

INDIGO Framework

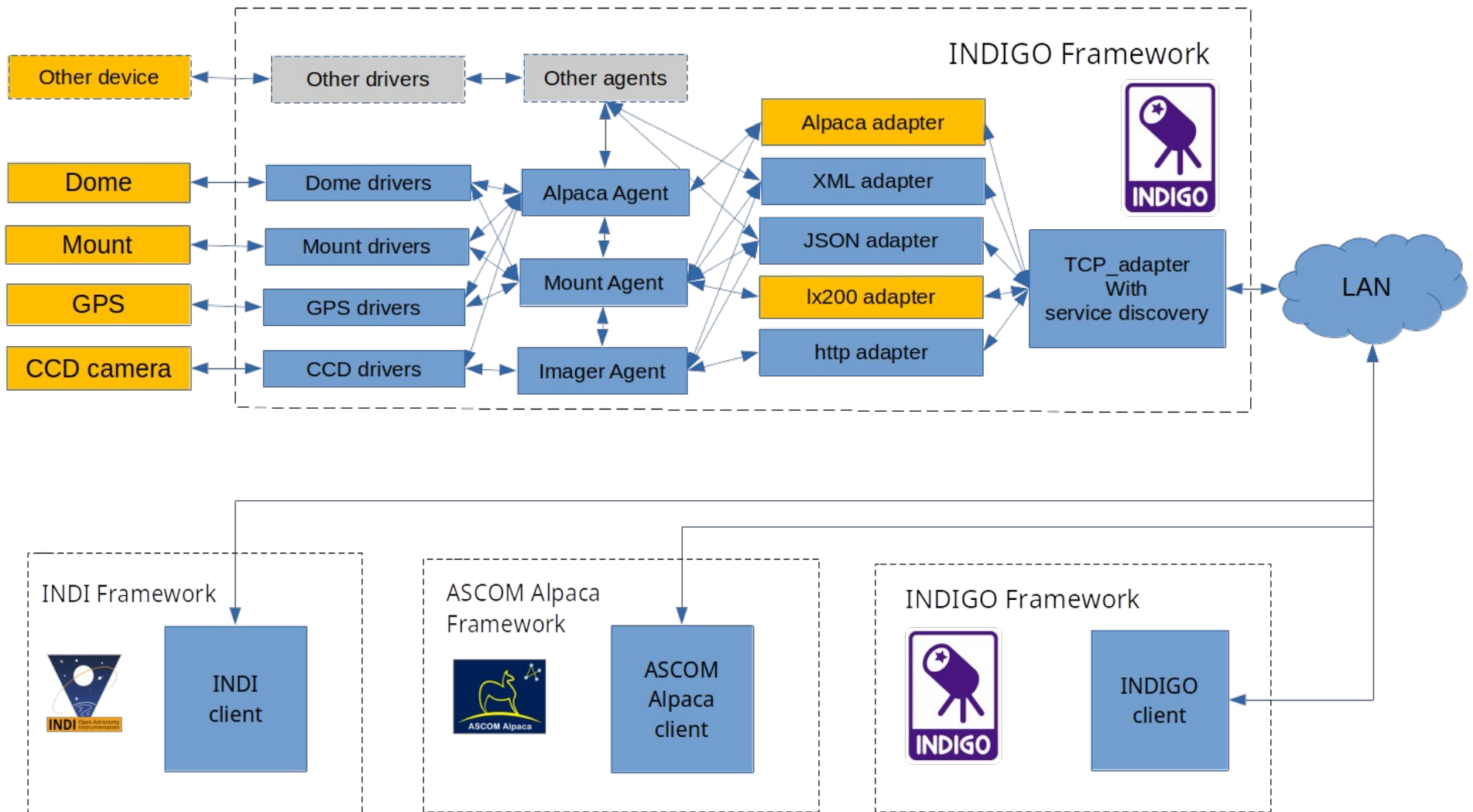
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What is INDIGO?

- INDIGO is a software framework for controlling Astronomical equipment via a **software bus**
- A set of **properties** are defined for each device - **mandatory, optional** and **device specific**
- The communication between different entities attached to the bus is achieved by **INDIGO messages** which contain property events – **definition, update** and **deletion**
- One can think of the properties as both **variables** and **routines**. Variables as they may store values like the width and height of the CCD frame or routines like start 1 second exposure.

INDIGO Architecture



Notes:

- INDIGO uses a software data bus - arrows show the logical data flow, not the hard communication lines.
- Clients will run their native frameworks.

INDIGO Drivers

- **Dynamic drivers** – fast communication, can be dynamically loaded and unloaded
- **Static Drivers** – can be used to be linked in one monolithic application, fast communication
- **Executable drivers** – old style drivers, these drivers can be loaded in INDI and this is how INDIGO can load INDI drivers, orders of magnitude slower communication.

INDIGO Agents vs Drivers

- Agents are high level drivers that provide application business logic
- Agents can communicate between each other
- Agents can access the devices through the device drivers
- Drivers translate INDIGO messages to device specific commands and provide unified interface to all devices
- Drivers are simple, only capable of basic operations no complex business logic
- Inter driver communication is possible through the agents

INDIGO Device Classes

Main

- **Mount**
- **Camera**
- **Guider**
- **Focuser**
- **Filter Wheel**
- **Dome**
- **GPS**
- **Adaptive Optics**
- **Field Rotator**

Auxiliary

- **AUX Joystick**
- **AUX Shutter**
- **AUX Power Box**
- **AUX SQM**
- **AUX Dust Cap**
- **AUX Light Box**
- **AUX Weather Station**
- **AUX GPIO**

INDIGO Agents

- **Imager agent**
- **Guider Agent**
- **Mount Agent**
- **Scripting Agent**
- **Astrometry Agent**
- **ASTAP Agent**
- **Auxiliary Agent**
- **Alpaca Agent**
- **Snoop Agent** (*obsolete*)
- **Lx200 Agent** (*obsoleted by Mount agent*)

INDIGO Server

- Provides network access to the devices
- Provides Access Control to the devices
- Can connect to another servers and reexport their devices
- Provides mDNS / Bonjour service discovery
- Can load and unload drivers
- Can operate headless – client can connect program it and disconnect then connect and download the data.

INDIGO Clients

- Clients can connect to INDIGO server and can control the remote devices
- Clients can load the drivers themselves and control the locally attached devices
- INDIGO clients can act like INDIGO servers
- INDIGO clients can provide a UI to control the infrastructure.
- INDIGO clients can detect INDI servers and automatically switch to the legacy communication mode.

Why INDIGO if INDI, Alpaca and ASCOM are here?

- ASCOM is windows only, **INDIGO is multi platform**
- **INDIGO is all about speed**, it is several times faster than ASCOM, Alpaca and INDI

By default INDIGO uses shared memory for communication on a single host which is many times faster than the pipes used by INDI and multiple data copies used by ASCOM.

Over the network INDIGO uses binary data transfer (optionally compressed) which is several times faster than the text encoded binary data used by INDI and Alpaca.

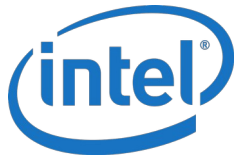
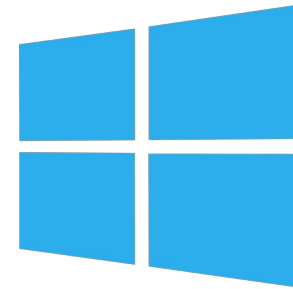
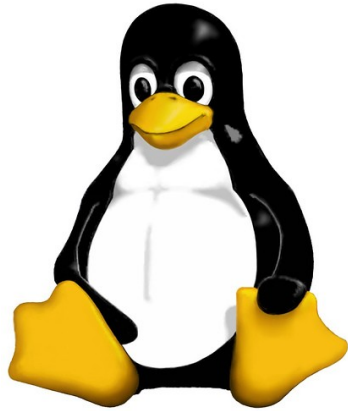
Why INDIGO if INDI, Alpaca and ASCOM are here? (continued)

- INDIGO has **agents** and all the business logic can be run on the server (*no other platform provides this*)
- INDIGO provides **service discovery** – no need to enter server address (*unlike INDI*)
- INDIGO supports **hot plug for USB devices** (*unlike INDI*)
- INDIGO **can work without a server** like ASCOM and with server like INDI and Alpaca

Why INDIGO if INDI, Alpaca and ASCOM are here? (continued)

- INDIGO can be extended with **INDIGO Script**, based on ECMA Script (*no other platform provides this*)
- INDIGO can operate in **headless mode** – clients needs to upload the plan and later to connect to collect the data (*no other platform provides this*)
- INDIGO provides **device access control** (*no other platform provides this*)
- INDIGO is **free and open source**, released under the very permissive and vendor friendly INDIGO license

INDIGO Supported Platforms



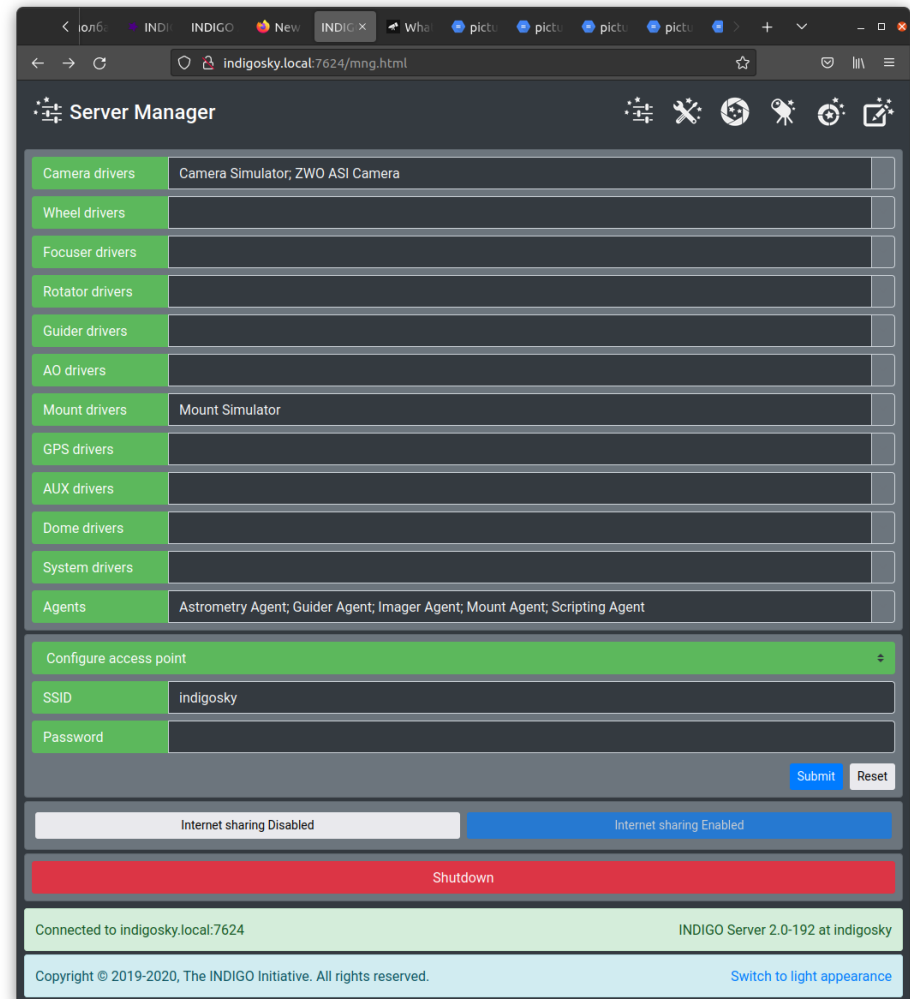
ARM



**Client only*

INDIGO Sky

INDIGO Sky is a free Integrated OS image for Raspberry Pi



INDIGO MacOS Apps

The screenshot displays the INDIGO MacOS software interface, which is used for controlling astronomical equipment. The interface is organized into several main sections:

- Top Menu:** Includes 'INDIGO A1', 'Console', 'Mount', 'Imager', 'Guider', 'View', 'Window', and 'Help'.
- Console (Top Left):** A log window showing system events such as '19:52:11.027 Moving west' and '19:54:08.140 Guiding finished'.
- Mount Simulator (Middle Left):** A star chart showing the current field of view with a green box indicating the target area. Stars like Betelgeuse and Rigel are labeled.
- Mount Parameters (Bottom Left):** A panel for configuring the mount, including 'No dome', 'No GPS', and 'No joystick' options.
- Imager/Imaging Simulators (Center):** Multiple windows for configuring the imager and guider. These include settings for 'Exposure (s)', 'Gain', 'Gamma', 'Offset', and 'Count'. There are also 'CCD Imager Simulator' and 'CCD Guider Simulator' windows.
- Camera Feed (Center Right):** A large window showing the live video feed from the camera. It includes a crosshair and a small inset showing the field of view.
- Statistics (Right Side):** Two panels displaying real-time statistics for the camera feed, including 'Frame size', 'Min', 'Max', 'Average', and 'Median' values. The bottom right panel also shows 'FWHM', 'HFD', and 'Peak' values.
- Bottom Dock:** A dock containing various system and application icons, including Finder, Spotlight, and several utility apps.

INDIGO Dashboard and Script Editor

The screenshot displays the INDIGO Dashboard and Script Editor interface. The dashboard is divided into several panels:

- Mount list @ Mount Agent:** Shows the status of the mount (No mount or Mount Simulator).
- Related agent list @ Mount Agent:** Lists agents like Imager Agent, Scripting Agent, and Guider Agent.
- Limits @ Mount Agent:** Configures HA tracking limit, time limit, and change threshold.
- LX200 Server configuration @ Mount Agent:** Sets the server port (4030).
- LX200 Server state @ Mount Agent:** Controls the LX200 server (Stop or Start).
- Set host time @ Mount Agent:** Configures host time for the mount or dome.
- Location coordinates source @ Mount Agent:** Selects the source of coordinates (agent, mount, dome, or GPS).
- Location @ Mount Agent:** Sets latitude, longitude, and elevation.

The central panel shows a star chart with labels for Andromeda Galaxy, Schedar, Cas, and Ceph. Below the chart are controls for position selection and abort motion.

The right panel displays the INDIGO Control Panel with settings for CCD Guider Simulator, Integral stack size (frames), and Dithering offset X (px).

