High precision radial velocities: the case for NIR

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Up to now

• Up-to-now 592 planets have been discovered using RVs
• All of them have been discovered using instruments working in the visible
• The most successful instruments (HARPS-HARPS-N and HIRES) achieve 0.3 m/s precision
• NIR instruments are well behind: better instruments achieve ~10 m/s accuracy
• Less RV signal, lack of spectral coverage and of accurate wavelength reference
HARPS-N vs GIANO

• Two instruments at the same telescope
• HARPS-N is an instrument fully optimized for RVs ➔ internal errors of ~0.3 m/s in best cases
• GIANO has currently several limitations (low fiber efficiency, unstable slit illumination, lack of an accurate wavelength reference) ➔ internal errors of ~10 m/s in best cases
Still there are niches for GIANO

- Approximate error HARPS-N
  - $\text{Err(km/s)} = 10^{0.2 \cdot V - 4.5}$

- Approximate error Giano
  - $\text{Err(km/s)} = 10^{0.2 \cdot H - 3.05}$

⇒ GIANO is better than HARPS-N for stars:
  - with $(V-H) > 7.25$ (later than M6.5)
V-H colour vs spectral type

Better GIANO

Better HARPS-N
Comparison HARPS-N vs GIANO
Bright active stars

Better GIANO
Better HARPS-N

Better GIANO
Better HARPS-N

Data from Wright 2005
Activity vs Age

→ bright young F-G stars

Data from Mamajek & Hillebrand 2008
GIARPS

• GIARPS (Claudi et al.) is the new common feeding for HARPS-N and GIANO

• GIANO will be fed by a train of optics rather than fibers
  – Higher efficiency
  – Elimination of modal noise
  – Stable slit illumination with a closed loop active tip/tilt mirror
    – Insertion of an ammonia cell for H and K bands

• Funded by WOW; should be ready at mid-2016
GIARPS makes GIANO a much better RV instrument

• Internal error should be reduced because of the higher efficiency
• Systematic errors reduced by the stable slit illumination
• Expected accuracy with ammonia cell ~3 m/s in best cases
• With simultaneous use of VIS-NIR HR spectrographs, GIARPS will be a forerunner for HIRES
V-H colour vs spectral type

Better GIANO
Better HARPS-N
V-H colour vs spectral type

- Better GIANO+GIARPS
- Better HARPS-N
Comparison HARPS-N vs GIANO

Bright active stars

Better GIANO

Better HARPS-N

Better GIANO

Better HARPS-N

Data from Wright 2005
Comparison HARPS-N vs GIANO

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Better GIANO+GIARPS
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Better GIANO+GIARPS

Better HARPS-N

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HIRES-Vis vs HIRES-NIR

• Approximate photon noise error HIRES-Vis
  – $\text{Err}(\text{km/s}) = 10^{0.2V-5.55}$

• Approximate photon noise error HIRES-NIR
  – $\text{Err}(\text{km/s}) = 10^{0.2H-4.35}$

• $\Rightarrow$ HIRES-NIR is better than HIRES-Vis for stars:
  – with $(V-H)>6$ (later than M5)
V-H colour vs spectral type

Better HIRES-NIR
Better HIRES-VIS
However this only concerns internal errors

- Stellar RV jitter is \(~1.5\) m/s for good (inactive) targets
- For inactive stars, HARPS-N RV jitter dominates over photon noise for \(V<8.4\)
- It is expected to be the major source of noise for all HIRES targets with \(V<13.6\) \(\Rightarrow\) e.g. all solar-type stars within 600 pc from the Sun
- Stellar RV jitter is expected to be about \(1/3\) in the NIR wrt to optical (Dumusque et al.)
Three regimes with HIRES

If a good reference (e.g. laser comb) will be available:

• For bright targets (~$V<11$), the lower jitter in the NIR implies that we need $\sim 1/10$ as many observations with HIRES-NIR than with HIRES-VIS to get similar confidence levels

• For very faint sources (~$V>13$), HIRES-VIS leads to more accurate results unless the source is very red

• For intermediate magnitudes, to be examined case-by-case (depends on activity/colour)
Conclusion

• For a wide range of cases, HIRES-NIR will be more efficient than HIRES-VIS for detection and characterization of planets using RVs
• This requires accurate wavelength reference for NIR
• GIARPS at TNG, simultaneously feeding HARPS-N and GIANO, is a very interesting forerunner for HIRES