ASTERO CHRONOMETRY

New light on the *Gaia* DR2 parallax zero-point

Influence of the asteroseismic approach, in and beyond the Kepler field

S. Khan

in collaboration with

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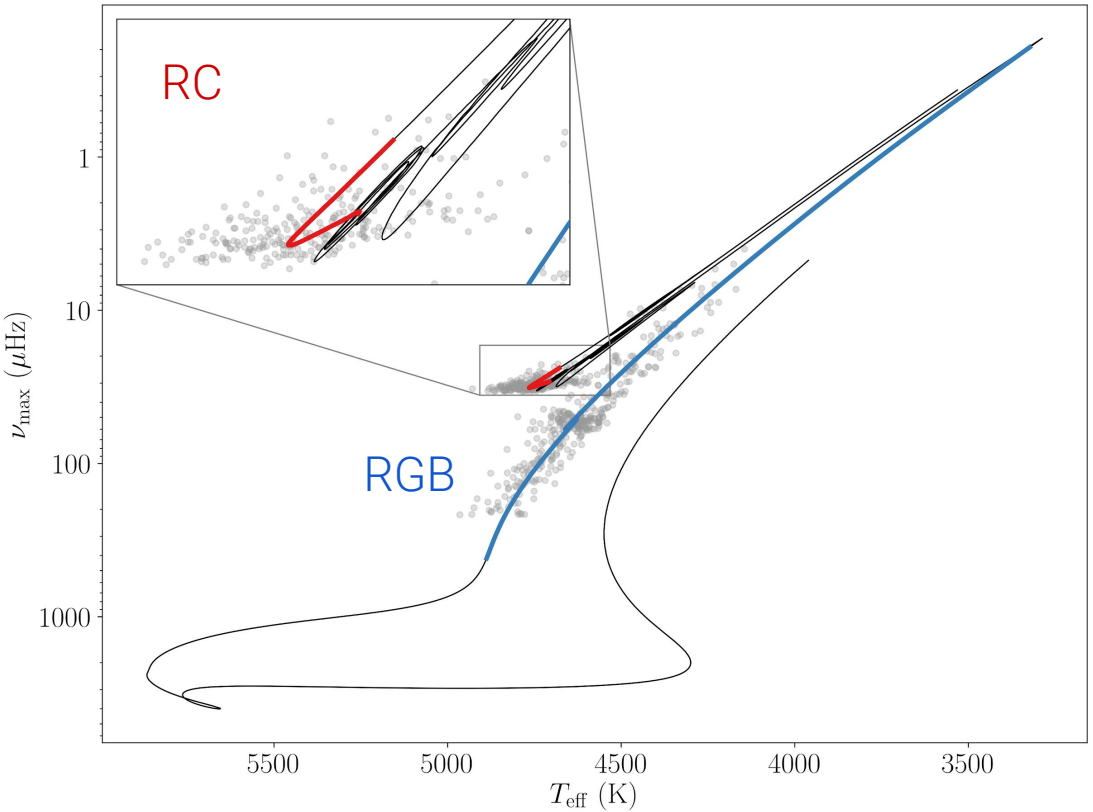
ESLAB #53 "the *Gaia* universe" - 09 / 04 / 2019

