Güneş-benzeri titreşim yapan yıldızların temel özelliklerinin titreşim frekanslarından bulunması

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02.02.2015,UAK 2015,ODTÜ, ANKARA

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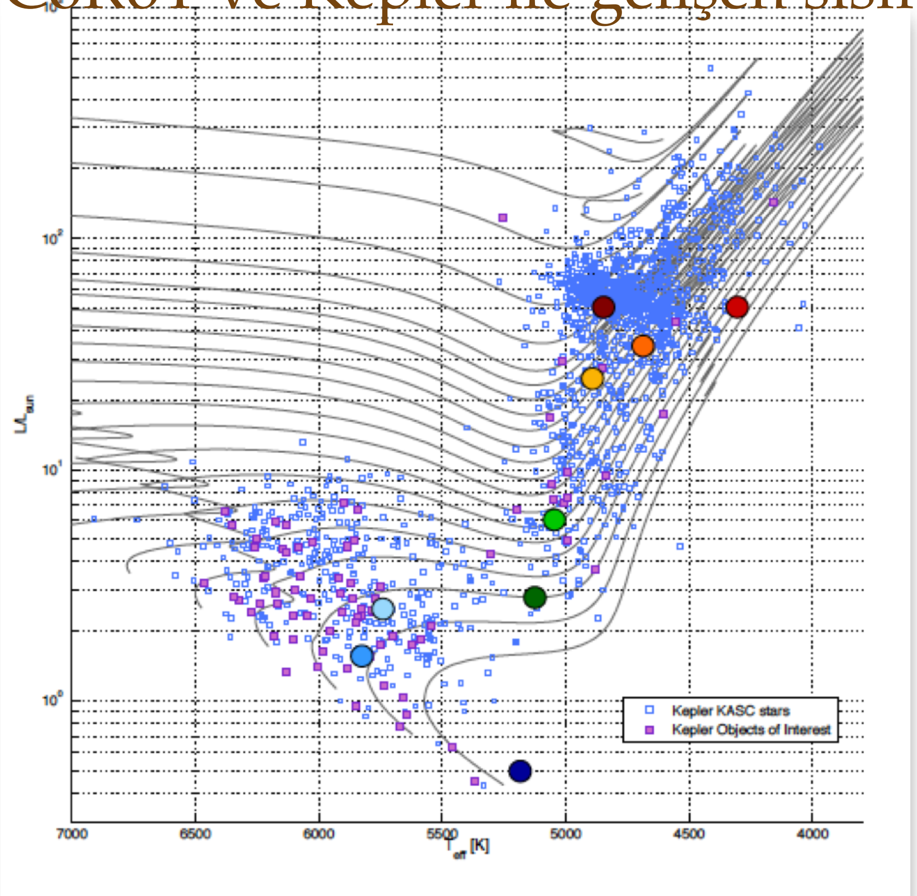
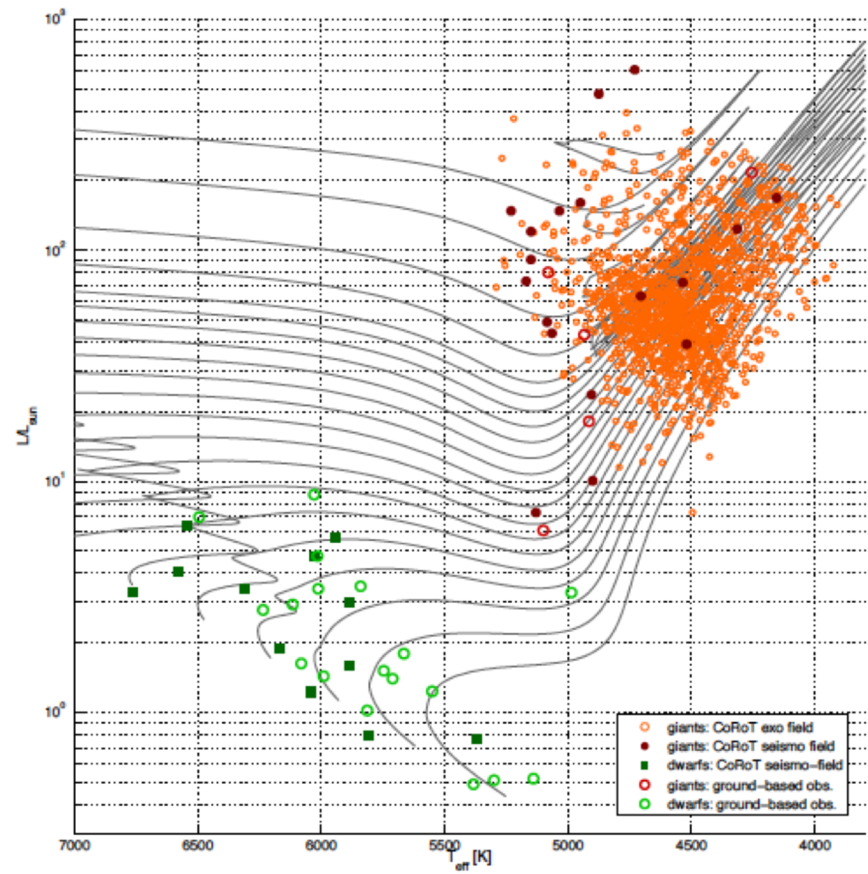
CoRoT ve Kepler ile gelişen sismoloji