The bottom panel is the Script Editor, showing a Lua script for a Meridian flip. The script includes comments and code for monitoring the meridian, initiating a flip, and slewing the mount.

```
56 LINE 99 - change to "east_of_pier = true;" since the mount simulator does not have this property
57 LINE 100 - change to "hour_angle = 0.3;" to make the script kick in immediately, without having to wait.
58
59
60
61
62 var monitor_freq = 300; // Test HA every x seconds. Under the sky checking every 5 min will do
63
64 var preview_exposure_time = 10; // Exposure time for preview to be used by plate solve
65 var PS_downsample = 10; // Astrometry Agent parameter; factor to downsample the source image before solving
66 var PS_depth = 30; // Astrometry Agent parameter; how deep to search for a solution
67 var PS_radius = 5; // Astrometry Agent parameter; Limiting the search radius to x degrees from current pos
68
69 var RMSE_threshold = 0.5; // RMSE threshold value (px), to resume the sequence when guiding has settled
70
71 var flip_in_progress = false; // Bunch of booleans to guide the entire process as a state machine.
72 var slew_in_progress = false;
73 var slew_completed = false;
74 var preview_in_progress = false;
75 var preview_completed = false;
76 var plate_solve_in_progress = false;
77 var plate_solve_success = false;
78 var plate_solve_failed = false;
79 var plate_solve_retry_in_progress = false;
80 var sync_is_starting = false;
81 var sync_in_progress = false;
82 var sync_completed = false;
83 var calibration_in_progress = false;
84 var calibration_completed = false;
85 var flip_completed = false;
86
87 var ha_timer; // Timer object that calls the test_hour_angle() function every monitor_freq seconds
88
89
90
91 // Monitor if we crossed the meridian while at the East side of pier, and initiate flip when we're 20min over the meridian
92
93 function test_hour_angle() {
94
95     var east_of_pier;
96     var hour_angle;
97     var RA_pos;
98
99     east_of_pier = indigo_devices ["Mount Agent"].MOUNT_SIDE_OF_PIER.items.EAST;
100    hour_angle = indigo_devices ["Mount Agent"].AGENT_LIMITS.items.HA_TRACKING;
101
102    // Flip when we're east-of-pier and 20 min over the meridian, hence the 0.3 hour (to deal with the mount being off due to sync)
103    if ( east_of_pier && hour_angle > 0.2 && !flip_in_progress) {
104
105        // Initiate meridian flip, here we go...
106        flip_in_progress = true;
107
108        // We make sure the mount slews and tracks on coordinates-set and set the current RA value again to initiate the slew
109        indigo_log("Meridian flip: Slew initiated...");
110        slew_in_progress = true;
111        RA_pos = indigo_devices ["Mount Agent"].MOUNT_EQUATORIAL_COORDINATES.items.RA;
112        indigo_devices ["Mount Agent"].MOUNT_ON_COORDINATES_SET.change ({TRACK: true});
113        indigo_devices ["Mount Agent"].MOUNT_EQUATORIAL_COORDINATES.change ({RA: RA_pos});
114
115        // Monitoring the slew for completion is performed in the SLEW_Handler
116    } else {
117
118        // Reschedule timer, continue to monitor, unless we're already flipping
119
120        if (!flip_in_progress) {
121            indigo_log("Meridian flip: Monitoring");
122        }
123    }
124 }
```


Linux and Windows apps

The image displays the INDIGO software interface, which is used for controlling astronomical imaging systems. It consists of several windows:

- Ain INDIGO Imager:** The main window, showing a menu (File, Edit, Settings, Help) and a toolbar (Capture, Focus, Guide, Telescope, Solver). The main area displays a FITS file: `/home/rumen/ref_img/Elephant Trunk 1200s_2021-08-10_Light_H-Alpha_000.fits` at 14% zoom. The left sidebar contains control panels for Mount Agent, RA/Dec, Az/Alt, LST, RA/Dec input, and various alignment and tracking options.
- INDIGO Control Panel:** A central window with a menu and a tree view of the system components. The tree view shows a hierarchy of agents and simulators, including:
 - Astrometry Agent @ indigosky
 - CCD File Simulator @ indigosky
 - CCD Guider Simulator (AO) @ indigosky
 - CCD Guider Simulator (guider) @ indigosky
 - CCD Guider Simulator @ indigosky
 - Main
 - CCD Imager Simulator (focuser) @ indigosky
 - CCD Imager Simulator (wheel) @ indigosky
 - Filter Wheel
 - Current slot
 - Slot focus offsets
 - Slot names
 - Main
 - CCD Imager Simulator @ indigosky
 - Camera
 - Cooler
 - Image
 - Binning
 - Custom FITS headers
 - Frame size
 - Frame type
 - Image data
 - Image file info
 - Image format
 - JPEG Settings
 - Main
 - DSLR Simulator @ indigosky
 - Guider Agent @ indigosky
 - Imager Agent @ indigosky

- CCD Imager Simulator @ indigosky . Image:** A window showing a simulated image of a galaxy. It includes a status bar with "Image data" and a URL: `http://127.0.1.1:7624/blob/0x558d76e000.fits`. Below the image are buttons for "View..." and "Save BLOB".

