does the DKIST have a Target of Opportunity Program?

Yes. A target of opportunity (ToO) program is defined as a standard program allowing for the study of solar phenomena that are rare, and whose occurrence is hard or even impossible to predict (in time and location). Typical cases include flares, appearance of  $\delta$ -spots, a sunspot at disk center, etc.

### 16. How much advance notice is required for pointing?

The question about advance notice is relevant only if a DKIST observing program is coordinated with other facilities, satellites in particular. The latter often require a few days of advance notice; DKIST can point at the target agreed upon without further restrictions.

For other programs, it is expected that most of DKIST observing will be conducted in service mode, i.e. with scientific observing requests queued and executed only when solar conditions (target availability) and weather conditions are suitable. This implies that actual telescope pointing is decided dynamically, with target selection performed most likely on the same day of the observations.

### 17. What is a DKIST Coordinated Program?

A coordinated program is a program where the DKIST and another facility are coobserving AND where details about temporal constraints and pointing information need to be communicated on a likely daily basis between identified stakeholders.

### 18. What is a DKIST Synoptic Program?

A synoptic program is a program that is supposed to be repeated/executed over a total period of time that is longer than one proposal cycle (i.e. over time scales of years, or, in general, solar cycle relevant time scales).

#### Further info & documentation:

The page <a href="http://dkist.nso.edu/CSP/instruments">http://dkist.nso.edu/CSP/instruments</a> contains all the necessary links to:

-- Tar file of IPC software. IPCs require IDL (version 8 and higher) and Java (at least Oracle Java 1.9 JRE).

- -- Beamsplitters software tool.
- -- Summary docs for all instruments.
- -- Description of DKIST in a "nutshell".
- -- Summary table of instruments capabilities.