Current Status and Future Prospect of Exoplanet Search in Xinglong

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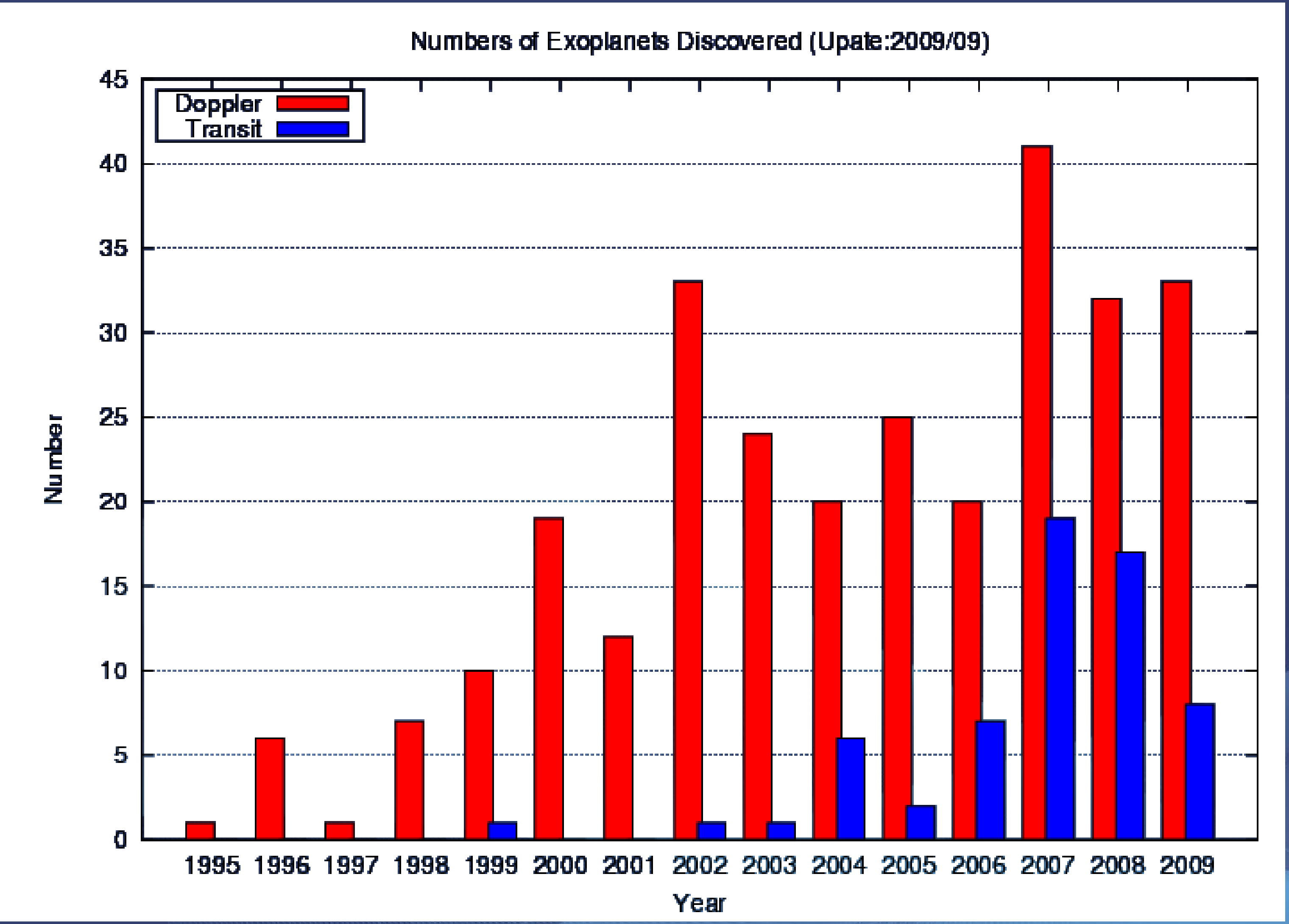
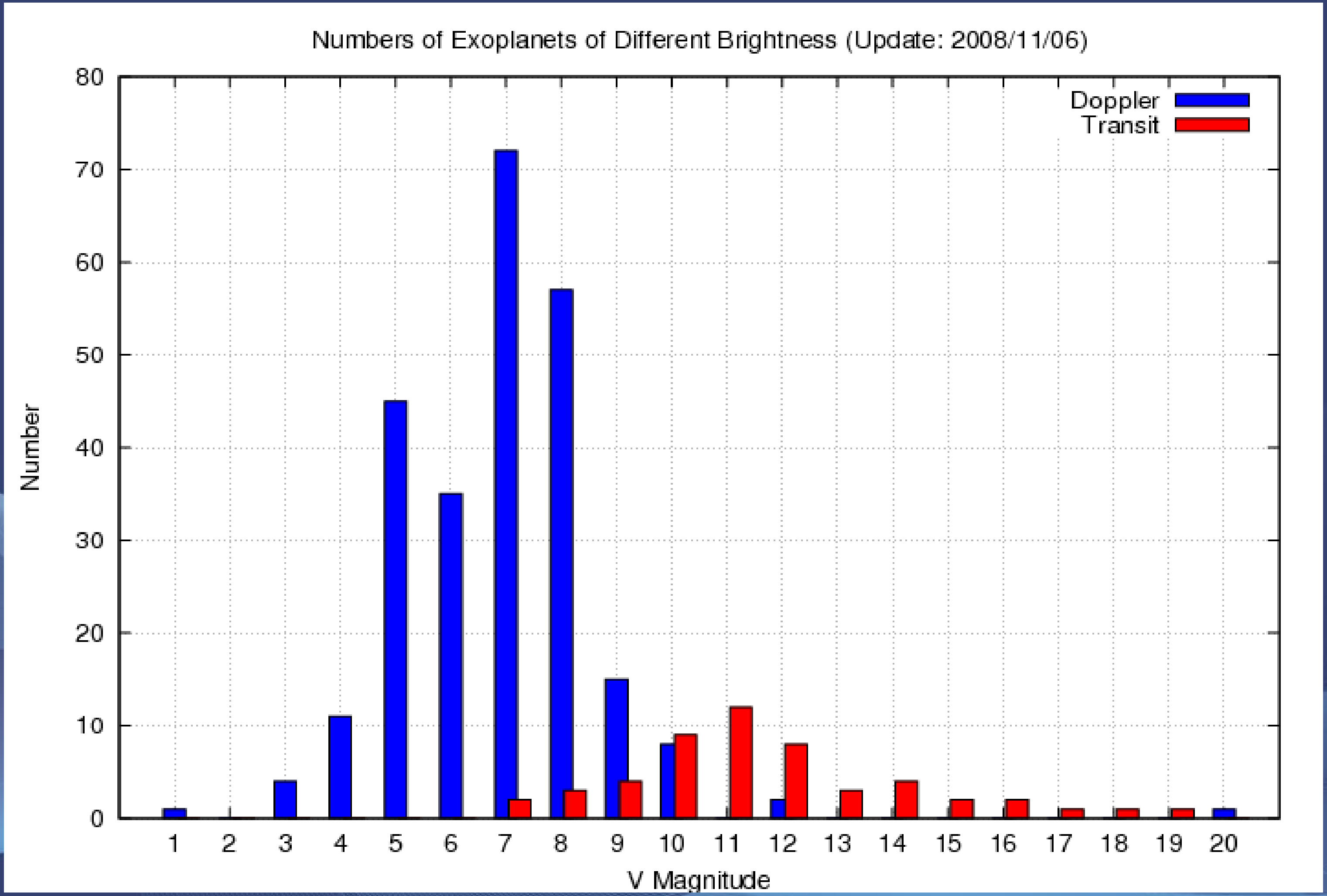
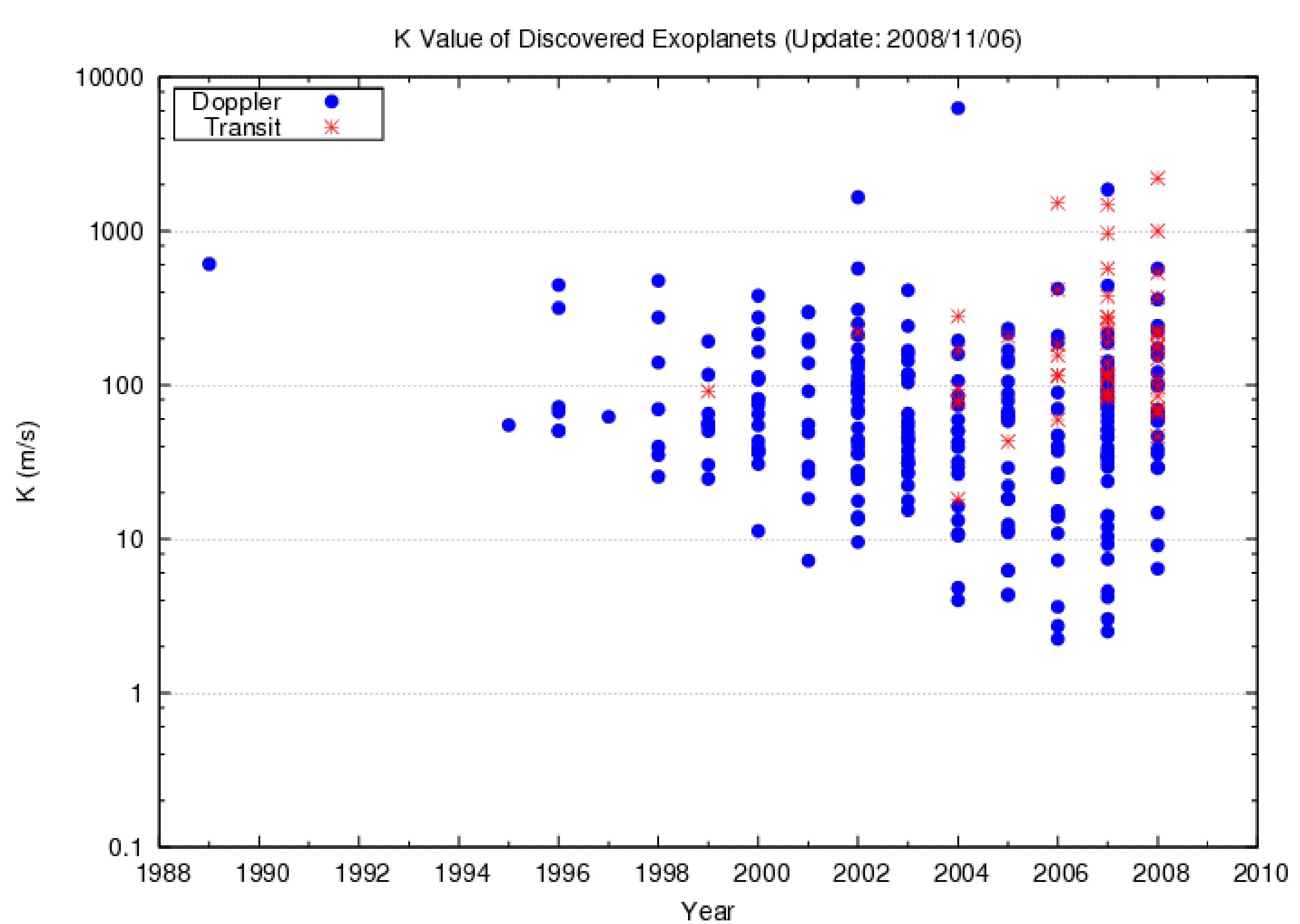
Histogram of Doppler & Transit Planet Detected by Year