At the bottom of the main window, a log shows the following messages:

```
02:05:42.735 Astrometry Agent @ indigosky.AGENT_PLATESOLVER_WCS: Exec
02:05:42.938 Solving failed
02:06:01.713 File uploaded for solving
02:07:01.419 Solved
```

At the bottom of the Control Panel window, a status bar indicates: `03:21:26.604 BLOBs enabled`

INDIGO Control Panel

The screenshot displays the INDIGO Control Panel interface. On the left is a sidebar with a tree view of device agents, including 'Astrometry Agent @ indigosky', 'CCD File Simulator @ indigosky', 'CCD Guider Simulator (AO) @ indigosky', 'CCD Guider Simulator (guider) @ indigosky', 'CCD Guider Simulator @ indigosky', and 'CCD Imager Simulator (focuser) @ indigosky'. The 'Focuser' sub-section is expanded, showing parameters like 'Abort motion', 'Absolute position', 'Compensation mode', 'Focuser speed', 'Movement direction', 'Relative move', 'Temperature', and 'Temperature compensation'. The main panel on the right is titled 'CCD Imager Simulator (focuser) @ indigosky . Focuser' and contains several control sections:

- Abort motion**: A checked status indicator and an unchecked checkbox.
- Absolute position**: A checked status indicator, a numerical input field with values '0' and '8', and 'Reset' and 'Set' buttons.
- Compensation mode**: A checked status indicator and two unchecked checkboxes: 'Manual control' and 'Automatic control'.
- Focuser speed**: A checked status indicator, a numerical input field with values '1' and '1', and 'Reset' and 'Set' buttons.
- Movement direction**: A checked status indicator and two unchecked checkboxes: 'Move inward' and 'Move outward'.

Ain Imager - Capture

The screenshot displays the 'Ain INDIGO Imager' software interface. The window title is 'Ain INDIGO Imager'. The menu bar includes 'File', 'Edit', 'Settings', and 'Help'. The main interface is divided into a control panel on the left and a large image window on the right.

Control Panel (Left):

- Buttons: Capture, Focus, Guide, Telescope, Solver
- Imager Agent: @ indigosky
- Camera: CCD Imager Simulator
- Wheel: CCD Imager Simulator (wheel)
- Frame: RAW 1600x1200, Light
- Exposure (s): 60.000, Delay (s): 0.000
- No frames: ∞, Filter: V
- Object: Rozette
- Buttons: Preview, Expose, Pause, Abort
- Status: Exposure: 46 of 60 seconds elapsed... Process: exposure 2 complete...
- Cooler (°C): 25.0, P: 0.0%, 0.00
- Image, Dithering, Camera, Remote images
- Preview exposure (s): 1.000
- Image format: FITS format
- ROI X: 0, Width: 1600
- ROI Y: 0, Height: 1200

Image Window (Right):

- Title: Rozette_2022-09-26_Light_V_001.fits
- Status: 48% [1055.6, 513.2] (1160)
- Image: A dark field of stars with a faint nebula, overlaid with a yellow crosshair.

Log (Bottom):

- 23:15:11.464 Image saved to '/home/rumen/ain_data/2022-09-26/Rozette_2022-09-26_Light_V_000.fits'
- 23:16:11.744 Image saved to '/home/rumen/ain_data/2022-09-26/Rozette_2022-09-26_Light_V_001.fits'

Ain Imager - Focusing

Ain INDIGO Imager

File Edit Settings Help

Capture Focus Guide Telescope Solver

Focuser: CCD Imager Simulator (focuser)

Absolute Position: 0

Move: 1

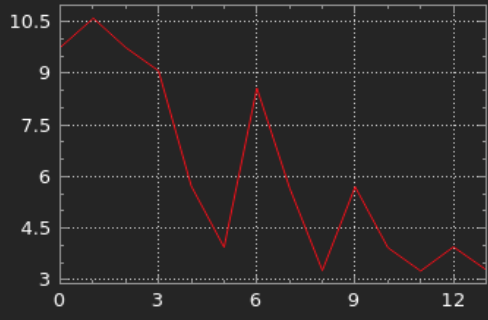
▶ Preview Ⓞ Focus ■ Abort >> | << |

Focusing: Complete

Reference T (°C): 25.0 Auto compensation

Statistics Settings Misc

Focus HFD (px):



Time (px)	HFD (px)
0	10.5
3	9.0
6	8.5
9	5.5
12	4.5

HFD (c/b): 3.29 / 3.26 FWHM: 2.12

Drift (X, Y): +0.00, +0.00 Peak: 64744

Unsaved.raw 400% [390.8, 617.5] (804)

23:27:10.887 Imager Agent @ indigosky: Focusing started
23:27:34.897 Imager Agent @ indigosky: Focusing finished

Ain Imager – Auto guiding

The screenshot displays the Ain INDIGO Imager software interface. The main window is titled "Ain INDIGO Imager" and features a menu bar (File, Edit, Settings, Help) and a toolbar (Capture, Focus, Guide, Telescope, Solver). The "Guide" tab is active, showing a "Guiding..." window with a 48% zoom level and navigation icons.

