On the age determination of the open cluster α *Per* using asteroseismology

With MultiModes: an efficient tool for a massive analysis of pulsating stars

Coauthors: Antonio García Hernández, Juan Carlos Suárez, Javier Pascual Granado, Sebastià Barceló Forteza, José Ramón Rodón

Contribución de la UGR a la misión espacial PLATO 2.0. Fases C/D-1

Ayuda: PID2019-107061GB-C64. Financiado por:

David Pamos Ortega - University of Granada -

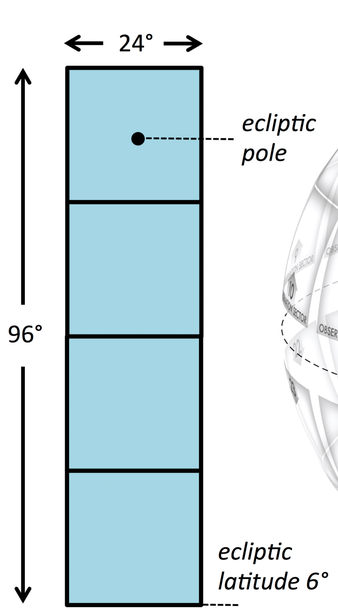
The content:

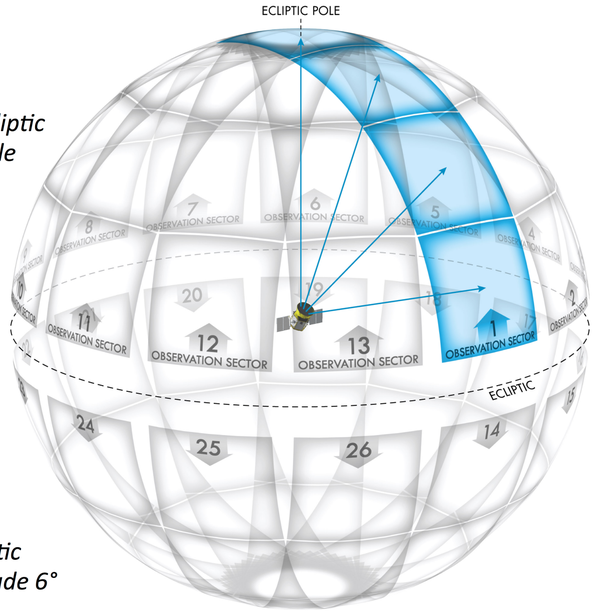
1. Space Missions: A huge amount of data about variability of stars
2. **MultiModes (MM)**: An efficient tool for a massive analysis of pulsating stars
3. Let's test it: On the age of the open cluster **Melotte 20 (α Per)**

1. Space Missions: A huge amount of data about variability of stars

Billions of targets to be analyzed!!

TESS Mission: 80% of the nearby entire sky (~200 ly)





~ 470 M of TIC objects

David Pamos Ortega - University of Granada -

2. MultiModes (MM): An efficient pipeline for a massive analysis of pulsating stars

INPUT

- LIGHT CURVES
- INITIAL PARAMETERS

WORK FLOW

FAST LOMB SCARGLE (Press and Rybicki, 1989)

HIGUEST AMPLITUD PEAK

REAL SIGNAL OR NOISE? (FAP or S/N)

NOISE → FILTER SPURIOUS AND COMBINED FREQUENCIES

SIGNAL

NON LINEAR OPTIMIZATION

REDEFINE MULTISINE FUNCTION

SIMULTANEOUS FIT OF 20 PEAKS

EXTRACTION AND RESIDUAL

OUTPUT

- PERIODOGRAMS
- RESIDUALS
- EXTRACTED PEAKS

With a little help from my friends:

SciPy

The Astropy Project

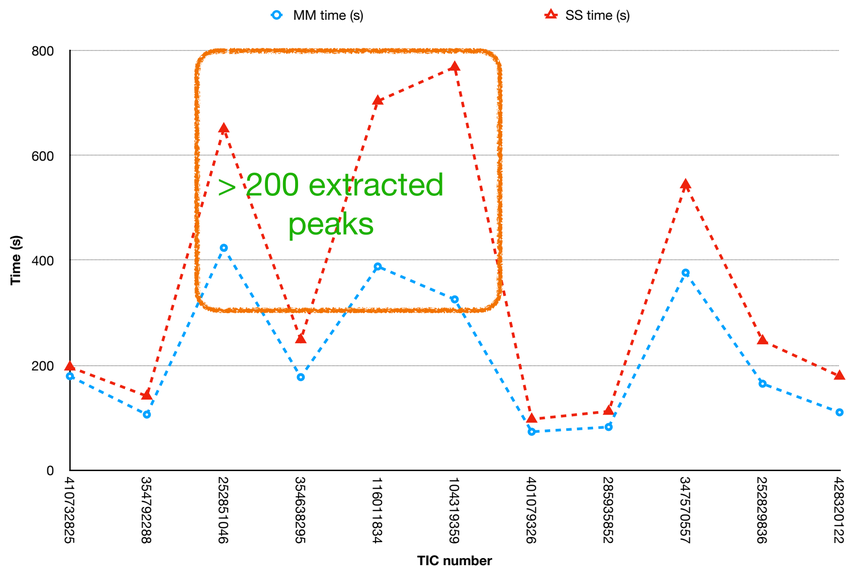
LMFIT

David Pamos Ortega - University of Granada -

MultiModes vs SigSpec (Reegen 2007)

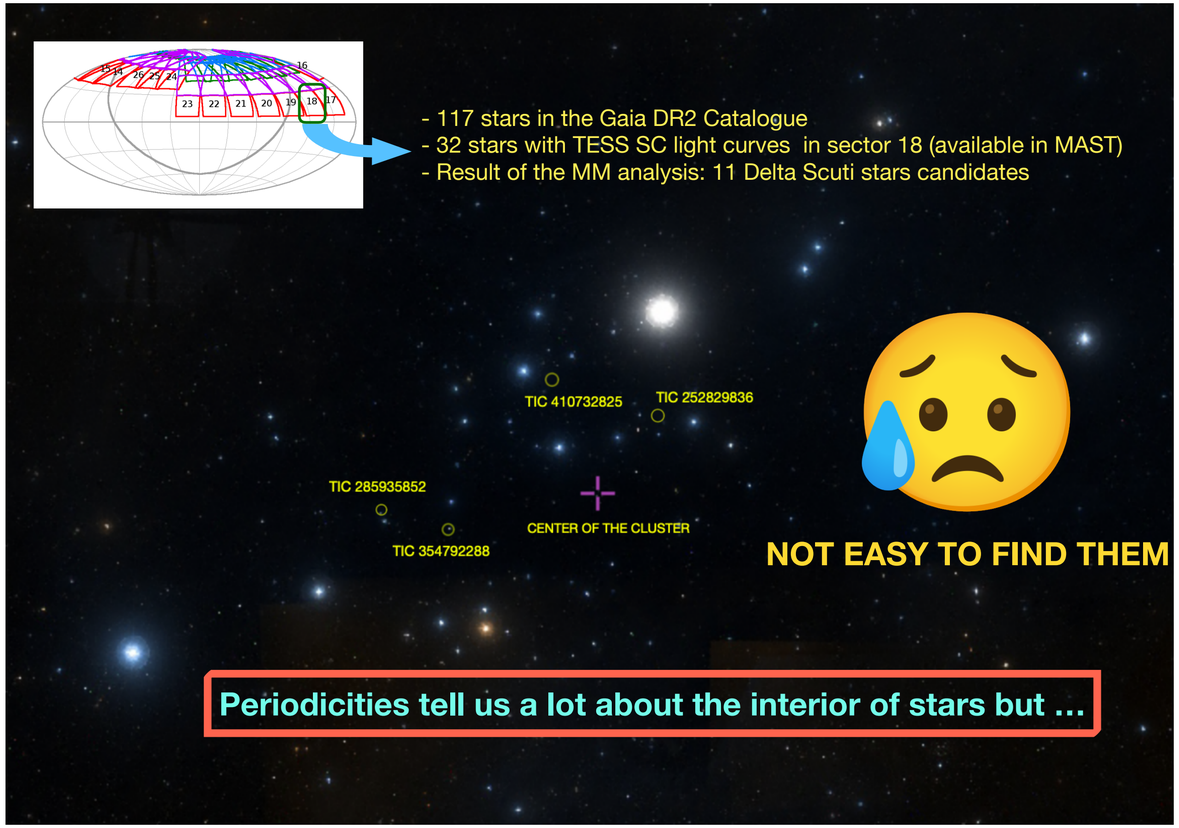
MM vs SS

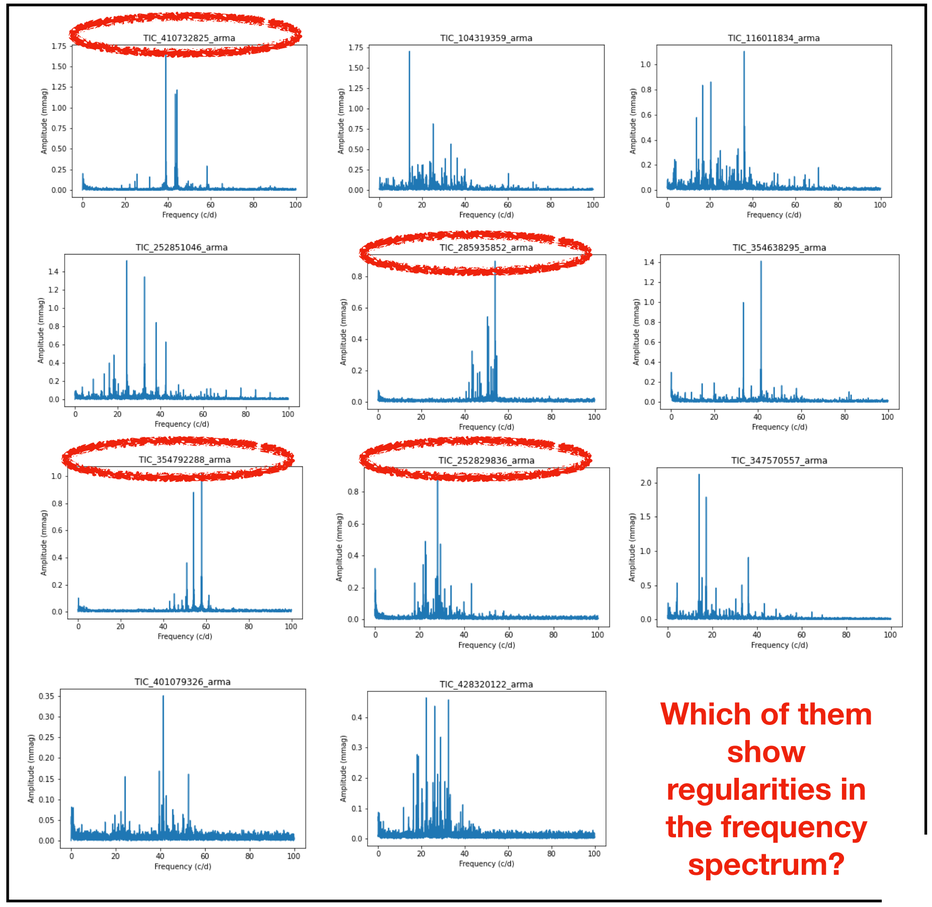
TIC	MM time (s)	SS time (s)	% MM_SS Coincidence
410732825	179,15	196,57	100
354792288	105,90	141,10	100
252851046	423,98	650,87	93,7
354638295	177,29	248,61	98,9
116011834	388,39	703,75	97,7
104319359	325,62	768,53	97,9
401079326	73,11	97,09	100
285935852	82,18	112,06	97,5
347570557	376,65	544,17	94,7
252829836	164,73	246,55	97,4
428320122	110,17	179,06	100
TOTAL	2407,17	3888,36	-



