THE UNIVERSITY OF CHICAGO PHYSICAL SCIENCES

Memorial Symposium to Honor Riccardo Giacconi

# Let's not forget the stars …


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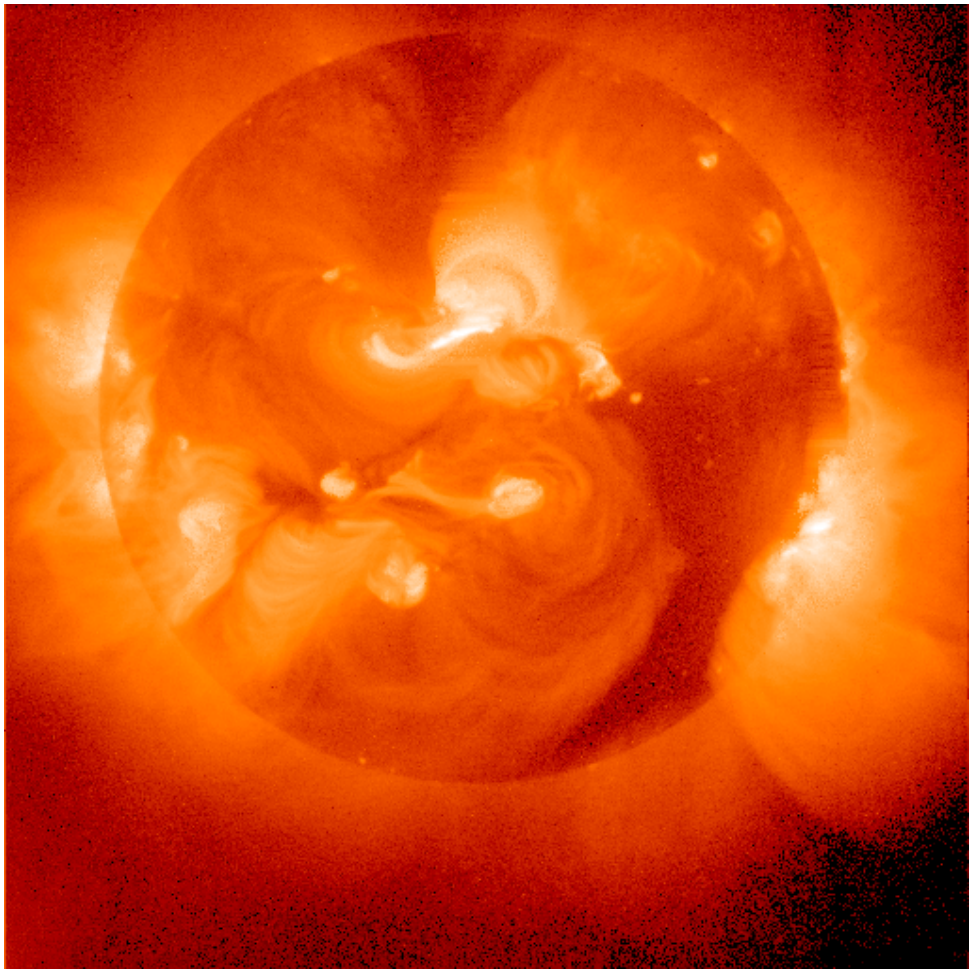
# This was my introduction to stellar x-ray astronomy …



- … and these were the folks I met then (1976-77):
  - Pippo Vaiana
  - Riccardo Giacconi
  - Leon Golub & Martin Zombeck
  - Rich Petrasso
  - Wally Tucker

# There were quite a few interesting science questions…

- What exactly is heating – and geometrically structuring – the Sun's corona?
- Are magnetic fields sufficient and necessary for solar activity?
  - How do magnetic fields lead to plasma heating and acceleration?
  - Are there non-magnetic processes also involved?
- How are the Sun's (or, more generally, stellar) magnetic fields created?
  - What stellar properties define the field production mechanism?
  - Can we predict magnetic dynamo properties from first principles?
- Is the Sun typical?
  - How does a star's activity depend on the star's extrinsic and intrinsic properties?
  - Could this shed light on how solar activity varied during the Sun's lifetime?