Histogram of Doppler & Transit Planet Detected by Magnitude



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 lauch 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

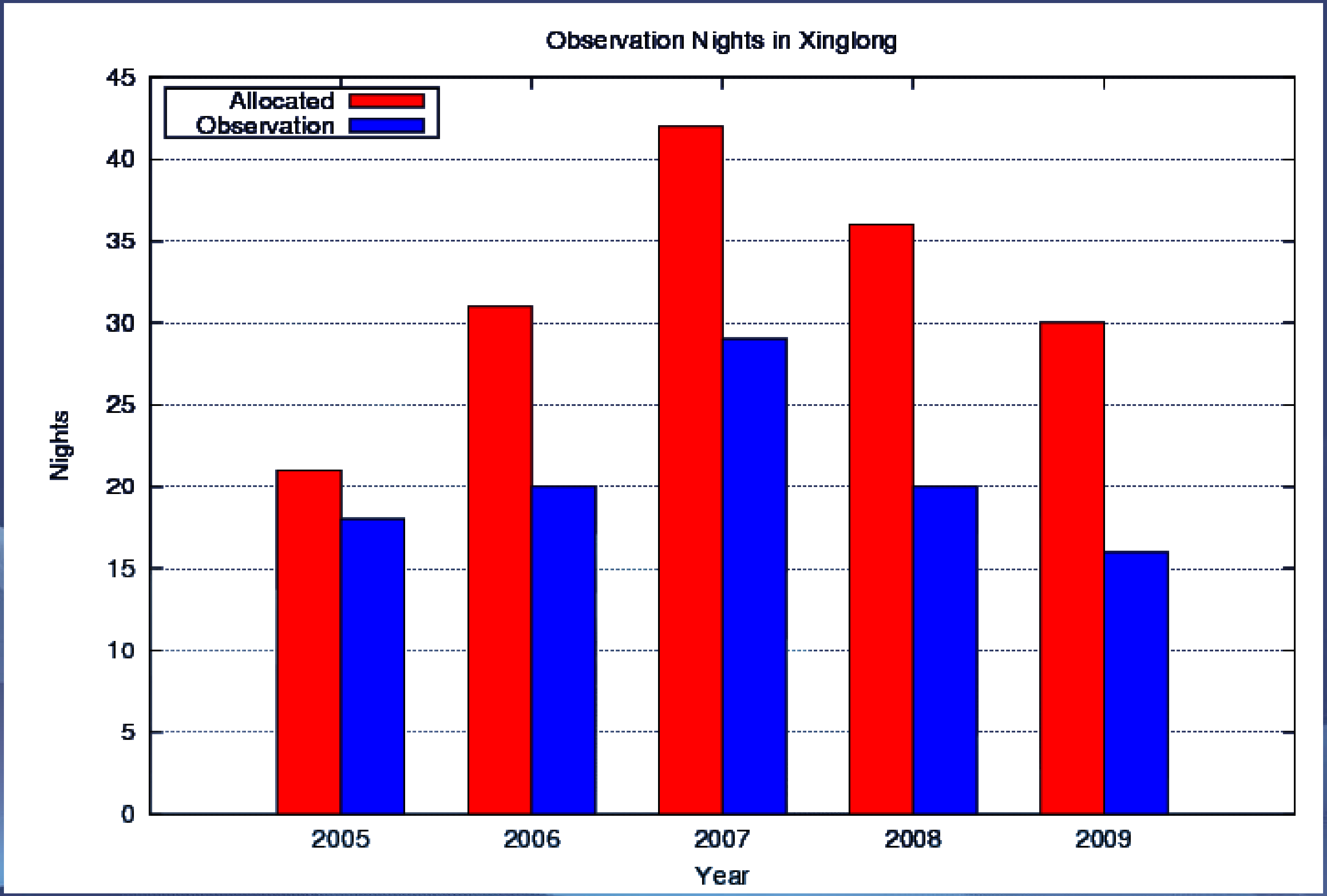
  wv. coverage: do not change

  slit: 0.5mm → 0.45mm

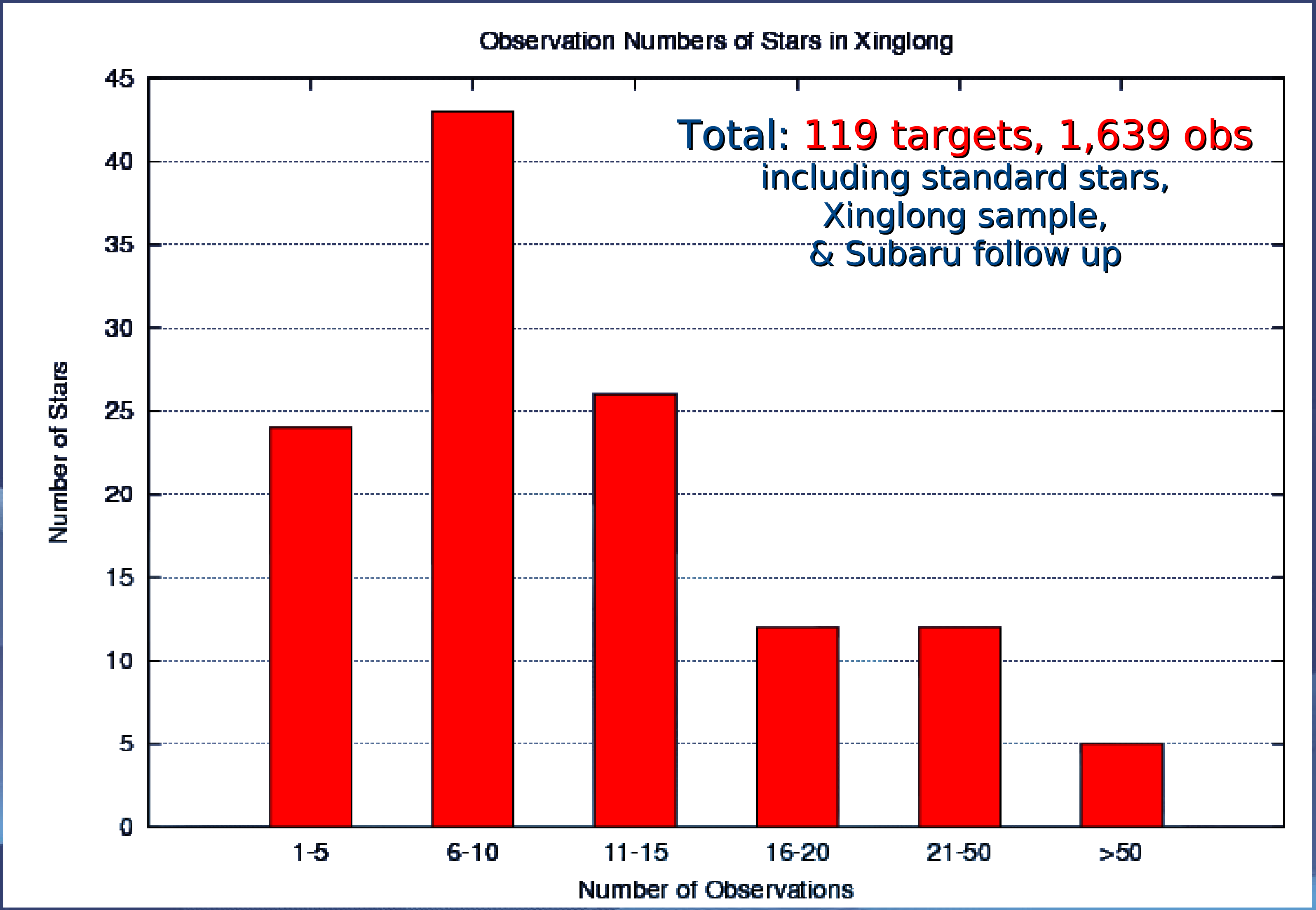
  CCD sampling: 1.6 pts → 2.9 pts

5 Years of Exoplanet Search in Xinglong

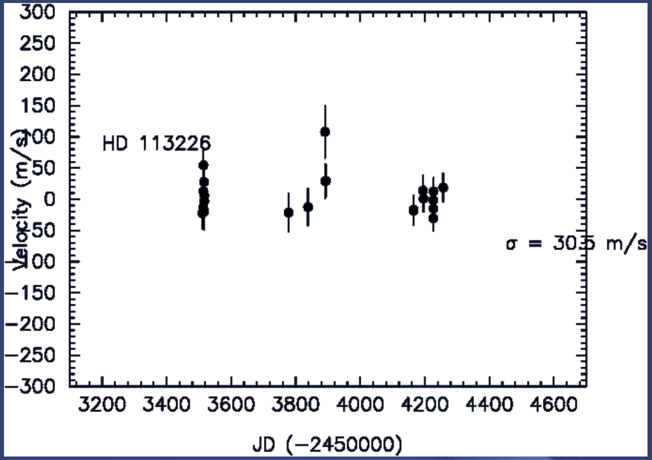
- Observation Nights

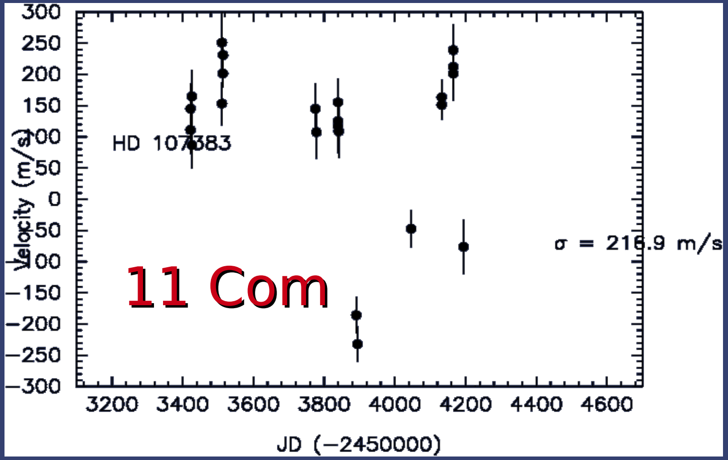


5 Years of Exoplanet Search in Xinglong
- Target Observations



