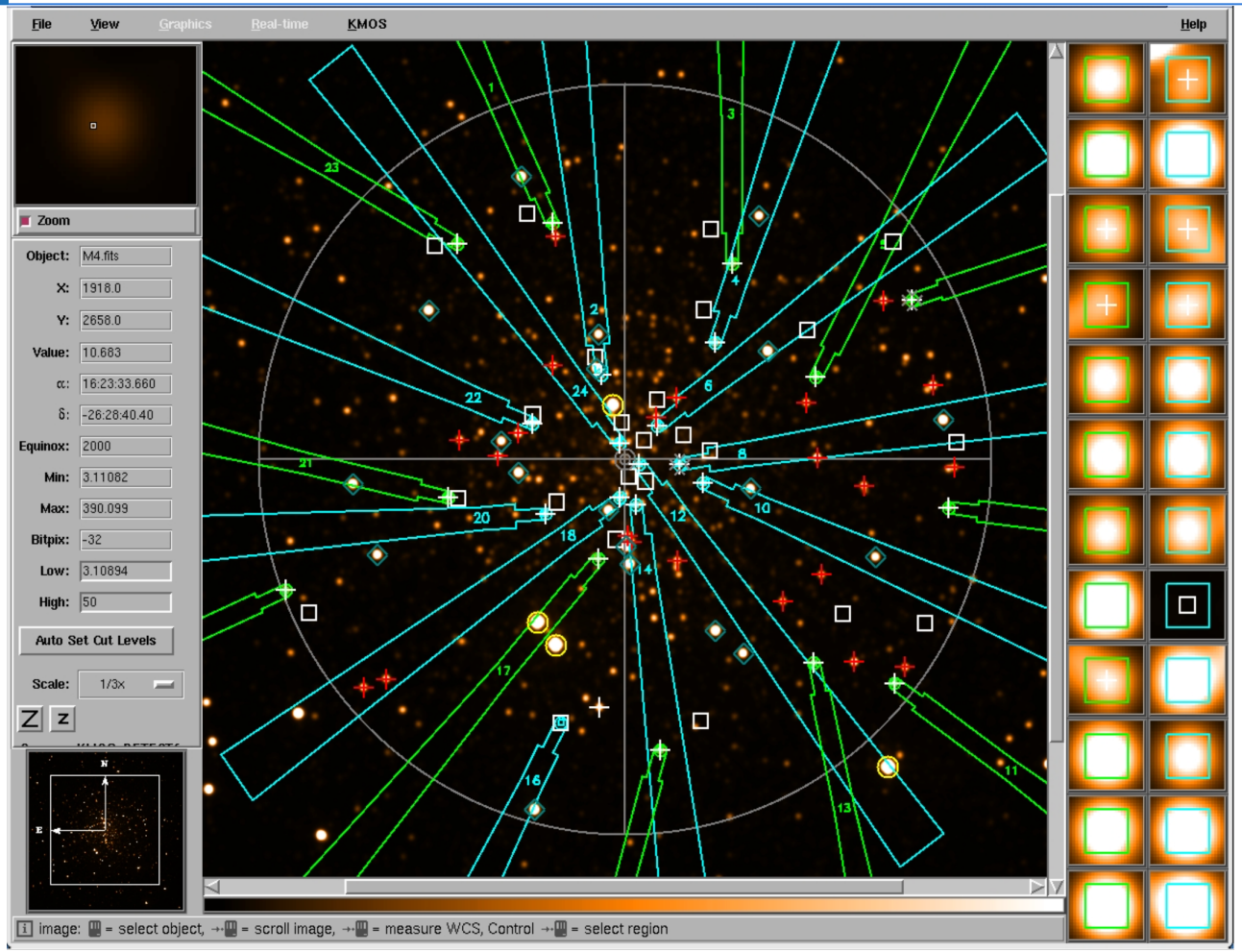
Observation Preparation for KMOS with KARMA



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User Support Astronomer for KMOS

Web page: http://www.eso.org/sci/observing/phase2/SMGuidelines/KARMA.html

User Manual: http://www.eso.org/sci/facilities/paranal/instruments/kmos/doc/VLT-MAN-KMO-146606-002_P96.pdf

Requirements and Benefits

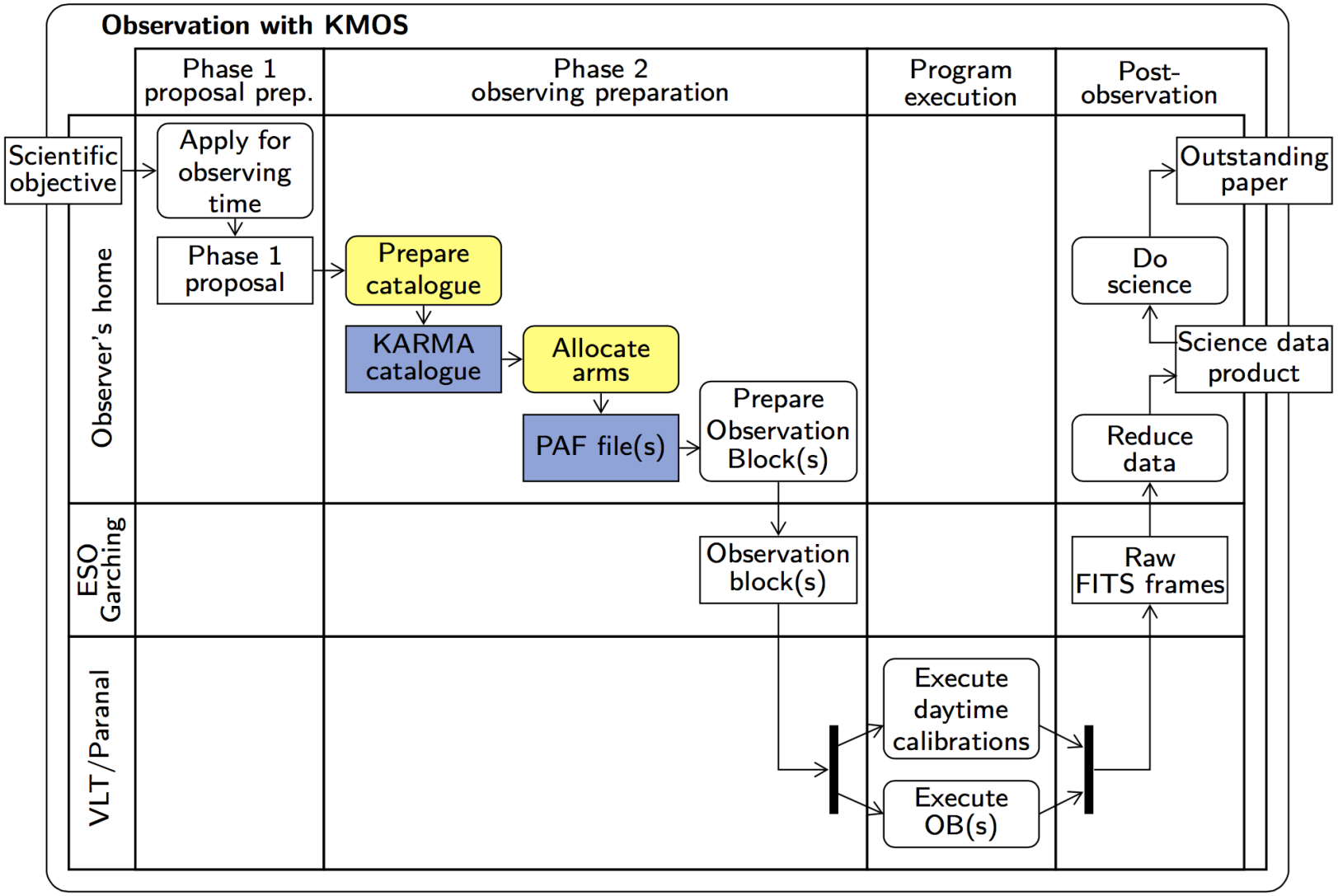
What you need:

- A predefined KARMA catalogue in ASCII format
- A sky (FITS) image (preferentially in the infrared), which covers at least the KMOS Field of View (FoV)
- A network connection (optional)

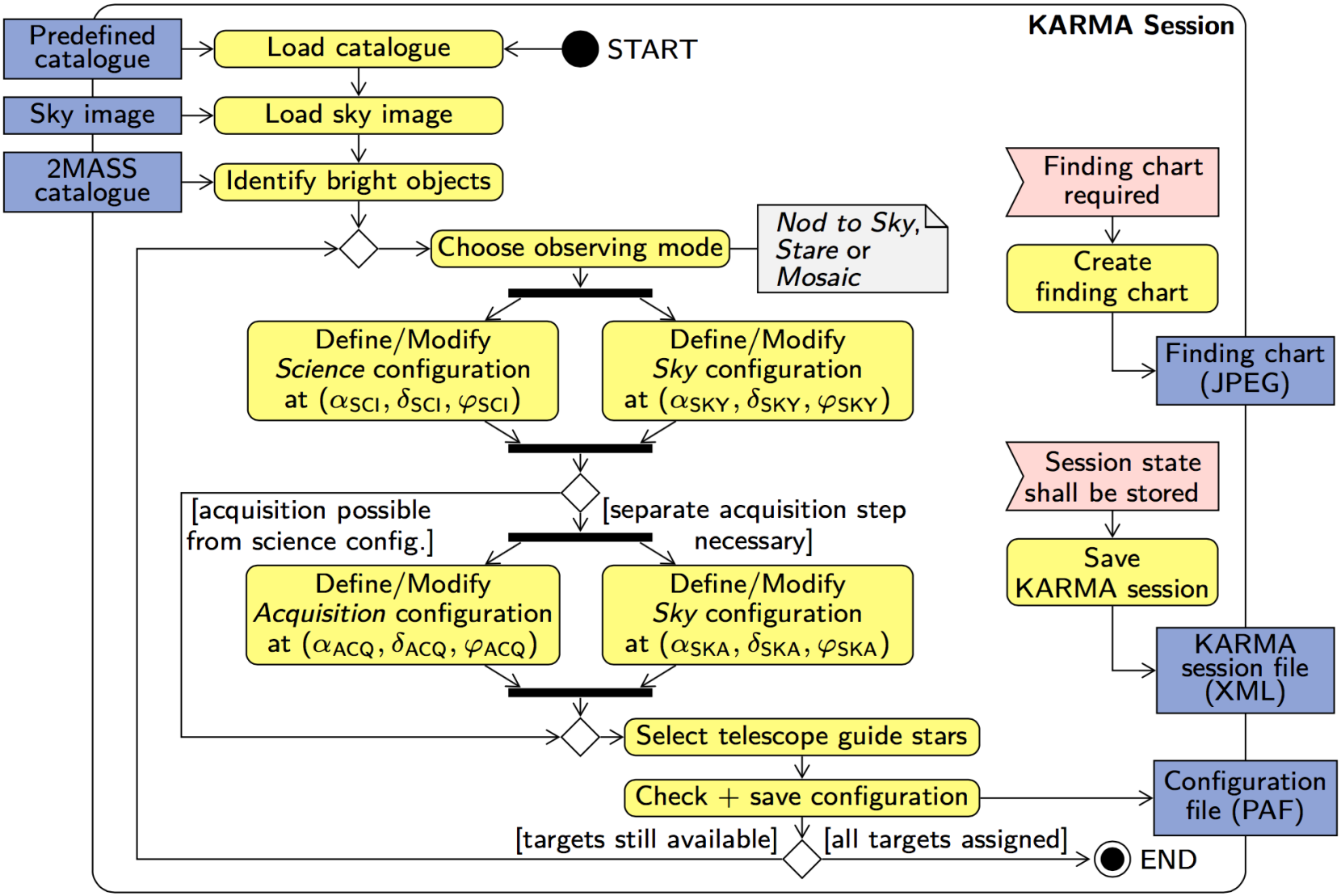
What you get:

- One or more ASCII file(s) in the ESO-specific proprietary ('PAF') format, so-called 'KMOS set up files' or 'PAF files'
- One or two jpeg KMOS finding charts created with the "Finding Chart" plug-in of Skycat

Main steps of a typical KMOS observation

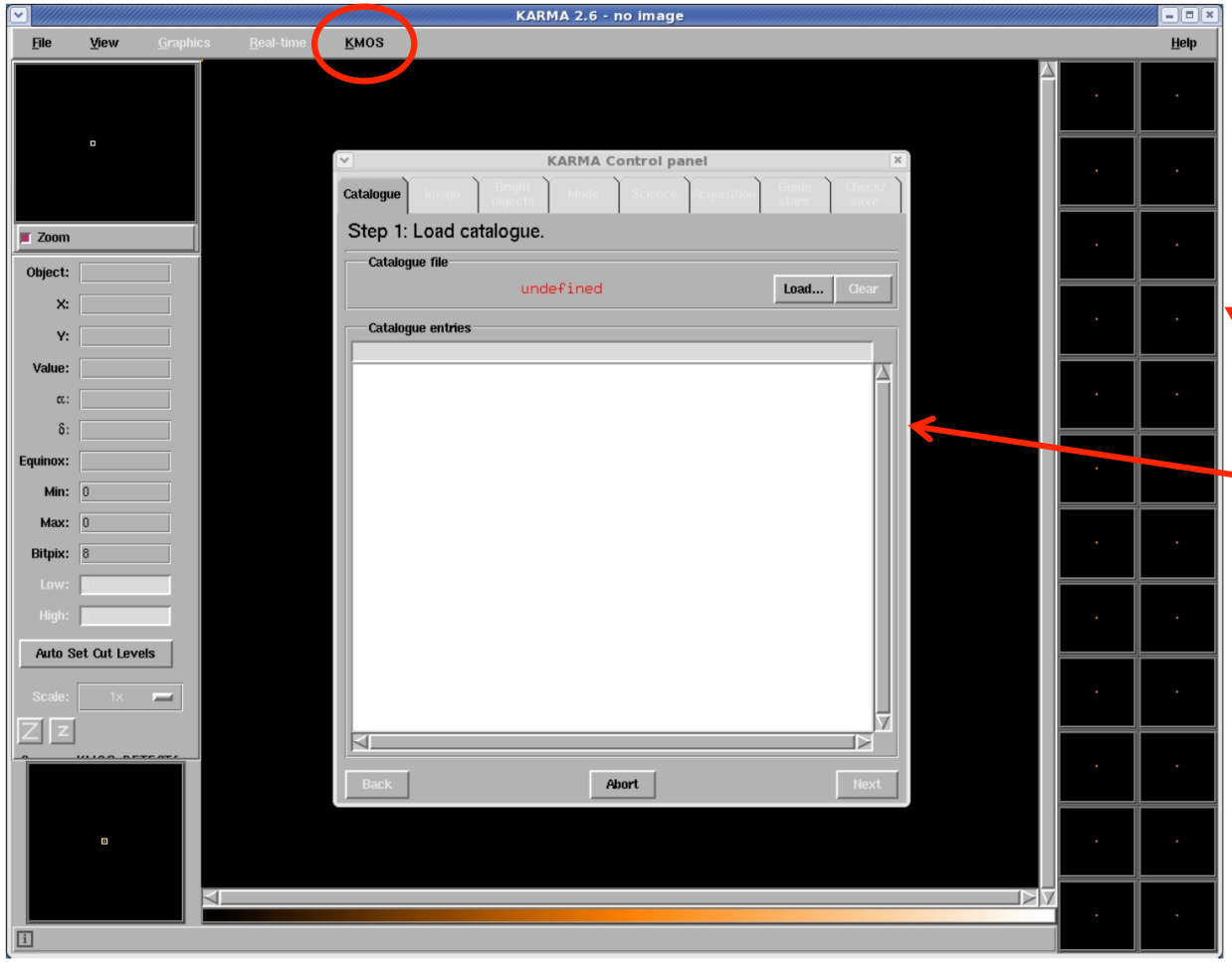


Typical sequence of steps in a KARMA session



Starting KARMA

Use the command: ./karma_bin_<machine>_<os>_<version>/bin/karma &
Then select 'New' from the 'KMOS' submenu.



Main window and Control panel

Step 1: Prepare and load catalogue

Mandatory columns:

- **ID**: The name of the object or position.
- **RA and Dec**: Right ascension (α) and declination (δ) of the object or position (in decimal degrees or sexigesimal).
- **Type**: Indicated by (at least) one or multiple character flags:
  - **O** - Scientific target (except *Mosaic* mode)
  - **R** - Reference target (at least two) [J<14]
  - **S** - Sky background position (optional)
  - **G** - Potential telescope guide star (at least one) [8<R<12]
  - **B** - Object brighter than a certain limiting magnitude (opt.)
  - **C** - Field centre (mandatory)
  - **M** - Marker position (optional)

	O	R	S	G	B	C	M
O	✗	✓				✓	✓
R	✓	✗		✓		✓	✓
S			✗			✓	✓
G		✓		✗	✓	✓	✓
B				✓	✗	✓	
C	✓	✓	✓	✓	✓	✗	
M	✓	✓	✓	✓			✗

Step 1: Prepare and load catalogue

Mandatory columns (cont'd):

- **Magnitude**: The apparent magnitude (if applicable) of the entry (mandatory for reference and guide stars).
- **Wavelength band**: This column refers to the previously given apparent magnitude (if any). It is mandatory for reference targets (preferably in NIR band) and guide stars (in R band).
- **Target priority**: Only applicable for targets. An integer between 1 (high) an 3 (low).

Optional column:

- **Any comment**: Since this is (if existing) always the last column, it can be arbitrarily long and can include spaces.

Step 1: Prepare and load catalogue

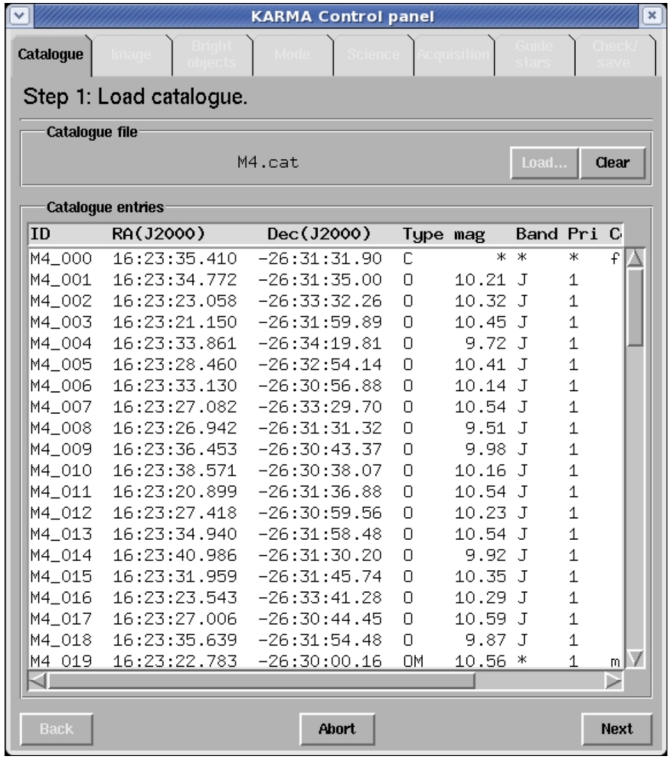
Most important: all entries in the catalogue (targets, reference and guide stars) have to be on the same astrometric system and should have a relative positional accuracy of <0.2". Moreover, coordinates of high proper motion stars have to be corrected to the epoch of observation.

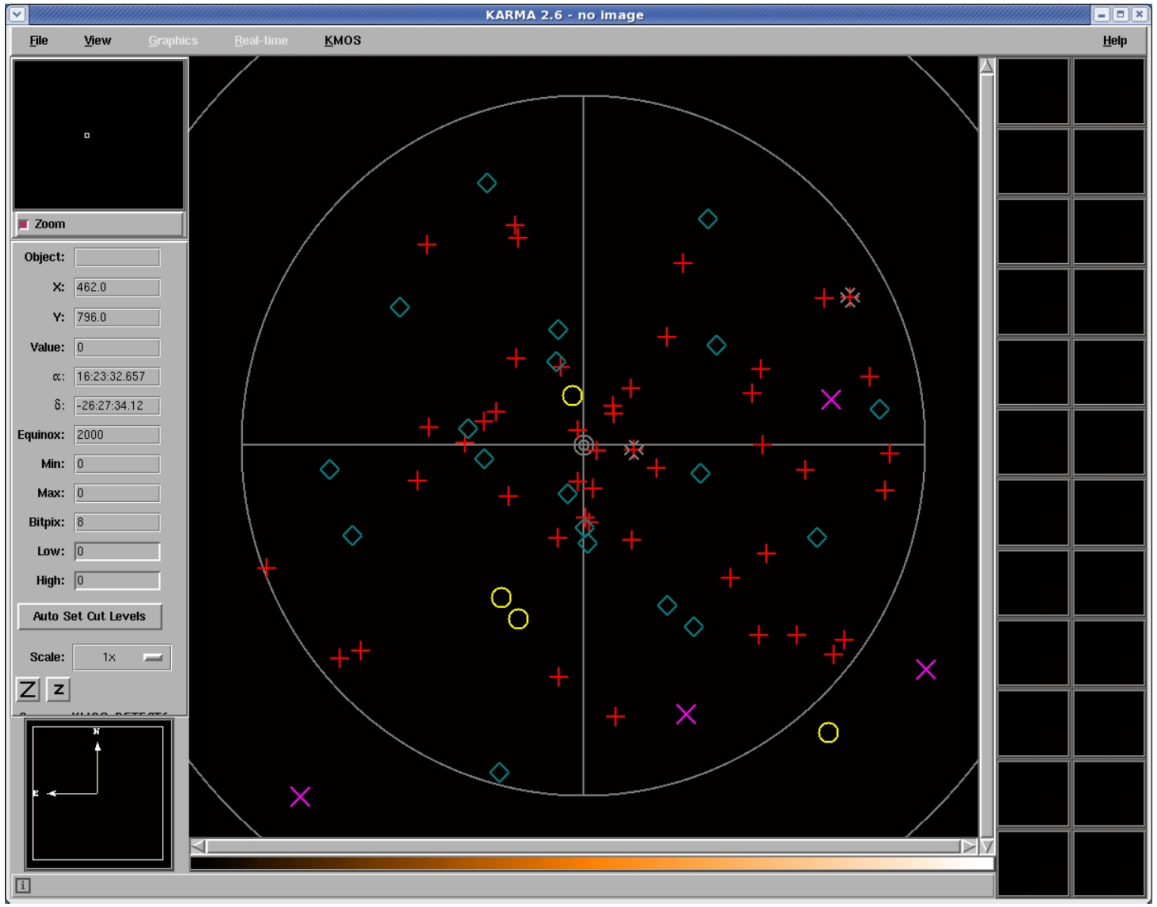
Example lines of a catalogue:

```
#-------------------------------------------------------------------------------
# ID    RA(J2000)      Dec(J2000)   Type   mag  Band Pri Comment
#-------------------------------------------------------------------------------
M4_000  16:23:35.410  -26:31:31.90  C        *  *    *   field centre of M4
M4_001  16:23:34.772  -26:31:35.00  O    10.21  J    1
M4_002  16:23:23.058  -26:33:32.26  O    10.32  J    1

M4_052  16:23:39.398  -26:34:54.33  R     8.46  J    1
M4_053  16:23:36.577  -26:30:20.04  R     9.35  J    1

M4_067  16:23:22.720  -26:22:16.86  G     9.72  R    *
M4_068  16:23:18.690  -26:23:43.28  G    10.60  R    *

M4_087  16:23:23.819  -26:34:29.76  B     7.01  J    *
M4_088  16:23:38.470  -26:33:19.25  B     6.97  J    *
```

Step 1: Prepare and load catalogue

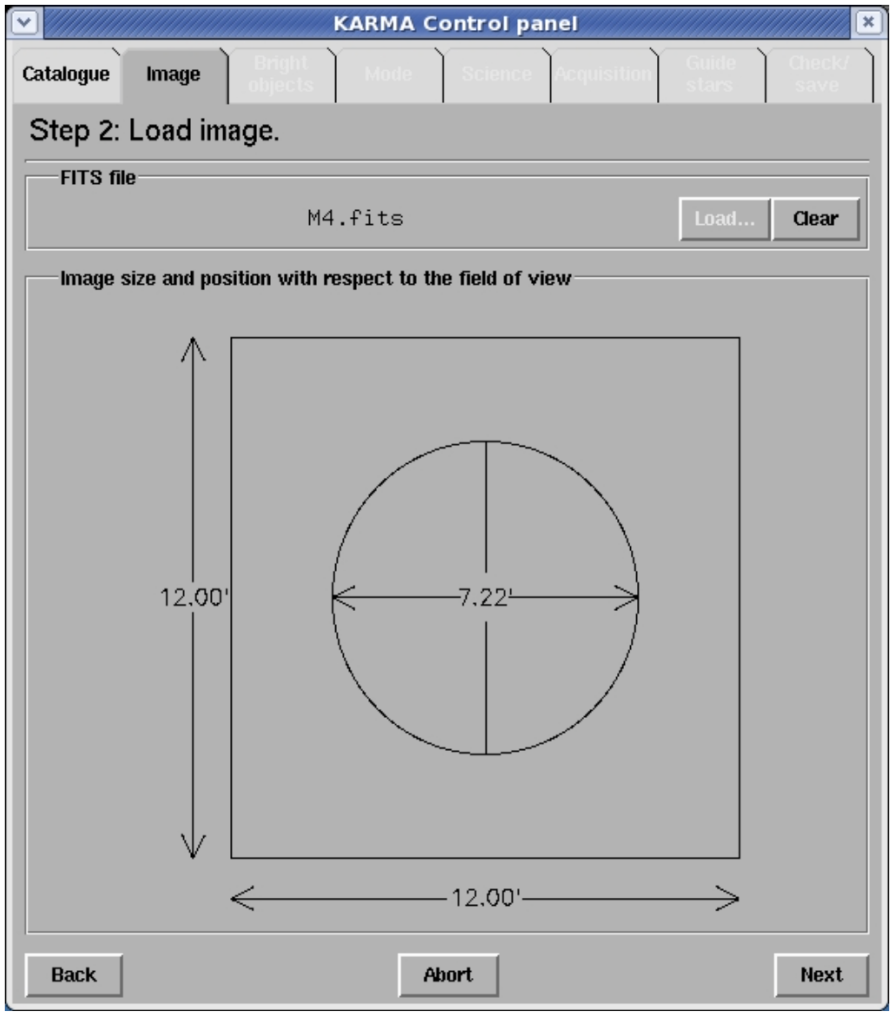
Load a catalog with the ‘Load’ button in the control panel:





Main window after having loaded an input catalogue (KARMA package example)

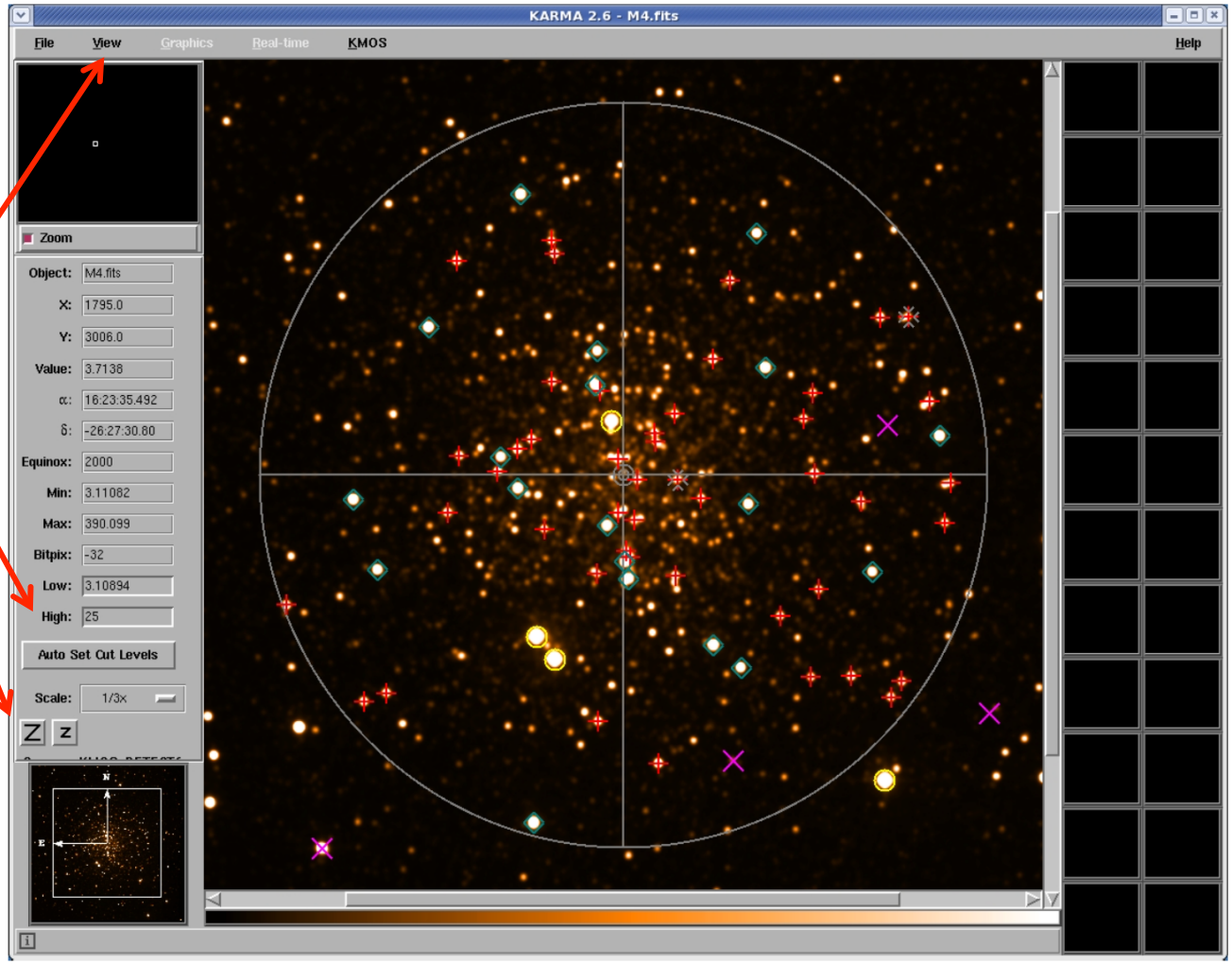
Step 2: Load image



Control panel before and after having loaded the example image

Step 2: Load image

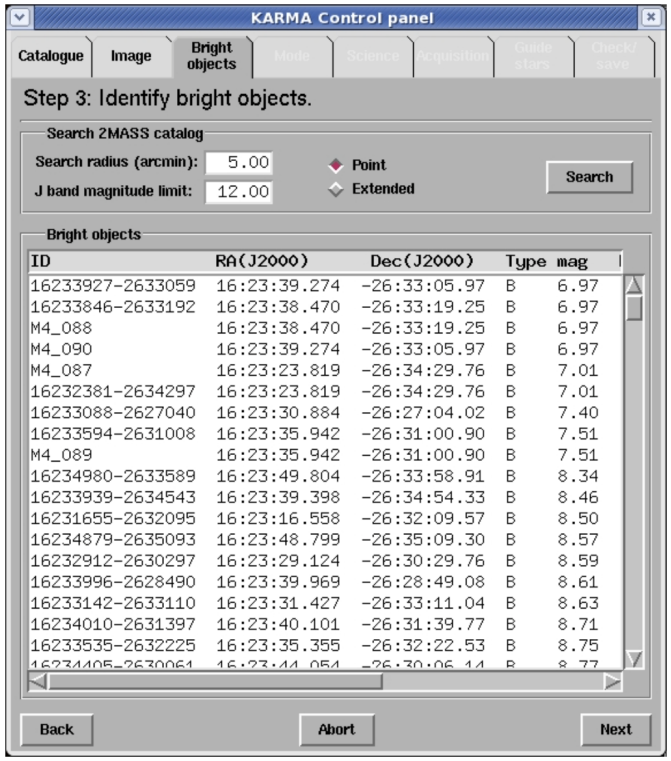
Use skycat options to adjust cut levels and zoom factor