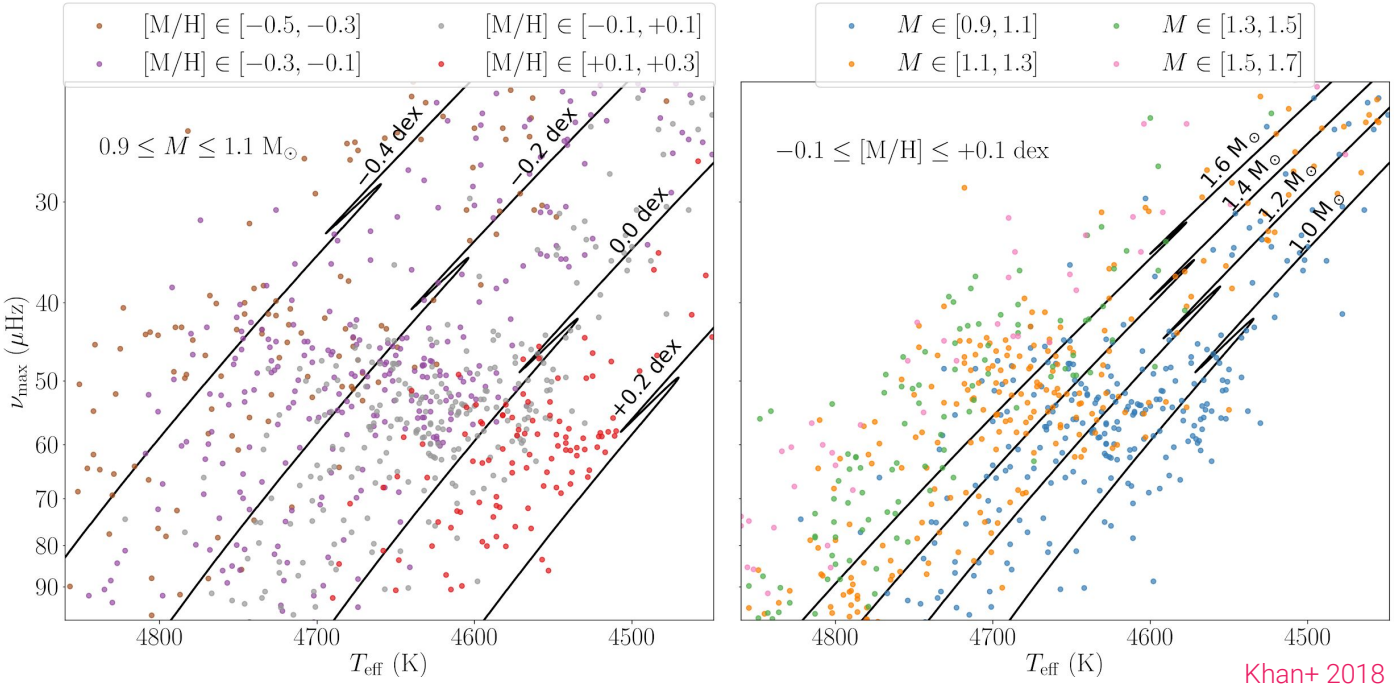
Red-giant stars



MOTIVATION

stellar ages
biases in seismic radii?

stellar structure
e.g. mixing processes

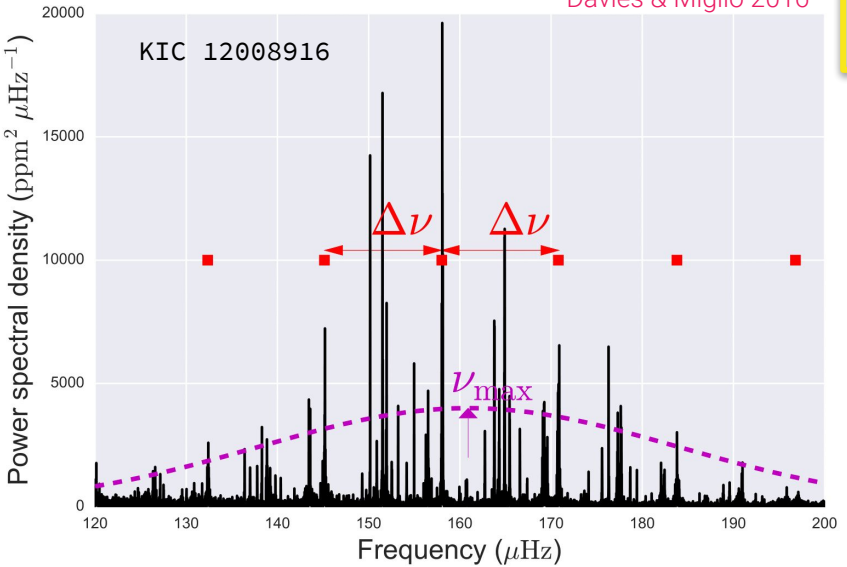


Khan+ 2018

Overview

1. Introduction
2. Observational framework
3. Analysis of the *Kepler* field
   a. Raw scaling relations
   b. Corrected ⟨Δν⟩ scaling relation
   c. ⟨Δν⟩ from individual frequencies: grid-based modelling
4. Positional dependence of the parallax zero-point
   a. K2 fields (C3/C6)
   b. Quasars and CMD
5. Conclusions

Introduction: asteroseismic methods



$$\langle\Delta\nu\rangle \propto \sqrt{\langle\rho\rangle} \propto \sqrt{\frac{M}{R^3}} \qquad \nu_{\rm max} \propto \frac{g}{\sqrt{T_{\rm eff}}} \propto \frac{M}{R^2\sqrt{T_{\rm eff}}}$$