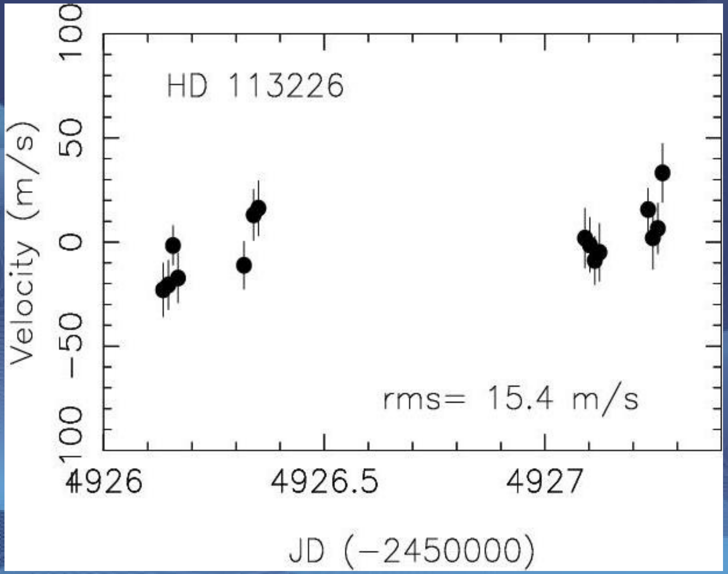
5 Years of Exoplanet Search in Xinglong
- Some results





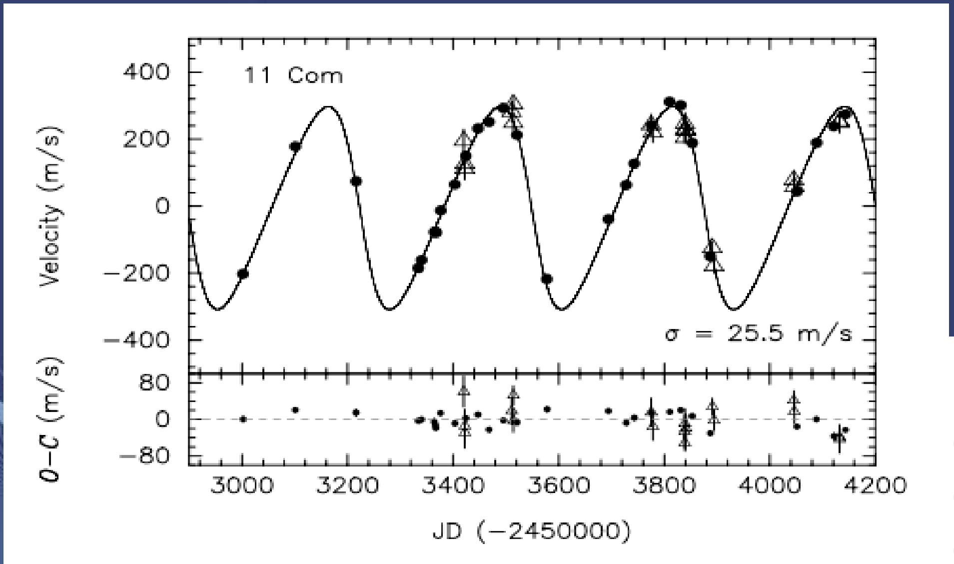
→

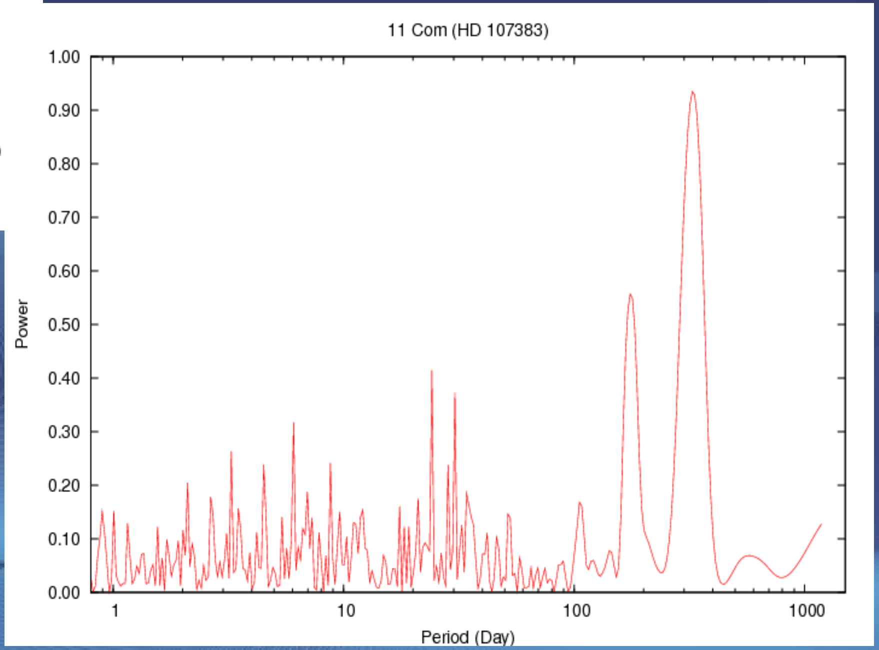
New CCD
Calculated by Sato, B.



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

- Brown dwarf candidate with minimum mass of 19 MJ (11 come b) in 2008 (Liu et al. 2009, *ApJ*, 672, 553)

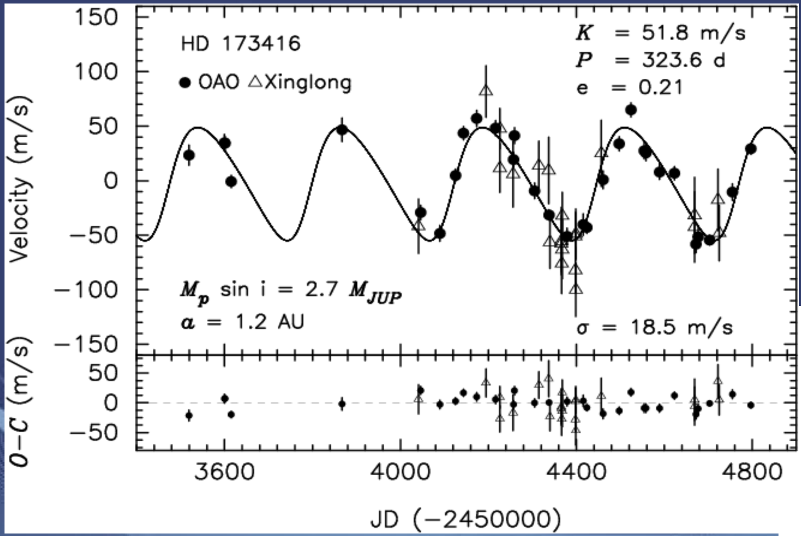


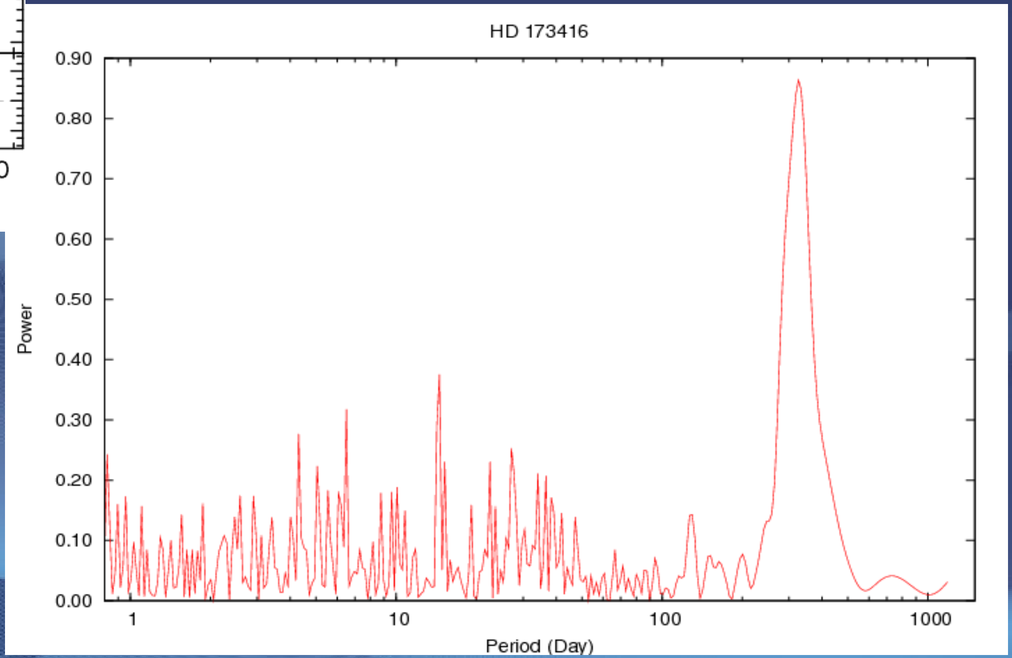


5 Years of Exoplanet Search in Xinglong

- Discoveries of China-Japan joint program (2)

