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# The MUSE observation preparation tool

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## ABSTRACT

MUSE (Multi Unit Spectroscopic Explorer) is an integral-field spectrograph which will be mounted on the Very Large Telescope (VLT). MUSE is being built for ESO by a European consortium under the supervision of the Centre de Recherche Astrophysique de Lyon (CRAL).

In this context, CRAL is responsible for the development of dedicated software to help MUSE users prepare and submit their observations. This software, called MUSE-PS, is based on the ESO SkyCat tool that combines visualization of images and access to catalogs and archive data for astronomy. MUSE-PS has been developed as a plugin to SkyCat to add new features specific to MUSE observations.

In this paper, we present the MUSE observation preparation tool itself and especially its specific functionalities: definition of the center of the MUSE field of view and orientation, selection of the VLT guide star for the different modes of operations (Narrow Field Mode or Wide Field Mode, with or without AO). We will also show customized displays for MUSE (zoom on specific area, help with MUSE mosaicing and generic offsets, finding charts ...).

**Keywords:** MUSE, VLT, observation, guide stars

## 1. INTRODUCTION TO THE MUSE PROJECT

MUSE is an integral-field spectrograph operating in the visible wavelength range. It will be located on the Nasmyth platform of the VLT. It has two main modes of operation: the Wide Field Mode (WFM) with a field of view (FOV) covering 1x1 arcminutes for surveys and general use; and the Narrow Field Mode (NFM) with a FOV of 7.5x7.5 arcseconds for achieving unprecedented spatial resolution across a sizable field [1].

The instrument is specifically designed to exploit the capabilities of the VLT Adaptive Optics Telescope Facility (AO), which uses four laser guide stars and a relatively faint natural guide star to apply corrections via a deformable secondary mirror. MUSE can also be used without AO, but only in WFM.

The main scientific goal of MUSE, as being carried out during the Guaranteed Time Observations, will be to study the high redshift Universe through the measurement of the Lyman-alpha signature in distant galaxies ( $2.8 < z < 6.7$ ). Other science topics include the study of nearby galaxies and intermediary redshift groups (up to  $z=0.8$ ) as well as globular clusters.

Users who have obtained observing time with the MUSE instrument will need to use the ESO Phase 2 Proposal Preparation Tool (P2PP) to create and manage Observation Blocks (OBs). These OBs are used to describe observing sequences with which MUSE instrument is operated and to provide the observatory with execution information [2]. A typical MUSE OB will contain MUSE setup, acquisition information, exposure information, target description, one or more finding charts ...

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The MUSE preparation software (MUSE-PS) is a graphical interface that will help the user design his observations. MUSE-PS uses public image servers and catalogs, as well as other ancillary data available to the user, and creates all the input files necessary to create the OBs in P2PP.

## 2. THE MUSE-PS SOFTWARE

### 2.1 MUSE-PS goals

The goal of MUSE preparation software is to help the MUSE user prepare the observations. It is a graphical interface that allows the user to visualize images and source catalogs from public archives and overlay a MUSE observing setup.

Via menus and mouse clicks, the user can:

- Define the observation mode.
- Define the position and the orientation of the MUSE field.
- Select guide stars.  
MUSE requires VLT Guide Star for guiding the telescope, reference star for Adaptive Optics (AO) and sources for the Slow Guiding System in WFM mode.
- Select a blank sky field.
- Visualize a mapping sequence of observations.
- Make finding charts.
- Generate an output file that will be ingested by P2PP.

### 2.2 MUSE-PS description

MUSE-PS is based on the ESO SkyCat tool. SkyCat is a tool that combines visualization of images and access to catalogs and archive data for astronomy. It lets the user load an image from the ESO server and shows on overlay the corresponding objects from a catalog [3]. MUSE-PS extends SkyCat by modifying existing features and by adding new functionalities specific to MUSE observations.

Starting the MUSE preparation software brings up a GUI with five components (see Figure 1):

- In the center, the main window displays a FITS image with the objects from a catalog plotted in the overlay.
- At the top, five different menus are available for the user: *File*, *View*, *Graphics*, *Go*, *MUSE*. The four first are in the SkyCat tool standard. The *MUSE* menu contains commands specific to MUSE observations.
- On the left side, the SkyCat information panel gives some information about the image and let the user zoom. Scale and orientation are visible.
- On the right side, a panel is dedicated to MUSE information. It displays data such as the mode of observation, the field of view center, the field of view rotation, the guide star location ... It is updated each time the user provides a new data.
- At the bottom, a table shows the detailed information on user selected objects from the catalog.

