The MIDAS Project

Moon Impacts Detection and Analysis System

JOSE M. MADIEDO

University of Huelva, Spain

Outline

- **Description of the project**

  The Moon Impacts Detection and Analysis System (MIDAS)

- **Software tools**

  The Impact flash detection and analysis software

Project description

INSTITUTIONS INVOLVED

- University of Huelva (UHU)

- Institute of Astrophysics of Andalusia, Spanish National Research Council (IAA-CSIC)

AIM

- Continue previous work started by Dr. Ortiz et al. (IAA-CSIC) in 1999

- Systematic monitoring of the night size of the Moon

Project description

SCIENCE

Focus on the analysis of parameters of interest for theoretical impact models:

- ❑ Luminous efficiency
- ❑ Crater size and location
- ❑ Impactor mass
- ❑ Impactor flux
- ❑ **Impactor source**

TECHNIQUES

- ❑ Monitoring of the night side of the Moon with small telescopes
- ❑ Input (synergy) from meteor observing stations operated by UHU and IAA-CSIC

Where?

OBSERVATORIES

- **Sevilla** (in operation since 2009)
- **La Hita** (in operation since 2013)
- **La Sagra** (testing phase)

Main equipment

Sevilla

- Two 14" Schmidt-Cassegrain telescopes
- Two 11" Schmidt-Cassegrain telescopes
- One 9.25 Schmidt-Cassegrain telescope
- High sensitivity CCD video cameras (Watec 902H Ultimate)

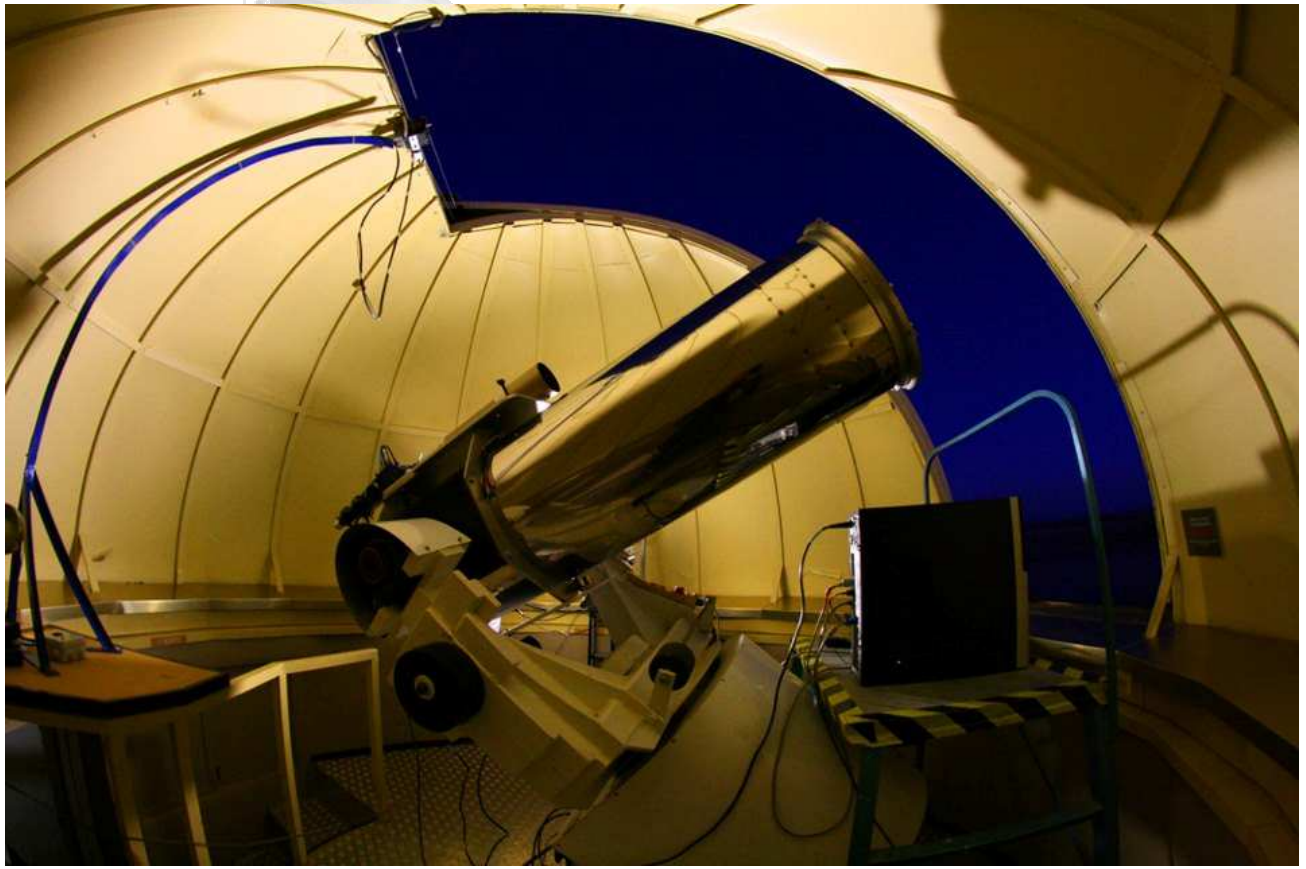
MIDAS-IR (monitoring in the infrared)

- Two 11" Schmidt-Cassegrain telescopes

Main equipment

La Hita Astronomical Observatory **(remotely operated)**

- One 16" Schmidt-Newtonian telescope
- High sensitivity video camera
  (Watec 902H Ultimate)



Main equipment

La Sagra **(Startup planned for September 2015)**

- ❑ Four 14" Schmidt-Cassegrain telescopes
- ❑ High sensitivity CCD video cameras
- ❑ Phase 1: operation "in situ"
- ❑ Phase 2: remote operation
- ❑ **2nd node for MIDAS-IR**

Procedure

- Monitor the dark side of the Moon with at least two telescopes
- Limitations:
  - Illuminated area must be, at most, about 50-60%
  - Avoid terminator
- Observing period: about 2 weeks per month
  - New Moon-First Quarter
  - Last quarter-New Moon
- High sensitivity CCD video cameras
- Focal reducers are employed
- Earthshine allows identifying features on the lunar surface

Procedure

- Monitor the dark side of the Moon with at least two telescopes
- Limitations:
  - Illuminated area must be, at most, about 50-60%
  - Avoid terminator
- Observing period: about 2 weeks per month
  - New Moon-First Quarter
  - Last quarter-New Moon
- High sensitivity CCD video cameras
- Focal reducers are employed
- Earthshine allows identifying features on the lunar surface

Input from meteor stations

CONTRIBUTION FROM METEOR STATIONS

- Analyze the behavior of meteoroids in the atmosphere
- Fact: meteoroid streams impacting Earth also impact the Moon
  (both bodies share a common meteoroid environment)
- Important to determine the source of meteoroids impacting the Moon
- Synergy with lunar impact monitoring

