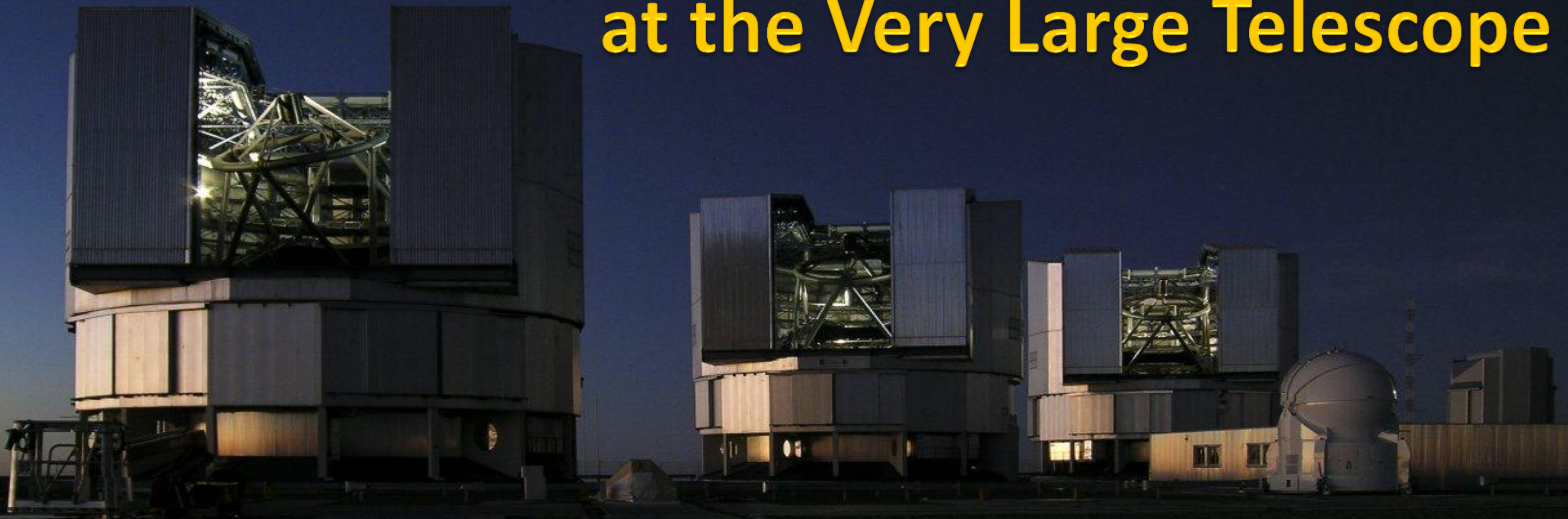
Rapid Response Mode to transient events at the Very Large Telescope



Fernando Comerón

With thanks to Paul Vreeswijk and the team who implemented the RRM at the VLT

The ESO Very Large Telescope

- 4 Unit Telescopes, each 8.2m diameter, on Cerro Paranal (Chile), at 2635m over sea level
- The telescopes can be connected to form a near-infrared interferometer, with baselines of up to 120m, also using three 1.8m Auxiliary Telescopes
- In operations since 1999
- Currently 11 instruments, plus 2 interferometry instruments, covering a broad range of wavelengths, resolutions, and techniques
- 3 more VLT instruments under construction

Why a Rapid Response Mode at the VLT?

- Great light collecting power: high S/N snapshots of quickly varying phenomena make it possible to study fast, faint transients in great detail
- Wide range of instrumentation available: imaging, long-slit and integral field spectroscopy, polarimetry, adaptive optics, high time resolution… both in the visible and near-infrared
- Rapid Response Mode offered since April 2004. Currently available at 6 instruments (FORS2, ISAAC, UVES, SINFONI, X-SHOOTER, HAWK-I)
- Used thus far for FORS2 (and formerly FORS1), ISAAC, UVES, X-SHOOTER

