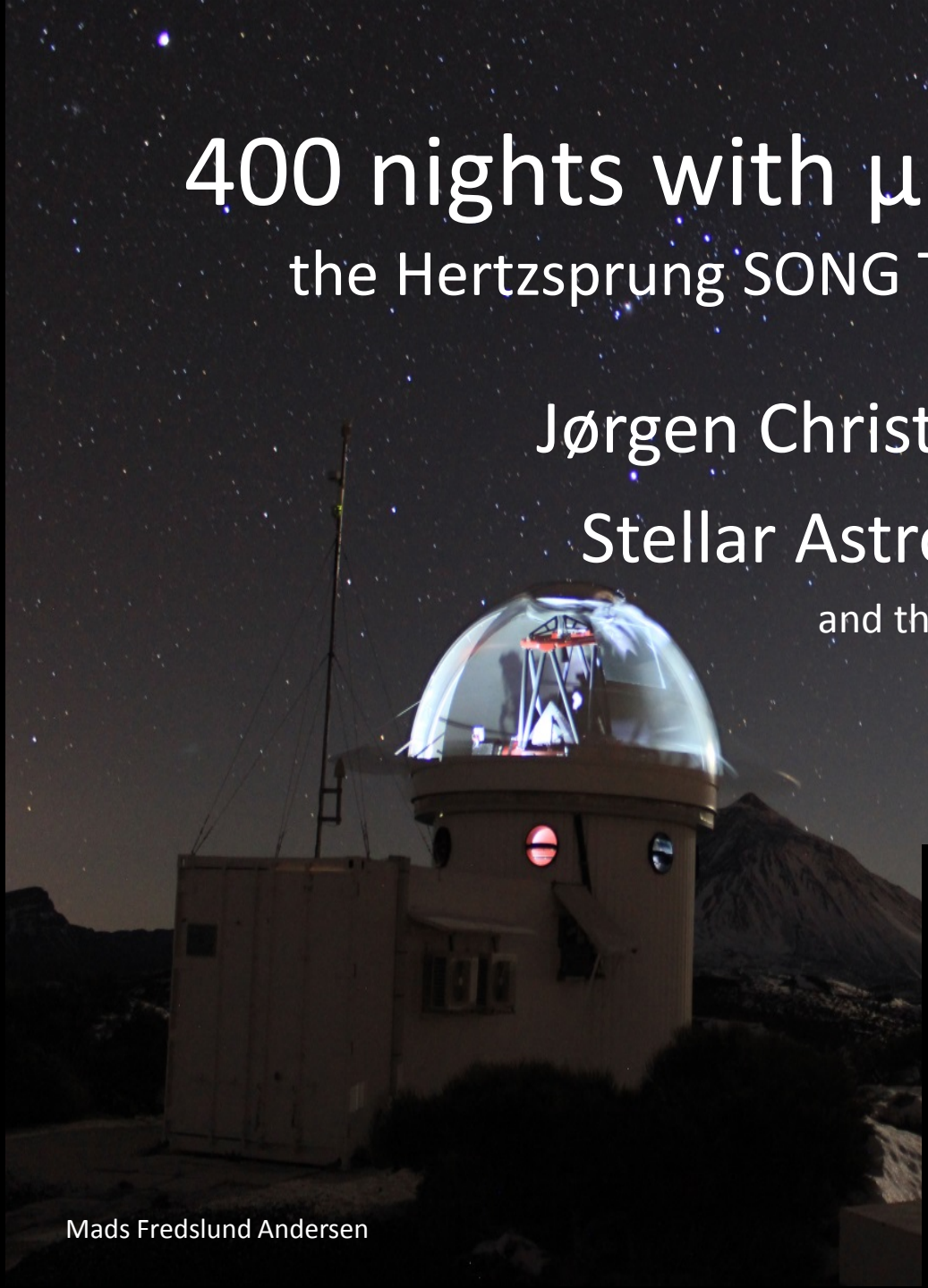
400 nights with μ Herculis

the Hertzsprung SONG Telescope

Jørgen Christensen-Dalsgaard

Stellar Astrophysics Centre

and the SONG Team

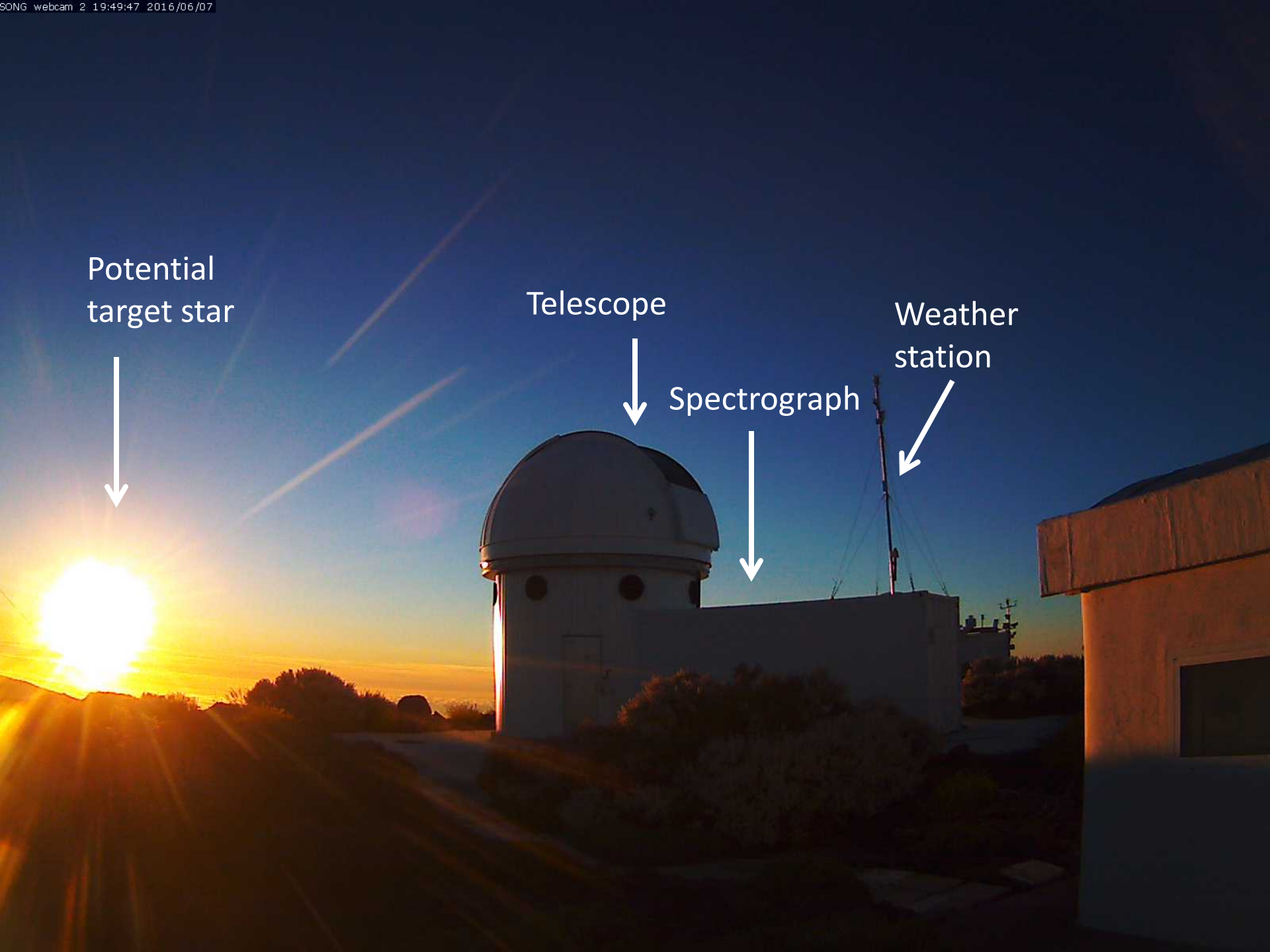


Mads Fredslund Andersen

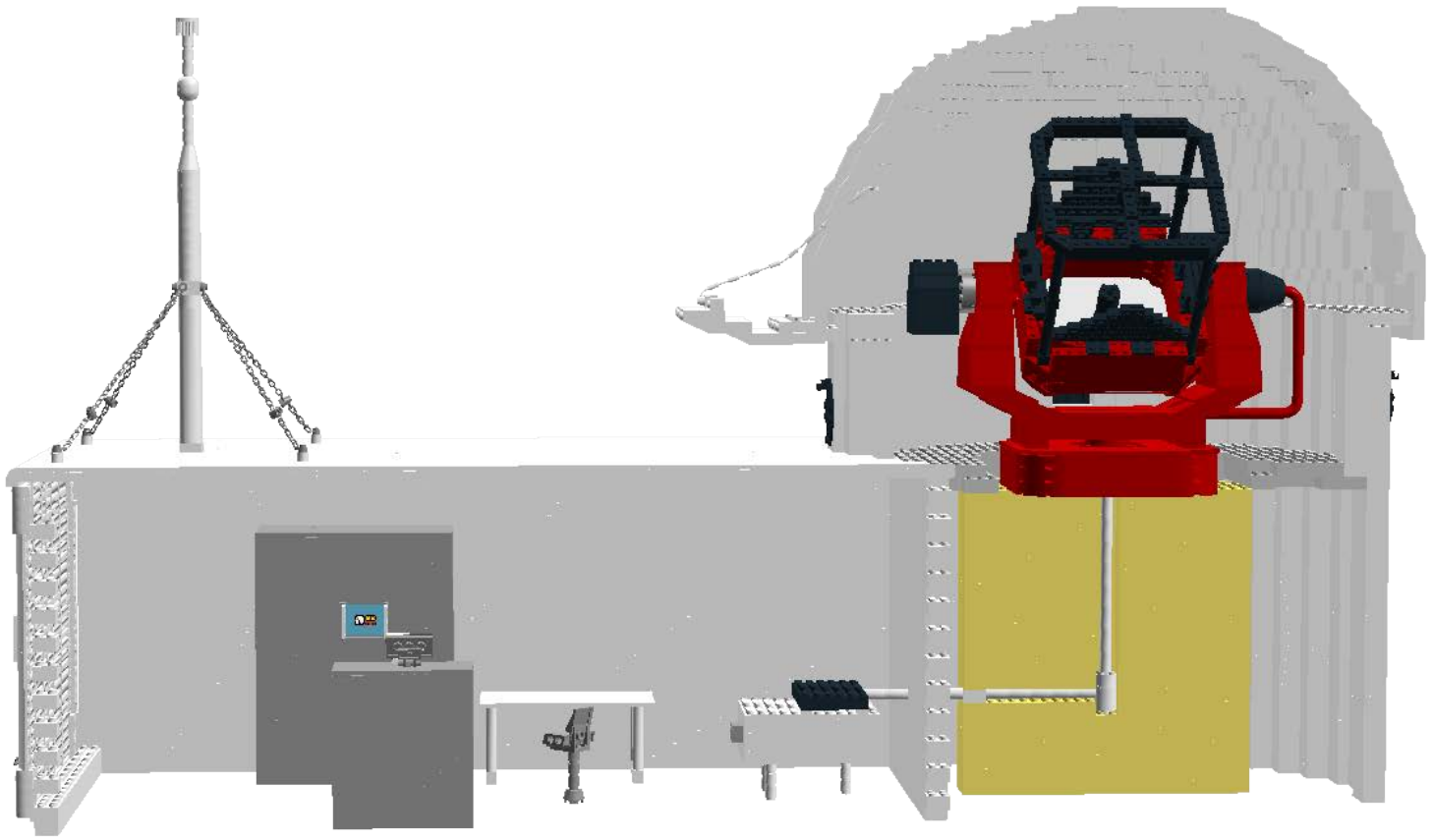
The SONG Team

- Frank Grundahl
- Hans Kjeldsen
- Mads Fredslund Andersen
- Søren Frandsen
- Vichi Antoci
- Rasmus Handberg
- Uffe Gråe Jørgensen
- Pere Palle
- Licai Deng
- ……

SONG webcam 2 19:49:47 2016/06/07


SONG webcam 2 19:49:47 2016/06/07
Potential target star
Telescope
Spectrograph
Weather station

How to build a SONG site



