MHD Physics in Stellar Environments

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starting point is Chandra, XMM-Newton's high spectral resolution observations of stars

but

results limited to brightest stars (bright=unusual?)

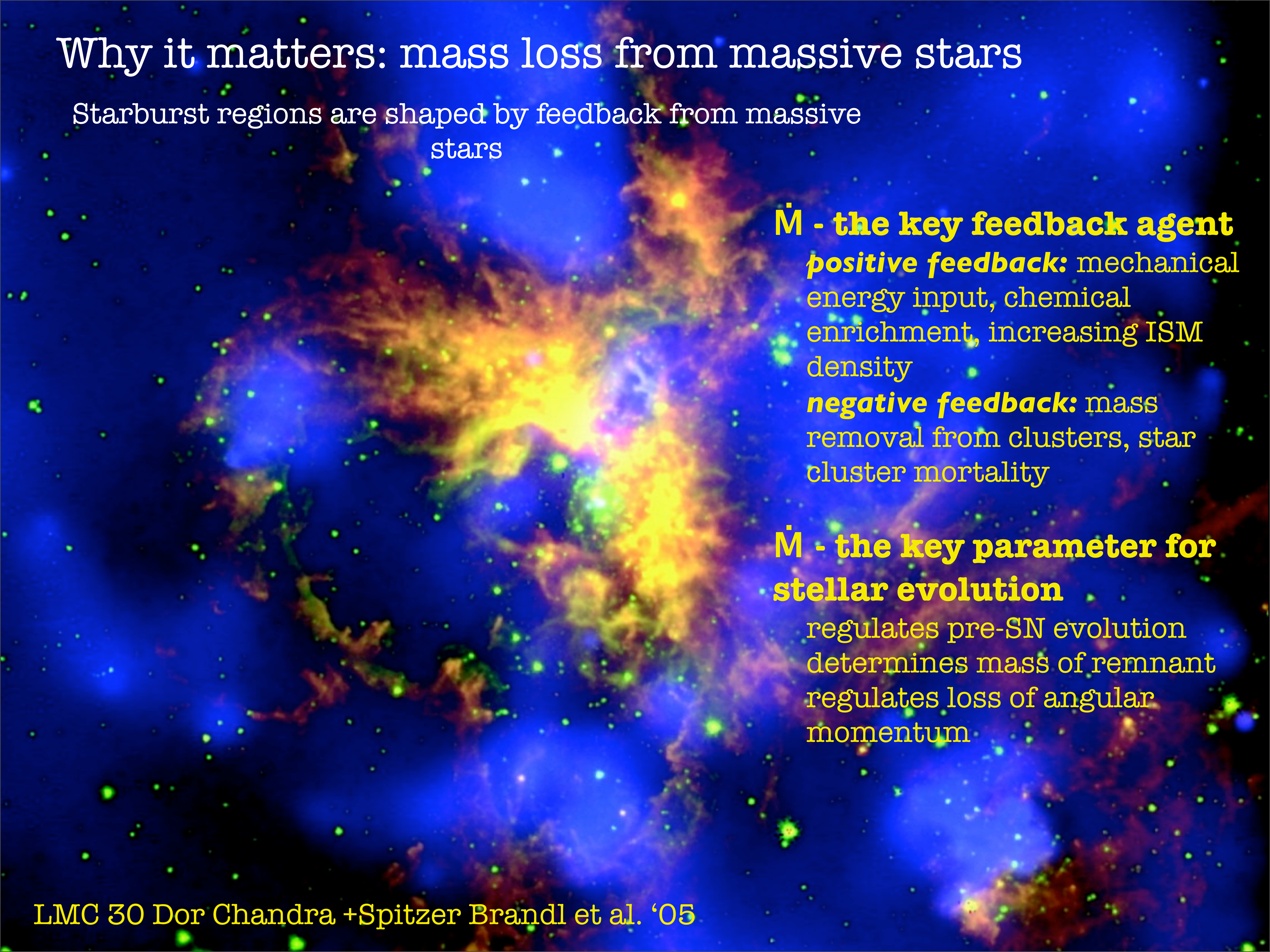
Key Questions

1. How rapidly do stars lose mass and angular momentum, and how do environment and mass loss feed back on each other?

2. How do magnetic fields shape stellar exteriors and the surrounding environment?

Why it matters: mass loss from massive stars

Starburst regions are shaped by feedback from massive stars



$\dot{M}$ - the key feedback agent

- ***positive feedback:*** mechanical energy input, chemical enrichment, increasing ISM density
- ***negative feedback:*** mass removal from clusters, star cluster mortality

