Daytime Stellar Doppler spectroscopy

First results and prospects

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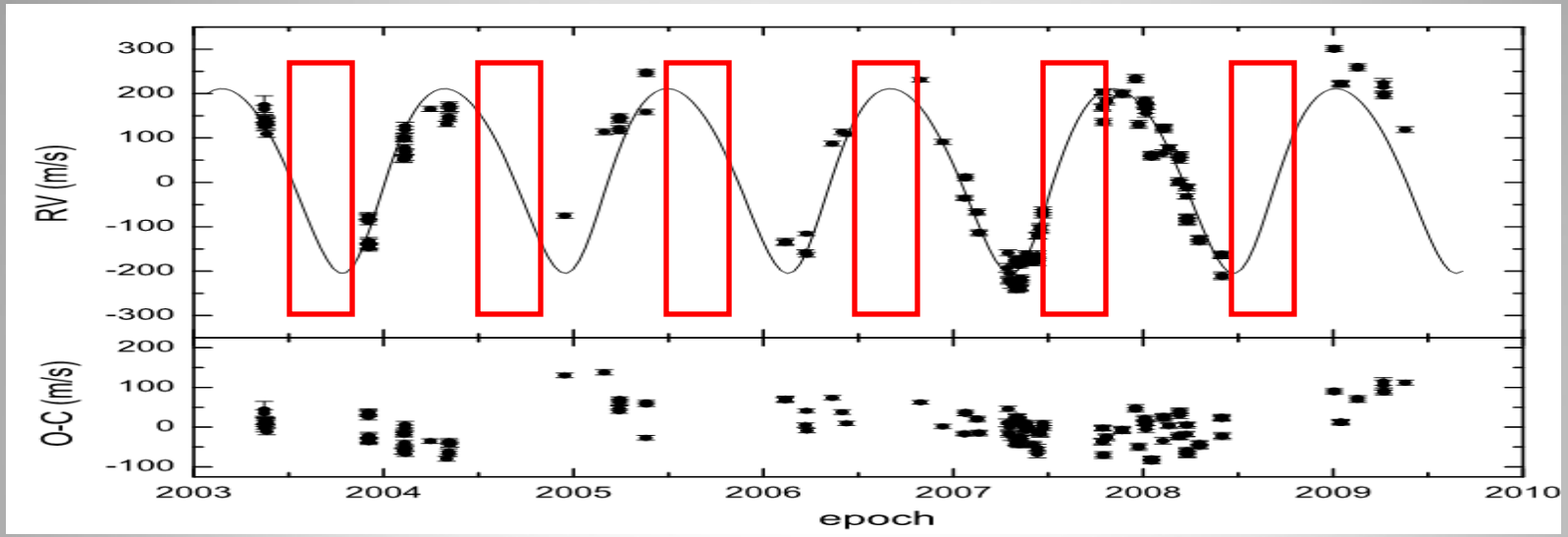
Seasonal gaps in the astrophysical observations



γ^1 Leo: K-giant with 429-day, 8.7$_{jup}$ mass exoplanet (S. Korea-Ukraine K-giant survey)

- **1 year and 1 day gaps in the data are serious obstacles for a long-period exoplanet studies and asteroseismology**

Question:

Whether we can overcome limitation caused by the daytime and seasonal gaps in the data ?

Answer is yes!

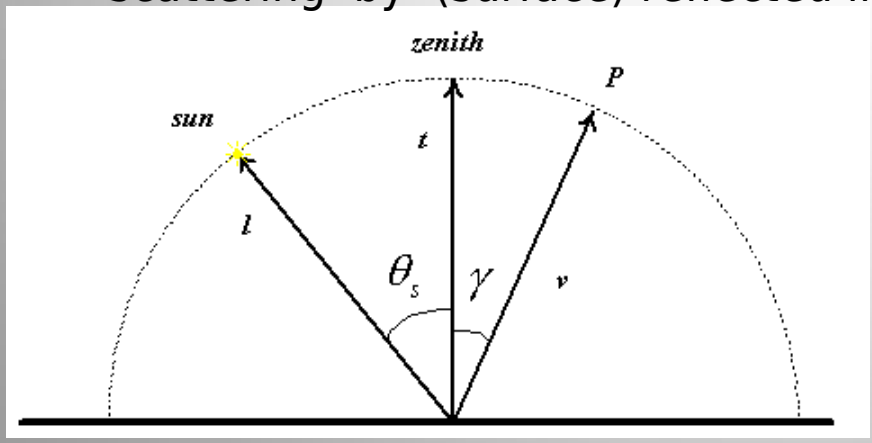
If we can get somehow ground based observations in daytime.