But the VLT was not designed to be a robotic telescope…

The VLT operations model

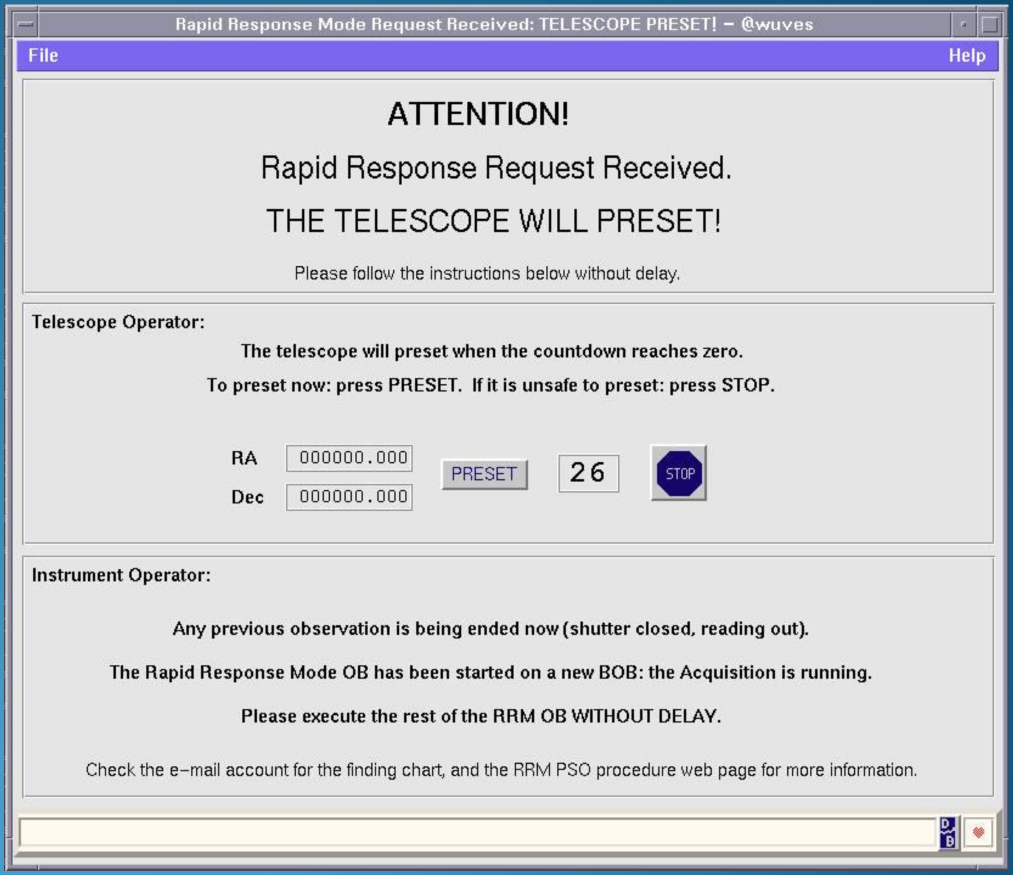
- Strongly based on *flexible scheduling*: most of the time (~70%) devoted to Service Mode observations, with user-specified constraints
- Short-term scheduling based on prevailing conditions, user-specified constraints, relative priorities among programmes, degree of completion, time criticality, instrument in use, optimization of the share of calibrations…
- Minor fraction (~30%) devoted to Visitor Mode, when real-time decisions based on science criteria are expected (also to keep a strong link between the observatory and the community)
- Target-of-Opportuntiy observations can be easily accommodated, non-disruptively, in the Service Mode schedule
- Rapid Response observations a bit more challenging, but also feasible…