David Pamos Ortega - University of Granada -

3. Let's prove it: On the age of the open cluster alpha Per

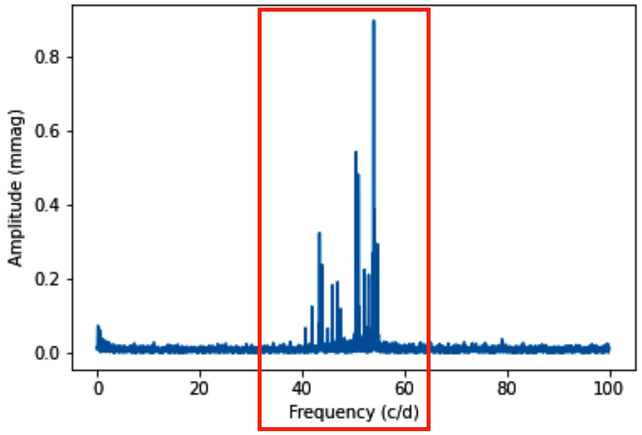




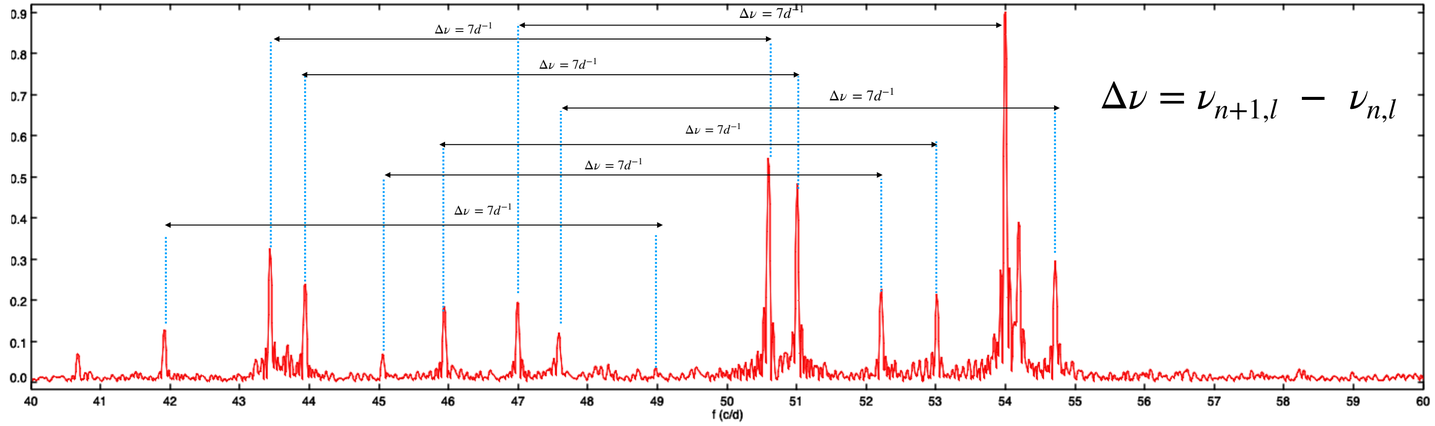
αPer : d < 200 pc and t < 200 Myr (Lodieu et al. 2019)

