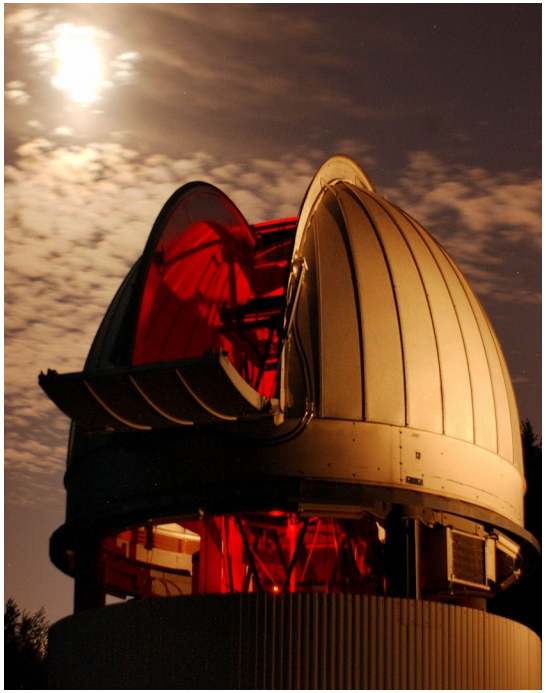
Observing Strategies and Planning Software



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Mount Wilson, CA

With contributions from:
Laurent Bourgès and Christopher Farrington

Outline

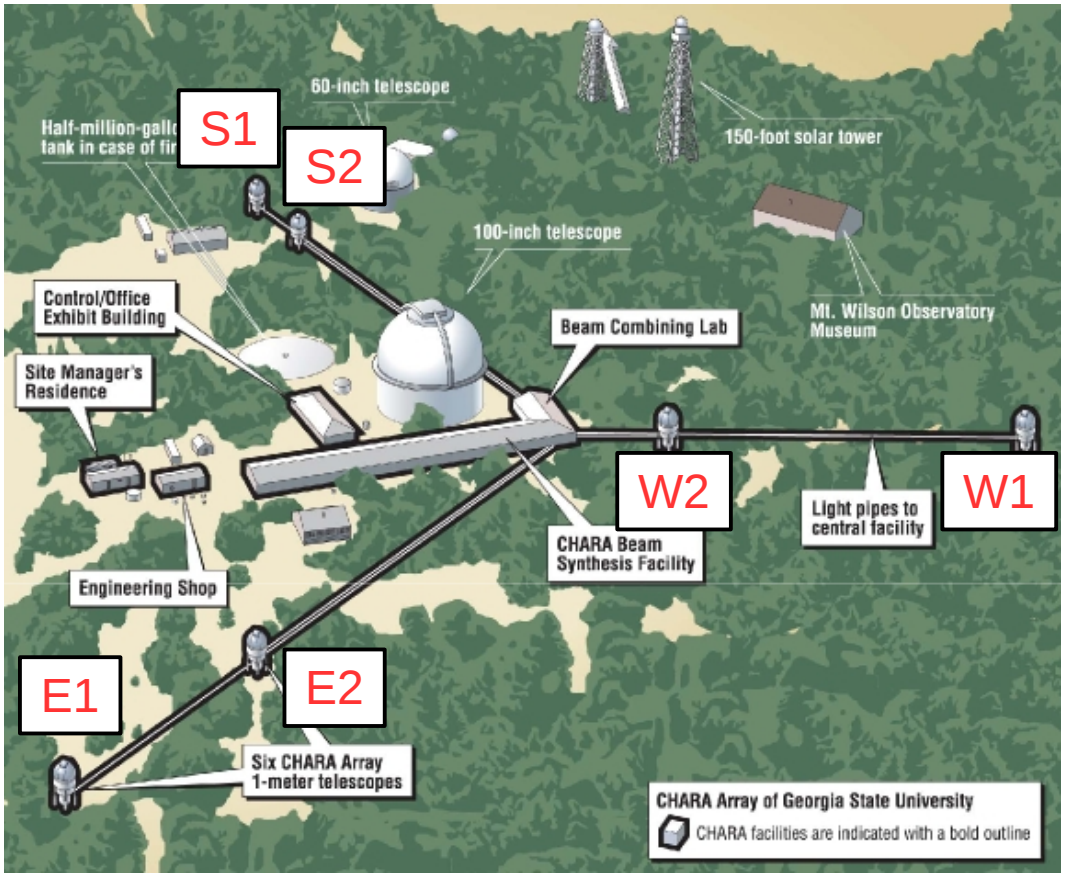
- Selecting a Beam Combiner
- Selecting Telescopes and Baselines
- Selecting Calibrator Stars
- Selecting Delay Settings (POP Configuration)
- Time Needed for Observations

Beam Combiners

Combiner	Num Tel.	Band	Typical Mag	Best Mag	Spec. Res.	Advantages
CLASSIC	2T	H or K	7.0	8.5	Broad	Sensitivity
CLIMB	3T	H or K	6.0	7.0	Broad	Sensitivity
JouFlu	2T	K	4.5	5.0	Broad	Precision
MIRC	6T	H	4.5	6.0	40	Imaging
PAVO	2T	630-900 nm	7.0	8.0	30	Sensitivity
VEGA – HiRes	2-3T	2 bands (7nm) in 480-850 nm	4.0	5.0	30000	Spectral Res
VEGA – MedR	2-3T	2 bands (35 nm) in 480-850 nm	6.5	7.5	6000	Spectral Res

