Magnetic Activity in Orion's Young Massive Stars

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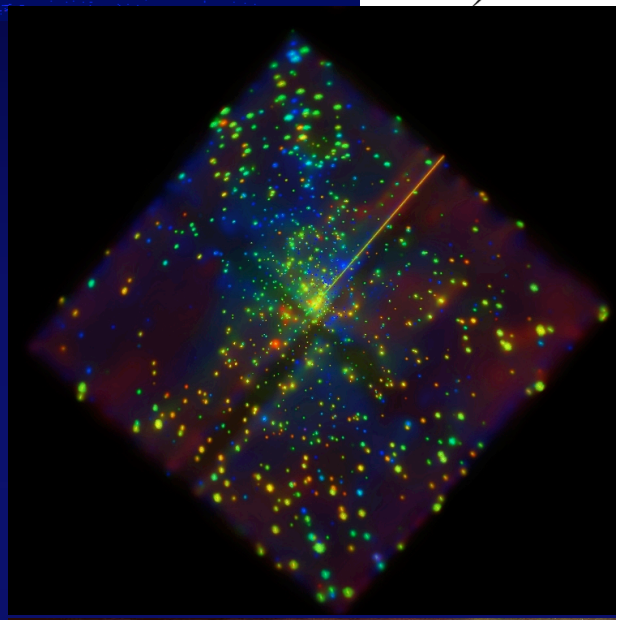
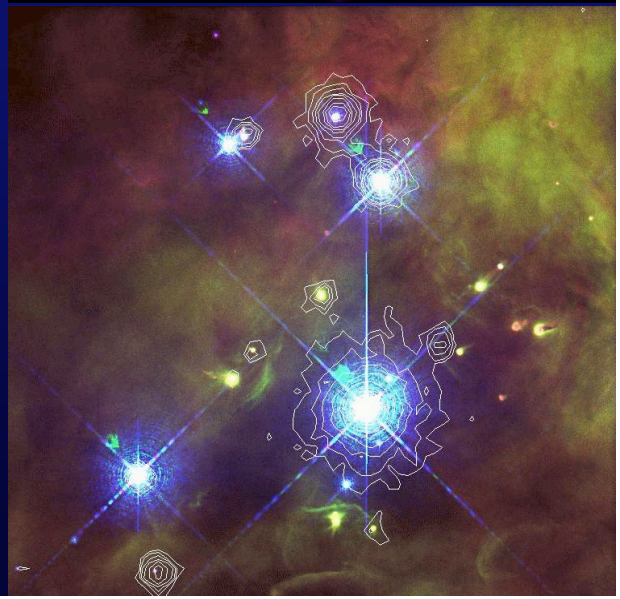
The HETG Orion Legacy Project





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Magnetic Activity in Orion's Young Massive Stars

The HETG Orion Legacy Project

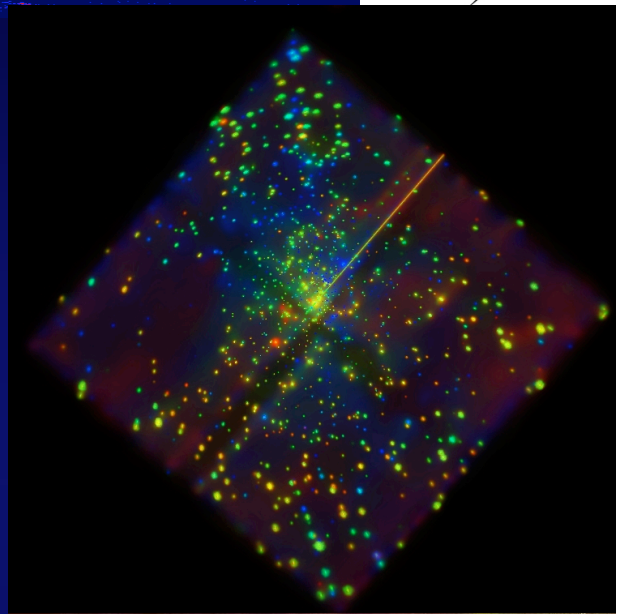
Massive Stars in the Orion Trapezium

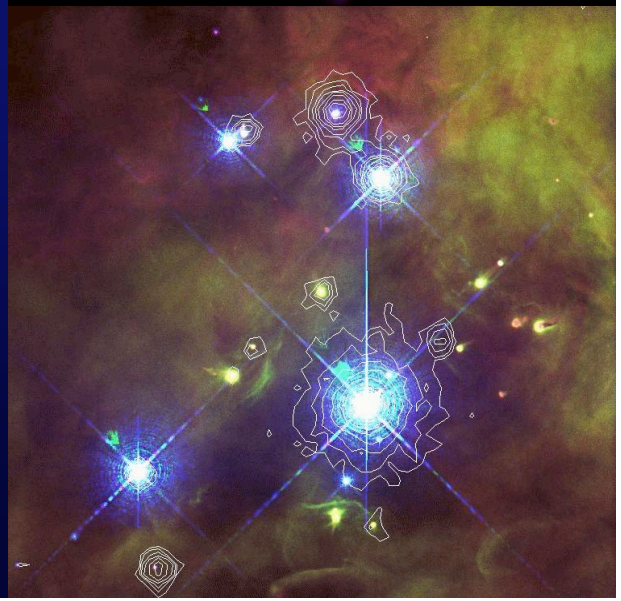
X-ray Production in
Cool Stars vs. Hot Stars

X-ray Properties of Massive Stars

Magnetic Signatures of Trapezium Stars

The Intermediate Mass Binary Θ^1 Ori E





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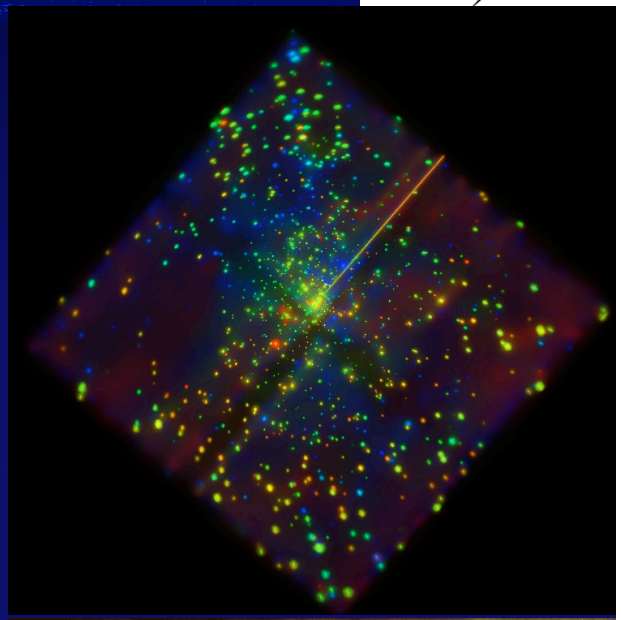
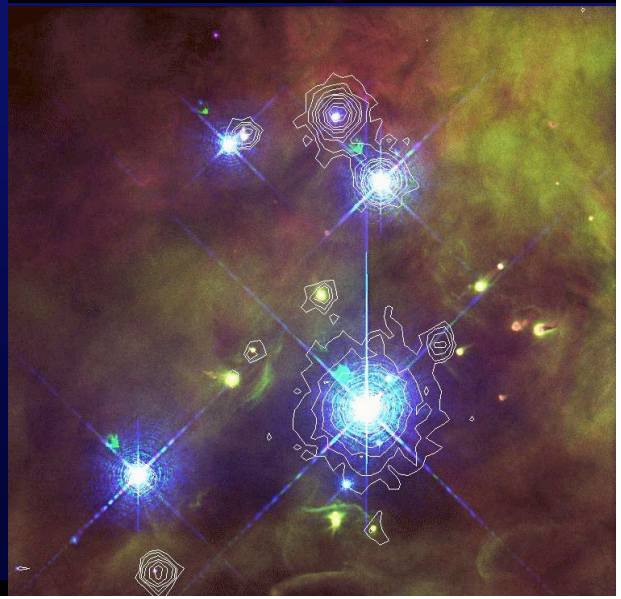
PMS Properties and Wavelength Bands