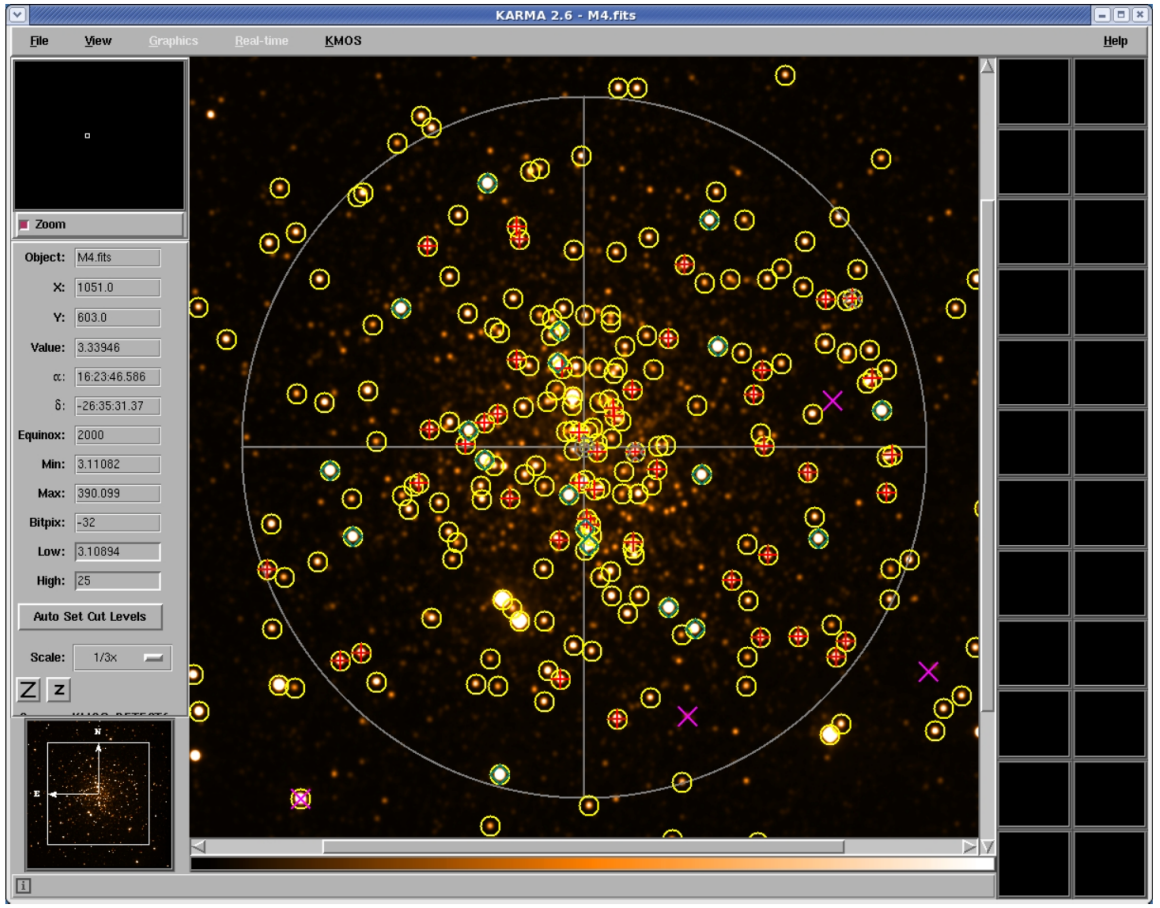


Main window after having loaded the example image

Step 3: Identify bright objects

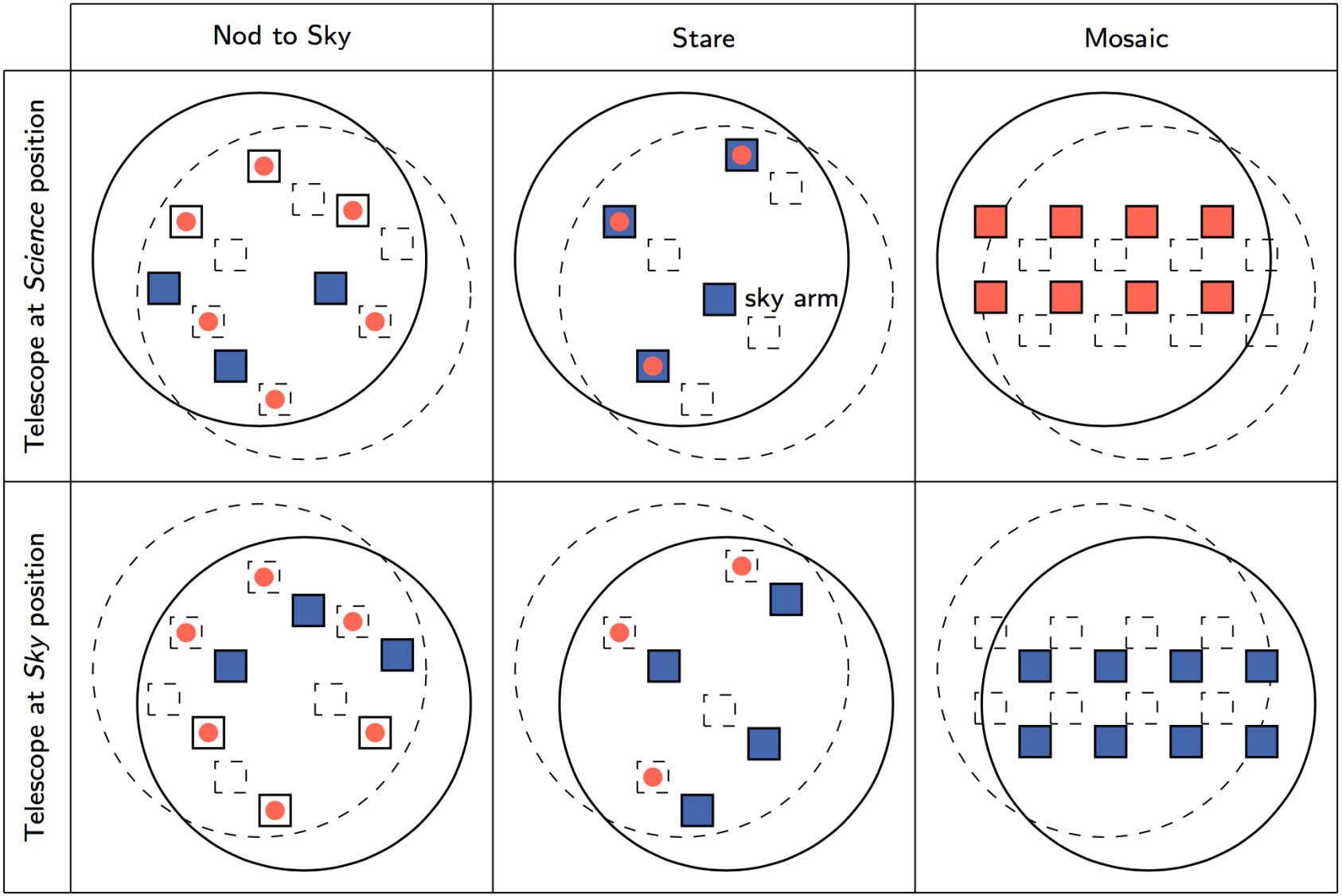
Set the bright object parameters and click the ‘Search’ button:





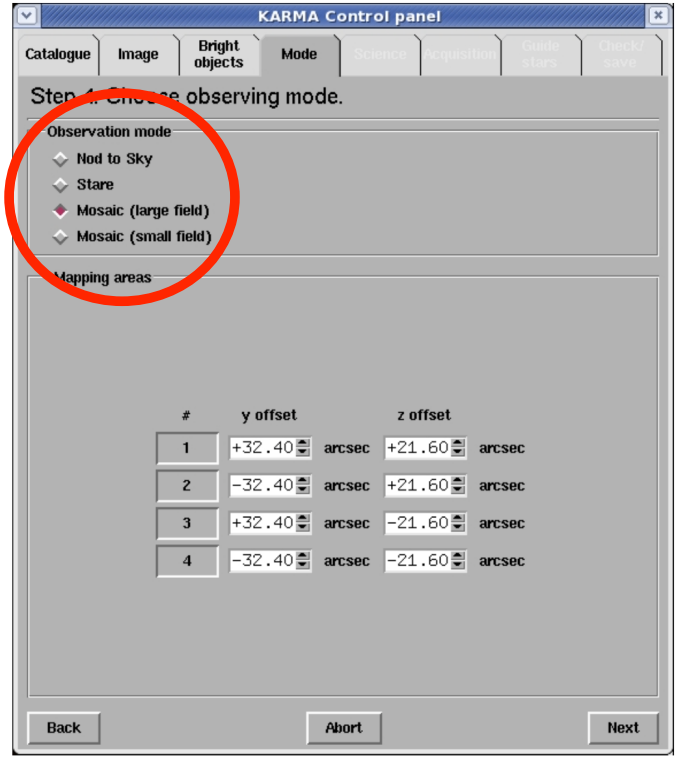
Main window after having retrieved additional bright object positions from the 2MASS online catalogue.

Step 4: Choose observing mode

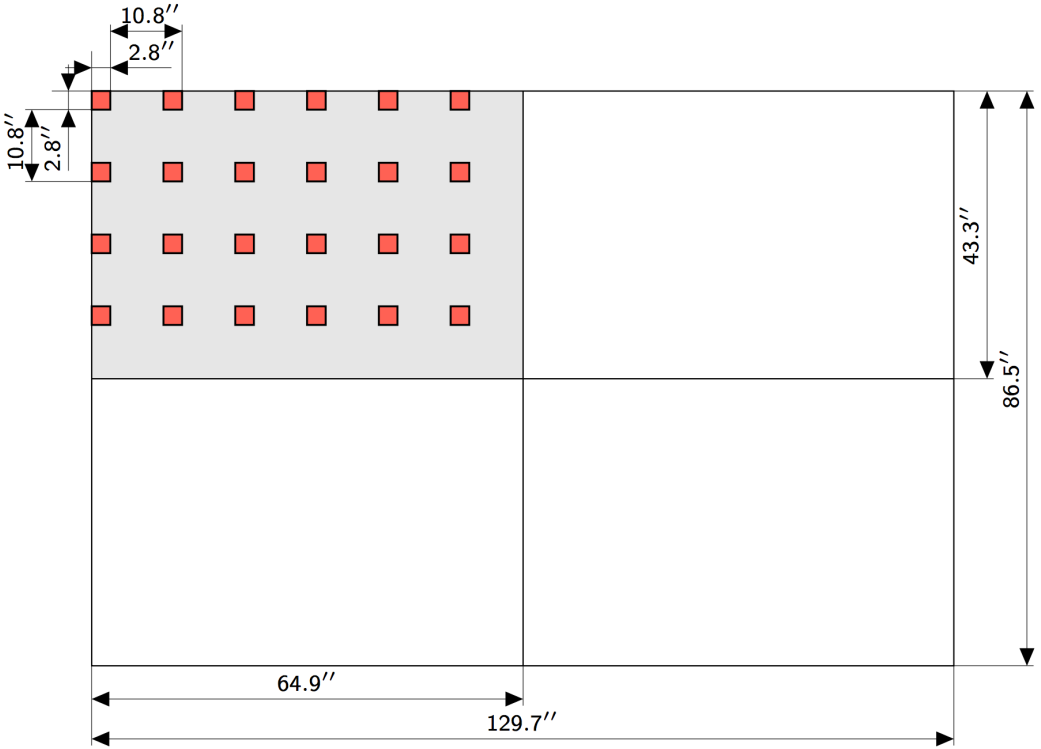


Step 4: Choose observing mode

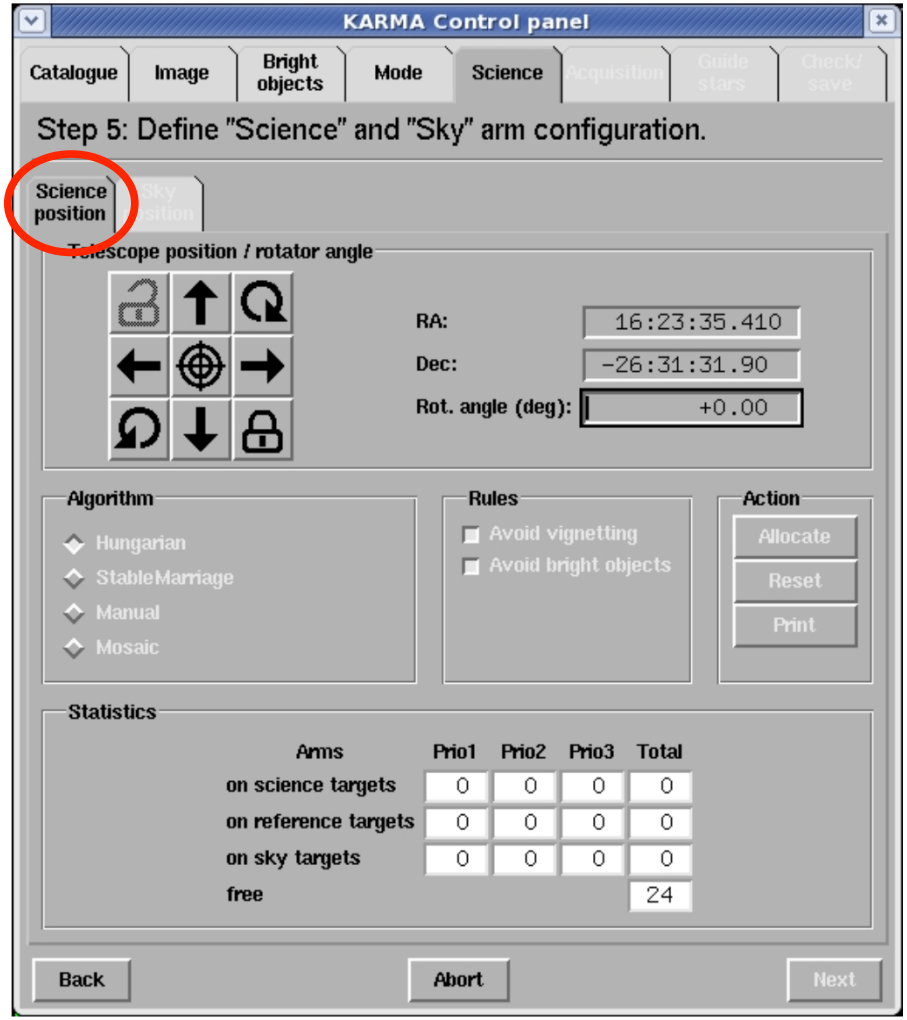
Switching between modes:

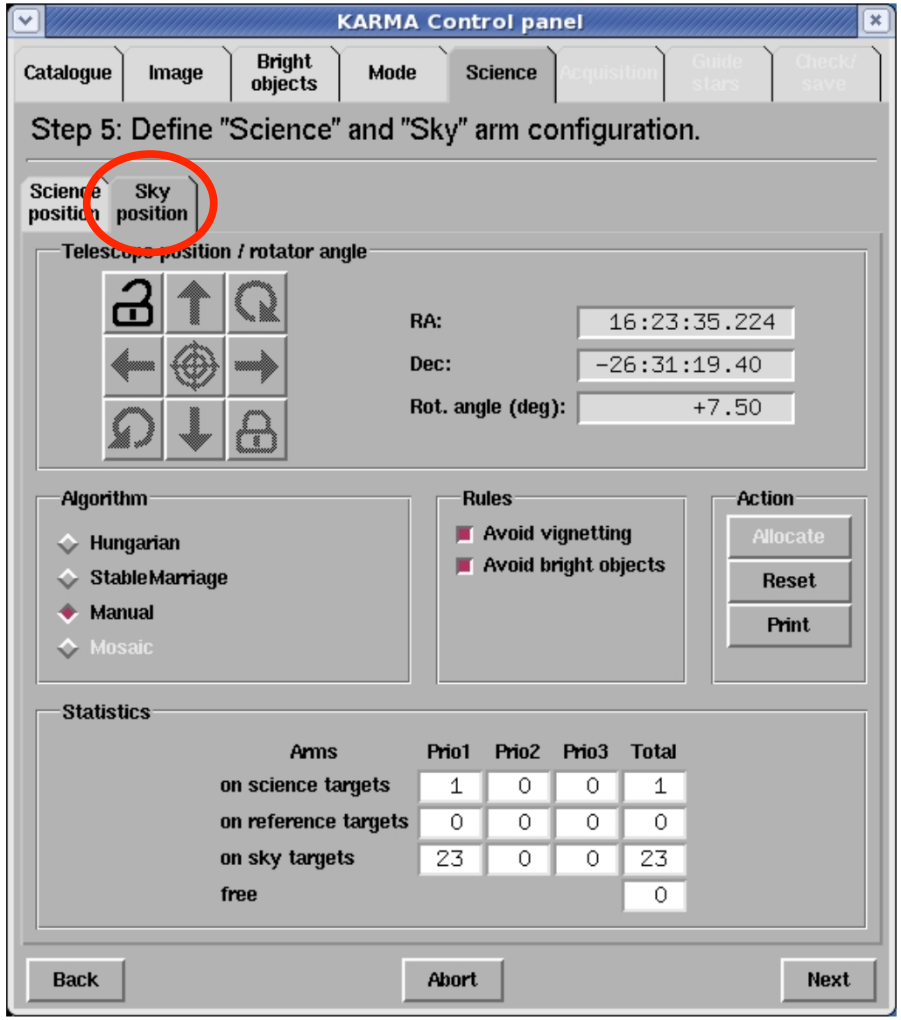


Creating 2x2 mosaics in *Mosaic* mode:



Step 5: Define arm configuration for science observation





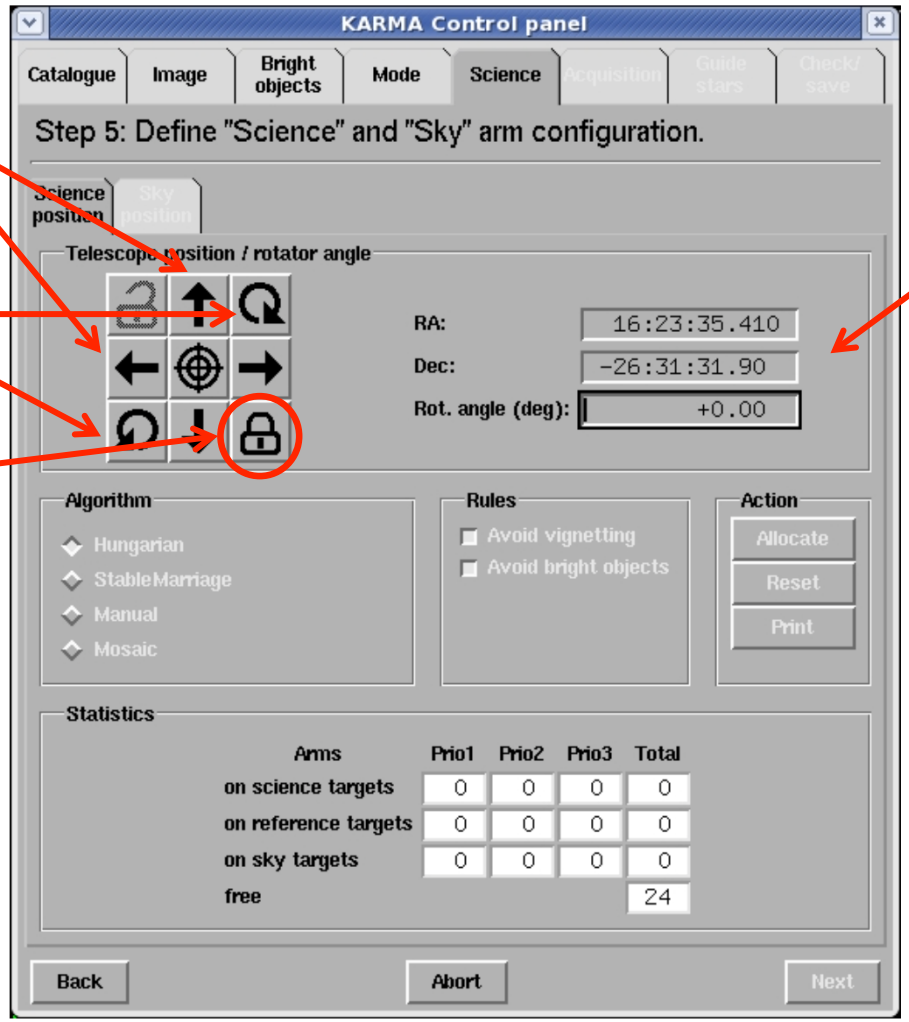
Control panel before and after having performed telescope adjustment and arm allocation

Step 5: Define arm configuration for science observation

Left-, right-, up-, down movement of FOV

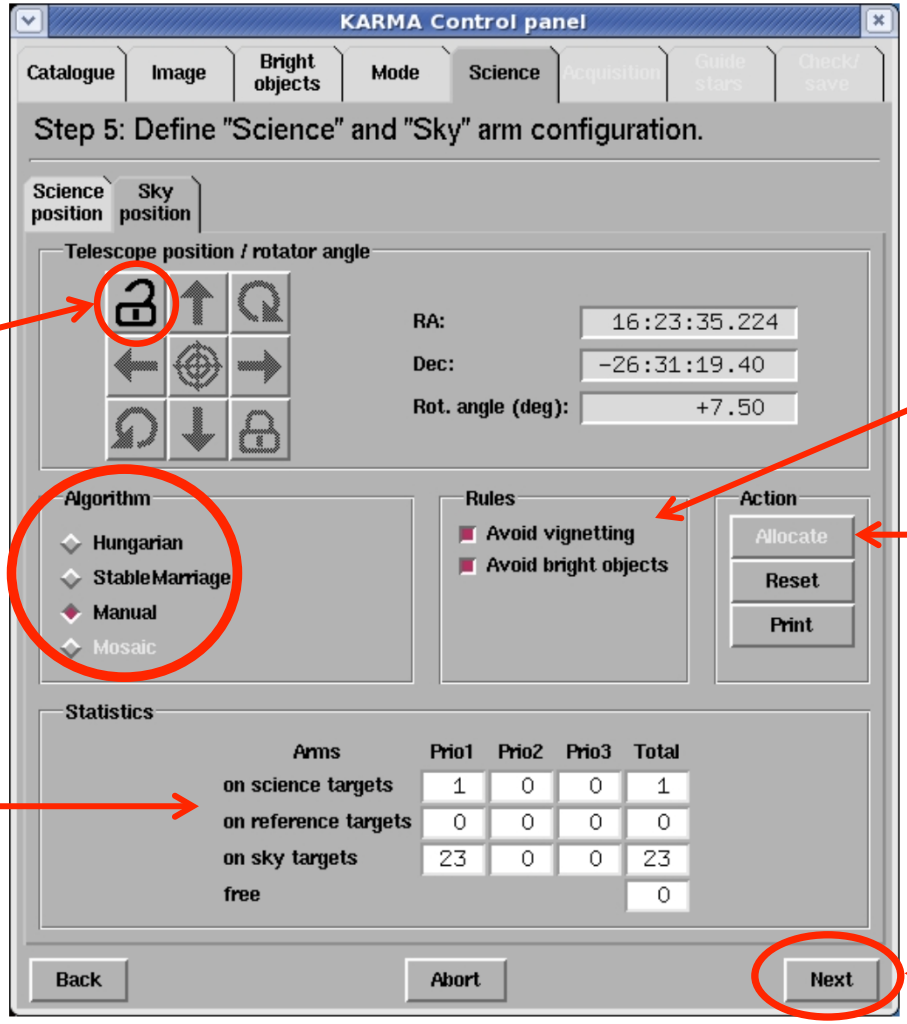
Left-, right- rotation of FOV

Lock position when satisfied



Manual input possible

Step 5: Define arm configuration for science observation



Unlock position if not satisfied with pointing

Choice of arm allocation algorithm

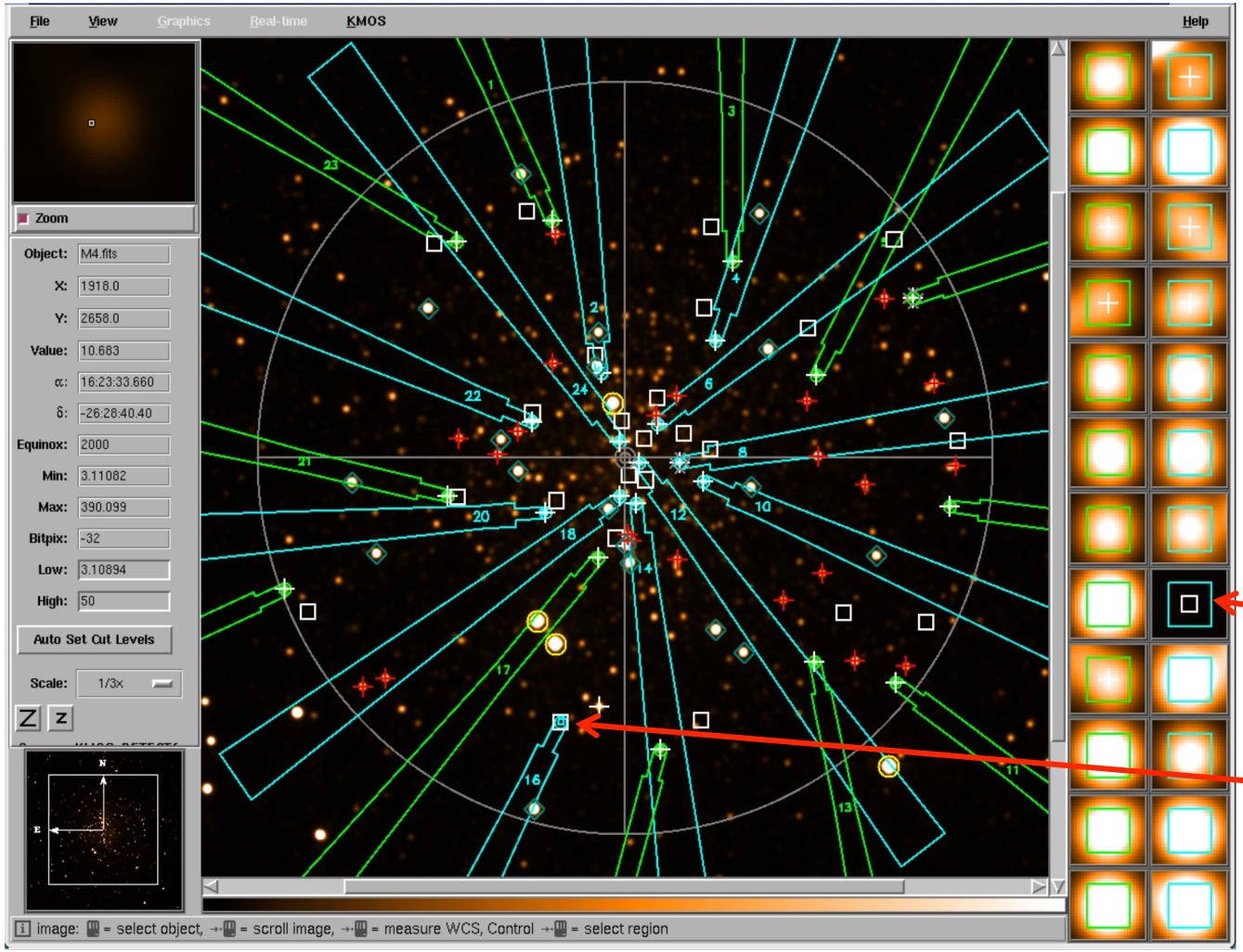
Result table

Further options

Allocate arms or reset

Continue with sky positions when science positions are fine

Step 5: Define arm configuration for science observation



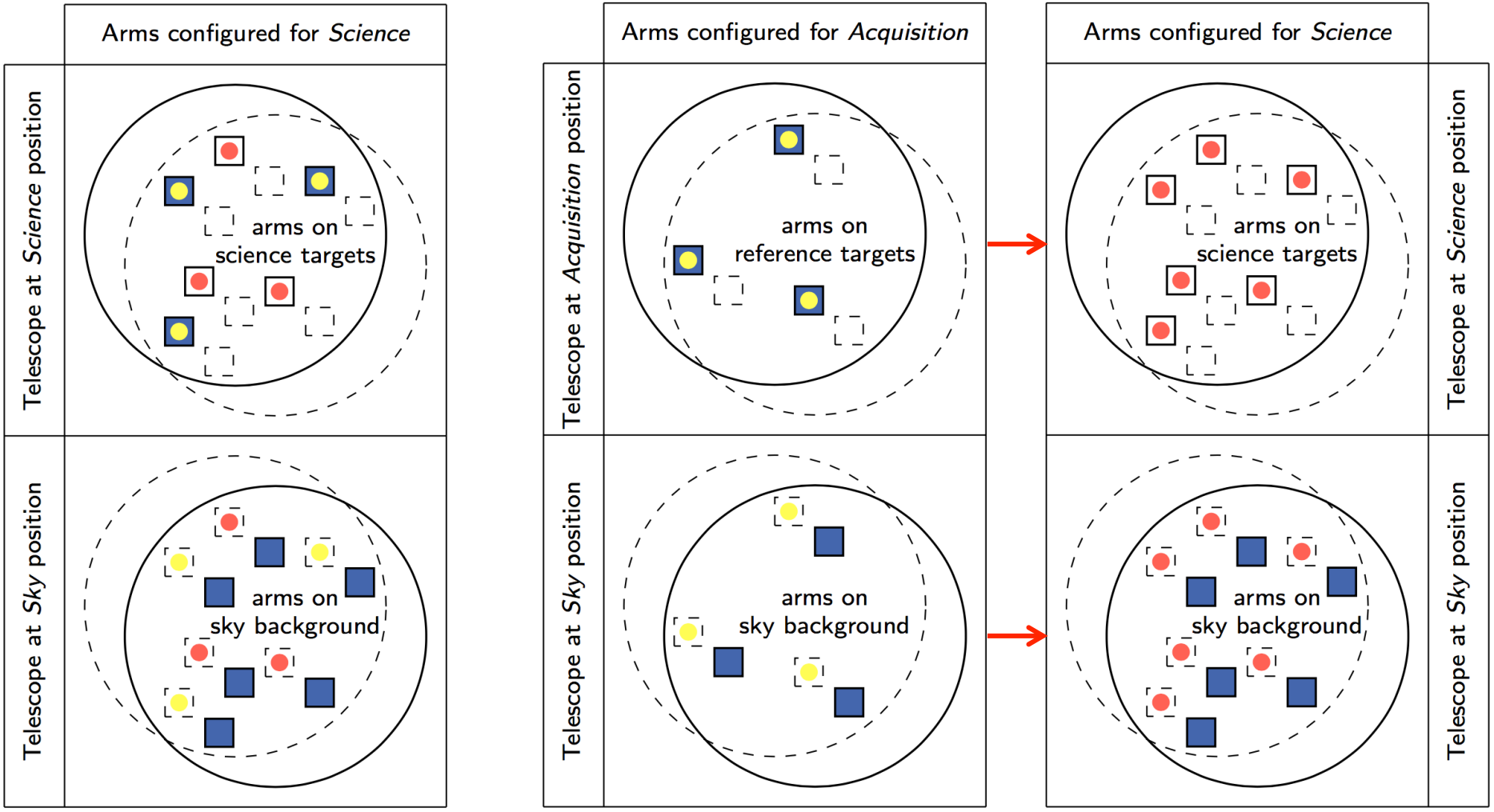
Arm 16 has been allocated manually at *Sky* position

Main window after automatic allocation with Hungarian Algorithm

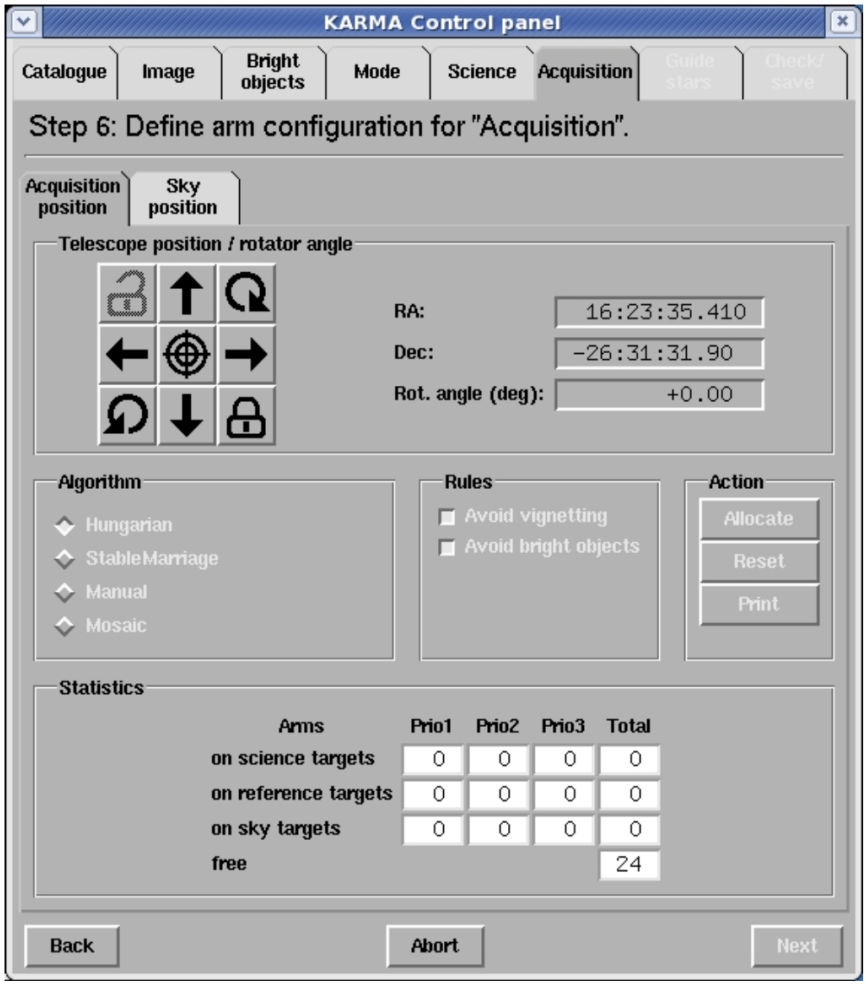
Step 6: Define arm configuration for acquisition

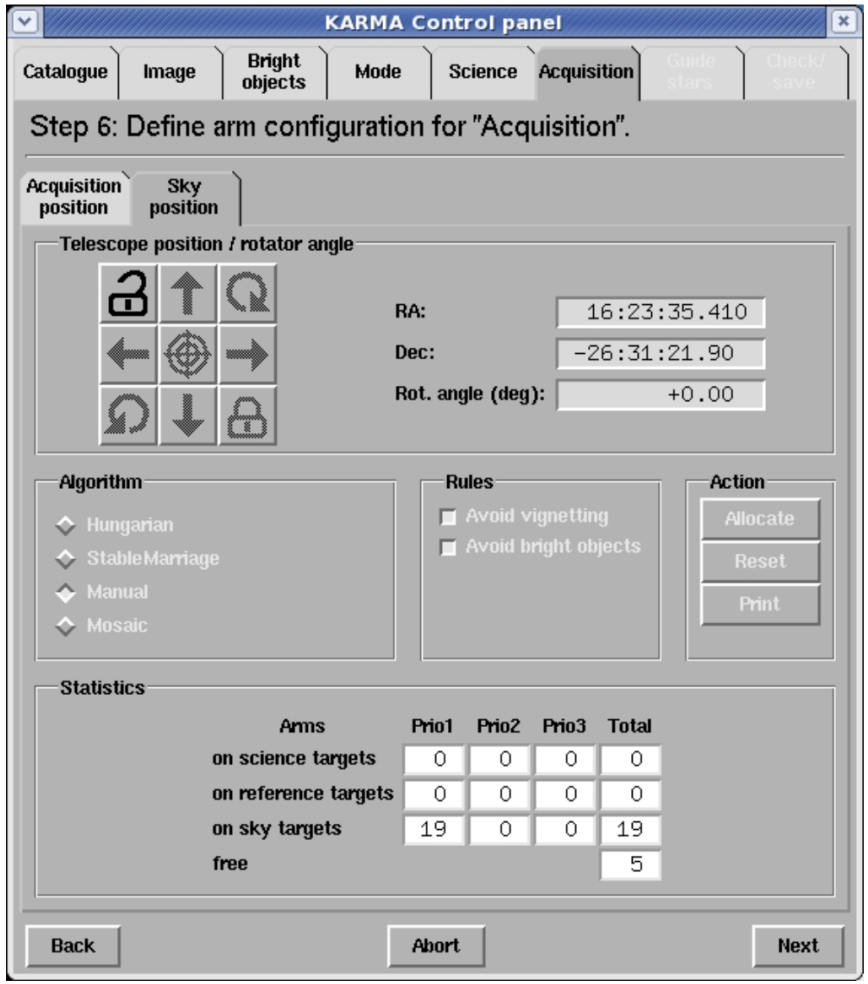
Acquisition from science targets

Acquisition from reference targets



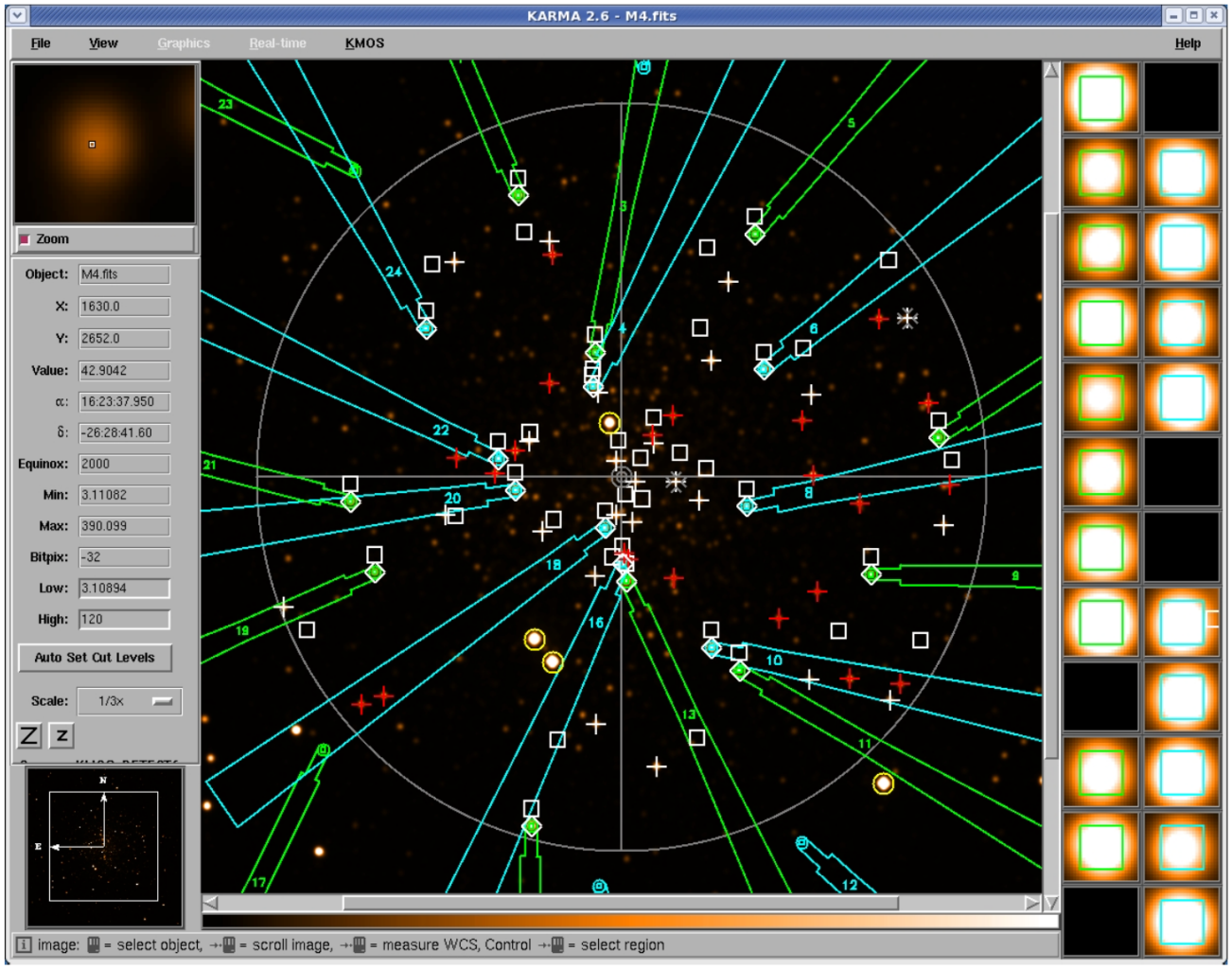
Step 6: Define arm configuration for acquisition





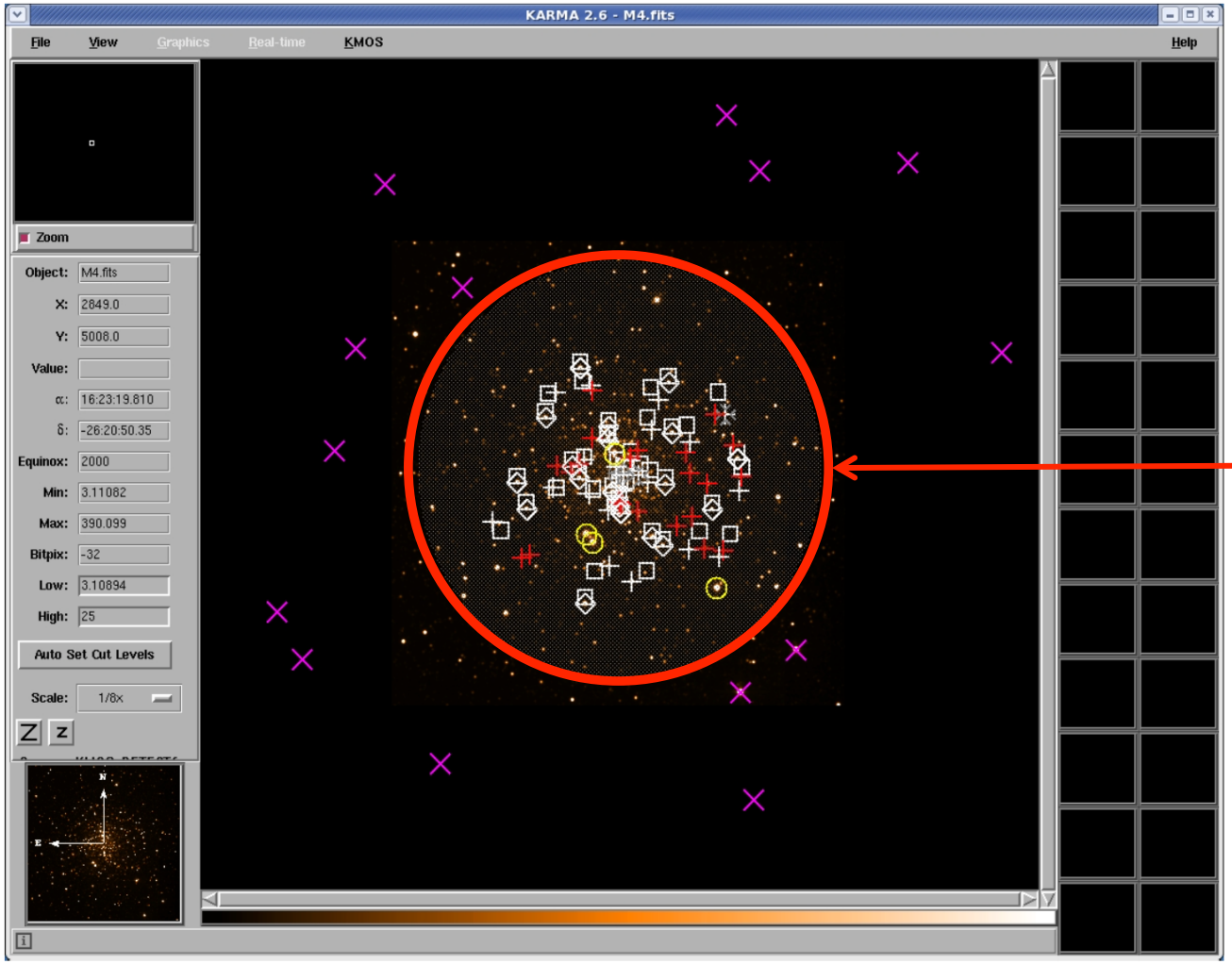
Control panel before and after having performed telescope/instrument adjustment and arm allocation in a dedicated acquisition preparation step

Step 6: Define arm configuration for acquisition



Main window after automatic allocation of reference targets

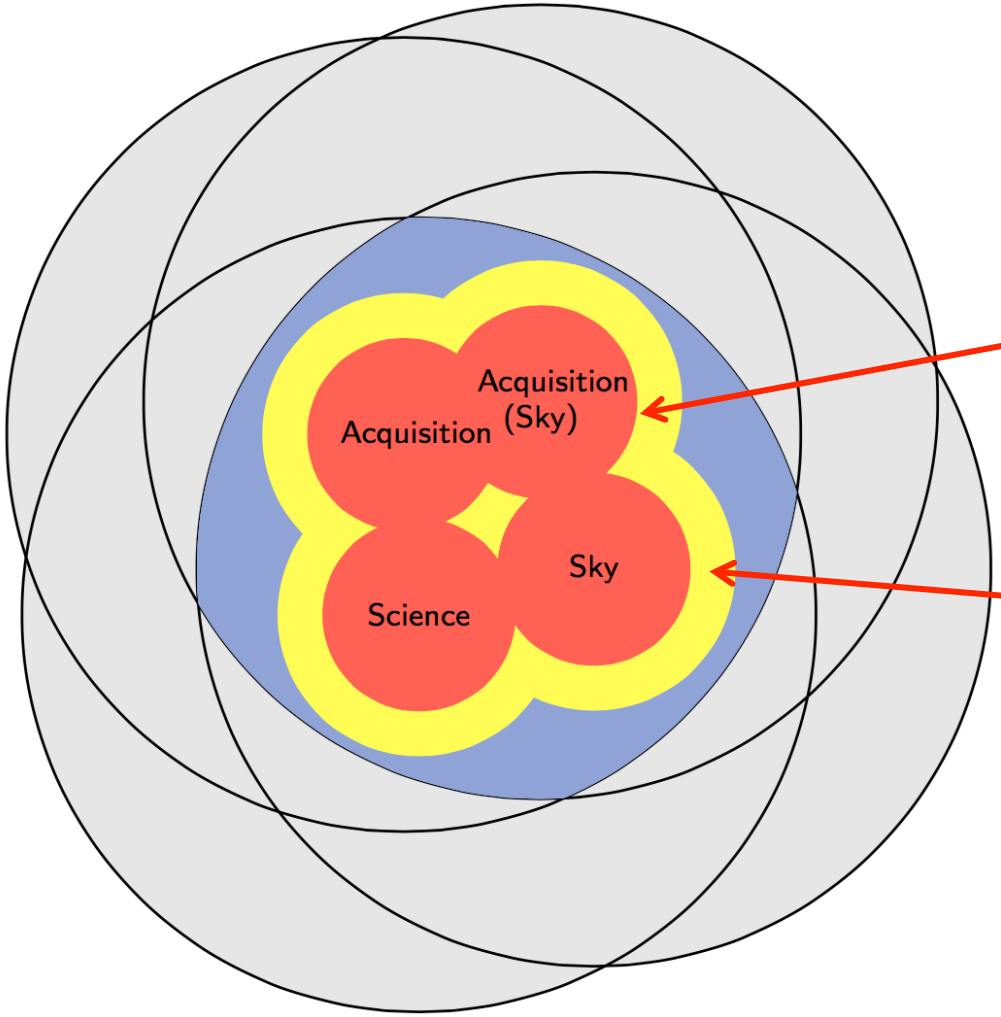
Step 7: Select telescope guide star



Guide star avoidance zone

Main window ready for telescope guide star selection

Step 7: Select telescope guide star

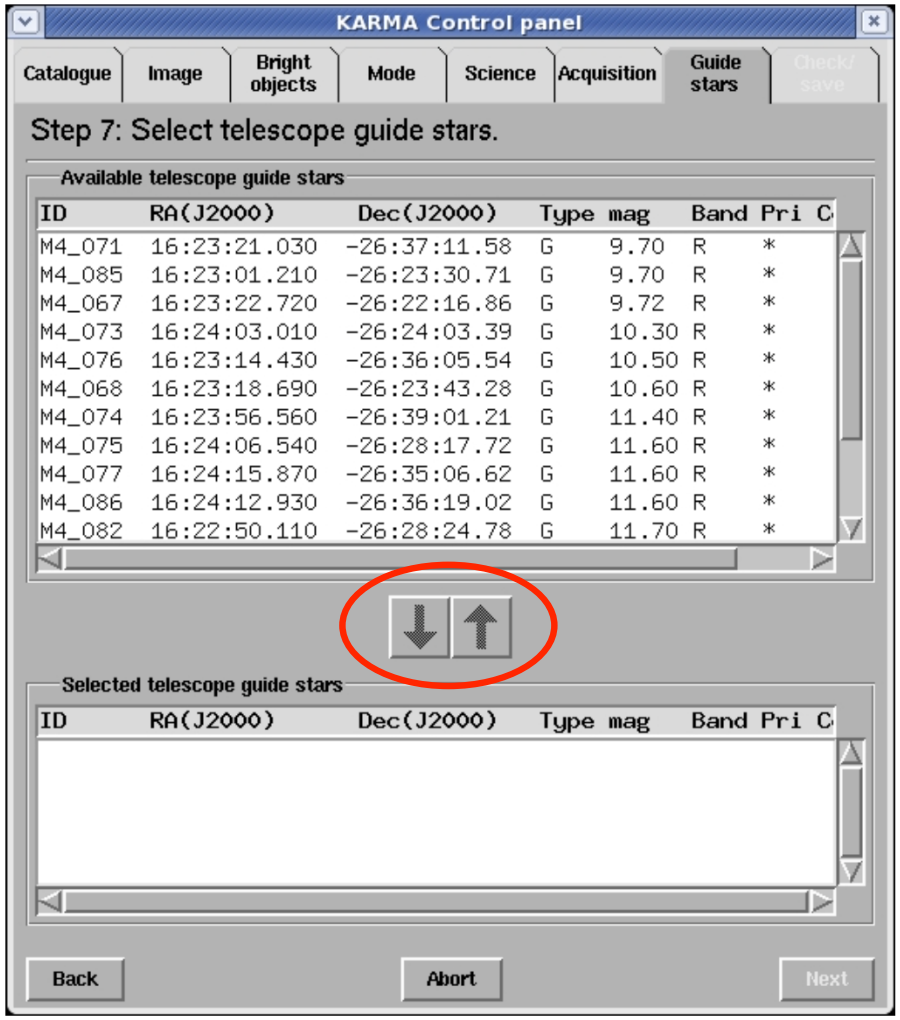


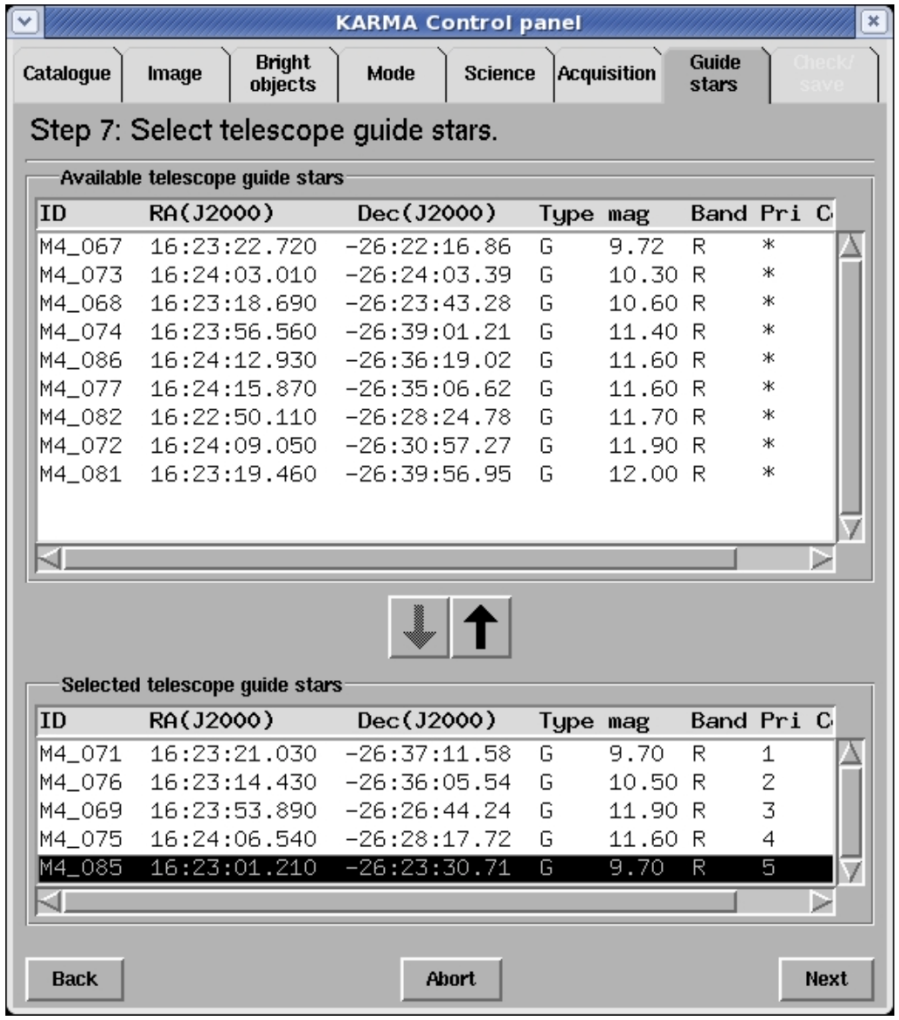
KMOS field-of-views

Additional margin

Allowed area for guide star selection (blue)

