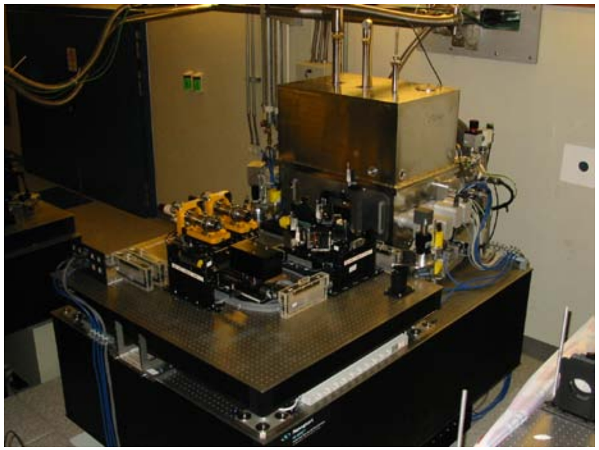
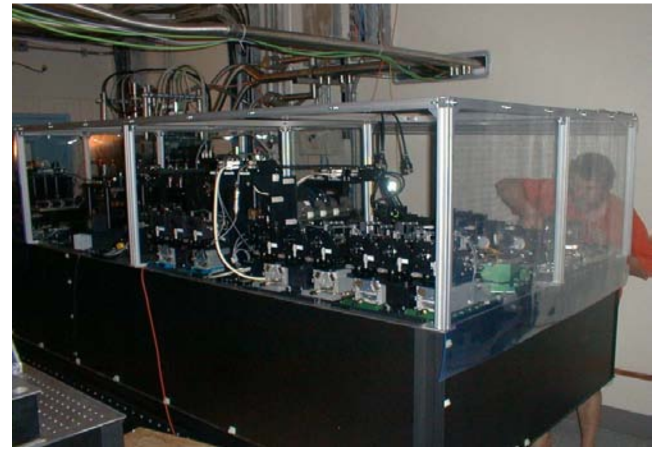
Using the VLT Interferometer AMBER and MIDI instruments





Tools session

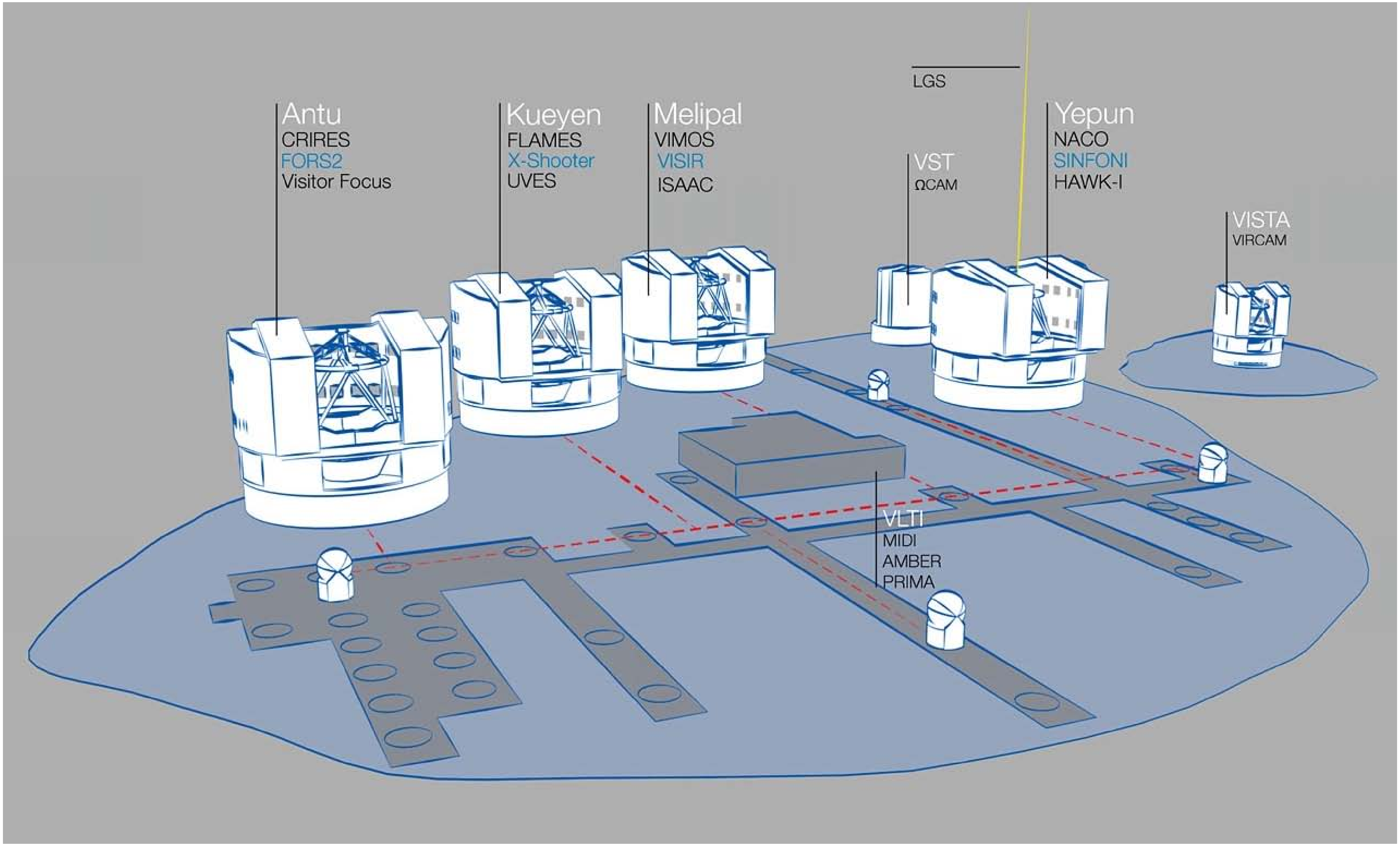
ESO Workshop “10 years of VLTI”