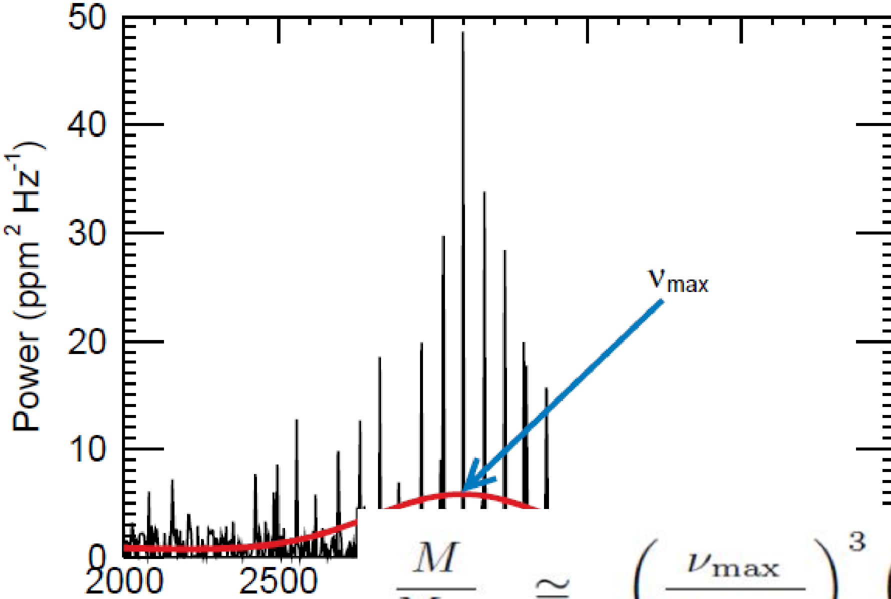


Kepler Yaklaşık 500 cüce ve altdev
14000 dev
4 kümede dev analizi



CoRoT: Çok sayıda güneş-benzeri titreşim yapan yıldız
20000 dev yıldız
NGC6633'te 4 dev yıldız

Ölçeklendirme ilişkisi (Scaling relation)

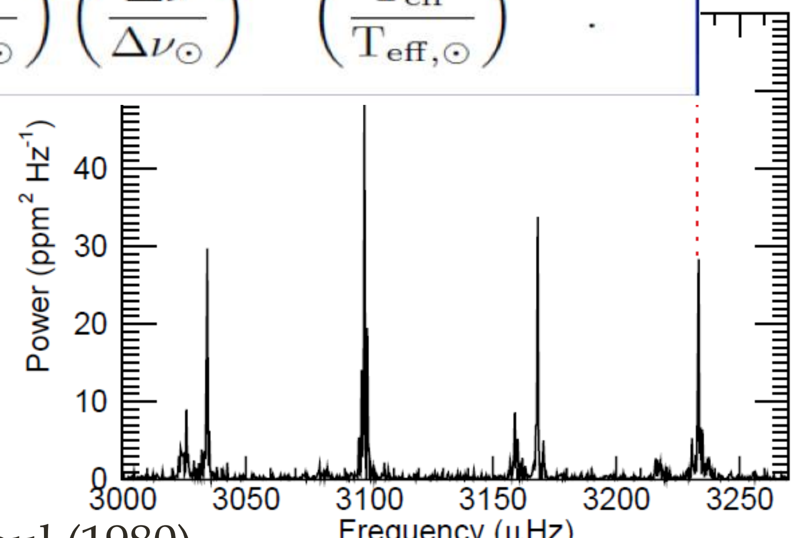


$$\left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right) \simeq \left(\frac{M}{M_\odot}\right)\left(\frac{R}{R_\odot}\right)^{-2}\left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{-0.5}.$$

Brown et al. (1991)

$$\frac{M}{M_\odot} \simeq \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right)^{3}\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-4}\left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{3/2}$$

$$\frac{R}{R_\odot} \simeq \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right)\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2}\left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{1/2}.$$



$$\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right) \simeq \left(\frac{M}{M_\odot}\right)^{0.5}\left(\frac{R}{R_\odot}\right)^{-1.5};$$

Tassoul (1980)

Monthly Notices
of the
ROYAL ASTRONOMICAL SOCIETY
MNRAS **441,** 2148–2158 (2014)
doi:10.1093/mnras/stu662

Fundamental properties of solar-like oscillating stars from frequencies of minimum $\Delta\nu$ – I. Model computations for solar composition

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Accepted 2014 April 3. Received 2014 March 31; in original form 2013 July 27

ABSTRACT
Low amplitude is the defining characteristic of solar-like oscillations. The space projects *Kepler* and *CoRoT* give us a great opportunity to successfully detect such oscillations in numerous targets. Achievements of asteroseismology depend on new discoveries of connections between the oscillation frequencies and stellar properties. In the previous studies, the frequency of the maximum amplitude and the large separation between frequencies were used for this purpose. In the present study, we confirm that the large separation between the frequencies has two minima at two different frequency values. These are the signatures of the He II ionization zone, and as such have very strong diagnostic potential. We relate these minima to fundamental stellar properties such as mass, radius, luminosity, age and mass of convective zone. For mass, the relation is simply based on the ratio of the frequency of minimum $\Delta\nu$ to the frequency of maximum amplitude. These frequency comparisons can be very precisely computed, and thus the mass and radius of a solar-like oscillating star can be determined to high precision. We also develop a new asteroseismic diagram which predicts structural and evolutionary properties of stars with such data. We derive expressions for mass, radius, effective temperature, luminosity and age in terms of purely asteroseismic quantities. For solar-like oscillating stars, we now will have five very important asteroseismic tools (two frequencies of minimum $\Delta\nu$, the frequency of maximum amplitude, and the large and small separations between the oscillation frequencies) to decipher properties of stellar interior astrophysics.

Key words: stars: evolution – stars: interiors – stars: late-type.

Modellerin ve Frekansların elde edilmesi

* ANKİ kodu (Ezer & Cameron 1965, Yıldız 2011)