Input from meteor stations

METEOR STATIONS OPERATED BY UNIVERSITY OF HUELVA

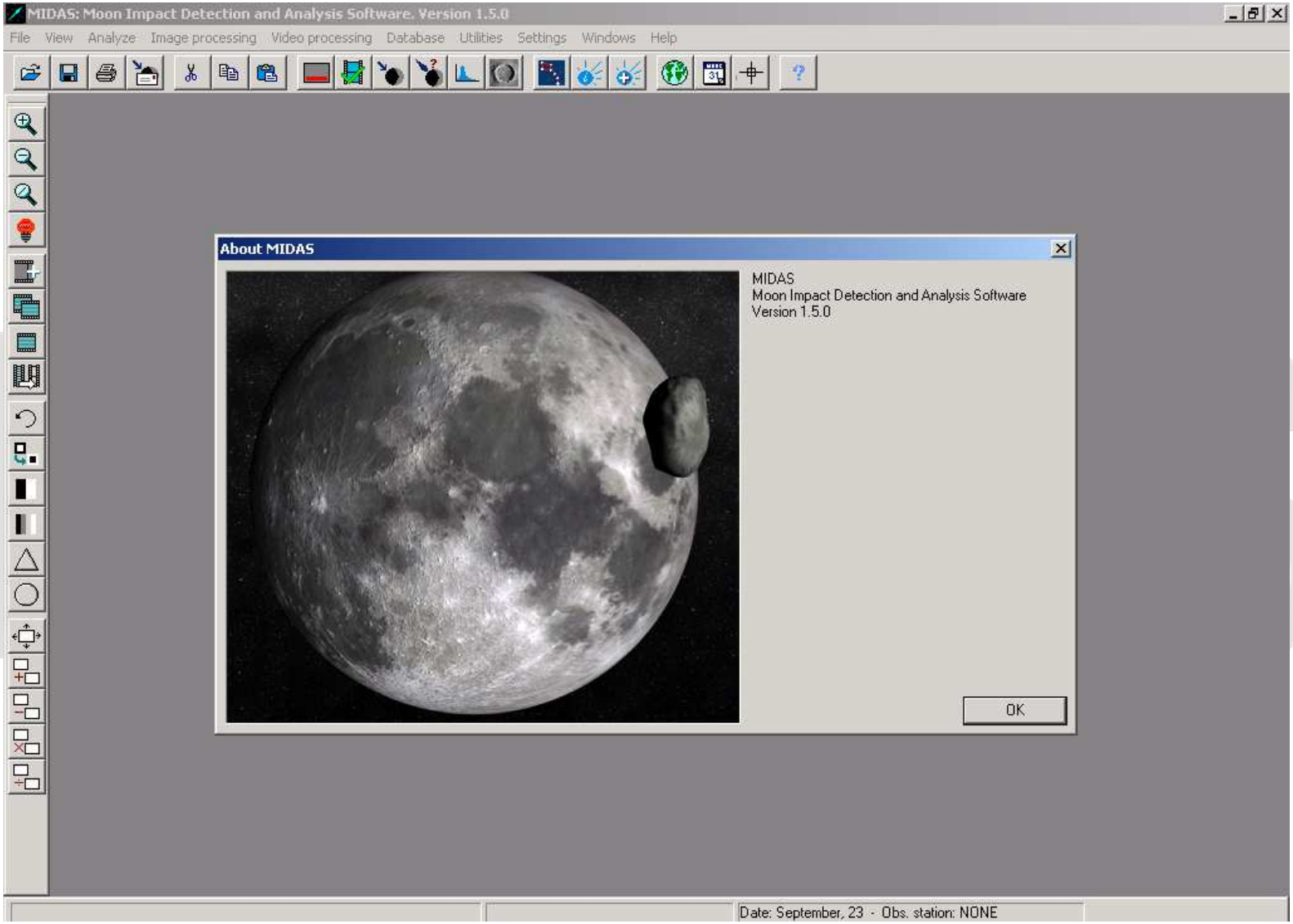
- ❑ 10 meteor stations
- ❑ Fully automated systems
- ❑ 50 CCD cameras
- ❑ Cover about 95% of the Iberian Peninsula and neighboring areas
- ❑ Collaboration with 15 extra stations operated by the Spanish Meteor Network

Software development

MAIN REASONS TO DEVELOP SOFTWARE

- ❑ Most impact flashes are dim and last a fraction of a second
- ❑ A large amount of video streaming is generated
- ❑ Impact flash confirmation requires simultaneous detection from at least two systems
- ❑ Flash identification with human eye is not practical

MIDAS: Moon Impacts Detection and Analysis Software



Moon impact flashes detection software. **Developed by J.M. Madiedo.**

MIDAS: Moon Impacts Detection and Analysis Software

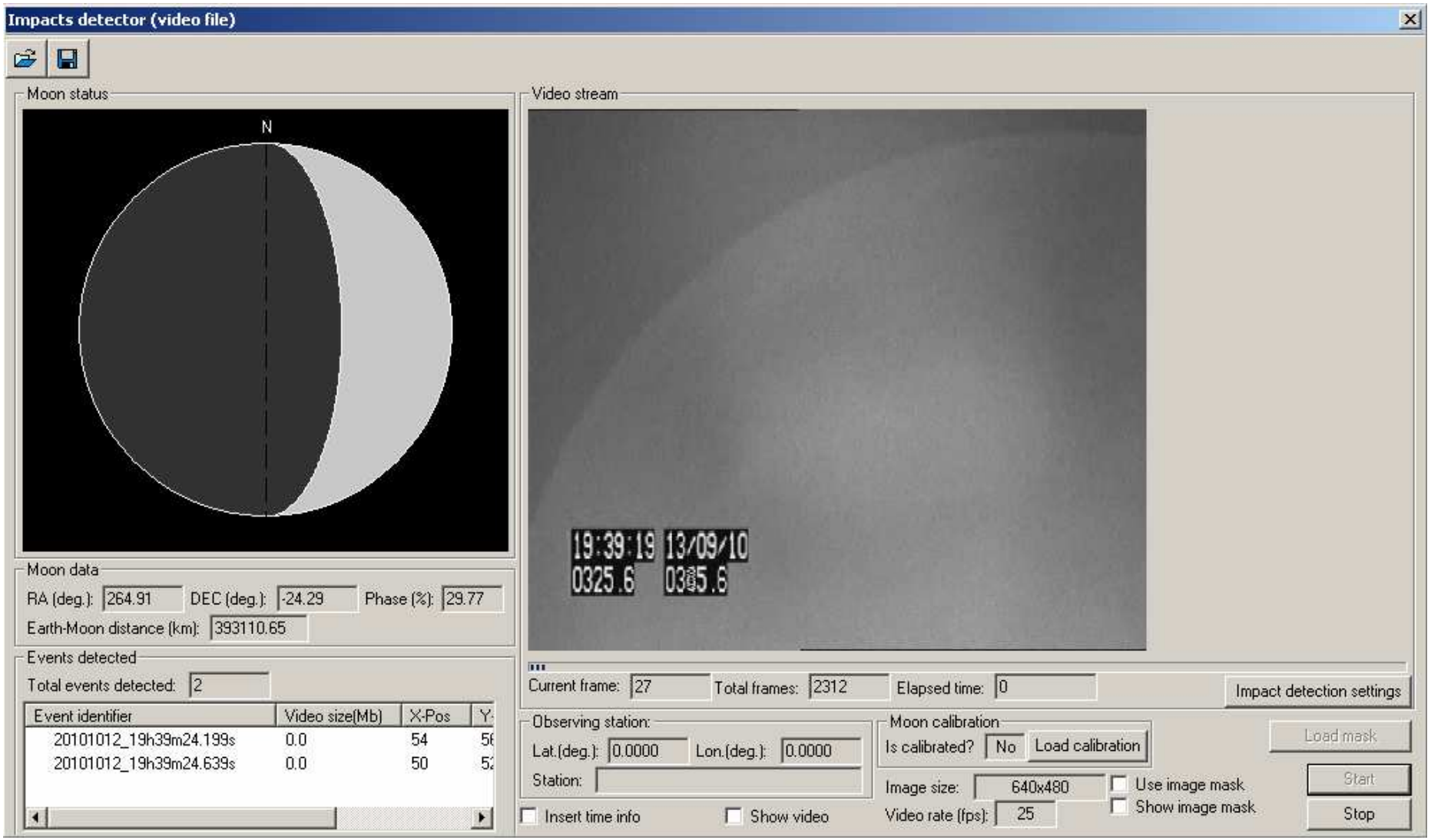
- Developed under C/C++
- MS-Windows platforms (XP, Vista, 7, 8)
- Easily portable to other platforms (maybe in future)
- Requirements for specific or special features:
  - Intranet connection
  - Internet connection
- Fast real time processing: up to 100 fps with 720x576 pixels with Pentium 4 PC 2.4 GHz (depending on detection algorithm)