Vandakurov 1967
Tassoul 1980
Ulrich 1986
Belkacem+ 2013

Brown+ 1991
Kjeldsen & Bedding 1995
Belkacem+ 2011

direct method

grid-based method

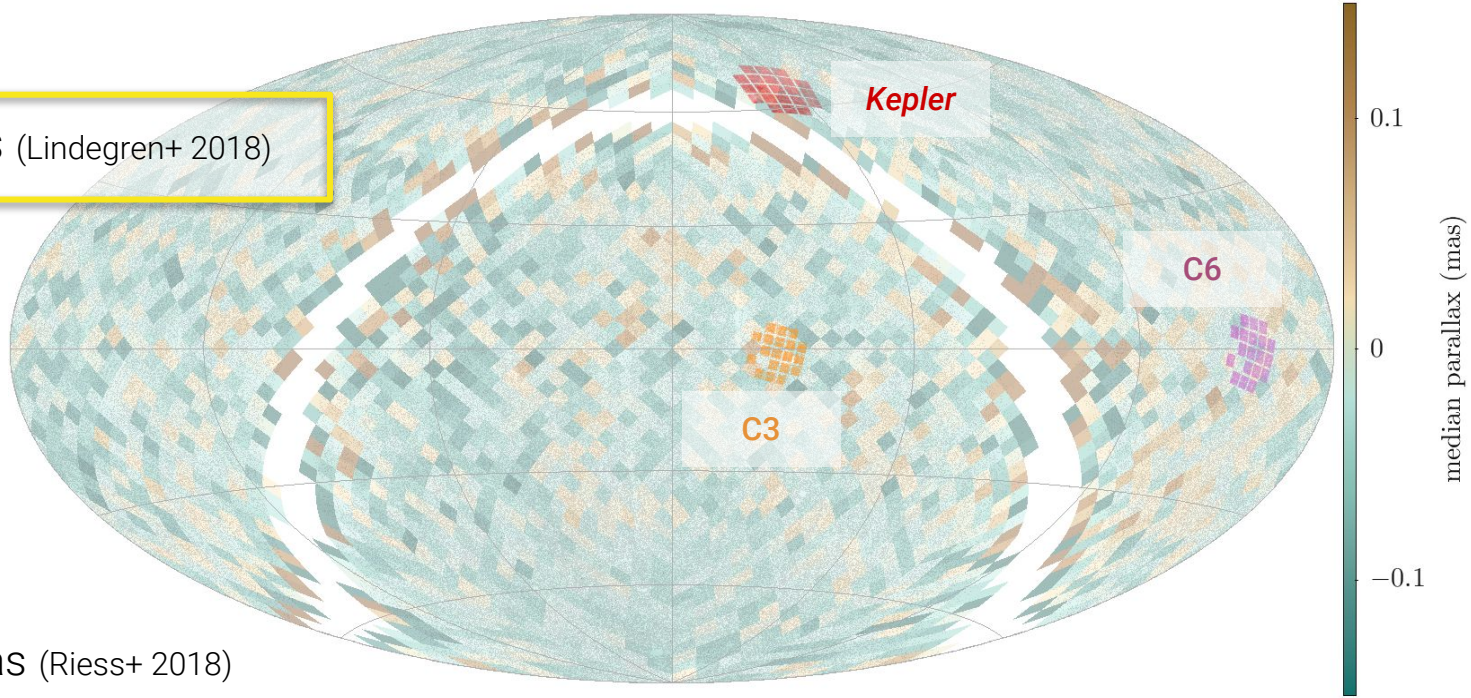
$$\varpi_{\rm scaling} = c_\lambda \left(\frac{\nu_{\rm max}}{\nu_{\rm max,\odot}}\right)^{-1} \left(\frac{\langle\Delta\nu\rangle}{\langle\Delta\nu\rangle_\odot}\right)^{2} \left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{-5/2}$$

where $c_\lambda = 10^{-0.2\,(m_\lambda + BC_\lambda + 5 - A_\lambda - M_{\rm bol,\odot})}$

comparisons of asteroseismic radii or distances with independent measurements (interferometry, clusters, eclipsing binaries, astrometry)

Introduction: *Gaia* DR2 parallax offset

quasars: −30 μas (Lindegren+ 2018)



Cepheids: −46 μas (Riess+ 2018)

EBs: −82 μas (Stassun & Torres 2018)

seismology: −53 μas (Zinn+ 2018)

DR2-RV: −54 μas (Schönrich+ 2019)

APOGEE: −52 μas (Leung & Bovy 2019)