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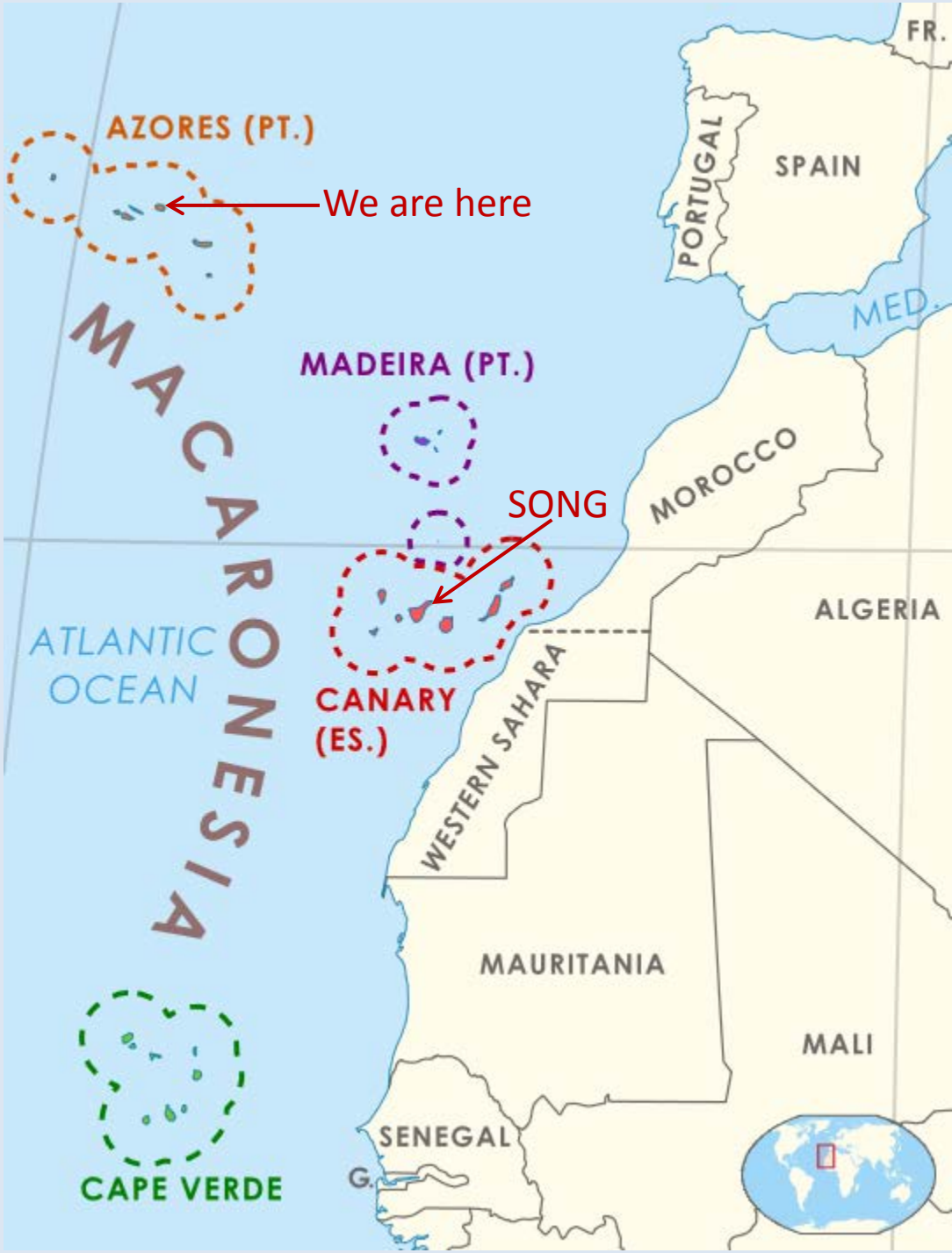
See poster PA.S2.6

Macaronesia



Punta del Hidalgo
Taganana
Anaga
Tegueste
San Andrés
TF-5
Tacoronte
Santa Cruz de Tenerife
Puerto de la Cruz
La Orotava
Buenavista del Nte.
Icod de los Vinos
Candelaria
Güímar
Masca
Las Cañadas del Teide
Tenerife
Pico del Teide
Parque Natural Corona Forestal
Acantilados de los Gigantes
TF-1
Porís de Abona
Abades
Adeje
Granadilla
Costa Adeje
TF-1
Los Cristianos
El Médano
Las Galletas

Lomas
TF-24
Arafo
La Hidalga
TF-1
TF-24
Güímar
Samarines
Teide Observatory
Las Cañadas
del Teide
Puertito
de Güímar
TF-28
Lomo
de Mena
Punta Prieta
El Escobonal
Zoom

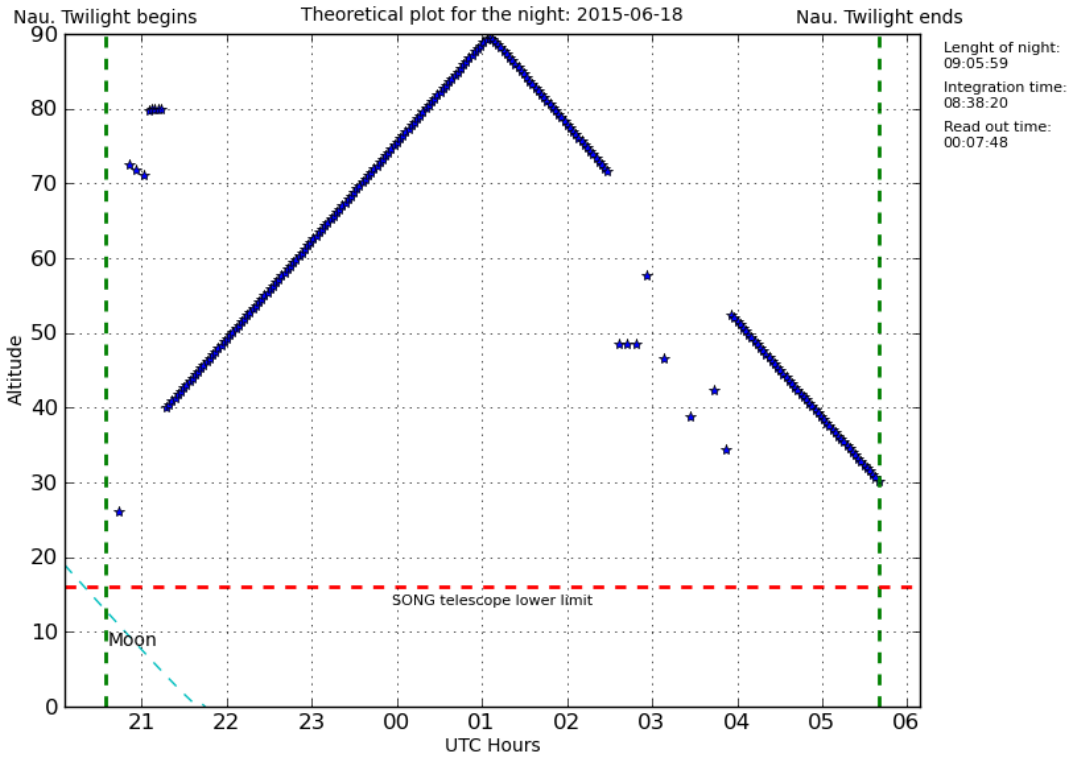
Inauguration, 25 October 2014

Inauguration, 25 October 2014

The Hertzsprung SONG Telescope

Robotic operations

Scheduled observations



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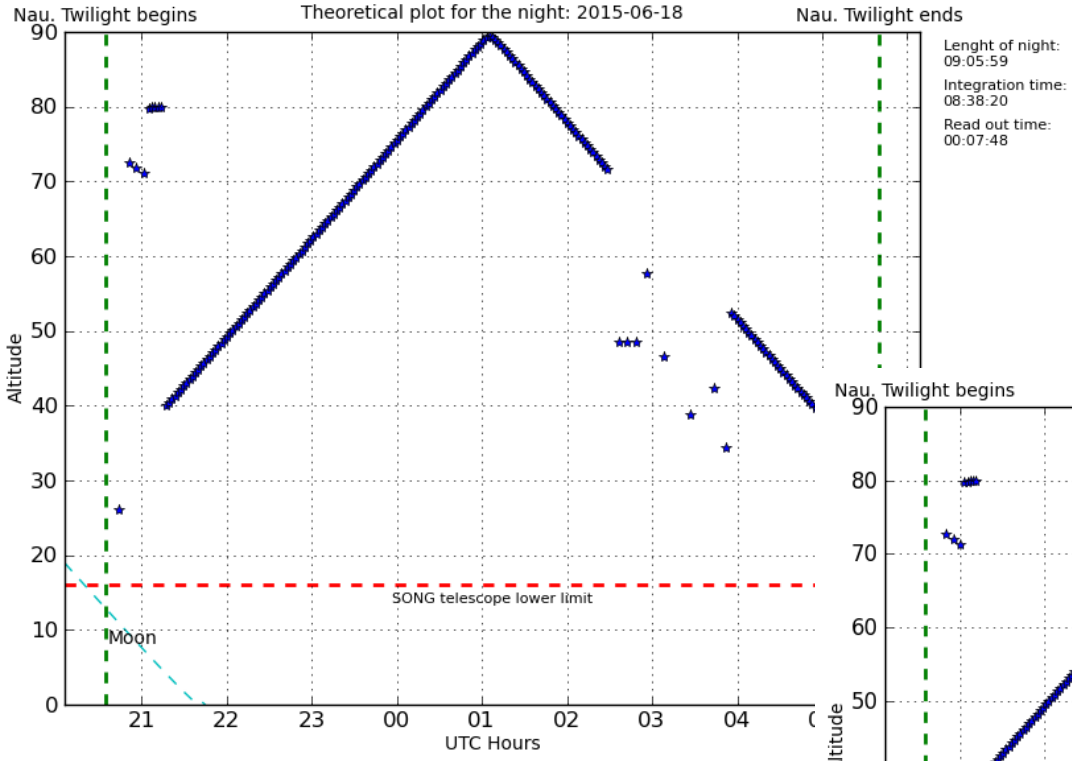