IR: Dust/Disk Properties,
PMS statistics, Dynamics

Optical: (Diffuse) Gas,
Clouds

X-Ray: Hot Plasmas,
Magnetic Activity,
PMS statistics





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The HETG Orion Legacy Project

Scope:

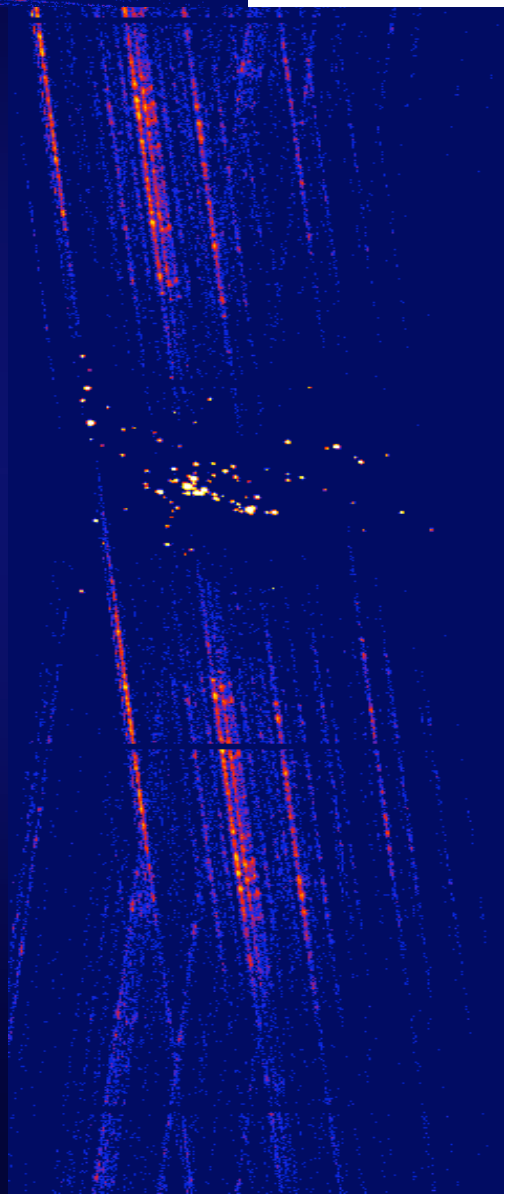
Obtain high quality X-ray spectra of

- the massive Trapezium stars (> 3 M_{sun})
- > a dozen class II/III spectra of T Tauri stars
- giant flares

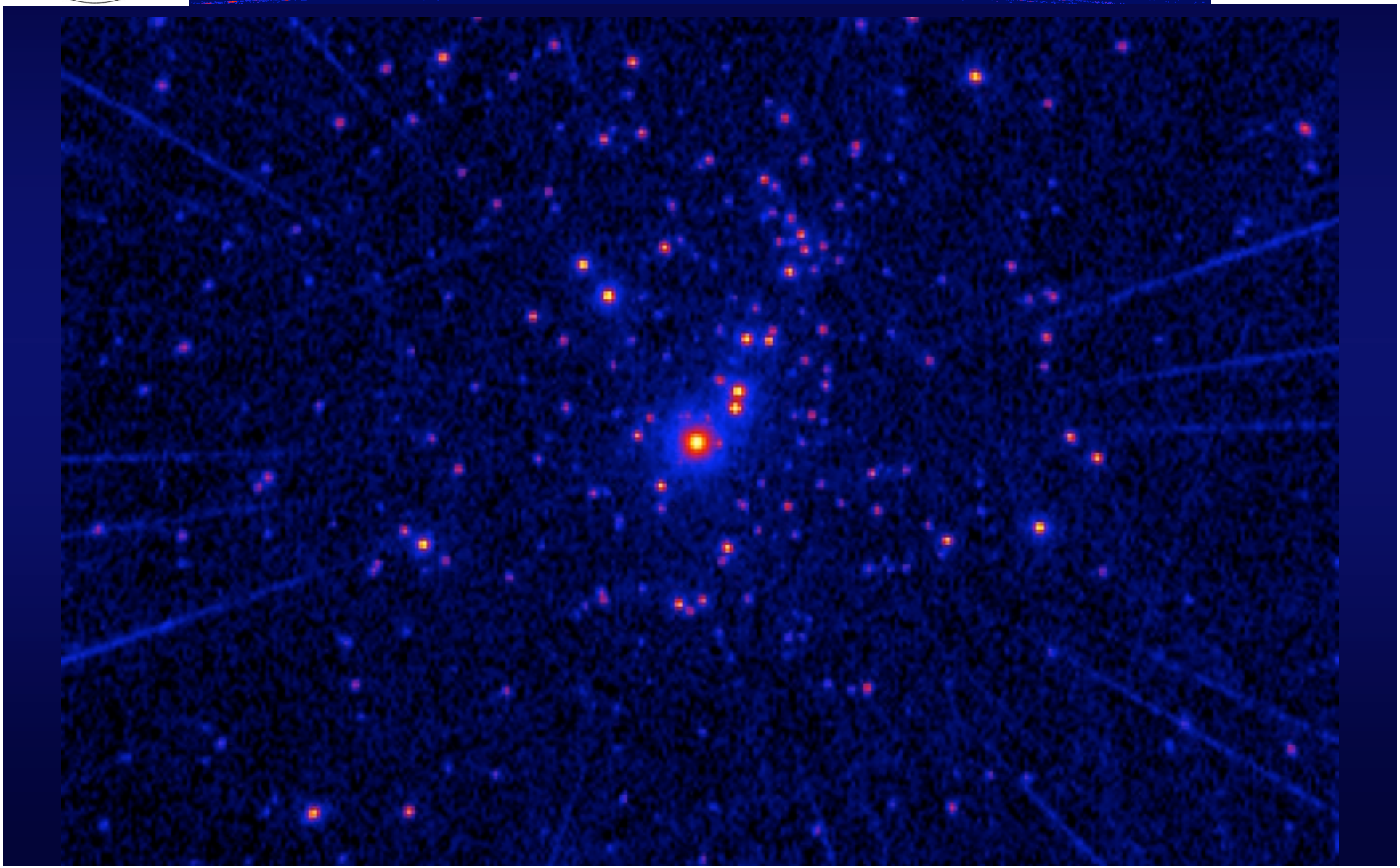
Science:

- Accretion in PMS stars
- Coronal activity in YSOs
- Magnetically Confined Winds
- Colliding Winds
- Fe fluoresence