- Exoplanet candidate with minimum mass of 2.7 MJ (HD 173416 b) in 2009 (Liu. et al. 2009, *Research in A&A*, 9, 1)

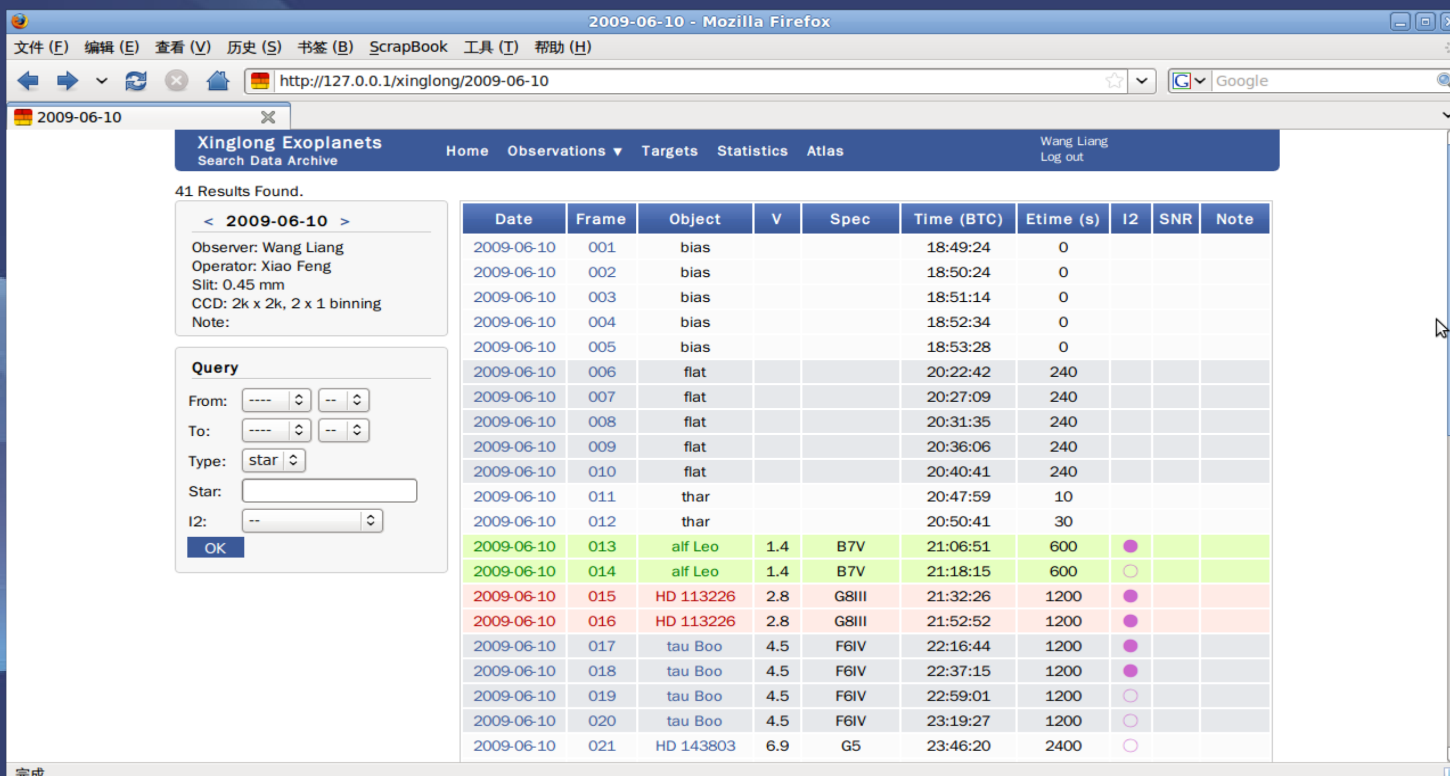




5 Years of Exoplanet Search in Xinglong

- Data archive system

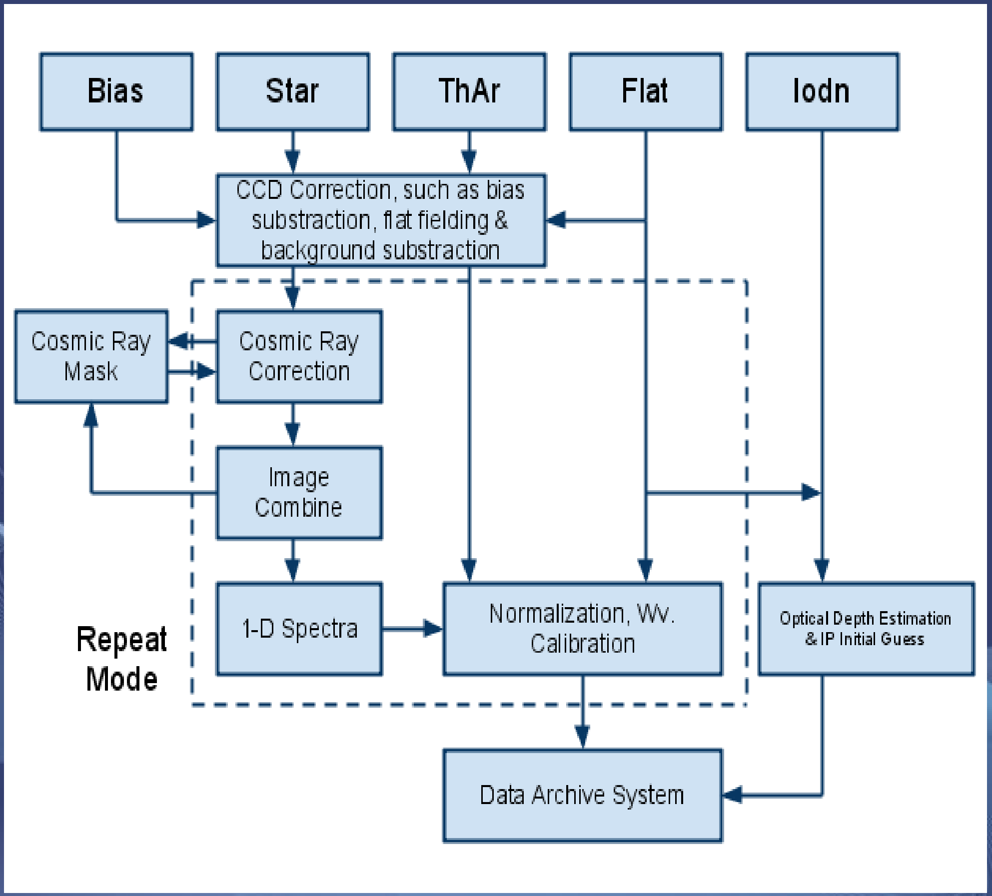
- Real-time logging
- Convenient historical query
- Automatic statistics & efficiency estimation
- Observing sequence optimization
- Different instruments & telescopes capability



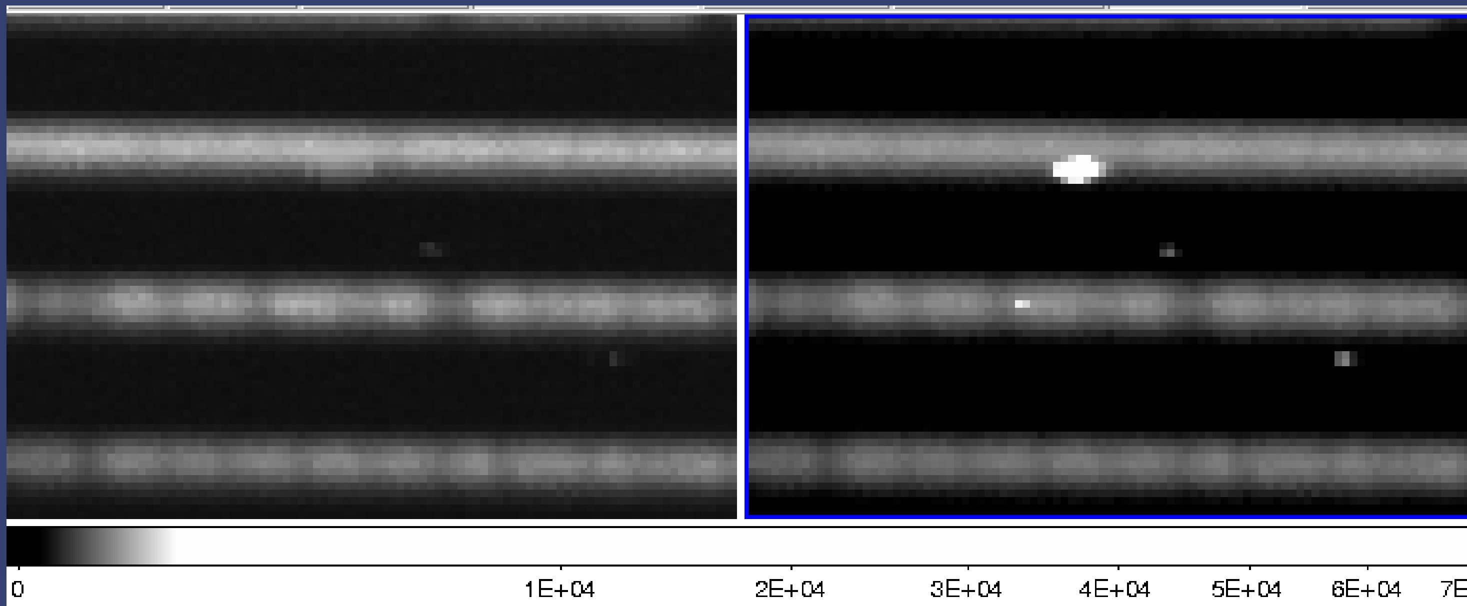
Date	Frame	Object	V	Spec	Time (BTC)	Etime (s)	I2	SNR	Note
2009-06-10	001	bias			18:49:24	0			
2009-06-10	002	bias			18:50:24	0			
2009-06-10	003	bias			18:51:14	0			
2009-06-10	004	bias			18:52:34	0			
2009-06-10	005	bias			18:53:28	0			
2009-06-10	006	flat			20:22:42	240			
2009-06-10	007	flat			20:27:09	240			
2009-06-10	008	flat			20:31:35	240			
2009-06-10	009	flat			20:36:06	240			
2009-06-10	010	flat			20:40:41	240			
2009-06-10	011	thar			20:47:59	10			
2009-06-10	012	thar			20:50:41	30			
2009-06-10	013	alf Leo	1.4	B7V	21:06:51	600	●		
2009-06-10	014	alf Leo	1.4	B7V	21:18:15	600	○		
2009-06-10	015	HD 113226	2.8	G8III	21:32:26	1200	●		
2009-06-10	016	HD 113226	2.8	G8III	21:52:52	1200	●		
2009-06-10	017	tau Boo	4.5	F6IV	22:16:44	1200	●		
2009-06-10	018	tau Boo	4.5	F6IV	22:37:15	1200	●		
2009-06-10	019	tau Boo	4.5	F6IV	22:59:01	1200	○		
2009-06-10	020	tau Boo	4.5	F6IV	23:19:27	1200	○		
2009-06-10	021	HD 143803	6.9	G5	23:46:20	2400	○		

