Young Stellar Populations in the Galaxy, X-rays, & WFXT

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Items of interest

- The nearby young (< 10^9 yr) stellar population & the recent star formation history in the Galaxy
- The nature of Gould Belt (Disk ?)
- Formation and evolution of Young Stellar Clusters (YSC) & their IMFs

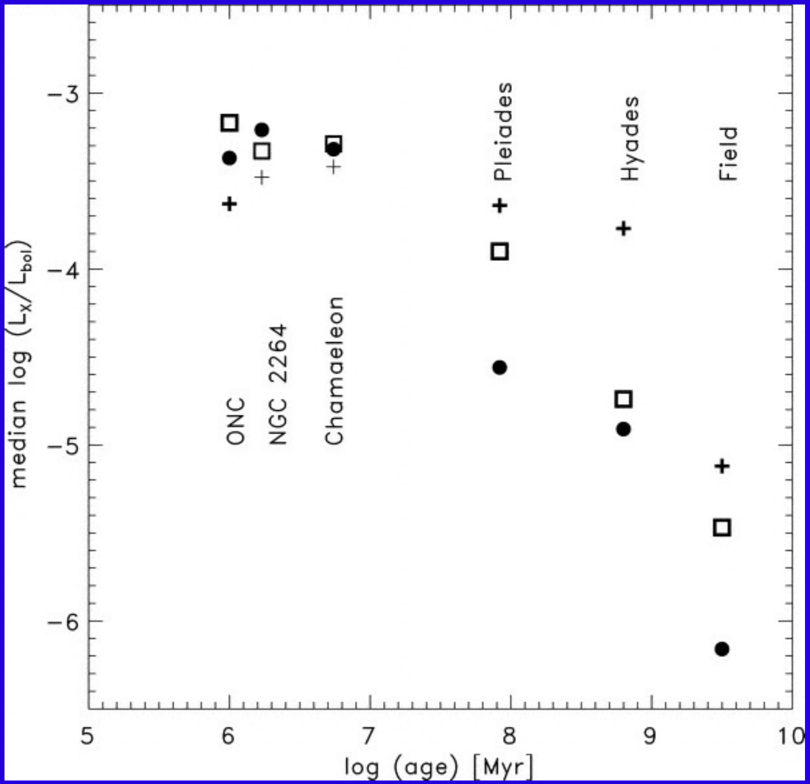
    Remarks: Multiwavelenght approach is generally needed. Spitzer, Kepler, Herschel & expecially Gaia … are/will be crucial parts of the game

Example of another possible program:

- X-ray Cycles of late-type stars
- ..... and serendipitous discoveries expected: BDs ..

A key propertie of stellar coronae

- X-ray luminosity decays by 1000-10000 from the PMS to the solar age, mainly during the main sequence.
- Explanation related to the complex rotation history



Preibisch & Feigelson 2005, ApJS

Different symbols refer to different masses

The nearby young stellar population

- X-ray surveys are essential to constrain
  - i) the spatial distribution of young (< 10^9 yr) stellar population (i.e. its density and scale height)
  - ii) the star formation rate in the last billion year

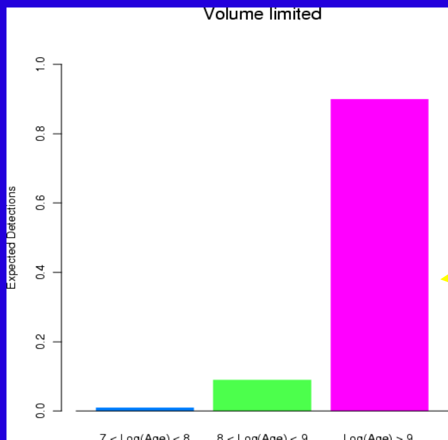
  Indeed at this ages optical surveys are "blind"
- Early results based on the EMMS -> Excess of yellow stars, either young or active binaries