David Pamos Ortega - University of Granada -

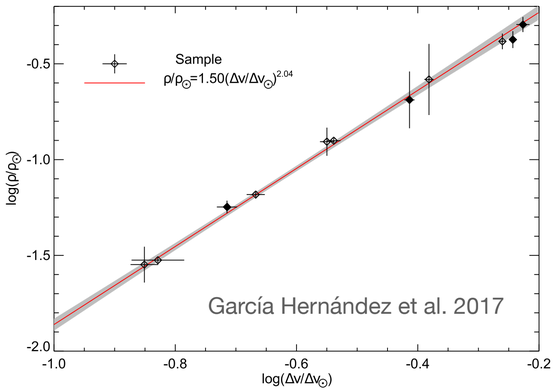
TIC 285935852



EVIDENCE OF REGULARITIES: THE LARGE SEPARATION



$$\Delta\nu = \nu_{n+1,l} - \nu_{n,l}$$



$$\rho \propto \Delta\nu^2$$

In the asymptotic regime (n >> l) for solar type stars

Aert et al. 2010
García and Ballot 2019

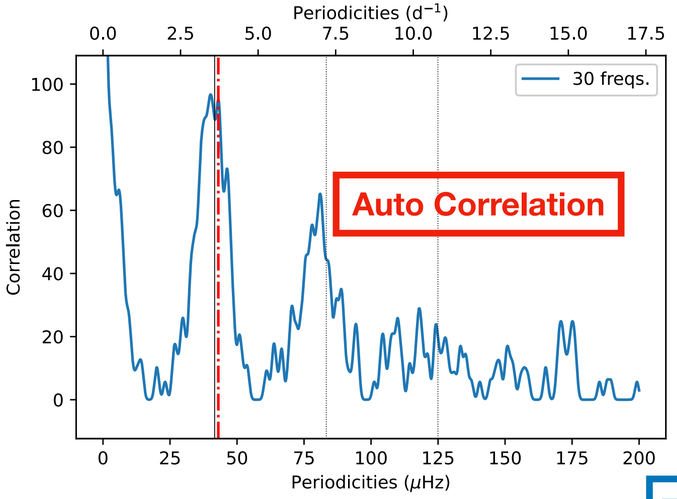
Also in the low radial order regime for Delta Scuti stars

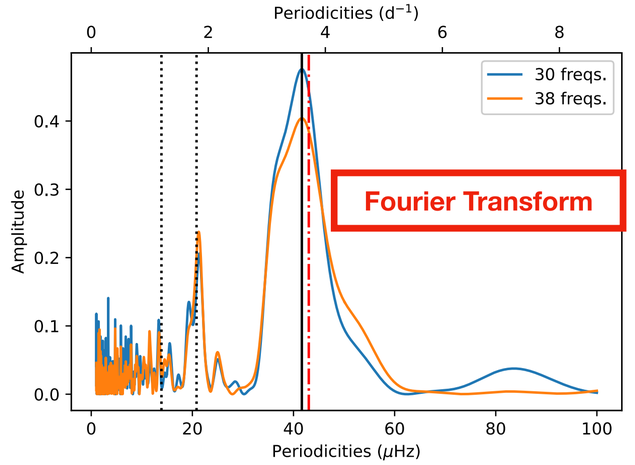
Suárez et al. 2014
García Hernández et al. 2015, 2017

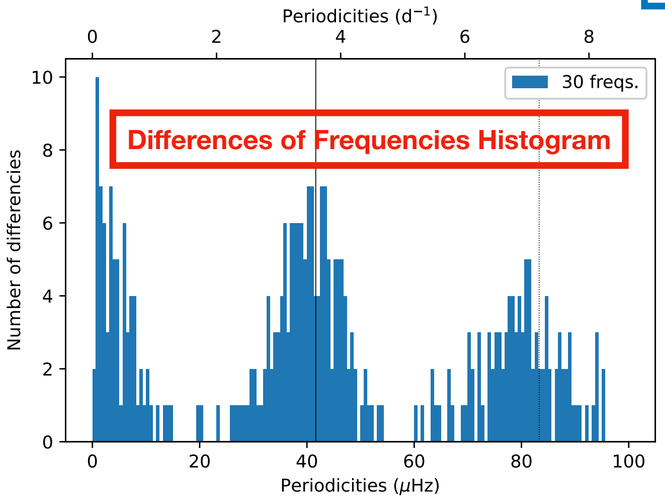
David Pamos Ortega - University of Granada -