$\dot{M}$ - the key parameter for stellar evolution

- regulates pre-SN evolution
- determines mass of remnant
- regulates loss of angular momentum

LMC 30 Dor Chandra +Spitzer Brandl et al. ‘05

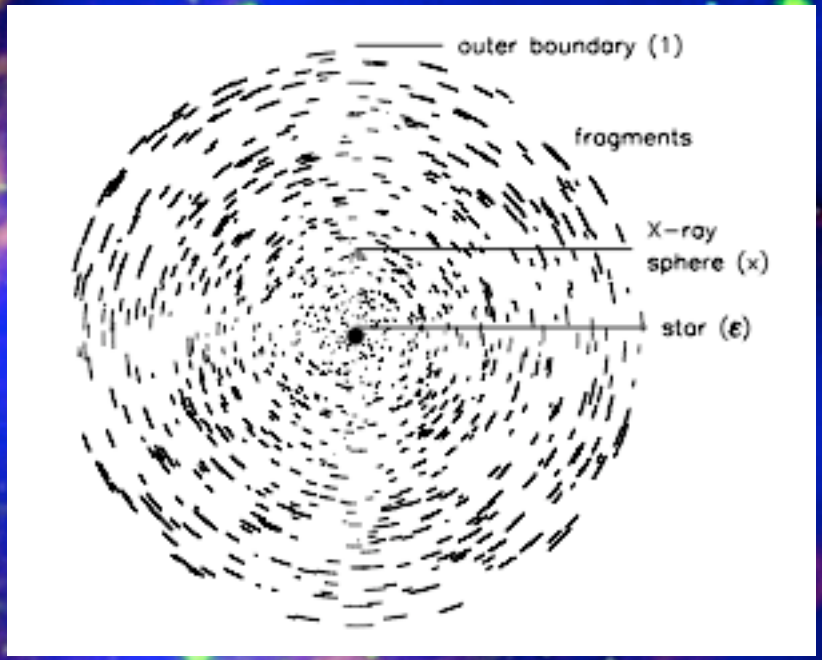
1. How rapidly do stars lose mass and angular momentum, and how do environment and mass loss feed back on each other?

measurements of mass loss via different methods differ by up to a factor of 10 (changes evolution of the stars):

-radio free-free, Hα $\propto n_e^2$ -> degree of clumping only gives upper limit to $\dot{M}$ (Puls et al. 2006)

-UV resonance lines -> uncertainties in ionization balance

+X-ray emission probes wind opacity, He-like f/i ratios locate X-ray-emitting shocks



schematic clumpy wind; Feldmeier et al. (2003)

However, large-scale clumps in stellar wind can reduce optical depth of wind to X-rays

$\Rightarrow$ degeneracy between amount of clumping & mass-loss rate

Smoothness/clumpiness of winds may introduce factor of 5 or more uncertainty to $\dot{M}$

need high SNR spectral line profiles to break degeneracy: currently only a handful of stars are bright enough for such observations with Chandra,XMM-Newton

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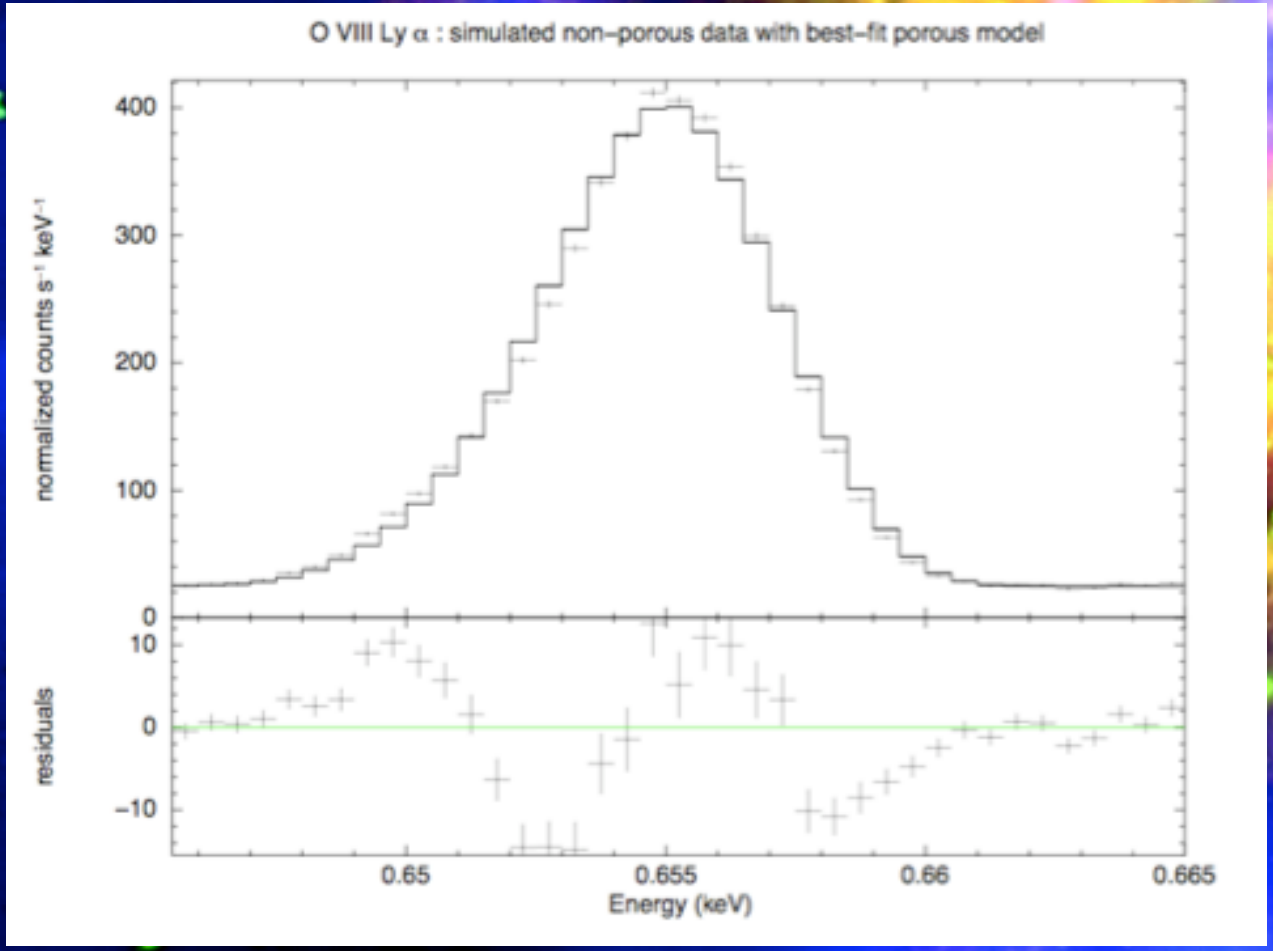
Observing strategy