 * Difüzyonsuz

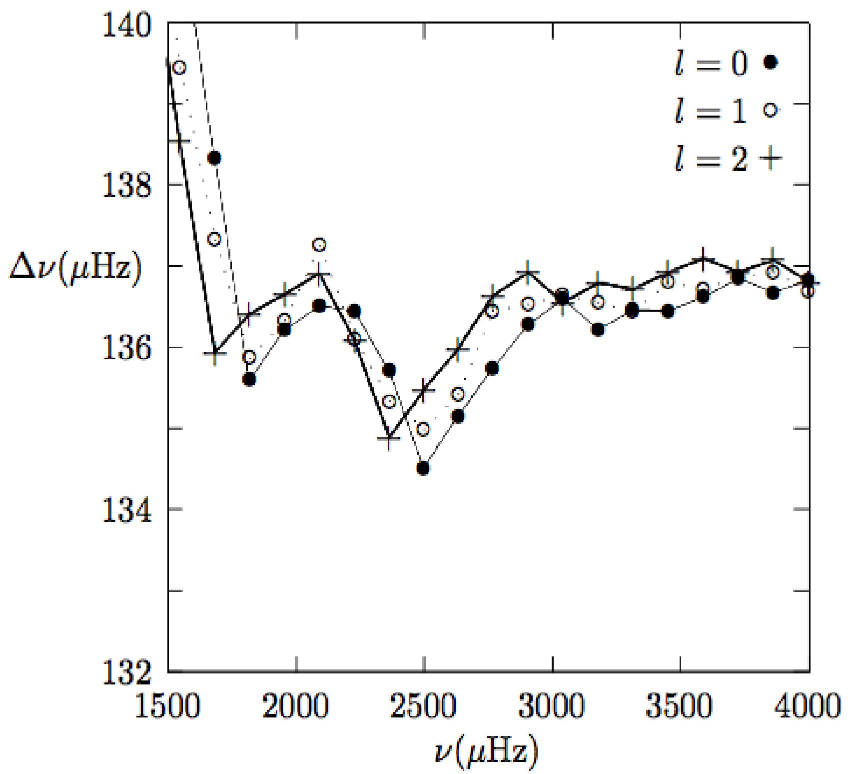
*Kimyasal kompozisyon Asplund ve arkadaşları (2009)

* 0.8-1.30 M_sun modelleri

* ADIPLS (Christensen-Dalsgaard, 2008)

* Elde edilen modeller için merkez hidrojen bolluğu 0.70, 0.53, 0.35 ve 0.17 için frekans hesabı yapıldı.

Güneş'te görülen minimumlar



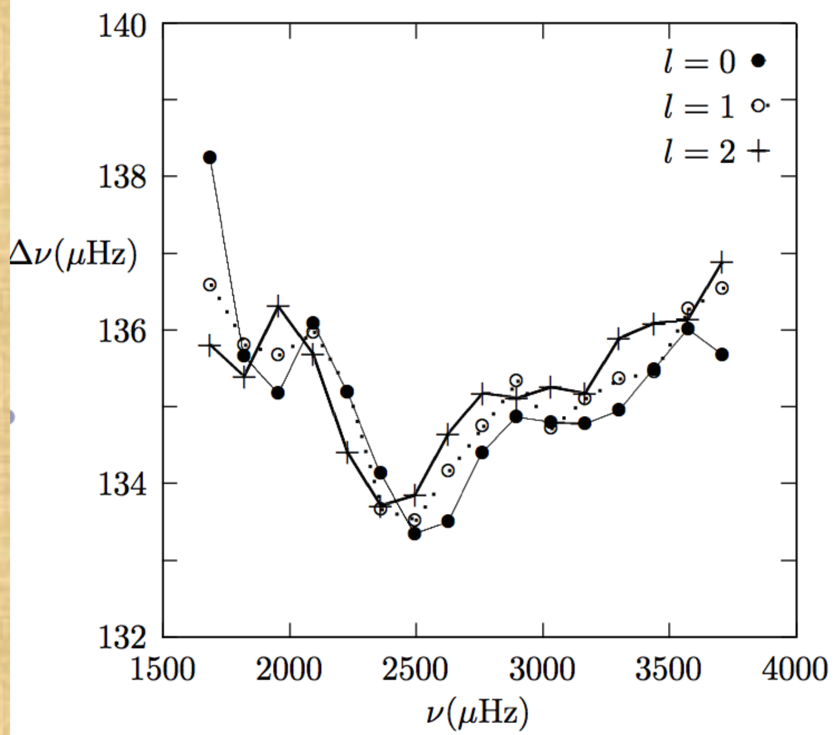


Figure 1. Variation of $\Delta\nu$ as a function of ν for the BiSON solar data

Farklı kütlelerde görülen minimumlar

1.00- 1.30 Msun kütle aralığı

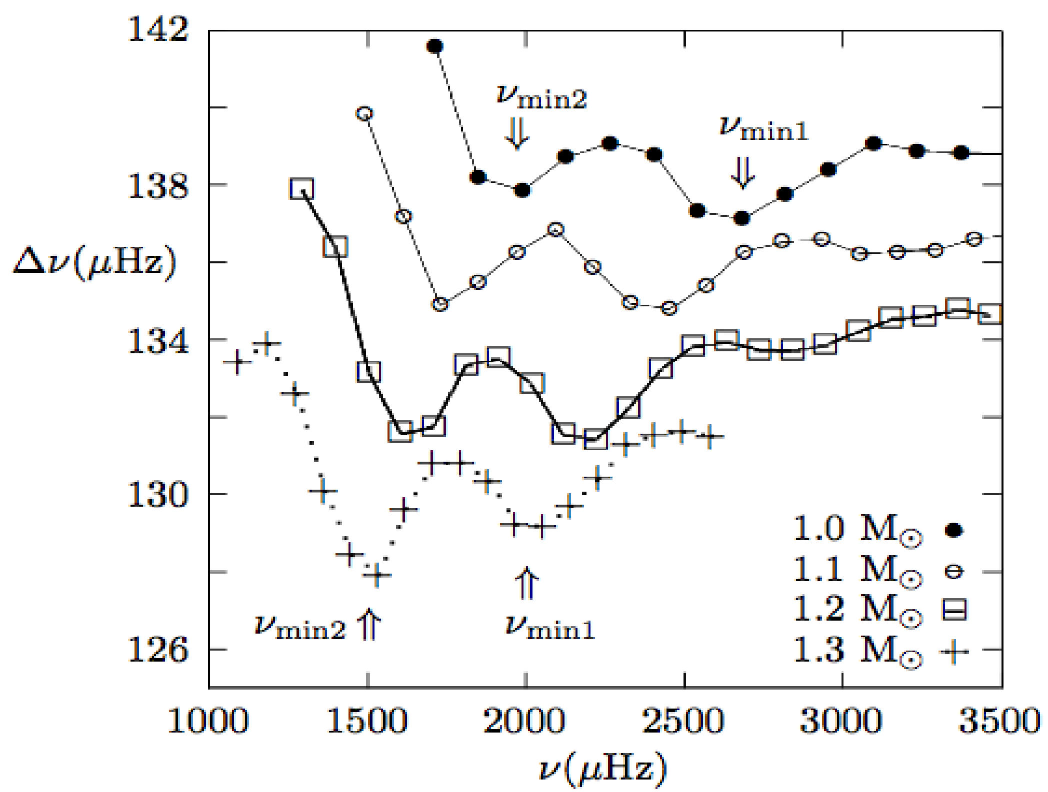


Figure 3. $\Delta\nu$ as a function of ν for 1.0-1.3 $M_\odot$ models with $X_c = 0.35$.