Observational framework

consistency in the definition of ⟨Δν⟩

Kepler

3159 RGB / 2361 RC

APOGEE

ν_{max} *using Mosser+ 2011*

⟨Δν⟩ *using Mosser+ 2011*

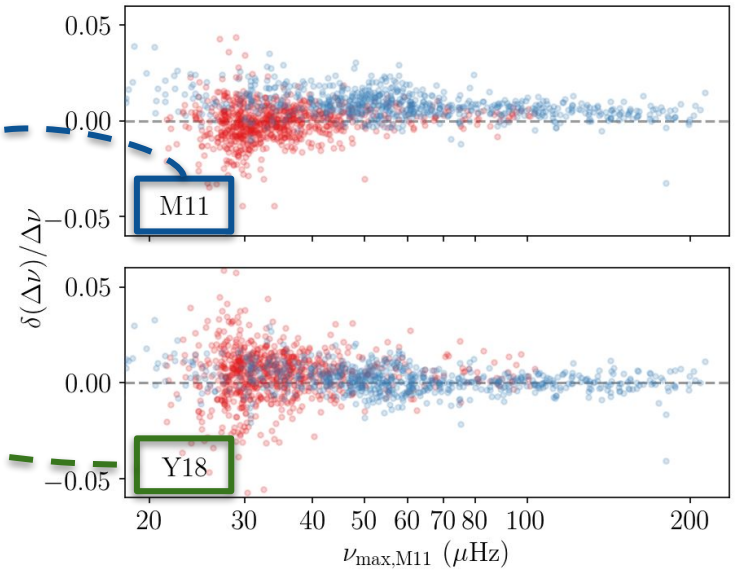
or Yu+ 2018

K2

505 C3 / 723 C6 (no distinction)

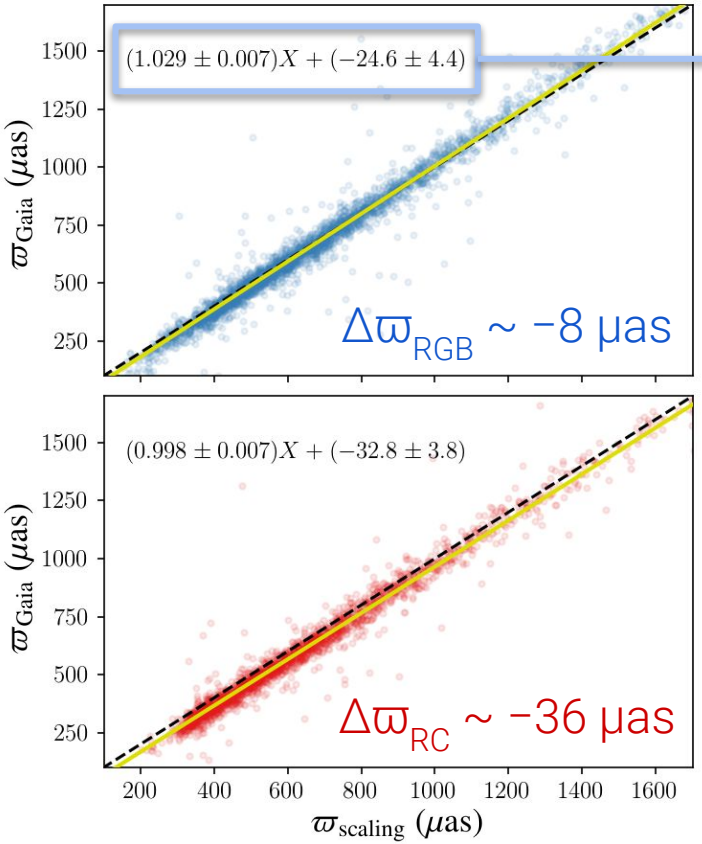
SkyMapper

ν_{max} *and* ⟨Δν⟩ *using Mosser+ 2011*



+ extinctions, bolometric corrections, *K*-band magnitudes, parallaxes

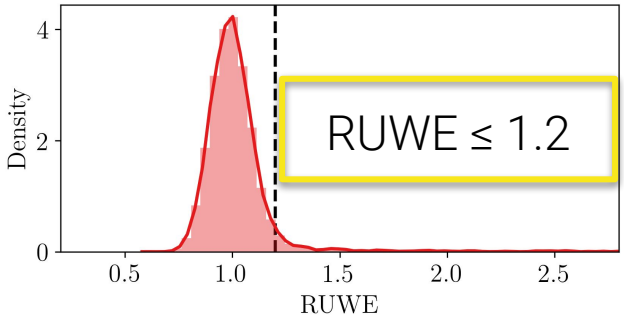
KEPLER FIELD: RAW SCALING RELATIONS



RGB: slope significantly ≠ 1

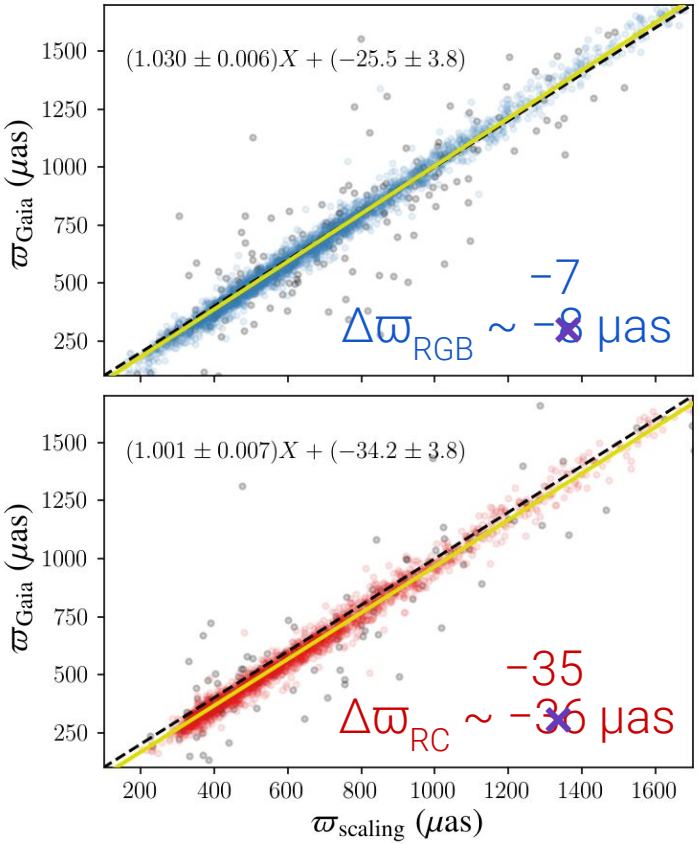
$\Delta\varpi_{RGB} \sim -8$ μas

$\Delta\varpi_{RC} \sim -36$ μas



RUWE: goodness-of-fit indicator for *Gaia* DR2 astrometry

KEPLER FIELD: RAW SCALING RELATIONS