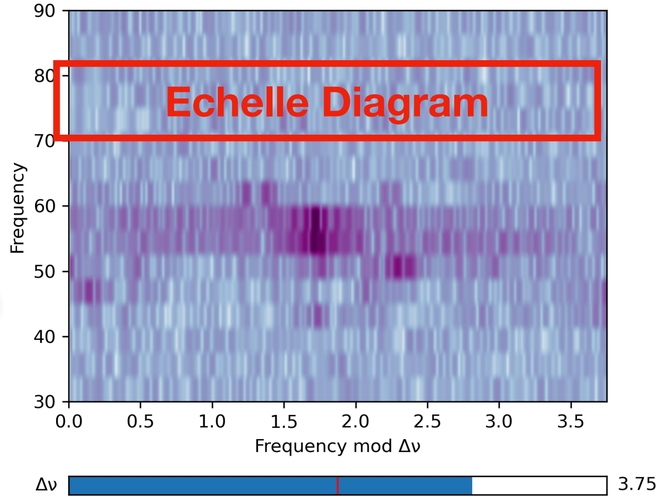
PLATO Mission Conference 2021

Regularities in TIC 354792288







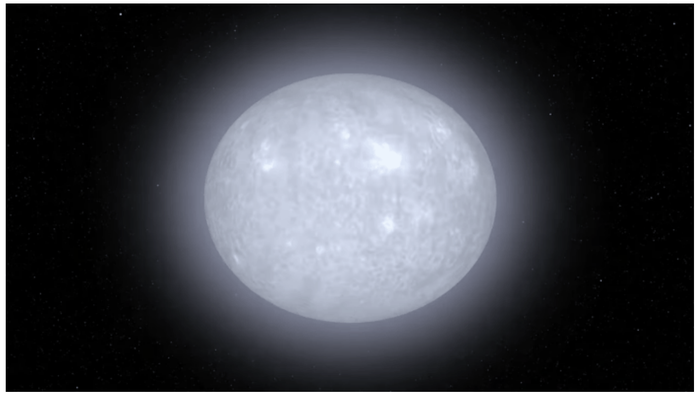


David Pamos Ortega - University of Granada -

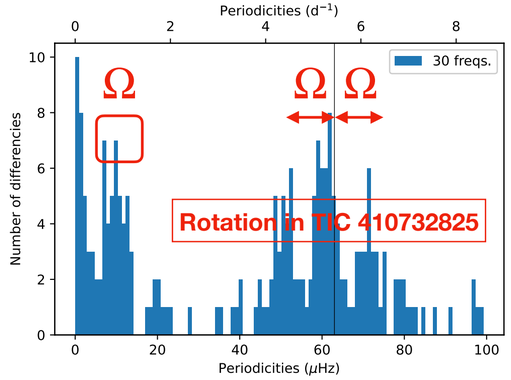
Done with Echelle 1.5.1 - Daniel Hey and Warrick Ball 2020 -

Other seismic indices

Rotation velocity (Ω)

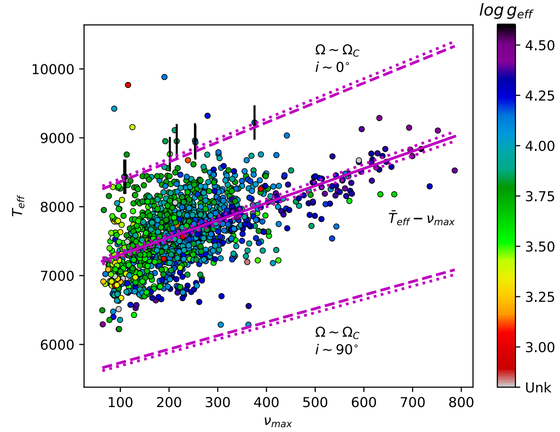


Delta Scuti star
Fuente: NASA's Goddard Space Flight Center



$$\omega_{nlm} = \omega_{nl} + m\Omega$$

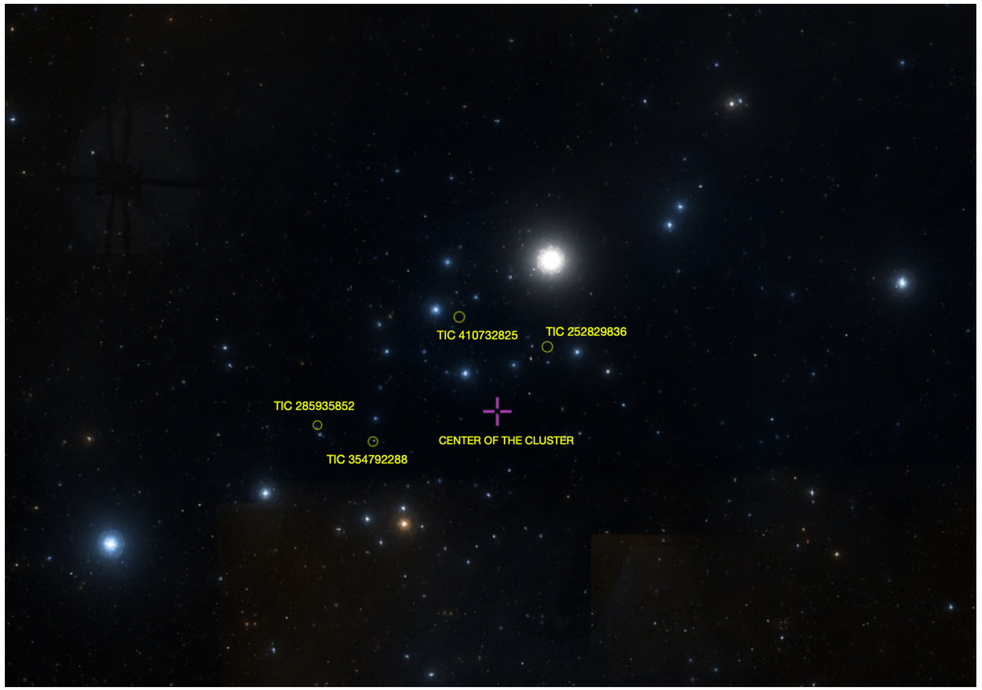
Frequency of maximum amplitude (ν_{max})