Younger than Pleiades, ~ Hyades age, Sun-like age

7<log t<8 | 8<log t < 9 | log t > 9

X-ray observations select active and young stars

Number of expected X-ray detections

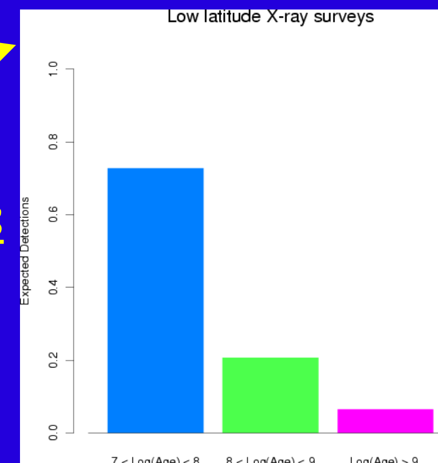


Volume limited

solar vicinity

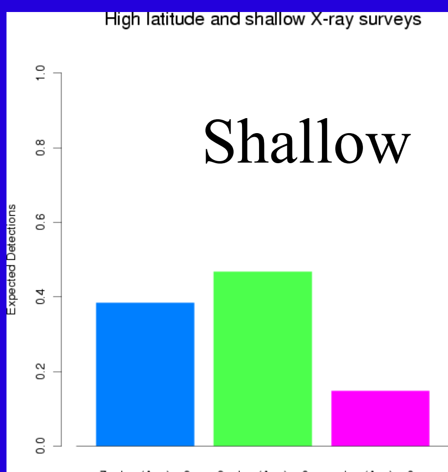
Low latitude

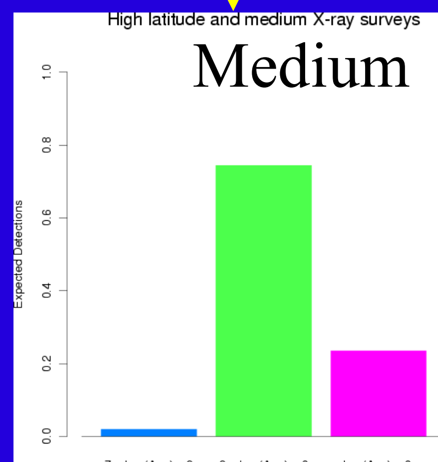
X-ray surveys

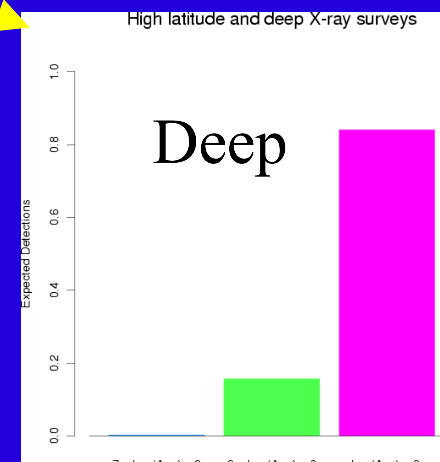


High latitude

X-ray surveys







The nearby young stellar population

- Why X-ray surveys? -> Lx decreases by 3-4 orders of magnitude during the main sequence lifetime
- We can observe young stars at much larger distances than old stars => *Young stars dominate shallow stellar X-ray selected sample while old stars dominate deep high latitude stellar X-ray selected samples.*
- Comparisons with stellar galactic models allow us to derive the spatial distributions of stellar populations
- Active binaries, with high Lx, are selected as well so companion optical data are required to disentangle the case

XCOUNT: A stellar X-ray Galactic model

Favata, Micela, Sciortino & Vaiana 1992

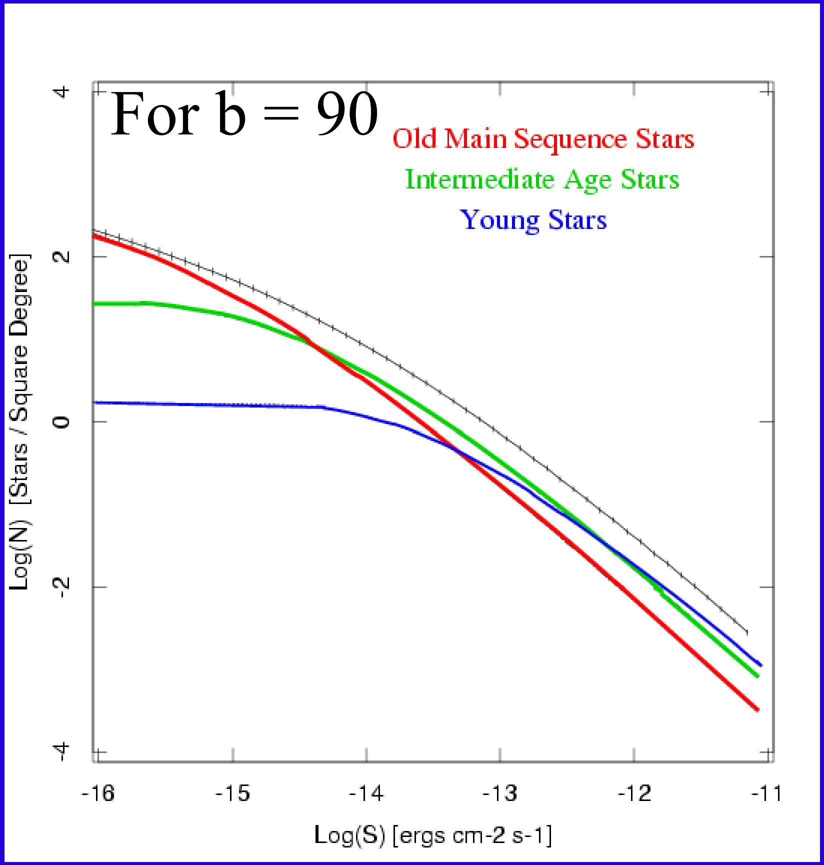
Micela, Sciortino & Favata 1993

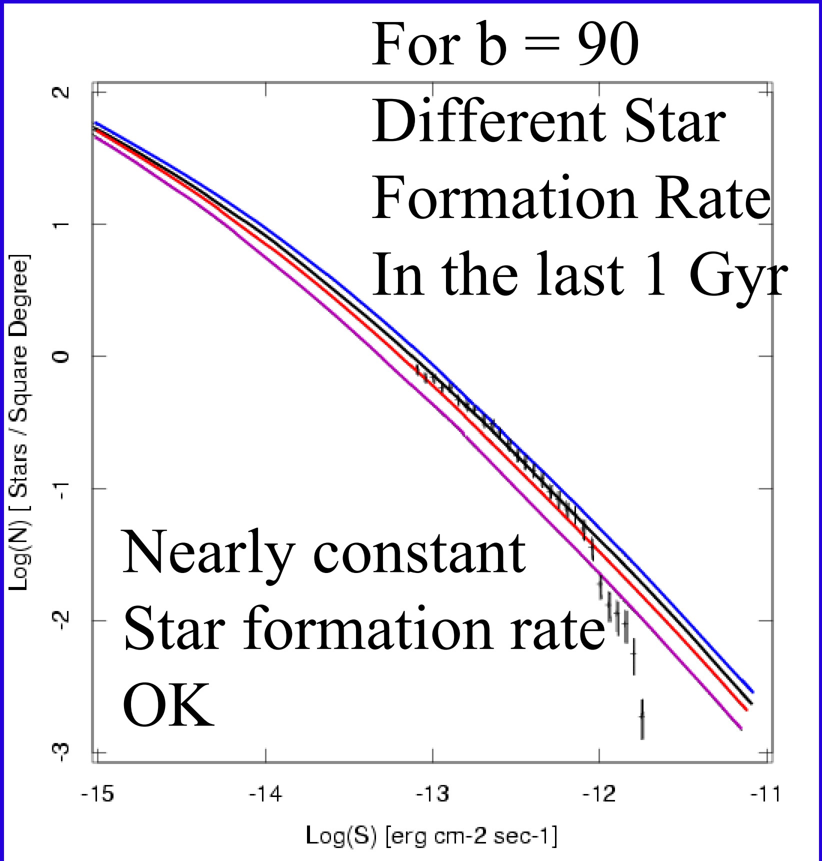
Sciortino, Favata & Micela 1995

- Average Stellar spatial distribution
- Average Spatial model of interstellar gas
- X-ray luminosity functions from selected well studied open clusters and stellar samples

Constraints on Stellar Birthrate

(Micela, Sciortino & Favata, 1993)





The pointed Rosat Galactic Plane Survey

(Morley, Briggs, Pye, Favata, Micela & Sciortino 2001)

The density of active stars in the Galactic Plane is larger than assumed in XCOUNT