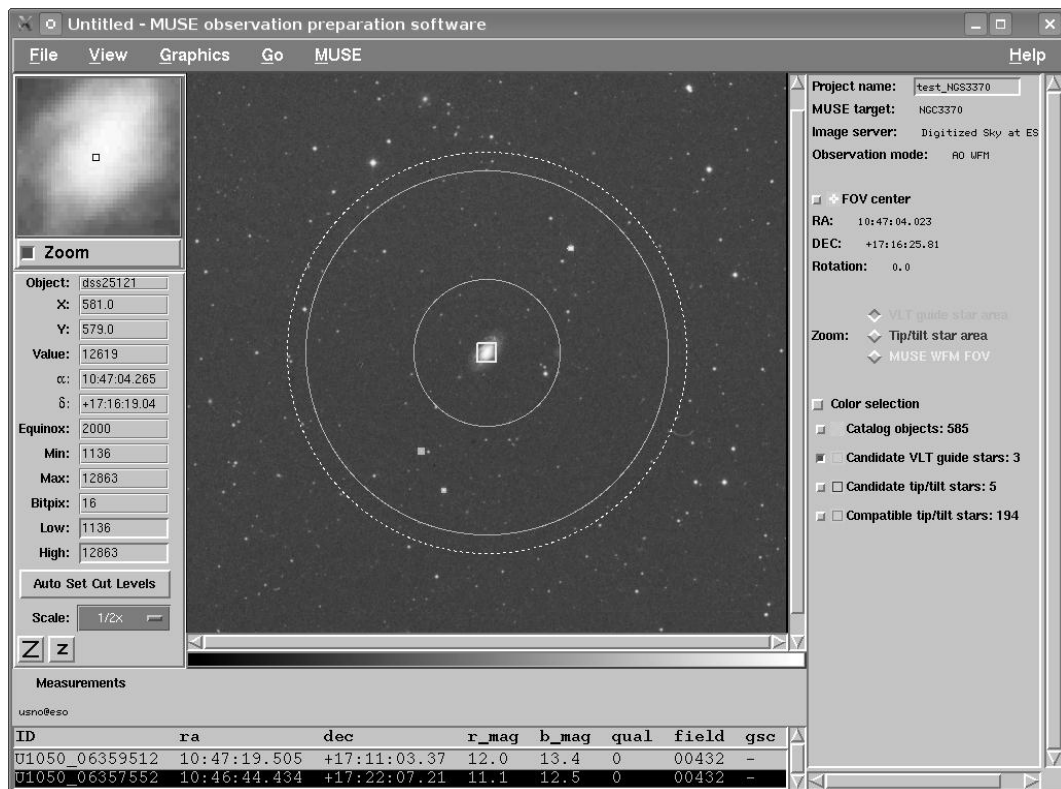


Figure 1: MUSE-PS main window.

### 2.3 Guide sources

The MUSE preparation software handles three different MUSE operational modes related to the use of the VLT Adaptive Optics (AO): Non-AO WFM mode, AO-WFM mode and NFM mode. MUSE requires selected guide stars for the following purposes:

- VLT Guide Star for guiding the telescope (all modes)
- Off-axis tip/tilt reference star in AO-WFM mode only: TTS (tip/tilt star)
- On-axis AO reference source in NFM mode only: OGS (on-axis guide source)
- Sources for the Slow Guiding System in WFM modes: SGSS.

The Table 1 describes the star guide areas. These areas are displayed on the image to help the user localize guide stars.

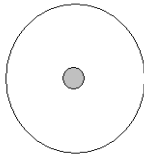
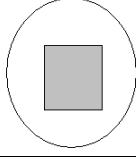

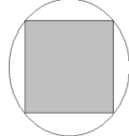
	<b>Guide Star Area</b>	<b>Shape</b>
<b>VLT guide star</b>	10 arcmin radius circle inside the unvignetted Nasmyth FOV 4 arcmin diameter circle excluded	
<b>TTS</b>	3.4 arcmin diameter circle MUSE FOV excluded	
<b>OGS</b>	Circle of 5 arcsec diameter centered on the MUSE FOV	
<b>SGSS</b>	“Banana” areas within a circle of 1 arcmin diameter and MUSE FOV excluded	

Table 1: Guide stars areas.