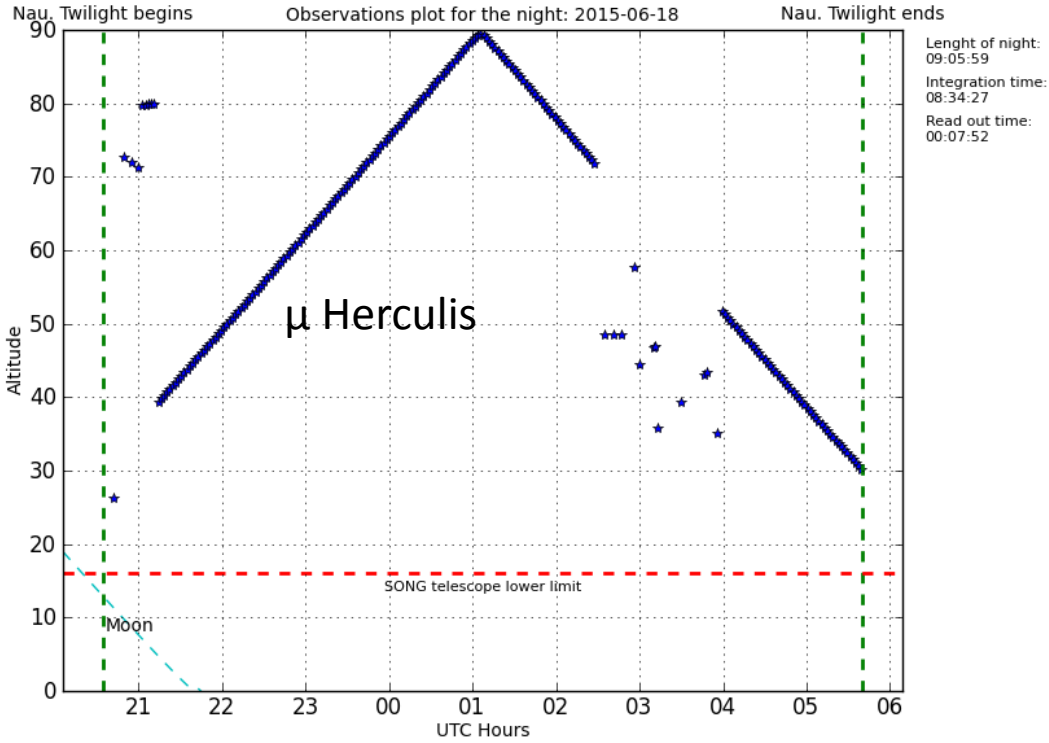
Robotic operations

Scheduled observations



Achieved observations



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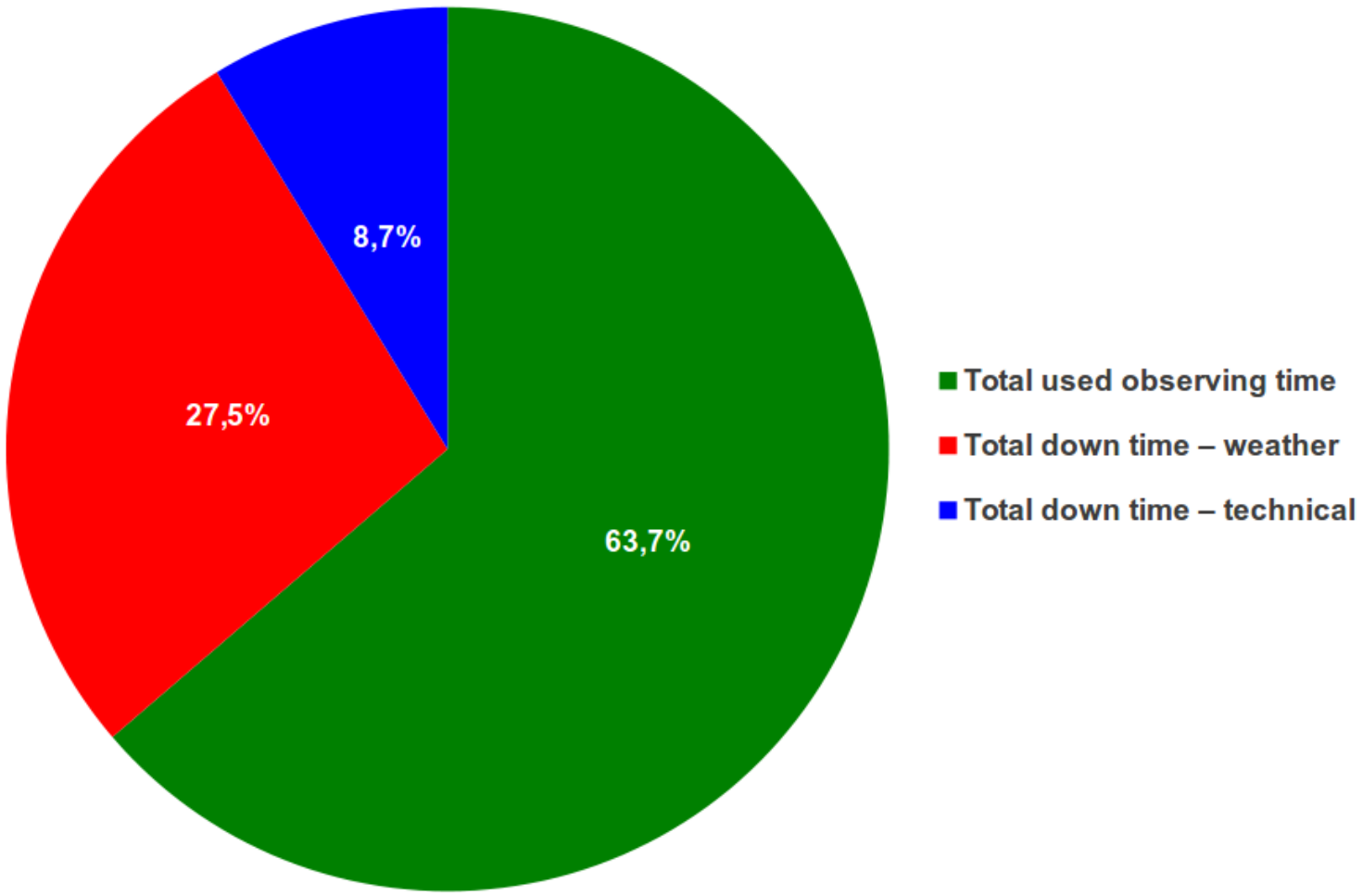
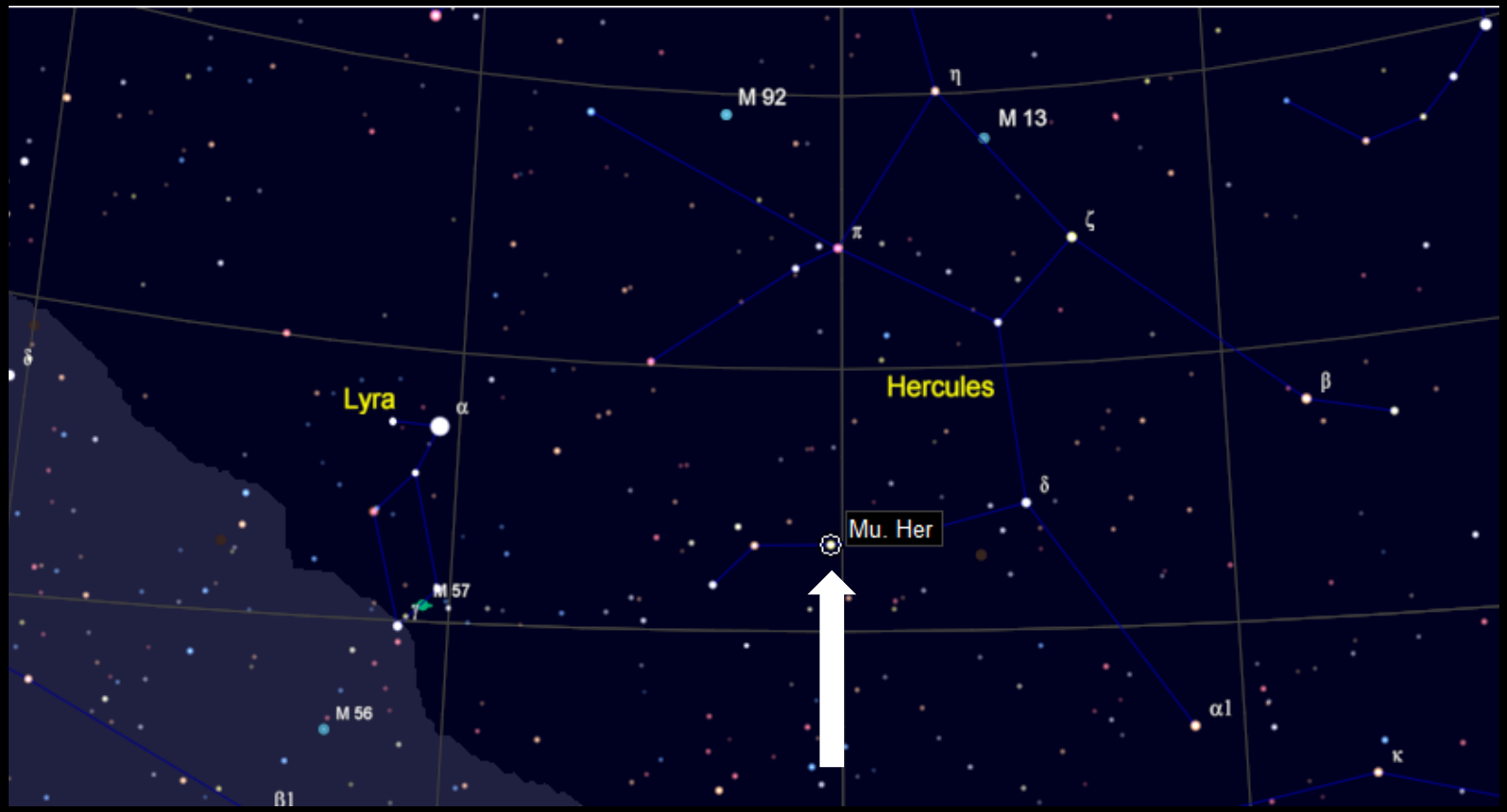
Operation statistics, 2014 - 2016