Emission line Doppler widths are ~ 1000 km/s: need large A_{eff} primarily



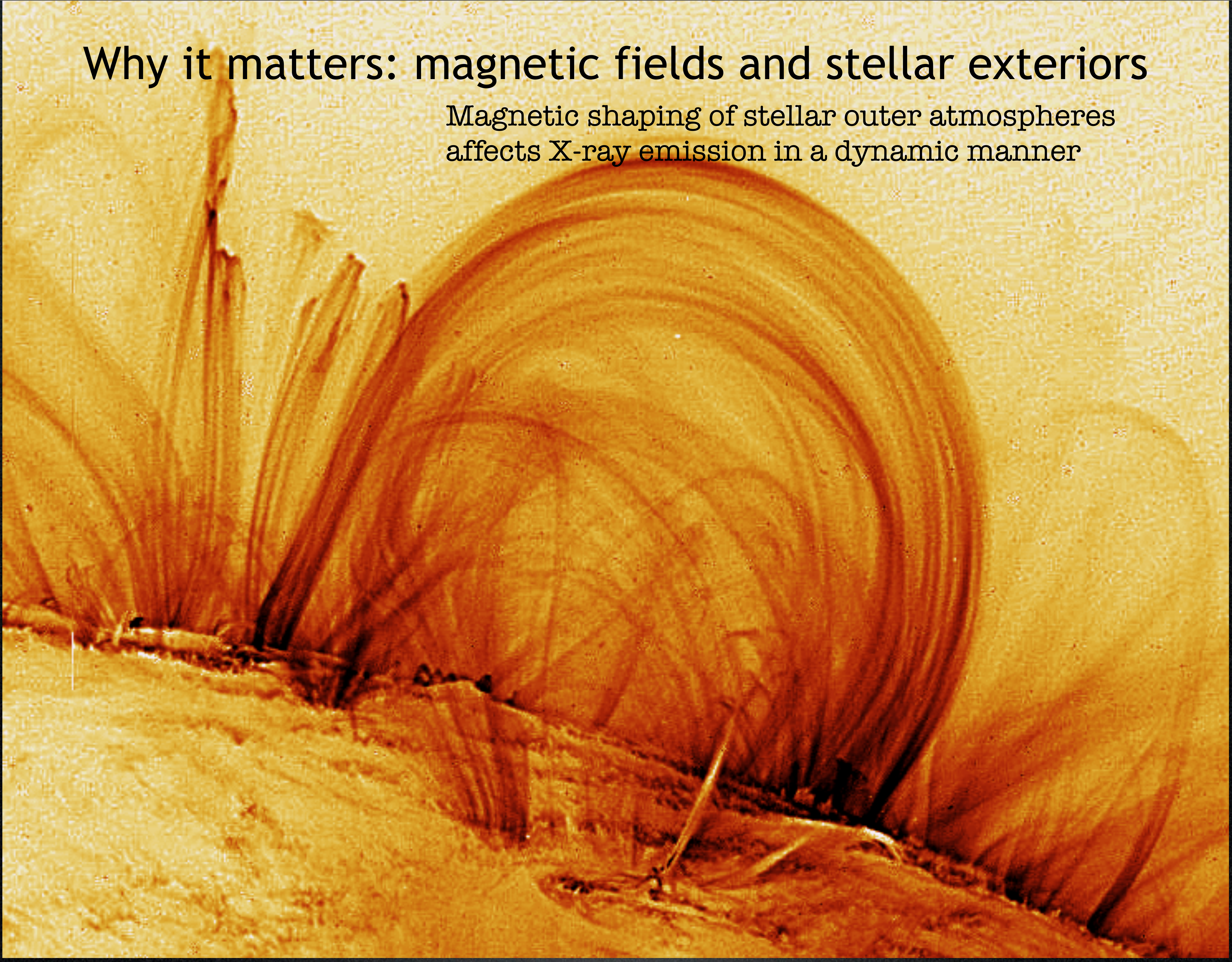
residuals detected in 50 ks IXO XMS observation are due to clumps in stellar wind; can do this analysis for ~36 stars

IXO will expand the results of Chandra, XMM-Newton high resolution spectroscopy of massive stars to a larger sample:

+ Survey mass loss in different Galactic environments
+ Explore X-ray production mechanism in OB stars
+ Use colliding-wind binaries as shock physics laboratories

Why it matters: magnetic fields and stellar exteriors

Magnetic shaping of stellar outer atmospheres affects X-ray emission in a dynamic manner



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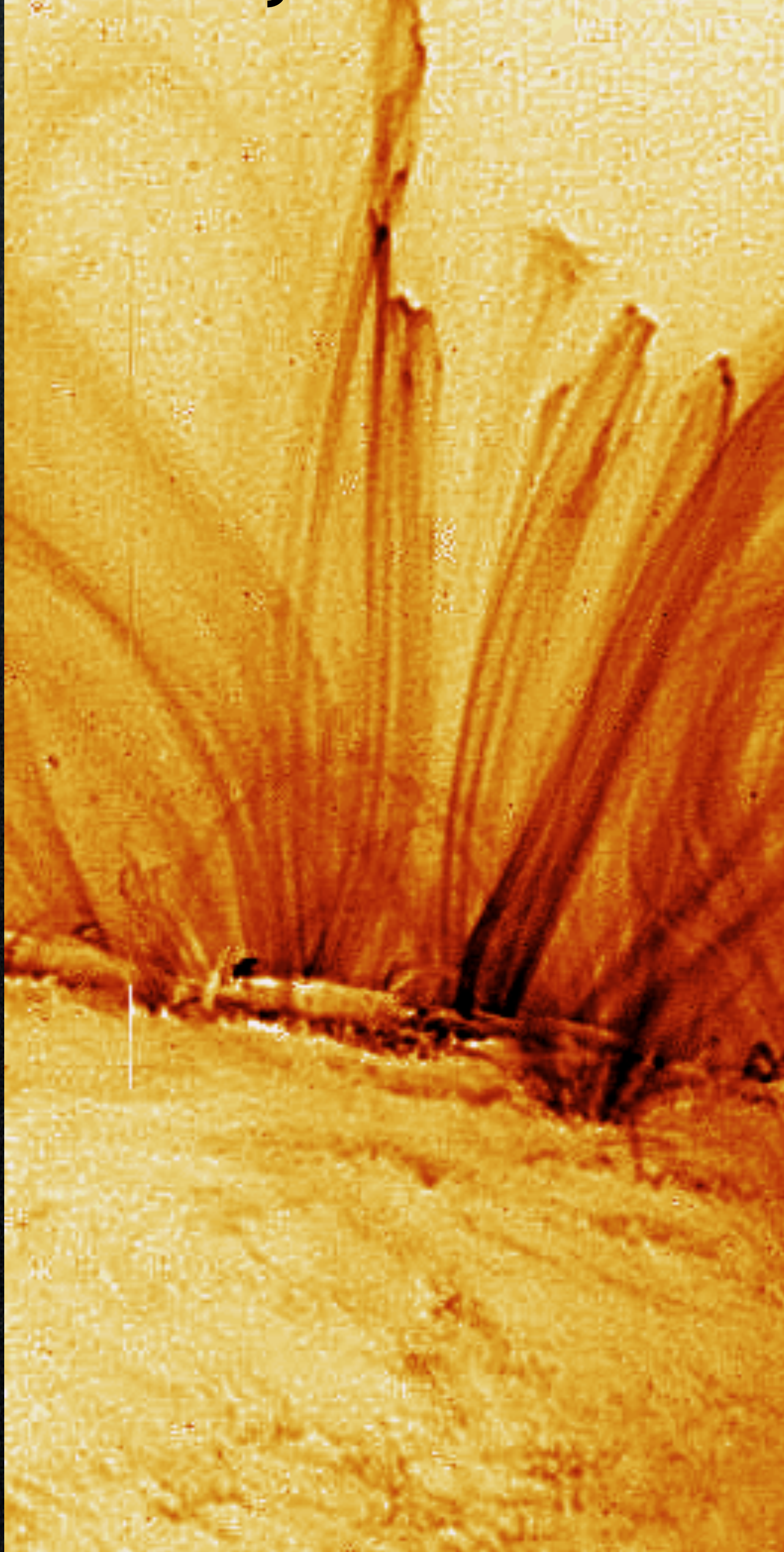