Limit for acquisition and tiptilt tracking: V = 10-12 mag

Telescopes and Baselines

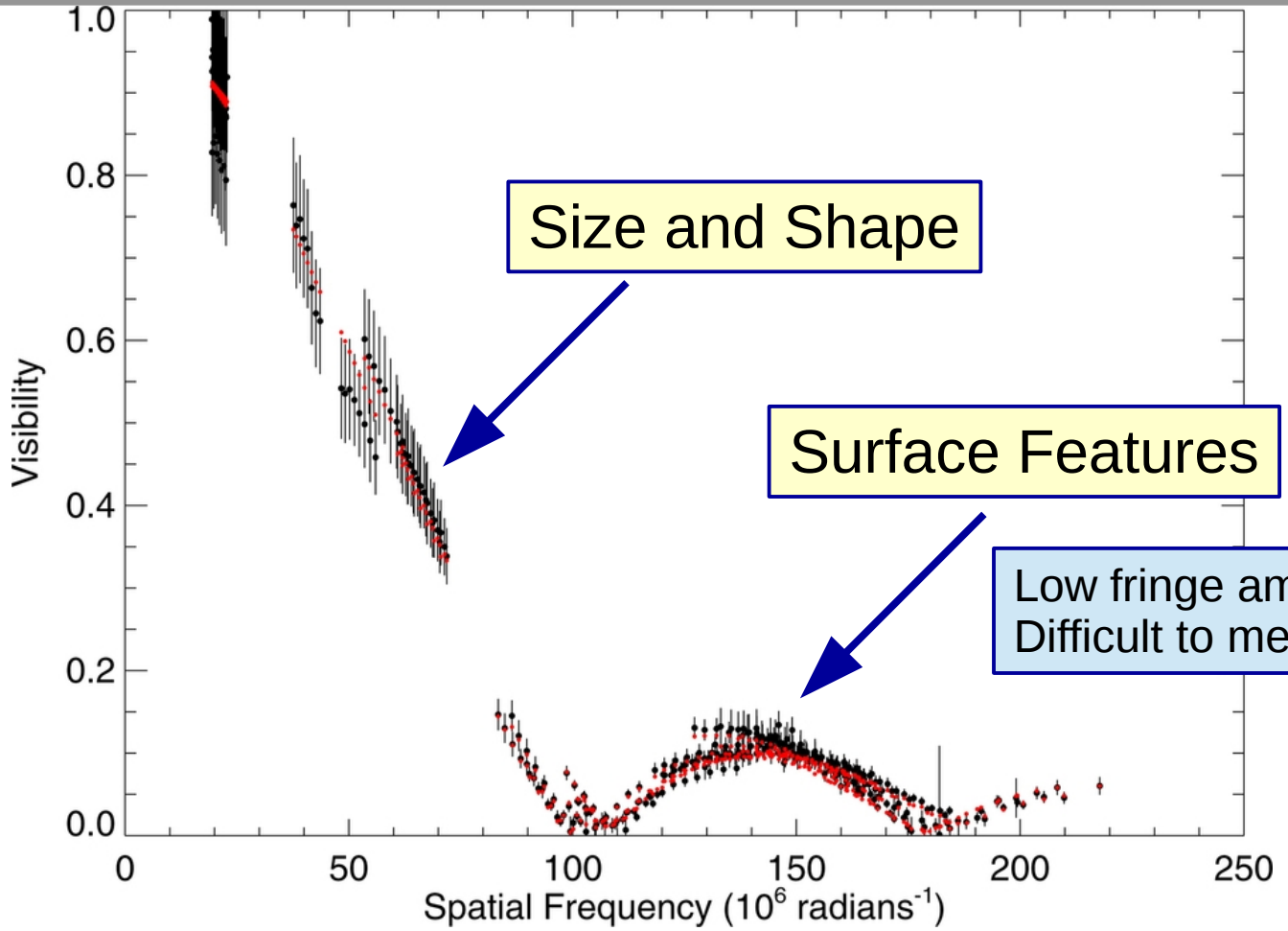


Baseline	Length (m)
E1-S1	331
W1-E1	314
E1-S2	302
E2-S1	279
W1-S1	279
W1-E2	251
W1-S2	249
E2-S2	248
W2-S1	211
W2-E1	222
W2-S2	177
W2-E2	156
W2-W1	108
E2-E1	66
S2-S1	34

Selecting Beam Combiner and Baselines

- Angular Resolution: 0.5 λ /B
  - 0.66 mas in K-band (2.13 μm)
  - 0.52 mas in H-band (1.67 μm)
  - 0.20 mas in visible at 650 nm
- Simple diameter:
  - Single baseline (two telescopes)
- Imaging complex sources: Rapid rotators, binaries, stellar surfaces
  - Multiple baseline projections
  - Sample beyond the first null (at 1.22 λ/B)