For the three first types of guide stars (VLT guide star, TTS or OGS), the user can select the guide star by a double mouse click on a candidate. Candidates are catalog stars which are within these permitted areas and which correspond to magnitude and color criteria in use (these criteria have been loaded from the MUSE-PS configuration file read at start-up). In AO-WFM mode, red boxes around stars indicate that they are TTS candidates (in the magnitude range, inside the TTS area) and blue boxes circle compatible TTS (in the magnitude range, outside the TTS area). In NFM mode, red boxes underline OGS candidates. In all modes, catalog stars are indicated by blue open crosses and candidate VLT guide stars are circled by green boxes. A click on the left mouse button on one of the star edits the associated measurements (conversely a click on the left button on one row of the measurement table highlights the associated object). When the user double clicks on a candidate to select it as guide star, a circle is drawn around the previous box that identified it as a candidate. The guide star data (location and magnitude) are added in the MUSE information panel. It is possible to repeat the operation until a suitable guide star is found (a new double click on a selected guide star removes the selection).

For Slow Guiding System, a specific command is available for WFM mode which checks if a star brighter than a magnitude  $R=8$  is within the SGS area. A warning is issued if this is the case.

### 3. TESTING THE MUSE-PS SOFTWARE

#### 3.1 Example of guide stars selection for the Hubble Ultra Deep Field

The setting window pops ups (Figure 2) via the *Set Input Data* option of the *MUSE* menu. The user is invited to enter a name for his project and the mode of observation. To define the field of view, the user can give the target name or the object coordinates. For example, the target name 'UDF' corresponds to the Hubble Ultra Deep Field (in this case Simbad database is used to search the corresponding position on the sky). The user must select a star catalog and an image server (the Guide Star Catalog II [4] and the ESO Online Digitized Sky Survey II in the following example).

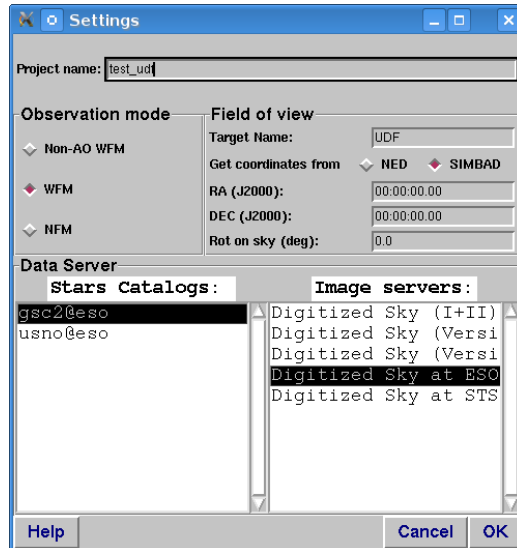


Figure 2: Settings pop-up window.

When pressing the *OK* button, the MUSE preparation tool downloads from the ESO server the image of the field. WFM has been chosen. A yellow box represents the MUSE WFM Field of view (FOV) and MUSE-PS zooms on the TTS area. White and red circles mark respectively the SGS and the TTS areas (see Figure 3).

MUSE-PS allows the user to zoom on WFM FOV, TTS area and VLT guide star area and switch between these preset zooms via radio buttons. If he/she chooses to zoom out on VLT guide star area, the tool draws (see Figure 4):

- a white circle for the Nasmyth FOV,
- a green circle for the VLT guide star area,
- a green circle for the forbidden instrument area.

Using check-boxes, the user can visualize:

- red boxes around candidate TTS (in the magnitude range, inside the TTS area),
- blue boxes around compatible TTS (in the magnitude range, outside the TTS area),
- green boxes around candidates VLT guide stars (in the magnitude range, inside the permitted zone).