μ Herculis



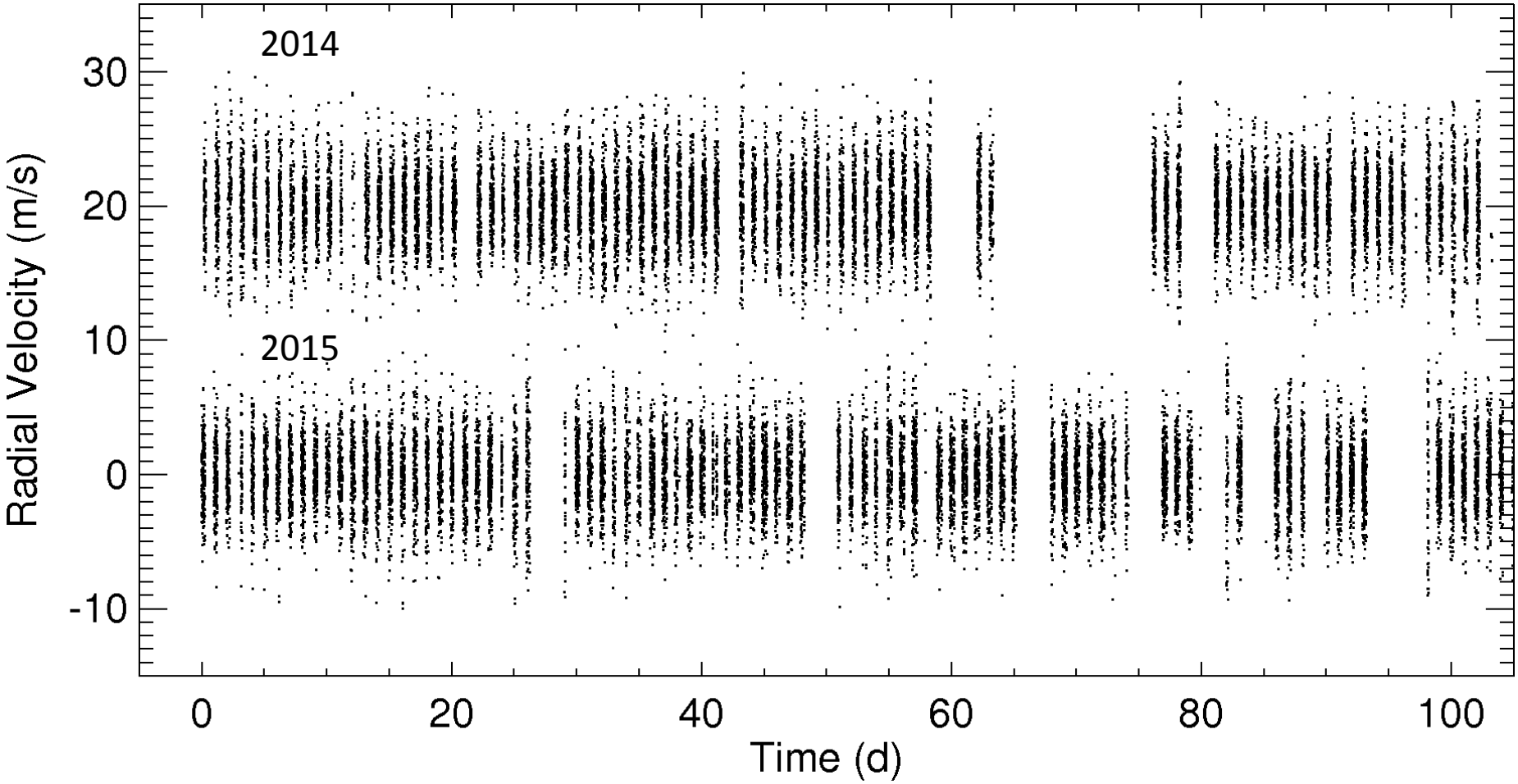
V = 3.42

Binary binary

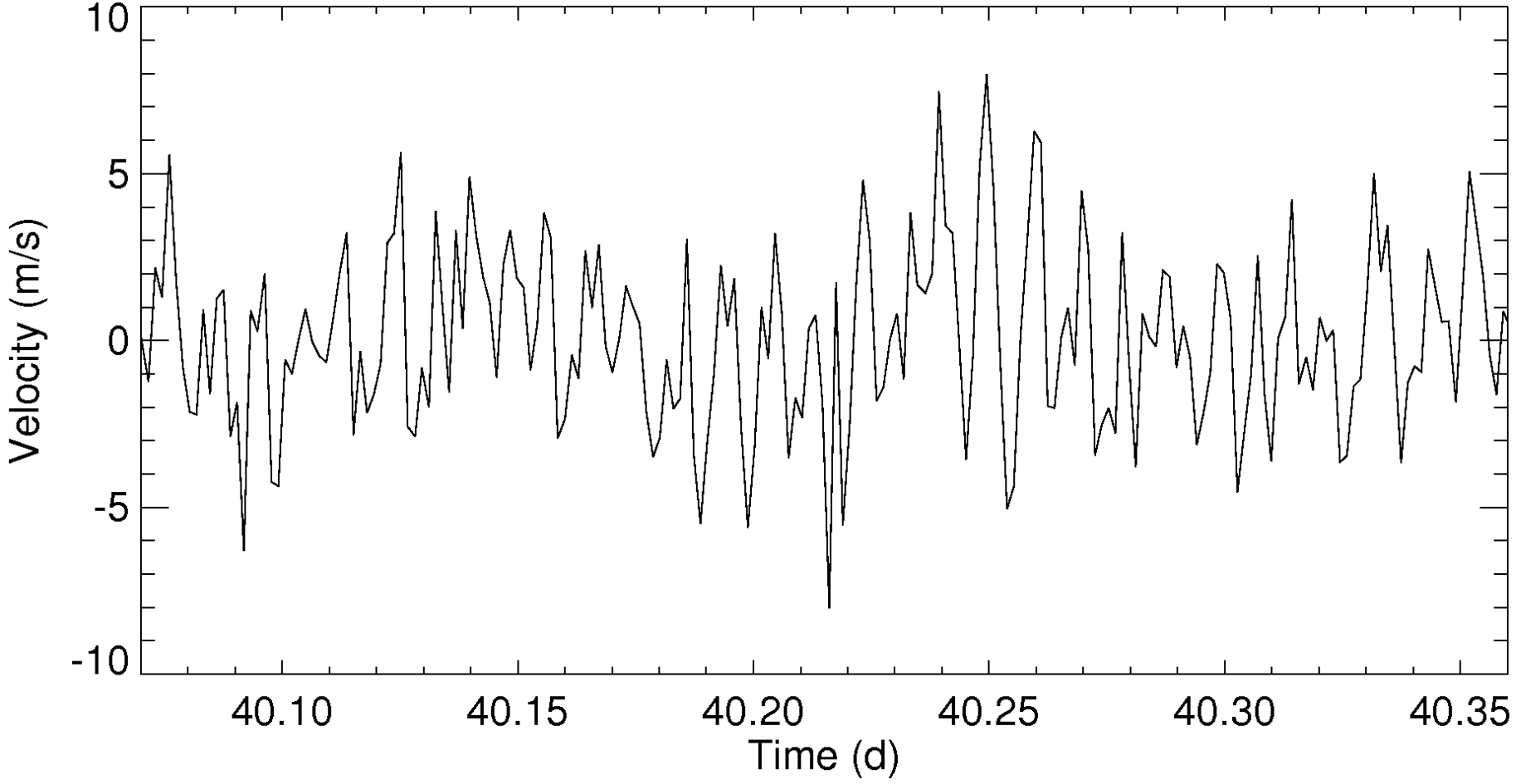
‘Classical’ parameters

Parameter	Value	Adopted errorbar
$T_{\rm eff}$(K)	5562	80
$[Fe/H]$	0.28	0.07
log$g$	3.98	0.1
$vsin\,i$	1.73	0.43
Parallax (mas)	120.33	0.16
$\theta_{\rm LD}$(mas)	1.96	0.03
$R/R_{\odot}$	1.75	0.02
$L/L_{\odot}$	2.64	0.06
M_V	3.82	0.03
M_{Bol}	3.73	0.03
Radial velocity	-17.07	0.12