Selecting Beam Combiner and Baselines

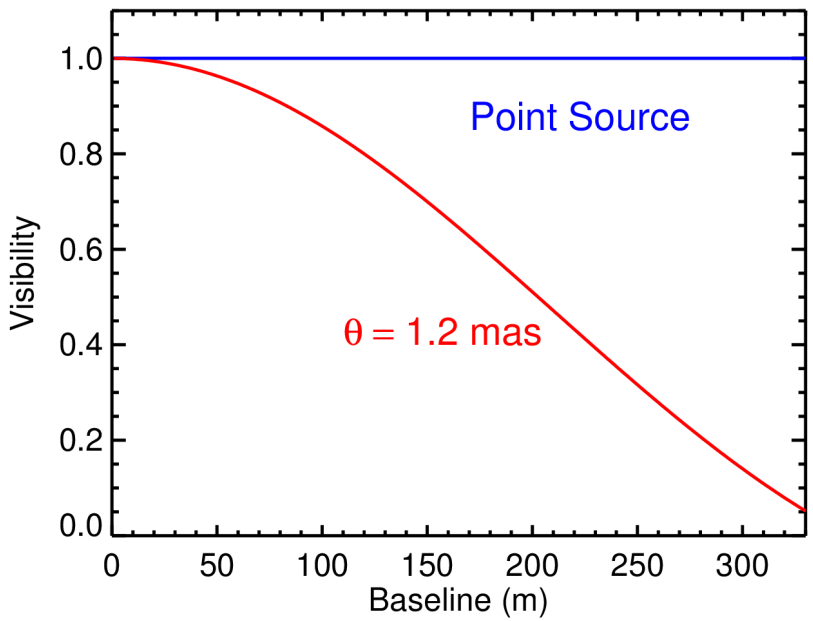


Wavelength Coverage

- Broad-band
  - Higher sensitivity for faint objects
  - Bandwidth smearing
- Spectrally dispersed visibilities
  - Increase u,v sampling by measuring fringes in different wavelength channels
  - Emission/absorption line studies
- Coherence length (width of fringe packet)
  - Sets the interferometric field of view

$$\frac{\lambda^2}{\Delta\lambda}$$

Calibrator Stars



- Unresolved point source:
  - Visibility = 1.0
- However, instrumental and atmospheric effects will cause a loss in coherence, causing a drop in the measured visibility.
- Observe unresolved calibrator stars to define the true visibility of the target.

Selecting Calibrators

- Unresolved stars or stars with a known angular diameter.
- Within 5-10 degrees on the sky from the science target.
- Within 1-2 mag in brightness from science target and similar in color.
- Avoid binary stars, rapid rotators, emission line stars.
- Minimum of two calibrators per object, three is better.
  - Discovery of unknown binaries

Selecting Calibrators

- SearchCal – developed by JMMC
  - http://www.jmmc.fr/searchcal_page.htm
- getCal – developed by NexSci
  - http://nexsciweb.ipac.caltech.edu/gcWeb/gcWeb.jsp

SearchCal

SearchCal [c1]

File Edit Query Calibrators Interop Help

Query Parameters

1) Instrumental Configuration

Magnitude Band : H

Wavelength (H) [µm] : 1.65

Max. Baseline [m] : 300.0

2) Science Object

Name : HD 69897

RA 2000 [hh:mm:ss] : 08 20 03.86158

DEC 2000 [+/-dd:mm:ss] : +27 13 03.7416

Magnitude (H) : 3.942

3) SearchCal Parameters

Min. Magnitude (H) : 3.0

Max. Magnitude (H) : 5.0

Scenario : Bright Faint

RA Range [mn] : 240.0

DEC Range [deg] : 20.0

Progress :

Get Calibrators

Found Calibrators (2041 sources, 1826 filtered)

Index	dist	HD	RAJ2000	DEJ2000	vis2	LDD	UD_V	UD_H	UD_K	SpType	V	H	K
1	**5.21E-6**	69897	**08 20 03.8602**	**+27 13 03.7380**	**0.374**	**0.701**	**0.662**	**0.686**	**0.689**	**F6V**	**5.13**	**3.942**	**3.868**
2	2.975	67542	08 09 35.1816	+29 05 35.0772	0.622	0.503	0.468	0.488	0.49	G0II	6.47	4.699	4.621
3	3.383	67544	08 09 24.8645	+24 49 34.0716	0.619	0.509	0.468	0.49	0.493	G8III	7.29	4.966	4.908
4	3.595	71730	08 29 40.0634	+24 20 40.9452	0.581	0.542	0.496	0.52	0.523	K0III	7.05	4.872	4.81
5	3.977	73080	08 37 22.1112	+28 17 39.8328	0.554	0.555	0.52	0.541	0.543	G5	6.63	4.702	4.591
6	4.945		08 10 54.7320	+22 43 43.1904	0.514	0.588	0.548	0.573	0.575	K0	8.026	4.909	4.698
7	6.121	65471	07 59 42.6055	+23 10 58.4652	0.506	0.594	0.554	0.579	0.581	K0	6.92	4.73	4.562
8	6.902	75216	08 49 45.3118	+29 26 55.9824	0.534	0.581	0.529	0.557	0.561	K2III	7.38	4.868	4.712
9	7.14	63138	07 48 28.8108	+28 45 51.2748	0.519	0.592	0.542	0.568	0.572	K0III	6.86	4.694	4.605
10	7.303	75646	08 52 00.4543	+25 43 07.1004	0.568	0.553	0.504	0.53	0.534	K2III	7.54	4.983	4.834
11	7.524		08 52 09.6634	+29 51 13.3848	0.515	0.588	0.548	0.572	0.575	K0	7.08	4.742	4.631
12	7.677		08 32 54.2333	+34 23 03.2748	0.544	0.565	0.524	0.549	0.552	K2	7.52	4.934	4.798
13	7.731	75783	08 53 00.0972	+29 57 41.5296	0.564	0.549	0.509	0.533	0.536	K2	7.35	4.982	4.813
14	*7.809*	74198	08 43 17.1466	+21 28 06.6000	0.774	0.366	0.351	0.362	0.362	A1IV	4.66	4.788	4.638
15	7.842	64092	07 53 01.0094	+22 20 04.3116	0.557	0.553	0.515	0.538	0.541	K0	7.05	4.85	4.755
16	7.845		08 03 34.1340	+20 20 18.6972	0.599	0.519	0.486	0.506	0.508	G5	7.03	4.836	4.742
17	8.769	67482	08 09 39.7601	+35 42 08.5032	0.58	0.535	0.498	0.52	0.523	K0	7.3	4.952	4.839
18	8.815	64602	07 56 01.9399	+34 22 10.4160	0.572	0.541	0.505	0.527	0.53	K0	7.57	4.972	4.827
19	8.917		07 48 06.8957	+32 51 25.0308	0.557	0.552	0.518	0.539	0.541	G5	7.204	4.952	4.548
20	10.159	60204	07 34 31.5922	+28 41 11.6808	0.519	0.583	0.547	0.569	0.571	G5	6.66	4.605	4.498
21	10.402	77694	09 04 51.4817	+24 36 18.5040	0.561	0.559	0.509	0.536	0.539	K2III	7.8	4.982	4.838