Minimumlar ile kütle arasındaki ilişki

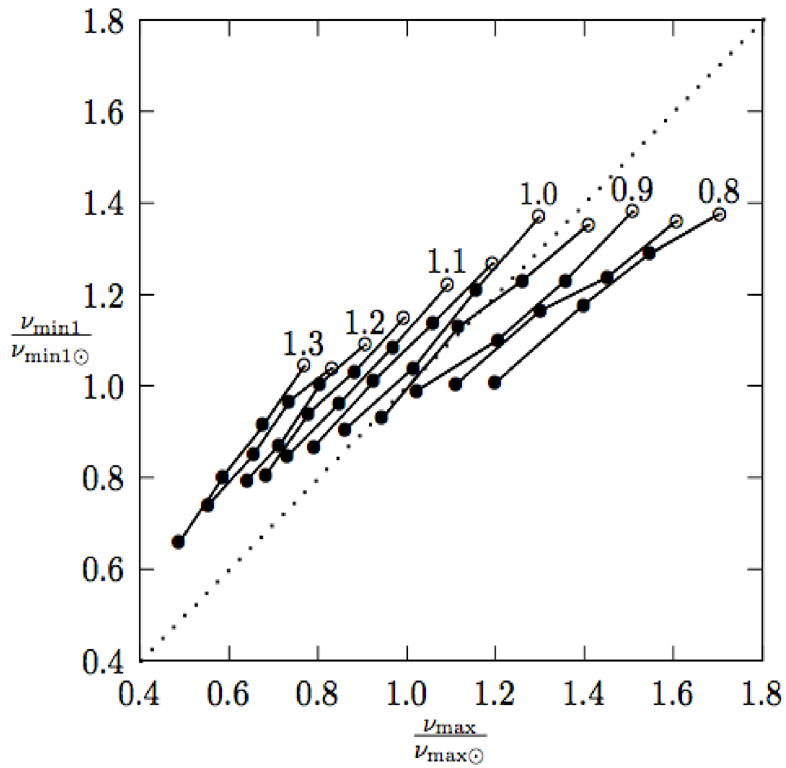


Figure 8. $\nu_{min1}/\nu_{min1\odot}$ with respect to $\nu_{max}/\nu_{max\odot}$. The circles show the models with $X_c = 0.7$, while the filled circles are for the models with

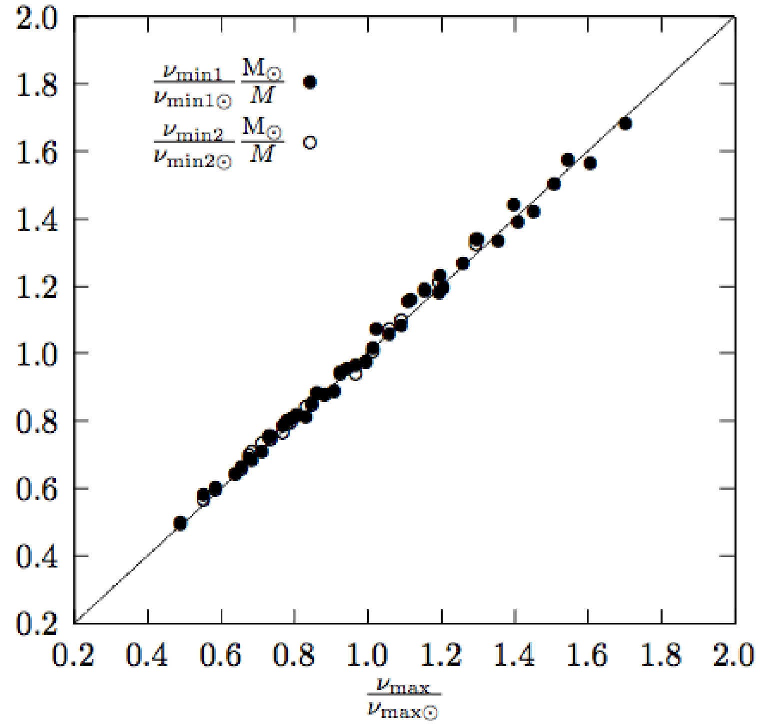


Figure 9. $\nu_{min1}M_\odot/\nu_{min1\odot}M$ (filled circle) and $\nu_{min2}M_\odot/\nu_{min2\odot}M$ (circle) are plotted with respect to $\nu_{max}/\nu_{max\odot}$. This shows that $\nu_{min1}M_\odot/\nu_{min1\odot}M = \nu_{max}/\nu_{max\odot}$. This equality is

KÜTLE

$$\frac{M}{M_\odot} = \left(\frac{(\nu_{\mathrm{min1}}/\nu_{\mathrm{min1}\odot})^3}{(\langle\Delta\nu\rangle / \langle\Delta\nu_\odot\rangle)^4} \left(\frac{T_{\mathrm{eff}}}{T_{\mathrm{eff}\odot}} \right)^{1.5} \right)^{1/4} \qquad (11)$$