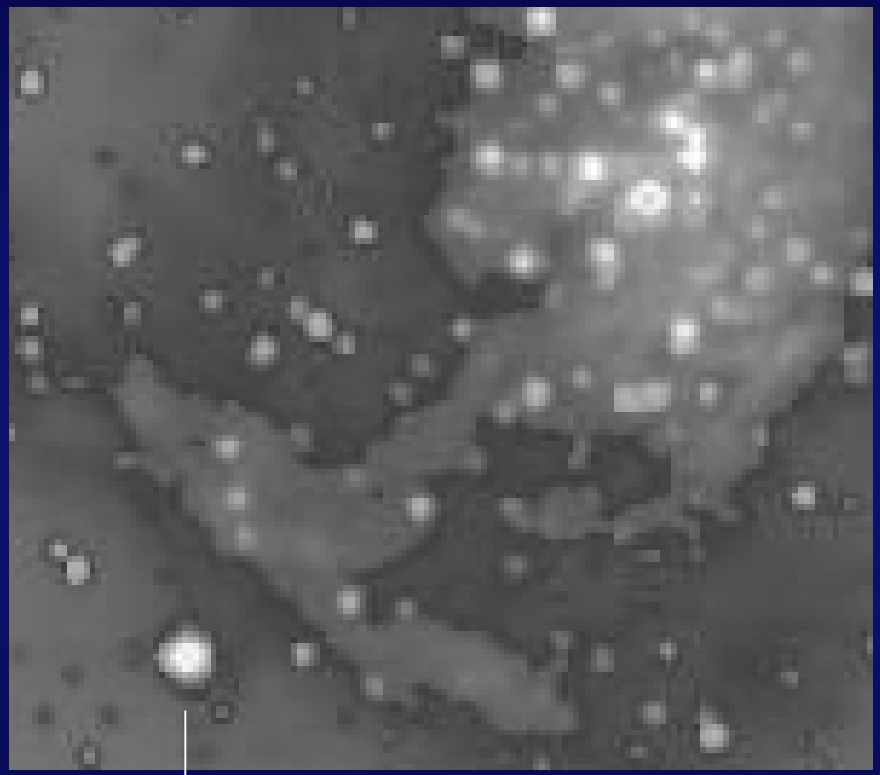
Exposure: 511 ks + 75 ks = 586 ks



The OTC HETG eventfile so far: obsid 3,4,2567,2568,7407-10: 271 ks



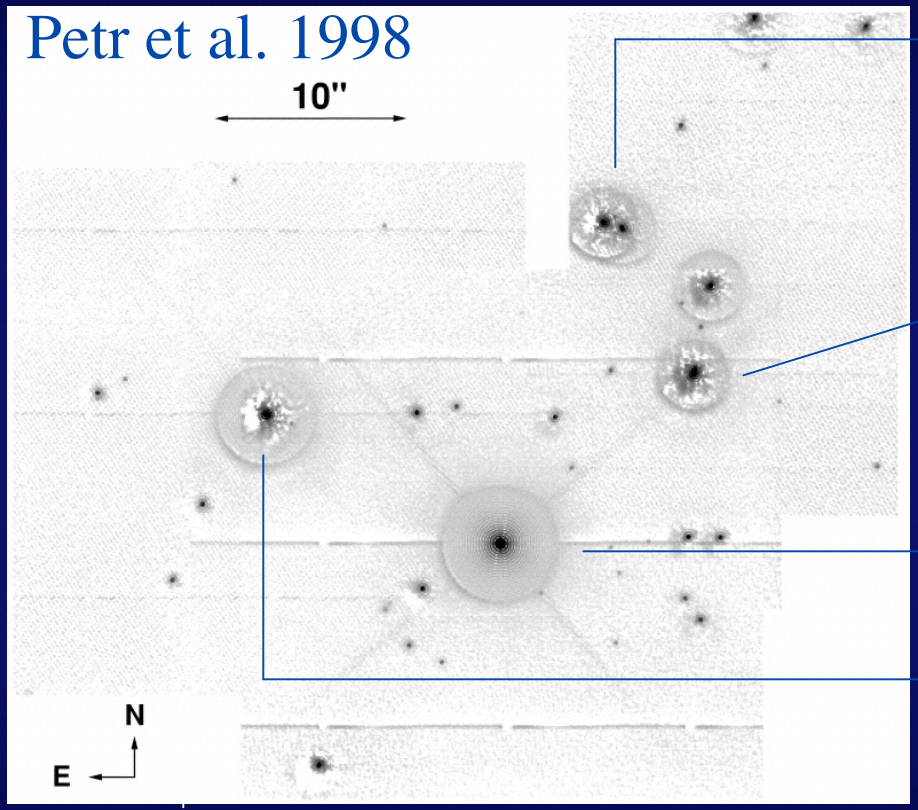
Massive Stars in the Orion Trapezium



Θ^2 Ori A: O9.5V, close 3 - 7 M_{sun} companion (0.43 AU) ,
dist. < 9 M_{sun} companion (173 AU)

(Abt et al. 1991, Preibisch et al. 1999)

Massive Stars in the Orion Trapezium



Θ^1 Ori B1: B1V
B2: B3V (Petr et al. 1998)

Θ^1 Ori A: B0V (O9.7V),
likely triple (ref)

Θ^1 Ori C1: O5.5Vp (34 M_{sun})
C2: O9.5 (15.5 M_{sun})

(Kraus et a. 2007)

Θ^1 Ori D1: B0V
D2: B5/K0 (Kraus et al 2007)

Θ^2 Ori A: O9.5V, close 3 - 7 M_{sun} companion (0.43 AU) ,
dist. < 9 M_{sun} companion (173 AU)

(Abt et al. 1991, Preibisch et al. 1999)

X-ray Production in Cool Stars

Solar Corona:

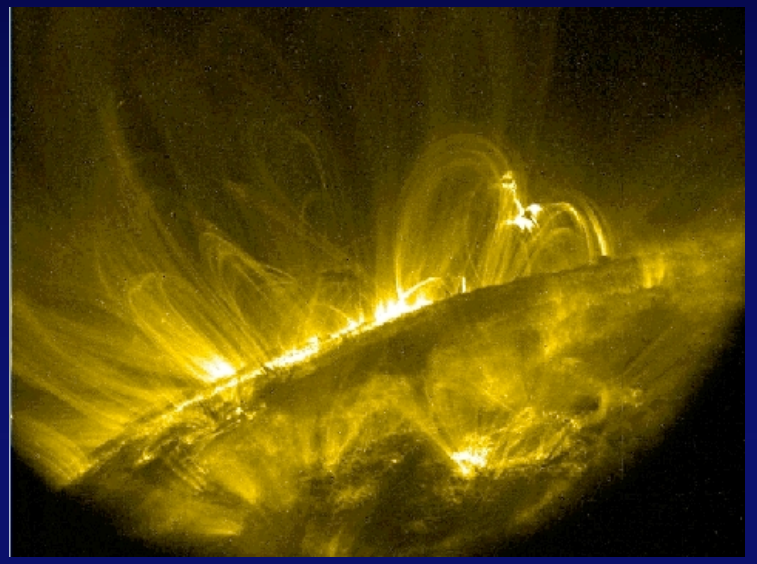
- hot. thin plasma halo
- magnetic reconnection
- energy loss in X-rays
- solar dynamo

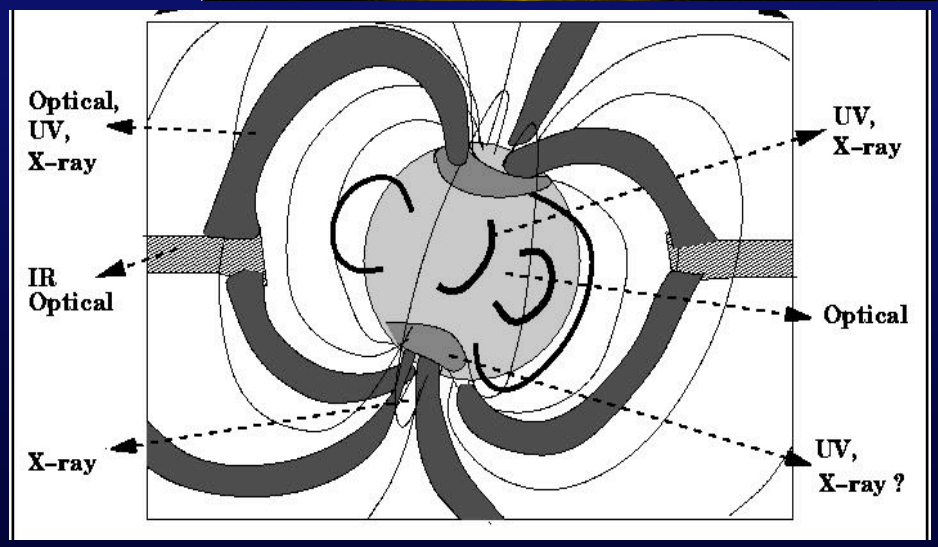
Active Coronae:

- binaries, orbits, rotation
- giant magnetic loops
- large X-ray EMs

PMS stars:

- late type (CTTS, WTTS)
- coronal activity
- star-disk interactions





X-ray Production in Hot Stars

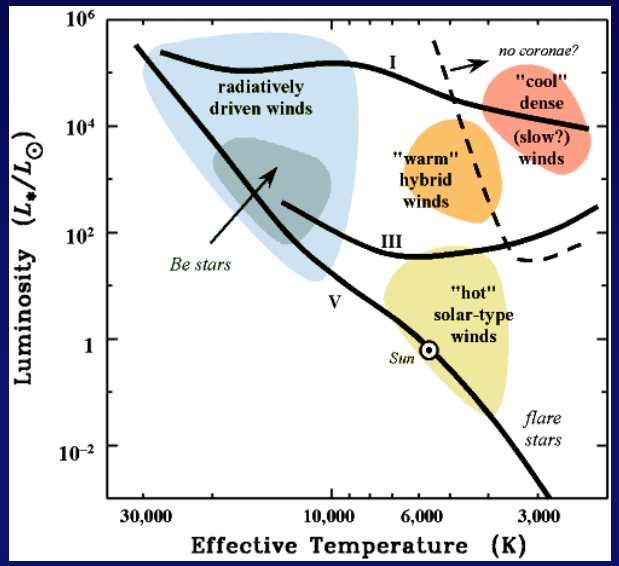
Radiation Driven Stellar Wind:
- momentum through line absorption
- momentum - luminosity relation
- soft X-rays from wind shocks
- opacity effects