How it works

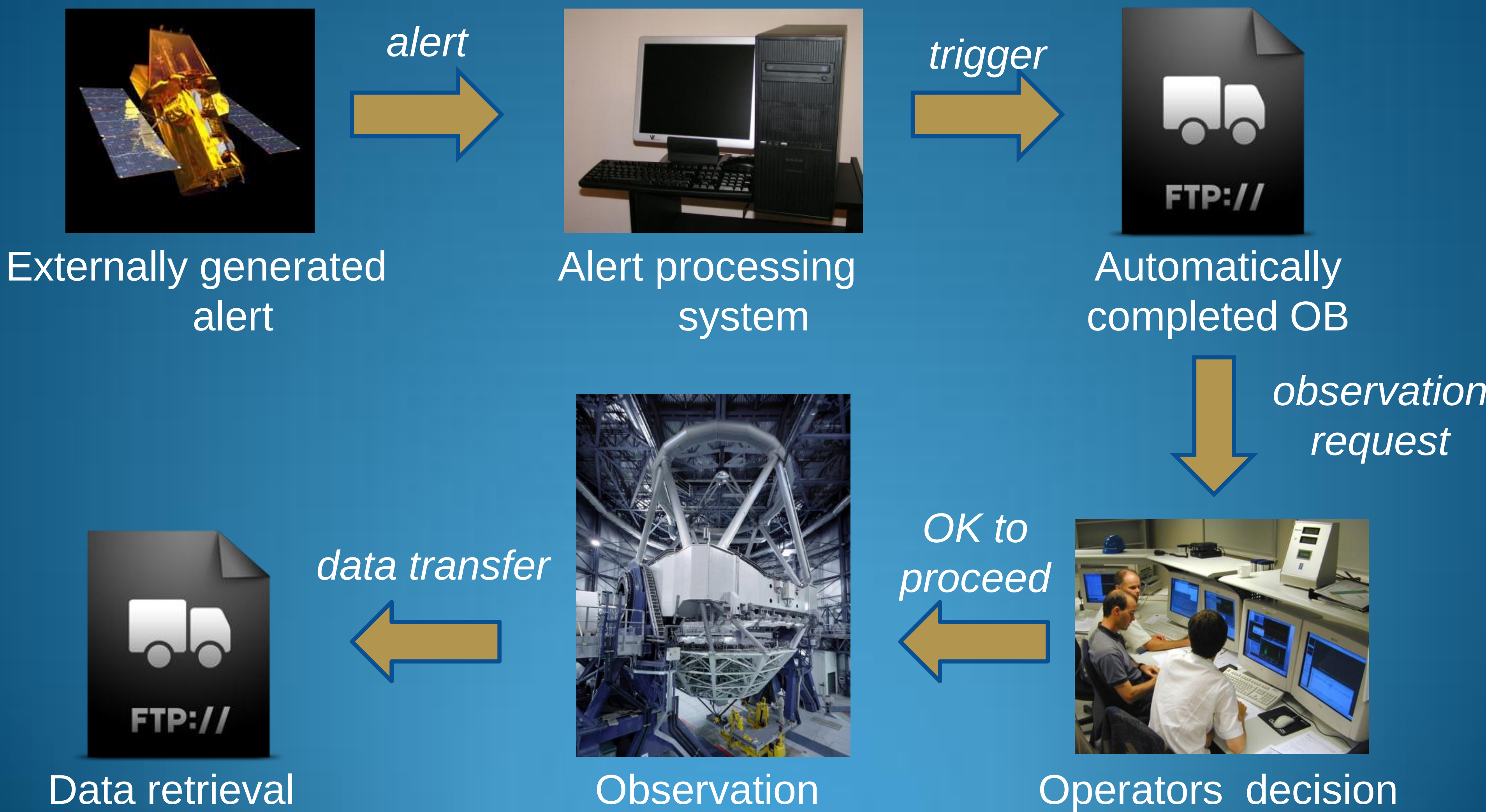
- A generic proposal is submitted, selected on scientific grounds
- Phase 2: generic Observation Blocks (OBs, logical units describing an observation) are submitted to ESO in advance of the trigger
  - RRM OBs contain instrument setup and exposure parameters, but not coordinates
- Trigger signal is an ASCII file submitted via ftp to a server in Garching, automatically checked every few seconds by Paranal
  - Name indicates instrument and OB to be executed
  - Content is just the coordinates
- Upon reception, the requested OB is completed (coordinates inserted) and sent for execution
- E-mail sent simultaneously to Paranal, including link to finding chart

How it works

- Executability checks performed immediately (target observability, instrument availability, distance to the Moon…)
- Ultimate decision on execution is on telescope operator
- The telescope can be observing the event *within 6 minutes* of the trigger arrival



How it works


alert
trigger
FTP://
Externally generated alert
Alert processing system
Automatically completed OB
observation request
OK to proceed
data transfer
FTP://
Data retrieval
Observation
Operators decision

Some policy issues

- RRM have overriding status over any observation currently being completed (other than strictly time-critical ones)
- Requested instrument must be in operation at the time of the trigger: no change of focus allowed
- RRM triggers accepted up to 4 hours after the event
- Follow-up observations after first OB are handled as normal Target-of-Opportunity
- For Gamma-Ray Burst (GRB) RRM observations, data are made immediately available to all teams having approved RRM GRB programmes
- All data are public through the ESO Archive after one year
- Time lost to RRM in Visitor Mode is compensated in Service.

