Current Status and Future Prospect of Exoplanet Search in Xinglong

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Histogram of Doppler & Transit Planet Detected by Year
Histogram of Doppler & Transit Planet Detected by Magnitude

Numbers of Exoplanets of Different Brightness (Update: 2008/11/06)
Histogram of Doppler & Transit Planet Detected by Semi-amplitude
Highlight of Exoplanet Search in the Past Year

- Imaging of the two planetary systems – Fomalhaut & HR 8799, both of which are A-type stars. (Kalas et al. / Marois et al.)
- Possible detection of planet around beta Pic (Lagrange et al.)
- CO$_2$ detected in HD 189733 b (Swain et al.)
- First transit super-Earth: CoRoT-7 b (Feb. 2009) (Rouan et al.)
- Two super-Earths, CoRoT-7 b & c (Sep. 2009) (Queloz et al.)
- First astrometry exoplanet candidate – VB 10 b (Pravdo & Shaklan)
- Successful launch of Kepler mission
- Gl 581 e, planet with the lowest mass discovered yet (Mayor et al.)
5 Years of Exoplanet Search in Xinglong
Instrument Configuration

- 2.16m telescope
- Iodine cell + Coude Echelle Spectrograph
- Resolution: 37,000
- Wv range: 47nm in 500~600nm

- CCD Upgrade in April, 2009
  - 1k x 1k CCD → 2k x 2k CCD
  - 25micron/pxl → 13micron/pxl
  - wv. coverage: do not change
  - slit: 0.5mm → 0.45mm
  - CCD sampling: 1.6 pts → 2.9 pts
5 Years of Exoplanet Search in Xinglong
- Observation Nights
5 Years of Exoplanet Search in Xinglong
- Target Observations

Total: 119 targets, 1,639 obs
including standard stars,
Xinglong sample,
& Subaru follow up

Observation Numbers of Stars in Xinglong

<table>
<thead>
<tr>
<th>Number of Observations</th>
<th>Number of Stars</th>
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<tbody>
<tr>
<td>1-5</td>
<td>25</td>
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<tr>
<td>6-10</td>
<td>40</td>
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<td>11-15</td>
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<td>16-20</td>
<td>10</td>
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<td>21-50</td>
<td>5</td>
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<td>&gt;50</td>
<td>5</td>
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5 Years of Exoplanet Search in Xinglong
- Some results

New CCD
Calculated by Sato, B.

11 Com
5 Years of Exoplanet Search in Xinglong
- Discoveries of China-Japan joint program (1)

5 Years of Exoplanet Search in Xinglong
- Discoveries of China-Japan joint program (2)

5 Years of Exoplanet Search in Xinglong
- Data archive system

- Real-time logging
- Convenient historical query
- Automatic statistics & efficiency estimation
- Observing sequence optimization
- Different instruments & telescopes capability
5 Years of Exoplanet Search in Xinglong
- New data reduction pipeline

• IRAF based
• “Repeat Mode” can significantly reduce the time consuming in data reduction process
• Cosmic Ray masks can generated by both algorithm & manual identification
• Bad pixels are repaired by cubic spline interpolation
• Images combined only if: two continual exposure for same targets. Do not use for radial velocity calculation but only for abundances analytics
Future of Exoplanet Search in Xinglong
- New echelle spectrograph

- Fiber-feed, two fibers simultaneously
  for star fiber: switch between 1.6" one and 2.4" one (core diameter)

- Resolution:
  32000~115000 (2.4" fiber)
  48000~115000 (1.6" fiber)

- 3.3 pixels sampling

- 4k x 4k CCD

- Wavelength coverage: 380~970nm.

- Thermal control $T<\pm 0.1{^\circ}\text{C}$
Two Major Calibration Techniques

ThAr Simultaneously Reference

Iodine Cell Technique

ThAr lines
Stellar spectra
Comparison of the two techniques

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<tr>
<th>ThAr Simultaneously Reference</th>
<th>Iodine Cell Technique</th>
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<tbody>
<tr>
<td>• Wide band (300~700nm), but sparse lines</td>
<td>• Dense line but narrow band (500~600 nm)</td>
</tr>
<tr>
<td>• ThAr lamp die with time</td>
<td>• Spectra polluted by iodine lines, low efficiency</td>
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<tr>
<td>• Complicated Technology</td>
<td>• Good long-term stability</td>
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<td></td>
<td>• Easy attached &amp; removed</td>
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<td>• Complicated radial velocity calculation</td>
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HARPS 6ν~1.2 m/s

AAPS 6ν~1-2 m/s
Looking for New Reference Source - Laser Frequency Comb

$f_{\text{rep}}$: repetition frequency
$f_{\text{FSR}}$: free spectra range
First Application of Astro-Comb

Residual=9m/s for 3 GHz repetition frequency

T. Steinmetz et al, Science, 321, 1335

German Vacuum Tower Telescope
R~20,000
An LFC Module in Institute of Physics, CAS

F~350 MHz, which is too low for high dispersion echelle spectrograph. For new R~115,000 spectrograph in Xinglong, proper frequency is around 24.5GHz. A close-loop, self-referenced Fabry - Perot cavity is needed for “filter” the comb every 70 ones.
Error Estimation of LFC

\[ 6v = A \frac{V_{fwhm}}{\text{SNR/sqrt}(n)} \quad V_{fwhm} = \frac{c}{R} \]

R \approx 100,000 \quad 4096\text{px CCD} \quad \sim 540 \text{ combs each order}

6v = 15\text{cm/s}

**Laser Frequency Comb is an ideal wavelength calibration source**
A problem is **wavelength coverage**! Current LFC worked on NIR band (>700 nm), in which the stellar spectra have too many telluric lines and too few feature to get a high precision.

- **mutli-channel cavity** to cover the 500-900 nm?
We must pay attention to the fiber, which links the telescope and spectrograph.

The laser frequency comb is one hundred times better than we need, the major limitation comes from the guiding error (such as HARPS), and the uniform illumination of the fiber.

We must pay attention to the fiber, which links the telescope and spectrograph.
Non-uniform Illumination of LAMOST Fiber
Non-uniform Illumination of Fiber

Un-symmetric illumination of fiber may also destroy the “gaussian” instrumental profile in far field, and make iodine spectra even harder to fit!
Fiber Scrambler

Pasquini, 2009
2009 Nobel Prize for Physics

Willard Boyle, Charles Kao (高锟), and George Smith

For their contribution on fiber and CCD!