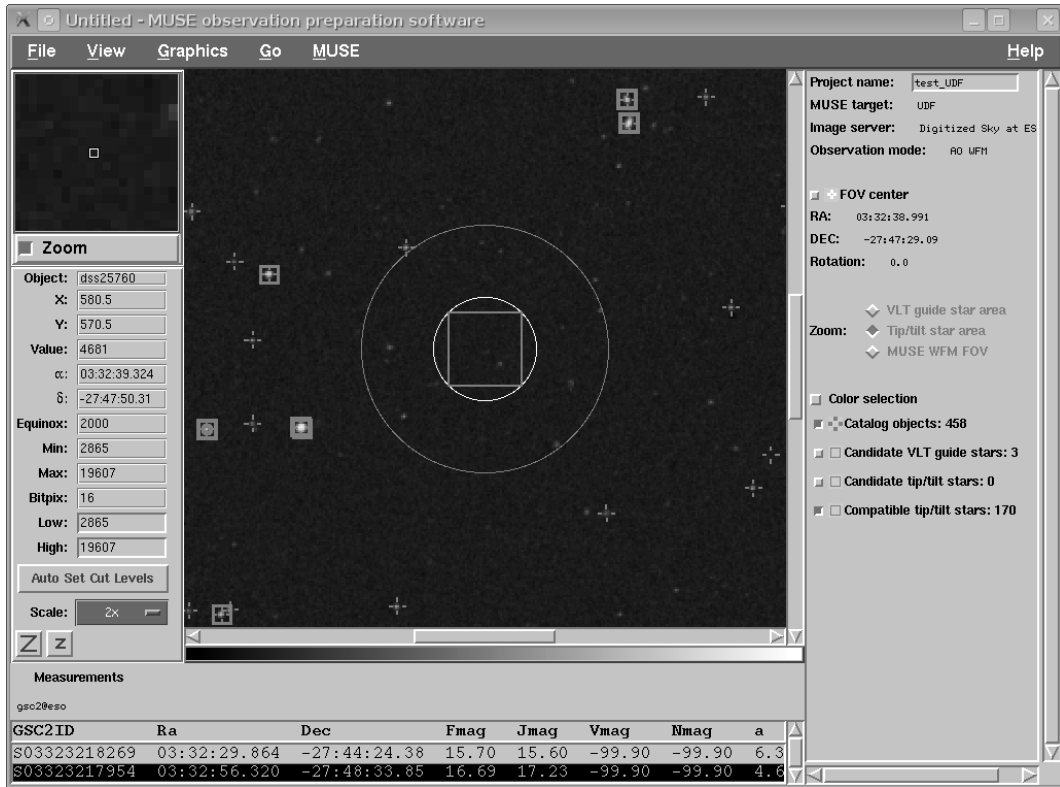


Figure 3: Zoom on the TTS area of the Hubble Ultra Deep Field.