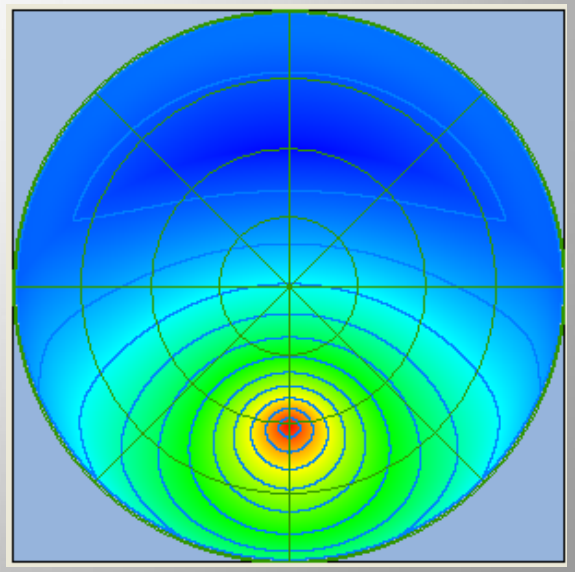
Brightness of daytime sky

$B=B_1+B_2+B_3$ full formulae in Livshits, Fedulin 1971, $B \sim \lambda^{-4}$

B_1, B_2 Direct and multi-scattering

B_3 – scattering by (surface) reflected light





Approximate brightness of daytime sky at zenith (sea level)

size of eye cell

1’

-5.2 mag

1” vs 1’ → 1/3600 times
Δm= 8.9m

1”

spectrograph fiber

□ 1” ~ 3.7m

ø 1” ~ 3.95m

Statement 1.

For many directions of spectroscopic studies of stars - radial velocity studies, asteroseismology , exoplanet search, double stars etc… - we can easily extract from the daytime (stellar+sky) light the Doppler shift information for stars as faint a 5-6^{m} and possibly fainter (for high-altitude observatories or/and telescopes with adaptive optics image reconstruction)

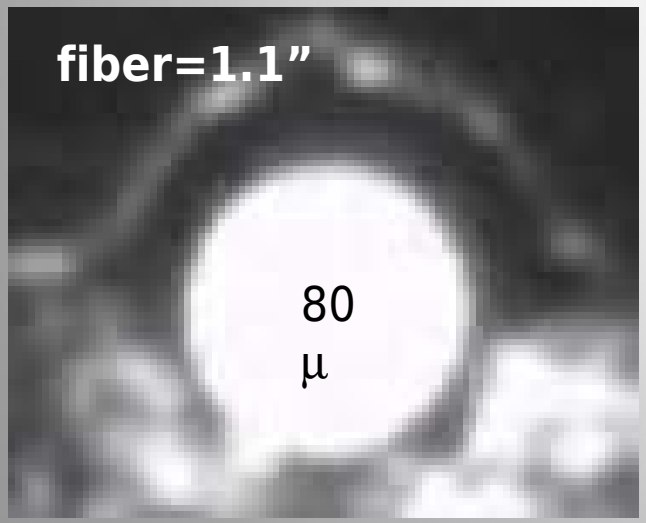
Statement 2.

Technical and methodological problems – pointing, guiding, disentangling of composite (solar and stellar) spectra - can be easily solved.

