Pulsating stars harboring planets

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Synergy

Characterization

Noise

Discovering

Future prospects
Guideline of the review

Why bother with asteroseismology while studying planets?
(Vauclair, S., EAS Publications Series, Volume 41, 2008)

1. Observations are done with the same instruments

SYNERGY

Pulsating stars harbouring planets
SYNERGY

Paradigmatic case of synergy

Astero $\rightarrow$ Exop: Most of the content of this talk

Exop $\rightarrow$ Astero: The presence of exoplanets can change stellar properties

More opportunities for space and ground-based projects
(alone you cannot, with friends… yes, you can!)

Pulsating stars harbouring planets
Guideline of the review

Why bother with asteroseismology while studying planets?
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1. Observations are done with the same instruments
2. “Some people’s noise is other people’s signal”

“NOISE”
Stellar variability (including pulsations) treated as noise by the exoplanet community

Title: Planetary detection limits taking into account stellar noise. I. Observational strategies to reduce stellar oscillation and granulation effects

But this noise is information that helps characterize the host star
The right understanding of pulsations increase the S/N for discovering planets

Pulsating stars harbouring planets
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3. Obtain precise values of the parameters of exoplanets-host star

CHARACTERIZATION

Pulsating stars harbouring planets
Current situation

**Transits**

\[
\frac{\Delta F}{F} = \left( \frac{R_P}{R_*} \right)^2
\]

**Direct imaging (age)**

**Radial Velocity**

\[
RV = f \left( \frac{M_P}{M_*} \right)
\]
Current situation

Homogeneous studies of transiting extrasolar planets. IV. Thirty systems with space-based light curves


Mean errors

<table>
<thead>
<tr>
<th>M.</th>
<th>R.</th>
<th>ρ.</th>
<th>Age</th>
<th>M_p</th>
<th>R_p</th>
</tr>
</thead>
<tbody>
<tr>
<td>9,3%</td>
<td>7%</td>
<td>13.7%</td>
<td>150%</td>
<td>10.6%</td>
<td>7.1%</td>
</tr>
</tbody>
</table>

Errors of $M_p$ and $R_p$ dominated by errors of $M_*$ and $R_*$. 
From asteroseismology
Precision obtained with Kepler

An uniform asteroseismic analysis of 22 solar-type stars observed with Kepler

<table>
<thead>
<tr>
<th></th>
<th>Individual frequencies not resolved</th>
<th>Individual frequencies resolved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>Radius</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Age</td>
<td>10%</td>
<td>2.5%</td>
</tr>
</tbody>
</table>
CHARACTERIZING: Real cases

i Horologii: Laymand & Vauclair, 2007; Vauclair et al., 2008
HD46375: Gaulme et al. 2010a,b
HAT-P-7: Christensen-Dalsgaard, 2010
TrES-2: Christensen-Dalsgaard, 2010
HAT-P-11: Christensen-Dalsgaard, 2010
HD52265: Soriano et al., 2007, 2008; Ballot et al., 2011
WASP-33: Herrero et al., 2011
HR8799: Zerbi et al., 1999; Moya et al., 2010a,b; Wright et al., 2011
β Pictoris: Koen et al., 2003
HD17156: Nutzman et al., 2010
KIC 9904059: Gilliland et al., 2010
V391 Pegasus: Silvotti et al., 2007
i Draconis: Hatzes & Zechmeister, 2008
HD13189: Hatzes & Zechmeister, 2008

Pulsating stars harbouring planets
CHARACTERIZING: Real cases

Pulsating stars harbouring planets
CHARACTERIZING: Real cases

**μ Arae**

<table>
<thead>
<tr>
<th></th>
<th>$M_*$</th>
<th>$\log g$</th>
<th>$R_*$</th>
<th>[Fe/H]</th>
<th>$T_{\text{eff}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Asteroseismology</td>
<td>4.6%</td>
<td>2.3%</td>
<td>23%</td>
<td>31%</td>
<td>1.7%</td>
</tr>
<tr>
<td>With Asteroseismology</td>
<td>1.8%</td>
<td>0.1%</td>
<td>4.4%</td>
<td>6.3%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

Very precise determination $Y=0.30\pm0.01$, $\text{Age}=6.3\pm0.8\ \text{Gyr}$

Pulsating stars harbouring planets
CHARACTERIZING: Real cases

ι Horologii

<table>
<thead>
<tr>
<th></th>
<th>$M_*$</th>
<th>$\log g$</th>
<th>$M_p$</th>
<th>[Fe/H]</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without</td>
<td>6.3%</td>
<td>2%</td>
<td>8%</td>
<td>30%</td>
<td>86%</td>
</tr>
<tr>
<td>Asteroseismology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With</td>
<td>0.8%</td>
<td>0.2%</td>
<td>0.7%</td>
<td>18%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Asteroseismology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

New determination mass of the planet: 
$2.26 \pm 0.18 \rightarrow 2.60 \pm 0.02$

$Y=0.255 \pm 0.015$, Age and Fe/H compatible with Hyades cluster

Pulsating stars harbouring planets
CHARACTERIZING: Real cases

KIC 9904059

Initial studies based on spectroscopy provided a $R_\star \approx 3.6 R_\odot$, that is, $R_p \approx 1.6 R_J$.