MIDAS: Moon Impacts Detection and Analysis Software

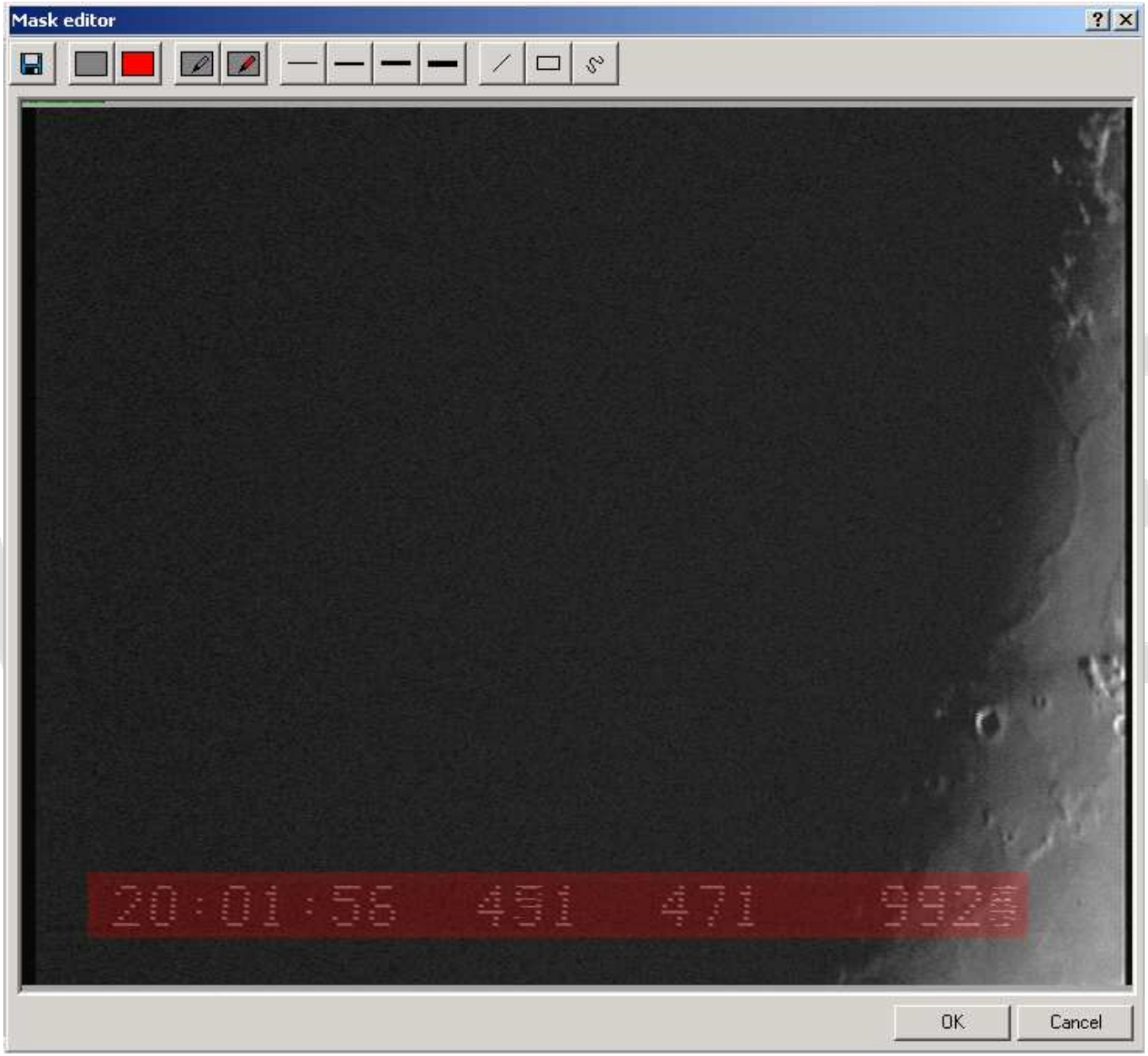
Main features

- Image capture (analogue and digital cameras)
- Image and video processing
- Moon Impact flashes identification
  - Method 1: on the fly
  - Method 2: on previously recorded video streaming **(preferred method)**
  - Very fast data reduction
- Moon impact flashes confirmation
- Photometry
- Calculation of impact parameters
- Determination of impactor source
- Adapted to indentify impacts on other bodies in the Solar System

Impact flash identification



Mask editor



Mask editor

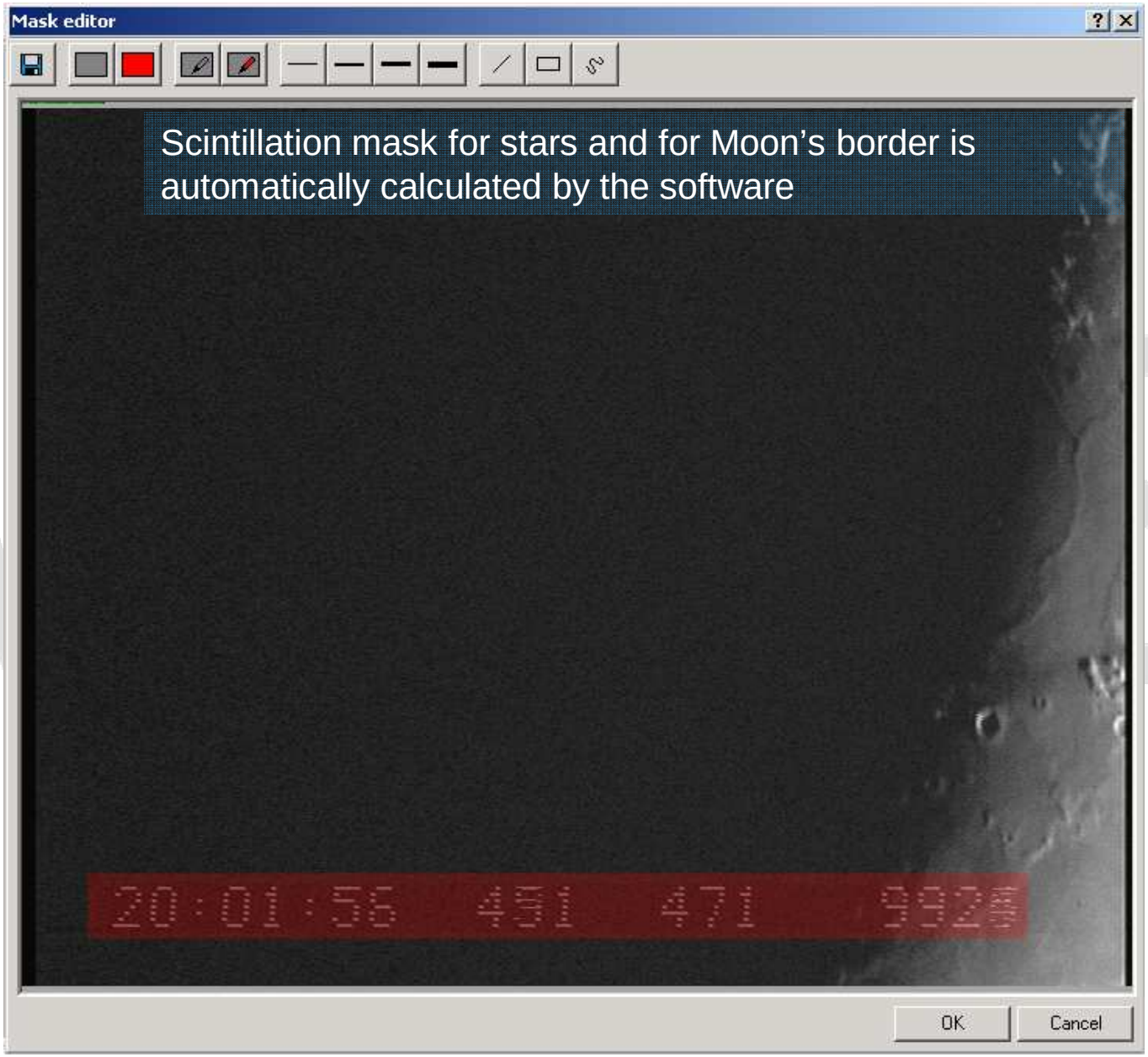
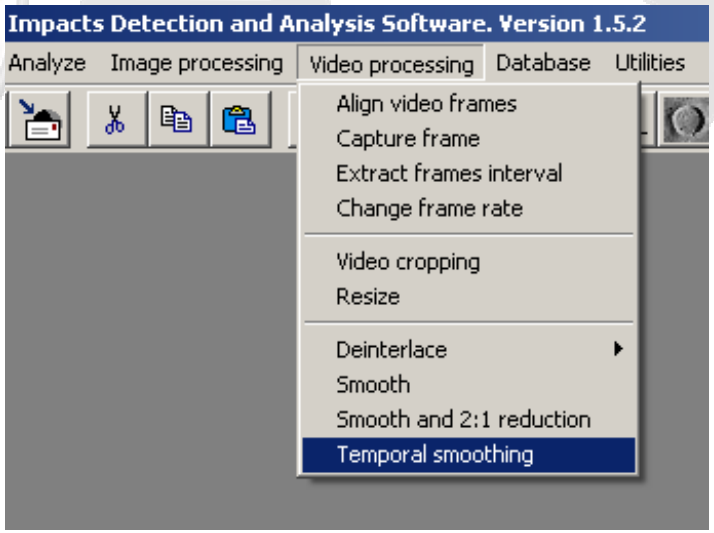

