Abstract

We review the principle of the dispersed fixed delay interferometer (DFDI) method and calculate the fundamental photon-limited radial velocity (RV) uncertainty of DFDI. The Q factor is a measure of flux-normalized doppler sensitivity. We compare $Q_{DFDI}$ and $Q_{DE}$, the Q factors for the conventional direct echelle (DE) method. We find that $Q_{DFDI}$ is a factor of 1.5–4 higher than $Q_{DE}$ at spectral resolution $R$ ranging from 5,000 to 20,000. $Q_{DFDI}$ and $Q_{DE}$ converge at very high $R$ ($R > 100,000$). We also find that DFDI is more advantageous to DE if given a limited detector resource. We simulate the performance of the InfraRed Exoplanet Tracker (IR-ET), which is a DFDI mode of the IRET/FIRST instrument that will be installed at the 3.5 m telescope of Apache Point Observatory in the winter of 2011. The predicted photon-limited RV uncertainty instrument that will be installed at the 3.5 m telescope of Apache Point Observatory in the winter of 2011. The predicted photon-limited RV uncertainty of DFDI is smaller than DE (see table above). For fast rotators ($V_{sin}$ is larger than $J_{DE}$) the advantage of Q factor for DFDI increases. $Q_{DFDI}$ for DFDI and $Q_{DE}$ converge at very high $R$ ($R > 100,000$). For very slow rotators ($V_{sin}$ is less than $J_{DE}$) the advantage of DFDI over DE is obvious at low and medium $R$ ($R < 20,000$). The improvement of DFDI is a 3.5 times ($R=5,000$), 2.5 times ($R=10,000$), and 1.8 times ($R=20,000$), respectively. In other words, optimized DFDI with $R$ of 5,000, 10,000, and 20,000 is equivalent to DE with $R$ of 17,500, 25,000, and 32,000, respectively in terms doppler sensitivity. The improvement of DFDI at $R$ from 20,000 to 50,000 is not as noticeable as low $R$ range. However, DE has to increase exposure time by a factor of at least 1.5 times in order to reach the same RV precision as DFDI assuming the same instrument throughput. The difference between DFDI and DE becomes negligible when $R$ is over 100,000. For relatively faster rotators (5 km/s < $V_{sin}$ < 10 km/s), the improvement brought by DFDI is less obvious than it is for very slow rotators.

Comparison of DFDI and Echelle Method

Instead of seeing a stellar spectrum, we see a fringing spectrum, which is a result of superimposing the interferometer comb on an intrinsic stellar spectrum. RV is measured by monitoring the phase shift of each wavelength channel.

Comparison With the Same CCD Detector

$\Delta \lambda = \frac{N_{\text{pixel}}}{R \cdot \epsilon \cdot \lambda}$

where $N_{\text{pixel}}$ is the number of pixels available on a detector, $\lambda$ is the central wavelength, $R$ is the spectral resolution, $\epsilon$ is the number of photons per resolution element (RE), and $F_{\text{detector}}$ is the number of pixels sampling one spectral order including the space between orders.

Earth-like Planet Search Around M Dwarfs

As of April 2011, there were only five M dwarf exoplanets discovered in the northern hemisphere. We compare the velocity semi-amplitude $K$ of these exoplanets and RV uncertainty predicted for IR-ET (see the table above). All of them would be detectable by IR-ET under photon-limited conditions. Therefore, IR-ET is a suitable instrument conducting follow-up RV measurement. We also compare the velocity semi-amplitude, $K$, if there is an Earth-mass planet located within the habitable zone (0.05 AU away from the host star) and the IR-ET photon-noise detection limit. We find that the RV uncertainty of IR-ET is slightly larger than $K$. However, it should be able to discover Earth-like exoplanets in HZ around bright stars under photon-limited conditions.