Magnetic shaping of stellar outer atmospheres affects X-ray emission in a dynamic manner

magnetic reconnection macroflares: determine kinetic energy input into corona, connection to coronal heating via microflares

coronal structures accessible through T, EM, density, abundances, length scale diagnostics

- -for fast rotators & binaries, diagnose discrete large-scale closed magnetic loops via Doppler mapping
- -determine how structures change with magnetic filling factor, down to solar minimum luminosities (L_X=2e26)

length scale diagnostics available:

- flare loop modelling
- n_e(T) + VEM(T)
- resonance scattering measurements
- 6.4 keV fluorescence line

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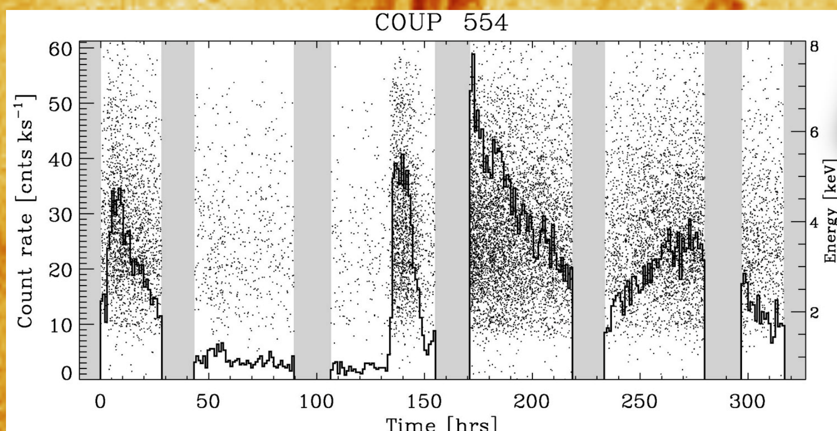
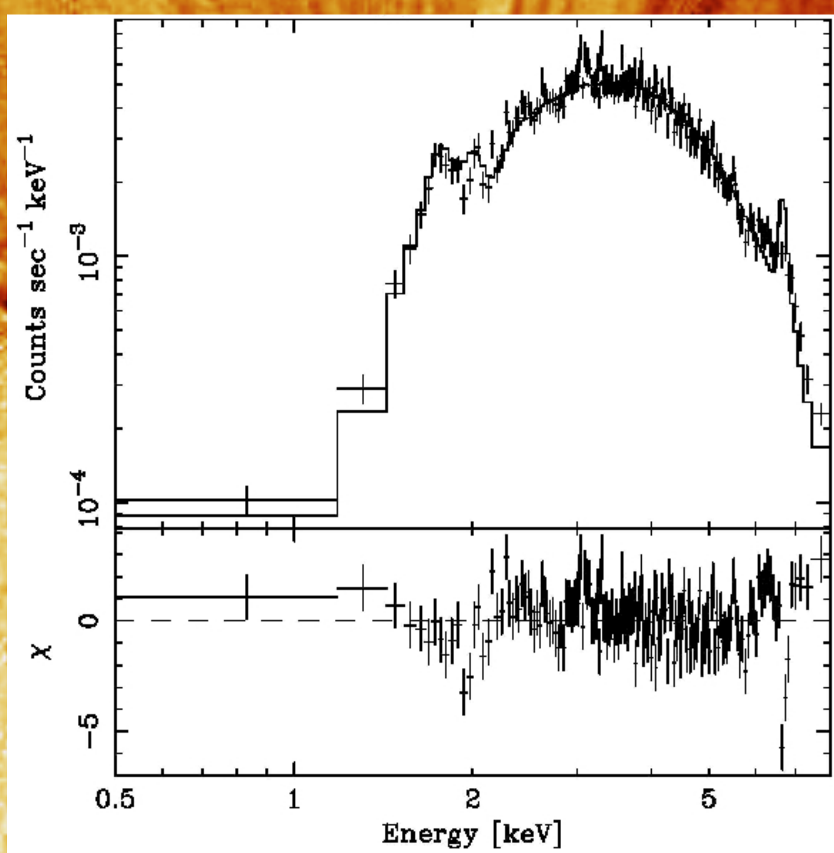
embedded young star (L_x 10^{31} erg/s at 450 pc) seen in COUP data