Mask editor
Scintillation mask for stars and for Moon’s border is automatically calculated by the software
OK
Cancel

Image and video processing kernels

- Video files must be processed before the flashes identification
  - Watec cameras generate interlaced video
  - Improve the detectability of fainter flashes
- Main processing routines
  - Video deinterlacing
  - Noise reduction filters
- Increase data reduction time

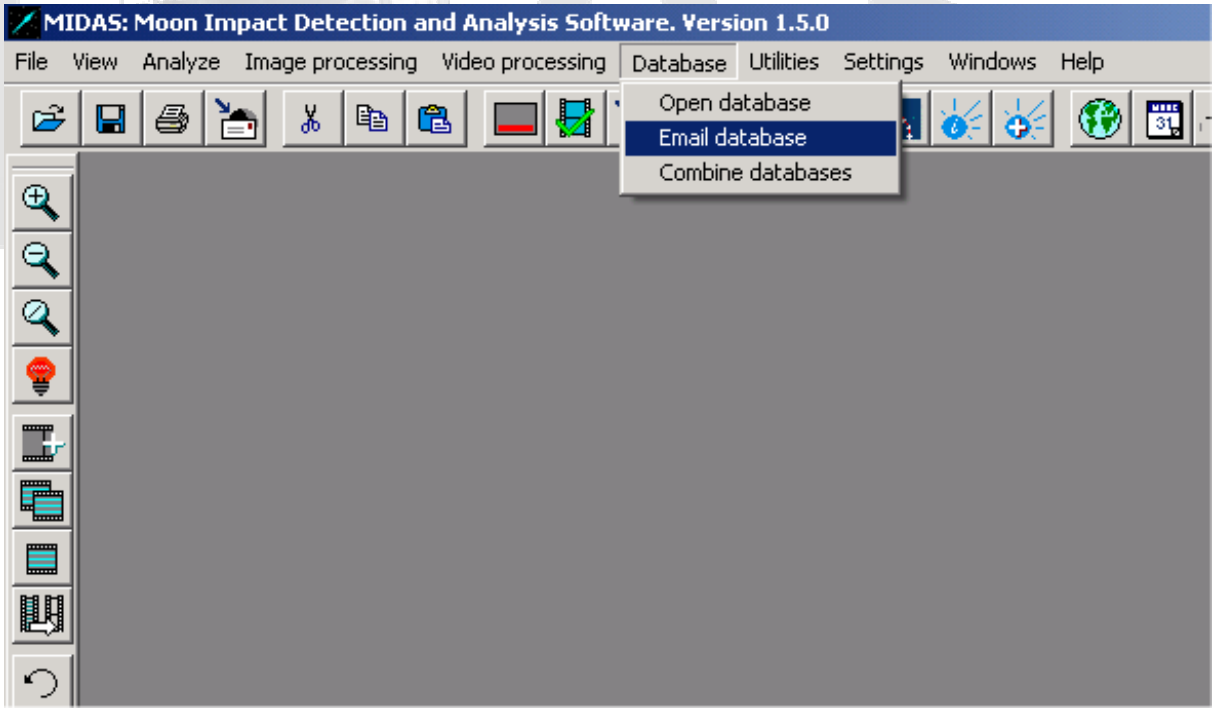


Inpact flash confirmation on the fly

- When a telescope detects an event, it communicates with other telescopes in the system via TCP/IP network protocol
- The other telescopes may then confirm or not the detected event
- If the event is confirmed, it is automatically stored in a database
- If event is not confirmed, it will be ignored (but recorded for manual inspection if necessary)
- Intranet and/or Internet connections are requested to use this feature
- Selenographic or X,Y coordinates are provided for impact flashes
  - Method 1: Previous calibration of the lunar disk
  - Method 2: Superposition of a lunar map

Inpact flash identification from previously recorded video

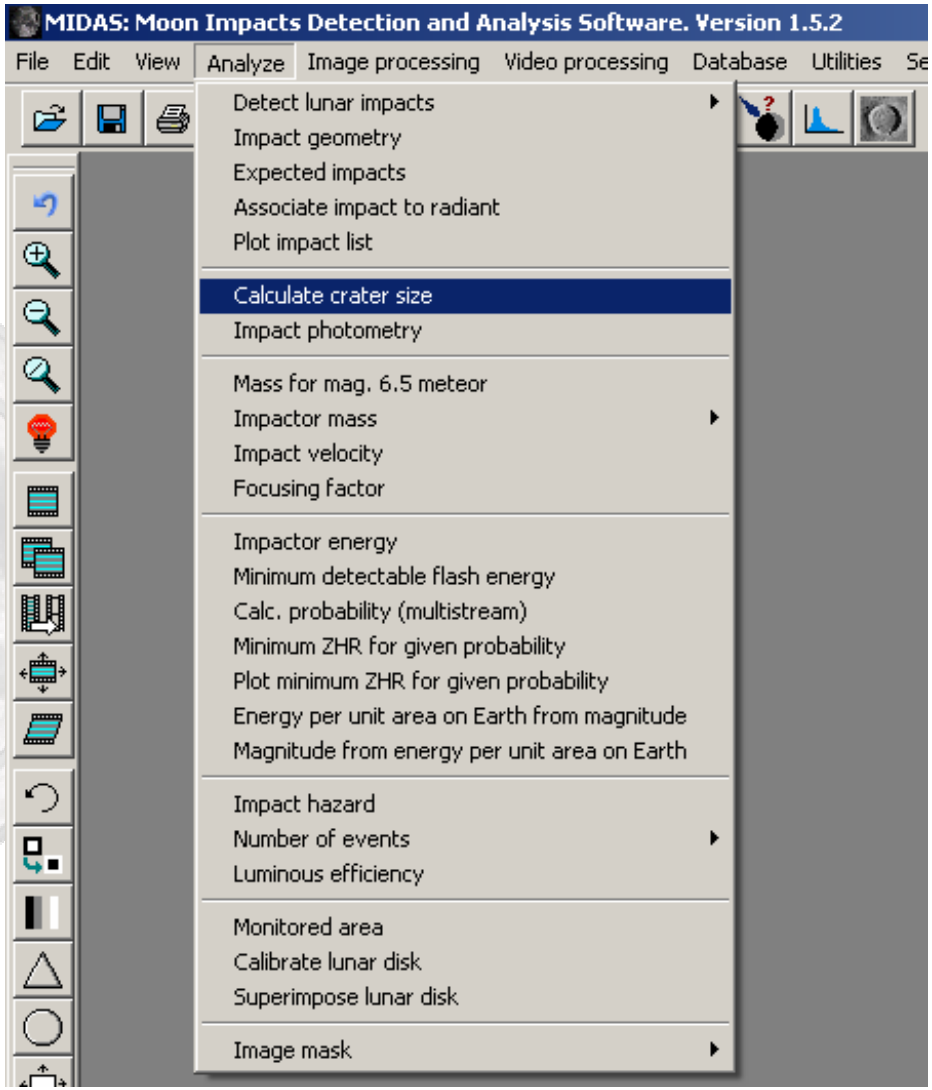
- A database with potential impact flashes is generated
- After the identification process is finished, the events database may be automatically emailed to the desired recipients
- Databases from different sources can be automatically compared by the software in order to search for common events