Usage and performance

- 14 programmes have made use of RRM observations thus far
- Triggered 39 times (as of 17 February 2011)
- 53h of integration time spent on RRM observations
- 28 papers including reference to observations made in this mode

84 P. M. Vreeswijk et al.: Rapid-response Mode VLT/UVES spectroscopy of GRB 060418

Fruchter et al. 2001; Draine & Hao 2002; Perna & Lazzati 2002; Perna et al. 2003). Detection of these time-dependent processes, with timescales ranging from seconds to days in the observer's frame, would not only provide direct information on the physical conditions of the interstellar medium (ISM) surrounding the GRB, but would also constrain the properties of the emitted GRB flux before it is attenuated by foreground absorbers in the host galaxy and in intervening gas clouds. In the X-ray, evidence has been found for a time-variable H I column density (Starling et al. 2005; Campana et al. 2007), presumably due to the ionization of the nearby neutral gas. In the optical, none of these processes have been observed until recently, when Dessauges-Zavadsky et al. (2006) reported a $\sim 3\sigma$ variability detection of Fe II $^6D_{7/2}$ λ2396[1], observed at two epochs roughly 16 h apart. Such observations are technically very challenging because high-resolution spectroscopy combined with the rapidly decaying afterglow flux requires immediate follow-up with 8–10 m class telescopes.

providing a $3'$ error circle localization. Observations with the *Swift* X-Ray Telescope (XRT) resulted in a $5''$ position about one minute later (Falcone et al. 2006b), which triggered our desktop computer to activate a VLT-RRM request for observations with the Ultra-violet and Visual Echelle Spectrograph (UVES). This was received by the VLT's unit telescope Kueyen at Cerro Paranal at 3:08:12 UT. The on-going service mode exposure was ended immediately, and the telescope was pointed to the XRT location, all automatically. Several minutes later, the night astronomers Stefano Bagnulo and Stan Stefl identified the GRB afterglow, aligned the UVES slit on top of it, and started the requested observations at 3:16 UT (i.e. 10 min after the *Swift* γ-ray detection). This represents the fastest spectral follow-up of any GRB by an optical facility (until the RRM VLT/UVES observations of GRB 060607, also triggered by our team, which were started at a mere 7.5 min after the GRB; Ledoux et al. 2006). A series of exposures with increasing integration times (3, 5, 10, 20, and 40 min, respectively) was performed with a slit width

UVES GRB afterglow sample

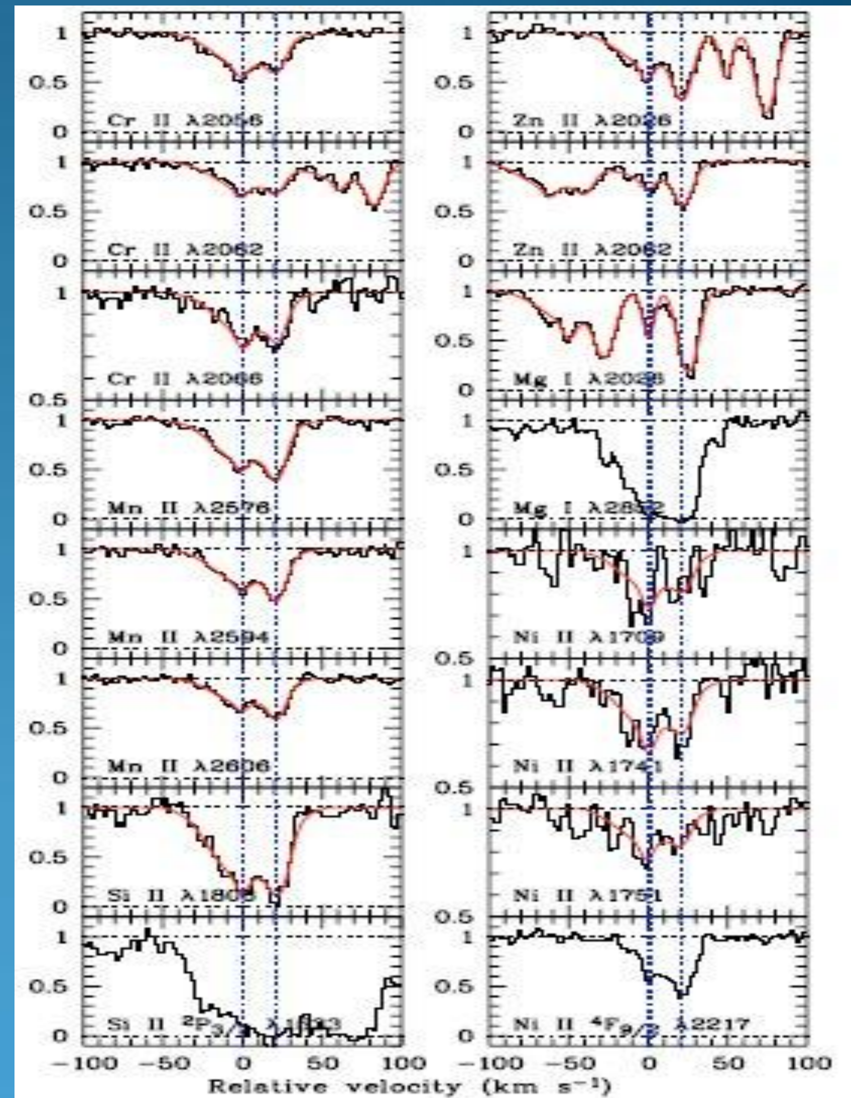
GRB	ΔT (hh:mm)	z	exptime (hours)	log N_{HI}	[X/H]
020813	20:48	1.255	2.1		
021004	13:31	2.329	2.0	19.0	
050730	04:09	3.969	1.7	22.10	-2.18
050820	00:34	2.615	1.7	21.05	-0.39
050922C	03:47	2.199	1.7	21.55	-1.82
060418	00:10	1.490	2.6		
060607	00:08	3.075	3.3	17.20	
071031	00:09	2.692	2.6	22.15	-1.73
080310	00:13	2.427	1.3	18.80	-1.39
080319B	00:09	0.937	2.1		
080330	01:32	1.51	2.3		
080413	03:42	2.435	2.3	21.85	-1.60
080804	00:50	2.205	1.3		
081008	04:30	1.967	1.1		
081029	00:23	3.848	0.5		