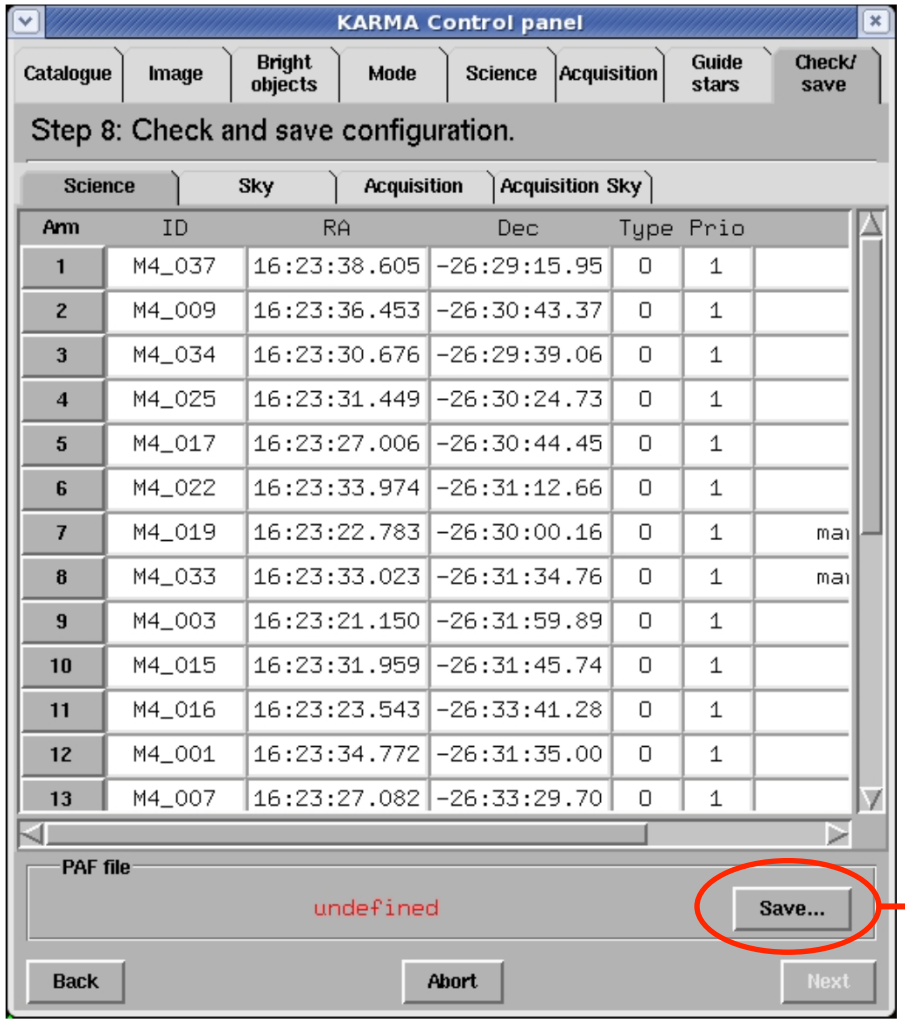
Step 7: Select telescope guide star

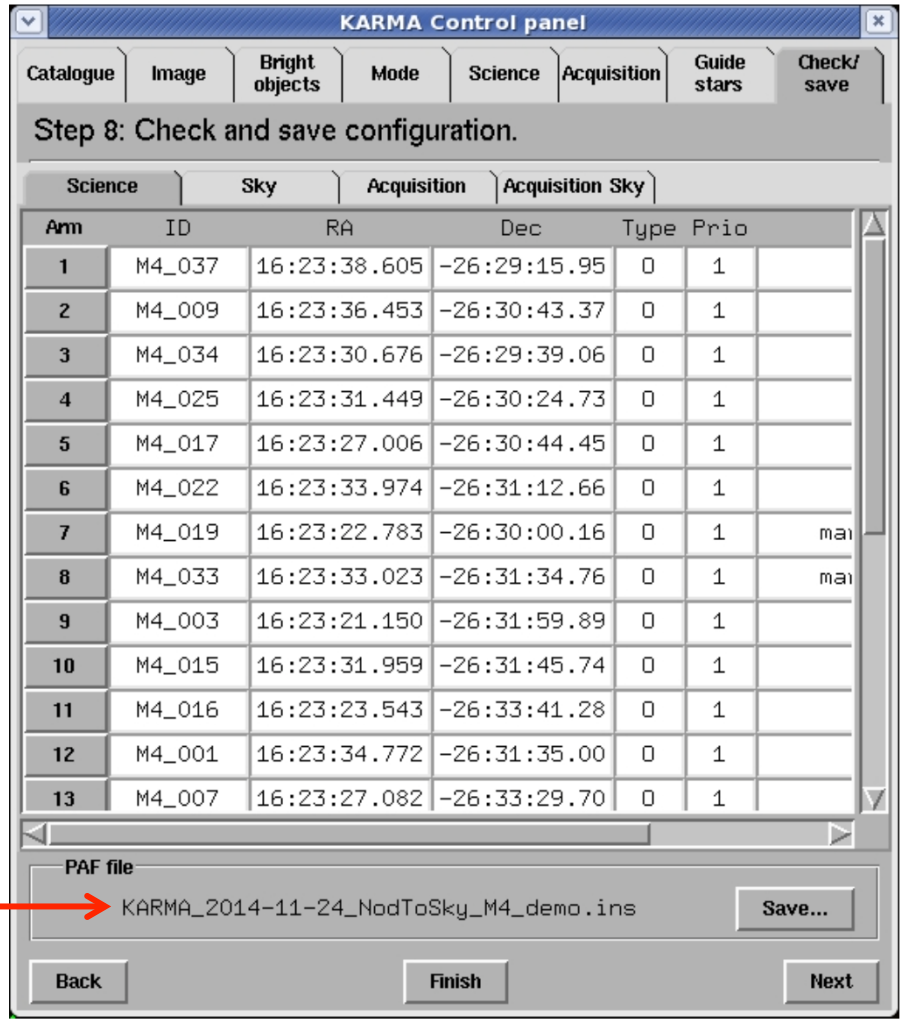




Control panel before and after 5 potential guide stars have been selected

Step 8: Save configuration (PAF) file





Summary of the arm allocations in the 4 telescope positions

Example PAF file (KARMA set up file)

```
# This file has been generated by the KARMA tool. Do not attempt to edit it by
# hand. Modified files will be rejected by P2PP3 tool.
#------------------------------------------------------------------------------
# PAF Header

PAF.HDR.START;
PAF.TYPE          "Paramfile";
PAF.ID            "KARMA_2015-02-12_NodToSky_M4_demo.ins";
PAF.NAME          "KARMA_2015-02-12_NodToSky_M4_demo.ins";
PAF.DESC          "KARMA PAF output";
PAF.CRTE.NAME     "KMOS OSS";
PAF.CRTE.DAYTIM   "2015-02-12T12:15:40";
PAF.LCHG.NAME     "";
PAF.LCHG.DAYTIM   "";
PAF.CHCK.NAME     "KMOS OSS";
PAF.CHCK.DAYTIM   "2015-02-12T12:15:40";
PAF.CHCK.CHECKSUM "2163840165";
PAF.HDR.END;
#------------------------------------------------------------------------------
# Primary Keywords

TEL.TARG.NAME                    "M4.cat" ;# name of the catalogue
TEL.TARG.EQUINOX                   2000.0 ;# epoch
TEL.TARG.ALPHA                162335.410000 ;# initial telescope pointing RA
TEL.TARG.DELTA               -263131.900000 ;# initial telescope pointing Dec
TEL.ROT.OFFANGLE                  0.000000 ;# initial rotator angle

OCS.OSS.VER                         "2.6" ;# KARMA release number
OCS.OSS.REVISION                 "264822" ;# KMOS SVN revision number

TPL.MODE.OBS                  "NOD_TO_SKY" ;# sky background subtraction mode
TPL.MODE.ACQ              "FROM_REFERENCE" ;# acquisition mode
#------------------------------------------------------------------------------
# Path for PAF file within INS
```

Header

Primary keywords (pointing, mode)

Example PAF file (KARMA set up file)

```
OCS.ARMS.INIT               F ;# Initialise arms (T) or just park (F)
#------------------------------------------------------------------------------
# Potential Instrument Guide Stars

TEL.GS1.ALPHA   162321.030000 ;# RA
TEL.GS1.DELTA  -263711.580000 ;# Dec
TEL.GS1.MAG              9.70 ;# magnitude as given in catalogue
OCS.GS1.BAND              "R" ;# wavelength band as given in catalogue

TEL.GS2.ALPHA   162314.430000 ;# RA
TEL.GS2.DELTA  -263605.540000 ;# Dec
TEL.GS2.MAG             10.50 ;# magnitude as given in catalogue
OCS.GS2.BAND              "R" ;# wavelength band as given in catalogue

TEL.GS3.ALPHA   162353.890000 ;# RA
TEL.GS3.DELTA  -262644.240000 ;# Dec
TEL.GS3.MAG             11.90 ;# magnitude as given in catalogue
OCS.GS3.BAND              "R" ;# wavelength band as given in catalogue
```

Guide Stars

Example PAF file (KARMA set up file)

```
# Bright objects in field

OCS.BRGH1.NAME          "M4_087" ;# name/id of bright object 1
OCS.BRGH1.ALPHA    162323.819000 ;# RA
OCS.BRGH1.DELTA   -263429.760000 ;# Dec
OCS.BRGH1.MAG              7.01 ;# magnitude as given in catalogue
OCS.BRGH1.BAND              "J" ;# wavelength band as given in catalogue
OCS.BRGH1.COMMENT            "" ;

OCS.BRGH2.NAME          "M4_088" ;# name/id of bright object 2
OCS.BRGH2.ALPHA    162338.470000 ;# RA
OCS.BRGH2.DELTA   -263319.250000 ;# Dec
OCS.BRGH2.MAG              6.97 ;# magnitude as given in catalogue
OCS.BRGH2.BAND              "J" ;# wavelength band as given in catalogue
OCS.BRGH2.COMMENT            "" ;

OCS.BRGH3.NAME          "M4_089" ;# name/id of bright object 3
OCS.BRGH3.ALPHA    162335.942000 ;# RA
OCS.BRGH3.DELTA   -263100.900000 ;# Dec
OCS.BRGH3.MAG              7.51 ;# magnitude as given in catalogue
OCS.BRGH3.BAND              "J" ;# wavelength band as given in catalogue
OCS.BRGH3.COMMENT            "" ;
```

Bright objects

Example PAF file (KARMA set up file)

```
# Arm configuration at acquisition/target position

OCS.TARG.ACQ.ALPHA     162335.410000 ;# telescope pointing RA
OCS.TARG.ACQ.DELTA    -263131.900000 ;# telescope pointing Dec
OCS.ROT.ACQ.OFFANGLE       0.000000 ;# rotator angle

OCS.ARM1.ACQ.NAME           "M4_062" ;# name/id of catalogue entry
OCS.ARM1.ACQ.ALPHA     162339.969000 ;# target RA
OCS.ARM1.ACQ.DELTA    -262849.080000 ;# target Dec
OCS.ARM1.ACQ.Y             35.888012 ;# y position of arm tip in device system
OCS.ARM1.ACQ.Z             95.459355 ;# z position of arm tip in device system
OCS.ARM1.ACQ.R            168.107181 ;# distance of arm tip from arm axis
OCS.ARM1.ACQ.THETA         -1.150209 ;# angular move of arm
OCS.ARM1.ACQ.PRIOR                1 ;# target priority
OCS.ARM1.ACQ.TYPE               "R" ;# target type: reference
OCS.ARM1.ACQ.MAG               8.61 ;# magnitude as given in catalogue
OCS.ARM1.ACQ.BAND               "J" ;# wavelength band as given in catalogue
OCS.ARM1.ACQ.HIT                "" ;# bright object(s) hitting the arm
OCS.ARM1.ACQ.COMMENT            "" ;

OCS.ARM3.ACQ.NAME           "M4_053" ;# name/id of catalogue entry
OCS.ARM3.ACQ.ALPHA     162336.577000 ;# target RA
OCS.ARM3.ACQ.DELTA    -263020.040000 ;# target Dec
OCS.ARM3.ACQ.Y              9.184491 ;# y position of arm tip in device system
OCS.ARM3.ACQ.Z             42.131627 ;# z position of arm tip in device system
OCS.ARM3.ACQ.R            229.892040 ;# distance of arm tip from arm axis
OCS.ARM3.ACQ.THETA          3.642493 ;# angular move of arm
OCS.ARM3.ACQ.PRIOR                1 ;# target priority
OCS.ARM3.ACQ.TYPE               "R" ;# target type: reference
OCS.ARM3.ACQ.MAG               9.35 ;# magnitude as given in catalogue
OCS.ARM3.ACQ.BAND               "J" ;# wavelength band as given in catalogue
OCS.ARM3.ACQ.HIT                "" ;# bright object(s) hitting the arm
OCS.ARM3.ACQ.COMMENT            "" ;
```

Acquisition: reference star positions

Example PAF file (KARMA set up file)

```
# Arm configuration at acquisition/sky position

OCS.TARG.SKA.ALPHA     162335.410000 ;# telescope pointing RA
OCS.TARG.SKA.DELTA    -263121.900000 ;# telescope pointing Dec
OCS.ROT.SKA.OFFANGLE       0.000000 ;# rotator angle

OCS.ARM1.SKA.NAME         "ARM1_SKA" ;# name/id of catalogue entry
OCS.ARM1.SKA.ALPHA     162339.968890 ;# target RA
OCS.ARM1.SKA.DELTA    -262839.080001 ;# target Dec
OCS.ARM1.SKA.Y             35.888012 ;# y position of arm tip in device system
OCS.ARM1.SKA.Z             95.459355 ;# z position of arm tip in device system
OCS.ARM1.SKA.R            168.107181 ;# distance of arm tip from arm axis
OCS.ARM1.SKA.THETA         -1.150209 ;# angular move of arm
OCS.ARM1.SKA.TYPE                "S" ;# target type: sky background
OCS.ARM1.SKA.HIT                 "" ;# bright object(s) hitting the arm
OCS.ARM1.SKA.COMMENT "corresponds to M4_062" ;

OCS.ARM3.SKA.NAME         "ARM3_SKA" ;# name/id of catalogue entry
OCS.ARM3.SKA.ALPHA     162336.576972 ;# target RA
OCS.ARM3.SKA.DELTA    -263010.040000 ;# target Dec
OCS.ARM3.SKA.Y              9.184491 ;# y position of arm tip in device system
OCS.ARM3.SKA.Z             42.131627 ;# z position of arm tip in device system
OCS.ARM3.SKA.R            229.892040 ;# distance of arm tip from arm axis
OCS.ARM3.SKA.THETA          3.642493 ;# angular move of arm
OCS.ARM3.SKA.TYPE                "S" ;# target type: sky background
OCS.ARM3.SKA.HIT                 "" ;# bright object(s) hitting the arm
OCS.ARM3.SKA.COMMENT "corresponds to M4_053" ;
```