<table>
<thead>
<tr>
<th>$\Delta \sigma$ (µHz)</th>
<th>$\sigma_{\text{max}}$ (µHz)</th>
<th>$\rho_\star$ (g·cm$^{-3}$)</th>
<th>$M_\star$ (M$\odot$)</th>
<th>$R_\star$ (R$\odot$)</th>
<th>$R_\odot$ ($\odot$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.77±0.07</td>
<td>143±3</td>
<td>0.0113±0.0001</td>
<td>1.72±0.13</td>
<td>5.99±0.15</td>
<td>0.45±0.11-0.07</td>
</tr>
</tbody>
</table>

The planet is probably a companion star.
Guideline of the review

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4. Links between asteroseismology and planet discovering

DISCOVERING

Pulsating stars harbouring planets
DISCOVERING: Timing

Timing method: “This method is based on the reflex motion of the parent star due to the companion, which changes periodically the star-observer distance, causing a delay (or advance) on the arrival time of the photons.” Silvotti et al., 2011

We need a precise astronomical clock:
1) Pulsars
2) EB’s
3) Pulsations
DISCOVERING: Timing

**V391 Pegasus**

SdB hybrid pulsator

The evolution of the star can be studied too

Silvotti et al., 2007

<table>
<thead>
<tr>
<th>$M_p \sin i$ [M$_J$]</th>
<th>a [A.U]</th>
<th>P [Yr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>1.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Pulsating stars harbouring planets
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5. Additional information about different physics (A. Moya)

BONUS TRACKS

Pulsating stars harbouring planets
BONUS TRACKS: Metallicities

Most of the exoplanet-host star are over-metallic

Sousa et al. 2011

Is this metallicity internal or accreted?
Motivation of the first works (μ Arae, i Horo)

Pulsating stars harbouring planets
BONUS TRACKS: Visual angle “i”

Having “v sin i”, R and the rotation period LPV can accurately determine “i”

HR8799 (Wright et al. 2011)

Planets and debris disk i ≤ 25° (Su et al., 2009; Reidermeister et al., 2009)

Spectroscopic determination of $i_*=65\pm25^\circ$
($\ell=1,m=1$)

First reported misalignment between $i_*$ and $i_{\text{debris}}$
BONUS TRACKS: False positives

Mentioned on Tingley et al., 2011 and Nutzman et al., 2010

Transits and asteroseismology offer independent measurement of the mean density

<table>
<thead>
<tr>
<th>Star</th>
<th>Ec1</th>
<th>Ec2</th>
<th>Spect</th>
<th>Astroseis</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAT-P-7</td>
<td>0.29±0.06</td>
<td>0.32$^{+0.08}_{-0.07}$</td>
<td>0.33$^{+0.07}_{-0.01}$</td>
<td>0.2712±0.0032</td>
</tr>
<tr>
<td>HAT-P-11</td>
<td>3.36±0.78</td>
<td>3.00$^{+0.45}_{-0.10}$</td>
<td>2.69±0.24</td>
<td>2.5127±0.0009</td>
</tr>
<tr>
<td>TrES-2</td>
<td>-</td>
<td>1.38±0.07</td>
<td>1.38±0.17</td>
<td>1.3233±0.0027</td>
</tr>
<tr>
<td>HD17156</td>
<td>0.45$^{+0.20}_{-0.03}$</td>
<td>0.50$^{+0.16}_{-0.10}$</td>
<td>0.59$^{+0.09}_{-0.11}$</td>
<td>0.5208±0.0040</td>
</tr>
</tbody>
</table>

RVs show HAT-P-7b non-eccentric orbit

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FUTURE PROSPECTS

1) Searching for life on other planets.
2) We need to find and study planets orbiting other stars.
3) Roadmap already designed: Exoplanet search, accurate characterization of these exoplanets, searching for biomarkers on their atmospheres.

Taken from: An European roadmap for exoplanets (Exoplanet Roadmap Advisory Team, October 2010)
THANK YOU!!!!!!!