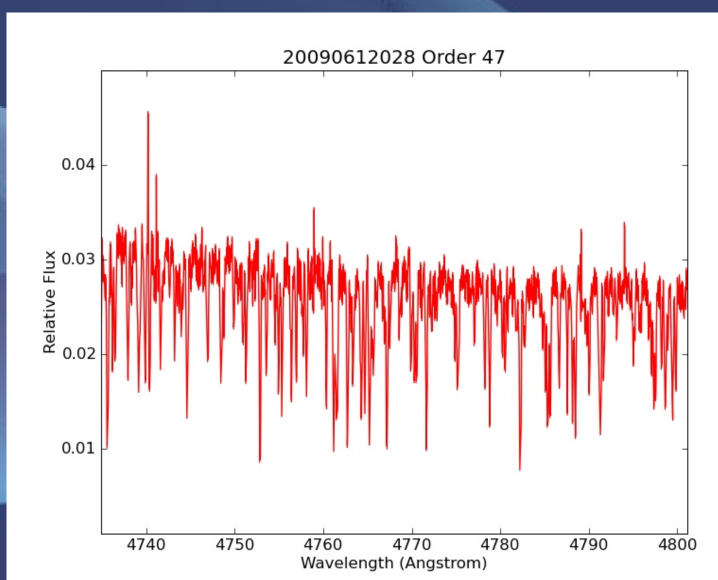
5 Years of Exoplanet Search in Xinglong

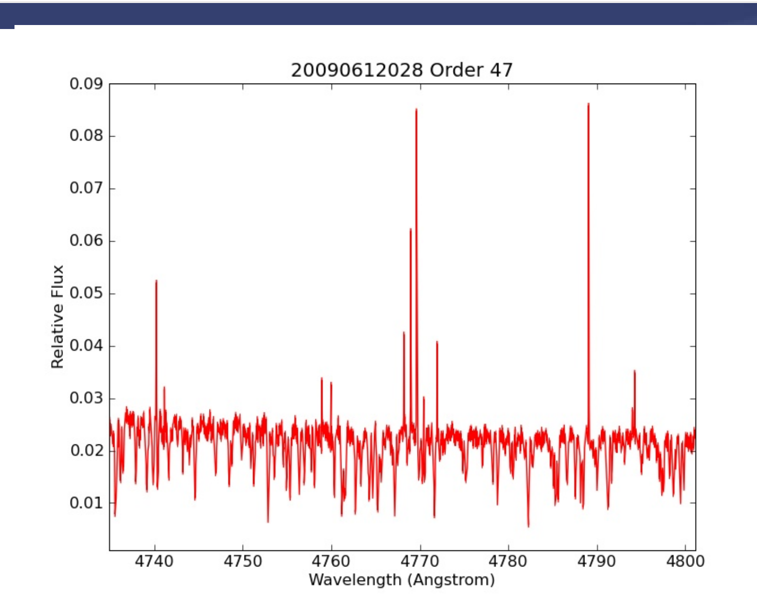
- New data reduction pipeline



- 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


0
1E+04
2E+04
3E+04
4E+04
5E+04
6E+04
7E+


20090612028 Order 47
Relative Flux
0.01
0.02
0.03
0.04
4740
4750
4760
4770
4780
4790
4800
Wavelength (Angstrom)


20090612028 Order 47
Relative Flux
0.01
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0.09
4740
4750
4760
4770
4780
4790
4800
Wavelength (Angstrom)

Future of Exoplanet Search in Xinglong
- New echelle spectrograph

- Fiber-feed, two fibers simultaneously

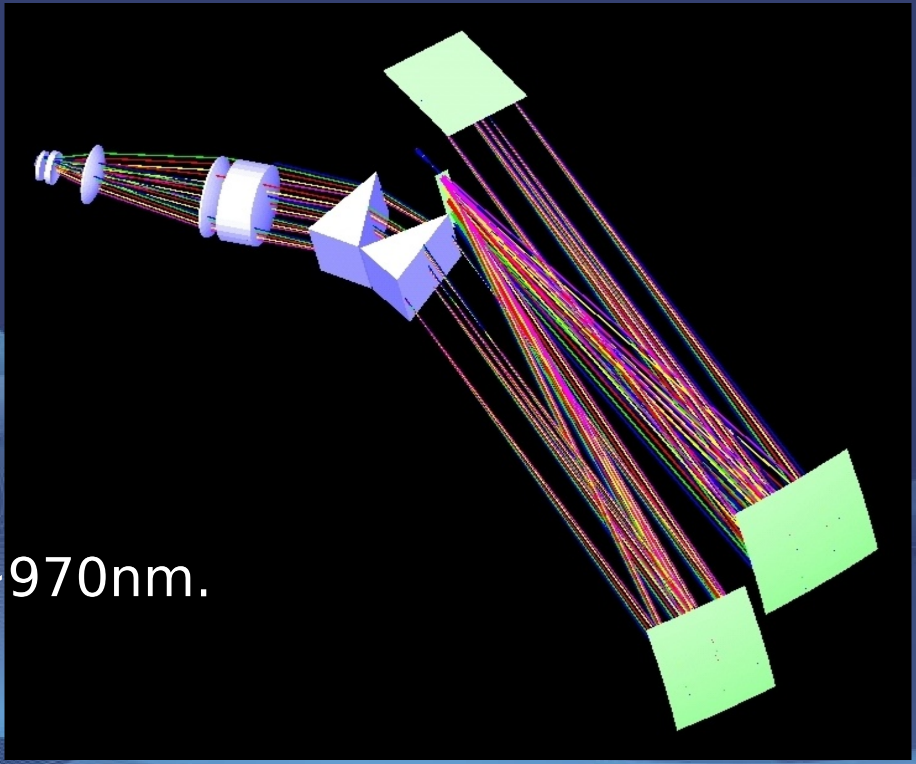
for star fiber: switch between 1.6" one and 2.4" one (core diameter)

- Resolution:

32000~115000 (2.4” fiber)

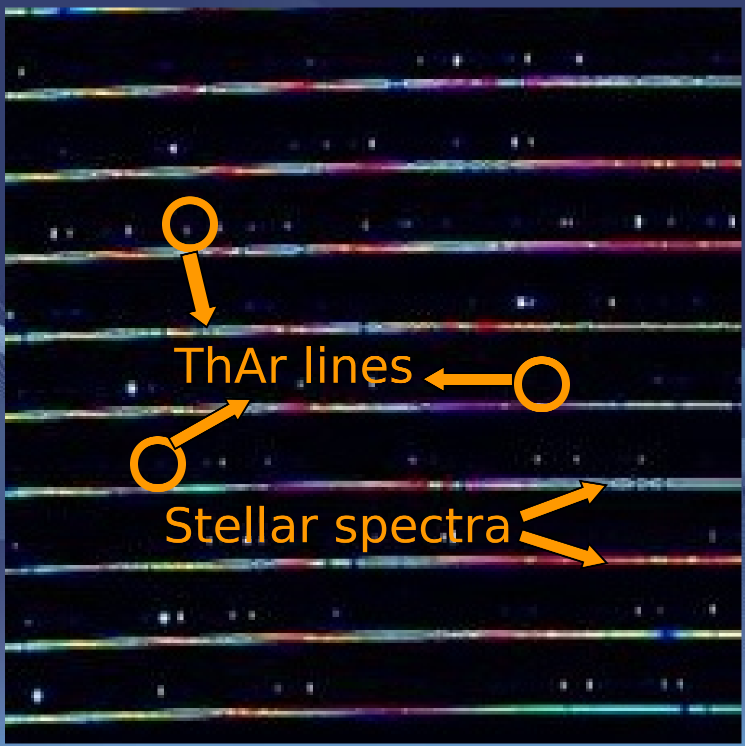
48000~115000 (1.6” fiber)

- 3.3 pixels sampling
- 4k x 4k CCD
- Wavelength coverage: 380~970nm.
- Thermal control T<±0.1˚C

