Study of Optical Fibers Scrambling to Improve Radial Velocity Measurements

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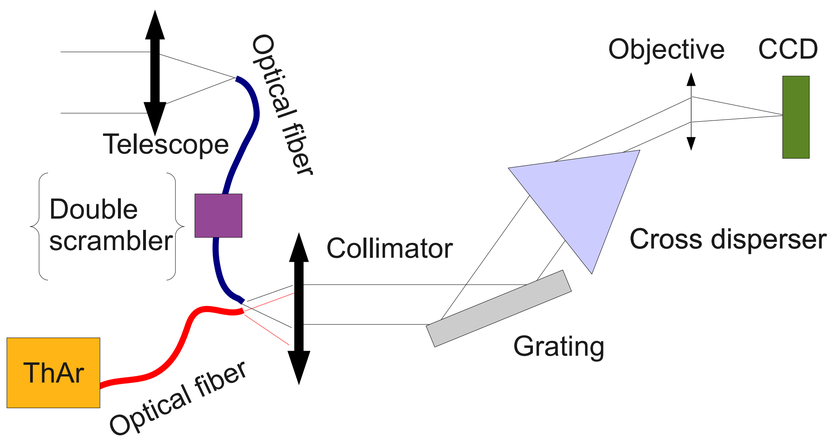
Abstract : The detection of extrasolar planets has been possible first thanks to the use of radial velocity (RV) measurements. This technique has accomplished extraordinary achievements and pushed the planet detection limits down to super-earths. The current precision achieved by RV is around 30 $cm.s^{-1}$. To reach the required precision to detect earth-like planets it is necessary to reach precision of the $cm.s^{-1}$. To rachieve this it is necessary to address astrophysical issues like intrinsic radial velocity noise due to stellar activity but it is also necessary to address some instrumental challenges, in particular in the stability domain, which is one essential element off the RV technique. This poster shows possible improvements in the image scrambling performed by optical fiber necessary to mitigate the effects of atmospheric turbulence and telescope guiding errors. Current state of the art instrument still suffer from residual fluctuations in their illumination : either in the “slit” space or in the pupil space. This produces direct shifts or in chromatic deformations of the spectrum that results in systematic errors on the RV measurement. We present an analysis of present performances of circular step index fibers and the properties of square optical fibers, through simulations and lab experiments, that could improve significantly the scrambling performances of RV instruments.

Analysis of High Precision Fiber-Fed Spectrographs

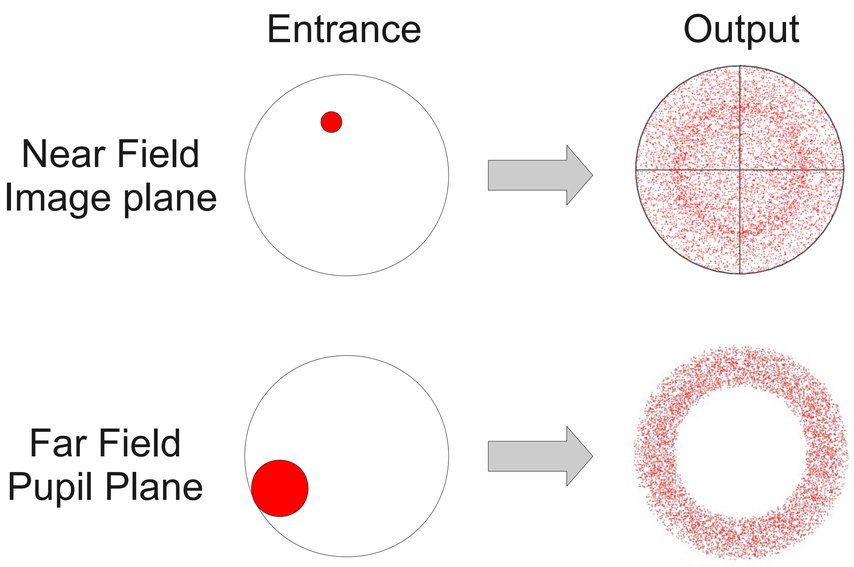
Stable Echelle spectrograph for RV measurement



Measuring λ with pixels :

- λ from a calibration on a known source
- λ from ~ « psf » barycenter
  - **Perturbation :** slit / optical fiber illumination
  - **Perturbation :** pupil illumination variations

Geometrical properties of the standard circular optical fibers

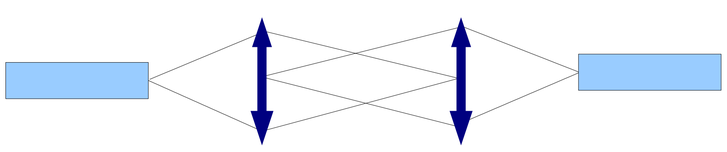


Fiber have a perfect azimutal scrambling, but radial dependance

In practice :

Optical fibers have residual azimutal scrambling imperfections coming from fiber imperfections and strains. Thus the use of double scrambling in order to use the telescope pupil stability.

