PALM-3000 Observing Scenarios
CIN #623

Document Owner: Antonin Bouchez

Revision Sheet

Release No.	Date	Revision Description
Rev. 0.2	2/6/07	Compiled Team Meeting #1 observing scenarios into single document; A. Bouchez.
Rev. 0.3	3/20/07	Added SWIFT scenario; A. Bouchez.
Rev. 0.4	6/4/07	Added P1640 scenario contributed by B. Oppenheimer; A. Bouchez.
Rev. 1.0	7/16/07	Added LGS-AO LOWFS acquisition, updated format; A. Bouchez

Contents

1 GENERAL INFORMATION

1.1 Purpose

This note documents notional observing scenarios for the PALM-3000 adaptive optics system, providing a more detailed look at the key science cases described in the PALM-3000 Science Requirements Document (SRD).

1.2 Definitions

None

1.3 Acronyms and Abbreviations

AO	Adaptive optics
CCD	Charge-coupled device
DM	Deformable mirror
IRTTS	Infrared Tip/Tilt Sensor
TWFS	Truth wavefront sensor
HOWFS	High-order wavefront sensor
LOWFS	Low-order wavefront sensor
LGS	Laser guide star
NGS	Natural guide star
PALM-3000	A 3000+ actuator upgrade to the Palomar AO system

1.4 Related Documents

PALM-3000 Science Requirements Document (SRD)
PALM-3000 Instrument Requirements Document (IRD)

1.5 Point of Contact

Antonin Bouchez
Email: abouchez@astro.caltech.edu
Tel: (626) 395-8915

2 INTRODUCTION

2.1 List of observing scenarios

I have attempted to compile observing scenarios for one high priority project per back-end instrument. Table 1 lists the observing scenarios included in this document at present.

Section	Project	Author	Instrument
3	Kuiper Belt object multiplicity	Bouchez	PHARO
4	Stellar populations in nearby galaxies	Bouchez	VImager
5	IFU spectroscopy of z=1 galaxies	Bouchez	SWIFT
6	Imaging hot young Jupiters	Oppenheimer	P1640

Table 1: **List of PALM-3000 observing scenarios**

2.2 PALM-3000 acquisition procedures

Every observing scenario begins with the acquisition of a target with PALM-3000, either in NGS or LGS modes. While the details of this acquisition procedure depend somewhat on the implementation choices of the various wavefront sensors, I list in this section two plausible acquisition procedures for the current baseline design (a branching design with single HOWFS, TWFS, IRTTS, and CCD acquisition camera). Individual observing scenarios will note deviations from these standard procedures.

2.2.1 NGS acquisition procedure

The following procedure could be used to acquire a target with a bright (V=8) off-axis NGS. It assumes that the acquisition camera field of view patrols with the HOWFS.
1. Slew the telescope to the science target location.
2. Setup steps which can be performed during the slew:
    a. Rotate the Cassegrain ring if necessary.
    b. Configure the AO system for NGS-AO.
    c. Offset HOWFS to the off-axis position of NGS with respect to science target.
    d. Set the HOWFS framerate to a value appropriate for the NGS.
3. Record an acquisition camera image; identify the NGS.
4. Offset the telescope to place the NGS on the HOWFS field stop.
5. Offset the telescope and acquire a HOWFS background frame.
6. Close the tip/tilt loop on the HOWFS.
7. Register the HOWFS lenslets to the DM actuators.
8. Close the high-order loop on the HOWFS.
9. Record the average DM actuator position and reinitialize the servo leak map (aka. flatmap).
10. Optimize HOWFS control loop.

2.2.2 LGS acquisition procedure with an IRTT WFS

The following procedure could be used to acquire a target with a faint (V=18) known off-axis NGS, using a fixed (with respect to the instrument optical axis) imaging/ROI infrared tip-tilt sensor (IRTTS), and a patrolling visible Shack-Hartmann truth wavefront sensor (TWFS).
1. Slew the telescope to the science target coordinates.
2. Setup steps which can be performed during the slew:
    a. Rotate the Cassegrain ring if necessary.
    b. Configure the AO system for LGS-AO.
    c. Offset the TWFS to the off-axis position of the NGS with respect to the science target.
    d. Set the HOWFS framerate to a value appropriate for the LGS.
    e. Set the IRTTS integration time for full-frame acquisition appropriate for the NGS.
    f. Set the TWFS framerate to a value appropriate for the NGS.
3. Acquire a HOWFS background on the sky.

4. Project the laser.
5. Record an acquisition camera image; identify the LGS.
6. Offset the UTT mirror to center the LGS on the HOWFS field stop.
7. Close the UTT loop.
8. Close the HOWFS loop.
9. Register the HOWFS lenslets to the DM actuators.
10. Offset the telescope and acquire IRTTS and TWFS background frames.
11. Offset back and record a full-frame IRTTS acquisition image.
12. Select the NGS and close the tip-tilt loop on the nearest IR-TT quad cell (note: this will shift the field by up to ~25 mas on the science instrument and the TWFS)
13. If necessary, (re)position the TWFS:
    a. If position of NGS was poorly known, offset the TWFS based on the measured position of the NGS in the IRTTS acquisition image.
    b. Null out measured tip/tilt in TWFS by offsetting it.
14. Close the focus loop on the TWFS.
15. Once focus has been offloaded from the DM to the HOWFS focus stage, record the average DM actuator position and reinitialize the servo leak map (aka. flatmap).
16. Optimize LGS, UTT, TT, and Focus control loops.