Filters

Reject stars farther than : Maximum RA Separation (mn) : 10.0 Maximum DEC Separation (degree) : 10.0

Reject stars with magnitude : below : 0.0 and above : 10.0

Reject Spectral Types (and unknowns) : O B A F G K M

Reject Luminosity Classes (and unknowns) : I II III IV V VI

Reject Visiblity below : vis2 : 0.5

Reject Visibility Accuracy above (or unknown) : vis2Err/vis2 (%) : 2.0

Reject Variability

Reject Multiplicity

Reject Invalid Object Types

Diameter quality : Maximum chi square : 2.0 Maximum relative error (%) : 10.0

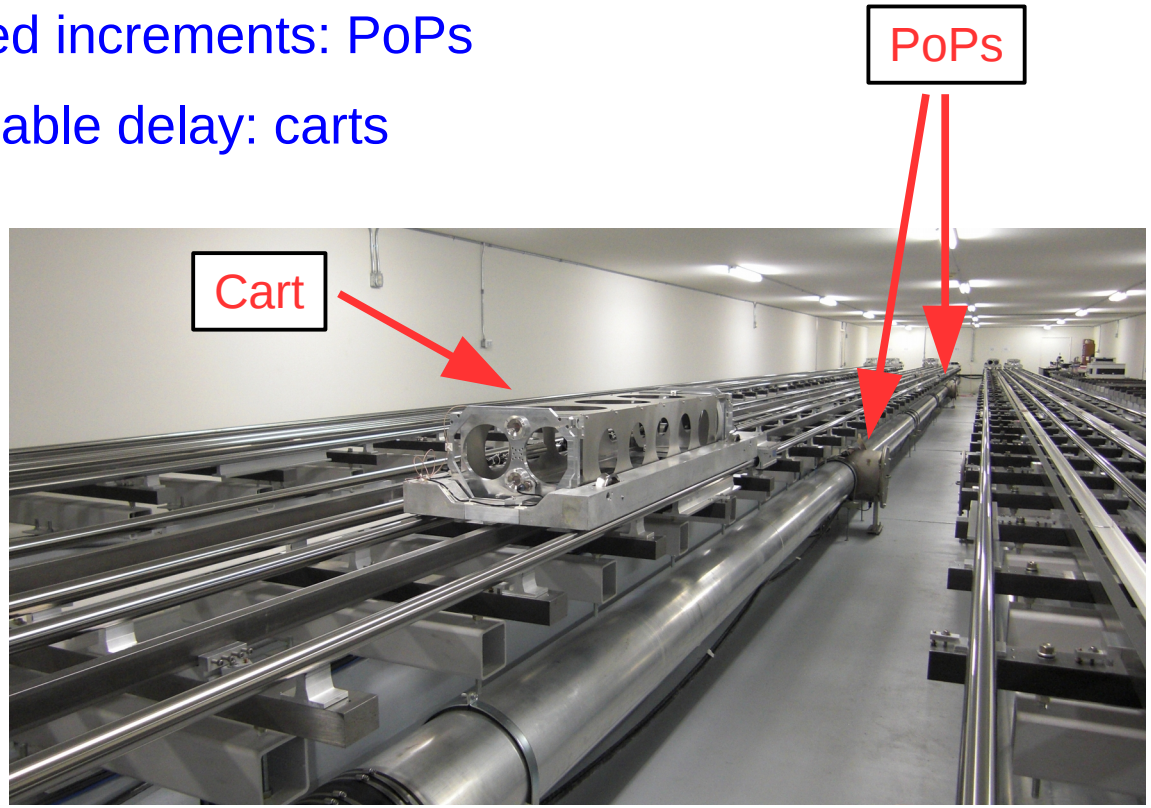
searching calibrators... done.

29 M

Provided by JMMC

Delay settings (sky coverage)

- Delay settings to equalize optical path length
  - Fixed increments: PoPs
  - Variable delay: carts