This device exchange far field and near field



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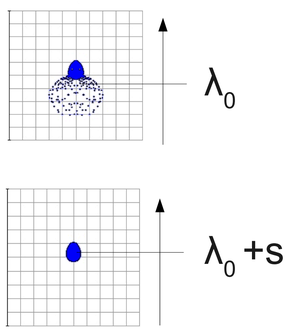
Pupil Effects in Double-Scrambler fed spectrographs

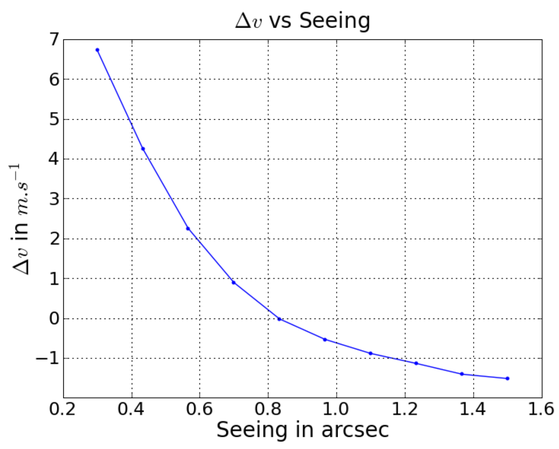
Two effect analysed :
- Seeing variation
- Guiding errors

➔ Specrometer pupil illumination variation
➔Instrument Profile modifications
➔Apparent line shift

Instrument pupil illumination

Instrument profile





Non sequential raytracing simulations of HARPS (fibers of 1" on sky), showing theradial velocity shift produced by the 2 effects

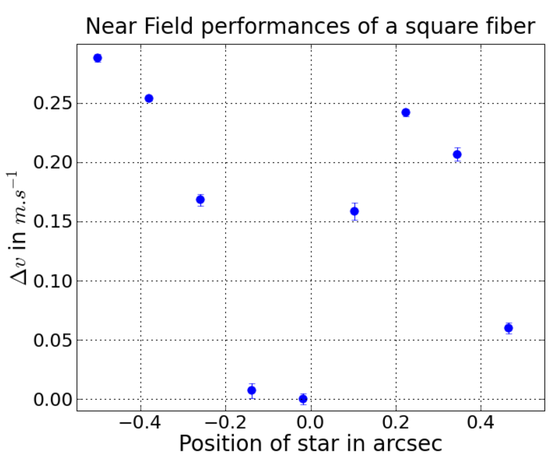
An interesting phenomenon under evaluation is the probable lateral amplification factor, due to obtical aberrations. It could be possible to diagnose and possibly correct these effects by measuring RV independantly on the right and the left of the CCD.

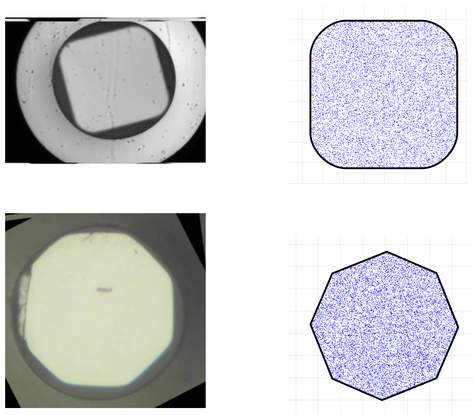
R&D to Reach Earth-Like Planet Detection Precision: New Core Shapes

We study new shapes to gain one order of magnitude in precision. Polygonal filbers are promissing canditate, they show, in simulation, quasi perfect near field scrambling properties. In the far field they are very similar to circular fibers due to the round corners necesary to avoid light losses.

They have to be used in a double scrambler scheme if one wants to get the full benefits of them.

Experimental caracterisations are underway. Preliminary results confirms the wonderful performance they have in the near field.





Photo, and simulation of square and octogonal optical fibers in the near field