**Extreme precision Doppler spectrographs**

*Christian Schwab, 2011*

**Goal:** to characterize Earth-like extrasolar planets in the habitable zone.

**Challenge:** to stabilize and calibrate high resolution spectrographs to a precision of $3 \times 10^{-10}$, corresponding to a Doppler signal of 10 cm/s.

3 key areas to improve:
- Illumination stability
- Calibrator coupling
- Optomechanical stability
  >>> need size reduction!

**Current spectrograph size:**

A single mode (SM) fiber fed spectrograph has a beam size of < 2 inches.

Keck HIRES spectrograph
Extreme precision Doppler spectrographs

- Illumination stability
- Calibrator coupling
  >>>> need to eliminate modal noise!

A SM fiber produces a ‘perfect’, invariant Gaussian beam, identical for the starlight and the wavelength calibrator.

Multi-mode fiber

Single-mode fiber
Extreme precision Doppler spectrographs

Technical problem: SM fiber coupling efficiency is very low

Photonic lanterns enable efficient coupling of SM fibers to a telescope. This is further improved by adaptive optics facilities that concentrate the starlight into a smaller aperture.

LBT AO system

Photonic lantern:

Noordegraaf et al., 2009
Extreme precision Doppler spectrographs

Christian Schwab, 2011

A single mode fiber coupled spectrograph will provide extraordinary wavefront stability, a very compact design and makes optimal use of new, highly accurate wavelength calibrators, leading to superior Doppler precision necessary for the study of earth-like planets.

SM spectrograph schematic: