Revealing the Properties of the Weak-lined T Tauri Binary HDE 245059 with Chandra and Keck

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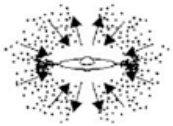
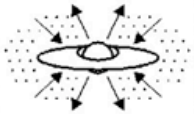
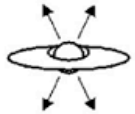
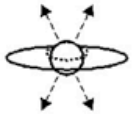
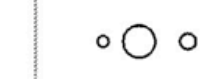
SED classification of low mass young stars ~ 0.2 - 3 M_{sun}

CTTS
strong Hα emission
W(Hα) ≥ 10 Å
infrared excess

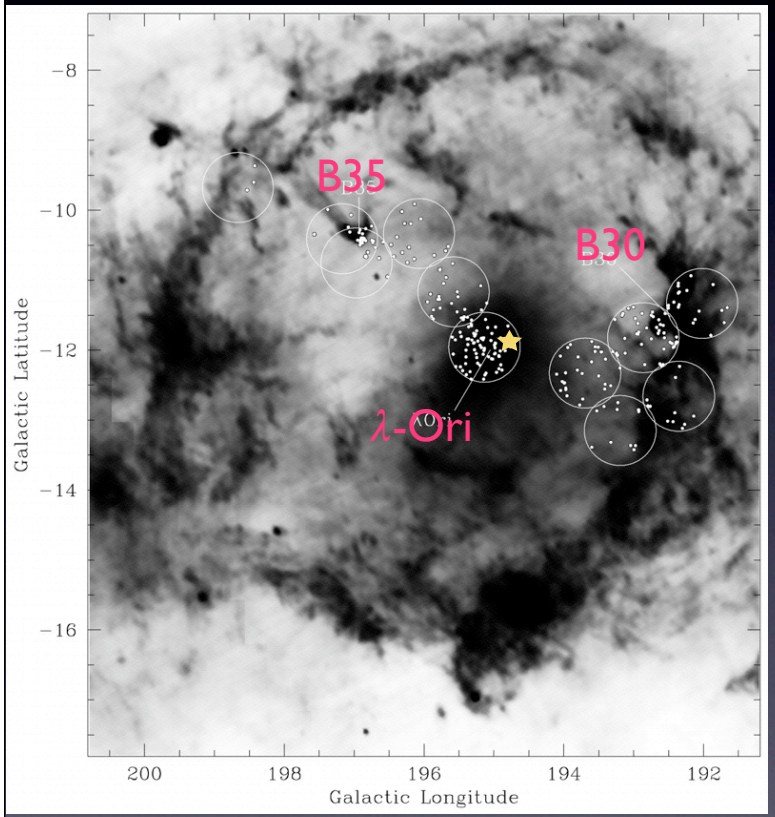
WTTS
weaker Hα emission
no infrared excess

Properties	*Infalling Protostar*	*Evolved Protostar*	*Classical T Tauri Star*	*Weak-lined T Tauri Star*	*Main Sequence Star*
Sketch					
Age (years)	10^4	10^5	10^6 - 10^7	10^6 - 10^7	> 10^7
mm/Infrared Class	Class 0	Class I	Class II	Class III	(Class III)
Disk	Yes	Thick	Thick	Thin or Non-existent	Possible Planetary System
X-ray	?	Yes	Strong	Strong	Weak
Thermal Radio	Yes	Yes	Yes	No	No
Non-Thermal Radio	No	Yes	No ?	Yes	Yes

Fiegelson & Montmerle 1999

HDE 245059

IRAS 60 μm
Dolan & Mathieu 2001



Among the brightest pre-main sequence stars in X-rays, $L_x \sim 10^{31}$ ergs/s

Previous ROSAT observations have shown soft emission (despite its high luminosity)