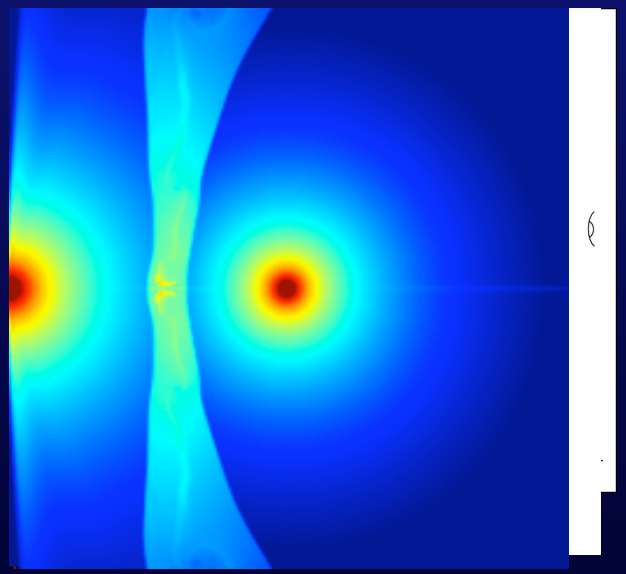
Magnetically Confined Wind:
- same as above but:
- existence of strong global B field
- mass loss vs. B field strength
- hard X-rays from dense hot plasma disk near Alfven radius

Magnetically Confined Local Plasma:
- hot emission line stars

Colliding Wind Plasmas:
- very early type binaries / WR binaries
- WR 140 , ε Carina

Binary Induced Magnetic Reconnection





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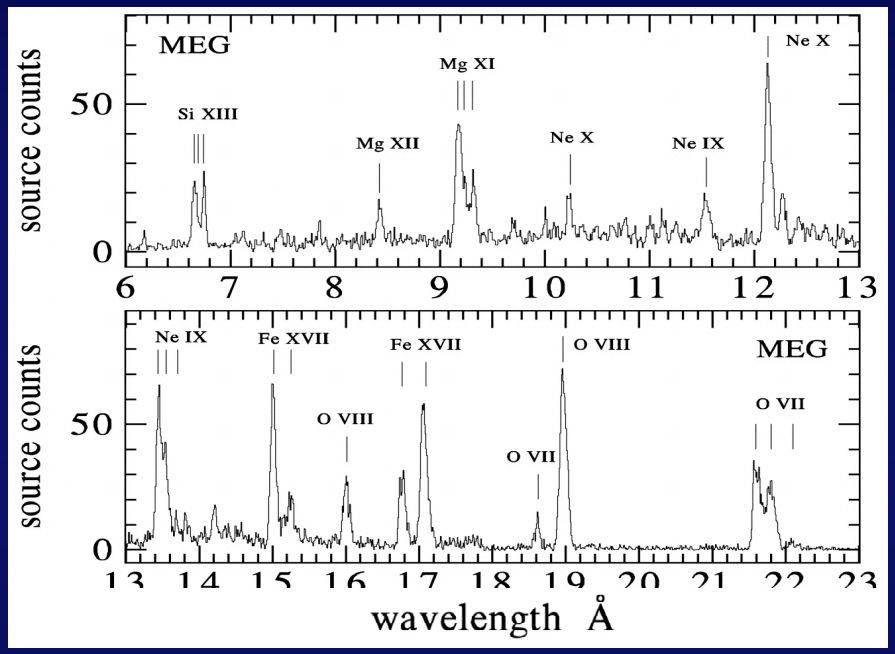
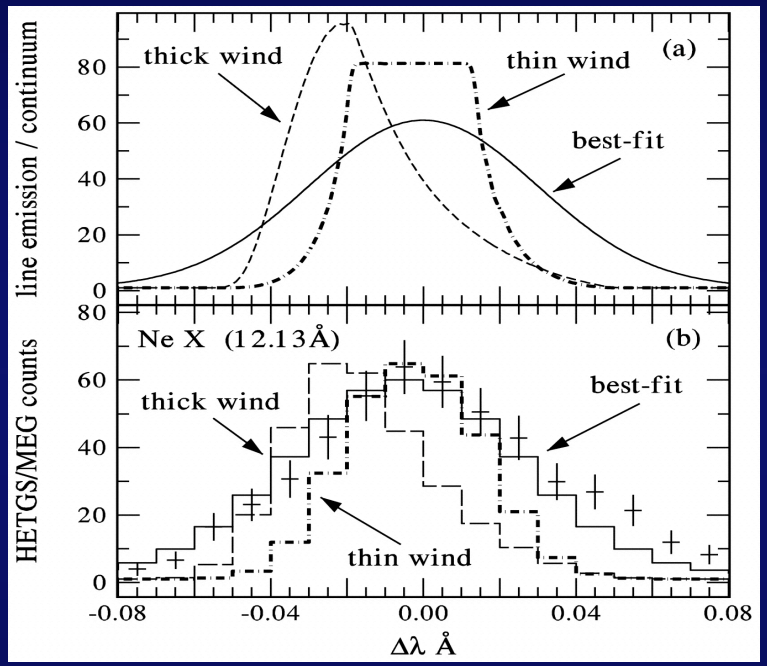
Soft X-rays from wind shocks

Soft X-rays from wind shocks:





(Waldron & Cassinelli 2001)

Star	type	log L_x [erg/s]	M [M_{sun}]	T [MK]	coronal
Θ^1 Ori B_1	B1V	30.2	10	5 -- 10	no
Θ^1 Ori B_2	B3V	< 29	8	N/A	no
Θ^1 Ori D_1	B0V	29.8	16	2 -- 7	no