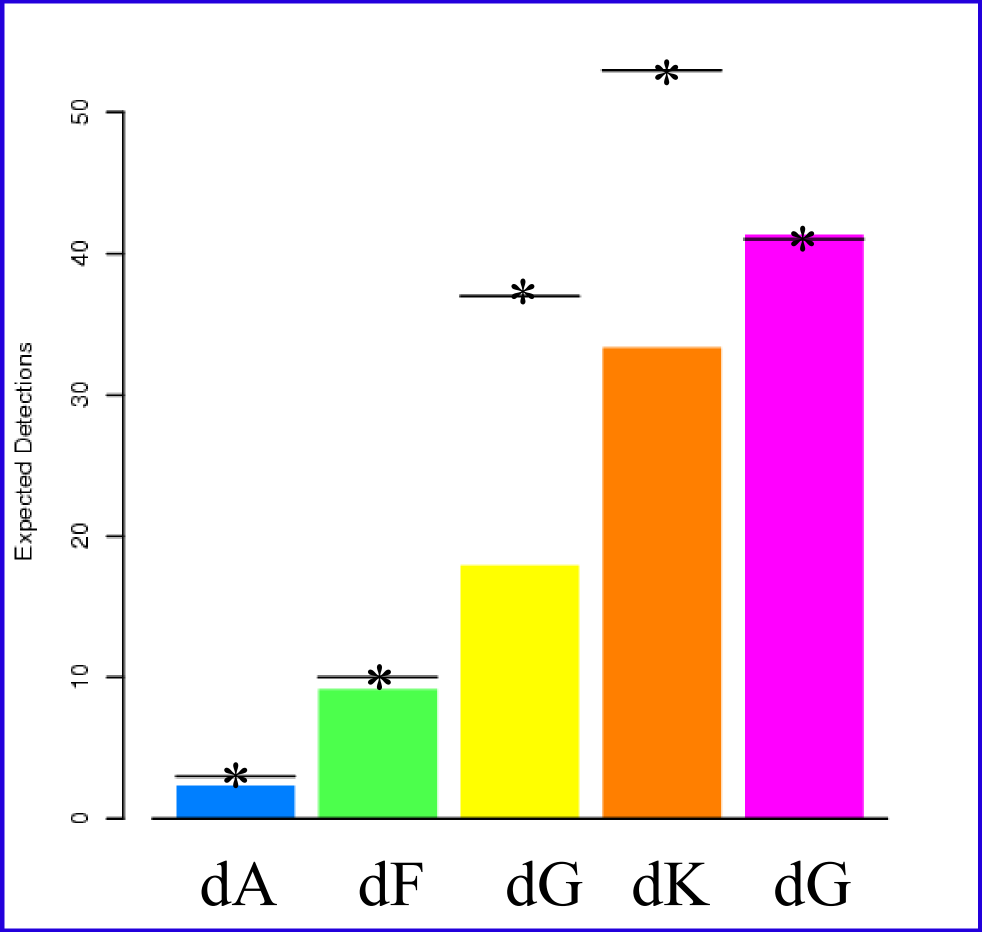
↓

The star formation rate is increased in the last billion year

OR

Scale heights are smaller tha assumed in XCOUNT (as in Besançon model)

ROSAT NEP: 9 x 9 sq. deg, 445 sources, 152 stars, Fx ~ 10^{-14} erg/s/cm^2



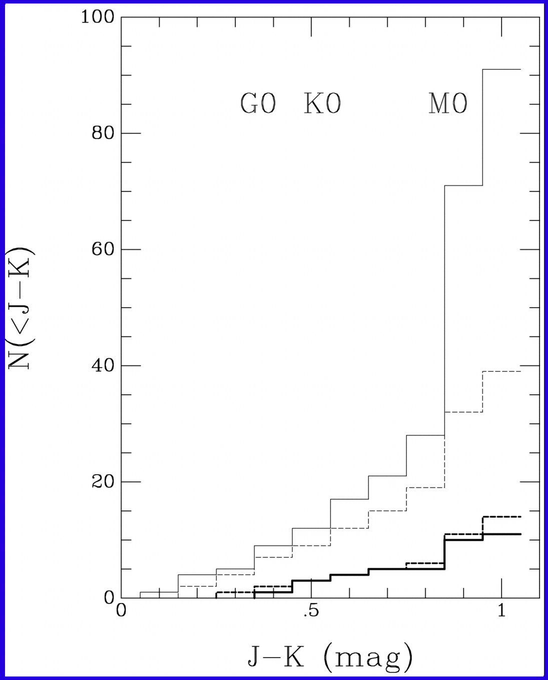
- A-F and dM predicted stars agree well with the observations.
- A significant excess of yellow stars is present, as in the EMSS

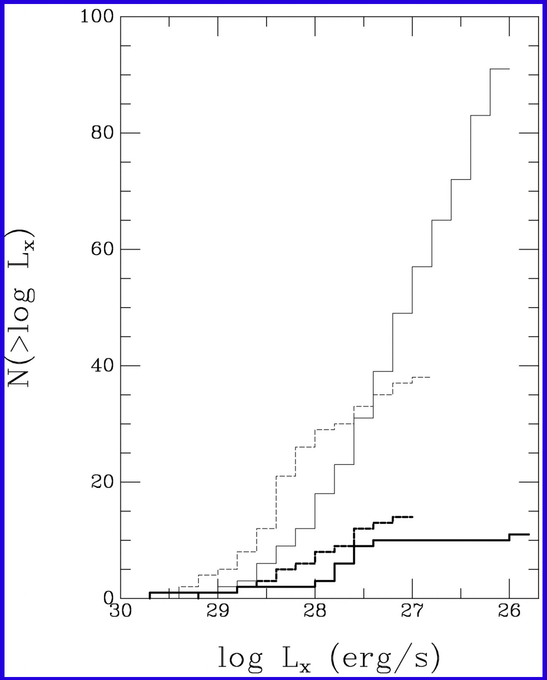
The Chandra and XMM/Newton contribution: Higher Sensitivity

- We reach and go beyond the scale heights of the youngest stars
- All young and intermediate age stars detected
  - Hence --->
- Stellar content of high-latitude deep X-ray surveys is dominated by old low mass stars

The case of CDFN (11 X-ray stars !)