- %2 duyarlılıkla

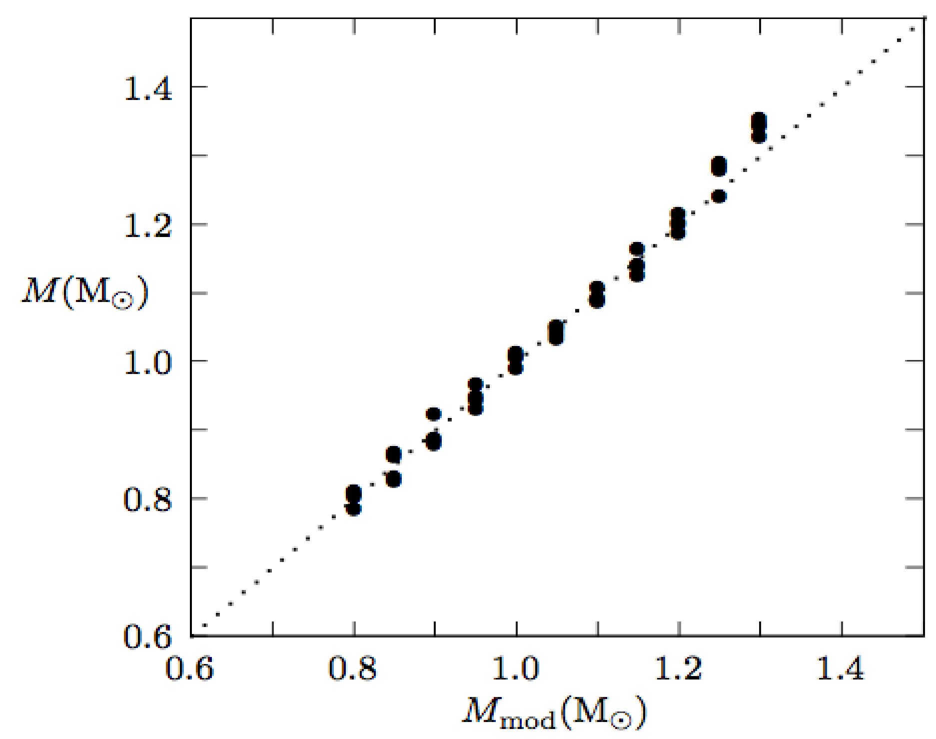
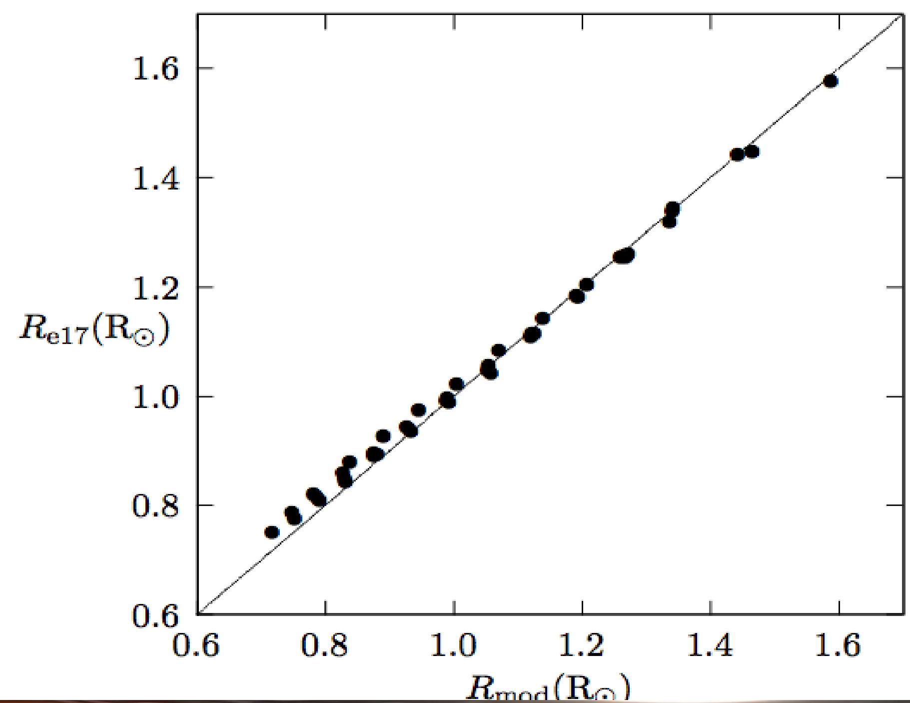


Figure 10. The computed mass (equation 11) from oscillation frequencies

Yarıçap

$$\frac{R}{\mathrm{R}_\odot} = \left(\frac{\nu_{\min 1}}{\nu_{\min 1 \odot}}\right)^{0.23} \left(\frac{\langle \Delta\nu_\odot \rangle}{\langle \Delta\nu \rangle}\right)^{0.99} . \qquad (17)$$

* %1.5 duyarlılıkla



Yaş

$$t(\mathrm{Gyr}) = 6.93\left(r_\nu\left(0.91 - \frac{\langle\delta\nu_{02}\rangle}{\langle\delta\nu_{02\odot}\rangle}\right) + 2.96 - 2.18\frac{M}{\mathrm{M}_\odot}\right)^{1.18} \quad (22)$$

$$r_\nu = \left(\frac{\nu_{\max}}{\nu_{\max\odot}}\frac{\langle\Delta\nu\rangle}{\langle\Delta\nu_\odot\rangle}\right)^{0.7},$$