2.2.3   LGS acquisition procedure with the LOWFS

The following procedure could be used to acquire a target with a moderately faint (V=17) known off-axis NGS, using the LOWFS rather than the IRTTS and TWFS.

1. Slew the telescope to the science target coordinates.
2. Setup steps which can be performed during the slew:
    a. Rotate the Cassegrain ring if necessary.
    b. Configure the AO system for LGS-AO.
    c. Offset the LOWFS to the off-axis position of the NGS with respect to the science target.
    d. Set the HOWFS framerate to a value appropriate for the LGS.
    e. Set the LOWFS framerate to a value appropriate for the NGS.
3. Acquire a HOWFS background on the sky.
4. Project the laser.
5. Record an acquisition camera image; identify the LGS.
6. Offset the UTT mirror to center the LGS on the HOWFS field stop.
7. Close the UTT loop.
8. Close the HOWFS loop.
9. Register the HOWFS lenslets to the DM actuators.
10. Offset the telescope and acquire a LOWFS background frame.
11. If necessary, position the LOWFS:
    a. If position of NGS was poorly known, offset the LOWFS based on the measured position of the NGS in the acquisition camera image.
12. Close the tip/tilt and focus loops on the LOWFS.
13. Once focus has been offloaded from the DM to the HOWFS focus stage, record the average DM actuator position and reinitialize the servo leak map (aka. flatmap).
14. Optimize LGS, UTT, TT, and Focus control loops.

3   KUIPER BELT OBJECT MULTIPLICITY

3.1   Introduction

Approximately 800 Kuiper Belt Objects are known, most with V>20. Several dozen of the larger KBOs have 18<V<20. They are quite red, with B-V≈1.0, V-J≈1.5, V-K≈2.5. In most cases, therefore, one would choose to perform low-order wavefront sensing on field stars near the KBO. This is aided by the fact that KBO's orbital motion (~1"/hr) allows one to time the observations such that the KBO is near a reasonably bright NGS. For this exercise, we'll assume that the KBO in question is passing within 40" of an R=18.0 star, identified from the USNO-B1.0 catalogue. This probably occurs ~2 times per month for

any given KBO, thus on any given night, approximately 30 KBOs are available (only a couple of which will have K<18).

The goal of the observations is to detect a faint satellite, which will typically have ∆K>3, a separation of 0.1-1.5", and an orbital period of several weeks.

3.2   Obsesrvations.

1. Follow the acquisition procedure described in section 2.2.2
2. Take a short exposure to confirm KBO centration (30s).
3. If not centered quite right. (NGS Dither)
    3.1. Offset telescope. (this is to keep FSM from saturating)
    3.2. Counter-offset LOWFS. (this moves the laser relative to the sky, but maintains laser on science instrument sweet spot)
4. Begin series of long exposures (60s maximum if motion is 1"/hr. Number of frames in each dither position depends on dithering overhead, to keep overhead <20% of total time.) The faster the dither cadence, the better the sky subtraction.
    4.1. For nonsideal object, perform NGS Dither during exposure.
5. Dither object on camera by 5" (laser tracks object) (LGS Dither)
    5.1. If LOWFS not behind SSMs
        5.1.1.   Offset telescope.
        5.1.2.   Counter-offset LOWFS
        5.1.3.   Offset SSMs (this keeps the laser at the same pointing on the sky while moving the laser relative to science camera (tracking the target, which also moved).)
        5.1.4.   UTT mirror moves to keep laser on HOWFS (- depending on isoplanatism and dither size, one may not care)
    5.2. If LOWFS behind SSMs
        5.2.1.   Offset SSMs (this keeps the laser at the same pointing on the sky while moving the laser relative to science camera (tracking the target, which also moved).)
        5.2.2.   Counter-offset telescope.
        5.2.3.   UTT mirror moves to keep laser on HOWFS (- depending on isoplanatism and dither size, one may not care)
6. Continue imaging sequence, 4 dither positions minimum.

3.3   Calibration
7. PSF Calibration: Repeat the above procedure on a pair of stars with identical separation, with the KBO surrogate being an IR-bright star. Science camera exposures will be short (2-10s).
8. Photometric Calibration: Image photometric standards with all loops open, dithering the stars on the detector at 4 locations separated by 10" (Telescope repointing)

4   STELLAR POPULATIONS IN NEARBY GALAXIES

4.1   Introduction

Studies of the stellar populations of nearby galaxies can greatly benefit from laser guide-star adaptive optics, which allows individual giant stars to be resolved and studied both photometrically and spectroscopically. This observing scenario describes observations of a nearby galaxy (M31, Andromeda) which require deep, high-resolution visible imaging over a large sky area. The NGS in this example is a V=15 foreground field star in our galaxy which happens to lie in the line of sight to the Andromeda galaxy bulge. We will use the VImager to image a 30"x30" region of the galaxy in 3 bands (V,R,I), centered 55" from the NGS.