ESO Headquarters Garching

27 October 2011

Markus Wittkowski

User Support Department (USD), ESO Garching



VLTI instruments and their operation are fully integrated into the general scheme of the VLT instruments.

Documents: Call for Proposals (CfP), Instrument User Manuals, Instrument and Operations Webpages.

VLTI Instruments

- **VINCI**: *K*-band

- **MIDI**: Mid-Infrared (8-13 μm) 2-way beam combiner.

  Spectral resolution R=30 (prism), R=230 (grism).

  Result: One visibility spectrum per observation (+photometric spectrum).

- **AMBER**: Near-Infrared (*J, H, K*; 1-2.5 μm) 3-way beam combiner.

  Spectral resolution R=30 (low resolution), 1500 (medium r.), 12000 (high r.).

  Result: 3 visibility spectra and 1 closure phase spectrum per observation.

- PRIMA: Phase Referenced Imaging and Micro-arcsecond Astrometry.

  -> Presentation by Gerard van Belle.

- Second generation VLTI instruments.

Overview of MIDI and AMBER

	MIDI	AMBER
Beams	2	3
Beam combination	Pupil plane	Image plane
Wavelength	8-13 μm	1-2.5 μm
Spectral resolution	30 (Prism); 230 (Grism)	30 (LR); 1500 (MR); 12000 (HR)
Limiting magnitude UT	*N*=4 (current)	*K*=8.5 (current)
Limiting magnitude AT	*N*=0.74 (current)	*K*=5.5 (current)
Visibility accuracy	<10-20% (1-5%)	1% (diff.), 3% (abs.), current 2-10%
Airy disk FOV	0.26'' (UT), 1.14'' (AT)	60 mas (UT), 250 mas (AT) in *K*
Spatial resolution 8-200m	260 - 10 mas	25-1 mas (*J*), 60-2 mas (*K*)

Limiting magnitudes MIDI, different modes

Telescopes	Beam combiner	Spectrograph	Limit (N mag)	Limit (Jy @ 12 μm)
UTs	HIGH_SENS	PRISM	4	1
UTs	HIGH_SENS	GRISM	2.8	3
ATs	HIGH_SENS	PRISM	0.74	20
ATs	HIGH_SENS	GRISM	0.31	30
UTs	SCI_PHOT	PRISM	3.2	2
UTs	SCI_PHOT	GRISM	2	6
ATs	SCI_PHOT	PRISM	0.0	40
ATs	SCI_PHOT	GRISM	-0.44	60