μ Herculis observations

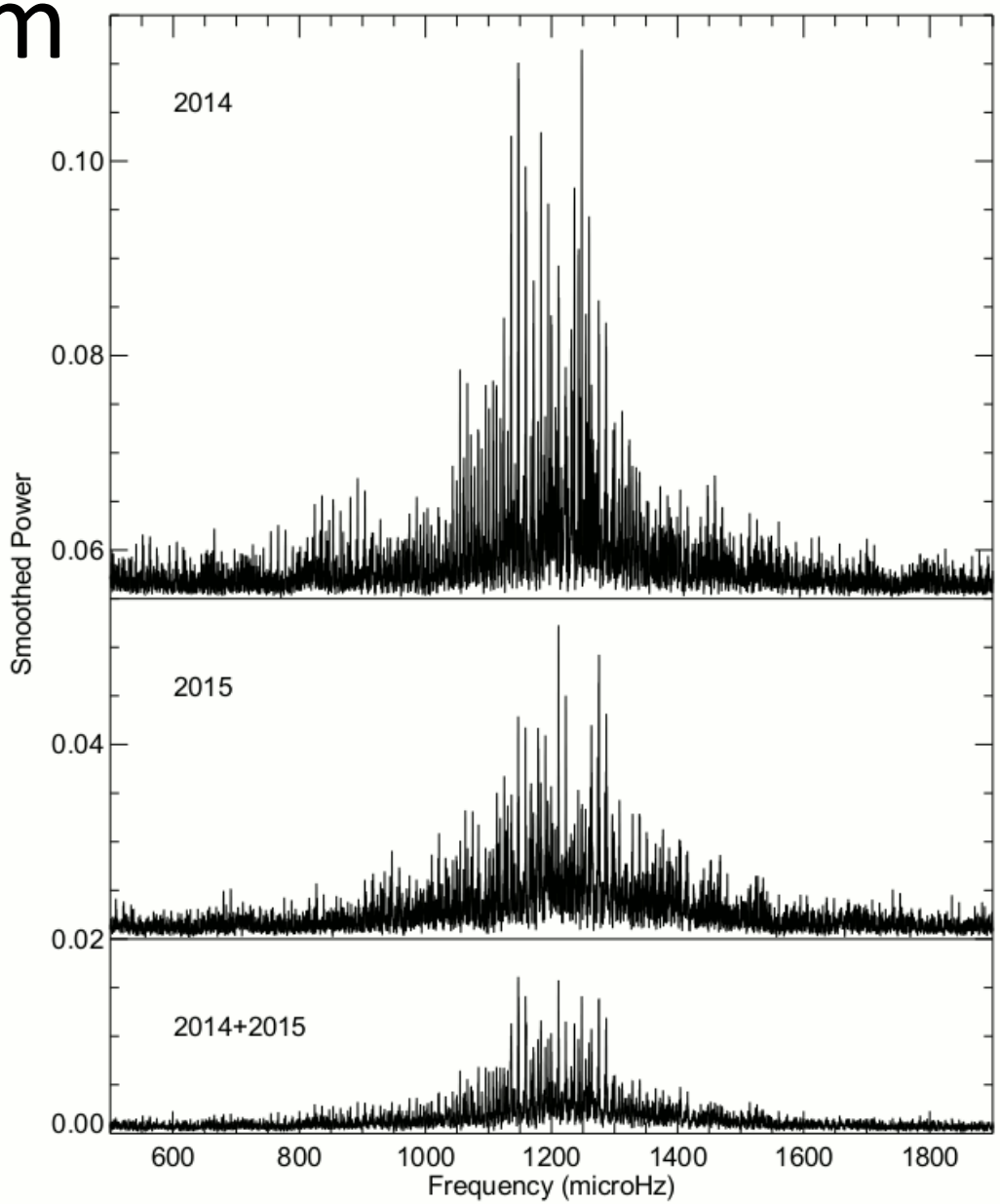


μ Herculis observations

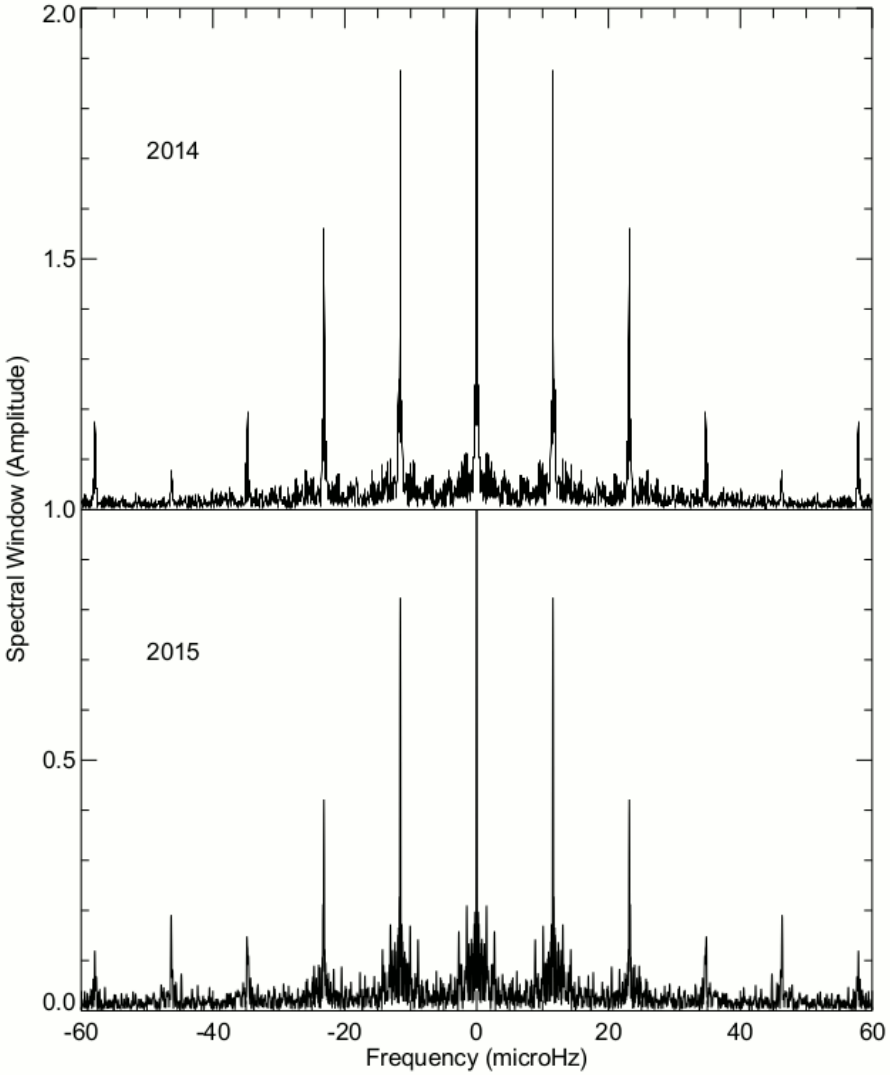


Power spectrum

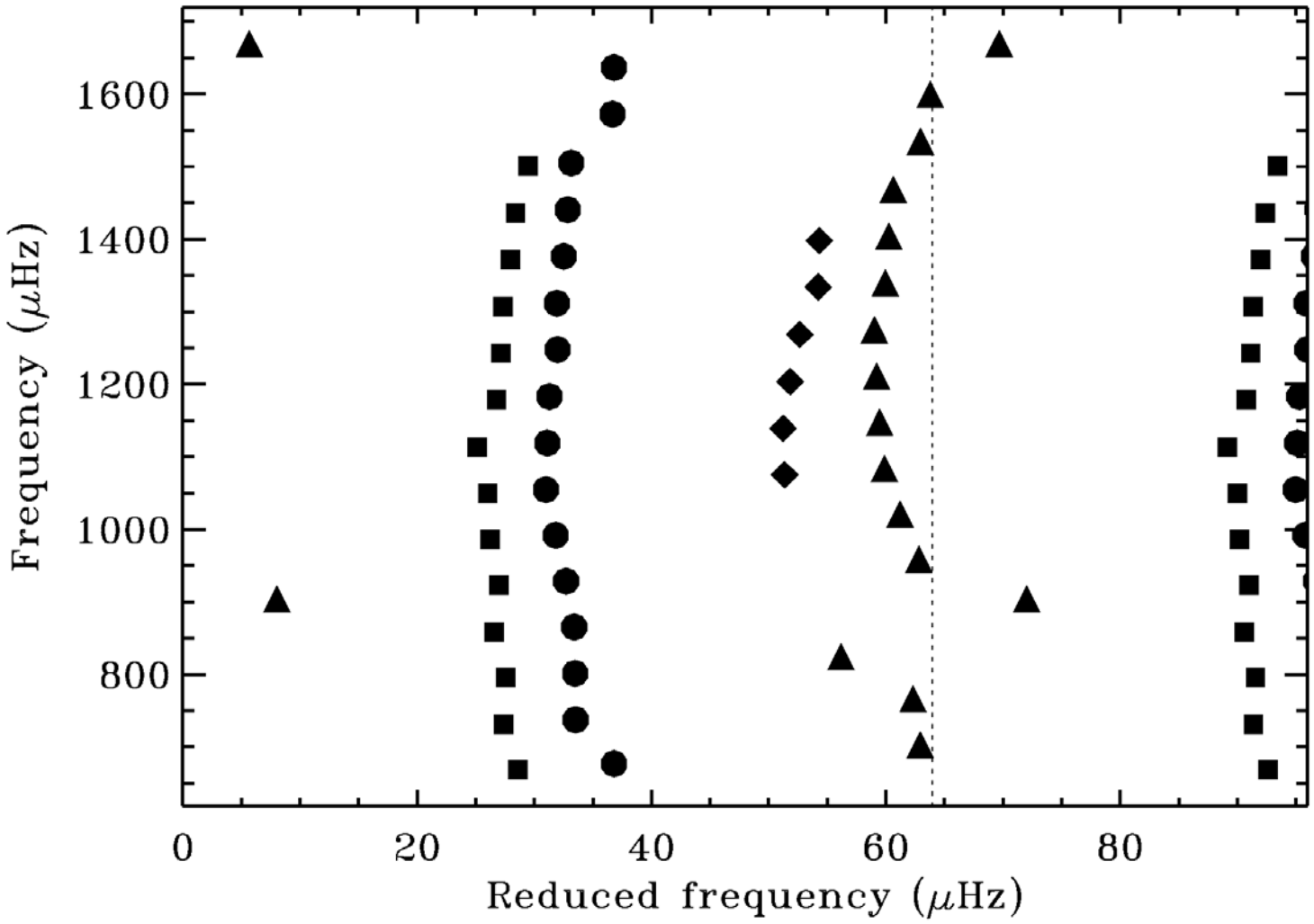
$\Delta \nu$ = 64.0 μHz



Window function



Observed échelle diagram



Fitting procedure

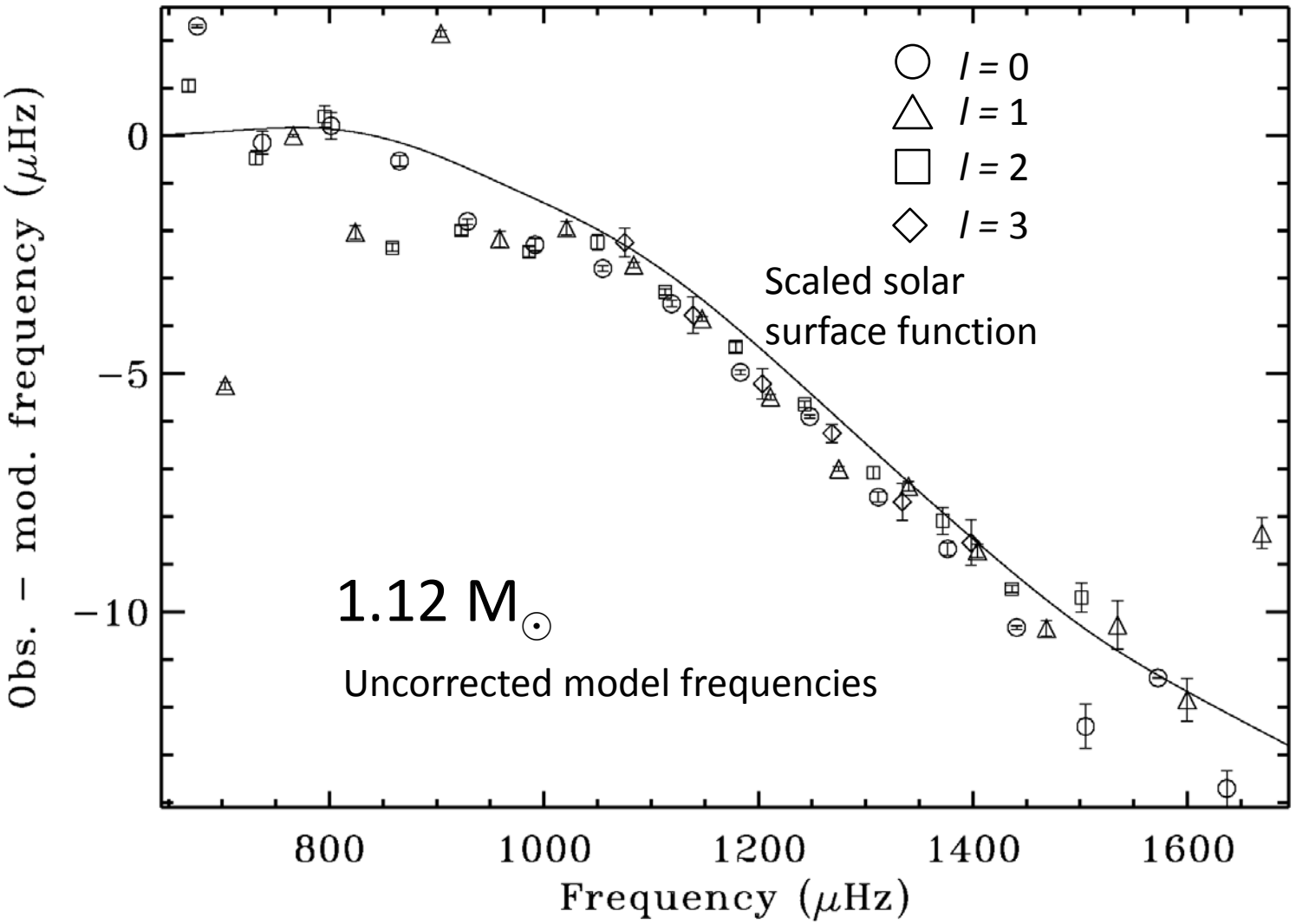
- Grid: M = 1.0(0.01)1.25 $M_\odot$,
  Z = 0.012 – 0.042, Δ Y/Δ Z $\simeq$ 1.4
- Minimize $\chi^2 = \chi^2_{\rm spec} + \chi^2_\nu$

$$\chi^2_{\rm spec} = \left(\frac{T_{\rm eff}^{\rm (obs)} - T_{\rm eff}^{\rm (mod)}}{\sigma(T_{\rm eff})} \right)^2 + \left(\frac{[{\rm Fe/H}]^{\rm (obs)} - [{\rm Fe/H}]^{\rm (mod)}}{\sigma([{\rm Fe/H}])} \right)^2$$

$$\chi^2_\nu = \frac{1}{N-1} \sum_{i=1}^{N} \left(\frac{\nu_i^{\rm (obs)} - \nu_i^{\rm (mod)}}{\sigma(\nu_i)} \right)^2$$