There are still few high resolution spectra of WTTS in the X-rays

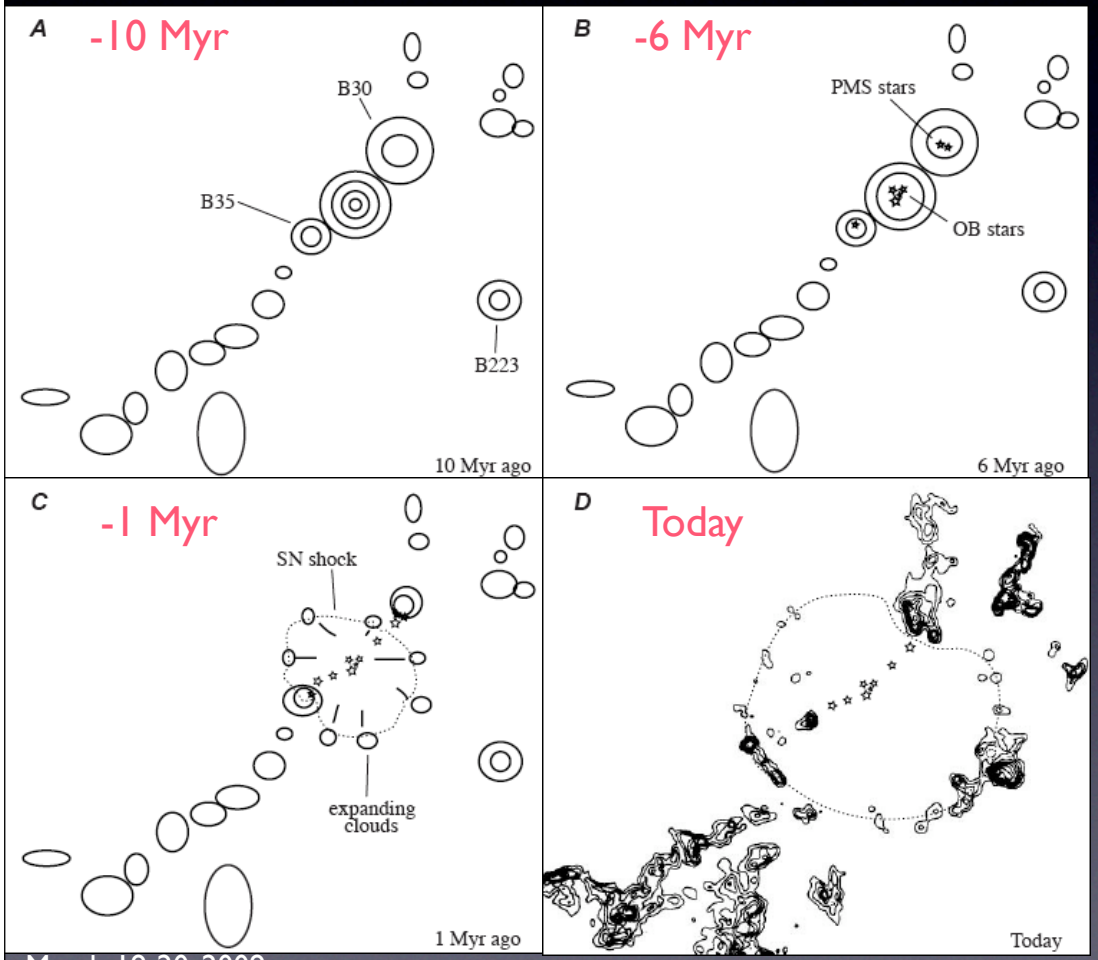
Did the history of the region affect the X-rays properties of the star?

$M = 2 - 3\ M_{sun}$ $T_{eff} = 5410 \pm 110$ K

$d = 400 \pm 40$ pc

History of the SFR

Dolan & Mathieu 2002



~10 Myr. Chain of molecular gas extended accross the present SFR including 3 massive clouds.

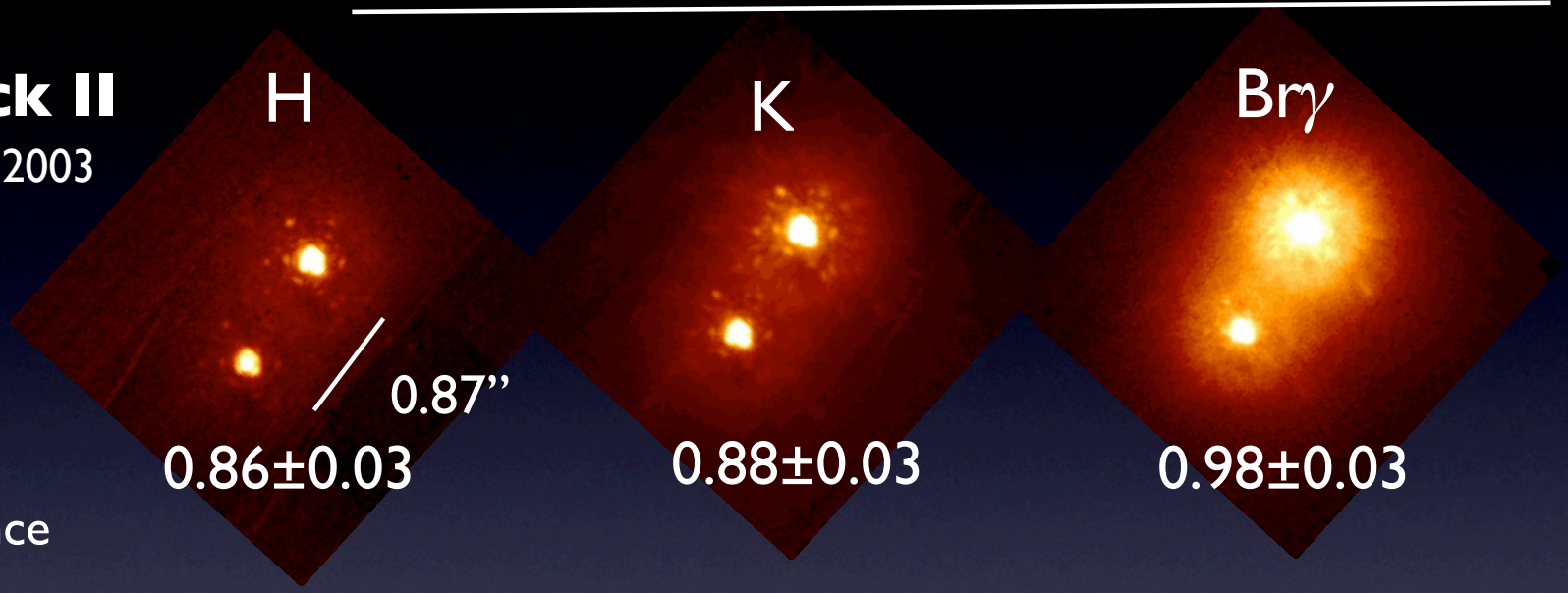
~6 Myr. star formation started in the most massive clouds. Several OB stars. SFR increasing gradually.