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Pippo Vaiana

Riccardo Giacconi

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Pippo Vaiana & Riccardo's agreement:

1. Demonstrate, via a tiny exploratory survey, based on optically selected stars and using data from the commissioning period, that real discovery material is there …
2. Do the work – to phenomenal success … and respond by constructing a major collaboration – joining with the *Einstein* guest investigator program – that initiated the flood of x-ray observations of stars throughout the H-R diagram

# … and here's the resulting landmark paper

## RESULTS FROM AN EXTENSIVE *EINSTEIN* STELLAR SURVEY

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### ABSTRACT

We report the preliminary results of the *Einstein* Observatory stellar X-ray survey. To date, 143 soft X-ray sources have been identified with stellar counterparts, leaving no doubt that stars in general constitute a pervasive class of low-luminosity galactic X-ray sources. We have detected stars along the entire main sequence, of all luminosity classes, pre–main sequence stars as well as very evolved stars. Early type OB stars have X-ray luminosities in the range $\sim 10^{31}$ to $\sim 10^{34}$ ergs $s^{-1}$; late type stars show a somewhat lower range of X-ray emission levels, from $\sim 10^{26}$ to $\sim 10^{31}$ ergs $s^{-1}$. Late type main-sequence stars show little dependence of X-ray emission levels upon stellar effective temperature; similarly, the observations suggest weak, if any, dependence of X-ray luminosity upon effective gravity. Instead, the data show a broad range of emission levels (~three orders of magnitude) throughout the main sequence later than F0. Comparison of the data with published theories of acoustically heated coronae shows that these models are inadequate to explain our results. The data are consistent with magnetically dominated coronae, as in the solar case.

*Subject headings:* stars: coronae — X-rays: sources

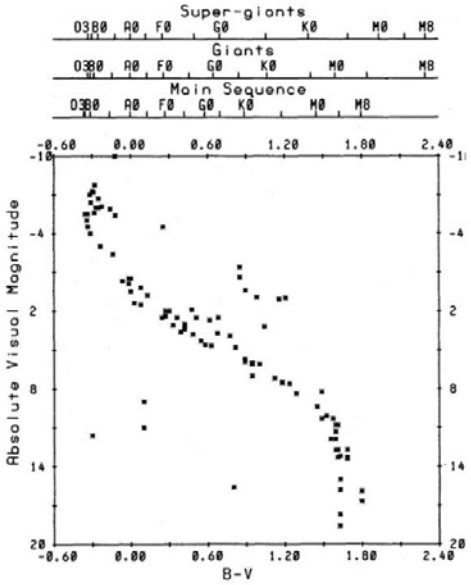
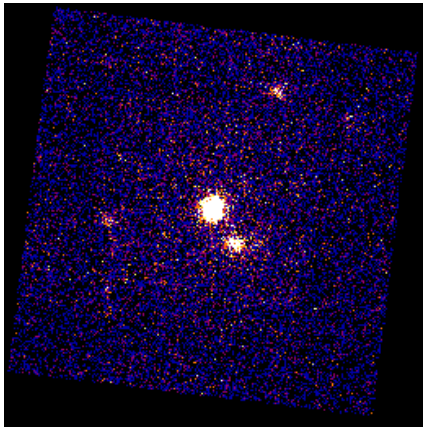
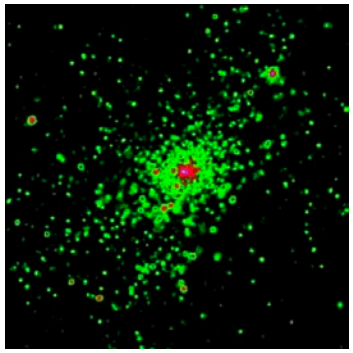



FIG. 1.—An H-R diagram for stars detected as soft X-ray sources

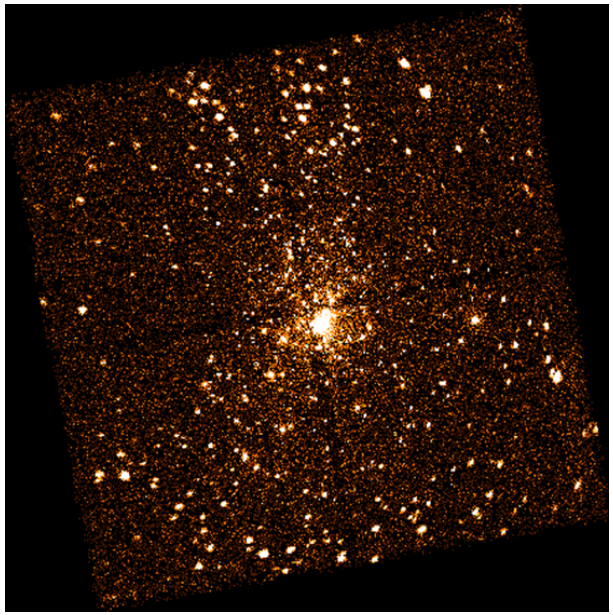
# … and the subsequent flood of stellar x-ray data: the birth of the stellar x-ray astronomy field