MIDAS: Moon Impacts Detection and Analysis Software

Data analysis kernel

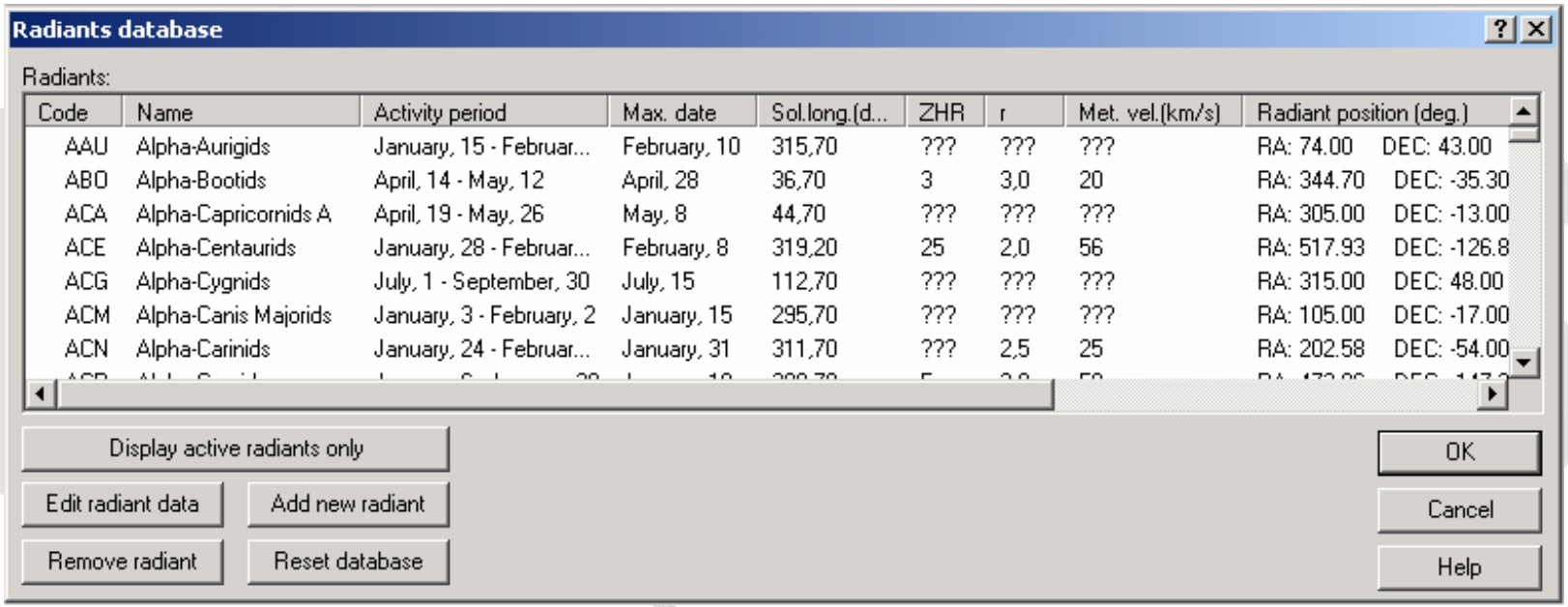
- ❑ Impactor source
- ❑ Photometry
- ❑ Impactor kinetic energy
- ❑ Impactor mass
- ❑ Crater size
- ❑ Luminous efficiency
- ❑ Other parameters



Impactor source identification

Meteoroid stream database (IAU Meteor Data Center)

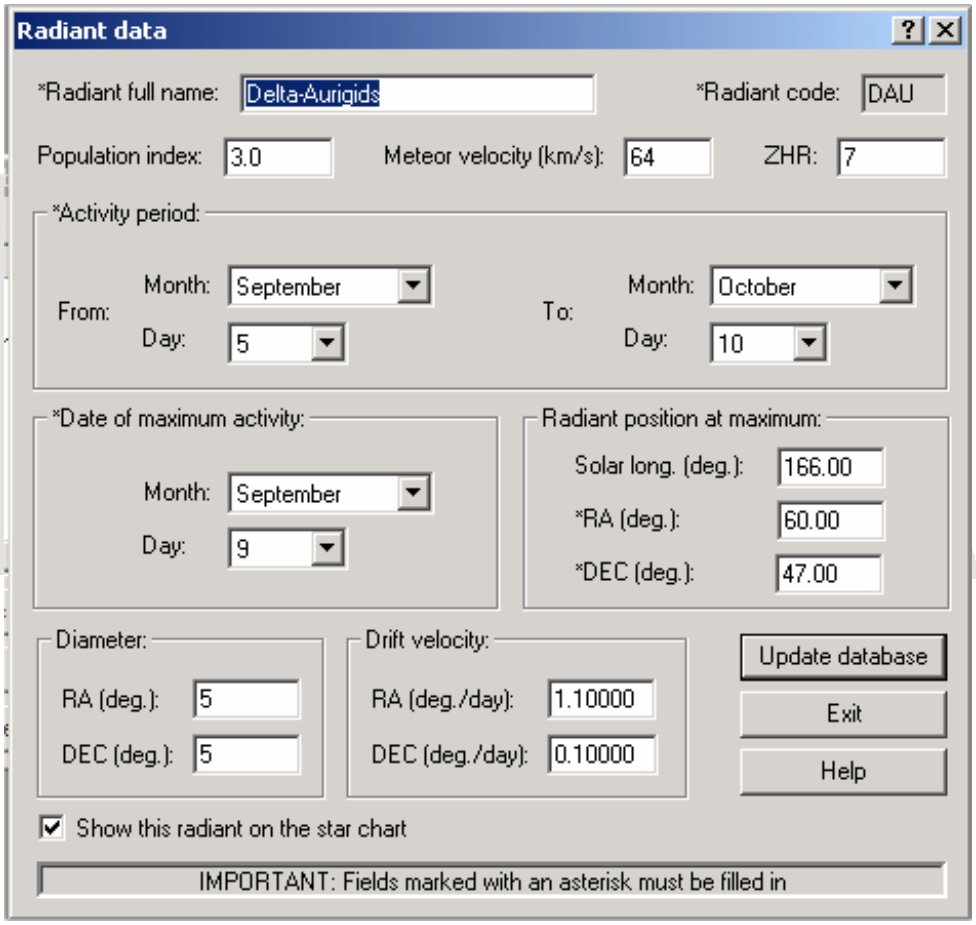
- Aim: to check for compatible impact geometry



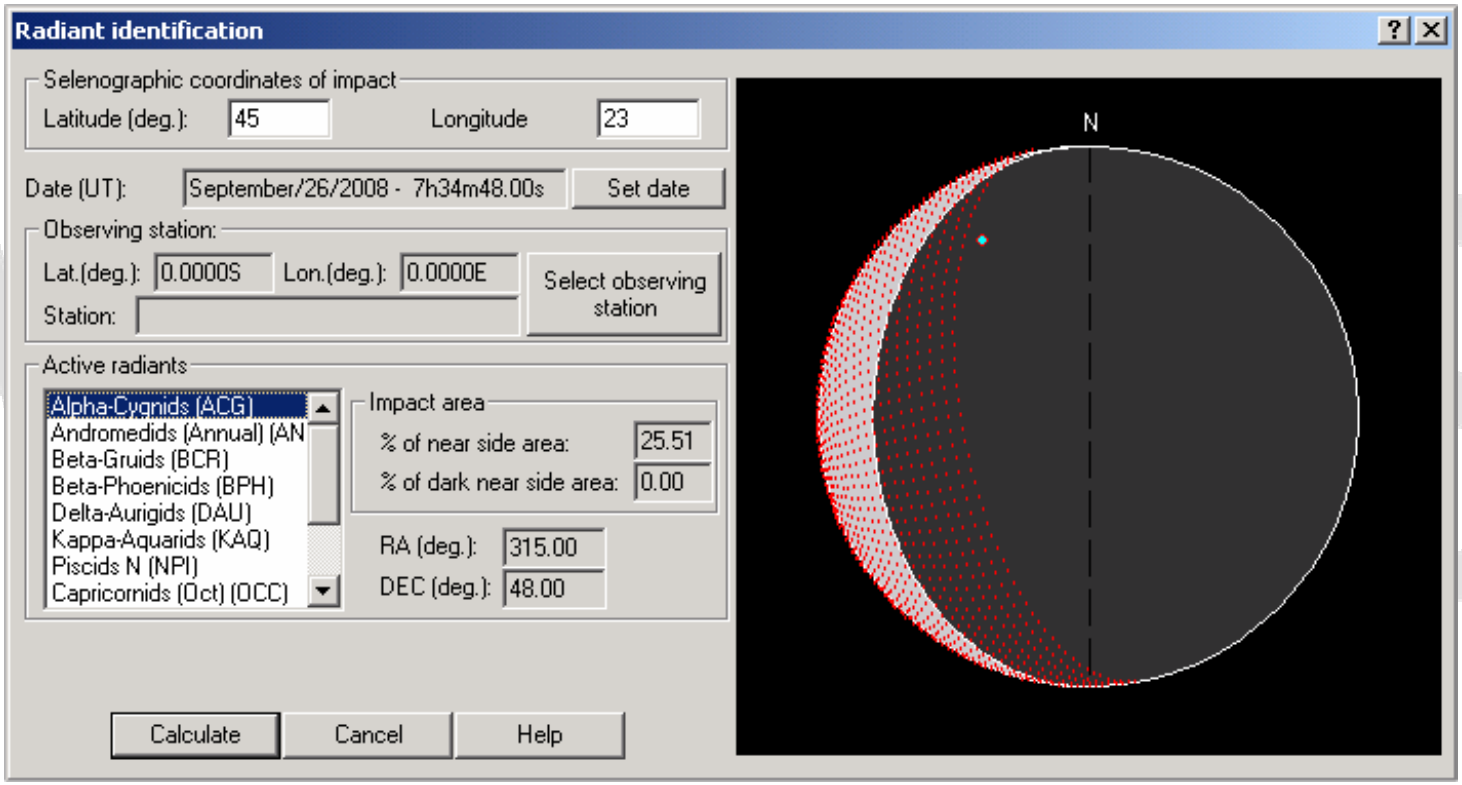
Impactor source identification

Meteoroid stream database (IAU Meteor Data Center)