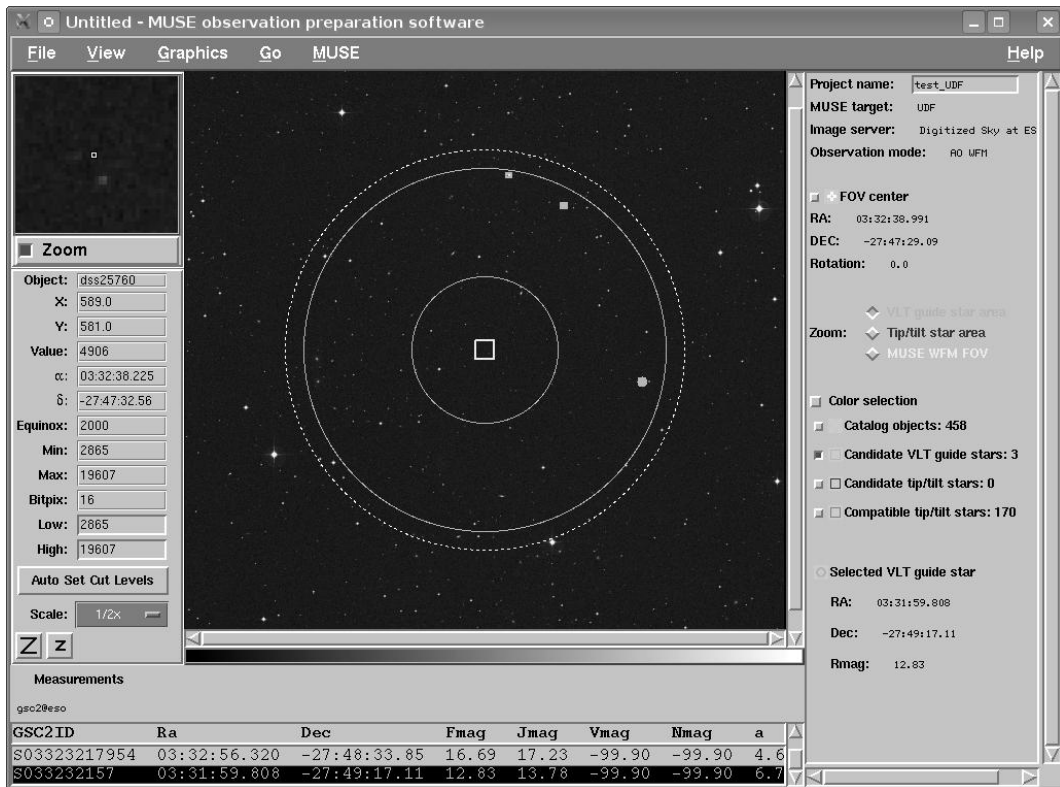


Figure 4: VLT guide star area of the HDF.

It is possible to adjust the center and the orientation of the field of view manually or using the mouse (Figure 5).

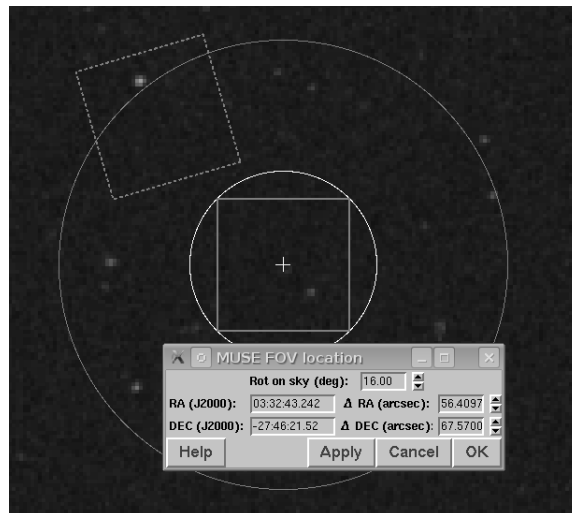


Figure 5: Move the MUSE FOV.

When pressing the *Apply* button, the new MUSE FOV moves in the center of the screen and the image and the star catalogs are updated accordingly.

At the end, via the command [MUSE][Save the project], MUSE-PS gathers and checks all information specified by the user. All these inputs are saved as keywords in the form of a MUSE configuration file that will be used to import the data to P2PP or re-open the project later in MUSE-PS.

### 3.2 Example of non functioning IFU

MUSE-PS displays eventual missing channels after loading at its start up the list of non functioning IFU from the MUSE Instrument Summary File. The Instrument Summary File (ISF) is a standard ESO file that contains keywords describing the instrument components in order to provide astronomers all the data they need to prepare their observations. This file is part of the Instrument Package released each semester for Phase II preparation and it is typically loaded by P2PP software. MUSE-PS has been developed as a standard VLT module, so it contains the ISF file.