~1 Myr. SN disrupted the central region decreasing SFR and unbinding central stellar population.

Today. SF continues at the edges of the molecular ring but has ceased close to the SN epicenter.

Revealing the binary

Keck II
Dec. 2003



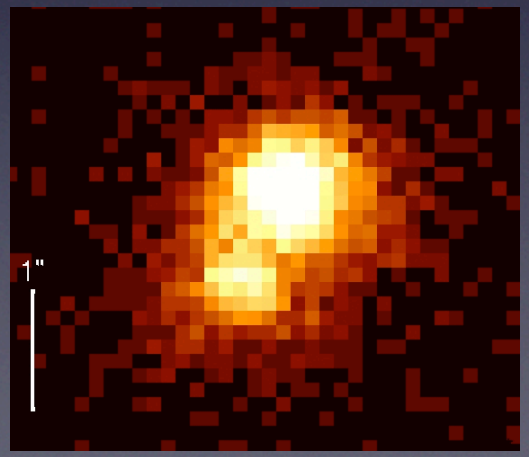
mag. difference

0.86±0.03

0.88±0.03

0.98±0.03

CXO
ACIS-S + HETG
Dec. 2005 - Jan 2006

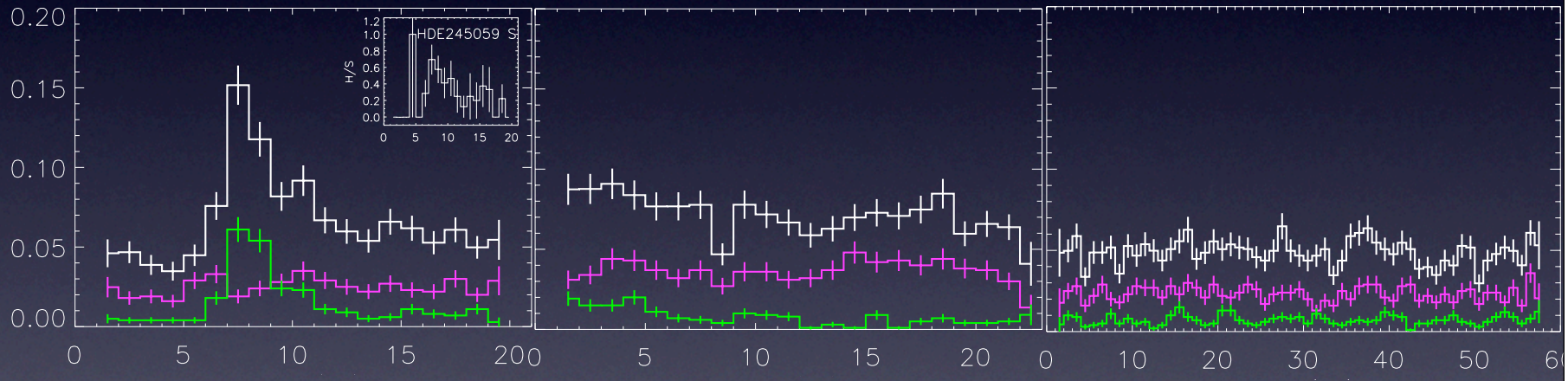


X-ray Analysis

Lightcurves

Binary
HDE 245059 N
HDE 245059 S

cts/s



t (ks)

total : 93 ks

We do not detect any influence of the flare in the spectral properties

X-ray Analysis

Spectral Fitting -The Models

We have used 3 models to fit the spectrum of the binary:

i) Discrete Emission Measure Distribution.
Uses several isothermal plasma models

ii) Continuous EMD
Chebyshev Polynomials $\varphi(T)=\alpha e^{\omega(T)}$, where $\omega(T)$ Ch. polyn n=8