Experimental daytime observations of Sirius A (V=-1.47, A1V) {Δm=4.87mag}

- **Telescope: 1.8 m tel., S. Korea**
- **Echelle-Spectrometer.: BOES, R=90,000**
- **Exposure: 3.5 - 4 sec**

(1%) neutral density filter for slit guiding CCD camera (FOV 2.4')



Journal of daytime observations 22.10.2005

5:02-5:07	N=2 night-time spectra
5:03-6:06	Preparations of ES
6:06 -7:35	Time-series observations of Sirius (N=17 spectra)
6:12	Sunrise
7:30	End of obs., Mz=2.2
7:48	Spectrum of sky (2' aside)

Pictorial journal of daytime high-resolution spectra of Sirius A

-1h 05 min (night)

-6 min (Mz=1.73)

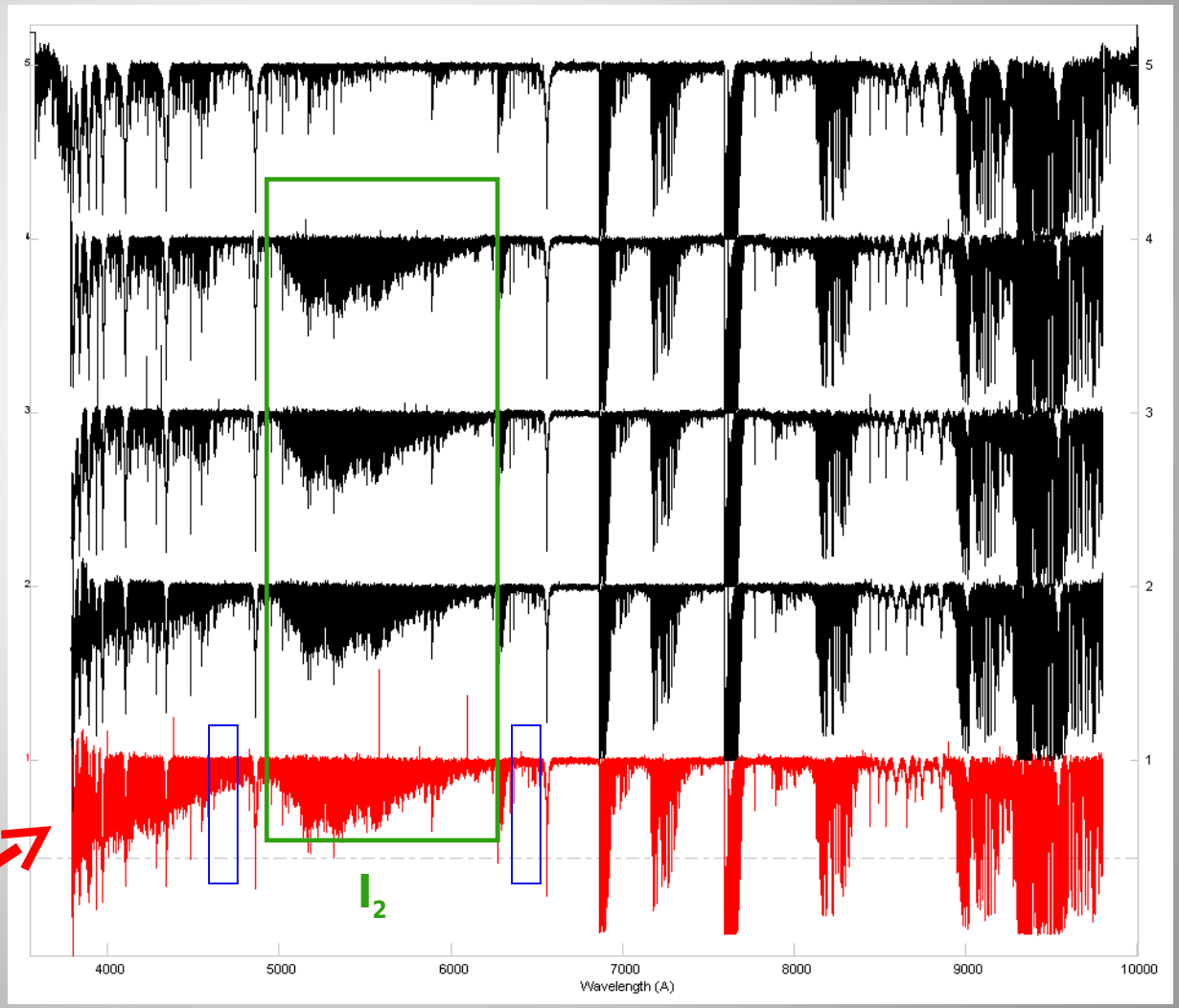
t=0 - sunrise

+25 min (Mz=1.85)

+53 min (Mz=2.07)