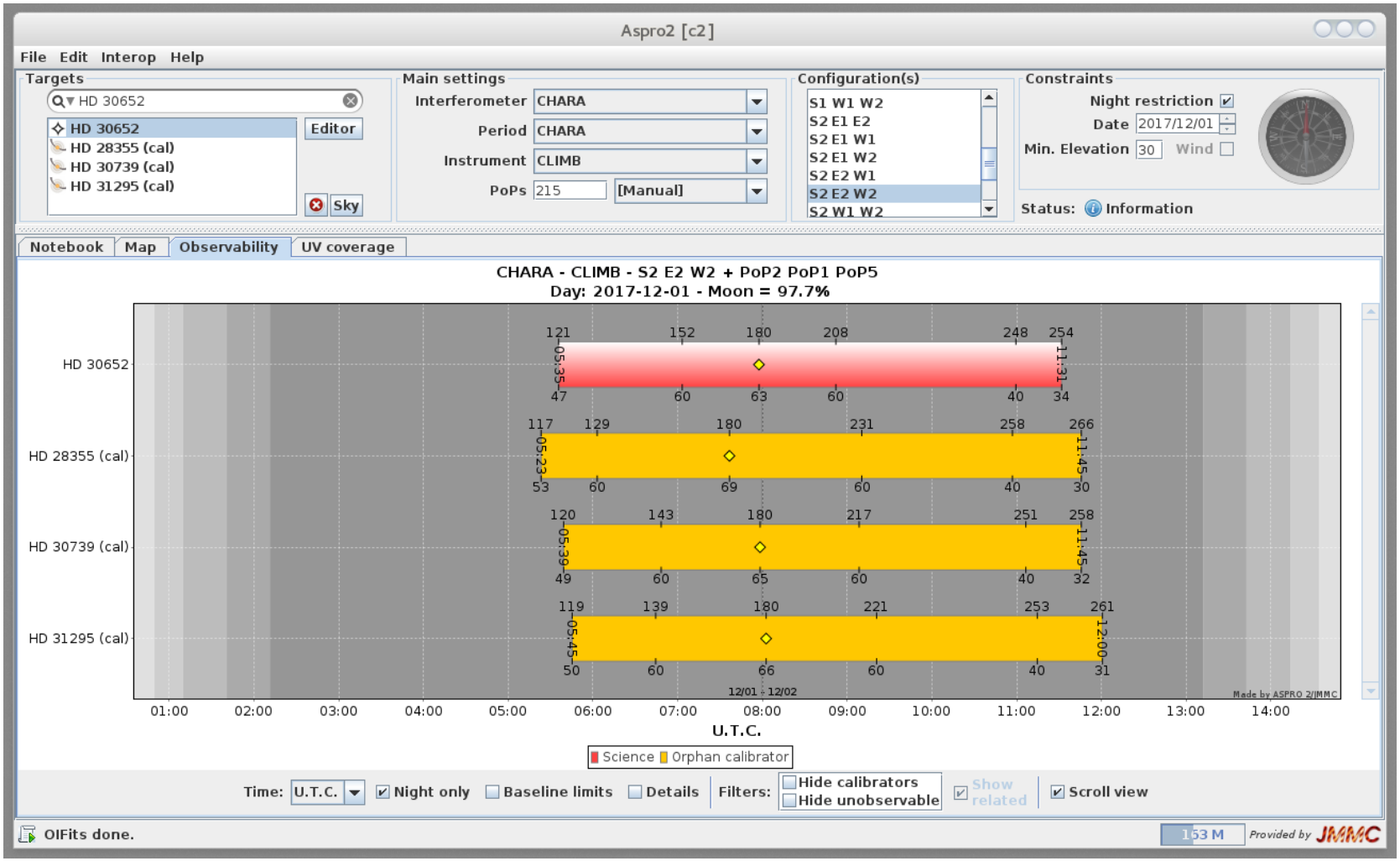


Planning Software

- ASPRO2 – developed by JMMC
  - http://www.jmmc.fr/aspro_page.htm
- CHARA_PLAN2 – developed by CHARA
  - http://www.astro.gsu.edu/~theo/chara_reduction/index.html