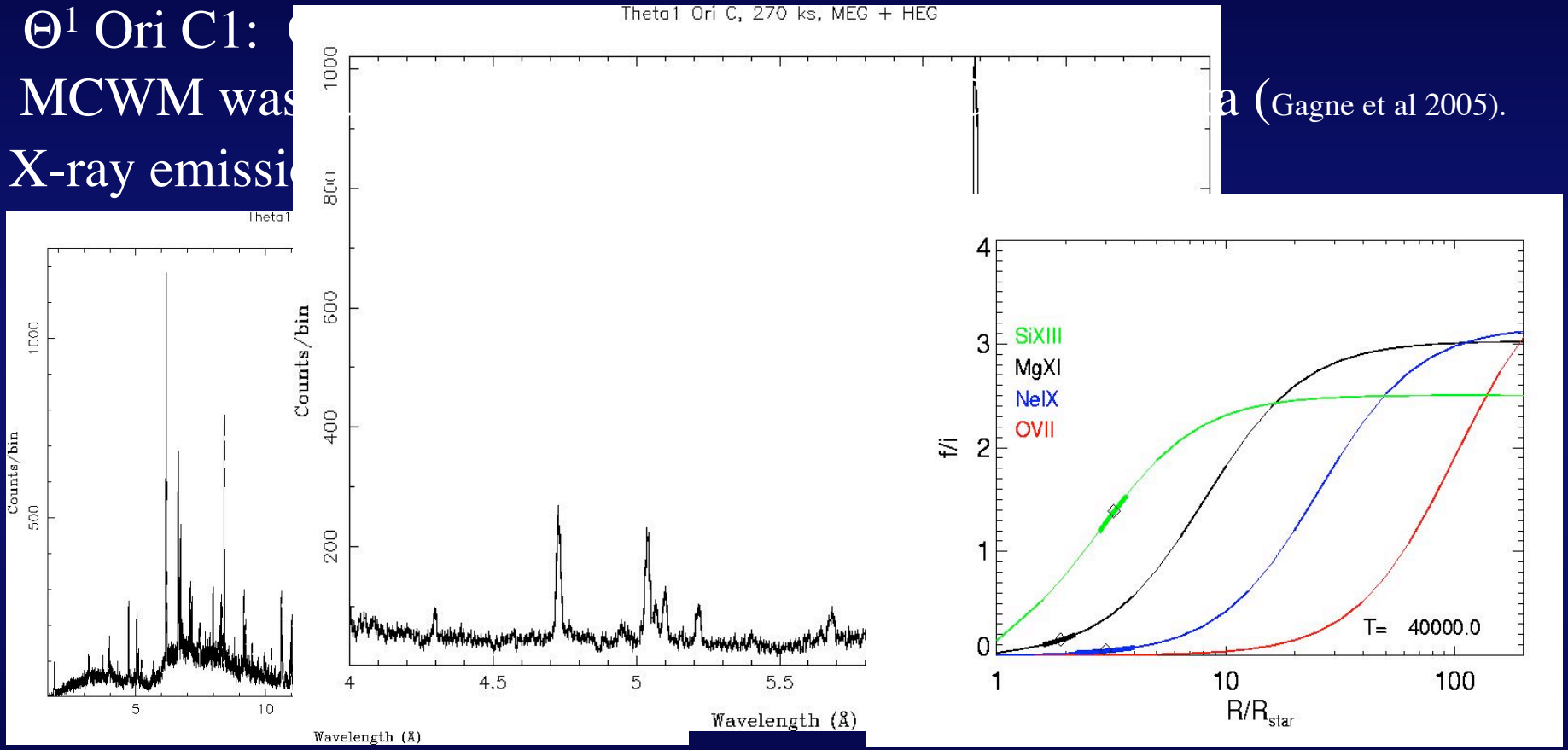
Magnetically Confined Winds: Θ^1 Ori C

Θ^1 Ori C1: (

MCWM was

a (Gagne et al 2005).

X-ray emissi



Star	type	log L_x [erg/s]	M [M_{sun}]	T [MK]	coronal
Θ^1 Ori C_1	O5.5V	33.1	35.5	7 -- 84	MCWM

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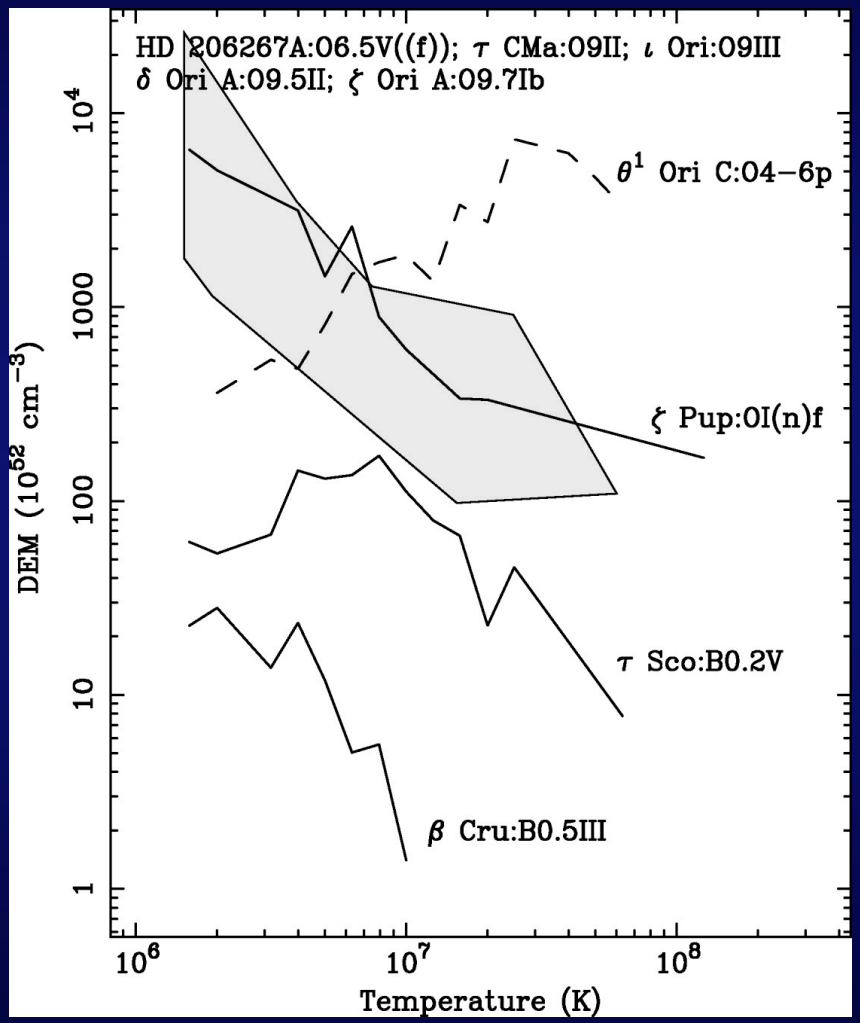
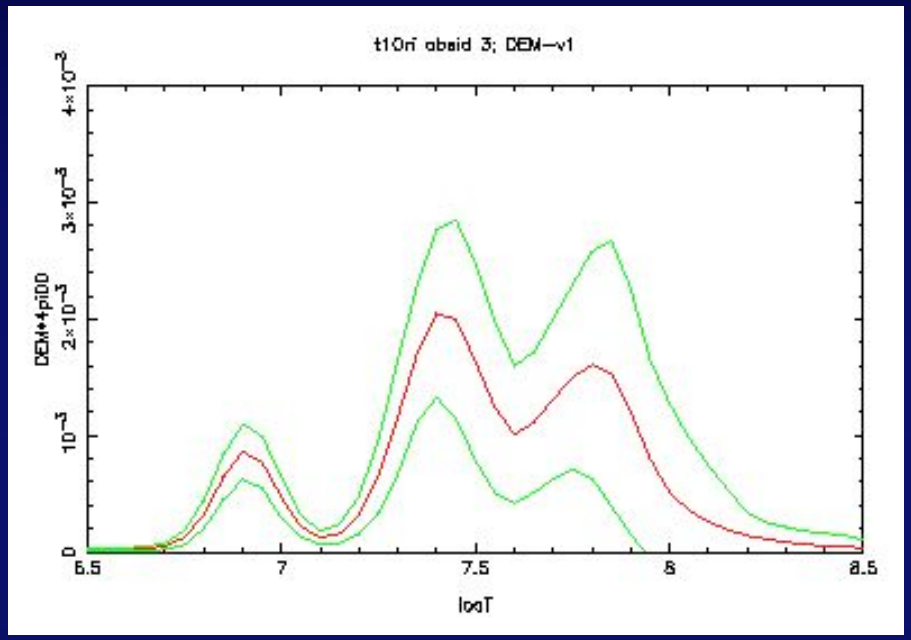
Magnetically Confined Winds: Θ^1 Ori C



(Wojdowski & Schulz 2005)

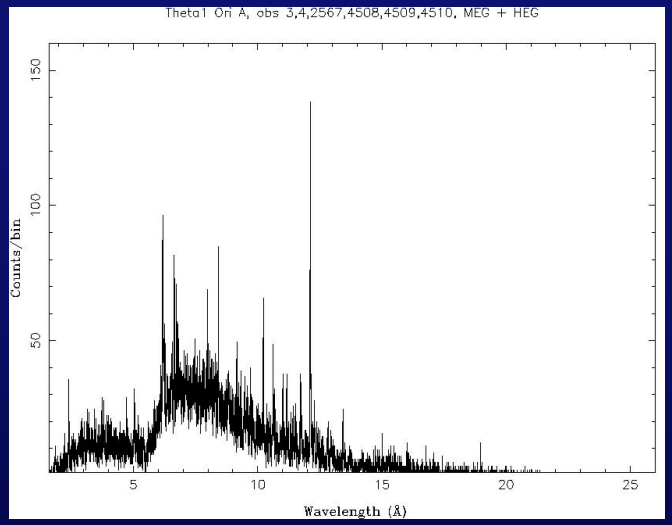


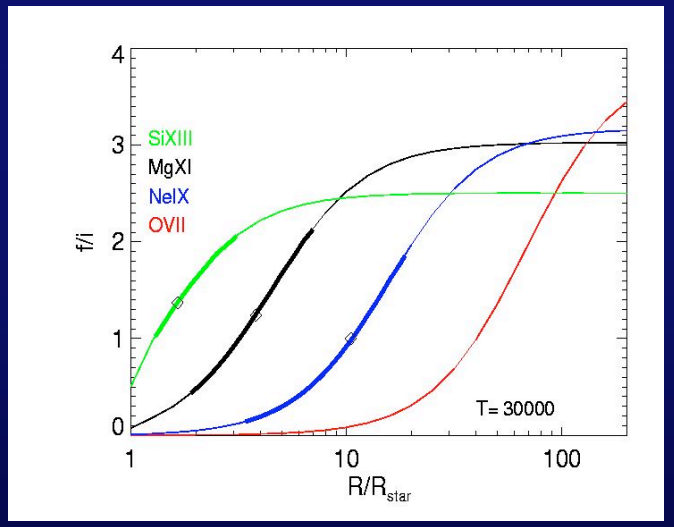
(Schulz et al. 2003)