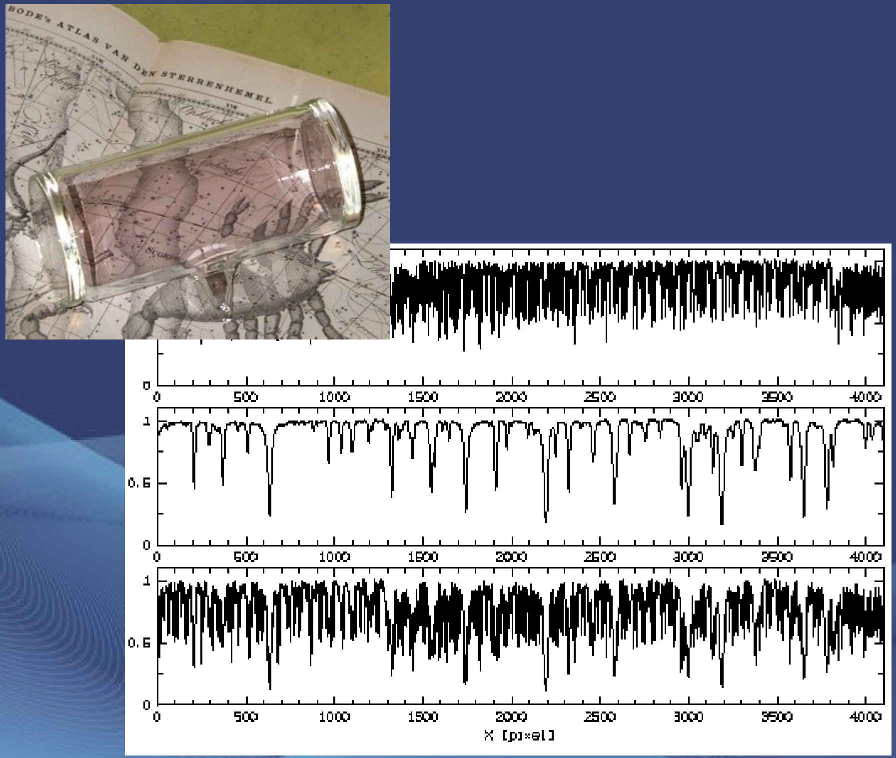


Two Major Calibration Techniques

ThAr Simultaneously Reference



Iodine Cell Technique



Comparison of the two techniques

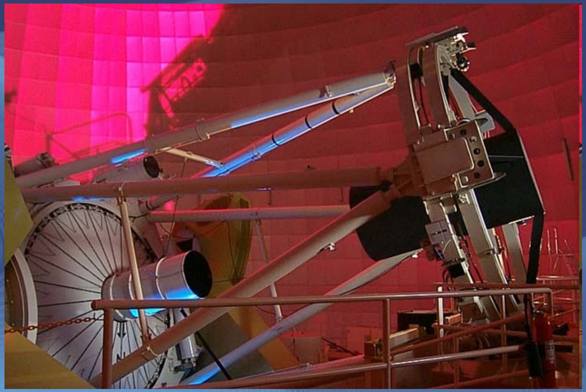
ThAr Simultaneously Reference

- Wide band (300~700nm), but sparse lines
- ThAr lamp die with time
- Complicated Technology

HARPS бv~1.2 m/s

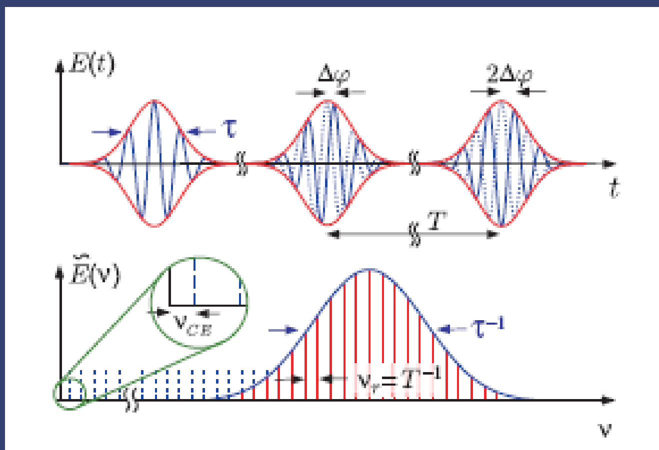
Iodine Cell Technique

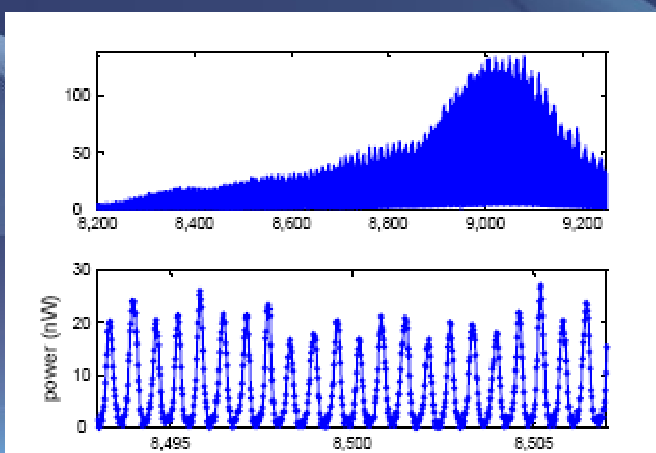
- Dense line but narrow band (500~600 nm)
- Spectra polluted by iodine lines, low efficiency
- Good long-term stability
- Easy attached & removed
- Complicated radial velocity calculation