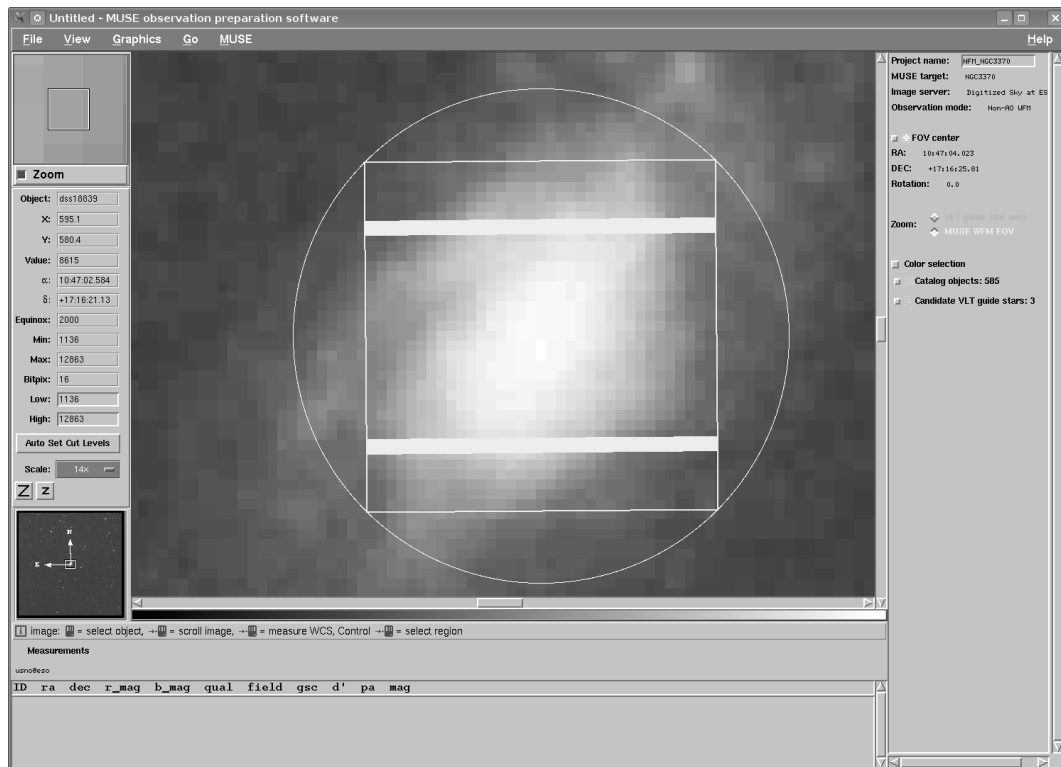


Figure 6: example of two missing channels on the target NGC3370 in Non-AO WFM mode.

### 3.3 Make a finding chart for the cluster NGC3603

This example prepares the observations on NGC3603, an open stellar cluster located in the Carina spiral arm of the Milky Way. Figure 7 and figure 8 shows the different zooms on this target.

In P2PP, a finding chart must be attached to each OB, stored as a JPEG file. It must follow these requirements:

- Clearly indicate the Observing Run ID, the PI Name, the OB Name or Target Name, as used in the OB to which it is attached.
- The target position must be clearly indicated.
- The MUSE field-of-view must be shown.
- North and East must be clearly indicated and the scale must be indicated by drawing a bar and writing the bar length in arcseconds or arcminutes.
- The wavelength range of the image must be indicated.
- The images should be negative, i.e. dark objects on light background.

MUSE-PS provides such ESO-compliant finding charts (see Figure 9) using option `[MUSE][Make finding chart]`.