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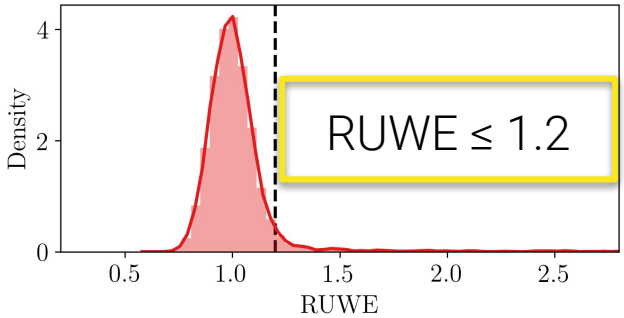
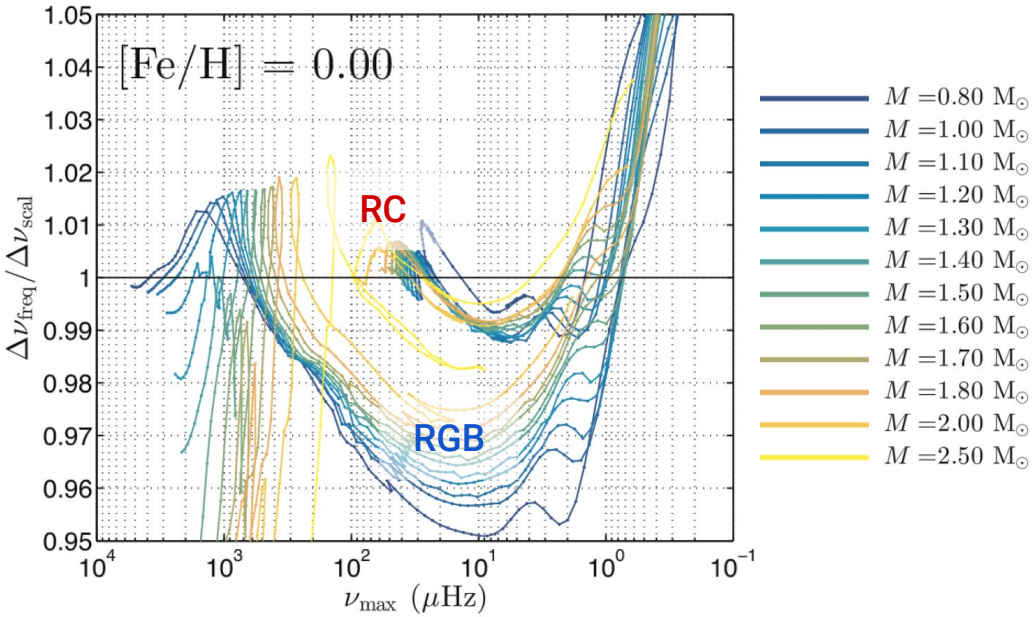


RUWE: goodness-of-fit indicator for *Gaia* DR2 astrometry

symptom of biases in the seismic scaling relations

KEPLER FIELD: CORRECTED ⟨Δν⟩ SCALING



Rodrigues+ 2017 (see also Sharma+ 2016)

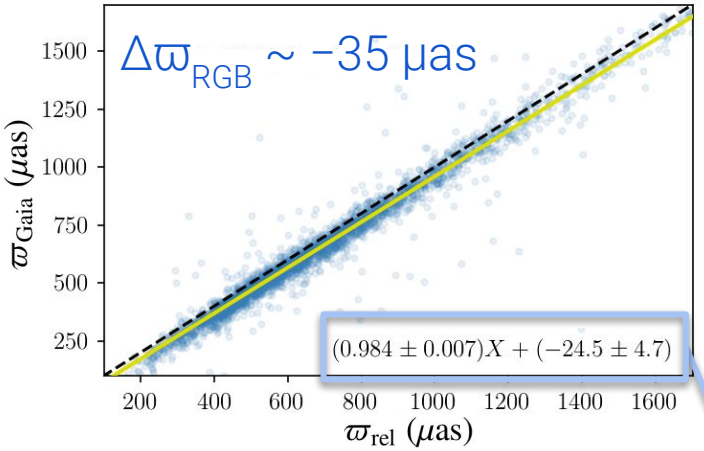
deviations from ⟨Δν⟩ scaling relation
= f (*M*, [Fe/H], evolutionary state)

NGC 6791 (Miglio+ 2012, Sharma+ 2016)

RGB: ⟨Δν⟩' ~ 0.973 ⟨Δν⟩

RC: ⟨Δν⟩' ~ 1.000 ⟨Δν⟩

KEPLER FIELD: CORRECTED ⟨Δν⟩ SCALING



$\Delta\varpi_{RC}$ ~ −36 μas

deviations from ⟨Δν⟩ scaling relation
= f (*M*, [Fe/H], evolutionary state)

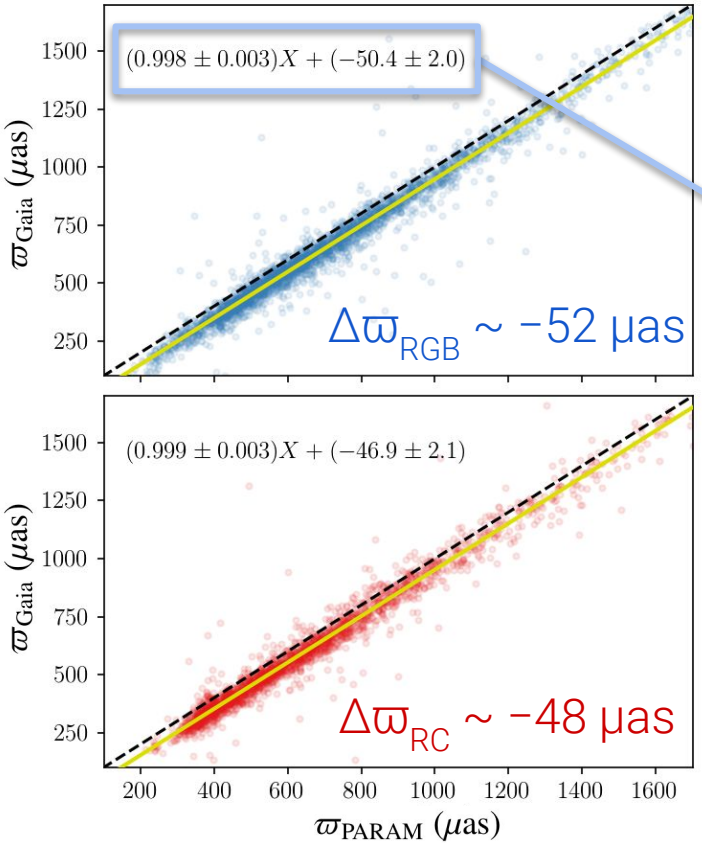
NGC 6791 (Miglio+ 2012, Sharma+ 2016)