Acquisition: sky positions

Example PAF file (KARMA set up file)

```
# Arm configuration at first ("Science") position

OCS.TARG.SCI.ALPHA     162335.410000 ;# telescope pointing RA
OCS.TARG.SCI.DELTA    -263131.900000 ;# telescope pointing Dec
OCS.ROT.SCI.OFFANGLE       0.000000 ;# rotator angle

OCS.ARM1.SCI.NAME           "M4_037" ;# name/id of catalogue entry
OCS.ARM1.SCI.ALPHA     162338.605000 ;# target RA
OCS.ARM1.SCI.DELTA    -262915.950000 ;# target Dec
OCS.ARM1.SCI.Y             25.149100 ;# y position of arm tip in device system
OCS.ARM1.SCI.Z             79.706718 ;# z position of arm tip in device system
OCS.ARM1.SCI.R            186.877826 ;# distance of arm tip from arm axis
OCS.ARM1.SCI.THETA         -2.228802 ;# angular move of arm
OCS.ARM1.SCI.PRIOR                1 ;# target priority
OCS.ARM1.SCI.TYPE               "O" ;# target type: science
OCS.ARM1.SCI.MAG              10.46 ;# magnitude as given in catalogue
OCS.ARM1.SCI.BAND               "J" ;# wavelength band as given in catalogue
OCS.ARM1.SCI.HIT                "" ;# bright object(s) hitting the arm
OCS.ARM1.SCI.COMMENT            "" ;

OCS.ARM2.SCI.NAME           "M4_009" ;# name/id of catalogue entry
OCS.ARM2.SCI.ALPHA     162336.453000 ;# target RA
OCS.ARM2.SCI.DELTA    -263043.370000 ;# target Dec
OCS.ARM2.SCI.Y             8.208126 ;# y position of arm tip in device system
OCS.ARM2.SCI.Z            28.453191 ;# z position of arm tip in device system
OCS.ARM2.SCI.R           240.759504 ;# distance of arm tip from arm axis
OCS.ARM2.SCI.THETA         1.052884 ;# angular move of arm
OCS.ARM2.SCI.PRIOR                1 ;# target priority
OCS.ARM2.SCI.TYPE               "O" ;# target type: science
OCS.ARM2.SCI.MAG               9.98 ;# magnitude as given in catalogue
OCS.ARM2.SCI.BAND               "J" ;# wavelength band as given in catalogue
OCS.ARM2.SCI.VIGNET               F ;# IFU vignetted (T) or not vignetted (F)
OCS.ARM2.SCI.COMMENT            "" ;
```

Science: target positions

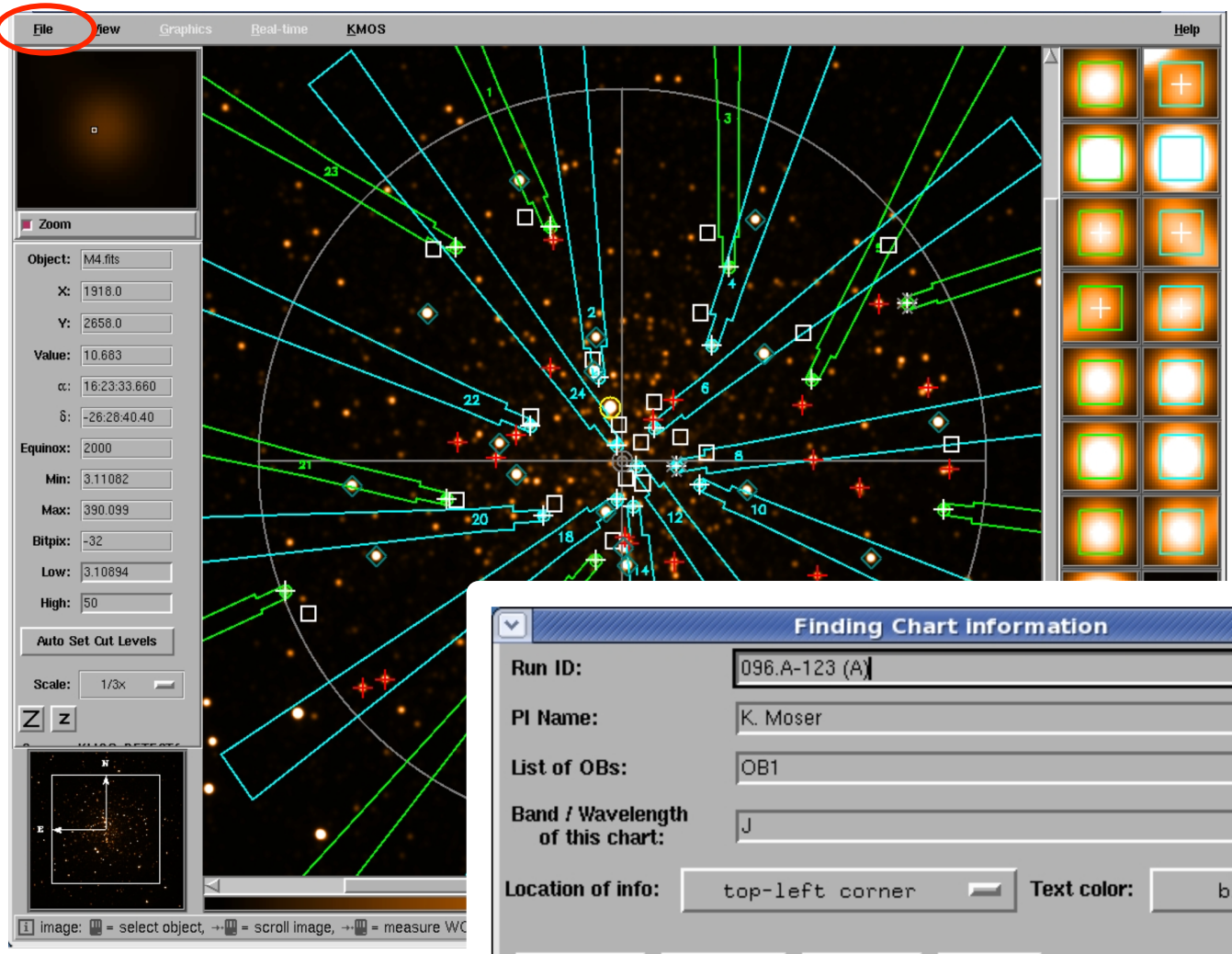
Example PAF file (KARMA set up file)

```
# Arm configuration at second ("Sky") position

OCS.TARG.SKY.ALPHA     162335.224000 ;# telescope pointing RA
OCS.TARG.SKY.DELTA    -263119.400000 ;# telescope pointing Dec
OCS.ROT.SKY.OFFANGLE       7.500000 ;# rotator angle

OCS.ARM1.SKY.NAME         "ARM1_SKY" ;# name/id of catalogue entry
OCS.ARM1.SKY.ALPHA     162339.713329 ;# target RA
OCS.ARM1.SKY.DELTA    -262910.209717 ;# target Dec
OCS.ARM1.SKY.Y             25.149100 ;# y position of arm tip in device system
OCS.ARM1.SKY.Z             79.706718 ;# z position of arm tip in device system
OCS.ARM1.SKY.R            186.877826 ;# distance of arm tip from arm axis
OCS.ARM1.SKY.THETA         -2.228802 ;# angular move of arm
OCS.ARM1.SKY.TYPE               "S" ;# target type: sky background
OCS.ARM1.SKY.HIT                "" ;# bright object(s) hitting the arm
OCS.ARM1.SKY.COMMENT "corresponds to M4_037" ;

OCS.ARM2.SKY.NAME         "ARM2_SKY" ;# name/id of catalogue entry
OCS.ARM2.SKY.ALPHA     162336.729960 ;# target RA
OCS.ARM2.SKY.DELTA    -263033.112260 ;# target Dec
OCS.ARM2.SKY.Y              8.208126 ;# y position of arm tip in device system
OCS.ARM2.SKY.Z             28.453191 ;# z position of arm tip in device system
OCS.ARM2.SKY.R            240.759504 ;# distance of arm tip from arm axis
OCS.ARM2.SKY.THETA          1.052884 ;# angular move of arm
OCS.ARM2.SKY.TYPE               "S" ;# target type: sky background
OCS.ARM2.SKY.VIGNET               F ;# IFU vignetted (T) or not vignetted (F)
OCS.ARM2.SKY.COMMENT "corresponds to M4_009" ;
```

