Time-Domain Astrophysics at LPO and ALMA

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Time critical science cases
(a non-exhaustive list)

- SN, GRBs, GWs (Mergers), X-ray binaries (NS and BH), magnetars, Tidal Disruption Events
- Planets, the Sun and the solar system objects
- Variable sources: stars, exoplanets, microlensing, ...
- AGN activity, FRBs counterparts and hosts

NTT/ PESSTO Lightcurve
SN2009ip: Smartt et al. 2013

ALMA detection of reverse shock in a GRB: Laskar et al. 2019

VLTI image of $\pi^1$ Gruis
surface: Paladini et al. 2018
# Similar workflows for LPO & ALMA

<table>
<thead>
<tr>
<th></th>
<th>Predictable</th>
<th>Unpredictable but foreseen</th>
<th>Unforeseen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Example science case</strong></td>
<td>Planet/variable star monitoring, (exo-)planet transit</td>
<td>SN, GRB, GW, comets, asteroids, X-ray binaries</td>
<td>Interstellar comet, Betelgeuse</td>
</tr>
<tr>
<td><strong>P1: proposals</strong></td>
<td>Normal, LP, <strong>Monitoring</strong></td>
<td><strong>ToO, incl LP/Monitoring</strong></td>
<td>DDT</td>
</tr>
<tr>
<td><strong>P2: observations</strong></td>
<td><strong>OB/SB</strong> defined with absolute and/or relative time constraints (<strong>time-link</strong>), VM, dVM</td>
<td><strong>ToO observations defined @P2 deadline updated at trigger time; contact with observatory staff</strong></td>
<td>absolute or relative time constraints or ToO (exceptional)</td>
</tr>
<tr>
<td><strong>Archive/P3</strong></td>
<td><strong>P3/SDP standard keywords encode multi-epoch info</strong></td>
<td>Prioritised data delivery, raw data immediately available from the archive, <strong>calibrated data &lt;24h</strong></td>
<td>Raw data immediately available from the archive</td>
</tr>
<tr>
<td></td>
<td><strong>Archive and catalogue interfaces &amp; programmatic access support time-series (lightcurve) data</strong></td>
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<td></td>
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<td></td>
<td><strong>Public Surveys</strong></td>
<td></td>
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</tbody>
</table>
Normal or Large programmes, Monitoring programmes

- Phase 1 proposals – time constraints propagate to scheduling
- Relative and absolute time constraints possible
- OBs/SBs prepared in advance
- Observations get high priority in the observing/scheduling tool when all constraints (incl time) fulfilled
Transients and (un)predictable events

■ Target of Opportunity (ToO)
  ➢ Pre-approved at the regular proposal review process
  ➢ Predictable (type of) targets, but unknown when & which
  ➢ PI/CoI decides to trigger → contact with the observatory
  ➢ Template OB/SB updated when triggered
  ➢ ToO execution within one hour to few days
    • ALMA execution within 1h to few days
    • ToO-Hard (<48h), ToO-Soft (2 – 7 days)
    • ToO-RRM (few min - 4h) & follow-up with normal SM or ToO runs
  ➢ High priority data transfer

■ DDT channel for unpredictable events
  ➢ e.g. the first interstellar comet
Triggering of Soft/Hard ToOs

- Preparation of OBs within a folder in p2
  - Delegate phase 2 permissions to other users
  - Copy template OBs into folder
- Activation ("certify", “trigger”)

![Image of ESO software interface with details on OBs, folder, and trigger form]
Triggering of ToOs (LPO example)
Staff interface (ALMA example)

13412: Trigger Ticket for 2017.A.00045.T AT2018co_a_07_TM1, AT2018co_a_03_TM1

Created: 28 June 2018 11:25 AM  Updated: 01 July 2018 11:31 PM

DEPARTMENT
Project Triggers

Staff Owner
AoD Lead

TYPE
Issue

STATUS
Closed

Evanthia Hatziminao...