RGB: ⟨Δν⟩' ~ 0.973 ⟨Δν⟩

RC: ⟨Δν⟩' ~ 1.000 ⟨Δν⟩

RGB: improvement in the slope but wide range of *M* and [Fe/H]

KEPLER FIELD: ⟨Δν⟩ FROM FREQUENCIES

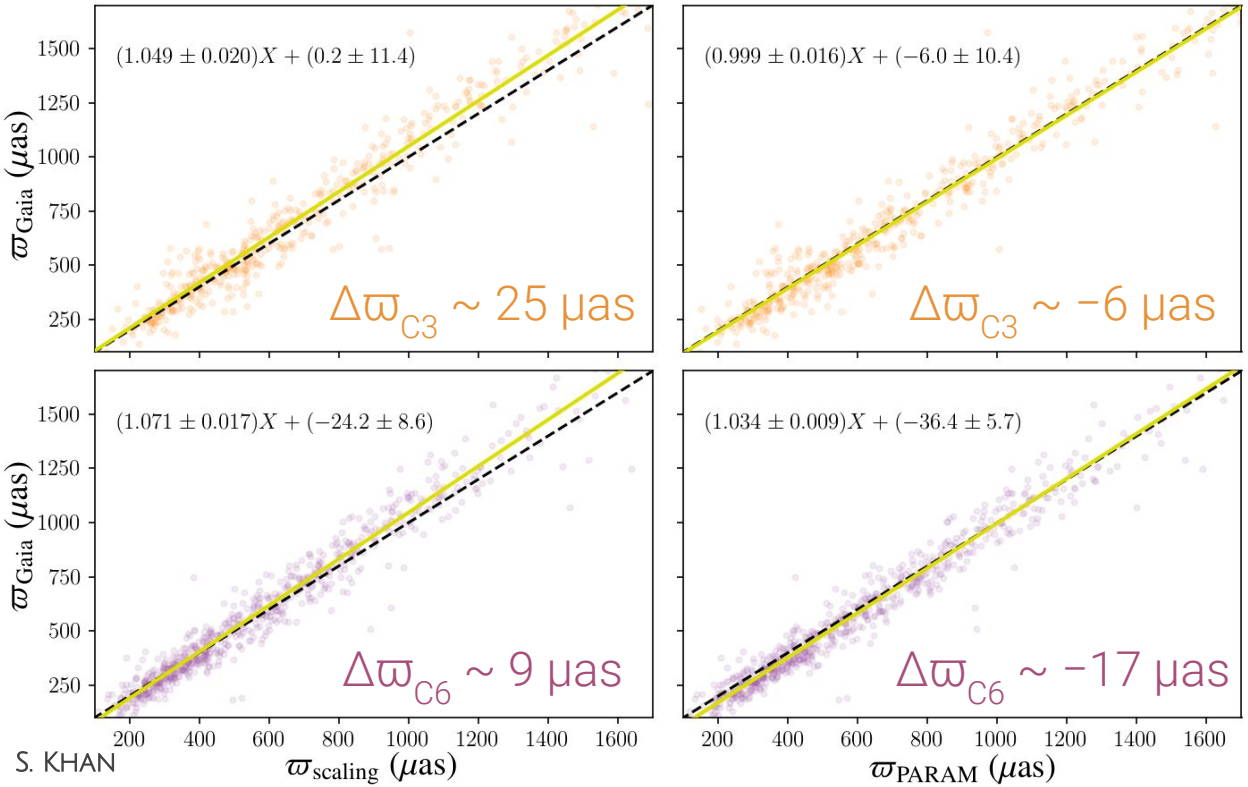


PARAM (Rodrigues+ 2017)
Bayesian grid-based method

RGB: slope ≃ 1

relevant to use PARAM with appropriate constraints

Positional dependence: K2 fields (C3/C6)



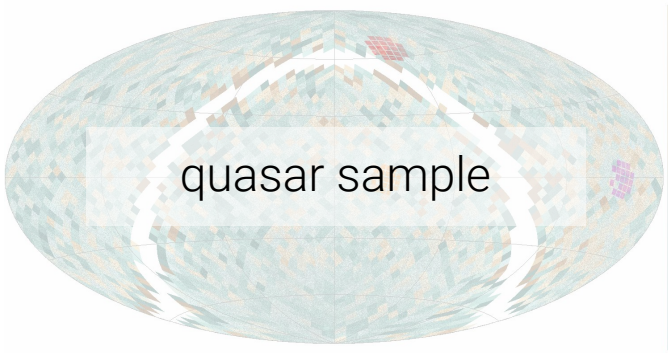
Δϖ =
f (position, colour, magnitude)