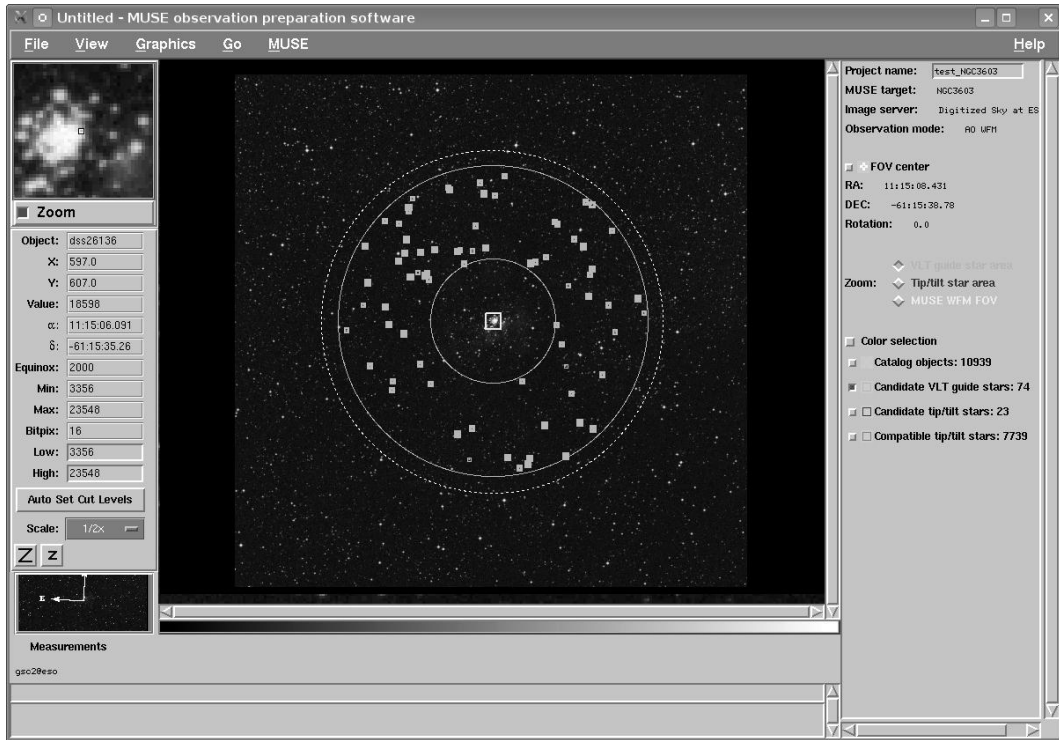


Figure 7: Nasmyth FOV centered on NGC3603

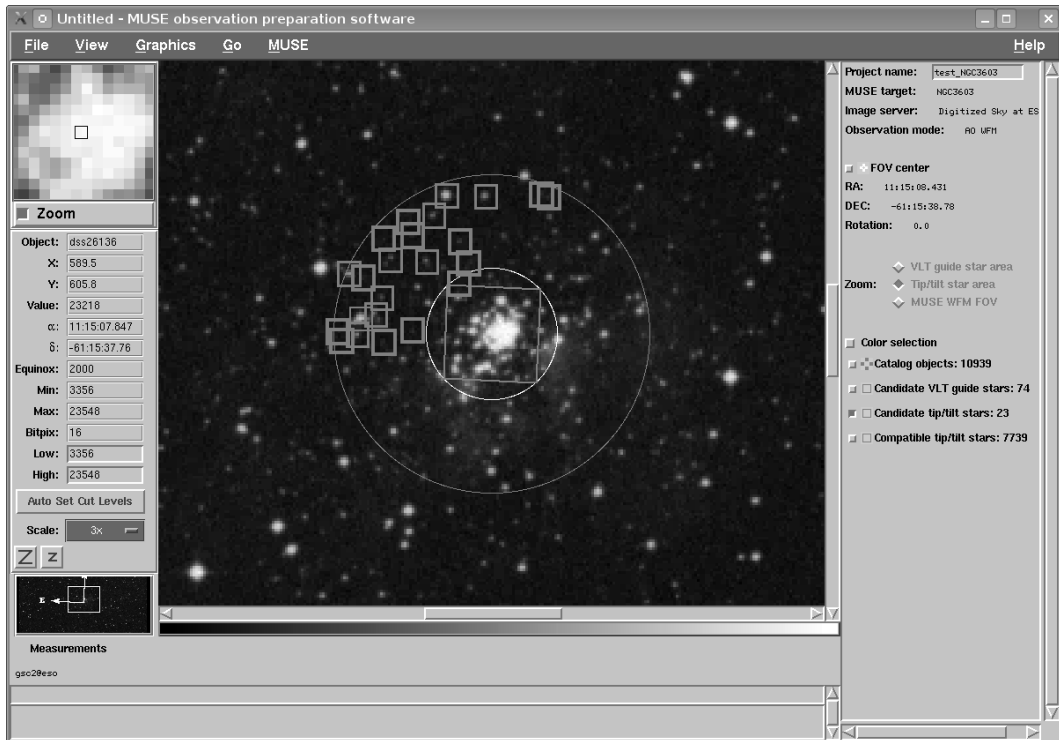


Figure 8: TTS area for NGC3603

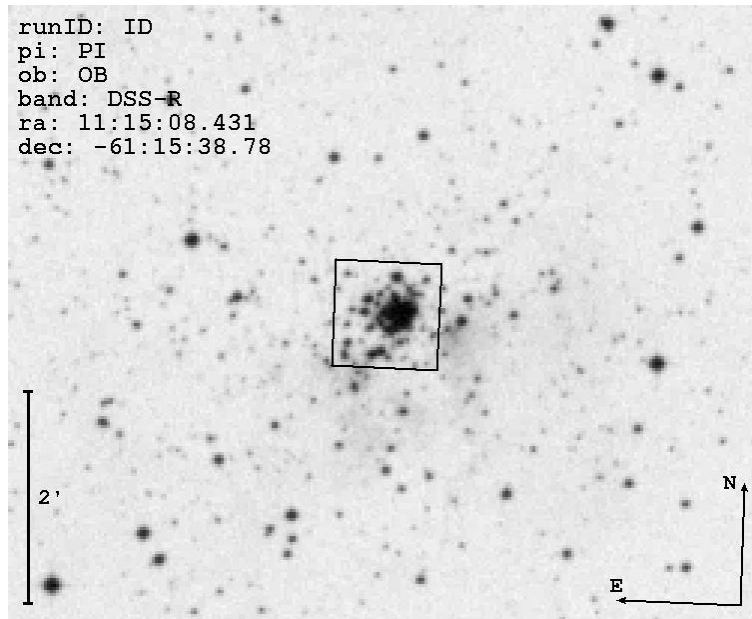


Figure 9: Finding chart for NGC3603 observation.

### 3.4 Help for mapping sequence

It is not possible to define a mapping sequence using MUSE-PS but MUSE-PS can be used to check a sequence of observation. *[MUSE][View a list of offsets]* command lets the user copy from P2PP a list of offsets in RA and DEC. These offsets correspond to telescope moves between two neighboring MUSE positions; they are in arcsec along the two axes aligned with the telescope axes. The corresponding fields of view are over plot on the current image. The color of the box depends of the type of observation: red for Sky and blue for Object, as specified in P2PP.

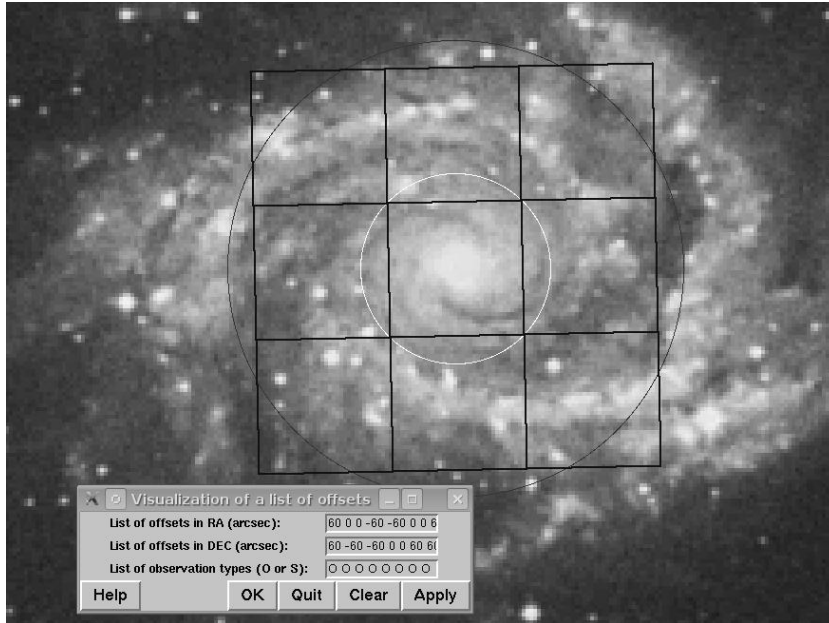


Figure 10: Visualization of a mapping sequence on the NGC2997 galaxy.

#### 4. CONCLUSION

The first version of the MUSE-PS software has been successfully tested by Paranal staff on the VLT site in Chile during the summer 2011. Then, MUSE-PS has been distributed to the MUSE consortium in autumn 2011. It is planned to work on a new release next summer including users' comments. The goal is to distribute a new release in September 2012, few months before the MUSE first light in 2013.

#### REFERENCES

- [1] Bacon R. "Probing Unexplored Territories with MUSE: a Second-Generation Instrument for the VLT", *The Messenger* 124, 5-9 (2006)
- [2] <http://www.eso.org/sci/observing/phase2/P2PPTool.html>
- [3] <http://archive.eso.org/cms/tools-documentation/skycat>
- [4] The Guide Star Catalogue-II is a joint project of the Space Telescope Science Institute and the Osservatorio Astronomico di Torino. Space Telescope Science Institute is operated by the Association of Universities for Research in Astronomy, for the National Aeronautics and Space Administration under contract NAS5-26555. The participation of the Osservatorio Astronomico di Torino is supported by the Italian Council for Research in Astronomy. Additional support is provided by European Southern Observatory, Space Telescope European Coordinating Facility, the International GEMINI project and the European Space Agency Astrophysics Division.