Programs by Vreeswijk et al., Fiore/D'Elia et al.

Some highlights

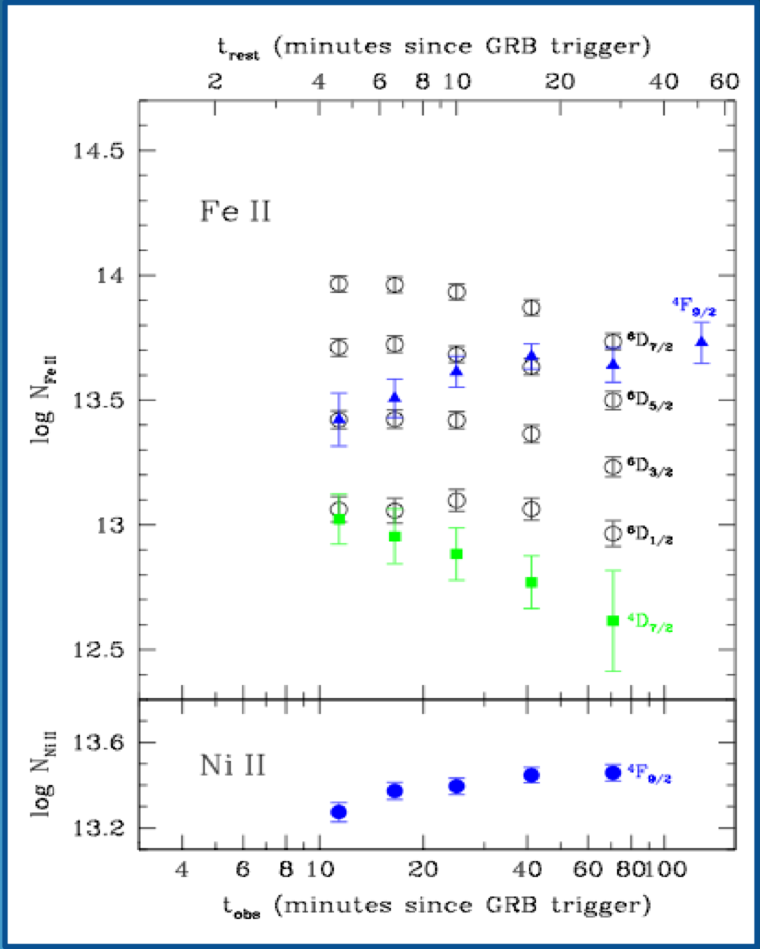
- Gamma-Ray Burst (GRB) afterglow photometric and spectroscopic follow-up
- Investigation of the intervening intergalactic medium (dust content, metallicity, reionization epoch) along the line of sight to distant GRBs
- Investigation of the interstellar medium surrounding the GRB (ionization, dynamics)
- GRB/Supernova connection