(Feigelson, Hornschemeier, Micela et al. 2004)



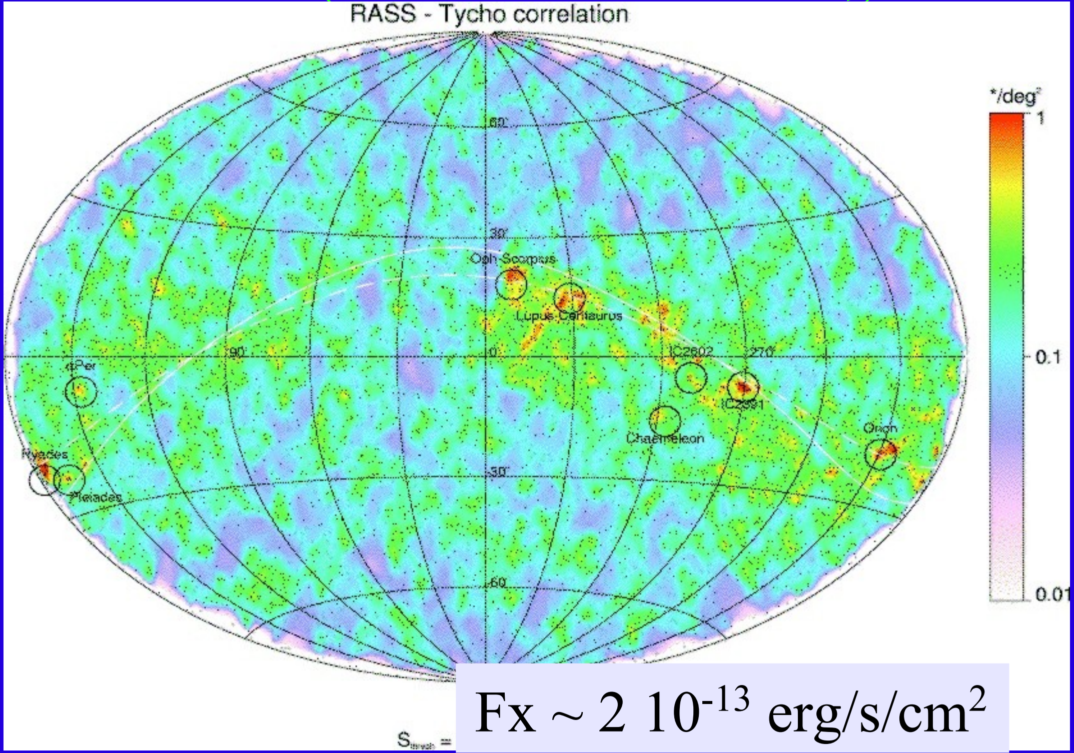


- Total Stellar Population with V < 22.5 (Thin solid)
- X-ray Selected Stellar population (Thick solid)
- "Standard" XCOUNT model prediction (Thin dashed)
- XCOUNT model prediction with rapid ($L_x \sim age^{-2}$) decay above 1 Gyr (Thick dashed)

Young stellar population from RASS

(Guillout et al. 1998)

Cross-IDs between RASS sources (S = 0.03 PSPC c/s,) and Tycho stars --> Putative structure of young stars in the solar neighborhood likely coincident with the Gould Belt



N X-ray star/sq.deg

Questions:

Real Physical Structure ?

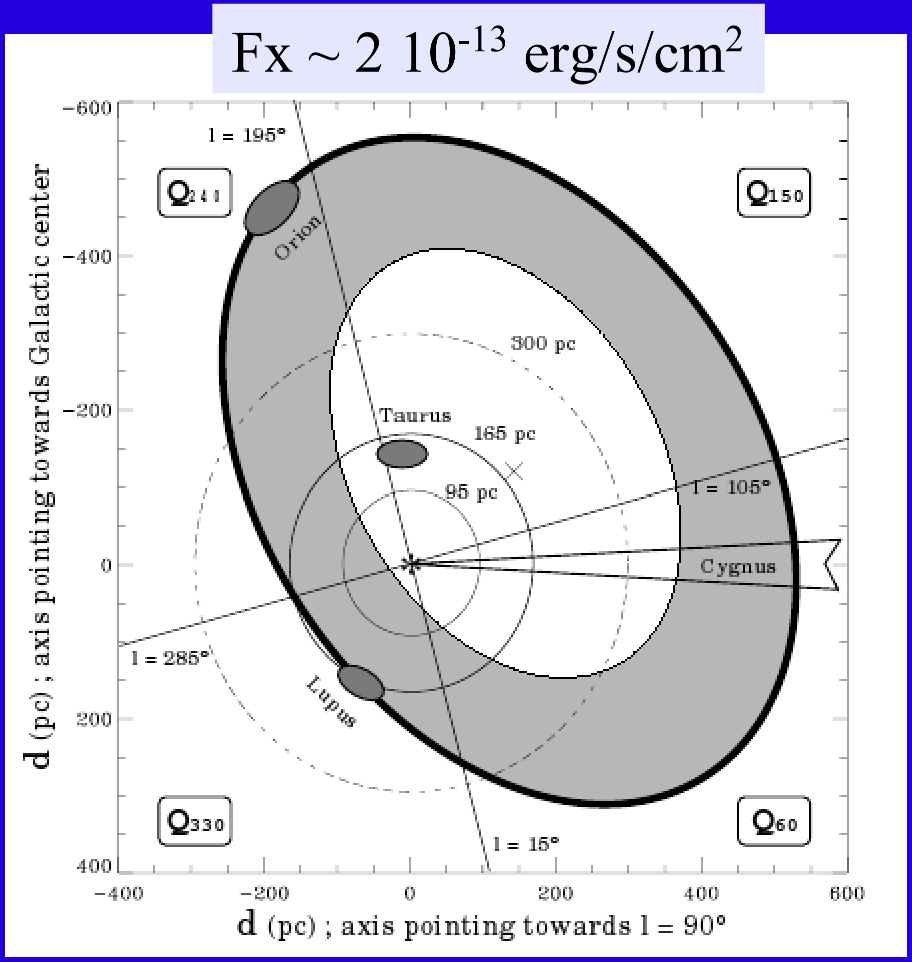
Belt or Disk ?

Nearby SF process(es) and triggering ?

X-ray survey (selection) & GAIA (dist, vel)

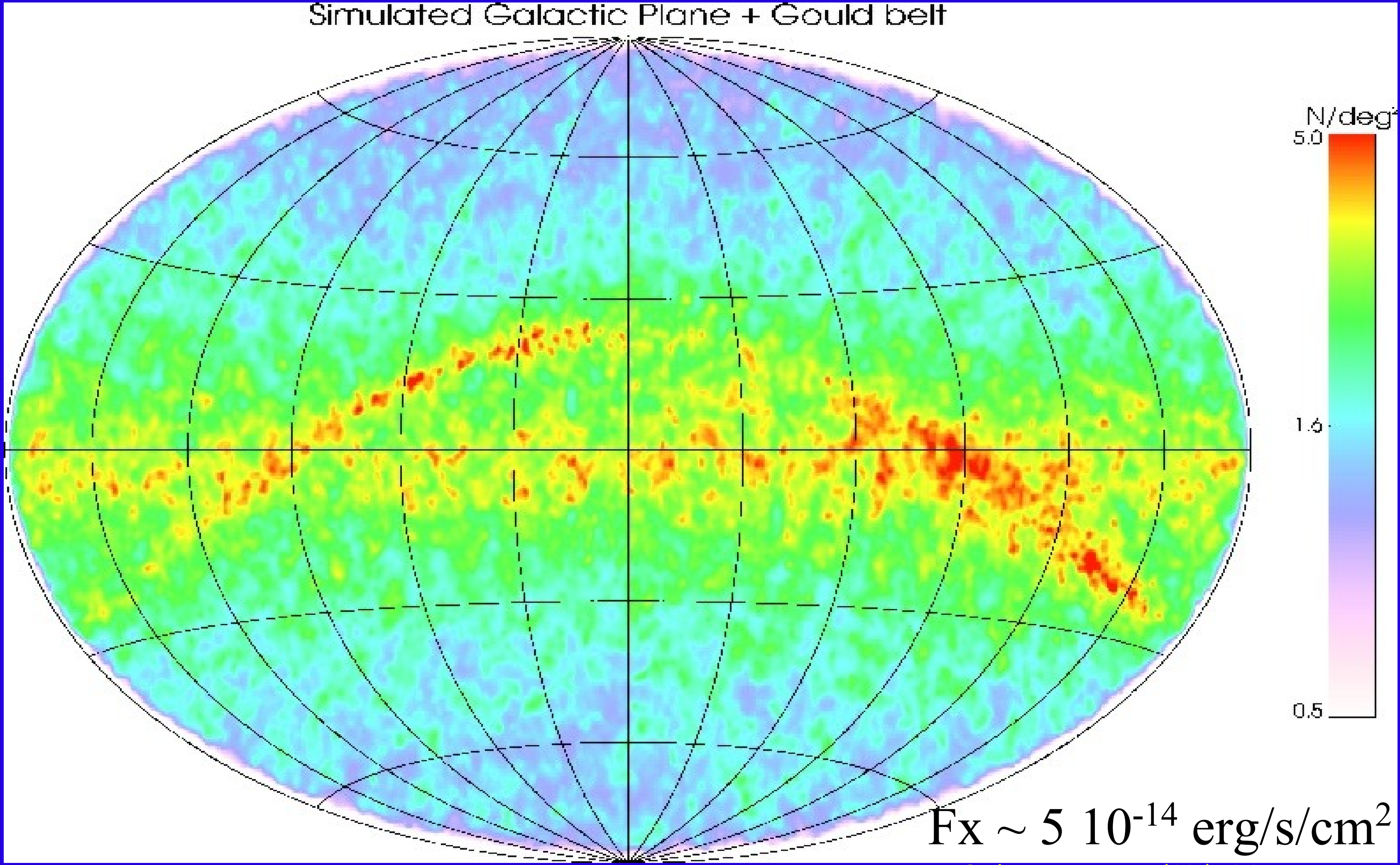
Will jontly sort out the questions

Gould Belt/Disk and (RASS) X-ray horizons



Going ~10 times deeper we have an horizon of ~ 1 kpc
→
Entire Gould Belt/Disk explored

Going deeper on large area with a shallow WFXT survey



$F_x \sim 5\ 10^{-14}$ erg/s/cm^2

Issues on the Formation and Evolution of YSCs embedded in GMCs ? (cf. Feigelson et al. 2009, Decadal White Paper)

- Do clusters form rapidly during a single collapse event or slowly over many crossing times ?
- Why are massive stars rare ? Do they form via accretion disks or stellar mergers ?
- How does the feedback from OB stars both halt and promote further star formation?
- Is the stellar IMF truly universal over a wide range of cloud conditions, and what produces its distinctive shape ?
- When and why does primordial mass segregation (if any) occur ?
- What effect do shocked OB winds have on the physics of the HII region and the confining GMC ?
- What fraction of stars in the Galaxy form from triggered processes?
- What determines whether a YSC survives the dispersal of its parental molecular gas and becomes a bound open or globular cluster?
- How does the cluster environment influence the evolution of protoplanetary disks and subsequent formation of planetary systems?

How to tackle these questions ?

- Pancromatic studies required: Optical, Infrared (from ground and space), millimiter (ALMA), **<u>as well as X-rays</u>** observations are needed.
- IRAC Spitzer data are having an impressive impact in the field, but, just as an example, IMF can hardly be derived from Spitzer data alone (missing a [large ?] fraction of WTTs)

Star Forming Regions: where we are currently

X-rays has discovered very young stars without or with weak disks and accretion (WTTS, e.g. Walter et al. 1988, then Rosat All Sky Survey)

X-rays are the best way to identify the WTTS

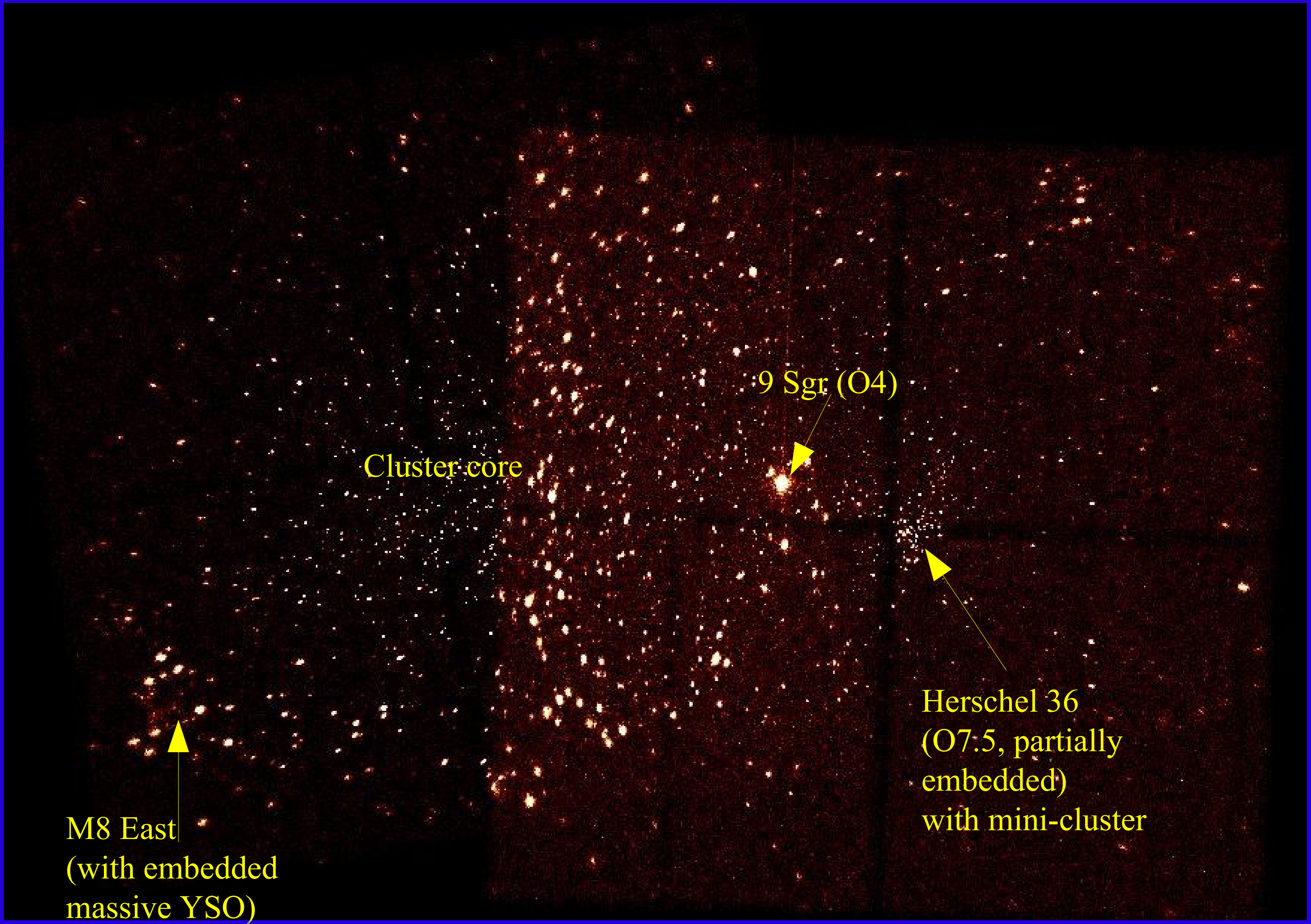
=> crucial tool for IMF study in the Galaxy

Chandra and XMM studies of several tens of SFRs:

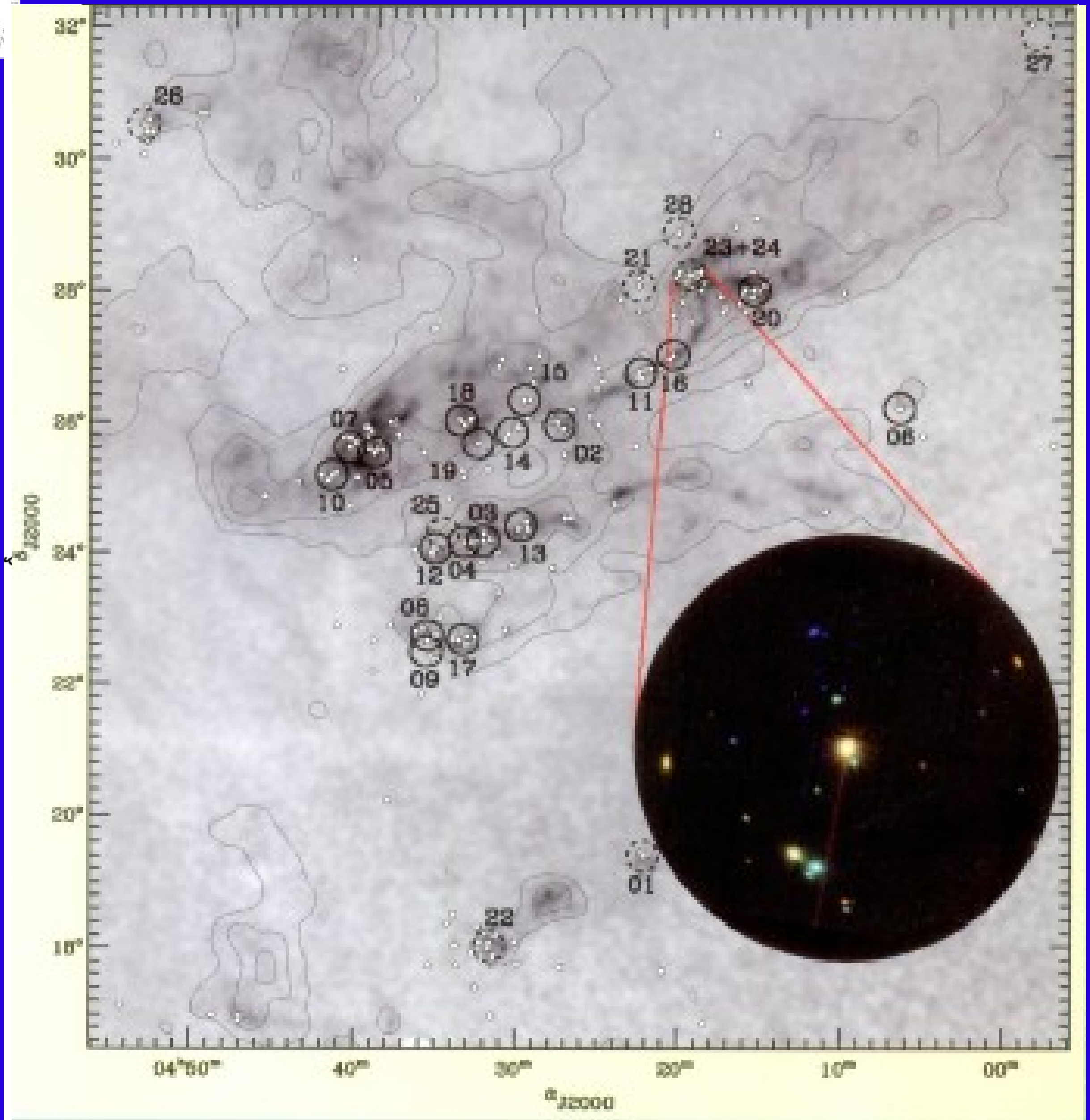
mostly down to ~ 1 Msun due to limiting sensitivity