Limiting magnitudes AMBER, with different modes and conditions

	AMBER	FINITO	Kcorr	Hcorr	H	VisK	VisH	AM	Vmag	Dist
UT	LR-HK	**no**	<8.0,7.0*	<8,7*	-	>10%	>10%	<2.0	1...17	<55"
	LR-HK	group tracking	<8.5,7.5*	<8.5,7.5*	> 1			<1.5	1...15	<13"
	LR-HK MR-K	fringe tracking	<8.0,7.0	<8.0,7.0						
	MR-H	fringe tracking	-	<5		-				
	HR-K	fringe tracking	<6	<6		>10%				
AT	LR-HK	**no**	<5.5 (4.1, 3.1)**	<5.5 (4.1, 3.1)**	-	>5%	>5%	<2.0	-1.7...13.5	<60"
	LR-HK	group tracking	<5.5 (4.5, 3.5)**	<5.5 (4.5, 3.5)**	> -2		>15%	<1.5	-1.7...11	<15"
	MR-H	fringe tracking	-	<4 (3, 2)		-				
	LR-HK MR-K HR-K	fringe tracking	<5 (4, 3)	<5 (4, 3)		>5%				

The table above assumes seeing<0.6" with CLR conditions,seeing<0.8" with CLR conditions, for the UTs. For the ATs, the conditions are supposed to be seeing<0.6" with CLR conditions, seeing<0.8" with CLR conditions and seeing<1.2" and THN conditions. **THK** conditions should not be used for AMBER observations. **PHO** conditions are not applicable because AMBER does not provide a photometric calibration to a high level of accuracy even under optimum conditions.

PIs should make sure, when submitting their proposals, that the proper seeing conditions are selected according to the correlated magnitudes of their objects.

Phase 1 constraints are binding !

Phase 1 resources

- Phase 1 Call for Proposals
  http://www.eso.org/sci/observing/phase1

- Instrument webpages including user manual, VLTI manual
  http://www.eso.org/sci/facilities/paranal/instruments

- VLTI telescope overview including offered configurations
  http://www.eso.org/sci/facilities/paranal/telescopes/vlti

- Preparation tools (VisCalc and CalVin)
  http://www.eso.org/observing/etc
- ESO User Support: usd_help@eso.org

Baseline configurations

- All available UT 2-telescope baselines for MIDI and 3-telescope triplets for AMBER. Baseline between 47m and 130m.

- ATs are currently offered in three quadruplets:

A1-G1-K0-I1, baselines between 47m and 128m

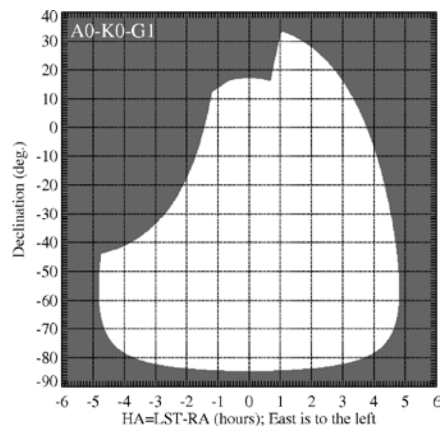
D0-H0-G1-I1, baselines between 32m and 82m

A1-B2-C1-D0, baselines between 11m and 36 m

Phase 1: Choice of quadruplet

Phase 2: Choice of MIDI baseline or AMBER triplet

- Sky constraints due to shadowing and delay line limits



ESO telescope bibliography/ Science Examples

The ESO telescope bibliography lists refereed publications directly based on ESO data: http://archive.eso.org/wdb/wdb/eso/publications/form

As of 26 Oct 2011:

- 48 publications based on VINCI data
- 83 publications based on MIDI data
- 60 publications based on AMBER data

- 174 publications based on VLTI data
- 90 different first authors (28 with more than 1 first-author VLTI publication)

Have a look at recent papers of the same instrument/instrument mode and of a similar type of objects.

Specific Requirements for Interferometry (I): Calibration

- The measured visibility function needs to be calibrated for the atmospheric and instrumental transfer function.
- This implies the need for alternating observing sequences of science targets and calibrators.

- The observer is requested to provide (1-)2 calibration star OBs for each science star OB. The OBs are executed in a row and are considered successfully completed if each of them was executed successfully.