4.2   Observations
1. Follow the acquisition procedure described in section 2.2.2
2. Perform NGS offset to first mosaic position (55"N, 30"E) center of field + (25"N, 25"E) 1st mosaic offset.

3. Pause until TT and focus loops are stable (avoid bad focus commands).
4. Insert V filter.
5. Run "lgs_bxy4_1" macro with one 120s integration at each position (4 positions, at the vertices of a 1 arcsecond box, using LGS dithers).
6. Repeat 4-5 in the R and I filters.
7. Perform NGS offset back to tip/tilt star for MASS/DIMM PSF calibration.
8. Insert V filter.
9. Run "lgs_bxy2_1" macro with one 10s integration at each position (2 positions, 1" apart, using LGS dithers).
10. Repeat 23-24 in the R and I filters.
11. Repeat 17-25 at 8 other mosaic positions.
12. Offset to blank sky and record skies in all filters and integration times.

Total time: ((720s + 15 ~1" LGS dithers + 2 filter changes + 1 ~50" NGS dither) +
                (60s + 9 ~1" LGS dithers + 2 filter changes + 1 ~50" NGS dither)
                x 8
Assumptions: 1" LGS dithers take: 3s
                50" NGS dithers take: 50s
                Filter changes take: 20s
                Then total time = 3.8 hr (86% open shutter efficiency) not including sky frames.

4.3   Calibration

13. Photometric Calibration: Image photometric standards with all loops open, dithering the stars on the detector at 4 locations separated by 10" (Telescope repointing)

5   DYNAMICS OF Z=1 GALAXIES

5.1   Introduction

The core science case for the SWIFT imaging spectrograph is the study of the internal dynamics of galaxies at z=1.0-1.5. This is a challenging observing scenario, and assumes a faint tip-tilt star (M_H=18) 30" from the galaxy, appropriate to a sky coverage fraction of 5%. The expected ensquared energy fraction at I band in an 80 mas spaxial using an 8W laser is ~20%. This scenario is written assuming an imaging/ROI infrared tip-tilt sensor (IR-TT), and a visible Shack-Hartmann TTFA sensor (V-TTFA).

5.2   Observations

1. Follow the acquisition procedure described in section 2.2.2
2. Acquire first long integration (900s?)
3. Offset the telescope to move the galaxy to the oposite end of the SWIFT FOV.
    3.1. Open TT and Focus loops.
    3.2. Offset the telescope (eg. 5" north)
    3.3. Change the IR-TT control pixels to a quad cell (5" to the south, here again the quantized locations of quad cells limit control to +/- 25 mas.)
    3.4. Offset the V-TTFA (5" south)
    3.5. Close TT and Focus loops.
4. Acquire second long exposure (~900s integration?)
5. Sky-subtract, identify target. If necessary, offset to adjust pointing. Repeat until sufficient SNR has been accumulated.
6. A new IR-TT backgrounds may be needed after every pair of 900s integrations, due to changing IR sky brightness with airmass.
    6.1. Open TT and Focus loops.
    6.2. Offset 60" to blank sky.
    6.3. Acquire IR-TT (and a V-TTFA background, if no overhead).
    6.4. Return to target and close TT and Focus loops.

5.3   Calibration

TBD

6   IMAGING HOT YOUNG JUPITERS

Contributed by Ben Oppenheimer

6.1   Introduction

We have very few requirements on the AO system's doing anything other than providing the corrected beam during observations. I presume we will need a little hand shaking in software for when AO is starting to lose lock or something like that, but otherwise it is simple. We can handle essentially all the movements of stars and fields, etc. No dithering in coronagraphy.

1640 is an IR multispectral imager preceded by a coronagraph, designed to detect companions and discs around target stars and extract spectral information. Outside of the obvious fact that we require Palomar to acquire, track a target, and provide photons, Project 1640 is, in a sense, a stand alone device.

6.2   Observations

Once Palomar is locked on to a target, our procedure is as follows:

1. Obtain from Palomar observing parameters: Start and end time of observation, any atmospheric data, and data on seeing, if available, AO settings, telescope pointing and telemetry, and any other feedback we can get from the TCS. (This is something we have done zero work on at this point and we will need any documentation on communicating with the TCS and AO system, if there is any.)
2. Acquire the image in our field of view.
3. Set integration times for acquiring "core" images, images of the target prior to being moved, by us, behind the coronagraph's occulting mask.
4. Take a few core images sets. (A set of data is a sequence of images taken under conditions of different polarizations.)
5. Move the target star behind the mask and lock our secondary tip/tilt system
6. Set integration time for data acquistion. (Likely to be between 7 sec and a few minutes)
7. Acquire multiple sets of data as per science requirements and SNR needs.
8. Obtain from Palomar observing parameters: Start and end time of observation, any atmospheric data, and data on seeing.

Move to the next target.