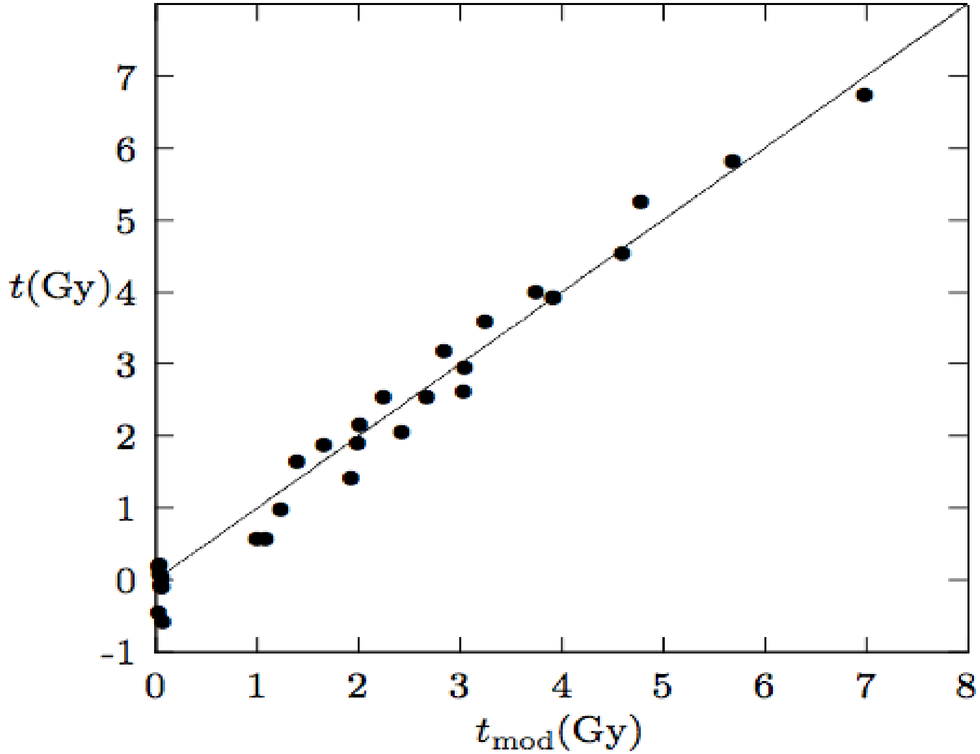
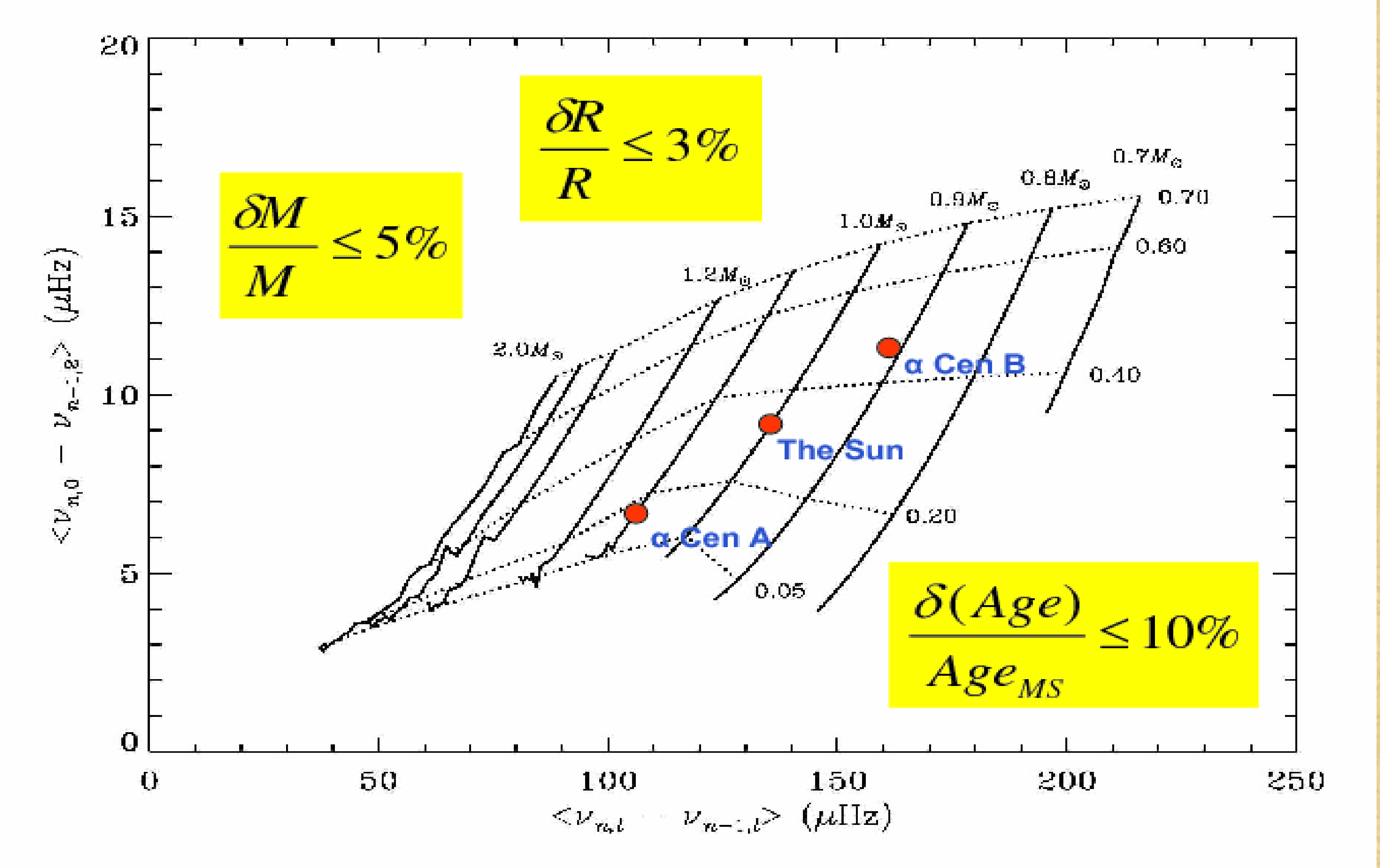


Figure 12. Age derived from oscillation frequencies (equation 22) with respect to model age.

Sismik HRD (Christensen-Dalsgaard 1993)



Asteroseismik Diyagram (AD)