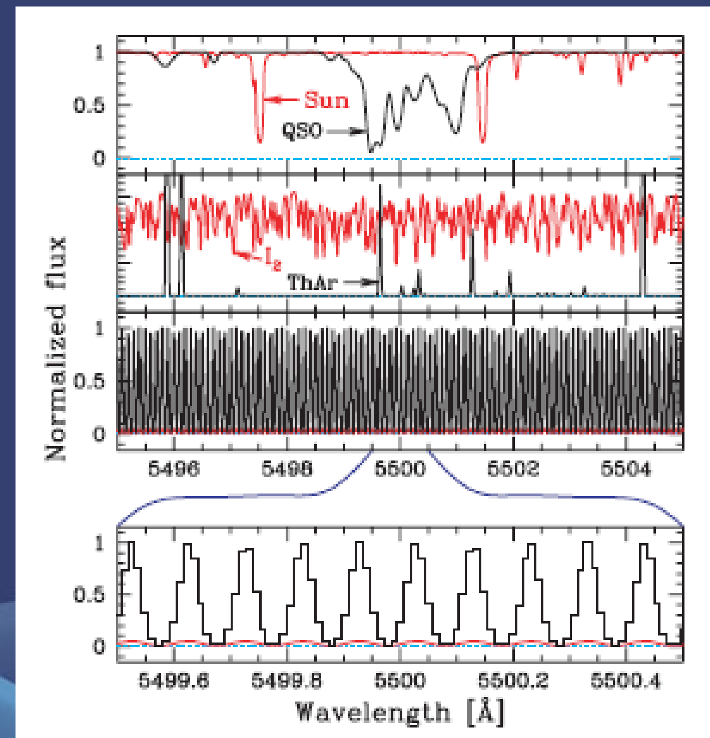


AAPS бv~1-2 m/s

Looking for New Reference Source - Laser Frequency Comb



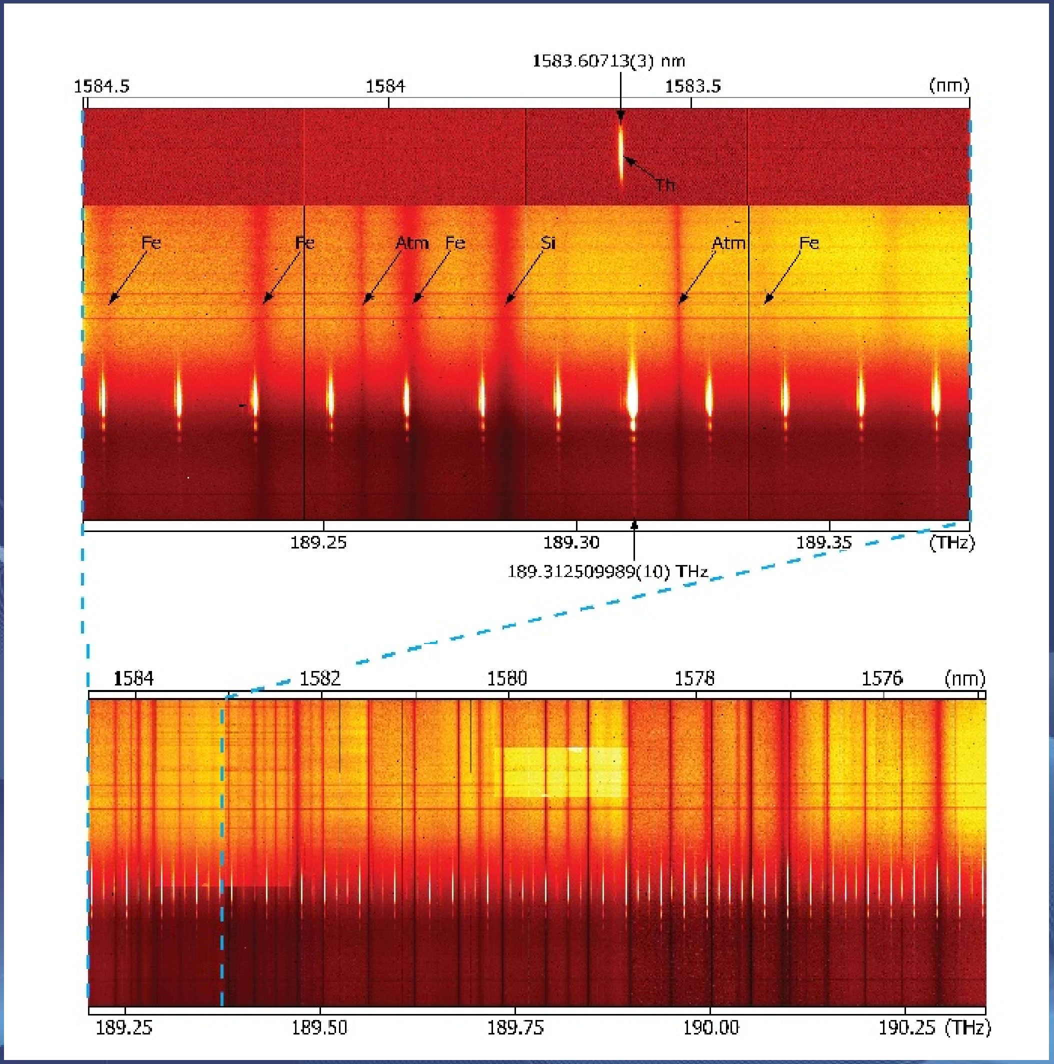




f_{rep}: repetition frequency

f_{FSR}: free spectra range

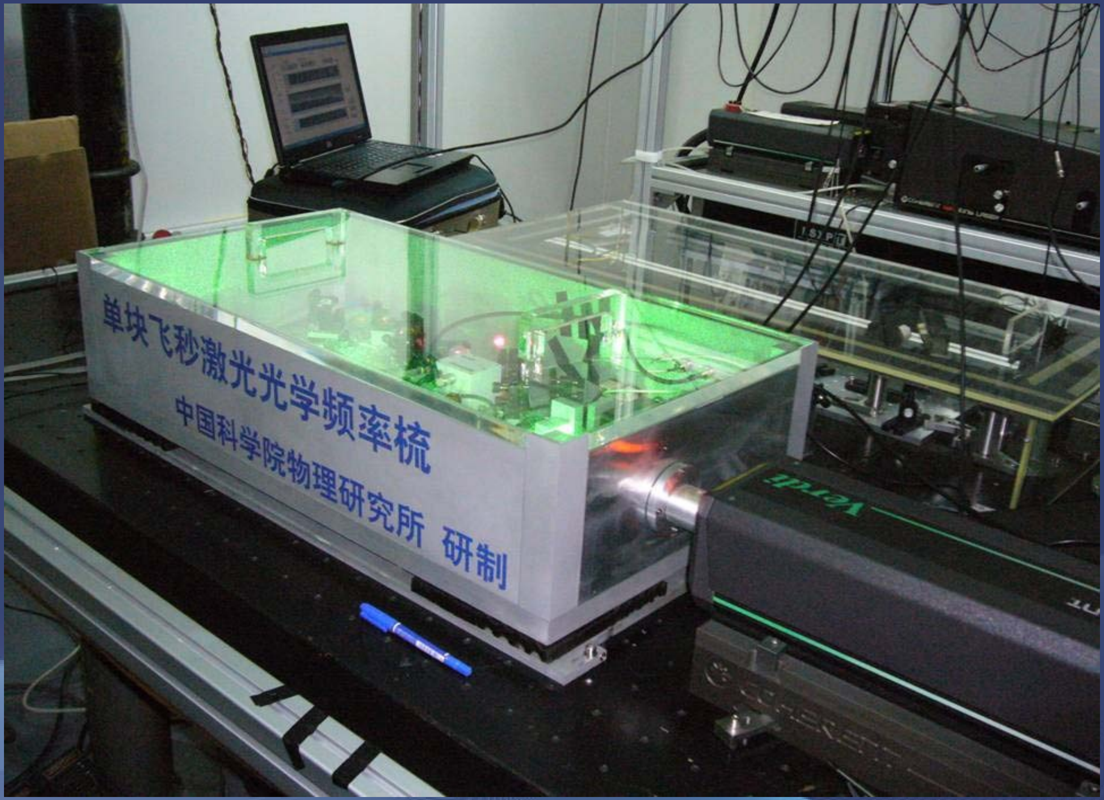
First Application of Astro-Comb



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

6$v = A * V_{fwhm} / SNR / sqrt(n)$ $V_{fwhm} = c/R$

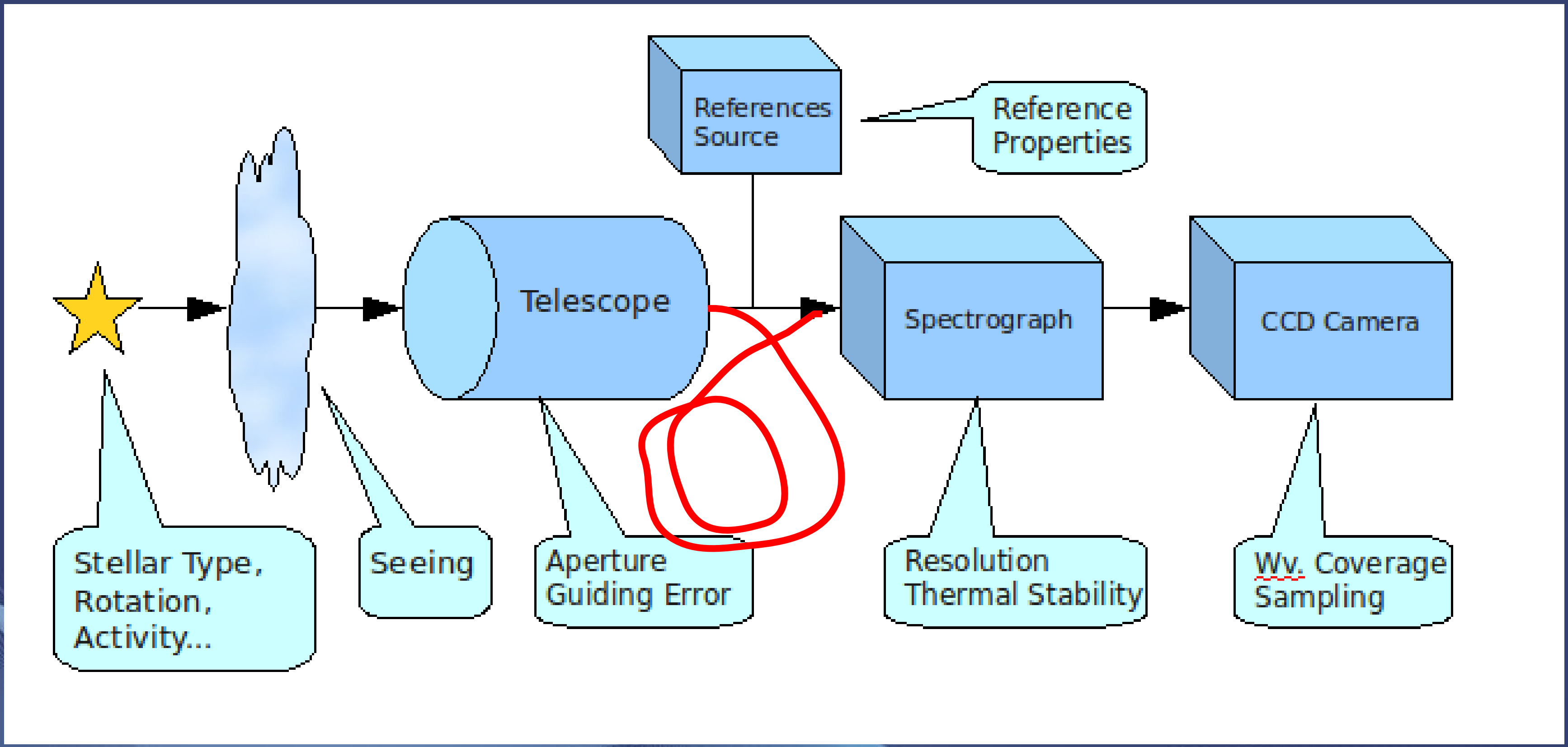
R~100,000 4096px CCD ~540 combs each order

6v= 15cm/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.

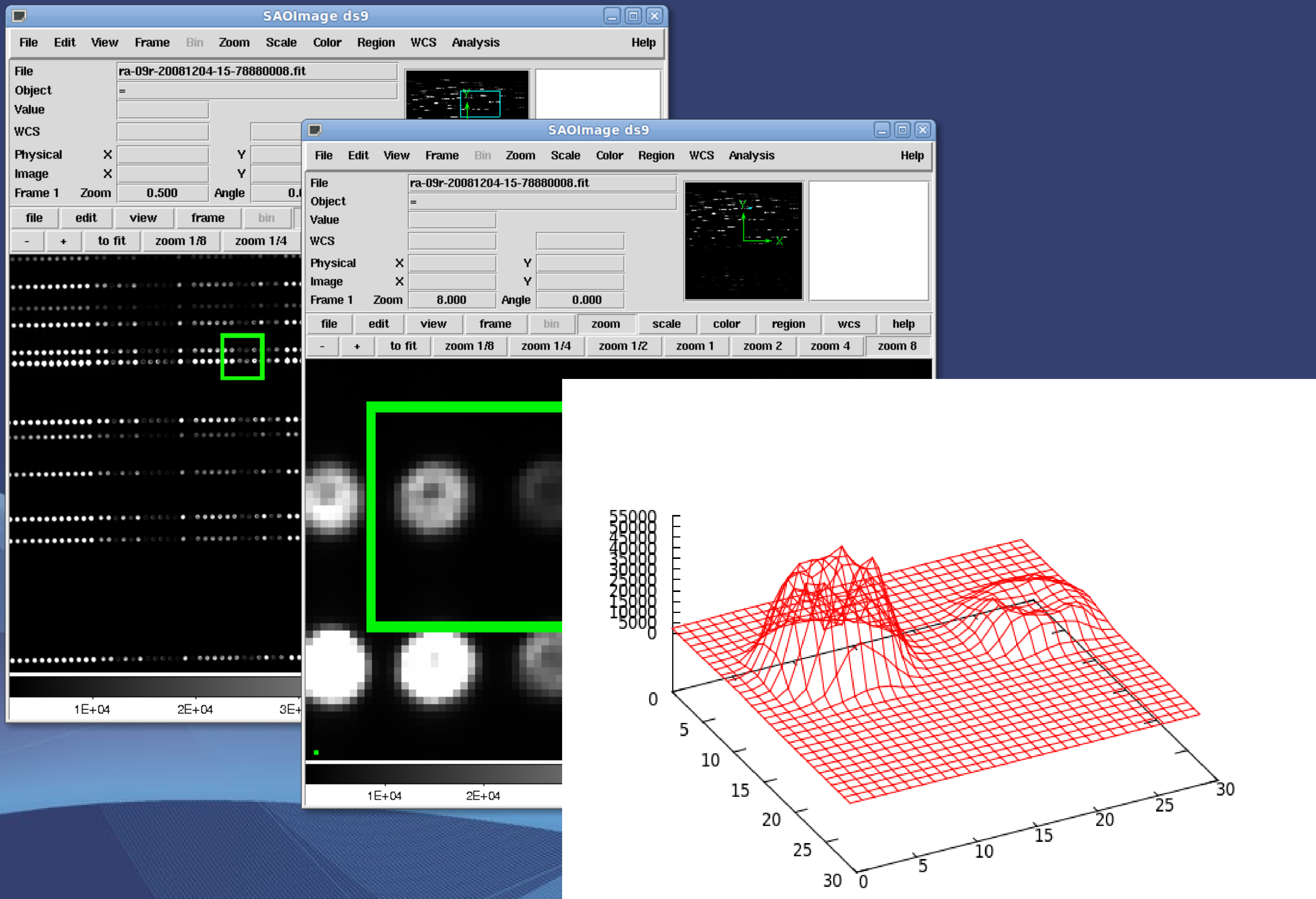
- mutli-channel cavity to cover the 500-900 nm ?