- Low luminosity hybrid wind shock component
- No binary induced X-ray component during periastron passage of massive companion

Magnetically Confined Winds: Θ^1 Ori A

Θ^1 Ori A: B0V (O9.7V)
X-ray spectrum very similar to Θ^1 Ori C
Brightest lines show $v_{turb} \sim 200$ - 300 km s^{-1} , T > 30MK, and
He-like triplet of Si ----> all consistent with MCWM
He-like triplets of Mg & Ne still less conclusive





Star	type	log L_x [erg/s]	M [M_{sun}]	T [MK]	coronal
Θ^1 Ori A_1	B0V	31.6	15.5	12 -- 55	MCWM

Binary Induced Magnetic Activity: Θ^2 Ori $A_{1/2}$

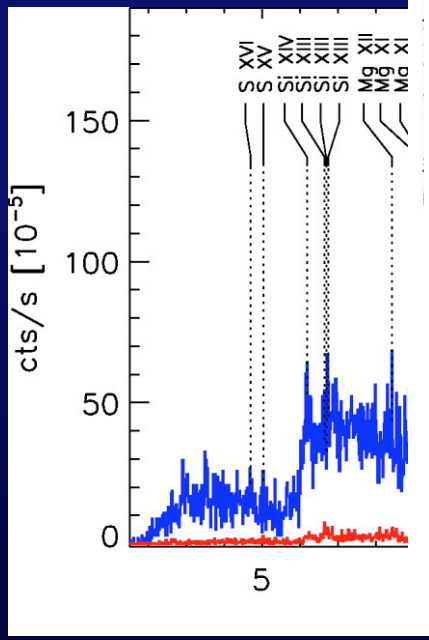
Θ^2 Ori A_1: O

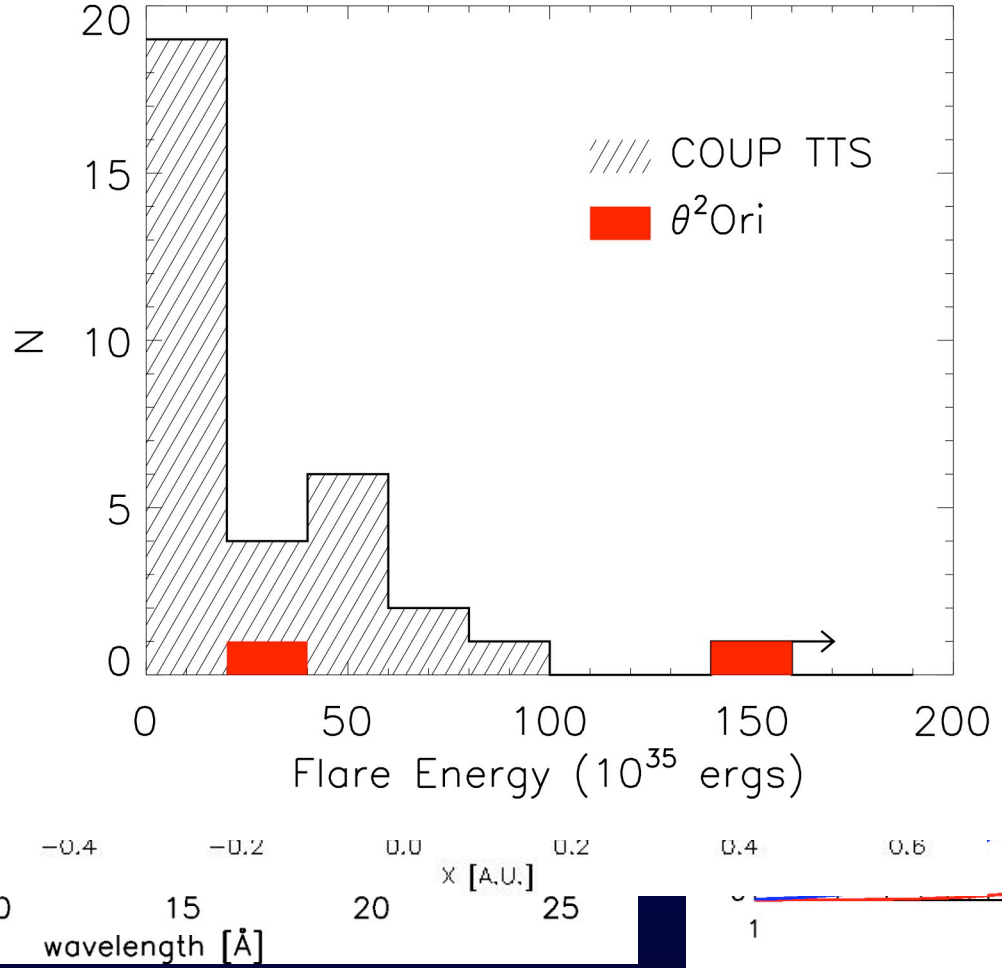
Low state con

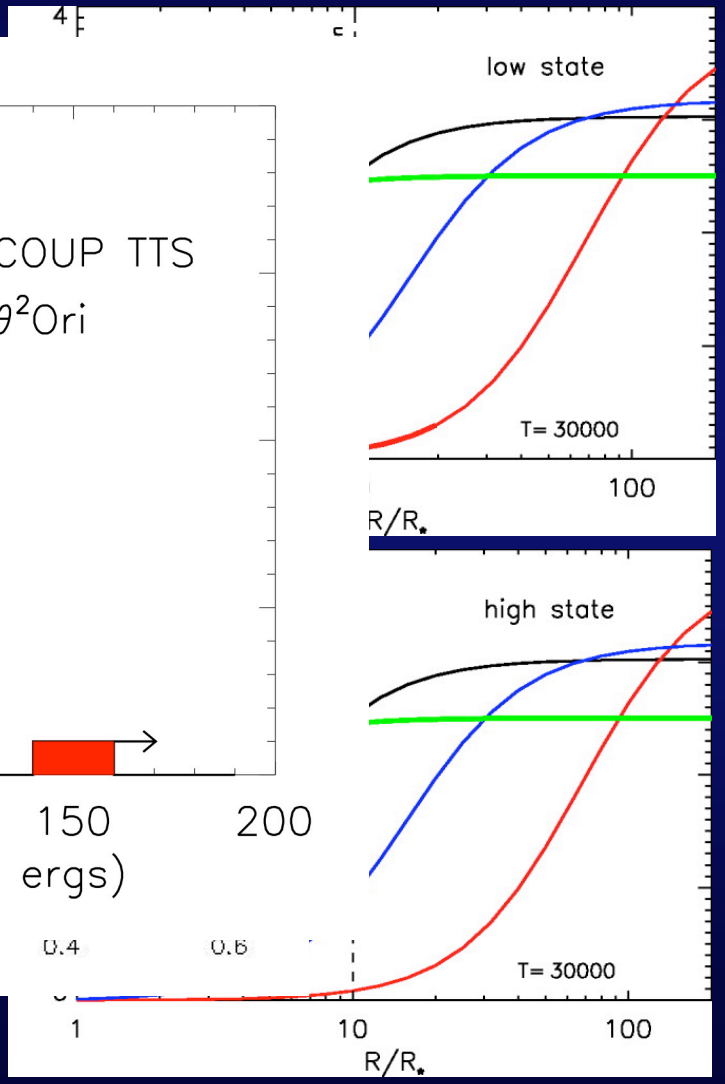
High state lik

with close bin

(Schulz et al. 2006)