averaging in time and/or wavelength glosses over important physics

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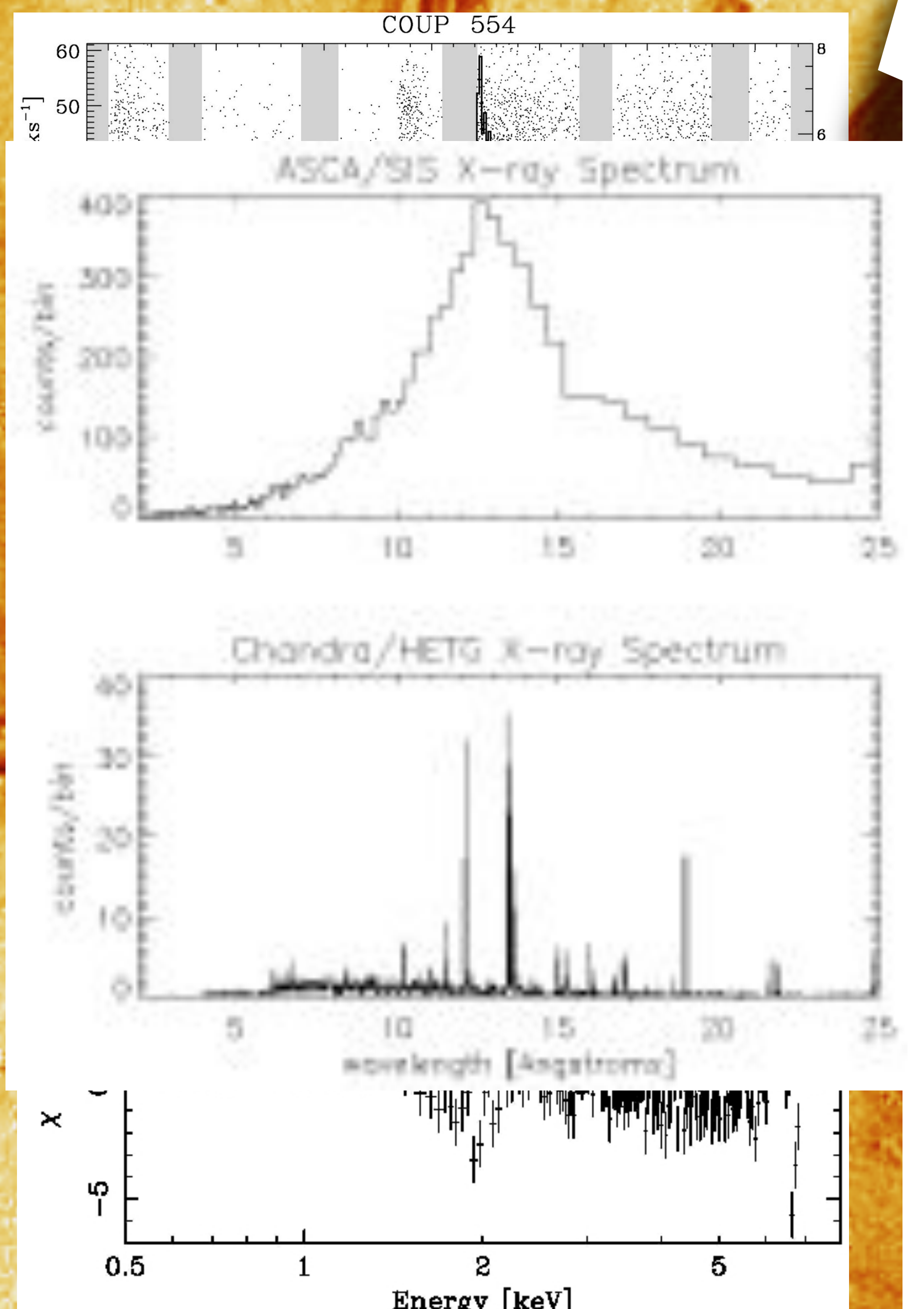