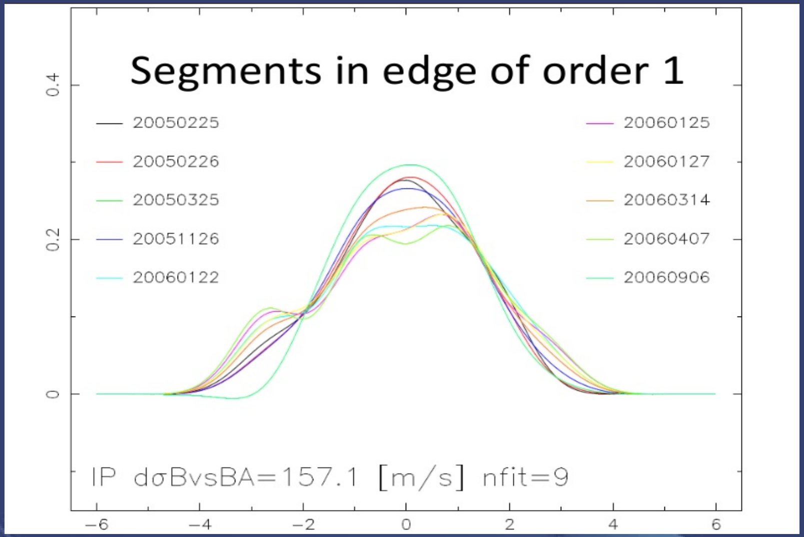
The laser frequency comb is one hundred times better than we need, the major limitation comes from the guiding error (such as HARPS), and the uniform illumination of the fiber.

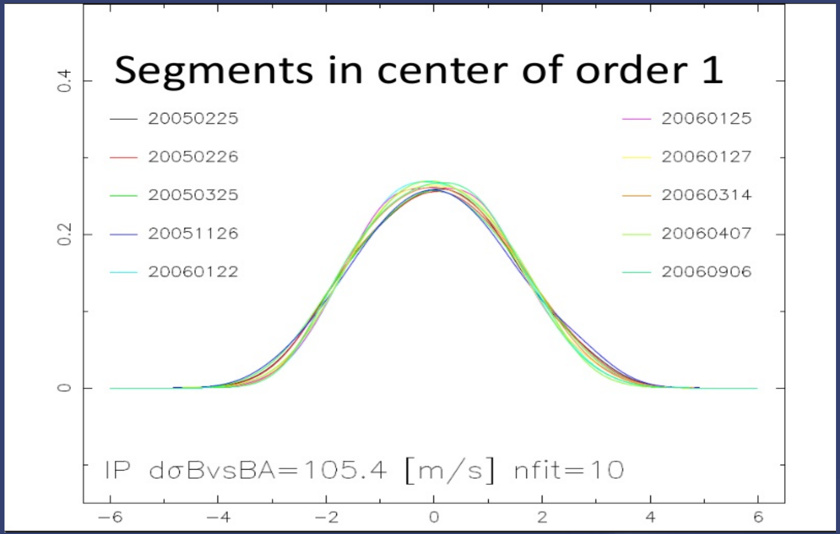
We must pay attention to the fiber, which links the telescope and spectrograph.

Non-uniform Illumination of LAMOST Fiber



Non-uniform Illumination of Fiber

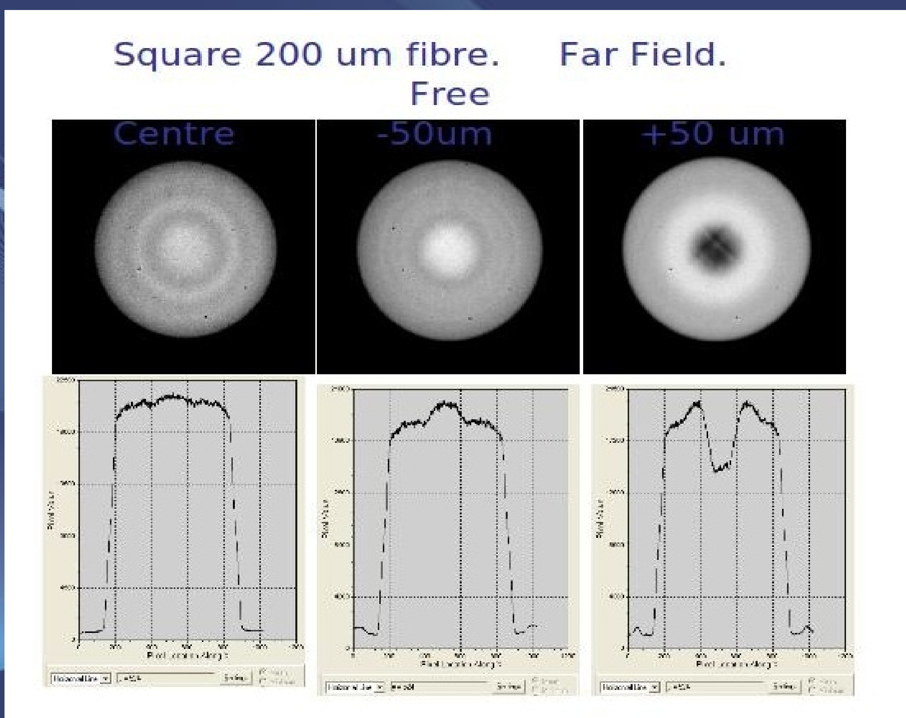


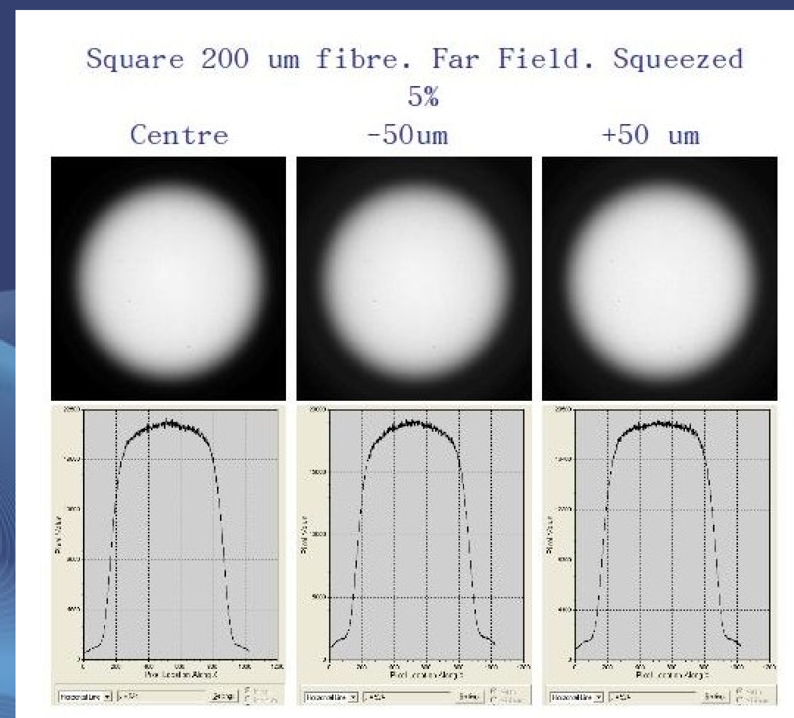


Instrumental Profiles of Fiber-feed BOES, Provided by Omiya, 2009

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

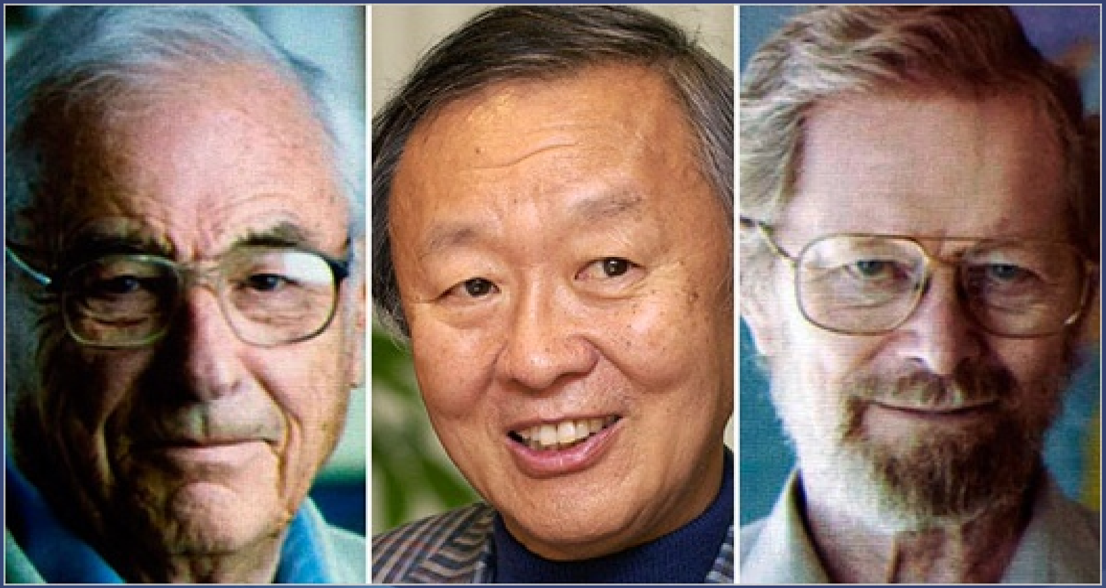
Fiber Scrambler





Pasquini, 2009

2009 Nobel Prize for Physics



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

For their contribution on fiber and CCD!