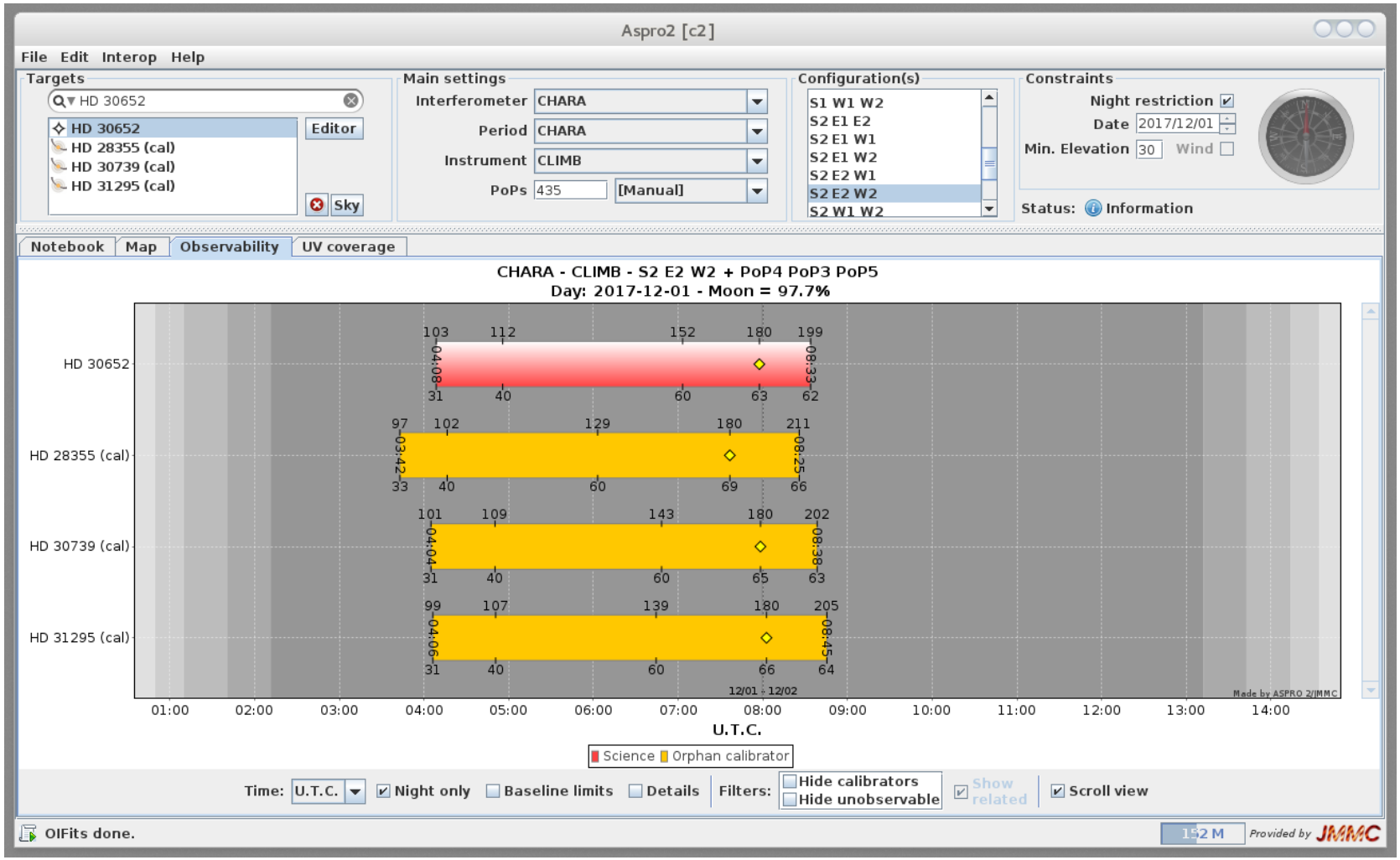
ASPRO 2

JMMC


Aspro2 [c2]
File Edit Interop Help
Targets
HD 30652
HD 30652
HD 28355 (cal)
HD 30739 (cal)
HD 31295 (cal)
Editor
Sky
Main settings
Interferometer CHARA
Period CHARA
Instrument CLIMB
PoPs 215 [Manual]
Configuration(s)
S1 W1 W2
S2 E1 E2
S2 E1 W1
S2 E1 W2
S2 E2 W1
S2 E2 W2
S2 W1 W2
Constraints
Night restriction
Date 2017/12/01
Min. Elevation 30 Wind
Status: Information
Notebook Map Observability UV coverage
CHARA - CLIMB - S2 E2 W2 + PoP2 PoP1 PoP5
Day: 2017-12-01 - Moon = 97.7%
HD 30652
HD 28355 (cal)
HD 30739 (cal)
HD 31295 (cal)
12/01 - 12/02
Made by ASPRO 2/JMMC
01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00
U.T.C.
Science Orphan calibrator
Time: U.T.C. Night only Baseline limits Details Filters: Hide calibrators Hide unobservable Show related Scroll view
OIFits done.
153 M Provided by JMMC

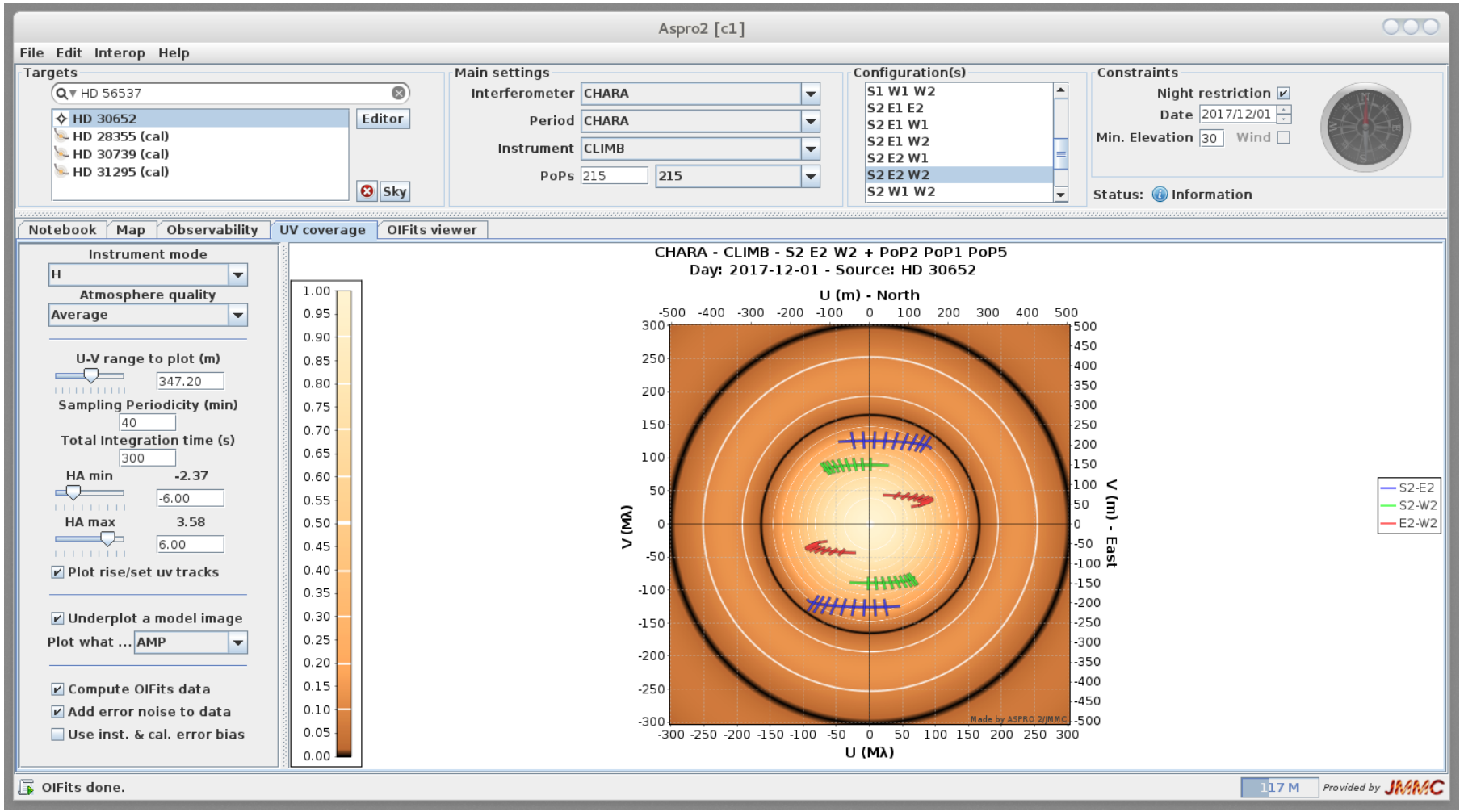
ASPRO 2

JMMC


Aspro2 [c2]
File Edit Interop Help
Targets
HD 30652
HD 30652
HD 28355 (cal)
HD 30739 (cal)
HD 31295 (cal)
Editor
Sky
Main settings
Interferometer CHARA
Period CHARA
Instrument CLIMB
PoPs 435 [Manual]
Configuration(s)
S1 W1 W2
S2 E1 E2
S2 E1 W1
S2 E1 W2
S2 E2 W1
S2 E2 W2
S2 W1 W2
Constraints
Night restriction
Date 2017/12/01
Min. Elevation 30
Wind
Status: Information
Notebook Map Observability UV coverage
CHARA - CLIMB - S2 E2 W2 + PoP4 PoP3 PoP5
Day: 2017-12-01 - Moon = 97.7%
HD 30652
HD 28355 (cal)
HD 30739 (cal)
HD 31295 (cal)
12/01 - 12/02
Made by ASPRO 2/JMMC
01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00
U.T.C.
Science Orphan calibrator
Time: U.T.C.
Night only
Baseline limits
Details
Filters:
Hide calibrators
Hide unobservable
Show related
Scroll view
OIFits done.
152 M
Provided by JMMC

ASPRO 2

JMMC

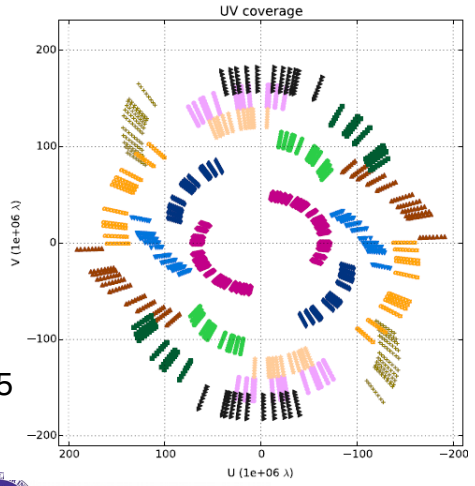

Aspro2 [c1]
File Edit Interop Help
Targets
HD 56537
HD 30652
HD 28355 (cal)
HD 30739 (cal)
HD 31295 (cal)
Editor
Sky
Main settings
Interferometer CHARA
Period CHARA
Instrument CLIMB
PoPs 215
Configuration(s)
S1 W1 W2
S2 E1 E2
S2 E1 W1
S2 E1 W2
S2 E2 W1
S2 E2 W2
S2 W1 W2
Constraints
Night restriction
Date 2017/12/01
Min. Elevation 30
Wind
Status: Information
Notebook
Map
Observability
UV coverage
OIFits viewer
Instrument mode
H
Atmosphere quality
Average
U-V range to plot (m)
347.20
Sampling Periodicity (min)
40
Total Integration time (s)
300
HA min -2.37
-6.00
HA max 3.58
6.00
Plot rise/set uv tracks
Underplot a model image
Plot what ... AMP
Compute OIFits data
Add error noise to data
Use inst. & cal. error bias
CHARA - CLIMB - S2 E2 W2 + PoP2 PoP1 PoP5
Day: 2017-12-01 - Source: HD 30652
U (m) - North
V (Mλ)
U (Mλ)
V (m) - East
S2-E2
S2-W2
E2-W2
Made by ASPRO 2/JMMC
OIFits done.
117 M
Provided by JMMC

How much time is needed?

- Calibration Strategies:
  - Cal1 – Obj – Cal2 – Obj – Cal1 ...
  - Cal1 – Obj – Cal2 – Cal1 – Obj – Cal2 ...
- Time to collect data on single object (star acq. + data)
  - Seeing and brightness dependent
  - Fast instruments (CLASSIC, CLIMB, PAVO, JouFlu):
    - 5 – 10 minutes
  - VEGA: 5 – 20 minutes
  - MIRC: 45 – 60 minutes
- Cal-Sci-Cal will take between 30 – 120 min

How much data is needed?