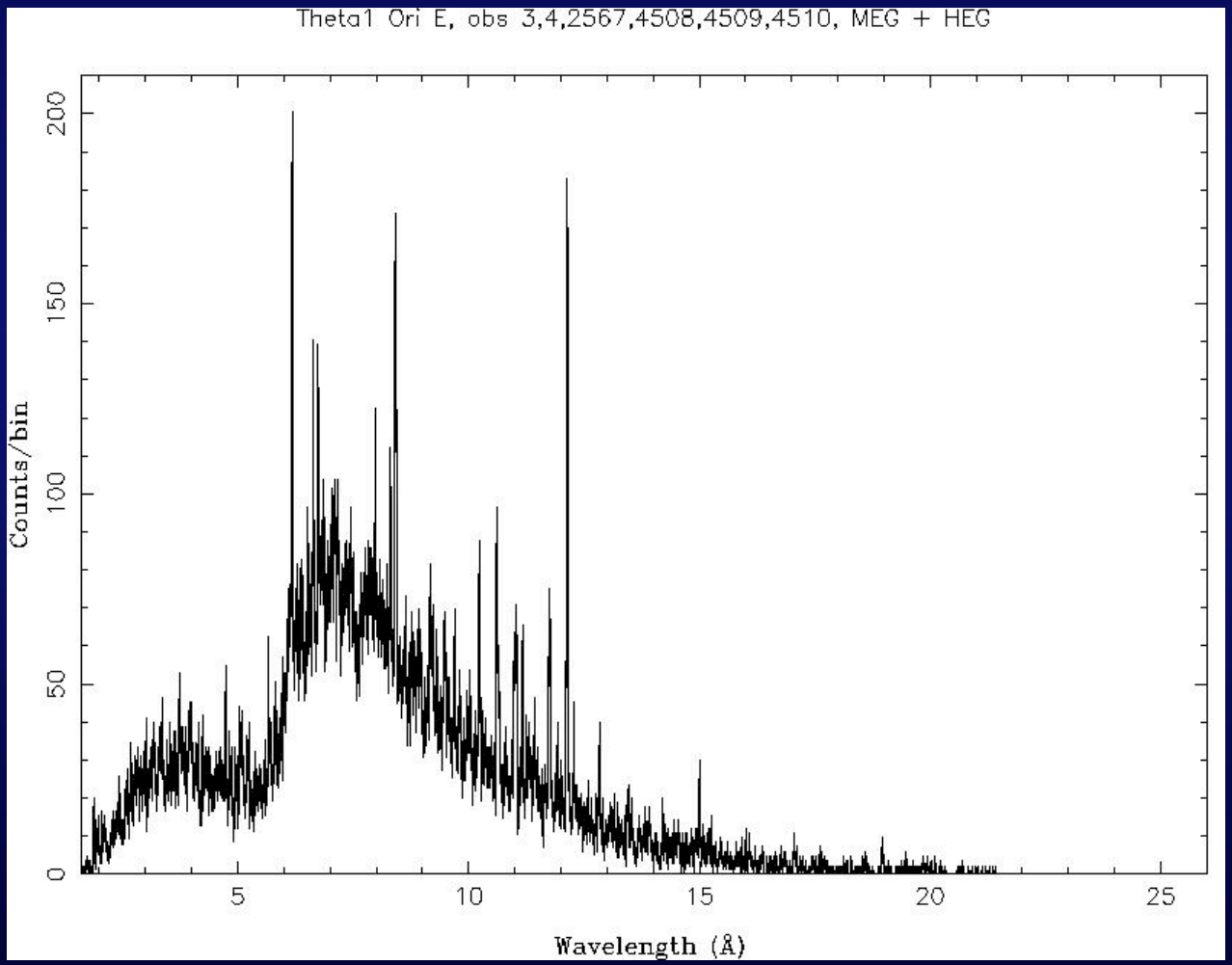






X-ray Emission from Young Intermediate Mass Stars: Θ^1 Ori E

Θ^1 Ori E is now identified as a close PMS Binary of G5III type:



$M_{1/2} \sim$ 3 -- 4 M_{sun}

$L_x = 0.7$ -- 1.1 x 10^{32} erg s^{-1}

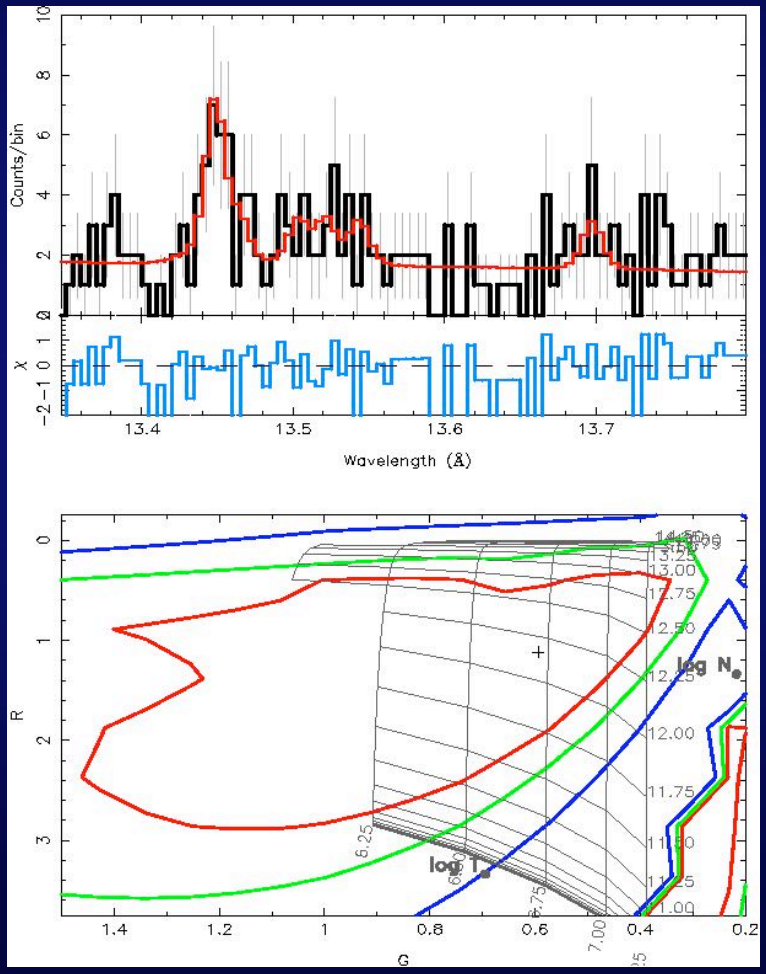
T = 20 -- 62 MK

$n_e = < 10^{14}$ cm^{-3}

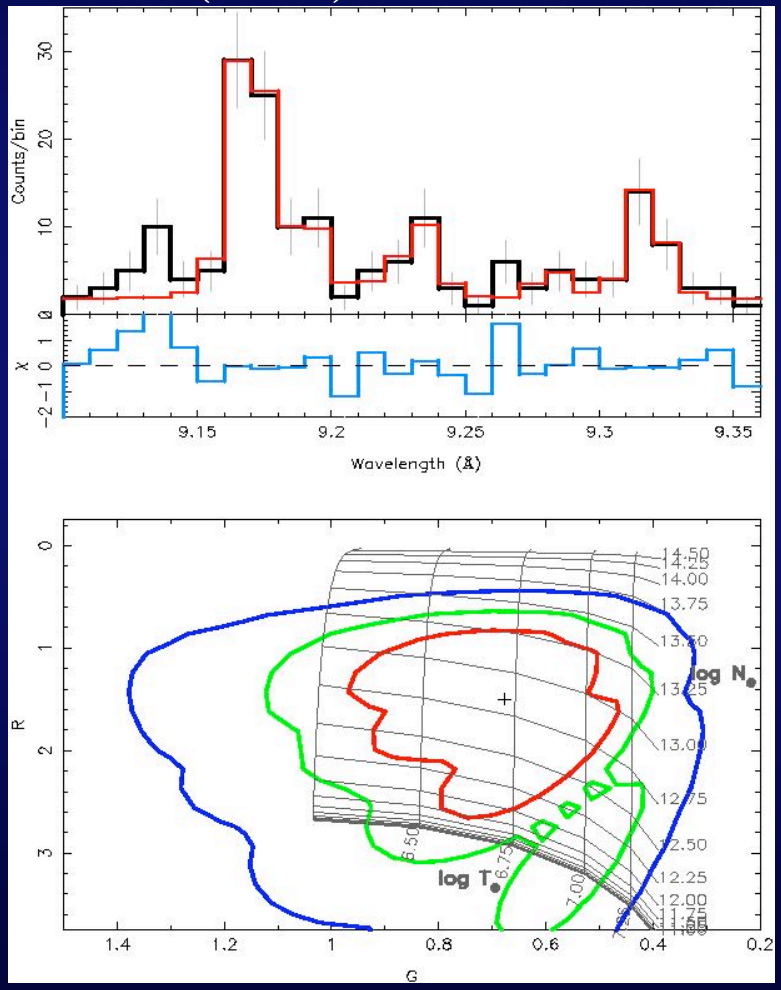
v_D < 150 km s^{-1}

X-ray Emission from Intermediate Mass Stars: Θ^1 Ori E

Θ^1 Ori E (Schulz et al. 2007):