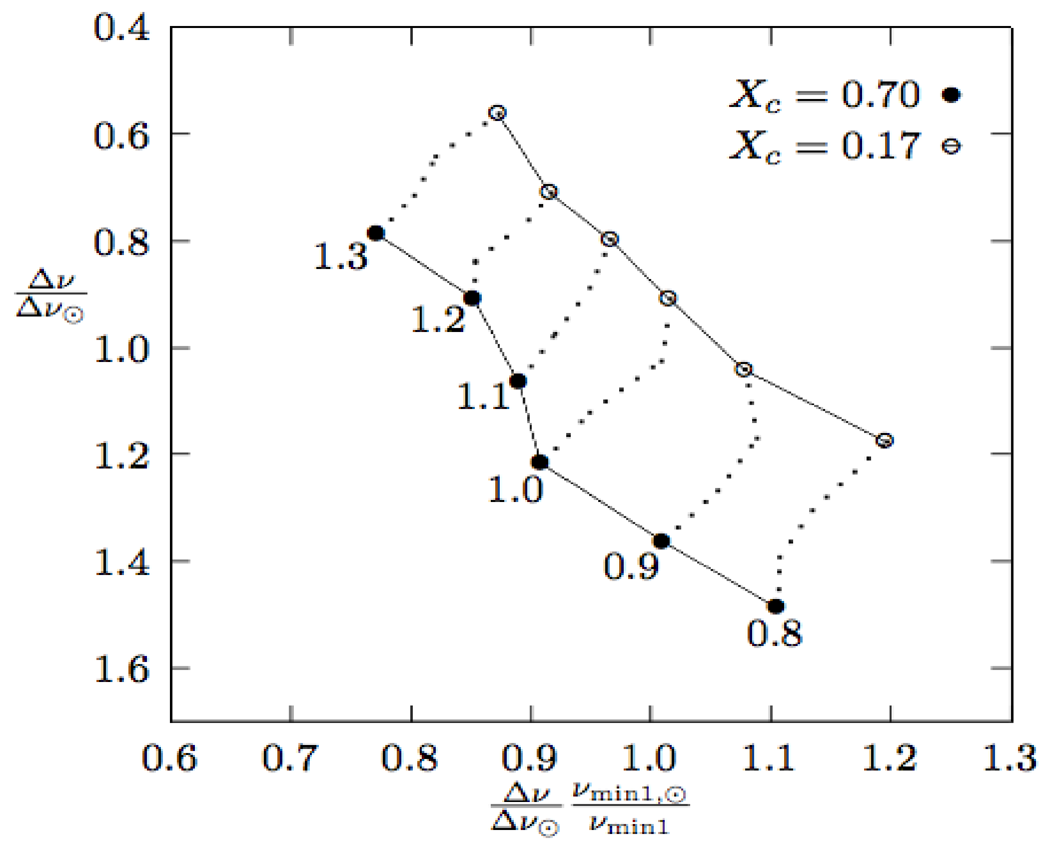


Figure 13. AD for solar-like oscillating stars. The numbers show the model masses in units of solar mass. This form of the diagram is compatible to the

Sonuçlar

* Büyük ayrılmaya karşın frekans grafiğinde iki farklı frekansa karşılık gelen iki tane minimum saptandı (numin1 ve numin2).
* Bu frekanslar kullanılarak kütle, yarıçap, log g, ışıtma ve yaş gibi yıldızın temel parametreleri arasında bağlantılar kuruldu.
* Bu temel parametreler sadece sismik veriler kullanılarak oldukça duyarlı bir şekilde elde edildi (%2-3).
* Yeni bir sismik HRD elde edildi (AD).
* Bu çalışma ANKİ evrim kodunun varolmasında ve gelişmesinde büyük katkıları olan Dilhan Hoca'ya adanmıştır.


TESS (NASA): 2017


PLATO (ESA): 2024
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E-ELT: 2024


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SONG: 2014


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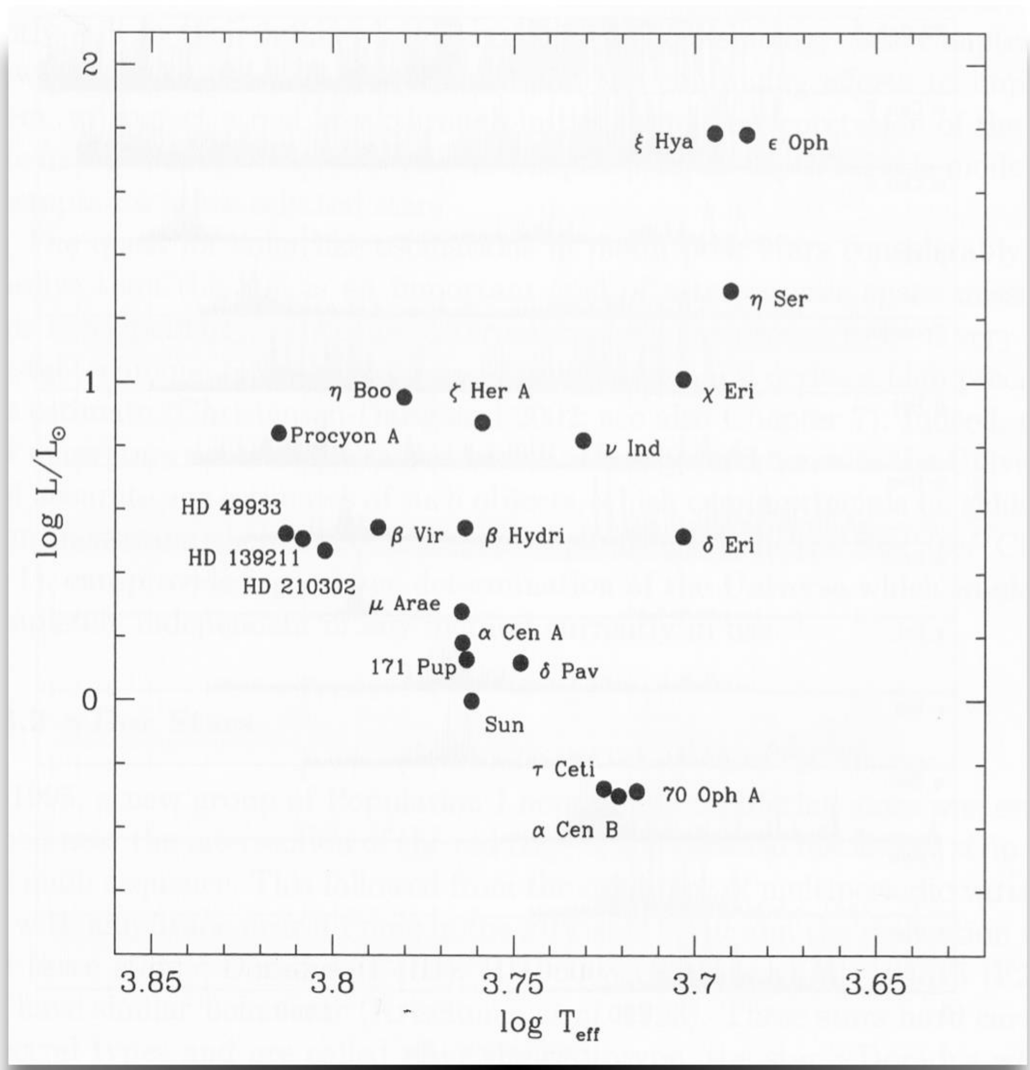
CoRoT ve Kepler Uzay Araçlarından Önce

