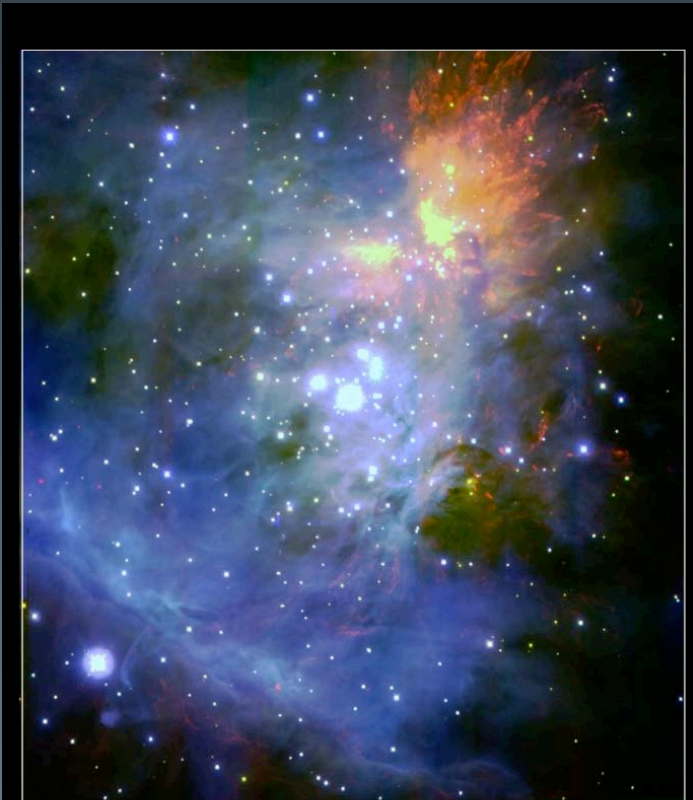


Superflares from young stars

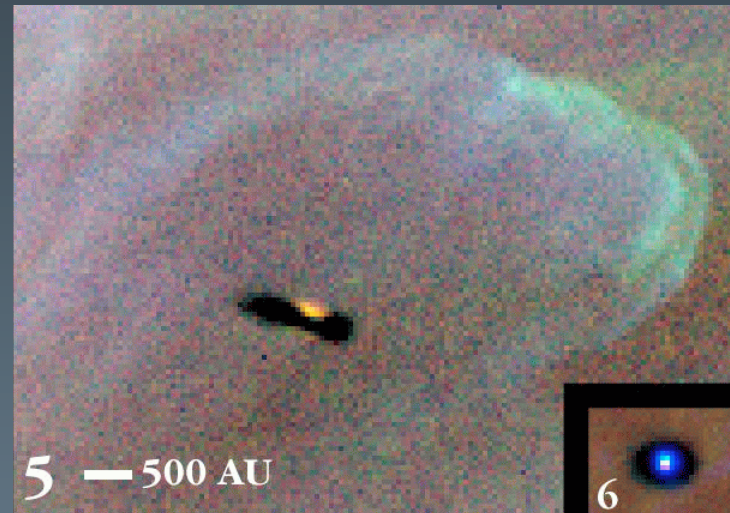
Eric Feigelson (Penn State)

X-rays and star/planet formation



 **Orion Nebula** CISCO (J, K' & H₂ (v=1-0 S(1)))
Subaru Telescope, National Astronomical Observatory of Japan January 28, 1999

Orion Nebula cluster & proplyd



Star formation occurs in molecular cloud cores at $T \sim 10-100$ K. Planet formation occurs in disks at $T \sim 100-1000$ K. This is neutral material (meV).

But high energy radiation is present in planet formation environments: keV photons & MeV particles are produced in violent magnetic reconnection flares.