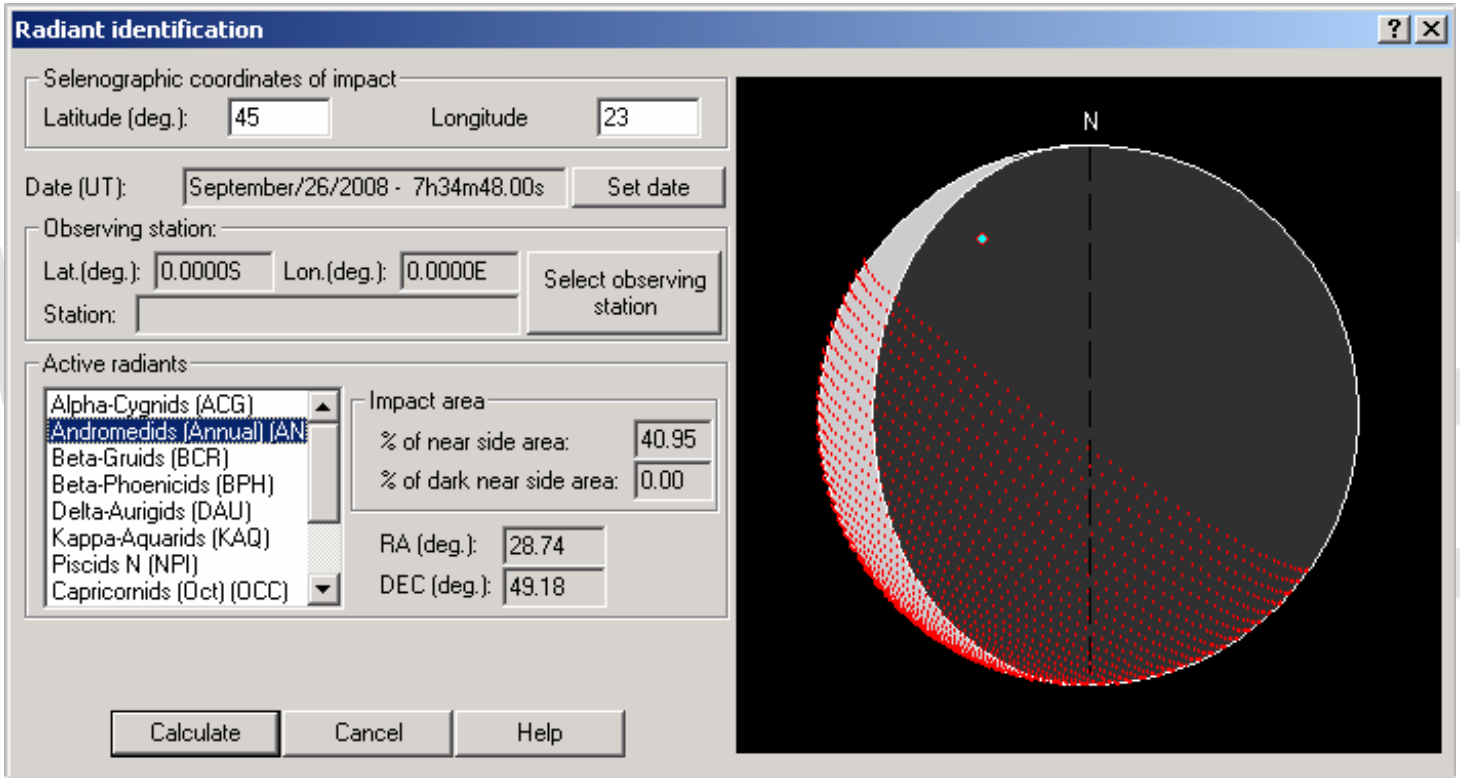
- Aim: to check for compatible impact geometry