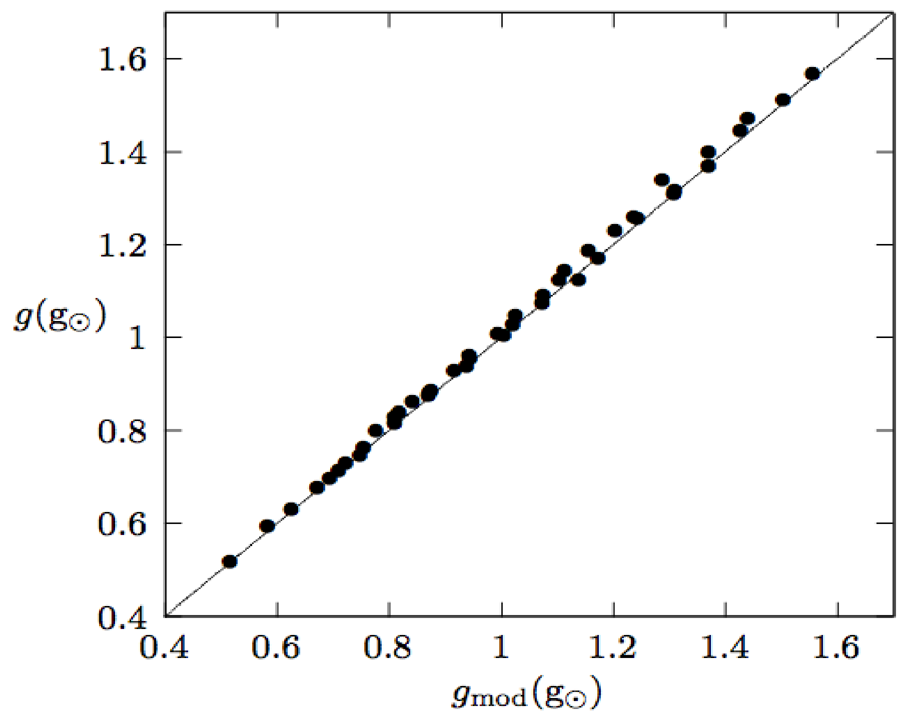


Straka et al. 2006, Carrier et al. 2005, Guenther 2004, Kjeldsen et al. 2003, Di Mauro et al 2002 , Christensen-Dalsgaard et al. 1995, Kjeldsen et al 1995, Provost et al. 2006, Claudi et al. 2005, Eggenberger et al. 2004, Martic et al. 2004, Eggenberger&Carrier 2006, Bedding et al. 2006, Carrier&Eggenberger 2006, Bouchy et al. 2005, Bazot et al. 2005, Bedding et al. 2001 Carrier & Bouchy 2001,2, …

Çekim ivmesi

$$\frac{g}{g_\odot} = \left(\frac{\nu_{\min 1}}{\nu_{\min 1 \odot}}\right)^{0.48} \left(\frac{\langle \Delta\nu \rangle}{\langle \Delta\nu_\odot \rangle}\right)^{0.78} . \quad (18)$$

*%2 duyarlılıkla



Işıtma

$$\frac{L}{\mathrm{L}_\odot} = 2.06 \frac{\nu_{\mathrm{min1}}}{\nu_{\mathrm{min1}\odot}} \frac{\langle \Delta\nu_\odot \rangle}{\langle \Delta\nu \rangle} \frac{\nu_{\mathrm{max}\odot}}{\nu_{\mathrm{max}}} - 1.01. \qquad (20)$$

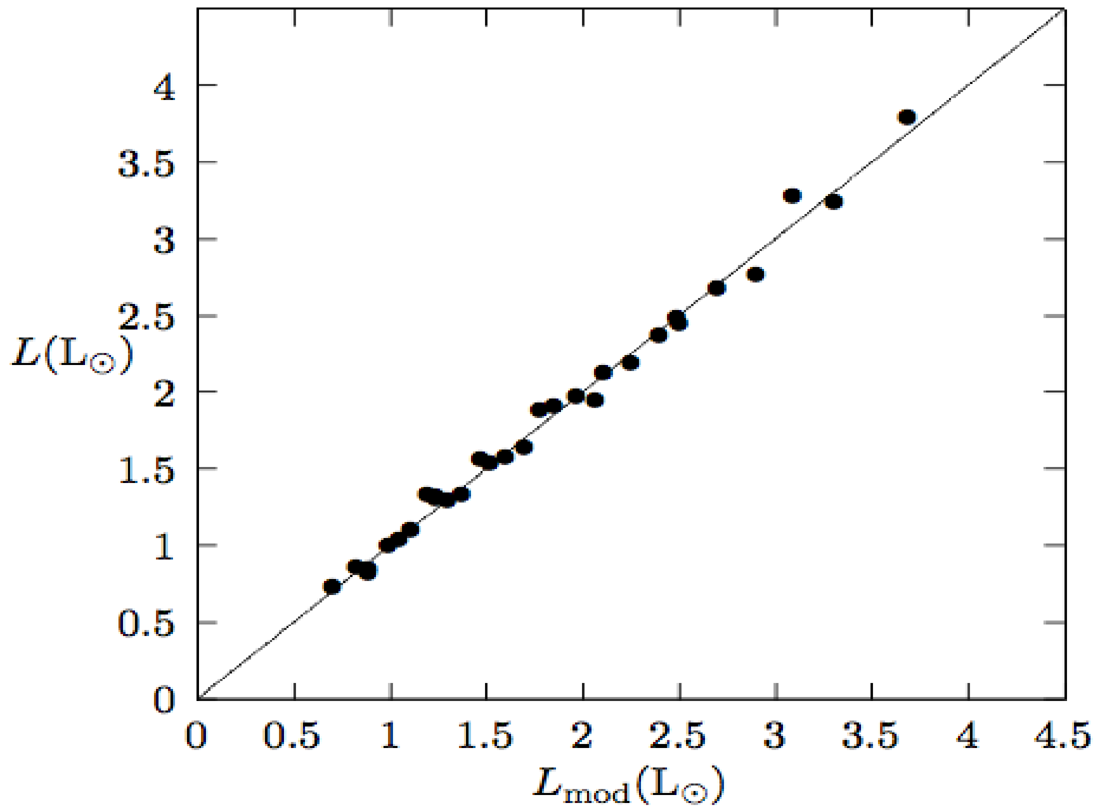


Figure 11. Luminosity derived from oscillation frequencies (equation 20) with respect to model luminosity.