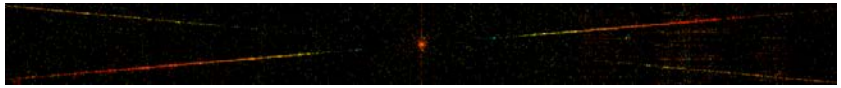
Einstein ObservatoryHyades//IPC



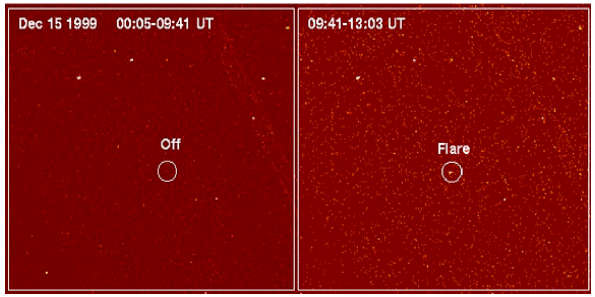
Chandra/NGC3603 (Corcoran et al. 2001)



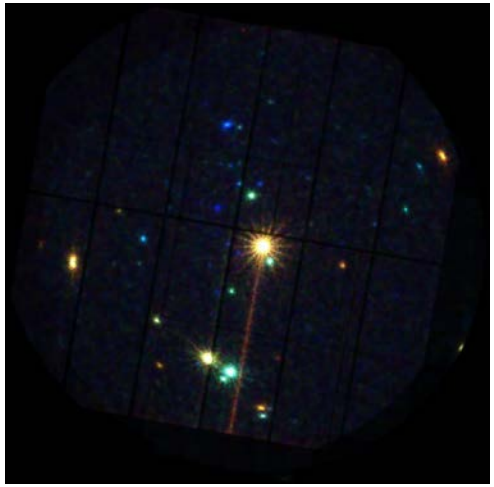
Chandra/Orion nebula (Feigelson et al. 2001)



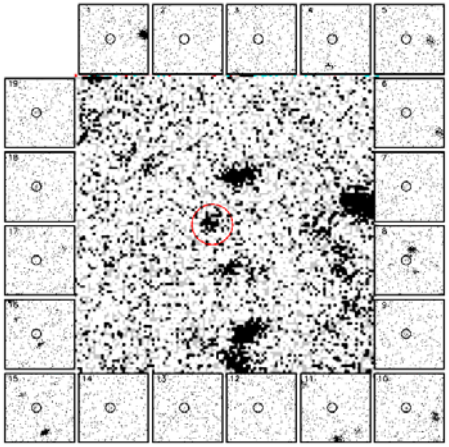
Chandra/HETGS/Capella




Chandra/Flaring brown dwarf: LP944-20 (Rutledge et al. 2000)



Young stars in Taurus region (courtesy XMM-Newton)



Chandra/Orion core composite

# “Turning the knobs” on stellar activity …

- Stars show much of the phenomenology associated with solar magnetic activity, but under potentially very different conditions …
  - Luminosity, mass, age, effective temperature, rotation, composition
- BUT: Stars exercise the limitations of solar models for activity – We should expect that models developed in the solar context will not always work …
  - Activity ‘saturation’, shut-off of surface convection, turn-on of core convection
- Some examples of what we’ve learned:

For stars like the Sun:

- Stellar X-ray luminosity scales with stellar rotation rate, $L_x \sim \Omega^2$
  - Stellar activity is clearly connected to stellar magnetic fields!
- Coronal temperatures resemble solar coronal temperatures, $T \sim 10^6$-$10^8$ K

For hot, young, massive stars:

- Stellar X-ray luminosity scales with stellar bolometric luminosity
- Some recent evidence for “plasma confinement”, as well as for emission from terminal collisionless shock region of winds … again – stellar magnetic fields appear to be relevant …

For young (“pre-main sequence”) stars:

- Stellar X-ray luminosity scales with neither stellar rotation rate nor bolometric luminosity
- Emission extremely intermittent

# Summary

- The past almost 40 years have led to the founding of a new field of astronomy, in which the ideas developed by solar astronomers have been applied to other stars, and in which entirely new stellar activity phenomena have been discovered.
- The theoretical framework for solar activity has proven to be quite appropriate for discussing activity for solar-like stars – but not for the others …
- The number of new questions which the new stellar data have given birth to is much larger than the number of questions that have been answered …
- These new questions have led to new or renewed ties to other disciplines …
  - Origin of life on Earth and its relation to the activity of the young Sun …
  - The birth of stars, and galactic “chemical” evolution
  - Atomic physics/nuclear physics/plasma physics/…

# … and that leads us to

QUESTIONS, DISCUSSION, …