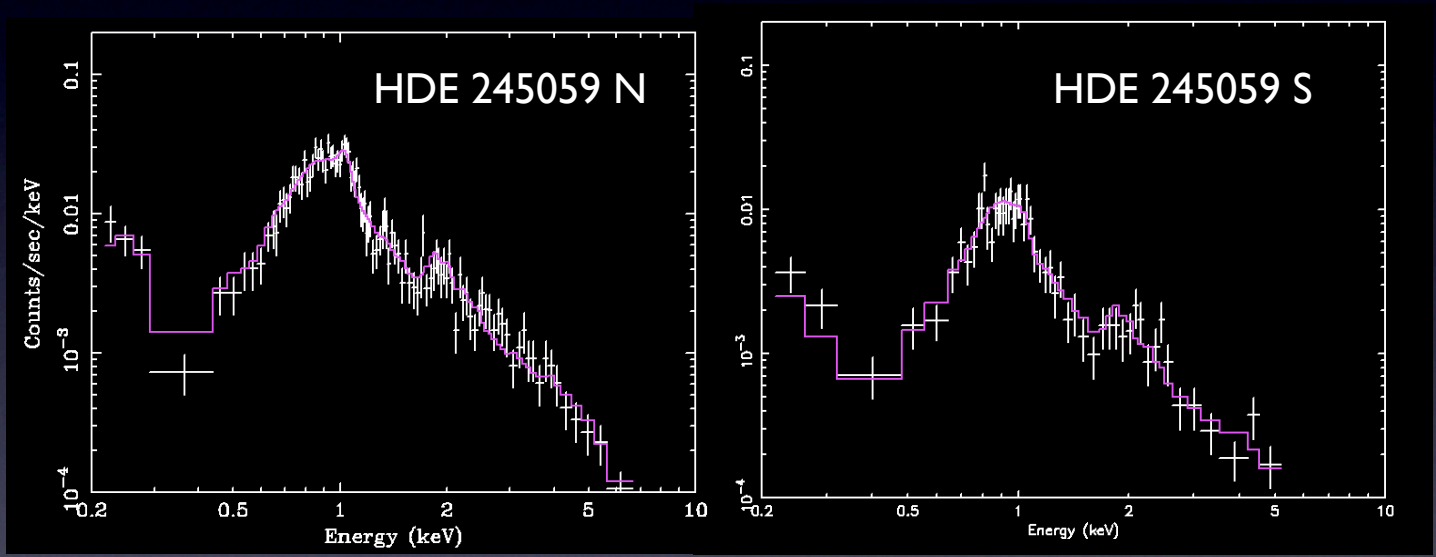
iii) Continuous EMD
Power Law approximation

$$\varphi(T) = EM_0(T/T_0)^{\alpha} \quad \text{for } T \le T_0$$
$$EM_0(T/T_0)^{\beta} \quad \text{for } T > T_0$$