+ 1h 48 min (Mz=2.21)
telescope limit

$I \sim \lambda^{-4}$

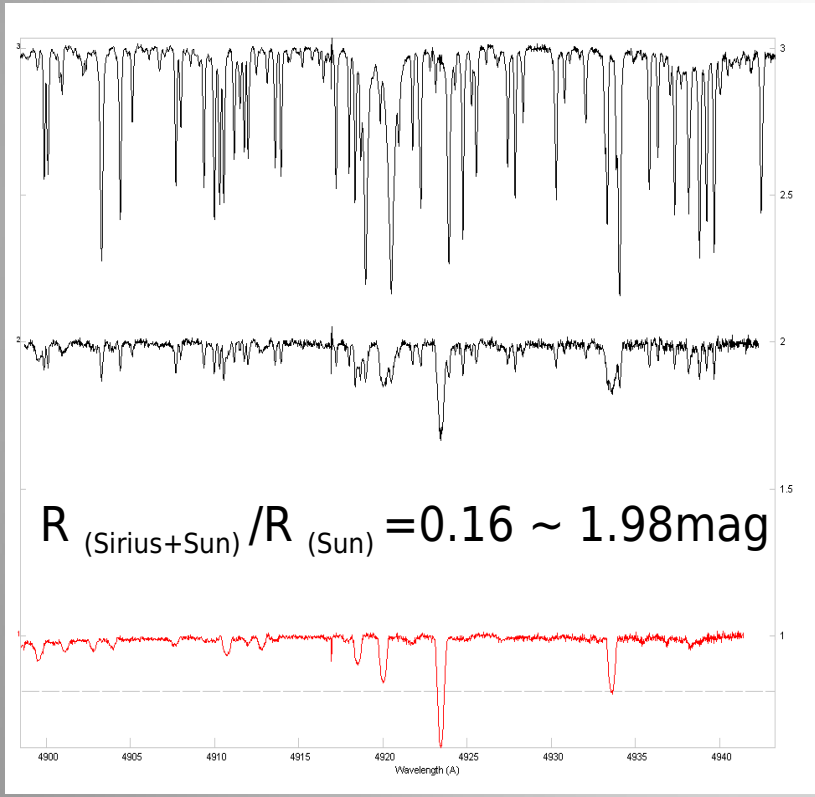


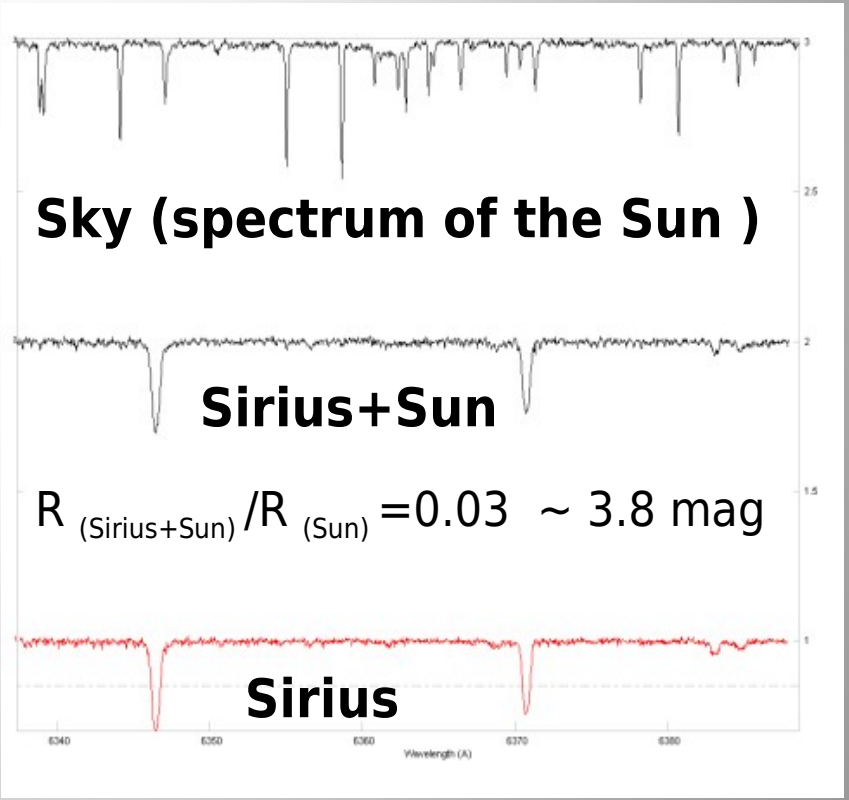
Contribution of scattered sunlight into daytime spectrum of Sirius in different spectral regions. t=+1h 48 m after sunrise {Δm=4.87}