- Scaled solar surface term

Fit to observed frequencies

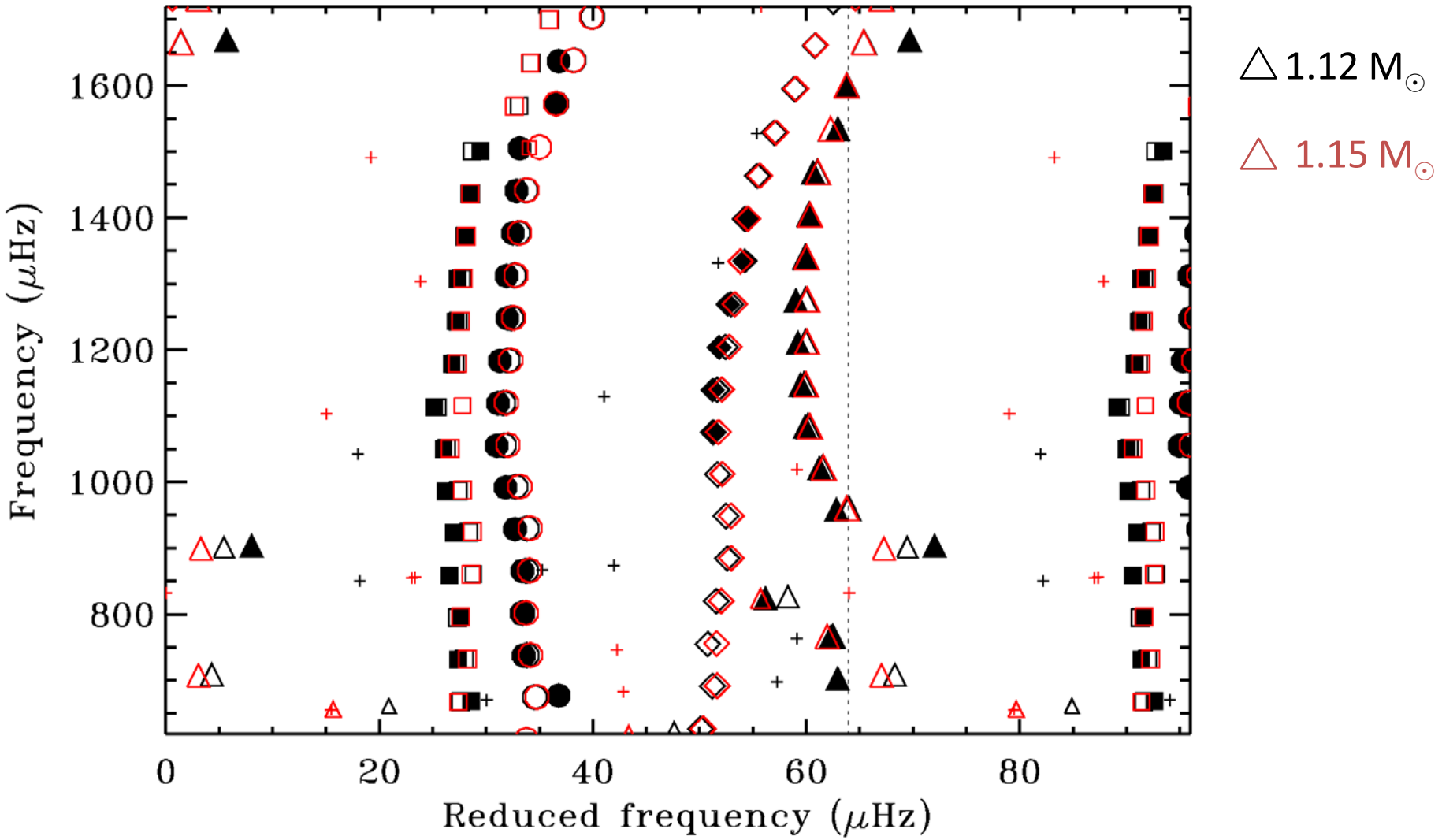


Results of fits

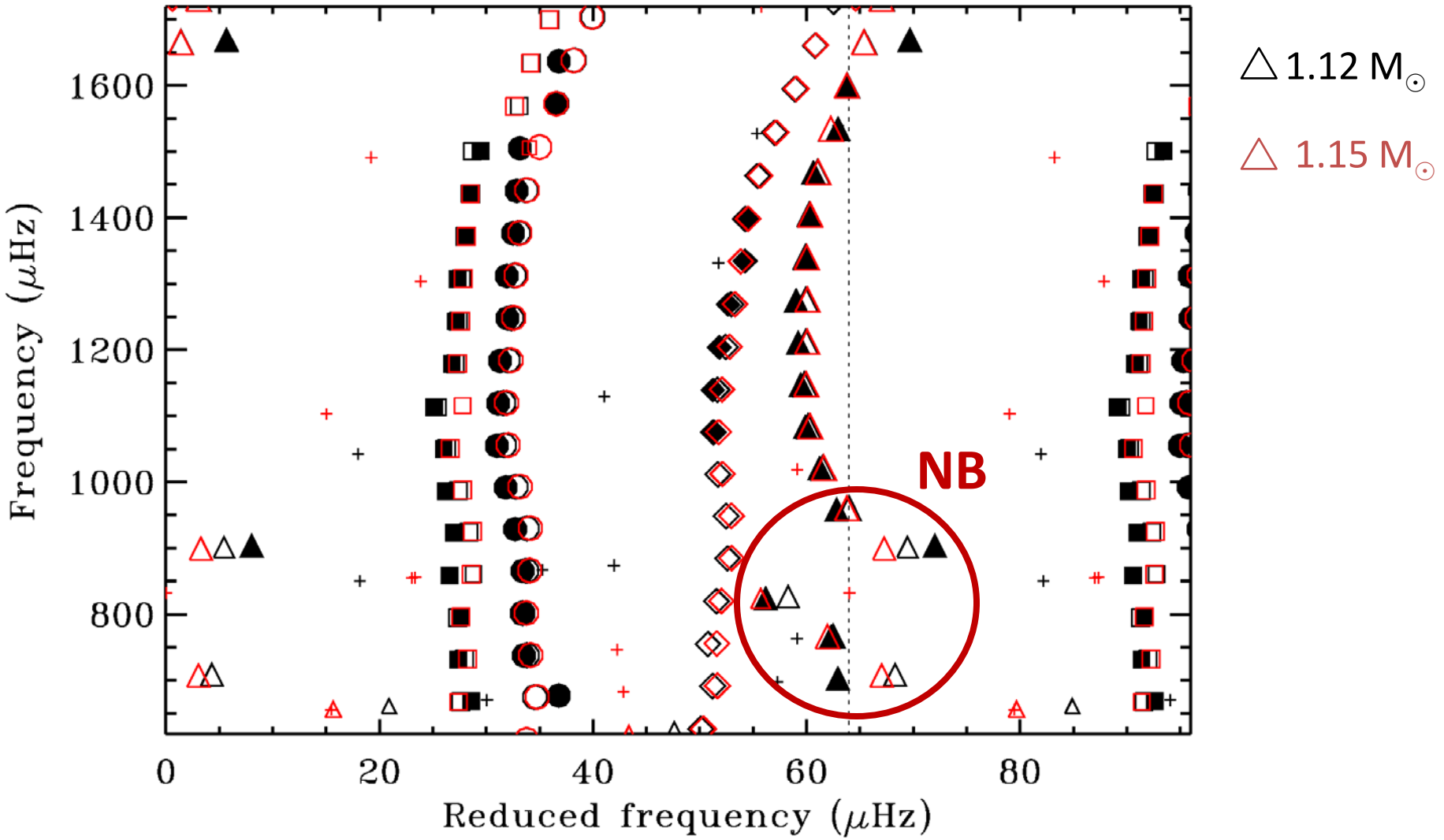
Model	$M/\,\mathrm{M}_\odot$	$R/\,\mathrm{R}_\odot$	$L/\,\mathrm{L}_\odot$	$T_{\rm eff}$ (K)	[Fe/H]	Age (Gyr)
ASTFIT1	1.12	1.712	2.679	5649	0.255	7.63
ASTFIT2	1.15	1.727	2.620	5592	0.296	7.86
BASTA*	$1.11^{+0.01}_{-0.01}$	$1.710^{+0.012}_{-0.015}$	$2.595^{+0.104}_{-0.140}$	5601^{+52}_{-52}	$0.208^{+0.056}_{-0.056}$	$7.79^{+0.34}_{-0.37}$
Obs.		1.727 ± 0.024	2.54 ± 0.08	5562 ± 80	0.28 ± 0.07	