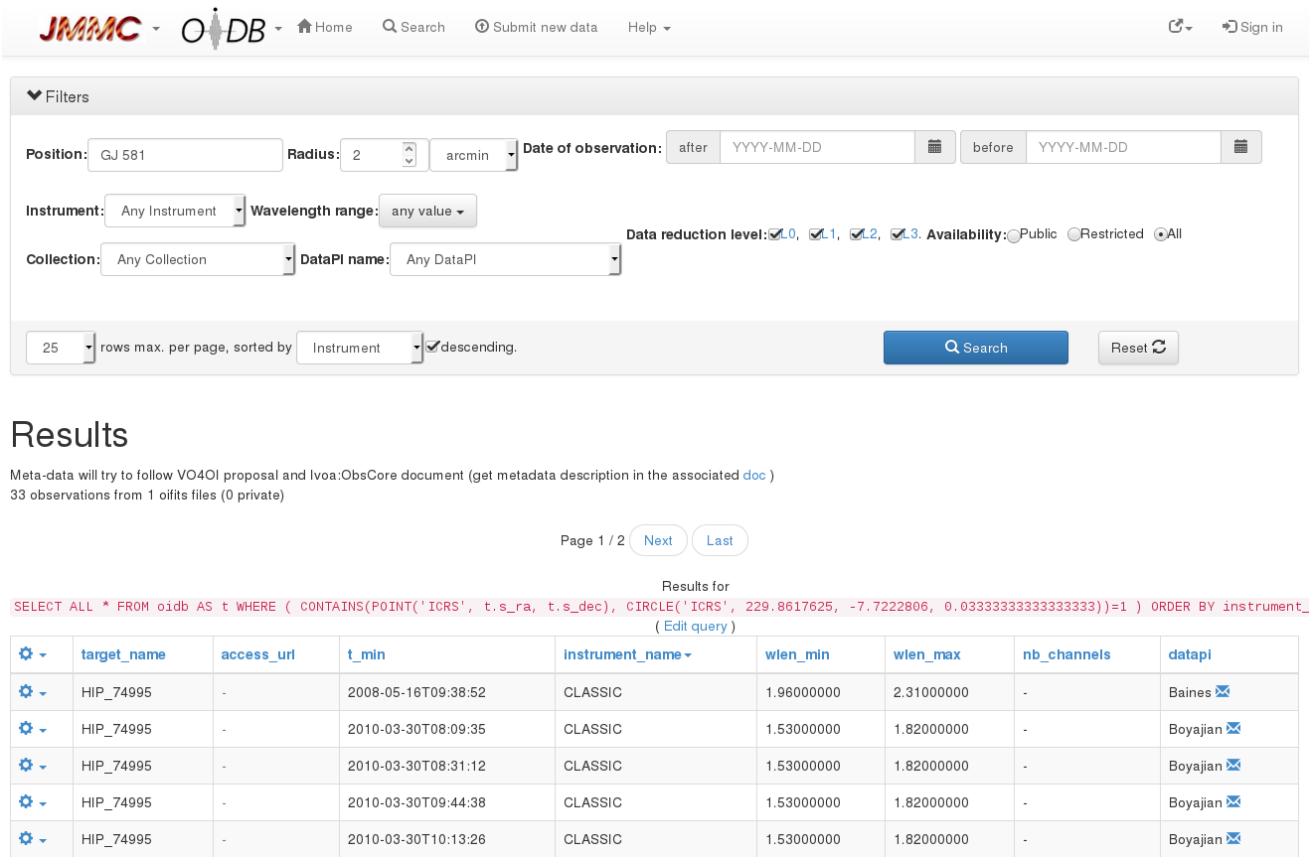
- Diameters – Several brackets of data per baseline on two separate nights.
- Binaries – Minimum of three brackets or observations on at least three baselines.
- Imaging – Many brackets on multiple baselines during the night to fill in the sky coverage.



Kloppenborg et al. 2015

Do observations already exist?

- OI Database
- Query and download data (OIFITS)
- CHARA observation logs for Classic, CLIMB, VEGA only



http://oidb.jmmc.fr/index.html

On the night of observation

- Observations will be carried out by CHARA staff
- Visitors are encouraged to travel to the Array to participate in the observations
  - Real-time input from PI on decisions that could impact the science objectives and priorities

Example 1: Angular Diameter

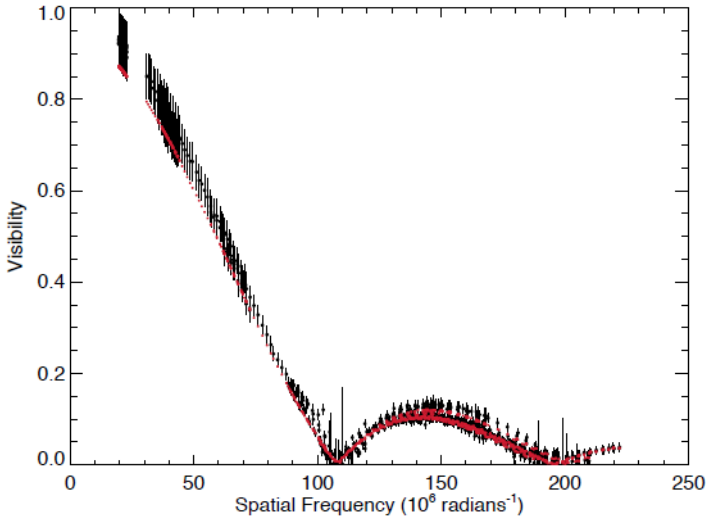
- Exoplanet host star: 55 Cnc (von Braun et al. 2012)
  - V = 5.6 mag, K=4.0 mag
  - θ = 0.71 mas
  - CLASSIC H/K-band, 2T combiner
  - Baselines longer than 250 m (ang res ~ 0.69 mas at H)
- Asteroseismic target: HD 182736 (Huber et al. 2012)
  - Subgiant showing solar-like oscillations
  - V = 7.0 mag, K = 5.0 mag
  - θ = 0.44 mas
  - PAVO R-band, 2T combiner
  - Baselines longer than 150 m (ang res ~ 0.43 mas at R)

Example 2: Binary Star

- Wolf Rayet Binary - WR 137 (Richardson et al. 2016)
  - V = 7.9 mag, H = 6.8 mag, K = 6.2 mag
  - sep ~ 4 - 10 mas, flux ratio ~ 60%
  - CLIMB H/K-band, 3T combiner [2D coverage, faint target]
  - Inner triangle (S2-E2-W2), baselines 140-250 m (~ 0.7 mas)
- Faint Cepheid companion – V1334 Cyg (Gallenne et al. 2015)
  - V = 5.9 mag, H=4.7 mag, K = 4.5 mag
  - sep ~ 8 mas, flux ratio ~ 3.1%
  - MIRC H-band, 6T combiner
  - All 15 baselines 34-331 m [high precision closure phases!]
  - 8 spectral channels [longer coherence length]

Example 3: Imaging

- Spotted giant star - sig Gem (Roettenbacher et al. 2017)
  - V = 4.3 mag, H = 1.8 mag
  - θ = 2.4 mas
  - MIRC H-band, 6T combiner [Good uv coverage on sky]
  - All 15 baselines (34-331 m)
  - Sample 2nd lobe in visibility curve!



Guide to planning observations available on the CHARA website:

http://www.chara.gsu.edu/observers/planning-an-observation