- Initial Mass Function
- Disk frequency and evolution => angular momentum evolution and formation of planetary systems
- Clues to Star-Disk "magnetic" interactions

NGC6530 and M8, Chandra ACIS mosaic (~20'x30'), ~1500 X-ray sources (central/eastern part studied by Damiani et al. 2004); a complex structure. ~ 200 ks of Chandra Time



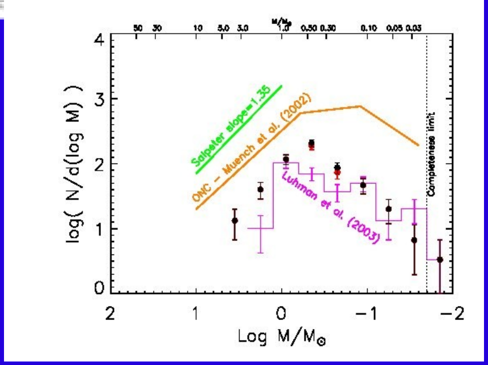
Too far, too crowded for WFXT ? Probably not if Ang. Res is ~ 5”



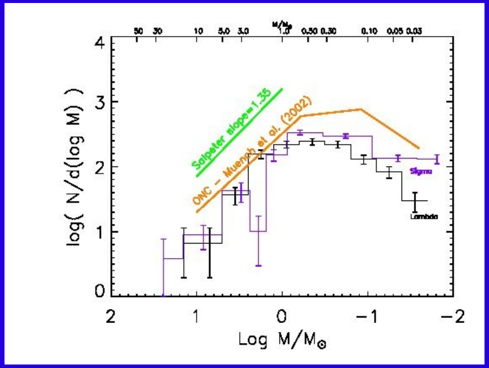
An XMM-Newton Survey of the nearby (140 pc) Taurus SFR

Only a limited coverage has been possible given the extent of XMM fov and realistic time allocation

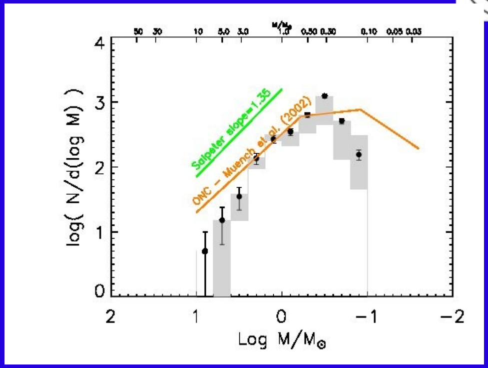
Taurus-Auriga



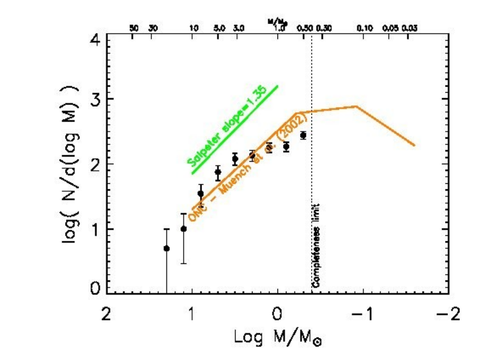
λ and σ Ori clusters



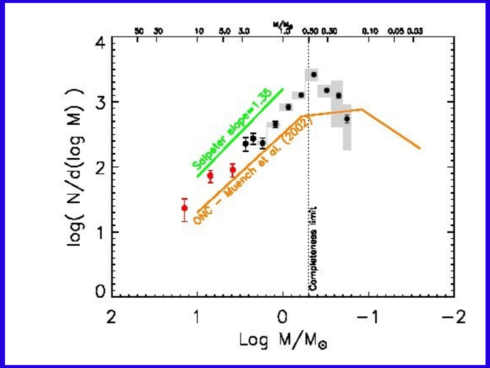
NGC 2264



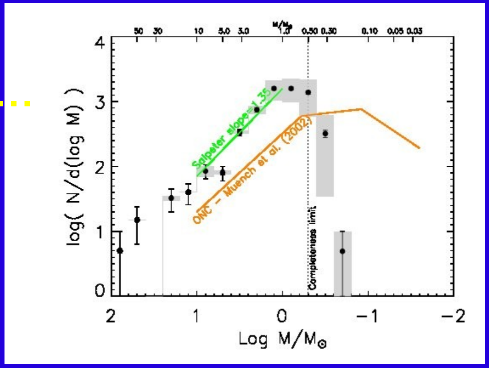
NGC 2362



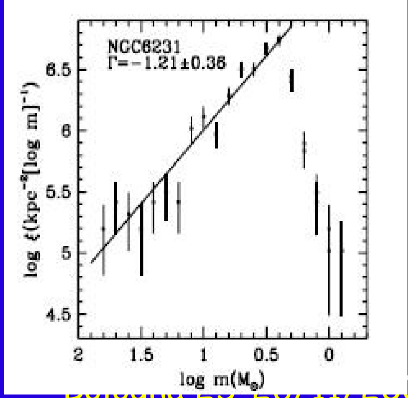
NGC 6530



NGC 6231…



…and its IMF from optical alone (Sung et al. 1998):