User only for GRB thus far, but potential goes beyond GRBs (one program currently accepted for RRM observations of giant stellar flares)



Absorption-line variability: probing the interstellar medium near GRBs

- Metastable and fine-structure levels of FeII, NiII at high z detected in absorption against GRBs
- UV pumping caused by the GRB followed by fluorescence reproduces model expectations; collisional excitation and direct excitation by infrared photons are discarded.
- GRB distance to absorbing clouds can be determined from models; from tens of pc to kiloparsecs (intervening material ionized by the GRB)
- GRB spectral slope and UV flux irradiating the cloud are determined too



GRB 060418 from Vreeswijk et al. 2007, A&A 468, 83

The future

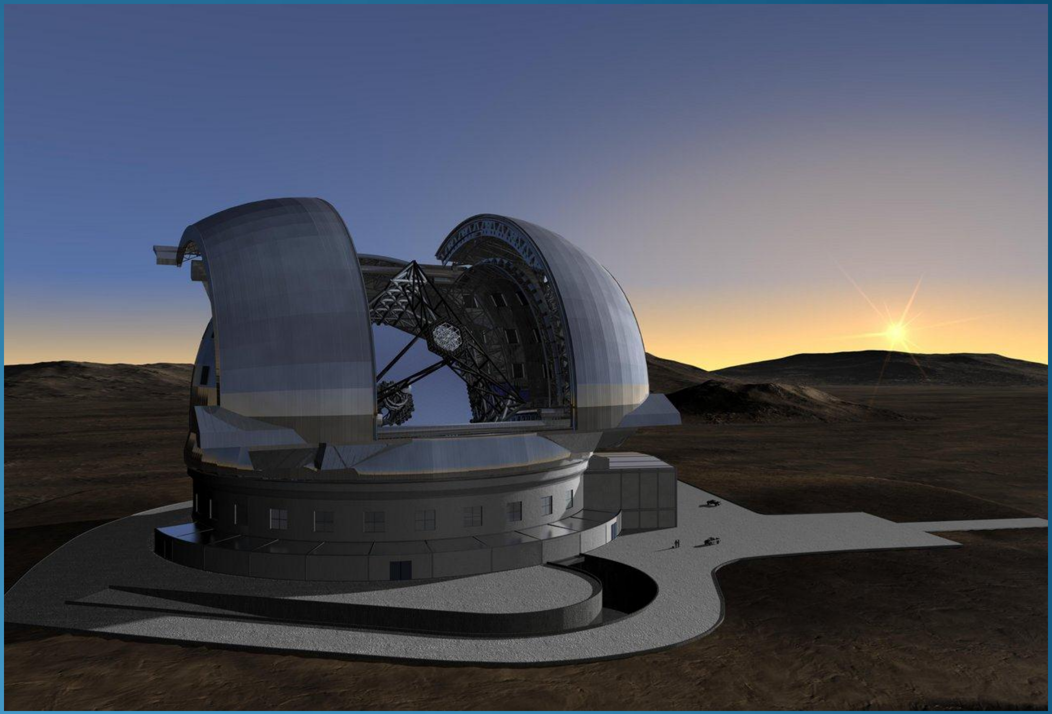
- A fast connection between Paranal and Europe will allow near-real time interaction, both ways, between an observer located (nearly) anywhere and the observatory
- EVALSO is a pilot project, funded by the European Union's Framework Program 7, to build a fiber link between Paranal and Cerro Armazones and the Chilean backbone near Antofagasta
- Installation completed in November 2010, integration in operations in 2011.
- EVALSO will provide Gbps capacity between the observatories and Europe

EVALSO

CAPACITIES

The future

- The European Extremely Large Telescope (E-ELT) will be a fully adaptive telescope, equipped to address a wide range of astrophysical and cosmological problems
- Rapid Response Mode can also be implemented at the E-ELT: diffraction-limited imaging and spectroscopy with a 40m-class telescope



- Nothing in the E-ELT design precludes its implementation: fast response time (<20 min after trigger is received) is expected to be possible
- Operations expected to begin around 2020

Concluding remarks

The operations model of large telescopes can accommodate a robotic-like mode for fast follow-up of transients

Enhanced possibilities opened up by remote real-time interaction

New science is possible by operating large telescopes in this mode –and it is happening already now