  Different sequences of cal/sci/cal or sci/cal OBs are executed independently.

- The selection of calibration stars is supported by the ESO tool “CalVin” based on different user-defined criteria.

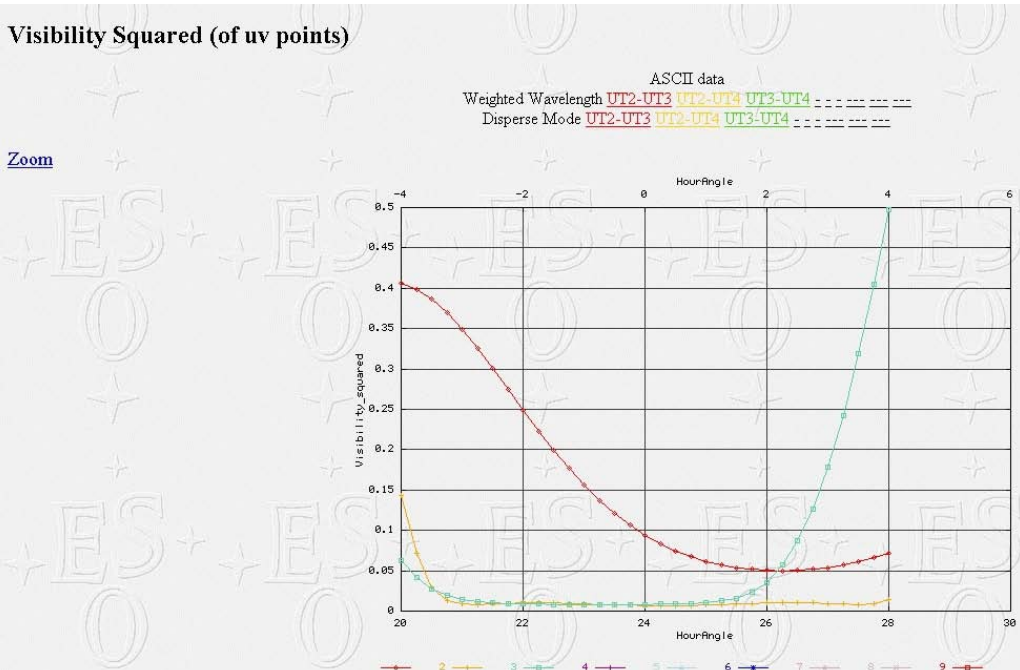
Specific Requirements for Interferometry (II): Combination of different baselines (aperture synthesis)

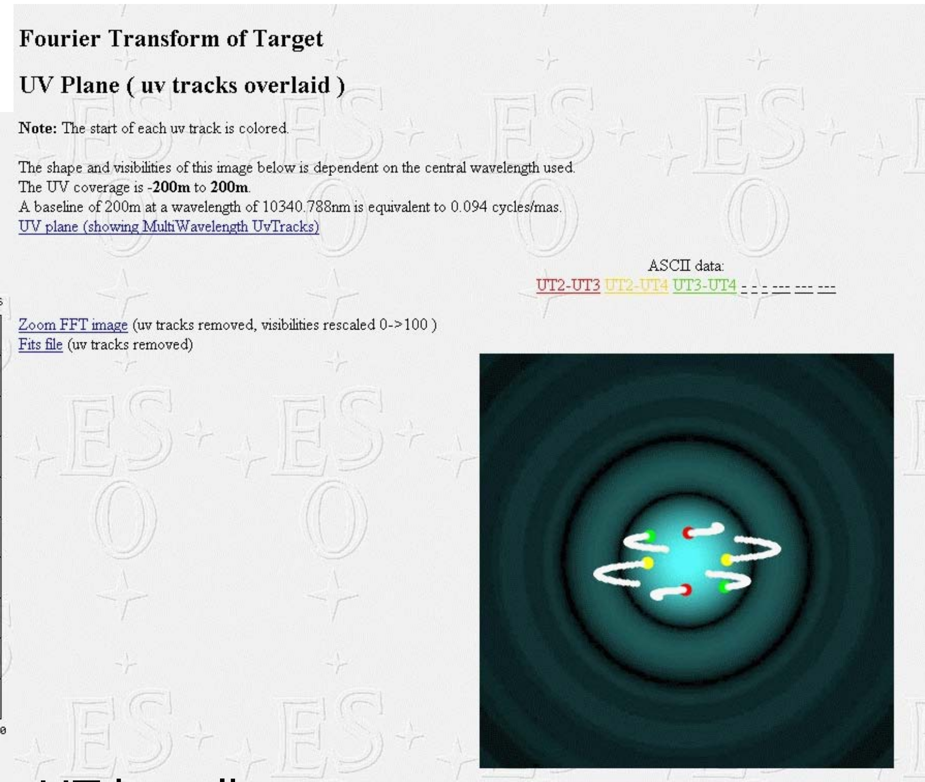
- The scientific goal of an interferometric observing campaign can often only be reached if visibility measurements at different projected baseline lengths and/or angles are combined.