These flares are similar to those discussed by Rachel Osten on RS CVn binaries with $\log L_x(\text{peak}) \sim 32$ erg/s

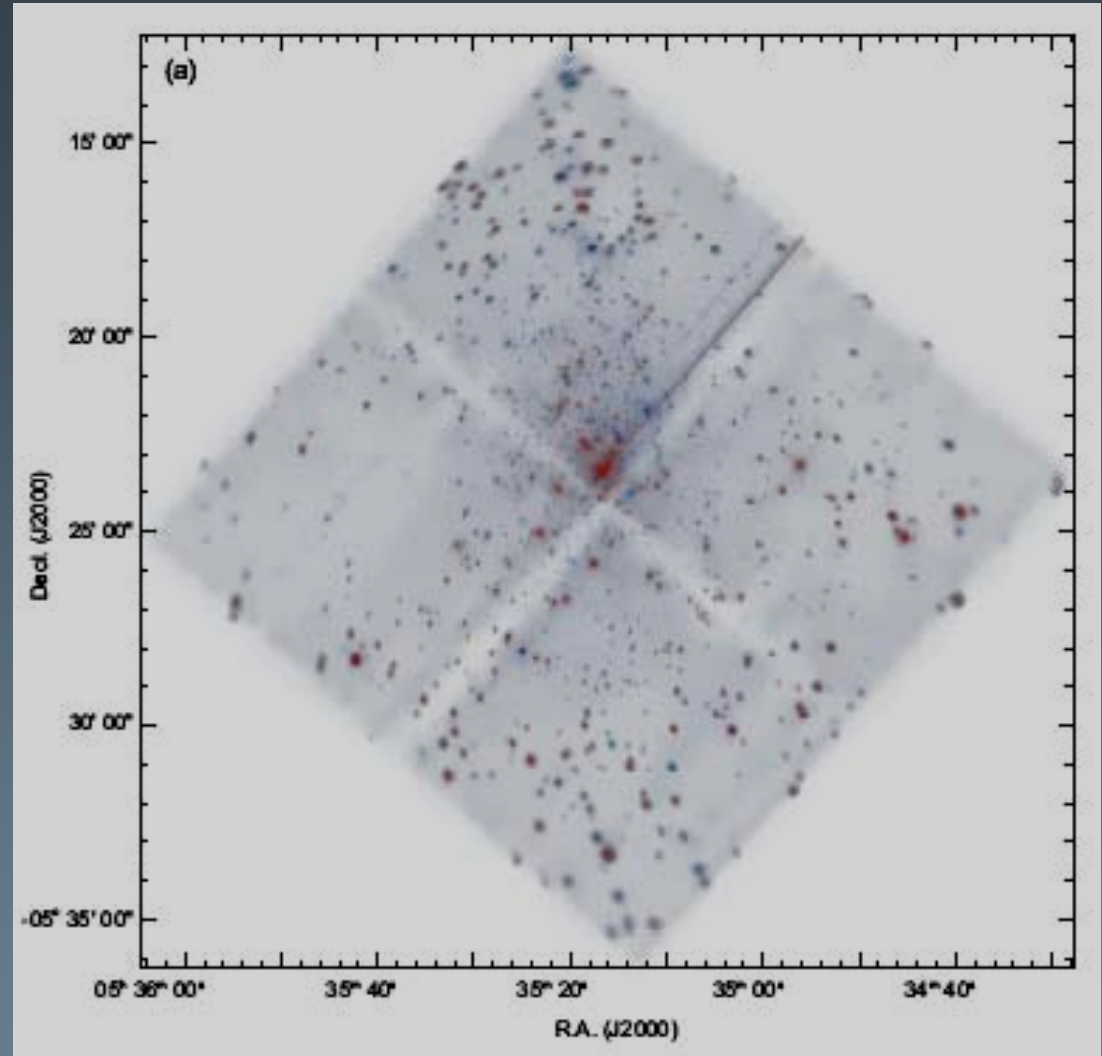
The nearest low-mass star formation regions with 10^2 stars are at $d=140$ pc, and the nearest massive star formation region with 10^4 stars is Orion at $d\sim 450$ pc. These are too distant for the flares to be readily detected by Swift.