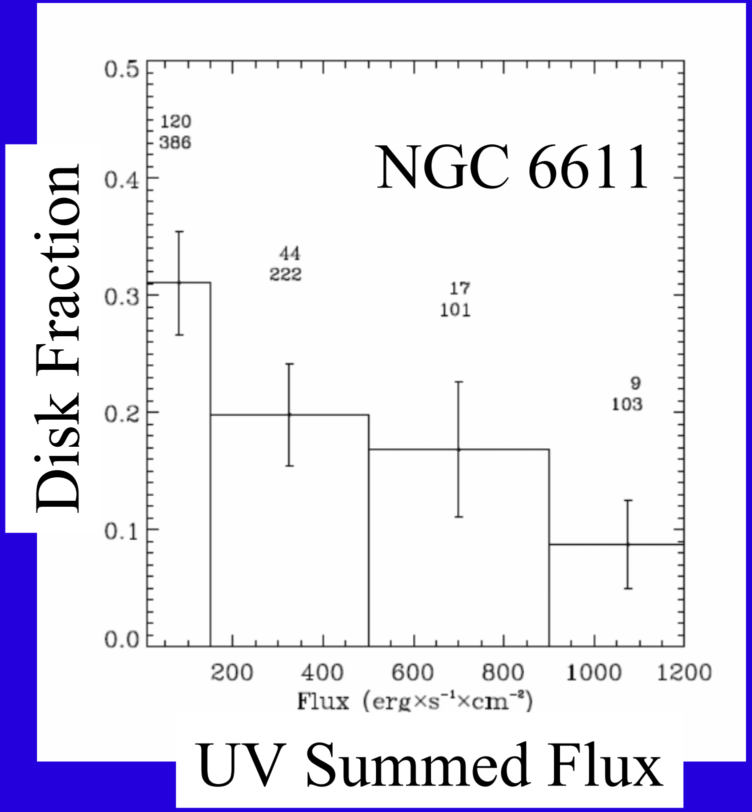


Disk frequency vs. age and environment

Possibly, low disk frequency (in *Cyg OB2* and *NGC6231*) caused by fast disk evolution under the effect of the radiation field of OB stars (*photoevaporation*). Disk frequency deduced by IR observations

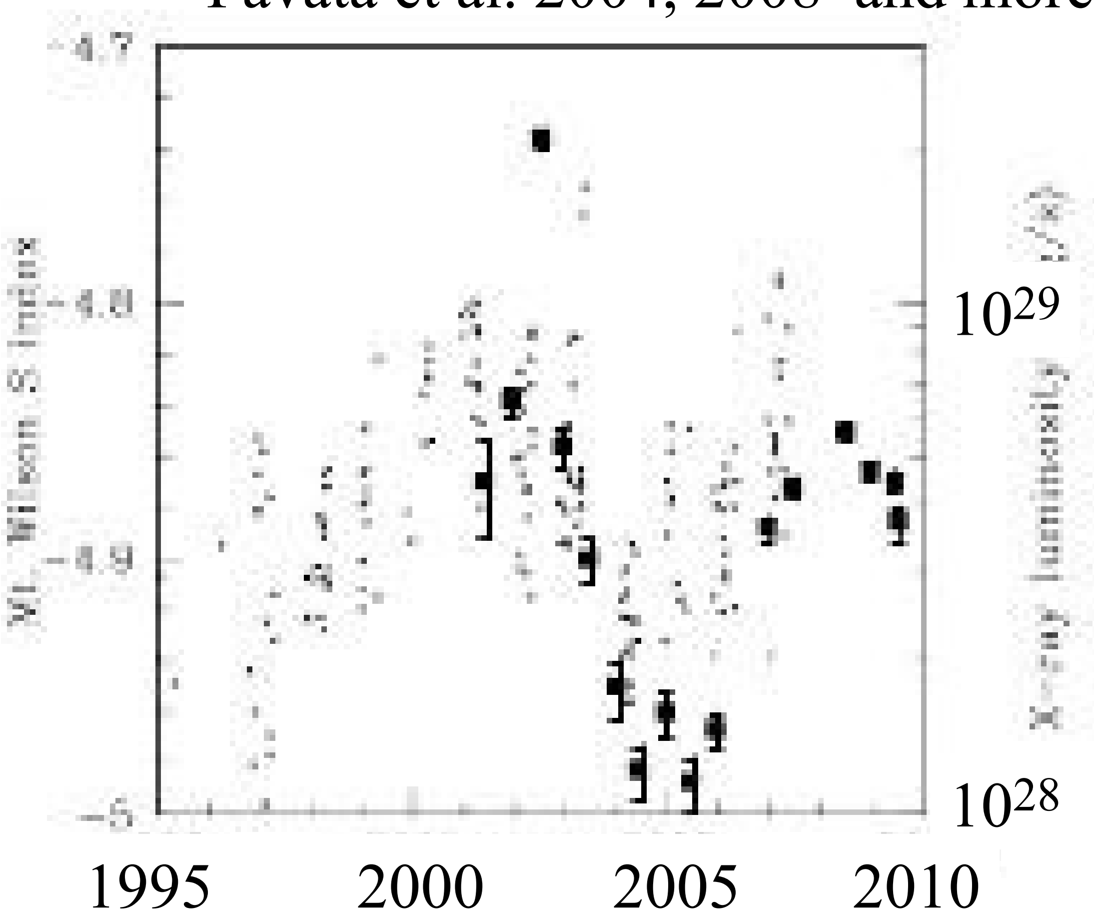
Another clue to the same effect
in *NGC6611*:
Disks are less frequent where OB stars summed UV flux is larger!
(Guarcello et al. 2007)

→ age is not the only relevant parameter for disk evolution.



CYCLE FOUND in HD 81809 - A Sun-like star

Favata et al. 2004, 2008 and more



Large squares: Lx measured with XMM since 2001.

Small dots: Ca II data available until 2007.

Apparent difference in behavior between the coronal and chromospheric cycles near the 2002 maximum. .

Summary

- WFXT surveys will allow deriving the properties of <10^9 yr old population in the Galaxy. A follow-up program is needed.
- The joint use of shallow, medium and deep WFXT surveys will allow determining densities and scale heights of young, intermediate and old stellar populations & of the (history of) star formation rate in the last billion year.
- A properly planned survey at low-galactic latitude will allow investigating the nature and origin of the Gould Belt/Disk and of its low-mass stellar population.
- WFXT can step forward our knowledge of various aspect of star forming process and of the physics at work in Young Stellar Clusters (& associated proto-planetary systems) formation and early evolution.
- Key laboratories are the nearby SFRs dispersed on a large areas of sky.
- Some time to be devoted to surveying properly selected regions of and/or around the Galactic Plane. Medium/Deep pointings are required.