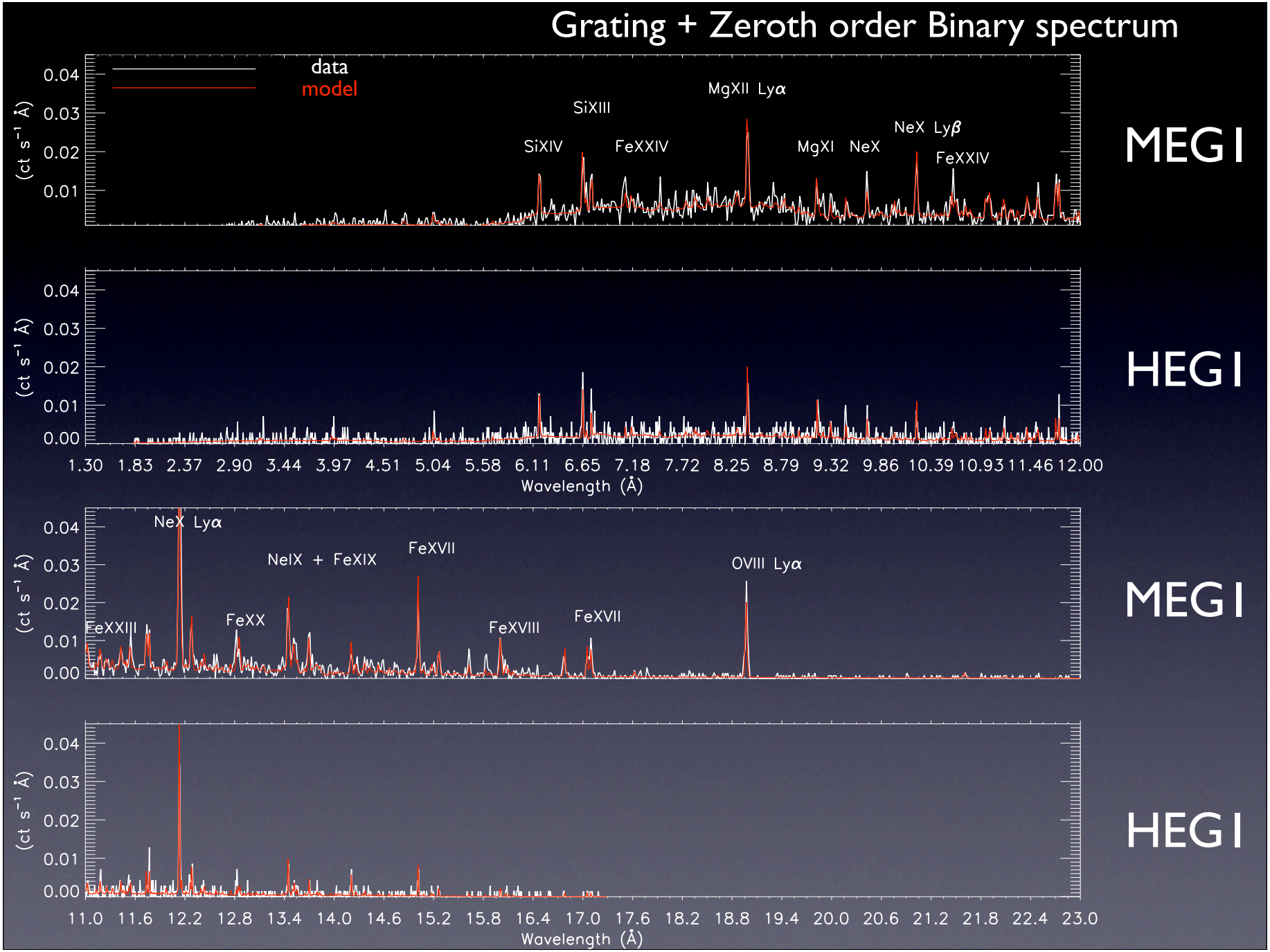
X-ray Analysis

Binary Components

Zeroth order spectrum - Discrete EMD

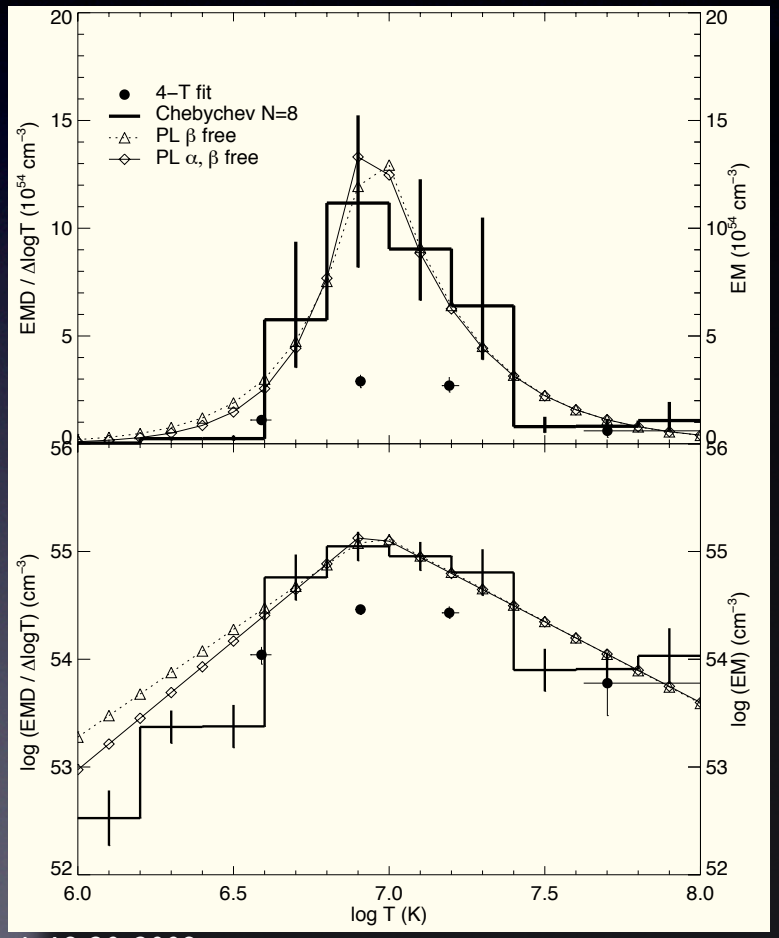


	N	S
log (L_x) (ergs/s)	30.5	30.2
EM_{total} ($10^{54}cm^{-3}$)	2.3	0.8
Tav (MK)	11.3	12.2


Grating + Zeroth order Binary spectrum
data
model
SiXIV
SiXIII
FeXXIV
MgXII Lyα
MgXI
NeX
NeX Lyβ
FeXXIV
MEG 1
HEG 1
NeX Lyα
NeIX + FeXIX
FeXVII
FeXXIII
FeXX
FeXVIII
FeXVII
OVIII Lyα
MEG 1
HEG 1
(ct s^{-1} Å)
Wavelength (Å)

X-ray Analysis

Spectral Fitting - Results



3 models used are consistent
$N_H \sim 8 \times 10^{19}$ cm^{-2}

Total emission measure ~ 7×10^{54} cm^{-3}

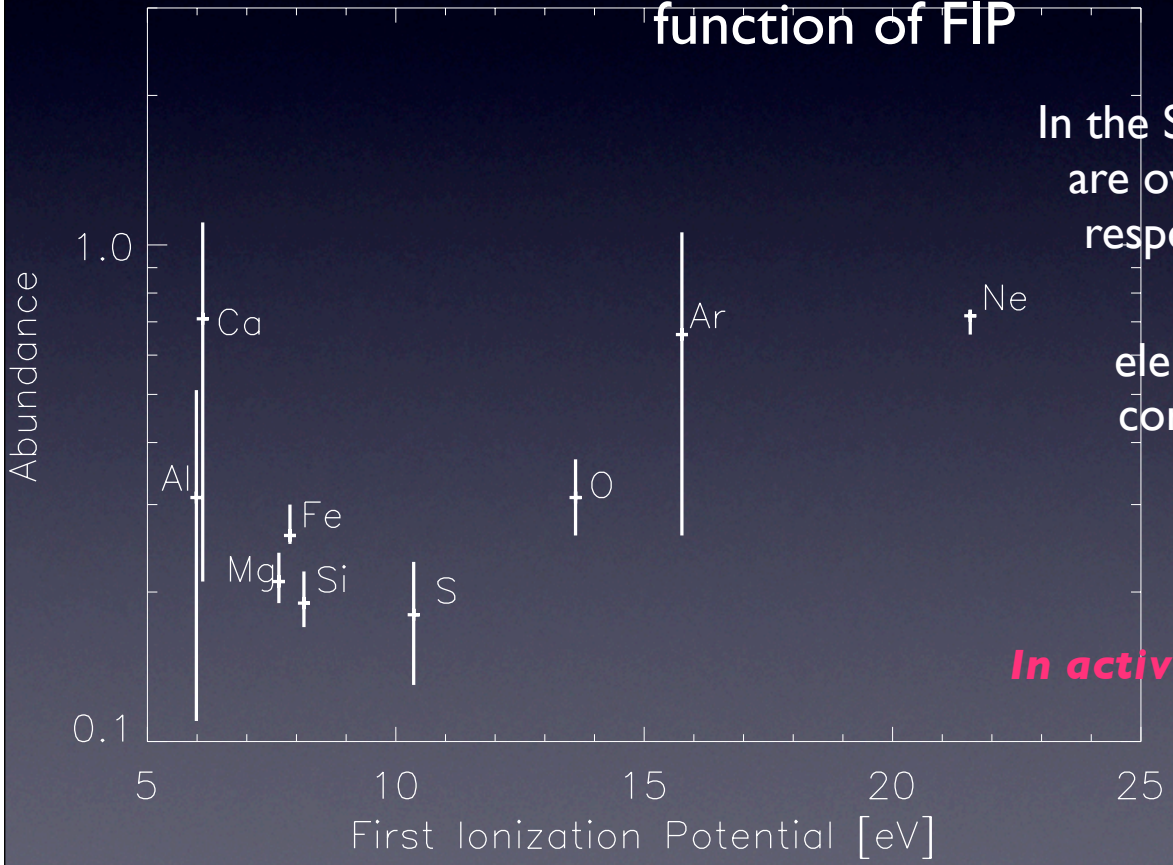
Emission dominated by plasma at
T~ 8 - 15 MK