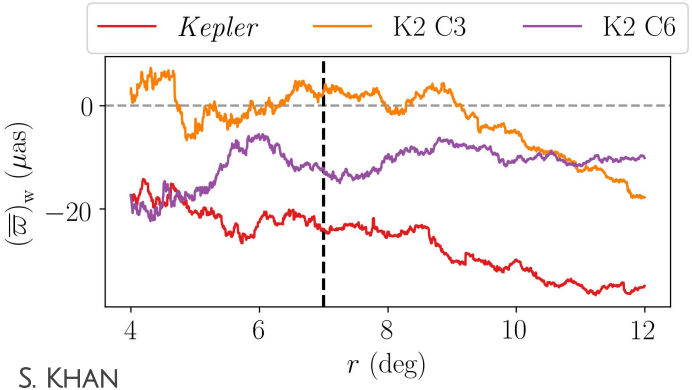
inhomogeneity in

T_{eff}, [Fe/H] ?

⟨Δv⟩ ?

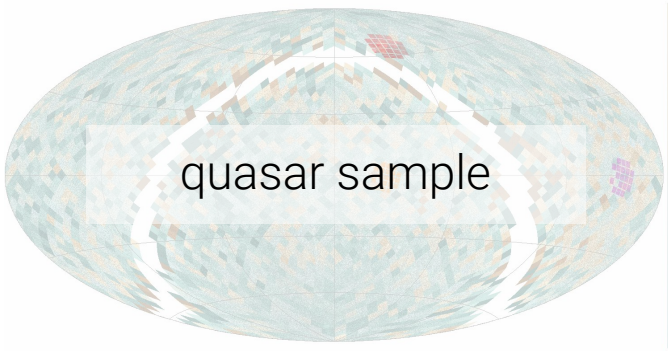
Positional dependence: quasars & CMD

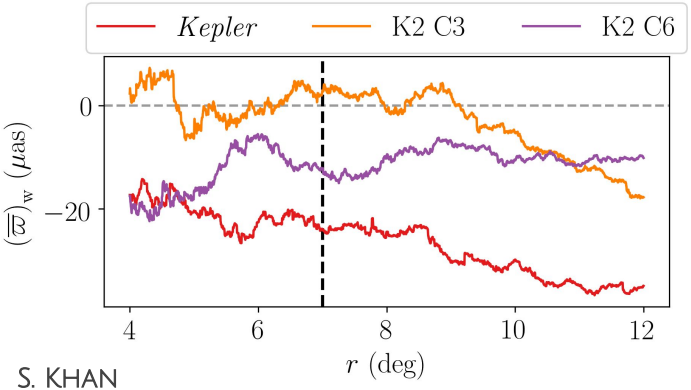


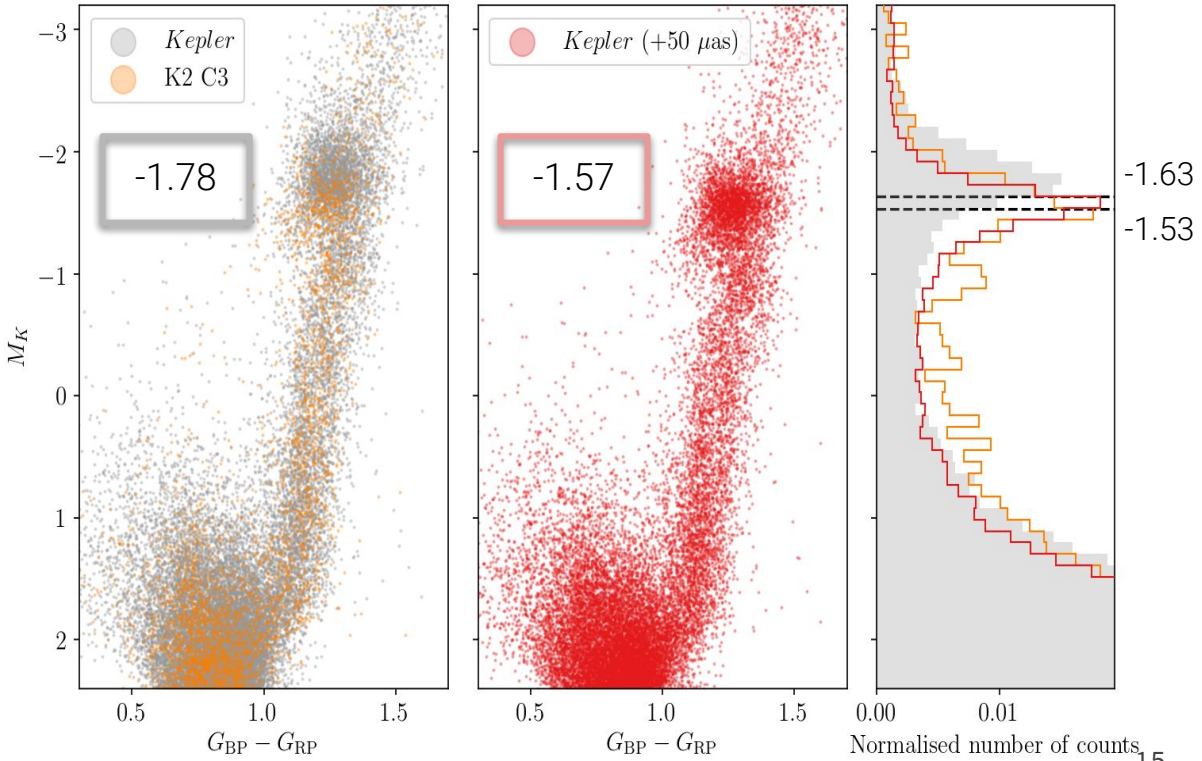


Positional dependence: quasars & CMD

see, e.g., Girardi 2016, Chen+ 2017, Hawkins+ 2017







Conclusions

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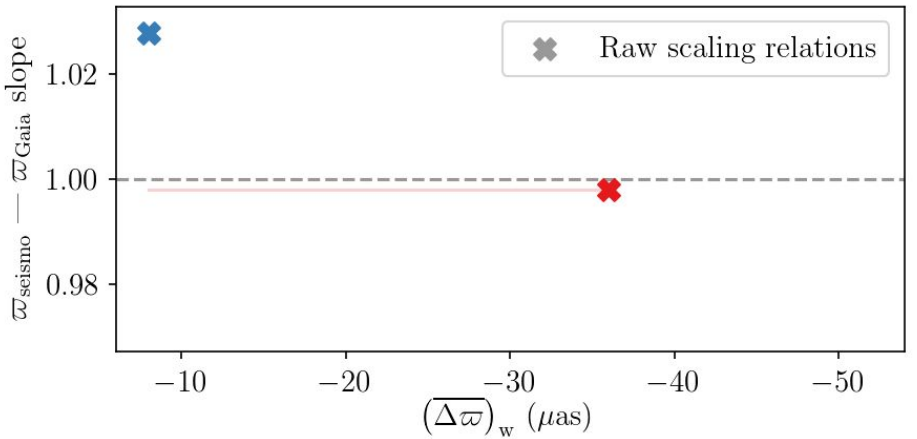