On the left side, the "Guide" panel includes a dropdown menu for "Guider Agent @ indigosky", "Camera:" set to "CCD Guider Simulator", and "Guider:" set to "CCD Guider Simulator (guider)". Below these are buttons for "Preview", "Calibrate", "Guide", and "Stop".

The "Statistics" section shows a "Drift RA / Dec (arcsec)" graph with a y-axis from -6 to 6 and an x-axis from 0 to 100. Below the graph, the following data is displayed:

Drift RA / Dec:	-0.32"	-0.52"
Drift X / Y:	-0.13	+0.06 px
Correction RA / Dec:	+0.04	-0.05 s
RMSE RA / Dec:	0.35"	0.34"

The main view shows a star field with a yellow crosshair. A "Guiding..." window is overlaid on the right side, showing a zoomed-in view of the star field with green circles around the stars.

At the bottom, a log window displays the following messages:

```
23:33:41.325 Guider Agent @ indigosky: Guiding finished
23:33:42.943 Guider Agent @ indigosky: Guiding started
23:34:53.518 Guider Agent @ indigosky: Guiding finished
23:34:54.293 Guider Agent @ indigosky: Guiding started
```

Ain Imager – Telescope Control

The screenshot displays the Ain INDIGO Imager software interface. The window title is "Ain INDIGO Imager". The menu bar includes "File", "Edit", "Settings", and "Help". The main interface is divided into several sections:

- Top Bar:** Contains tabs for "Capture", "Focus", "Guide", "Telescope", and "Solver". The current view is "Unsolved.raw" at 48% zoom, with coordinates [1041.9, 485.8] and a resolution of (1207).
- Left Panel (Telescope Control):**
 - Mount: Agent @ indigosky
 - Mount: Mount Simulator
 - RA / Dec: 6: 30:40.3, 50 00 47.2
 - Az / Alt: 84° 27' 09.8", 37° 46' 42.1"
 - LST: 3:03:15.39
 - RA / Dec input: 6:30:40.3, 5:00:47.2
 - Buttons: Goto, Sync, Abort
 - Sub-tabs: Main, Object, Solver, Site, GPS, Polar align
 - Directional buttons: N, W, E, S
 - Tracking: Tracking
 - Guide rate: Guide rate
 - Centering rate: Centering rate
 - Finding rate: Finding rate
 - Max rate: Max rate
 - Go home: Go home
 - Unparked: Unparked
 - Stop guiding on slew: Guider Agent
- Right Panel (Image):** Shows a live image of a star field with a yellow crosshair overlay.

Ain Imager – Telescope (Solver)

The screenshot displays the 'Ain INDIGO Imager' software interface. The window title is 'Ain INDIGO Imager'. The menu bar includes 'File', 'Edit', 'Settings', and 'Help'. The main toolbar has tabs for 'Capture', 'Focus', 'Guide', 'Telescope', and 'Solver'. The 'Telescope' tab is active, showing the following settings:

- Mount: Agent @ indigosky
- Mount: Mount Simulator
- RA / Dec: 6:30:40.3, 5° 00' 47.2"
- Az / Alt: 84° 24' 14.3", 38° 36' 05.7"
- LST: 3:06:33.93
- RA / Dec input: 6:30:40.3, 5:00:47.2
- Buttons: Goto, Sync, Abort

The 'Solver' sub-tab is active, showing:

- Status: Solved (indicated by a green dot)
- Image source: Imager Agent
- Exposure time (s): 1.000
- Buttons: Solve & Center, Solve & Sync