4895–4945 AA

I_2

6337–6387 AA





Least Square Decomposition (LSD) profiles of daytime spectra of Sirius A

Significant contribution from sky **4500-4832 A; 4880-4964 A**

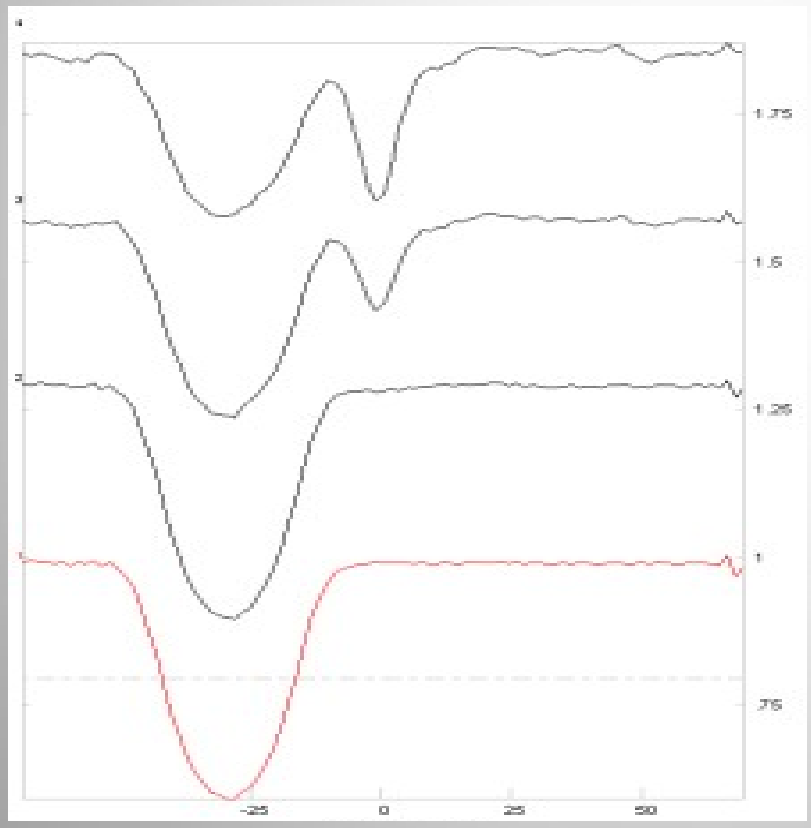
No contribution from sky **6138 - 6461 A**