influence of the seismic method



Conclusions

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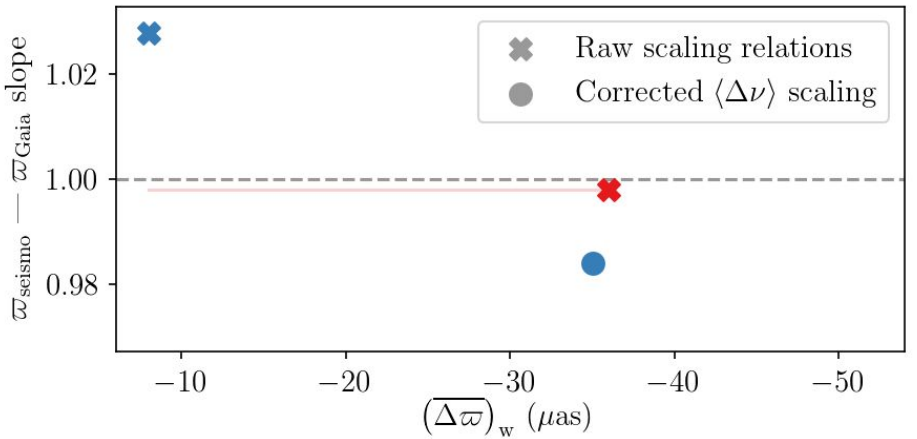


Conclusions

influence of the seismic method

necessity to go beyond the ⟨Δν⟩ scaling…

uncertainties related to stellar models,

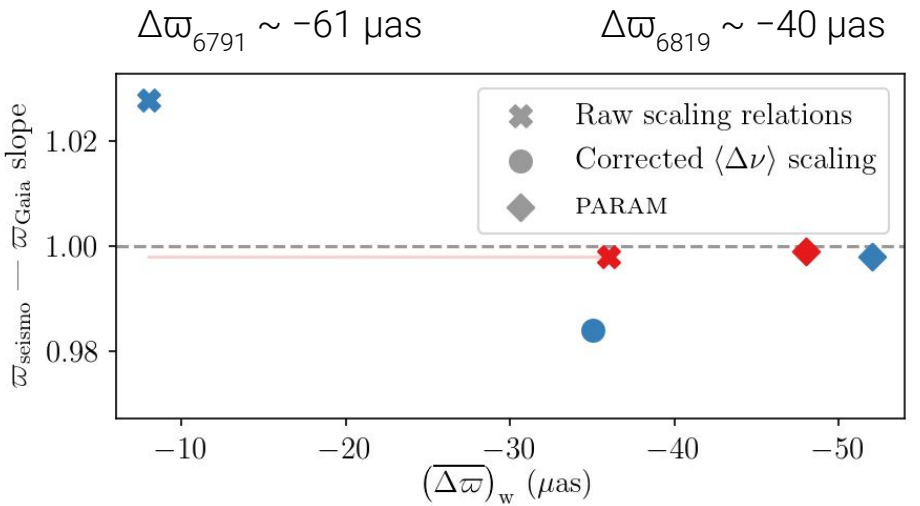
spatial correlations of parallax errors

(~10 μas uncertainty)

positional dependence of Δϖ

trend reproduced by quasars,

red clump luminosity




THANKS FOR
LISTENING!