- Each instantaneous visibility measurement requires the submission of one OB. Multiple observations of the same source require the submission of multiple OBs.
- For each OB, the local sidereal time (LST) and the ground baseline has to be specified, as part of the instrument-specific constraint set.
- The pairs of science/calibrator OBs can effectively be considered as stand-alone entities, and are executed independently (for service mode).
- The choice of baselines and LST ranges is supported by the visibility calculator VisCalc.

VLTI Preparation Tools (I) – VisCalc www.eso.org/observing/etc

Calculation of observability and visibility amplitudes for a given target geometry and chosen VLTI configuration.





Declination +7 deg., UD diameter 40 mas, three UT baselines.

VLTI Preparation Tools (II) – CalVin www.eso.org/observing/etc

Selection of suitable calibrators from an underlying fixed list based on different user criteria.

List of Calibrators

6 calibrators found

ASCII file format - the first column is the universal time

Comparative graphs for *"Target"* vs. 7 calibrators:- Normalized Visibilities Loss of Correlated Magnitudes Target Altitudes Shadow

No.	Name	R.A. (h,m,s)	Dec. (d,m,s)	Ang. Dist. (deg°)	Ang. Diam. (mas)	Mag_N	Spec. Type	Lum. Class	Qual. Flag	Normalized Visibility ave ± err range	Loss of Correlated Magnitude ave ± err range	RiseTime SetTime Duration	Culmination MaxAltitude	Shadowing
1 (0)	*"Target"*	5 55 10.30	7 24 25.40	0.0	40.00 ± 0.00					0.45 ± 0.000 0.30-0.69 graph ascii	1.72 ± -0.00 2.62-0.82 graph ascii	25.25UT 33.75UT 8.50hrs	29.75 UT max = 57° graph ascii	max = 1% graph ascii
2 (195)	hd50778	6 54 11.40	-12 2 19.10	24.4	3.95 ± 0.22	0.67	K4III	III	1	0.99 ± 0.001 0.99-0.99 graph ascii	0.02 ± 0.00 0.02-0.01 graph ascii	25.75UT 33.75UT 8.00hrs	30.75 UT max = 77° graph ascii	max = 0% graph ascii
3 (197)	hd61421	7 39 18.12	5 13 30.00	26.0	5.25 ± 0.21	-0.58	F5IV-V	IV-V	1	0.99 ± 0.001 0.98-0.99 graph ascii	0.03 ± 0.00 0.04-0.01 graph ascii	27.00UT 33.75UT 6.75hrs	31.50 UT max = 60° graph ascii	max = 0% graph ascii
4 (198)	hd48915	6 45 8.92	-16 42 58.00	27.1	6.06 ± 0.13	-1.23	A1	V	1	0.98 ± 0.001 0.98-0.98 graph ascii	0.04 ± 0.00 0.05-0.04 graph ascii	25.50UT 33.75UT 8.25hrs	30.75 UT max = 81° graph ascii	max = 0% graph ascii
5 (192)	hd29503	4 38 10.82	-14 18 14.50	28.9	2.58 ± 0.12	1.30	K1III	III	2	1.00 ± 0.000 1.00-1.00 graph ascii	0.01 ± 0.00 0.01-0.00 graph ascii	23.25UT 33.75UT 10.50hrs	28.50 UT max = 79° graph ascii	max = 1% graph ascii
6 (199)	hd36079	5 28 14.72	-20 45 34.00	28.9	2.97 ± 0.16	0.90	G5II	II	2	1.00 ± 0.001 0.99-1.00 graph ascii	0.01 ± 0.00 0.01-0.01 graph ascii	24.00UT 33.75UT 9.75hrs	29.25 UT max = 85° graph ascii	max = 0% graph ascii
7 (200)	hd65953	8 1 13.33	- 1 23 33.40	32.6	3.05 ± 0.59	1.07	K4III	III	2	1.00 ± 0.002 0.99-1.00 graph ascii	0.01 ± 0.00 0.01-0.01 graph ascii	27.00UT 33.75UT 6.75hrs	32.00 UT max = 66° graph ascii	max = 0% graph ascii