$$T_{eff} \propto \nu_{max}$$

Barcelò Forteza et al. 2020
Bowman and Kurtz 2018

Four stars to determine the age of a cluster?



TIC	$\Delta\nu(\mu Hz)$	$\omega(\mu Hz)$	$\nu_{max}(\mu Hz)$
410732825	[62:64]	[9:11]	[517:519]?
354792288	[82:84]	-	[622:624]
285935852	[81:83]	-	[578:580]
252829836	[70:72]	-	[329:331]?

David Pamos Ortega - University of Granada -

The mesh of 1-D rotating models with MESA (Paxton et al. 2019) and FILOU (Suárez and Goupil 2008)

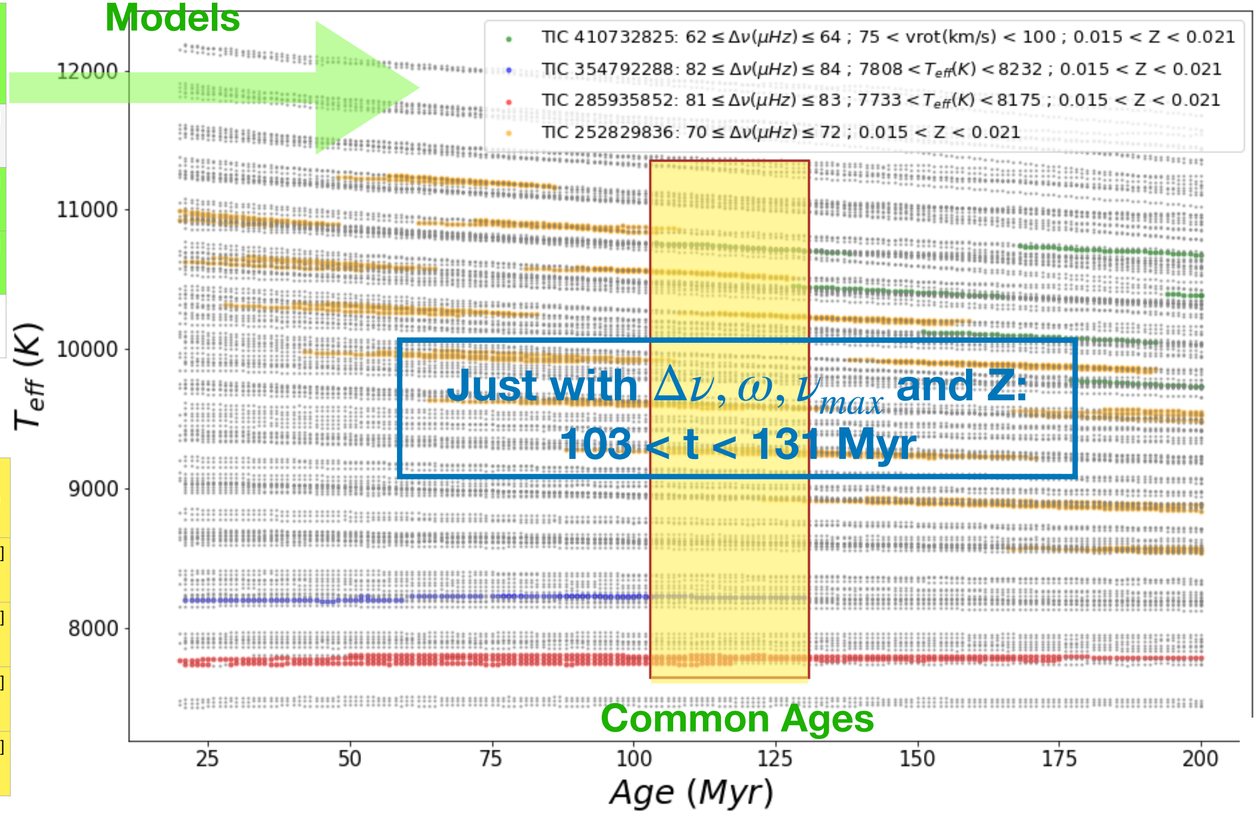
Observed parameters:

TIC	R (R_{sun}) (Stassun+ 2019	log L (Lsun) (Gaia DR2)	Log g	M (M_{sun}) (Stassun+ 2019)	T_{eff} (K) (Stassun+ 2019)	v sin î (km/s) (Kounkel+2019)	$v_{âr}$ (km/s)	Dnu (μHz)	T_{nu_max} (K)
410732825	[1.592:1.686]	1.17	[4.30:4.45]	[1.983:2.651]	[8851:9453]	[71:107]	[75:100]	[62:64]	[7640:8042]
354792288	[1.518:1.624]	0.99	[4.27:4.44]	[1.666:2.370]	[7849:8605]	[107:119]	-	[82:84]	[7808:8282]
285935852	[1.545:1.645]	0.88	[4.20:4.36]	[1.465:2.063]	[7363:7815]	[68:73]	-	[81:83]	[7733:8175]
252829836	[1.617:1.747]	0.83	[4.10:4.27]	[1.313:1.863]	[6994:7272]	[37:39]	-	[70:72]	[7340:7614]

Constrained MESA-FILOU parameters:

TIC	Z_0	R (R_{sun})	Log L (L_{sun})	Log g	M (M_{sun})	T_{eff} (K)	V_{rot} (km/s)	Dnu (μHz)	Age (Myr)
410732825	[0.016:0.020]	[1.95:2.09]	[1.49:1.70]	[4.20:4.24]	[2.3:2.6]	[9731:10759]	[96:99]	[62:64]	[104:200]
354792288	[0.016:0.020]	[1.49:1.50]	[0.95:0.96]	[4.31:4.32]	[1.65:1.75]	[8192:8231]	[70:114]	[82:84]	[21:130]
285935852	[0.016:0.020]	[1.45:1.48]	[0.84:0.86]	[4.30:4.32]	[1.55:1.65]	[7736:7806]	[68:112]	[81:83]	[20:200]
252829836	[0.016:0.020]	[1.68:1.94]	[1.13:1.71]	[4.24:4.30]	[1.9:2.6]	[8541:11248]	[69:126]	[70:72]	[103:131]

Constrained Models



David Pamos Ortega - University of Granada -

CONCLUSIONS:

1. **MultiModes** is an **efficient** tool, in terms of computing time, for **massive analysis of pulsating stars**.
2. MultiModes has been tested with a sample of 32 stars from the field of **alpha Per**, with a result of **11 Delta Scuti stars**.
3. We have obtained the seismic index **large separation** in four of them: **TIC 410732825; TIC 354792288; TIC 285935852 and TIC 252829836**.
4. One of these four stars, **TIC 410732825**, show a **rotation of about 75-100 km/s**. If we take into account its value for the projected velocity of around 71-107 km/s, measured by Kounkel et al. 2019, it is showing us an **equatorial vision**.
5. Considering that they are ZAMS stars, we used the corresponding relation $T_{eff} - \nu_{max}$ of Barceló Forteza et al. 2020, and also the one of Bowman and Kurtz 2018, to try to constrain, even more, **the age of alpha Per between 103 and 131 Myr.**

Thank You

Contribución de la UGR a la misión espacial PLATO 2.0. Fases C/D-1

Ayuda: PID2019-107061GB-C64. Financiado por:

David Pamos Ortega - University of Granada -