Precise Radial Velocities with iSHELL update

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Goal precision: ~3-5 m/s

Balance any iSHELL RV program against science goals and strengths of:
- HPF
- CARMENES
- NIRPS
- SPIROU
- IRD
- CRIRES+
- iLocater
- PARVI
- GIANO
- iGRINS
- NIRSPEC+
- MAROON-X
- MINERVA-RED
(not on sky yet)

Leverage advantages of $\lambda > 2\mu$m;
iSHELL only NIR PRV on NASA facility & only NIR PRV with public access to US PIs & on-sky now!
iSHELL could provide TESS mission Follow-Up (key project?)
- 120 night RV program over N semesters
- Double (hedge) Level 1 mission req.
  (at quadrature of 50 stars, N_{obs}=4/star, 6 hr/epoch)
- NASA-owned facility (Keck, LBT, WIYN)
- Reddest, most active (young) stars with most massive TESS candidates
- Confirm and/or rule out higher-mass exoplanets, activity
Exploit $\lambda$-dependence of stellar activity

- Dumusque et al., 2012
- $\alpha$ Cen B
- Spots
- Plages
- Granulation
- Limb-Darkening

Scaled from Bottom et al. (2013)

Vanderburg et al. (2016)
Plavchan et al. (2015)

$\sigma_{RV}$ m/s

Reiners et al., (in prep.)

RV vsini = 2, 5, 10, and 30 km/s

amplitude

Stellar Temperature

0.5 1.0 1.5 2.0 2.5 Wavelength (microns)

Limb-Darkening

CO band-head

Reiners et al. (2010)

Active M stars with corotating spots

RVs in the near-infrared

Reiners et al. (in prep.)
Gas cell assembled and integrated in CSHELL, Sept 2010

Yi et al. 2016, Nature Comm., 710436
Plavchan et al. 2013a, SPIE, 8864, 1J
Plavchan et al. 2013b, SPIE, 8864, 0G
Anglada et al., 2012, PASP, 124, 586
+ candidate exoplanet?... in prep.
iSHELL $^{13}$CH$_4$ gas cell, 2016

$^{13}$CH$_4$ Gas Cell provided by Plavchan et al.
Gas Cell Lines

2.18- 2.47 μm
Fringing in Science Images and Flatfields

Recommended iSHELL solution:
- Take flat-fields directly after science observations
  - OK for SNR<30
- Not good enough for PRVs
  - Different illumination: different LSF; amplitude, phase
  - Solution: Band-pass filter fringing from flatfields, forward model in data
Fringing

1 fringing component Model

Data
2nd Component Fringing

1 fringing component Model

Data
Residuals
ALL ORDERS!
• Not a normal fringing pattern!
• Period runs from big to small
• "resets" and repeats every order
• Moderate finesse to cavity too!
• Immersion grating possible culprit
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ALL ORDERS!
Barnard's star - 2 orders: 17 m/s rms

Preliminary!
Barnard's star - 10 orders: 29 m/s rms

3-8 m/s over a week

Preliminary!
Fringing iSHELL order. $x=\text{wave}+21000\text{nm}; \ y = \text{fringing period (nm)}$. model: $\text{period} = A/(\text{wave-order}_{\text{start}}); \ P=67/(\text{wave}-738)$

\[ Fr(\lambda) = A \sin\left(2\pi \frac{(\lambda - \lambda_0)^a}{P + \phi}\right) \]

plus finesse
Fr(\(\lambda\)) = A \sin \left\{ n\pi \left[ \frac{\ln (\lambda - \lambda_0)/(\lambda_2 - \lambda_0)}{\ln (\lambda_1 - \lambda_0)/(\lambda_2 - \lambda_0)} \right] \right\} \\
plus finesse
Moving Forward

• With CSHELL we obtained \( \sim 3 \) m/s on M Giant SV Peg, nightly floor of 2 - 6 m/s, and long-term 20 m/s for M dwarfs

• For iSHELL, we are starting where we left off with CSHELL

• Continue to test and refine fringing model --> more, better RVs!