Cal. for Betelgeuse. Angular distance < 35 deg., diameter 0..8 mas, magn 1.3.. -5

INFORMATION NEEDED AT PHASE1 PREPARATION

- Scientific case
- Feasibility of the science case: Brightness in V (off-axis guide star)? Brightness at K band ? Brightness at H band (for FINITO) ? Angular size ?
- Baseline configuration(s)
- Number of visibility points
- Absolute visibility calibration (cal-sci-cal sequence) or relative visibility (cal/sci pairs)
- Spectral resolution
- Required conditions for the correlated magnitudes !
- Use of the fringe tracker FINITO ?

Phase 2 resources

- Phase 1 resources
- Phase 2 proposal preparation:

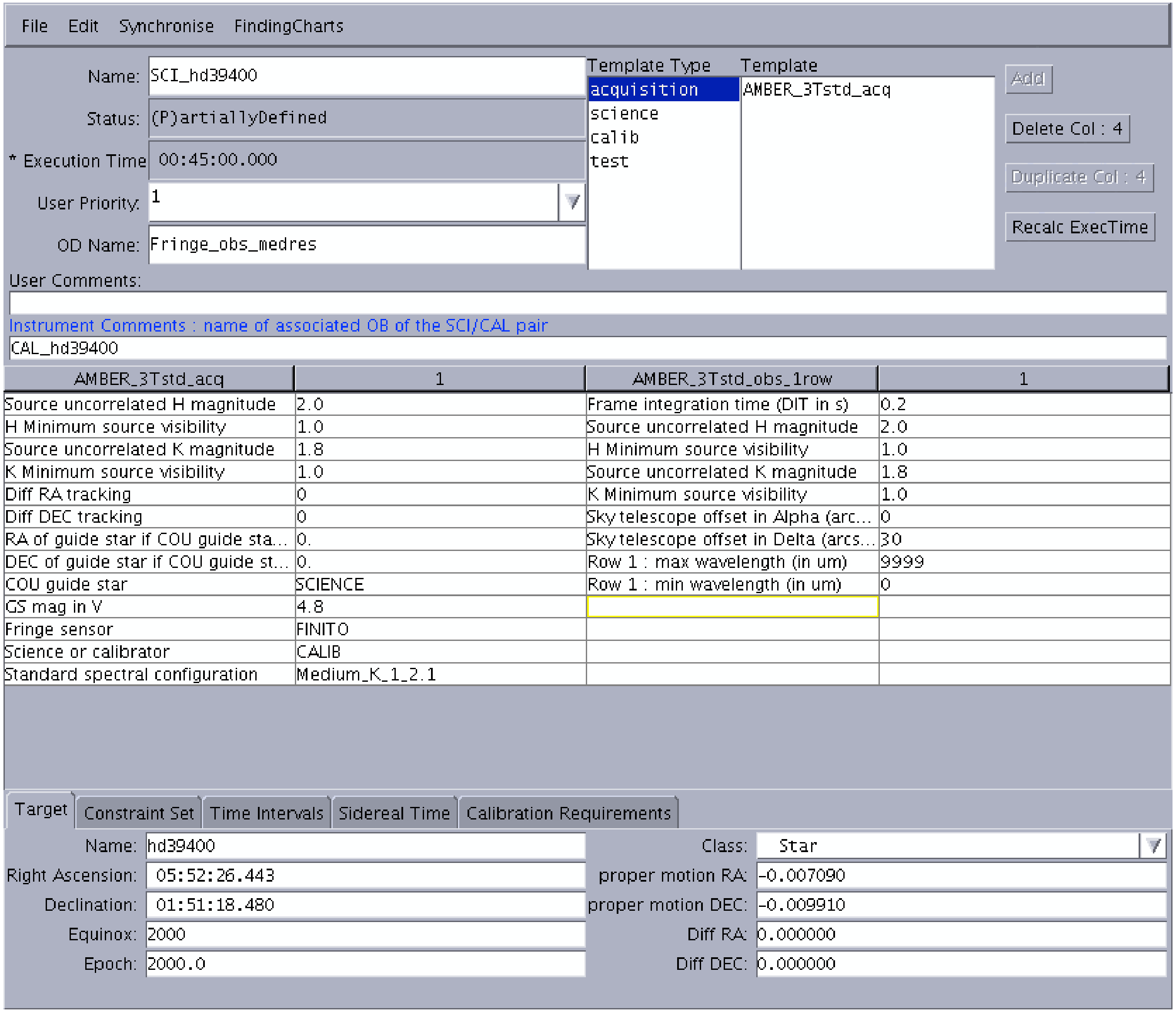
  http://www.eso.org/observing/phase2.html