soft component ~ 4 MK
hard component ~ 50 MK

X-ray Analysis

Inverse FIP effect

Coronal abundances (wrt solar Grevesse & Sauval 1998) as a function of FIP



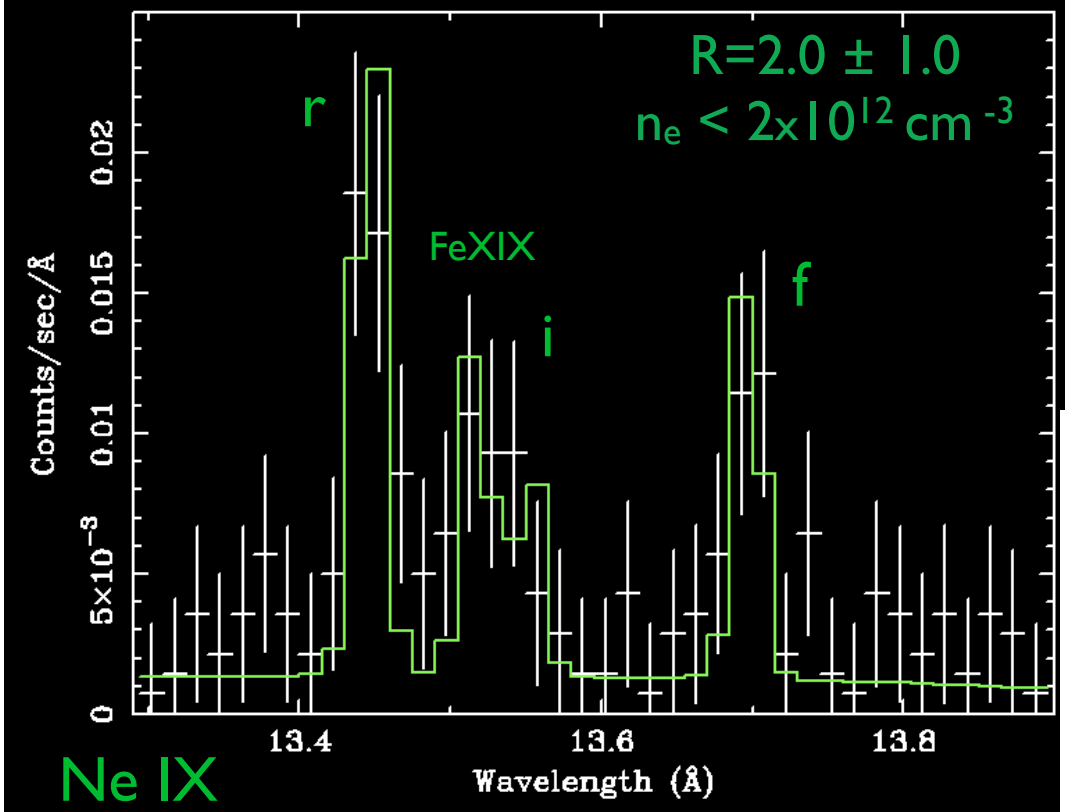
In the Sun: elements with **FIP ≤ 10 eV** are overabundant in the corona with respect to the photosphere (x 4-5)