The main view shows a star field image titled 'Unsaved.fits' at 48% zoom. The coordinates are [587.1, 473.4] (6h 29' 35.5", +4° 48' 13.6"). The image is overlaid with a yellow crosshair. The bottom status bar shows the following log entries:

- 23:42:20.095 Astrometry Agent @ indigosky: Done
- 23:42:20.096 Astrometry Agent @ indigosky: Downloading 4110...
- 23:43:13.115 Astrometry Agent @ indigosky: Done
- 23:43:18.901 Astrometry Agent @ indigosky: Solved

Ain Imager – Telescope (P. Align)

The screenshot displays the 'Ain INDIGO Imager' software interface. The window title is 'Ain INDIGO Imager'. The menu bar includes 'File', 'Edit', 'Settings', and 'Help'. The main interface is divided into several sections:

- Top Bar:** 'Capture', 'Focus', 'Guide', 'Telescope', and 'Solver' tabs. The 'Telescope' tab is active. The main image area shows 'Unsaved.raw' at 48% zoom, with coordinates [973.6, 471.3] (3h 56' 01.4", +5° 06' 16.8").
- Left Panel (Telescope Settings):**
 - Mount Agent @ indigosky
 - Mount: Mount Simulator
 - RA / Dec: 3: 50:40.3, 50° 00' 47.2"
 - Az / Alt: 68° 41' 45.2", 78° 39' 26.9"
 - LST: 3:09:28.41
 - RA / Dec input: 6:30:40.3, 5:00:47.2
 - Buttons: Goto, Sync, Abort
- Bottom Left Panel (Polar Alignment):**
 - Image source: Imager Agent
 - Exposure time (s): 1.000, Comp. AR checkbox
 - Hour Angle move (°): 20.00
 - Buttons: Start alignment, Recalculate error, Stop
 - Polar error: 6.83'
 - Azimuth error: -5.62' move C.C.W. ↺
 - Altitude error: +3.88' move Up ↑
- Bottom Panel (Log):**
 - 23:46:26.470 Astrometry Agent @ indigosky: Solved
 - 23:46:26.563 Astrometry Agent @ indigosky: Polar error: 6.83'
 - 23:46:26.563 Astrometry Agent @ indigosky: Azimuth error: -5.62', move C.C.W. (use azimuth adjustment knob)
 - 23:46:26.563 Astrometry Agent @ indigosky: Altitude error: +3.88', move Up (use altitude adjustment knob)

Ain Imager – Solver

Ain INDIGO Imager

File Edit Settings Help

Capture Focus Guide Telescope Solver

Astrometry Agent @ indigosky

Image source: Imager Agent

Exposure time (s): 1.000 Solve

WCS solution: ● Solved

Frame center RA : 5h 35' 19.4"

Frame center Dec : -5° 19' 13.2"

Frame size: 1.756° x 1.315°

Rotation angle (E of N): 94.397°

Scale: 3.948"/px

Parity: negative

Used index file: 4110

Solver hints:

RA (h) / Dec (°): 5:00:00.0 -5:00:00.0 Set

Search radius (°): 0.00


Downsample: 2

Parity: 0

Depth: 0

Time Limit (s): 180

Unsaved.jpeg 48% [845.7, 538.2] (5h 35' 02.2", -5° 21' 54.4")



00:58:32.942 Astrometry Agent @ indigosky: Solved
00:59:25.245 Astrometry Agent @ indigosky: Solved
00:59:44.199 Astrometry Agent @ indigosky: Solved

Third Party INDIGO Apps

- **PixInsight** – replaced INDI with INDIGO
- **APT** – uses INDIGO framework
- **MountWizzard4** – native INDIGO
- **CCDCiel**
- **PHD2**
- **Ekos** - can use INDIGO server in legacy mode

What can INDIGO control?



Who uses INDIGO?

- Several thousands amateur astronomers and astro-photographers around the world, running telescopes from 50mm to 90cm
- Several professional observatories including Calar Alto (Spain), Osservatorio Astronomico G. V. Schiaparelli (Italy), Astronomical Observatory at Skalnaté Pleso (Slovakia).

Thank you!