Post: 28 June 2018 11:25 AM

PI submits a TOO request for project 2017.A.00045.T
SB(s)=AT2018co_a_07_TM1, AT2018co_a_03_TM1
option=Target of Opportunity
Source Name=AT2018cow
Coordinates=16:16:00.22 +22:16:04.83 Reference Frame=ICRS
Velocities= Reference Frame=LSRK

Comments:
Hi, could you activate the trigger for the dates June 29 and June 30. Please, let us know if the observation cannot be scheduled. Cheers, Steve
Scheduling@ALMA

Time critical observation appears when due.
RRM specifics

- Offered for some instrument modes of FORS2, X-SHOOTER, UVES, SPHERE, HAWK-I, MUSE
- Trigger is send via ASCII file to ftp server
- When a trigger is found (cron job), the ongoing SM/VM observation is automatically ended
RRM specifics

- Telescope automatically presets to coordinates in the ftp file
- Instrument executes automatically the requested OB
- Manual acquisition by operator
Statistics of ToO programs

<table>
<thead>
<tr>
<th>Period</th>
<th>Allocated time (hours)</th>
<th>Used time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P104 (Oct 2019)</td>
<td>574/18.5 for ToO/RRM</td>
<td>117 (20%)</td>
</tr>
<tr>
<td>P103 (Apr 2019)</td>
<td>481</td>
<td>176 (37%)</td>
</tr>
<tr>
<td>P102 (Oct 2018)</td>
<td>459</td>
<td>81 (18%)</td>
</tr>
<tr>
<td>P101 (Apr 2018)</td>
<td>292</td>
<td>74 (25%)</td>
</tr>
<tr>
<td>P100 (Oct 2017)</td>
<td>175</td>
<td>91 (52%)</td>
</tr>
<tr>
<td>P99 (Apr 2017)</td>
<td>230</td>
<td>111 (48%)</td>
</tr>
<tr>
<td>P98 (Oct 2016)</td>
<td>213</td>
<td>54 (26%)</td>
</tr>
<tr>
<td>P97 (Apr 2016)</td>
<td>187</td>
<td>32 (17%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Projects (A+B)</th>
<th>SBs (A+B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approved</td>
<td>Fully Observed</td>
</tr>
<tr>
<td>7 (ongoing)</td>
<td>20</td>
<td>220</td>
</tr>
<tr>
<td>6</td>
<td>16</td>
<td>175</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>67</td>
</tr>
</tbody>
</table>
Electromagnetic radiation

- Optical (near-UV to near-IR)
- Mid-IR
- Radio, sub-mm
- High-energy (UV, X-ray, gamma-ray)

Neutrinos

Cosmic Rays

Gravitational waves
Spectral coverage of instruments used to observe NGC 4993

- Ultraviolet: VST/OmegaCAM, VLT/VIMOS, VLT/MUSE, VLT/FORS2, VLT/X-shooter, NTT/EFOSC2, MPG/ESO 2.2-m/GROND, REM
- Visible: VISTA/VIRCAM, VLT/NACO, VLT/HAWK-I, VLT/VISIR
- Infrared: NTT/SOFI
- Millimetre: ALMA

Graph showing brightness vs. wavelength with peaks at different wavelengths.
Archive Science Portal: search by confidence contours

GW170817
Improving the ToO process

- Observation Preparation
  - One preparation tool
  - Visualization of pointing, offsets, windowing
  - Selection of blind offset stars, AO & VLT guide stars

- Time accounting
  - Night log tool/User portal

- Fast access to reduced data & quality information

- ToO in monitoring & LPs
Currently a necessary condition is that the requested instrument is in use, i.e. no instrument (focus) changes for RRM.

P105 at UT2 & UT3 (UVES, X-SHOOTER)

- No on-focus restriction: automatic focus change
  - Users can specify if they accept the additional overhead
  - Max response time until start of observations is 10-15 min

Automatic check whether the currently running observation is protected against RRM triggers
Summary

- Increase of detection of transient events in the coming years
  - Massive sky surveys (GAIA, LSST, EUCLID)
  - Gravitational wave missions (LIGO, LISA)

- Facilitate fast follow-up observations with instruments offered through ESO
  - Optimization of tools and procedures
  - Time domain in La Silla: NIRPS & SOXS
  - Coordination between facilities

Improvements contact: usd-help@eso.org & https://help.almascience.org