* Only acoustic modes

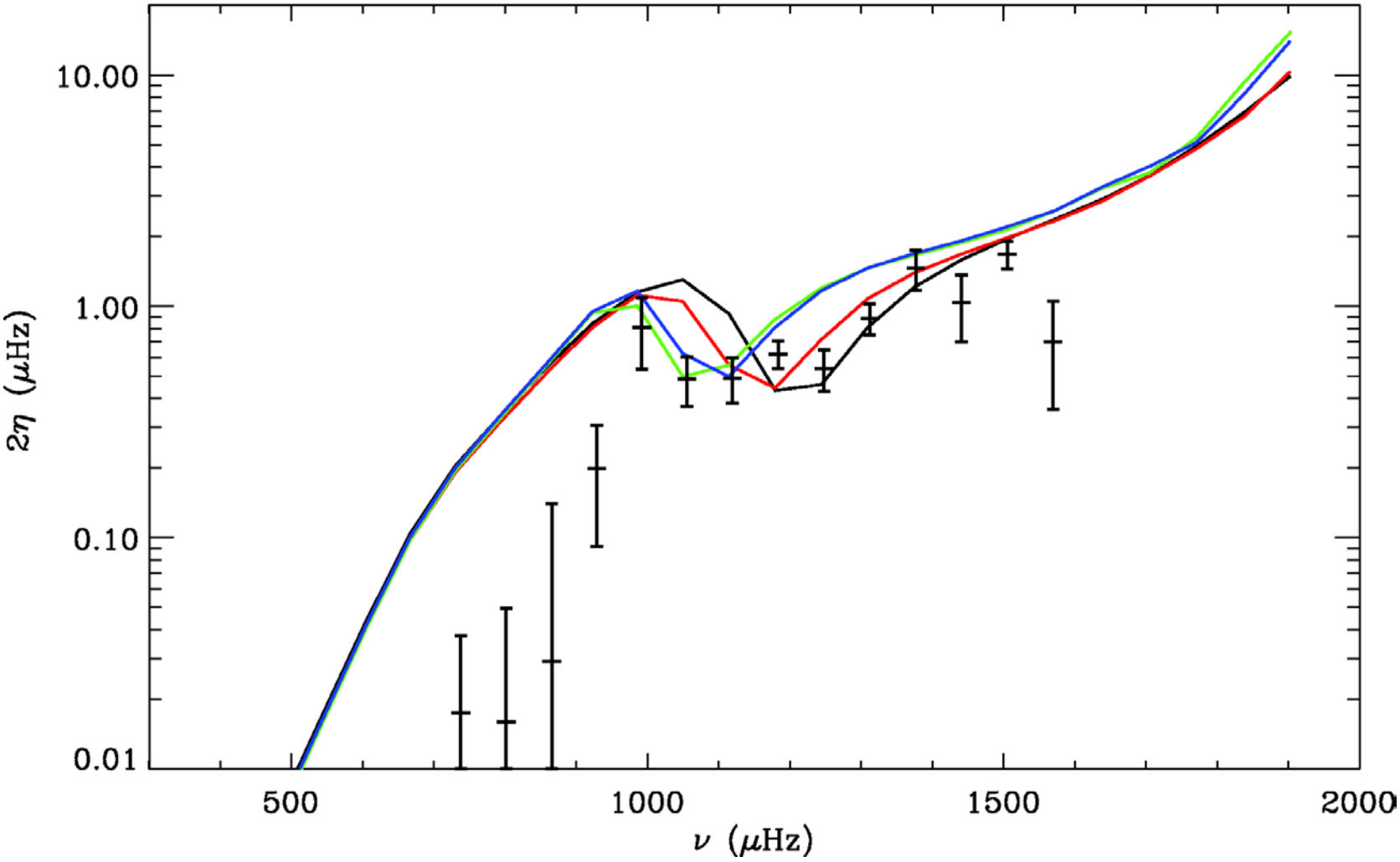
‘Well-fitting’ models



‘Well-fitting’ models

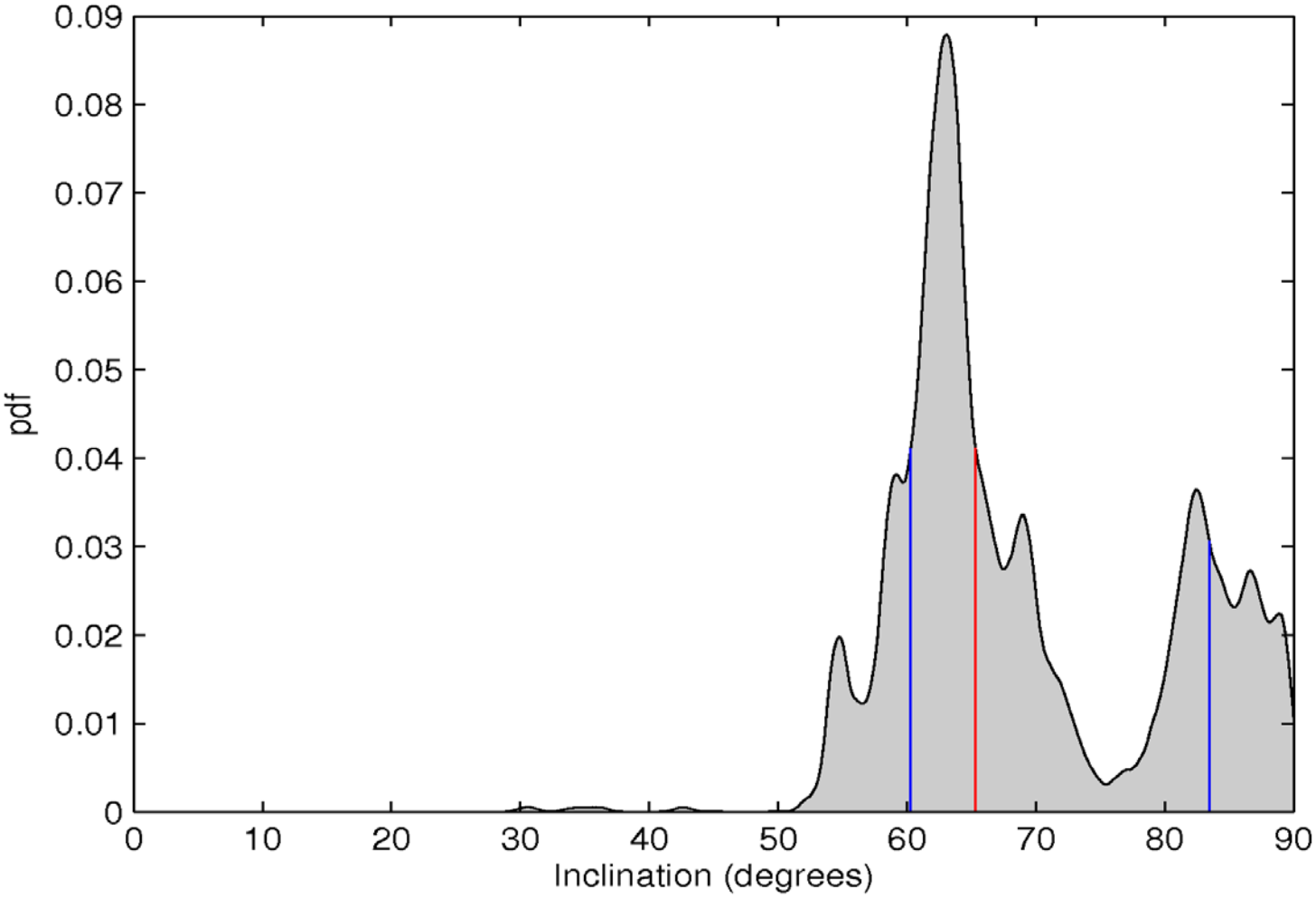


Observed and modelled linewidths



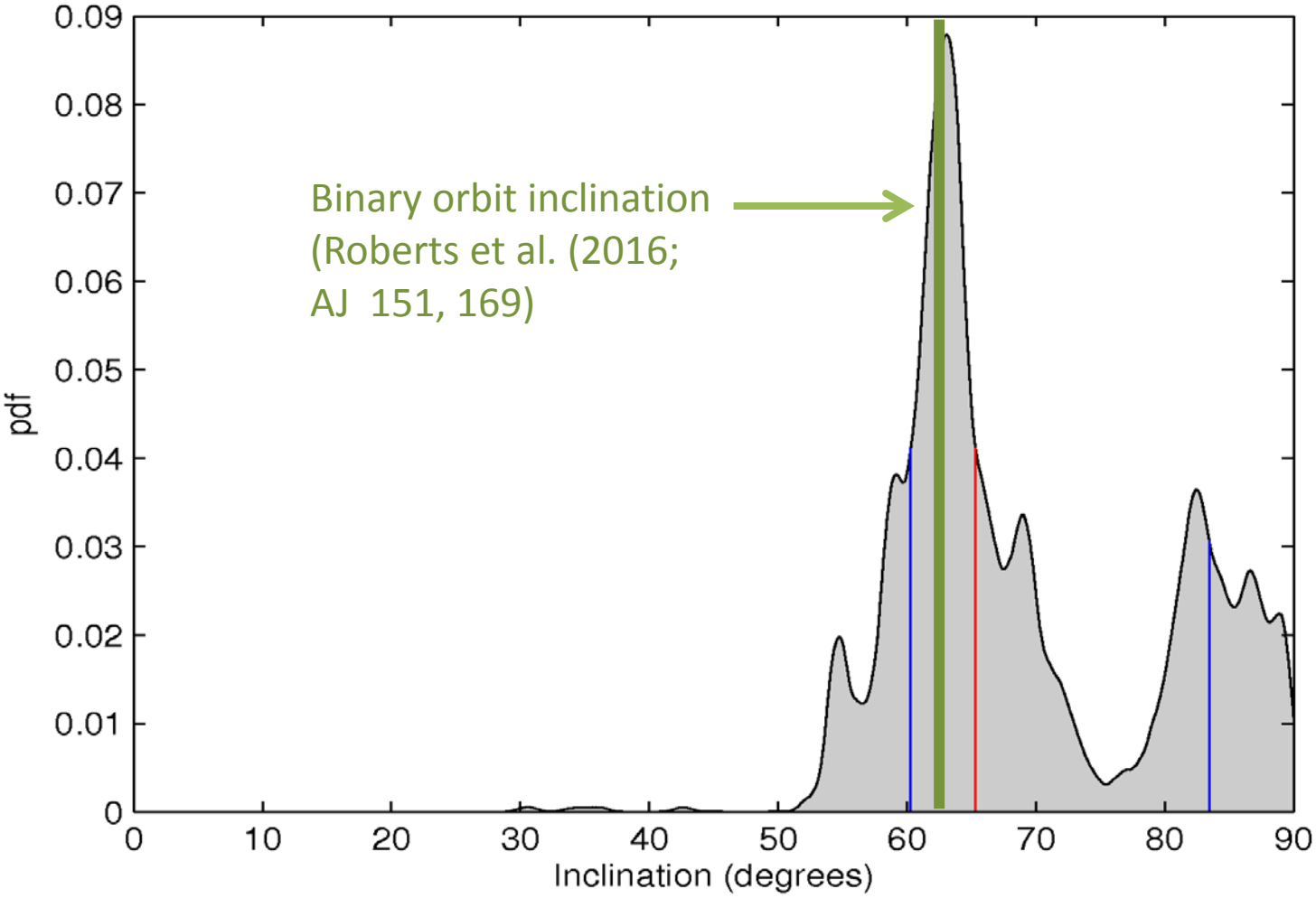
Modelling: Günter Houdek

Inclination of rotation axis



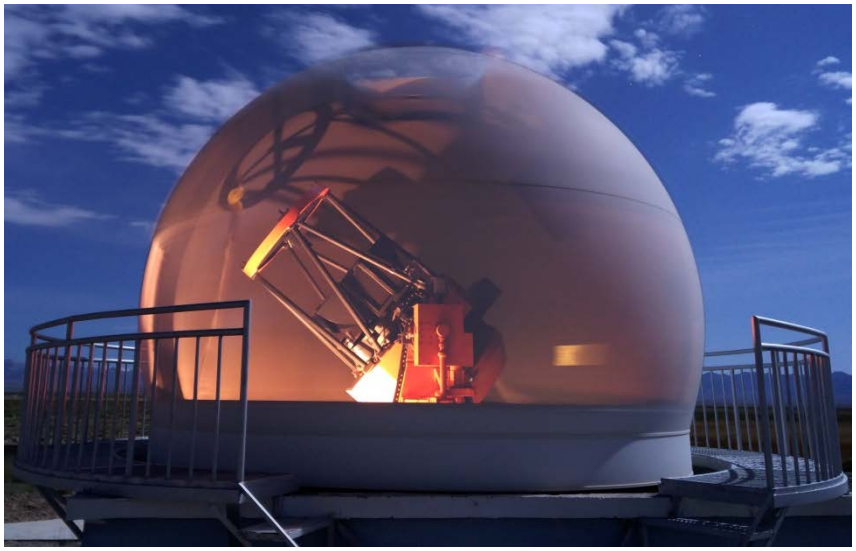
MCMC analysis: Rasmus Handberg

Inclination of rotation axis



What is next?

- Another 100 nights with μ Herculis
- Chinese node becoming operational



- SONG node no 3, 4, …. **Who is next!**