+1h 48m

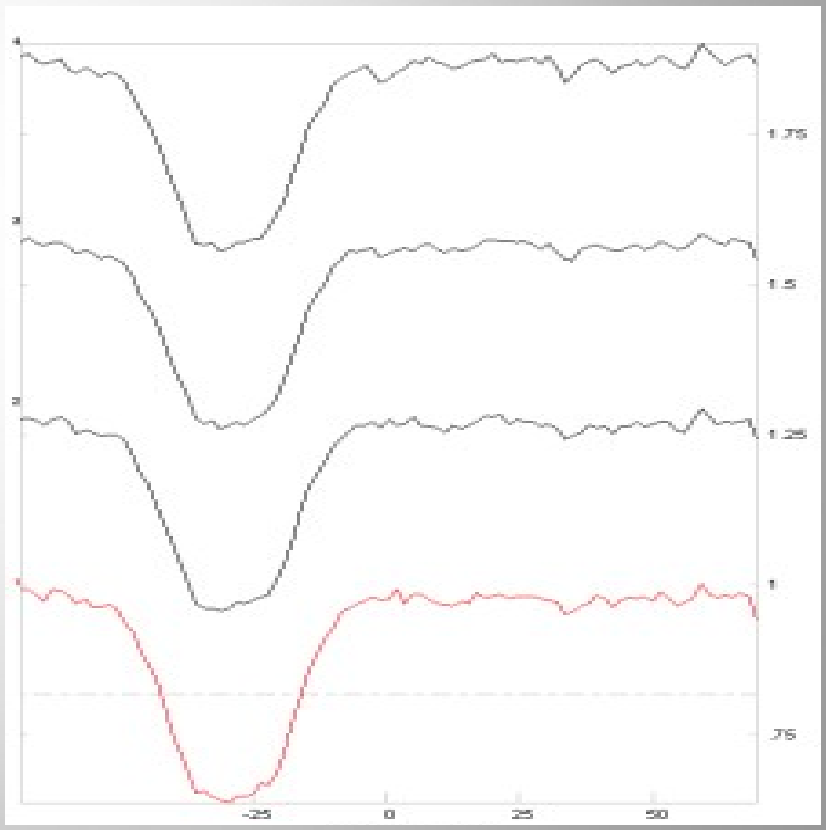
+53m

+25m

-6m



km/s



km/s

LSD profiles of night-time and morning-time spectrum of RZ Cas

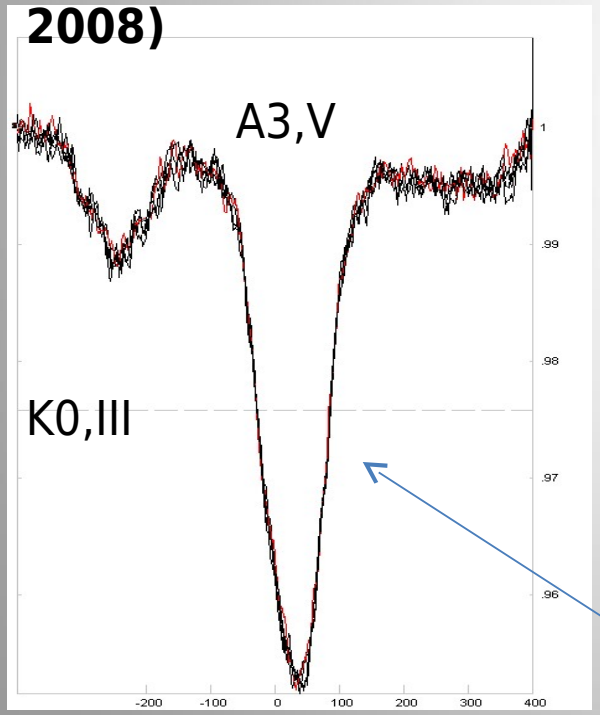
RZ Cas, V=6.18^m, A3V+KOIII
vsini=79km/s, P_{puls}=22.4 min

Belongs to a class of oEA stars (Mkrtichian et., 2002)

Lehmann & Mkrtichian (2004, 2008)

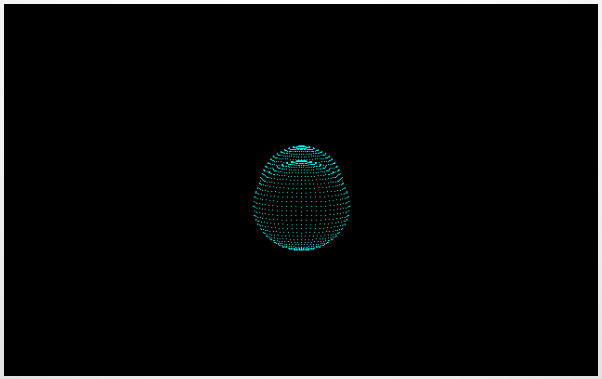
MAGNITUDES AND COLORS OF RZ CASSIOPEIAE AND ITS COMPONENTS

Photometric Band	System	Primary	Secondary
U	6.40	6.46	9.65
B	6.32	6.39	9.51
V	6.18	6.27	8.91
J	5.76	6.04	7.37
K	5.50	5.98	6.63