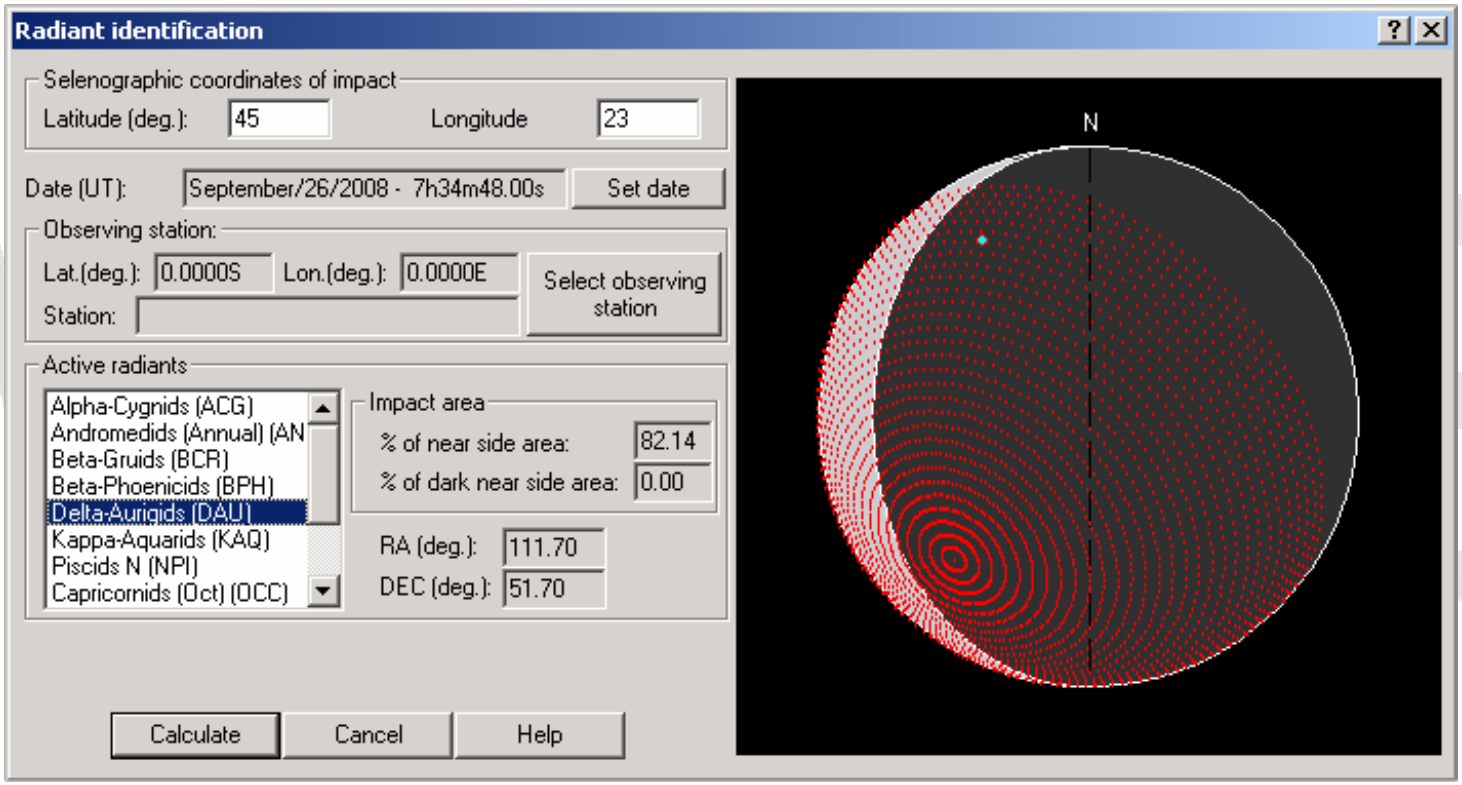
Impactor source identification



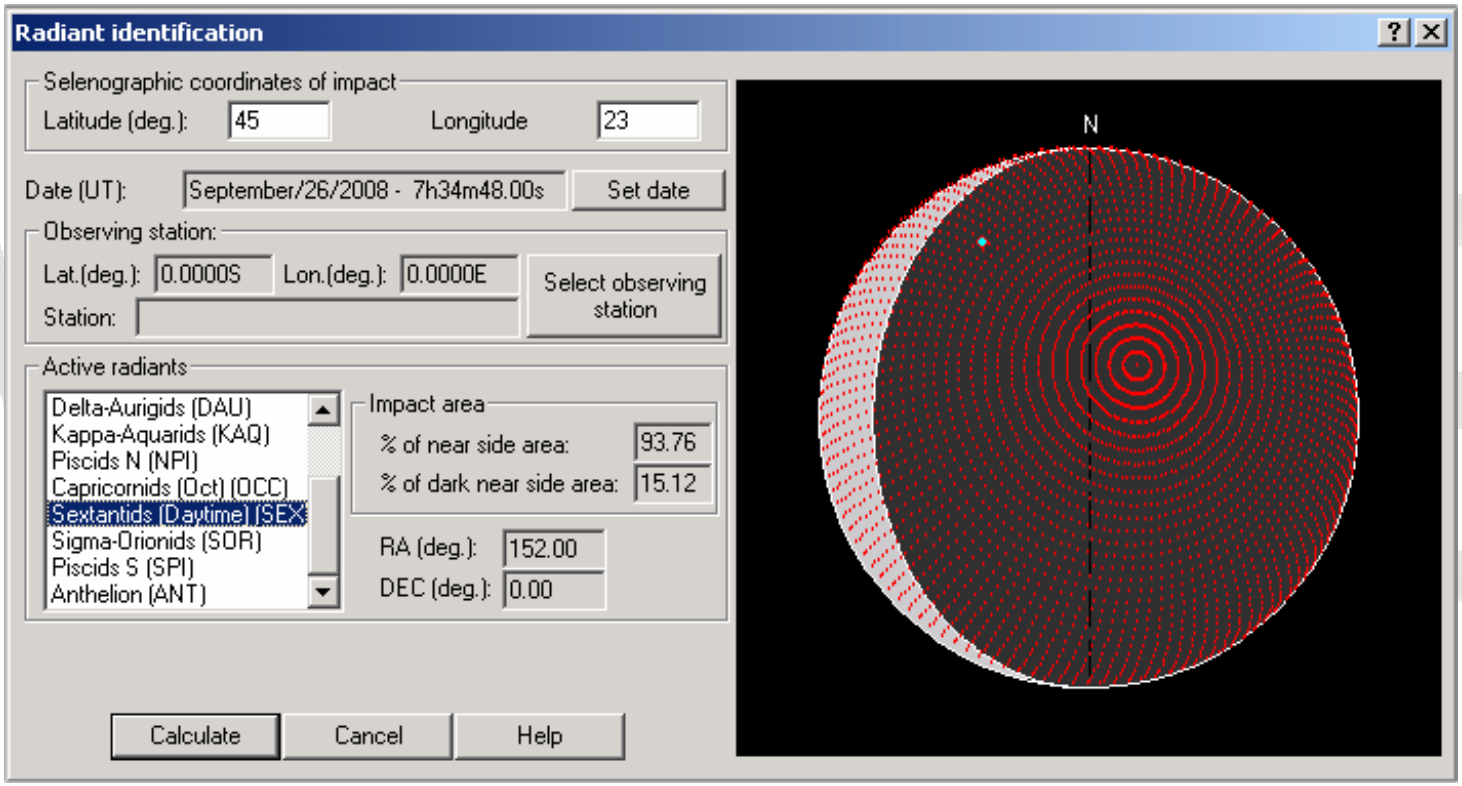
Impactor source identification



Impactor source identification



Impactor source identification



Impactor source identification

- An impact flash is associated to a given meteoroid stream if
  - The impact geometry is compatible
  - The event takes place during or next to the activity period of the corresponding meteor shower
- If the conditions above are not fulfilled, the impact is associated to the sporadic background.

Problems

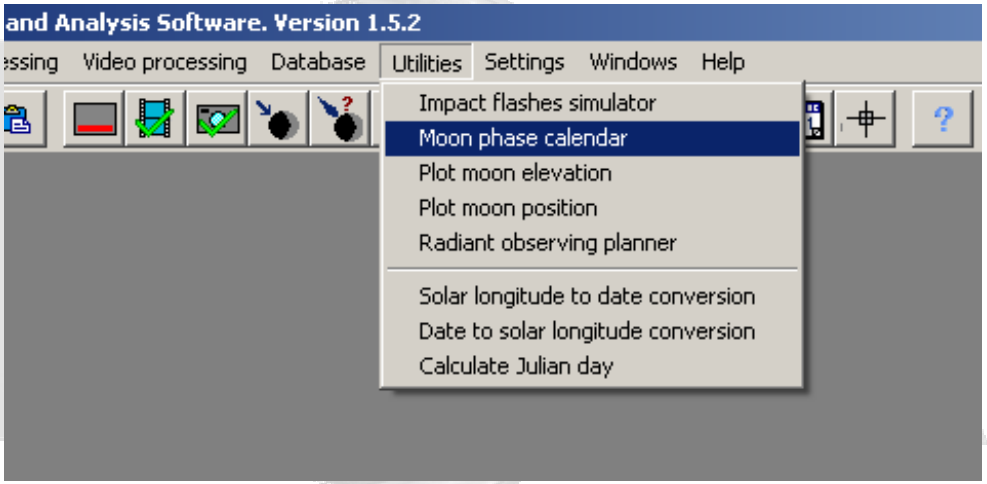
- This "classical" procedure does not quantify the link
- Can provide wrong results

Solution

MIDAS employs a new method to quantify the link between an impact flash and a meteoroid source

