Outline

- Description of the project
  - The Moon Impacts Detection and Analysis System (MIDAS)

- Software tools
  - The Impact flash detection and analysis software
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
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
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
Monitor the dark side of the Moon with at least two telescopes

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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
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
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
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)
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 identify impacts on other bodies in the Solar System
Impact flash identification
Mask editor
Scintillation mask for stars and for Moon’s border is automatically calculated by the software.
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

MIDAS: Moon Impacts Detection and Analysis Software
Impact 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
Impact 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.
Data analysis kernel

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

MIDAS: Moon Impacts Detection and Analysis Software
**Meteoroid stream database (IAU Meteor Data Center)**

- **Aim:** to check for compatible impact geometry

<table>
<thead>
<tr>
<th>Radiant</th>
<th>Code</th>
<th>Name</th>
<th>Activity period</th>
<th>Max. date</th>
<th>Sol.long (d...)</th>
<th>ZHR</th>
<th>r</th>
<th>Met. vel (km/s)</th>
<th>Radiant position (deg.)</th>
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<tbody>
<tr>
<td>AAU</td>
<td>AAU</td>
<td>Abha-Aurigds</td>
<td>January, 15 - February...</td>
<td>February, 10</td>
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<td>Abha-Bootids</td>
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<td>April, 28</td>
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<td>Abha-Centaurids</td>
<td>January, 28 - February...</td>
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<td>ABC</td>
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<td>January, 18</td>
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<td>5</td>
<td>3.0</td>
<td>50</td>
<td>RA: 572.00 DEC: 117.30</td>
</tr>
</tbody>
</table>

- **Display active radianents only**
- **Edit radiant data**
- **Add new radiant**
- **Remove radiant**
- **Lock database**
Impactor source identification

Meteoroid stream database (IAU Meteor Data Center)

- Aim: to check for compatible impact geometry
Impactor source identification

Selenographic coordinates of impact
- Latitude (deg.): 45
- Longitude: 23

Date (UT): September 25, 2008 - 7h34m48.00s

Observing station:
- Lat (deg.): 0.0000S
- Lon (deg.): 0.0000E

Active radiants:
- Alpha-Cygni (ACG)
- Andromedids (Annual)
- Beta-Grind (BCR)
- Beta-Phoenix (BPH)
- Delta-Aurigids (DAlt)
- Kappa-Aquarids (KAA)
- Piscids N (NPI)
- Capricornids (Oct. UCC)

Impact area:
- % of near side area: 40.95
- % of dark near side area: 0.00

RA (deg.): 28.74
DEC (deg.): 43.18

Calculate  Cancel  Help
### Radiant Identification

#### Selenographic coordinates of impact:
- **Latitude (deg.):** 45
- **Longitude:** 23

#### Date (UT):
- **September 26, 2008, 7h34m48.00s**

#### Observing station:
- **Lat. (deg.):** 0.00005
- **Lon. (deg.):** 0.0000E

#### Active radiants:
- **Alpha-Cygni (ACG)**
- **Andromedids (Annual) (AN)**
- **Betegrupoids (BCP)**
- **Beta-Phoenicia (BPH)**
- **Gamma-Cruci (GCR)**
- **Kappa-Aquariids (KAQ)**
- **Pscids N (NPI)**
- **Capricornids (Ct) (OCC)**

#### Impact area:
- **% of near side area:** 82.14
- **% of dark near side area:** 0.00

#### RA (deg.):
- **111.70**

#### DEC (deg.):
- **51.70**

---

**Calculate** | **Cancel** | **Help**
Impactor source identification

Selenographic coordinates of impact:
Latitude (deg.): 45
Longitude: 23

Date (UT): September 26, 2008 - 7h34m48.00s
Set date

Observing station:
Lat. (deg.): 0.00005
Lon. (deg.): 0.0000E
Select observing station

Active radiants
- Delta-Aurigids (DAJ)
- Kappa-Aquarids (KAQ)
- Pscids N (NPI)
- Capricornids (Cot) (OCC)
- Seta-Aurigids (STJ)
- Sigma-Oriids (SOR)
- Pscids S (SPI)
- Anthelion (ANT)

Impact area
- % of near side area: 93.76
- % of dark near side area: 15.12

RA (deg.): 152.00
DEC (deg.): 0.00

Calculate
Cancel
Help
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
Testing 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

![Impact flash simulator parameters]

- Flash position
  - X: 0
  - Y: 0
- Flash size
  - Max. diameter (pixels): 2
  - Flash max. magnitude: 7.0
- Video parameters
  - Start frame: 0
  - Flash duration (frames): 1
  - Flash duration (ms): 0.0
  - Total frames: 14
  - Video rate (fps): 30
Planning tools: Moon Phase Calendar
Planning tools: which area should be monitored?

Expected impacts

- **Date (UT):** May/15/2015 - 0h:0m:0.00s
- **Observing site:** 37.0000S 6.0000W
- **Alpha Capricornids (ACA), Alpha Virginids (AVB), Beta Cor, Austroids (CAU), Eta Aquarids (ETA), Gamma Capricornids (GCA), Kappa Scorpiids (KSC), Northern Urophucls (NUF), Scorpids Sagittans (SAG)**
- **Impact area:**
  - % of near side area: 93.53%
  - % of dark near side area: 98.04%
- **Moonrise (UT):** 4h:0m:11s on May 15
- **Moonset (UT):** 15h:48m:3s on May 15

[Graph showing expected impacts and areas]
MIDAS Project

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
Thank you!

Moon Impacts Detection and Analysis System