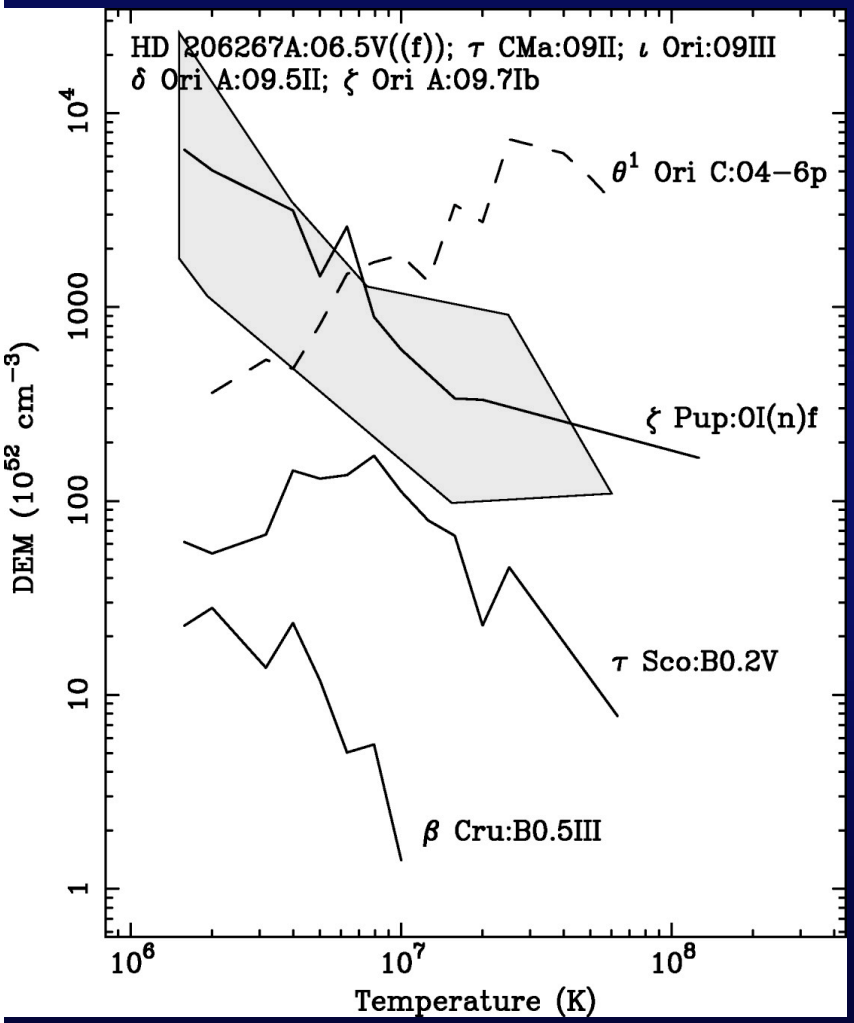


ε Cha (HAe) (Testa et al. 2007):

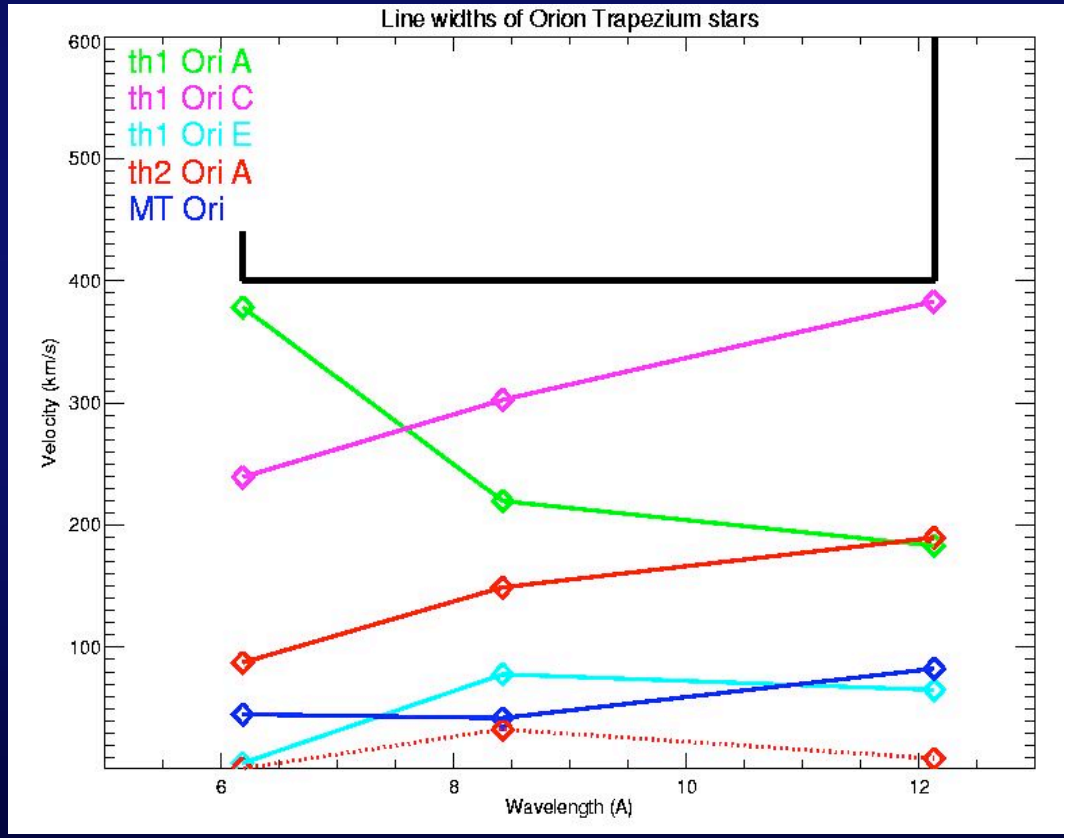


Comparison with evolved Hot Stars

Emission Measure:



Line Widths:



X-ray Properties of Massive Orion Trapezium Stars

Star	type	log L_x [erg/s]	M [M_{sun}]	T [MK]	coronal
Θ^1 Ori A_1	B0V	31.6	15.5	12 -- 55	MCWM
Θ^1 Ori B_1	B1	30.2	10	5 -- 10	no
Θ^1 Ori B_2	B3	< 29	8	N/A	no
Θ^1 Ori C_1	O5.5V	33.1	35.5	7 -- 84	MCWM
Θ^1 Ori D_1	B0V	29.8	16	2 -- 7	no
Θ^1 Ori $E_{1/2}$	G5 III	32.1	3 -- 4	10 -- 60	bright/hot
Θ^2 Ori A_1	O9.5V	31.8	15.5	10 -- 55	MCWM

Summary & Confrontations

- Massive Trapezium stars show a variety of unusual phenomena
- Θ^1 Ori B,C,D show that young massive ZAMS are X-ray weak unless they are enhanced by external interactions
  (see also Trifid [Rho et al. 2003])
- Wind enhancement in Orion is likely all due to magnetic interactions, i.e. in form of magnetic wind confinement and binary induced magnetic reconnection
- No evidence for colliding winds
- Not all massive Trapezium stars are magnetic.
- Θ^1 Ori E is X-ray peculiar, may provide coronal link to X-ray production in HAEBE stars