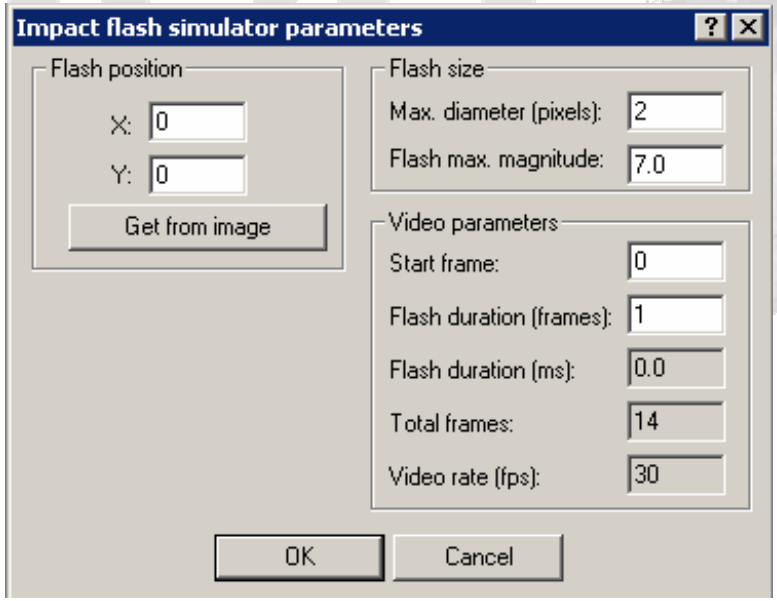
ADDITIONAL TOOLS

- ❑ Testing tools
- ❑ Monitoring planning tools

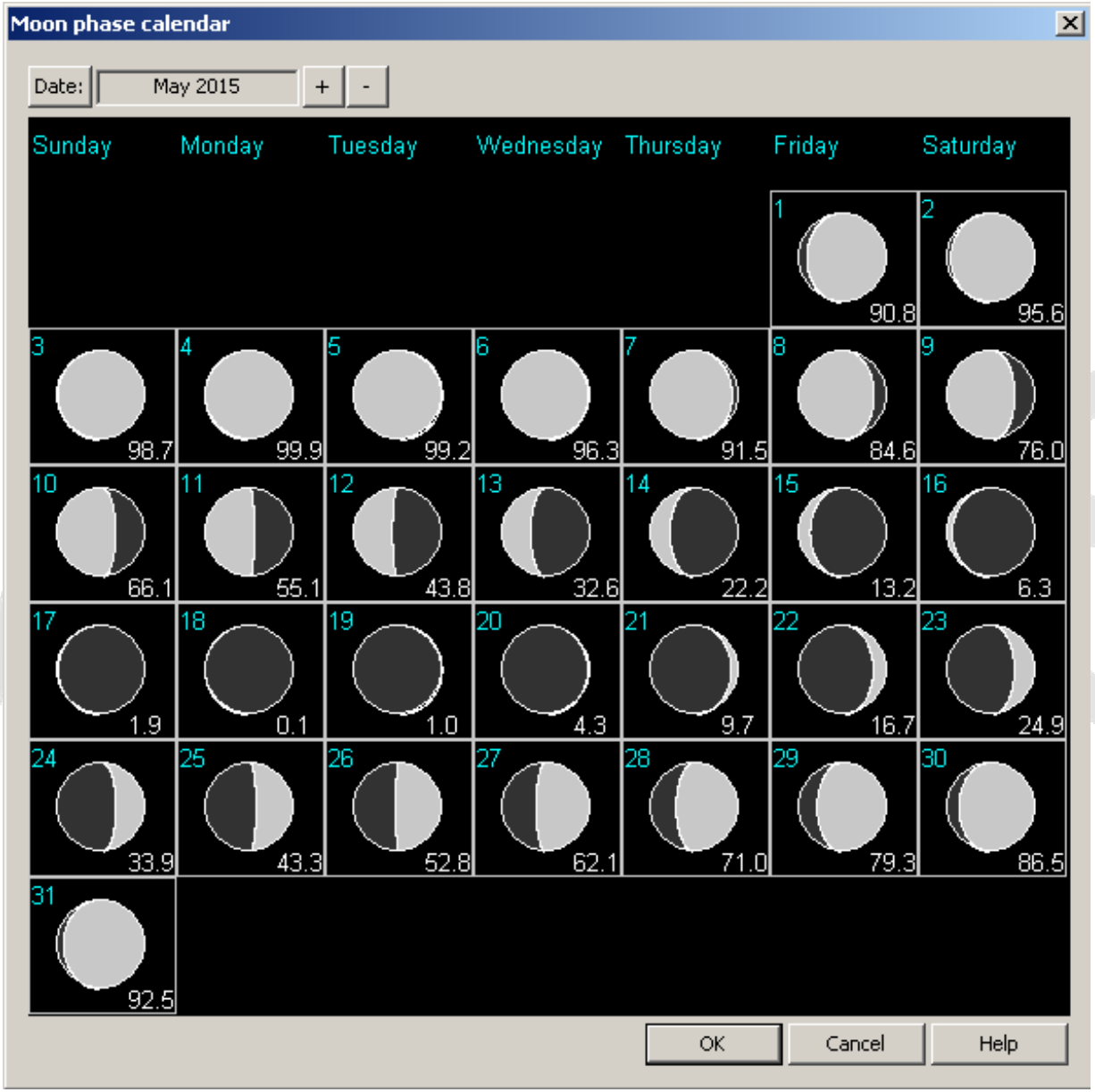


IMPACT FLASH SIMULATOR

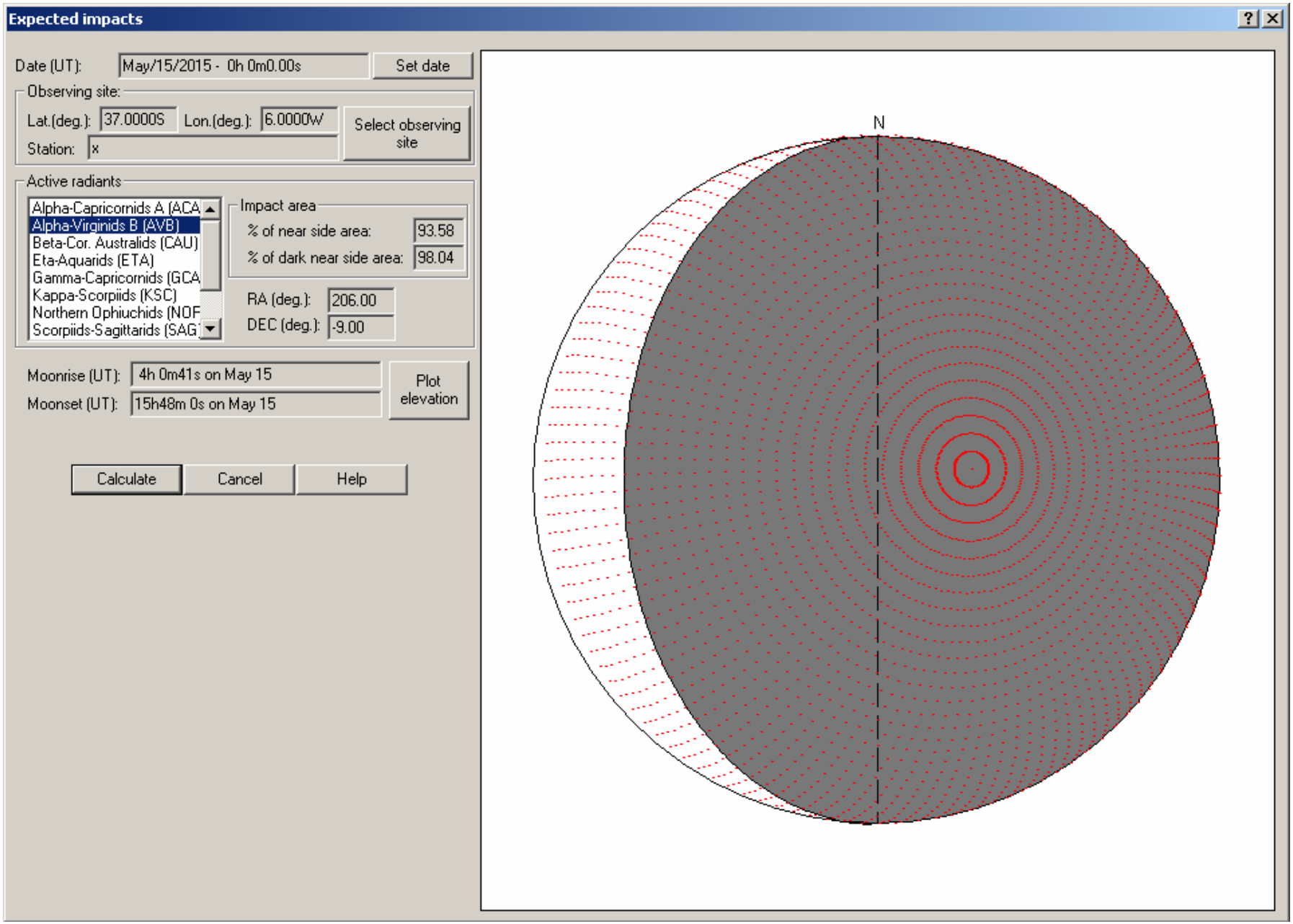
- Inserts a simulated flash on real footage
- Useful to...
  - Optimize impact flash identification parameters (noisy images, IR, etc.)
  - Know the limitations of a given experimental setup



Planning tools: Moon Phase Calendar



Planning tools: which area should be monitored?



Current status

- Systematic monitoring of impact flashes
  - V-band
  - IR band
- Setting up of new facilities at La Sagra Astronomical Observatory
- New version of the MIDAS software
- Analysis of data recorded before 2009
- Preparation of new publications

Future software developments

Software tool to establish the source of meteoroids impacting the lunar surface

- Web-based tool?

- Open for the impact flash monitoring community

- Joint project with additional partners?

Conclusions

- We have set up a system to monitor lunar impact flashes in Spain
  - Two stations in operation
  - Monitoring in V and IR bands
- We are setting up another system in Southwest Spain (La Sagra Astronomical Observatory)
  - Four 14" telescopes
  - Monitoring in V and IR bands
- Between 300 and 250 clear nights/year favor the observing tasks
- Software has been developed to identify and analyze impact flashes.
- Method to analyze the source of meteoroids impacting the Moon
  - Important synergy with meteor observing stations

MIDAS

Thank you!

Moon Impacts Detection and Analysis System