The Chandra Orion Ultradeep Project

13-day observation of the Orion Nebula

1616 COUP sources:
849 low- N_{H} ONC stars
559 high- N_{H} stars, incl.
75 new members

16 foreground stars
159 probable AGN
23 uncertain



Getman & 22 others 2005 COUP #1 & #2

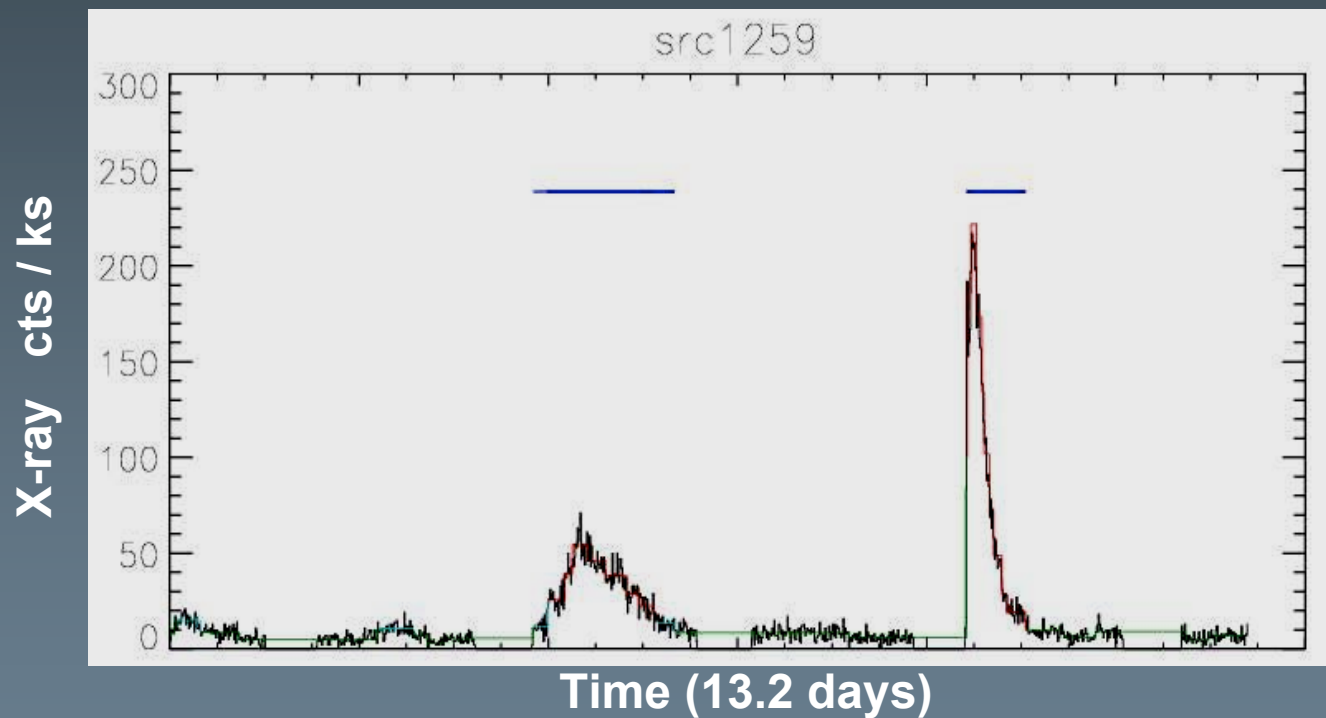
COUP: The Movie



Extraordinary flares in Orion pre-main sequence stars

1

2



JW 738

K=10.5

Age ~ 10 Myr

Mass ~ 1 Mo

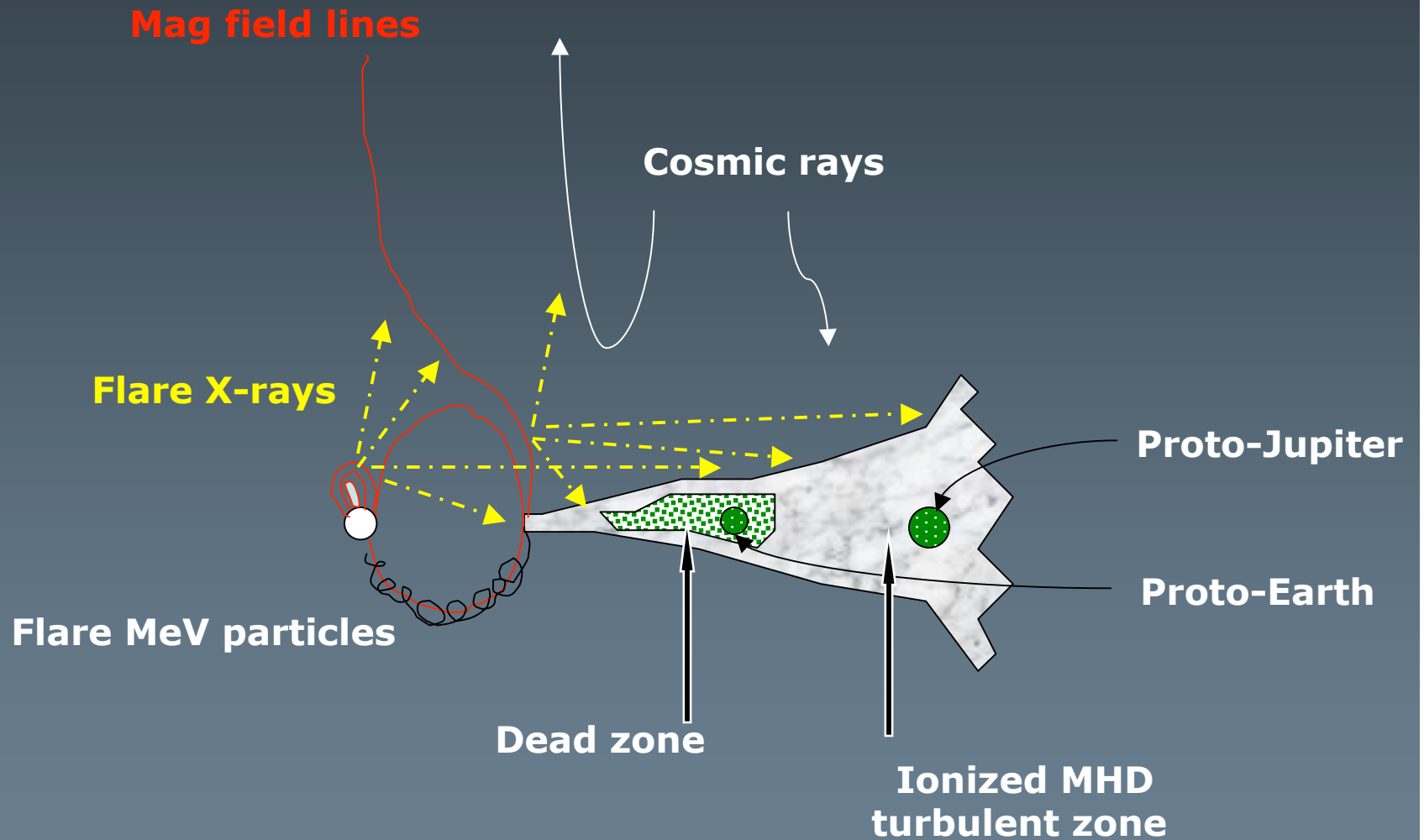
log Lp = 32.6 erg/s

Wolk et al. 2005 COUP #5

But there are reasons to think twice about Swift & young stellar flares ...

- T Tauri flares may involve reconnection in star-disk magnetic field lines, which may not be restricted to $\log L_x(\text{peak}) \sim 32$.
- Superflares with $\log L_x(\text{peak}) \sim 33$, even if rare, may be particularly important for the effects on early Solar System solids (primitive meteorites): chondrule melting, short-lived radionuclides.
- X-rays likely affect the gas phase of protoplanetary disks (heating, ionization, chemistry, turbulence, viscosity, shocks, melting & spallation of solids), and occasional superflares may also be important (e.g. disrupting the 'dead zone' where terrestrial planets form).

X-ray influence on planet formation



Feigelson et al., Protostars & Planets V review 2007

*Planetary systems form in
cool dark disks*

....

*which are irradiated by 10^8 violent
magnetic reconnection flares*