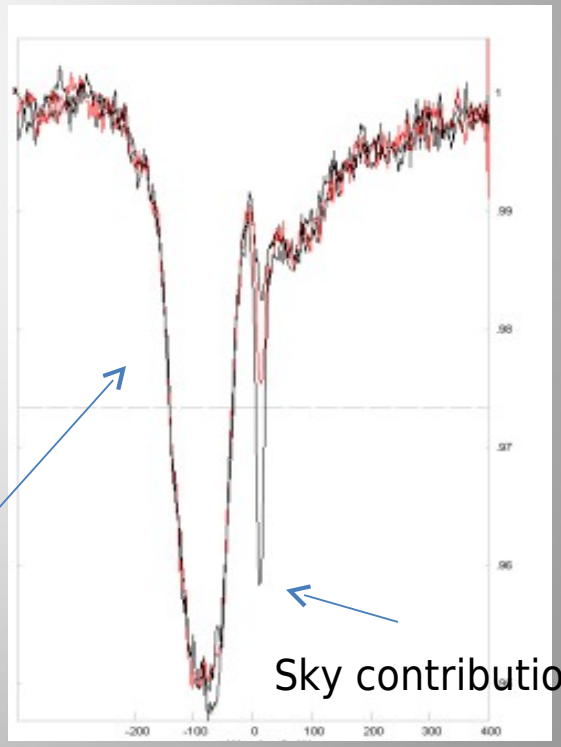
km/s

Δm(A-B)=3^m



m_p=4^m+ 3^m= 7^m

Night and morning spectra of RZ Cas



km/s

Search for pulsations in Sirius A in day-time and night-time

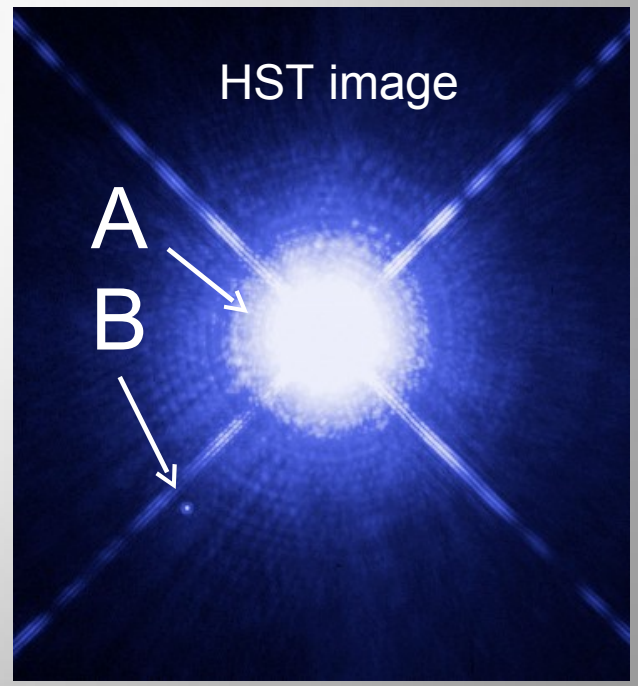
Dates, telescope, spectrometer

- **1.8м BOAO, BOES, R=90,000**
- **Iodine cell**

Sirius A:
M=2.20, R=1.713,Te=9440 K

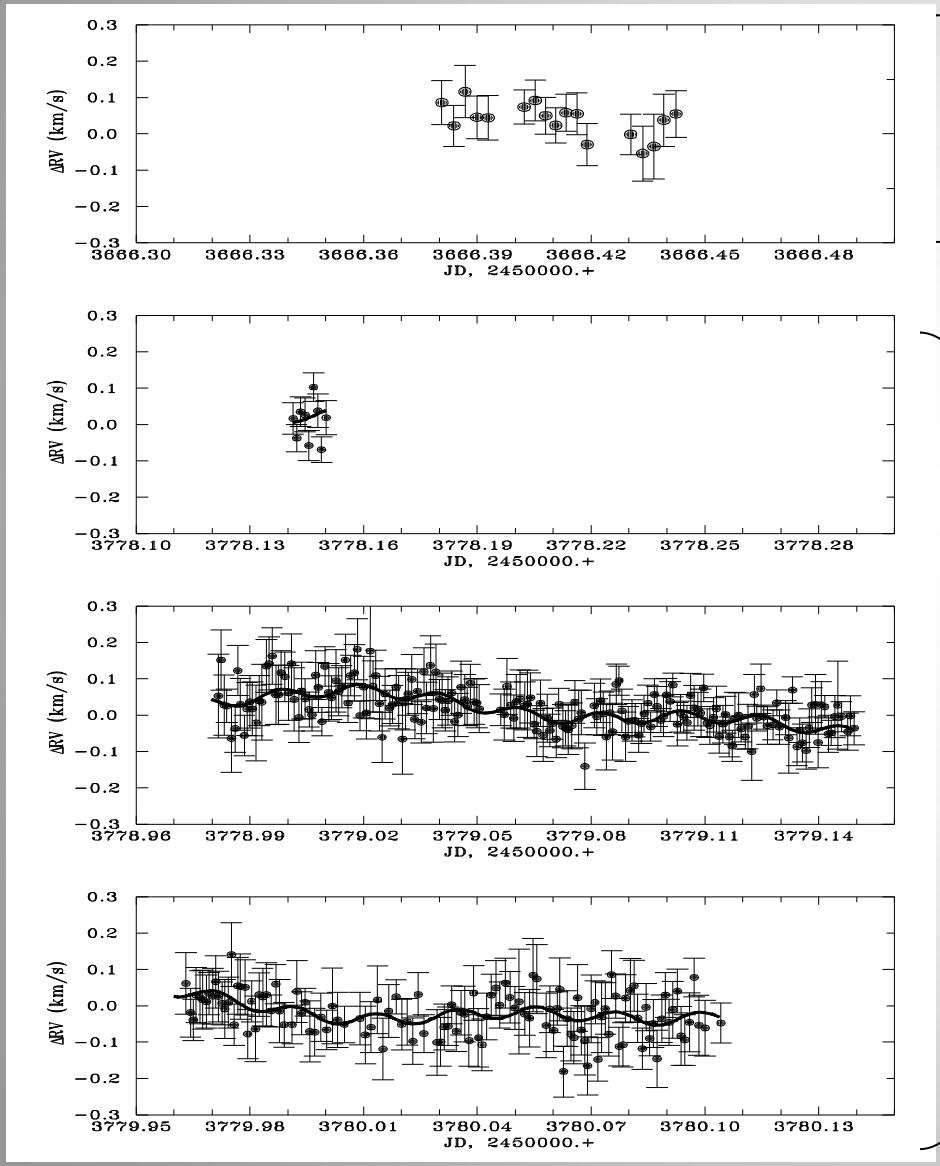
Sirius B: WD, P=49.9 yr
M=0.978, R=0.0084, Te=25200 K

- 2005 22 October (N=17)
- 2006 , 11 February(N=31)
- 2006 , 12 February(N=203)
- 2006 , 13 February(N=84)
- 2007, 15 February (N=2)
- 2007, 22 October(N=23)



Sirius A is located near the blue border of the instability strip

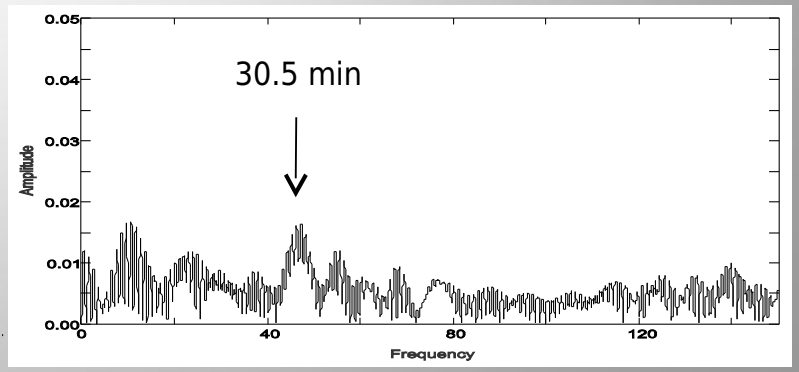
Precise radial velocity measurements of Sirius A



Day-time observations

Night-time observations

Sirius A is stable to within ±16 m/s. There is an evidence of possible low-amplitude 30.5 min oscillations.



Conclusions

- The Sirius A is stable to within ±16 m/s.
- On the example of Sirius we show that daytime Doppler spectroscopy is a valuable tool for exoplanet searches and asteroseismology of bright stars.
- This technique can be applied to stars as faint as 5-7^m at sites with a good daytime seeing.

Examples of bright stars projects:

- S. Korea-Ukraine K-giant exoplanet survey (<5^m)
- Japanese G-giant exoplanet survey (<7 ^{m})
- Stellar Oscillation Network Group (SONG) (<6^m)