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High Resolution Spectroscopy of Binaries Using GAOES

Gunma Astronomical Observatory

http://www.astron.pref.gunma.jp/

High Resolution Spectroscopy of Double-lined Detached Eclipsing Binaries Using the Gunma Astronomical Observatory Echelle Spectrograph

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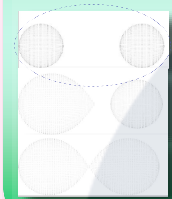
On the basis of collaboration between Gunma Astronomical Observatory in Japan and Institut Teknologi Bandung in Indonesia, high-resolution spectroscopy of stellar objects using the newly designed Gunma Astronomical Observatory Echelle Spectrometer (GAOES) installed at a 1.5 meter telescope has been actively carried out since 2004. GAOES has several advantageousnesses against conventional echelle spectrographs, i.e. its compactness, higher throughput and stability that enable one to conduct high-resolution spectroscopy (R ~ 70,000) on relatively faint objects. Double-lined eclipsing binaries are, so far, the only objects for which fundamental and simultaneous determinations of absolute physical parameters can be deduced. In the case of detached eclipsing binaries of this type, mutual interaction can be neglected and analyses of observables can yield in simultaneous absolute dimensions for the two single stars. Further, evolutionary models should be able to predict the same age for both components for a certain chemical composition.We have made high-resolution optical spectroscopic observations using GAOES of several double-lined detached eclipsing binaries, i.e. CD Tau, EE Peg, Beta Aur and IQ Per in 2006. Among them, CD Tau has been monitored since 2004 up to now. With the introduction of new camera system of GAOES, significant improvement on the obtained S/N data lead us to better spectra for analysis on line profiles and radial velocities.

Interest in Double-lined Detached Eclipsing Binaries

A "typical" Astrophysical Laboratory

- Photometry → Double-lined eclipsing binaries → • Light curves
- Spectroscopy → Double-lined eclipsing binaries → • Rad.velocity curve

Masses, radii



Detached *double-lined eclipsing binaries*

-No mass transfer, no mutual interaction

-Components independently evolve from a common origin both in time & chemical composition

Constraints for the evolutionary models

→ similar *isochrone* fits to eclipsing binary pair's physical parameters

Problems

(Ribas et al. 2000)

Current evolutionary models unable to describe observed properties of low-mass eclipsing binaries (0.7–1.1 $M_\odot$)

(Popper 1997, Clausen et al 1999):

* Radius too small (log *g* too large)
* Effective temperature too high

Possible explanations (Clausen et al 1999):

* Observational problems
* Lack of chemical composition determination
* Inaccuracies of the physics of the models i.e. *mixing length* parameter

Purpose

High-resolution spectroscopy exploratory work

* To apply standard reduction technique (IRAF-based) to the echellograms
* To obtain heliocentric radial velocities for primary and secondary components
* Detailed profile analyses: Deblending, equivalent widths, abundance

About CD-Tauri

◆HD 34335, HIP 24663:
An eclipsing binary & a double-line spectroscopic binary

◆$\alpha = 5^h\ 17^m\ 31.2^s$, $\delta = +20°\ 07'\ 54.6''$ (J2000.0)

◆$V_{system,max} = 6.75^m$

◆Spectral Classes : F6V (primary)+ F6V (secondary)

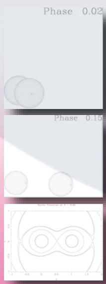
Min I (HJD)=2441619.4075+3.435137^{d}E

Radial velocity curve solution
(Lehman-Filhés method for double lines radial velocity)

- K_A=96.8 kms^{-1} , K_B=102.1 kms^{-1}
- $q = M_B/M_A = 0.948$
- $a = 13.52\ R_\odot$
- $\gamma = -29.3$ kms^{-1}

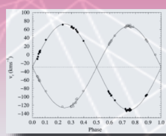
Light curves solution
(Wilson-Devinney code)

- e=0
- i=87.7°
- r_A=0.1330 r_B=0.1172
- L_B/L_A (B)=0.770 L_B/L_A (V)=0.772
- T_{eff_B}/T_{eff_A}=0.999



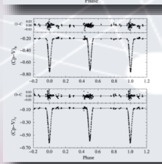
Radial velocity curves

- Popper (1971) : Poor quality
- Ribas *et al*. (1999): CORAVEL @ 1 m Obs. De Geneve telescope



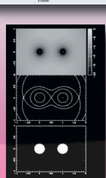
Light curves
(photoelectric photometry)

- Srivastava (1976): *UBV*
- Wood (1976): Strömgren
- Gulmen et al (1980): *BV*



Physical Properties

M_A=1.44±0.02 $M_\odot$	M_B=1.37±0.02 $M_\odot$
R_A=1.79±0.02 $R_\odot$	R_B=1.58±0.02 $R_\odot$
log g_A=4.09±0.01	log g_B=4.17±0.01
T_{eff_A}=6200±50 K	T_{eff_B}=6200±50K



Observation of CD-Tauri

Date :
20041021, 20041023, 20041027
20050210, 20051127, 20061222
20061230, 20061231, 20070101
20070104, 20080130, 20080131
20080201

Telescope : GAO-150cm Reflector
Instrument : GAOES
Setting : 1" slit (R~70,000)
Exposure : 30-60 min x 2-4 times
S/N : 30-130

Strategic **advantages** for **GAOES**

High-resolution **:**
Tough against **light pollution**

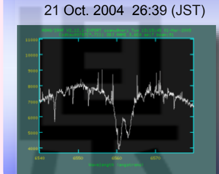
Wide slit **:**
Tough against **poor seeing**

Independent Operation (as a public observatory) :
Plenty observation time on a **small number of specific subjects**

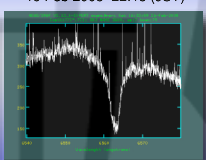
Results for CD-Tauri

Hα absorption lines

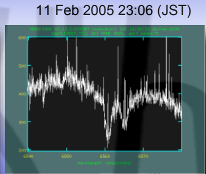
21 Oct. 2004 26:39 (JST)



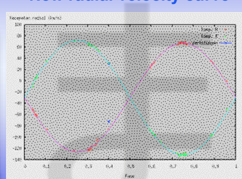
10 Feb 2005 22:15 (JST)



11 Feb 2005 23:06 (JST)



New radial velocity curve



Current Programs (up to 2010)

Star	V	Period (days)	Remarks
CD Tau	6.3	3.4	Almost full orbital phase coverage (2004-2009)
Beta Aur	1.9	3.9	2006 - 2009
EE Peg	7.9	2.6	2007 - 2010
IQ Per	7.7	1.7	2007 - 2010