- ESO User Support Department: usd_help@eso.org

INFORMATION NEEDED AT PHASE 2 PREPARATION

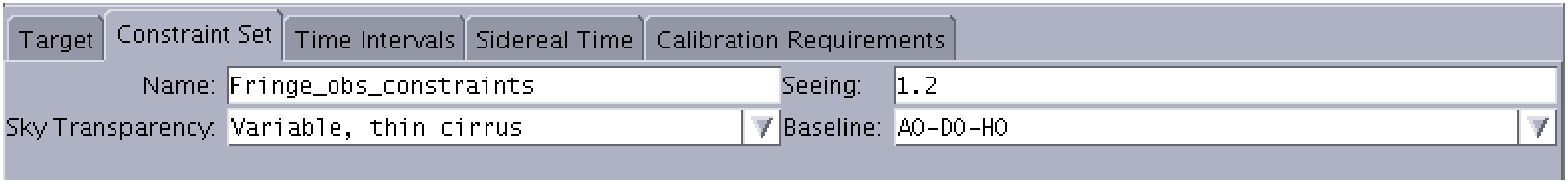
- All the information from Phase 1
- Choice of a MIDI baseline, AMBER triplet
- Definition of LST constraints for each visibility point
- Selection of a calibration star that is observable at the same LST

Proposal preparation (Phase 2) - AMBER

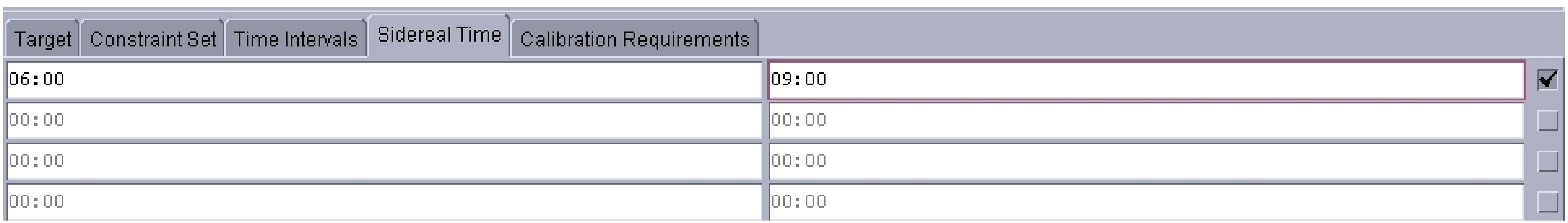


Proposal preparation (Phase 2) – Constraint set

AMBER constraint set:



LST constraints:



Conclusion

- The VLTI with the mid-infrared instrument MIDI and the near-infrared instrument AMBER is offered to the astronomical community for regular service mode and visitor mode observations.

- The same kind and level of support is offered to users of the VLTI instruments as to users of any VLT instrument.

- The complexity of interferometry and the VLTI are hidden to the regular users. Only the main instrument modes and parameters need to be chosen. The observation preparation is rather simple compared to some other VLT instruments.

- However, be aware of the complexity of interferometry and the caveats for the analysis and interpretation of the data.