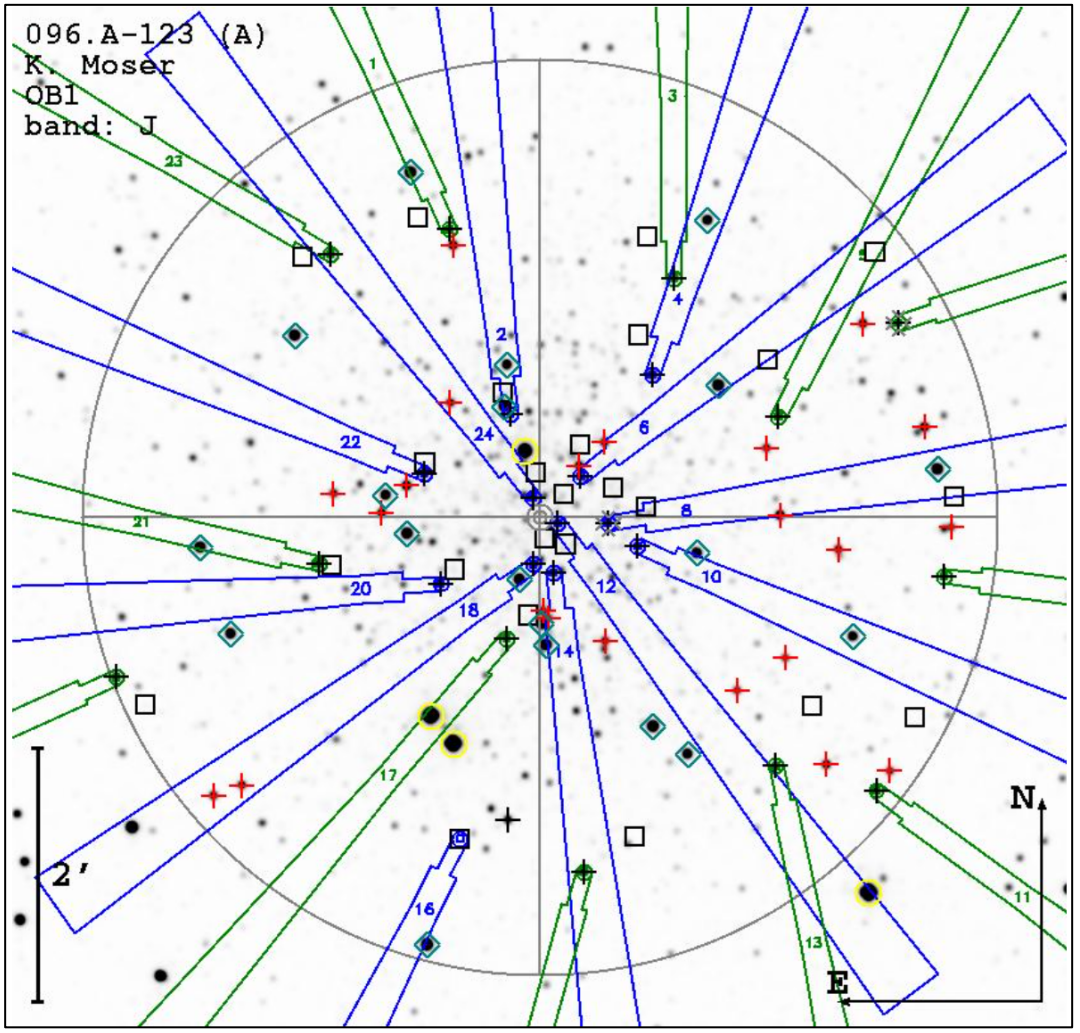
Science:
sky positions

Finding Charts for KMOS observation

File menu:
Make finding chart…

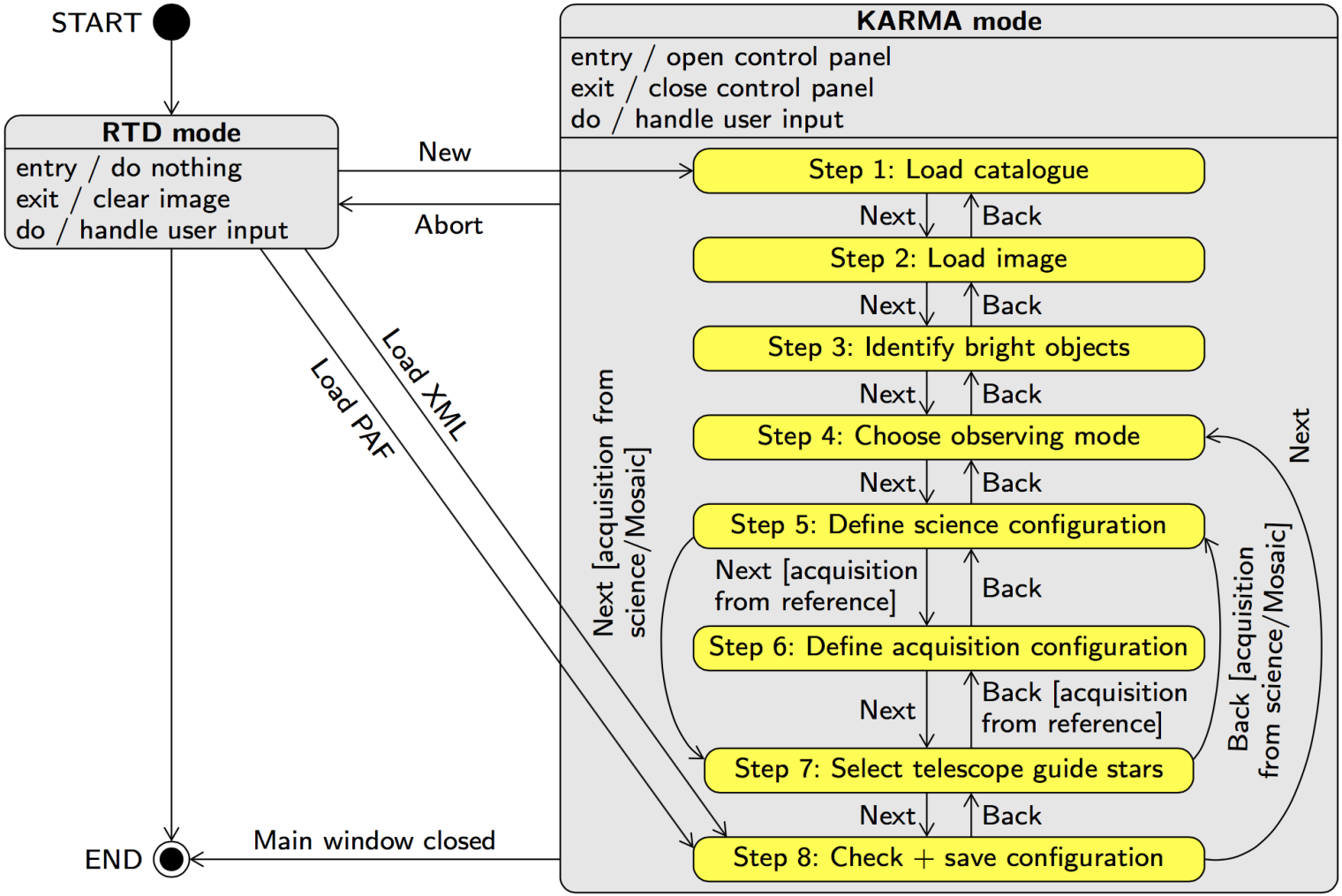


Finding Charts for KMOS observation



KARMA finding chart in JPEG

Looping through a KARMA session

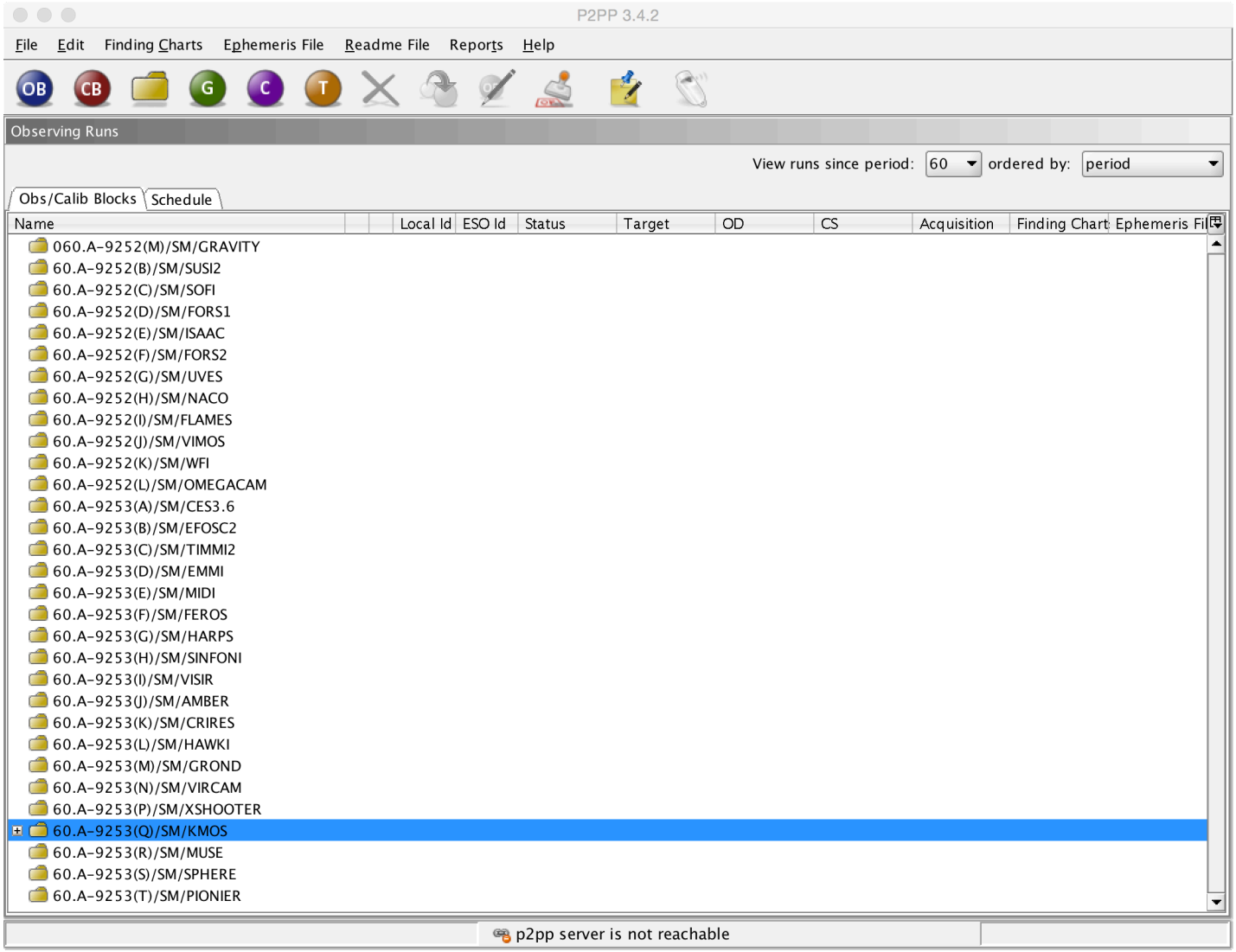


State chart illustrating the different ways to start and finish a KARMA session

Creating KMOS OBs with P2PP

P2PP tutorial account:

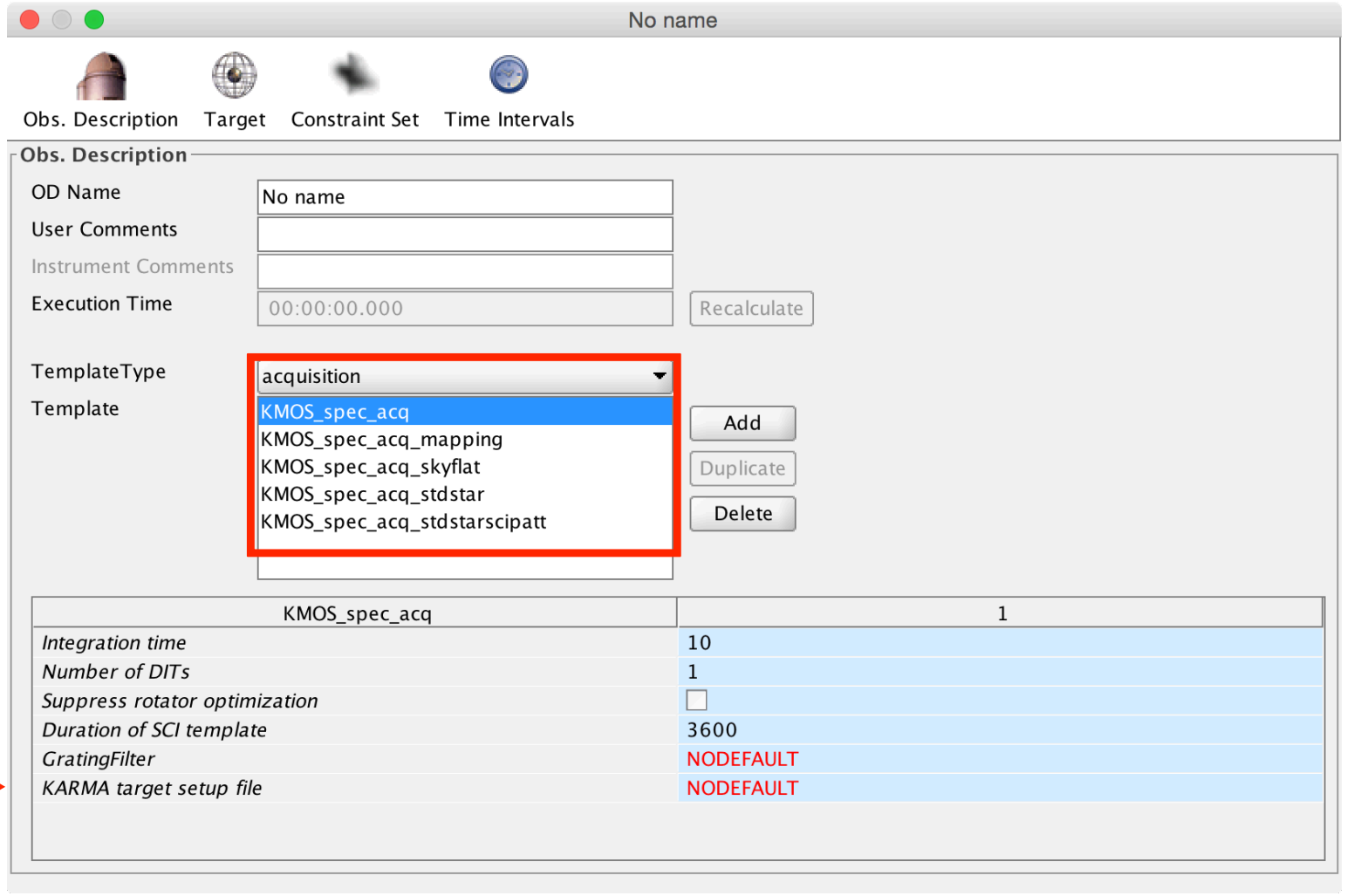
P2PP ID:
52052
password:
tutorial



Creating KMOS OBs with P2PP

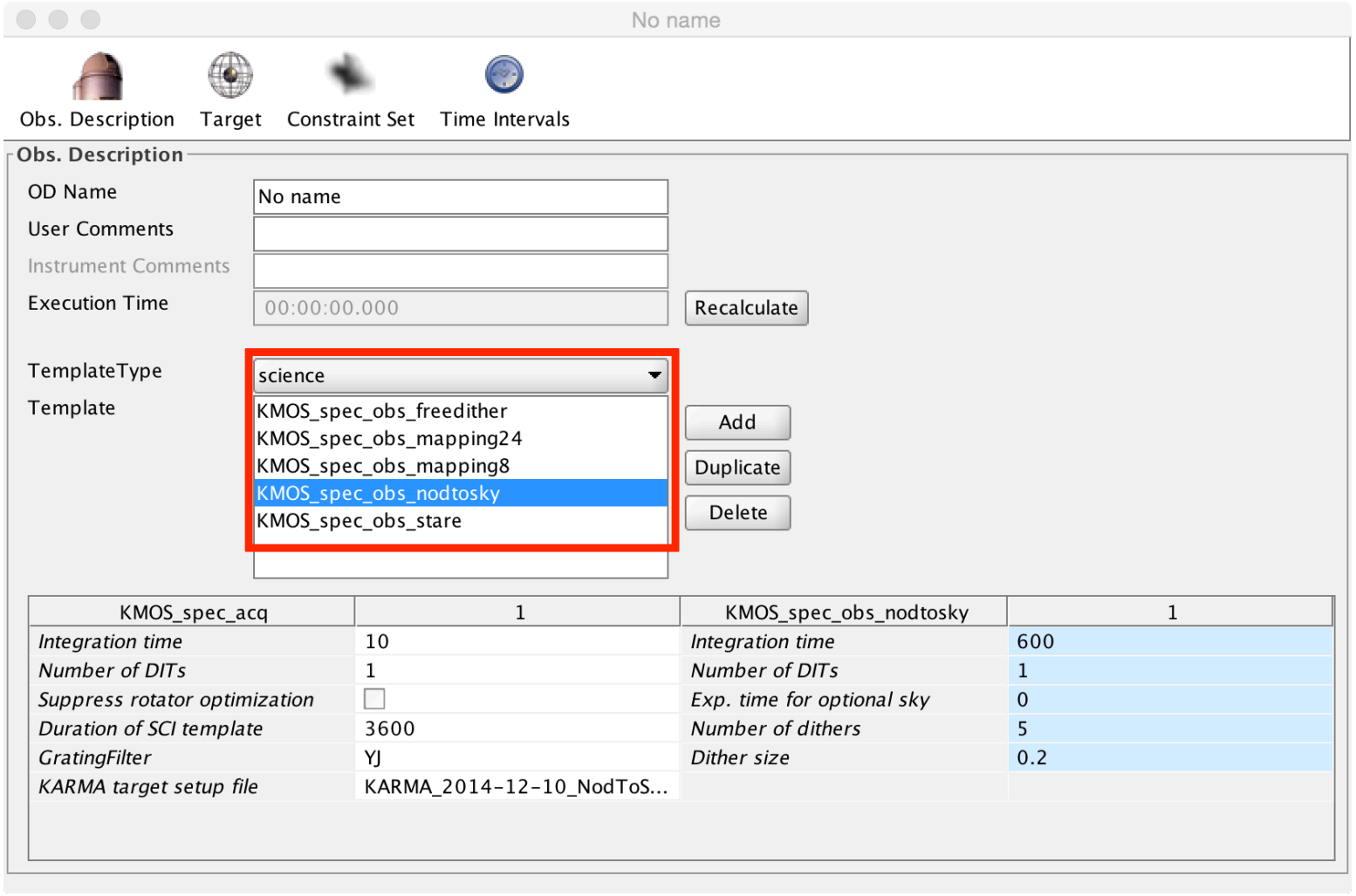
Selection of acquisition template

PAF file →



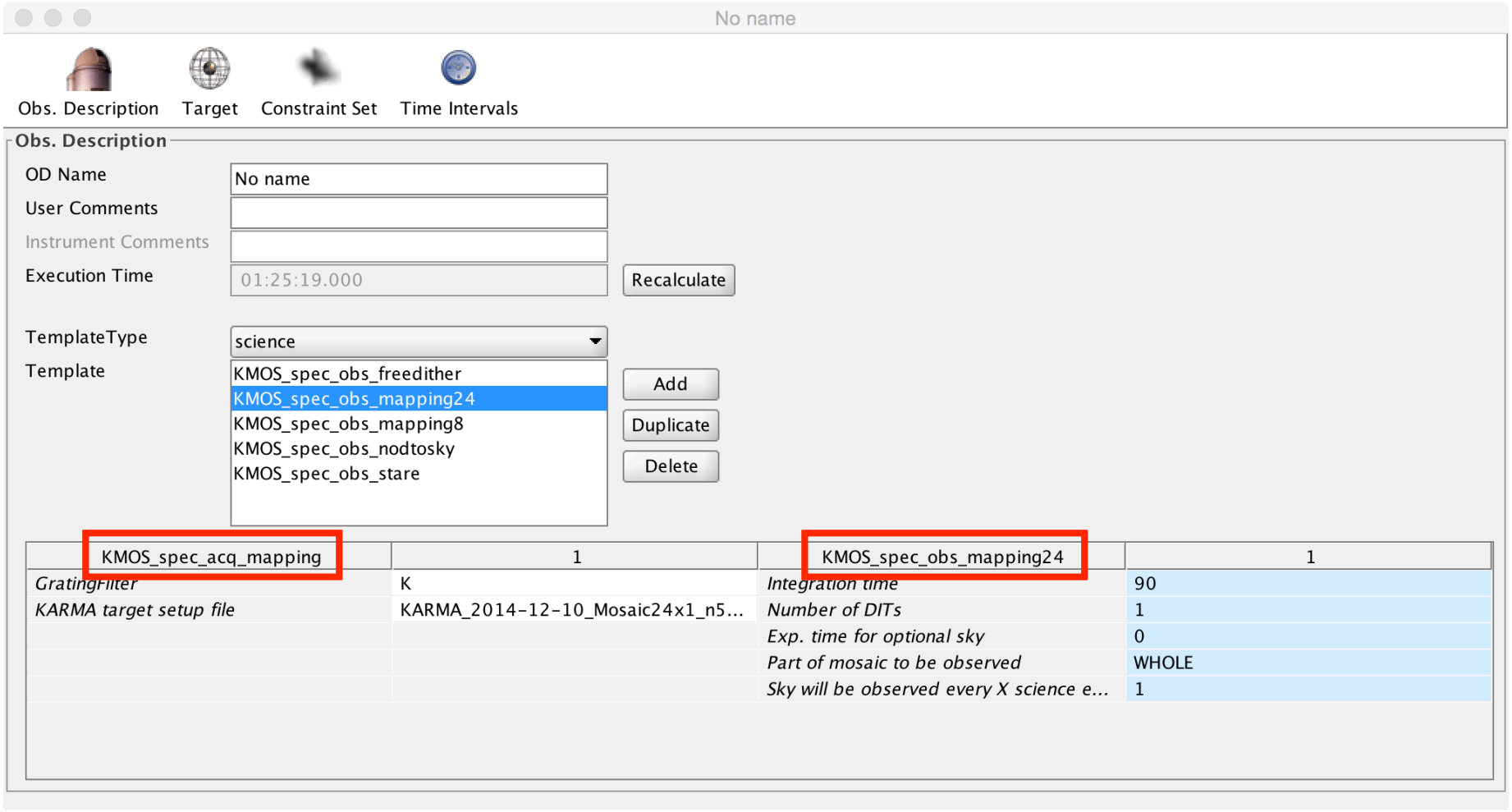
Creating KMOS OBs with P2PP

Selection of science template



Creating KMOS OBs with P2PP

Case of mosaic observation



Hints and tips for preparing KMOS observations

6 Summary of hints and tips for preparing observations

- **Astrometry**. Make sure that science targets, guide stars and reference stars are all on the same coordinate system. UCAC4 on Vizier can be used to find stars with accurate astrometry or use stars extracted from the same images as the science targets.
- **Always correct for proper motion.**
- Choose Telescope Guide stars with magnitudes in the R-band: $8 < \mathrm{R_{Vega}} < 12$
- Choose at least 3-4 Reference stars in the magnitude range 8-14, in the same band as the science observations. However, the more stars you provide the better the alignment will be.
- If possible, use the same rotator angle for acquisition and science observations, since a significant difference in the rotator angle might introduce some positioning error (up to 2-3 pixels shift of the science targets on the IFU for large rotations).
- To avoid persistence, it is recommended to observe simultaneously only sources with similar magnitudes - within a range of 3-4 magnitudes. Choose the DIT and NDIT using the ETC such that fluxes are at most 5,000 ADUs/DIT/pixel ($\approx 2,500\mathrm{e}^-$/DIT/pixel), even for significantly better conditions than foreseen (e.g. using seeing $0.4''$ in the ETC).

Hints and tips for preparing KMOS observations

- Do not observe sources brighter than 6th magnitude (Vega) in all bands, because that would saturate and cause severe persistence.
- For observations of faint targets (which will not be detected in each single exposure), it might be useful to have one or two IFUs dedicated to observe a brighter star, which will be detected in a single exposure and therefore can be used to cross-check the registration of the frames. For example if the main science targets are faint galaxies ($H_{AB} \approx 23$) observed with several 300sec exposures, it can be useful to dedicate one of the 24 IFUs to observe simultaneously a star of $H_{AB} \approx 19 - 20$ in the field.
- Use a [AB AB ...] or [ABA ABA ...] nodding pattern to obtain best sky subtraction (sky frequency 1 or 2).
- IZ observations in dark or grey time, YJ observations in grey time, or bright time if $> 90°$ away from the moon; H and K observations in any conditions.
- Background dominated observations are reached for exposures longer than 300 sec.

Chapter 6 of the KMOS User Manual

Remember Giacomo's words: *"Read the f….. Manual!"*