elements with **FIP > 10 eV** have coronal abundances similar to the photosphere

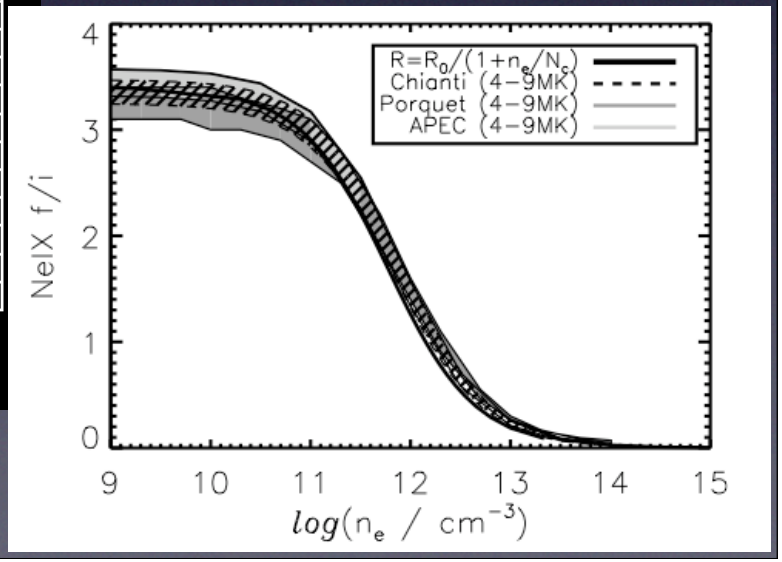
In active stars, FIP effect is inverted

X-ray Analysis

He-like triplets from grating HEG+MEG

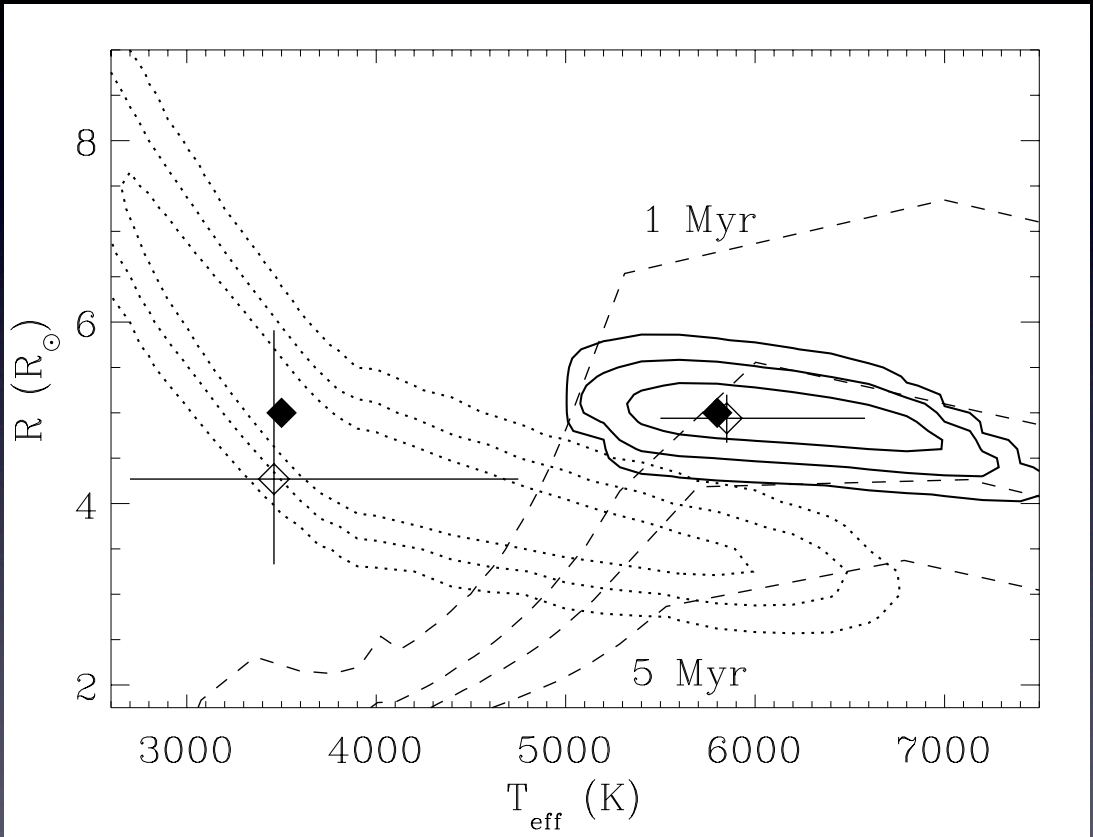


90%	R	n_e (cm^{-3})
Mg XI	1.4±1.0	$<10^{13}$
Si XIII	2.3±1.6	$<3x10^{14}$



Ness et al. (2004)

Binary Properties



Contours: 68, 96, and 99.7% confidence levels

Estimations based on 2MASS photometry, H and K flux ratios, fit to the optical and infrared SED

$t = 2 - 3$ Myr

$T_{eff}\ N = 5880\ ^{+730}_{-370}$ K

$T_{eff}\ S = 3540\ ^{+1420}_{-660}$ K

$R_N = 4.9 \pm 0.3\ R_{sun}$

$R_S = 4.3\ ^{+1.4}_{-1.0}\ R_{sun}$

$M_N = 3\ M_{sun}$

$M_S = 2.5\ M_{sun}$

Summary

Chandra and Keck reveal a binary of young stars

X-ray properties are similar with T~8-15 MK (N brighter on average x2)

N_H consistent with interstellar absorption, further indication of clearing of the inner region of λ Ori SFR

Densities from He-like give only high upper limits with no evidence of densities above 10^{12} cm^{-3}

Properties of the binary show that N component has higher T_{eff} and mass, while both stars show similar radii

In conclusion, the coronal properties of HDE 245059 are similar to what is observed in other WTTS; the history of the region had little impact on them.