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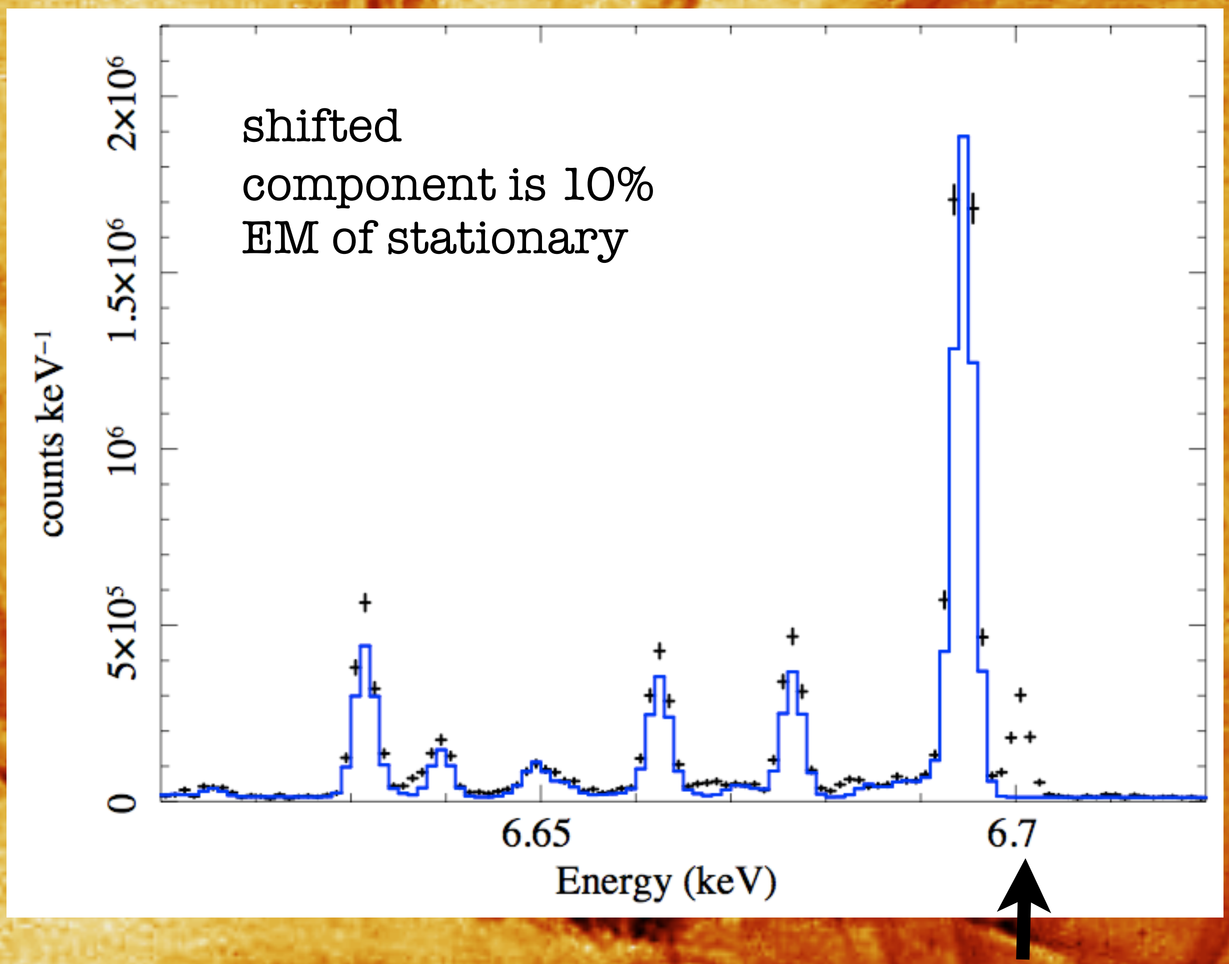
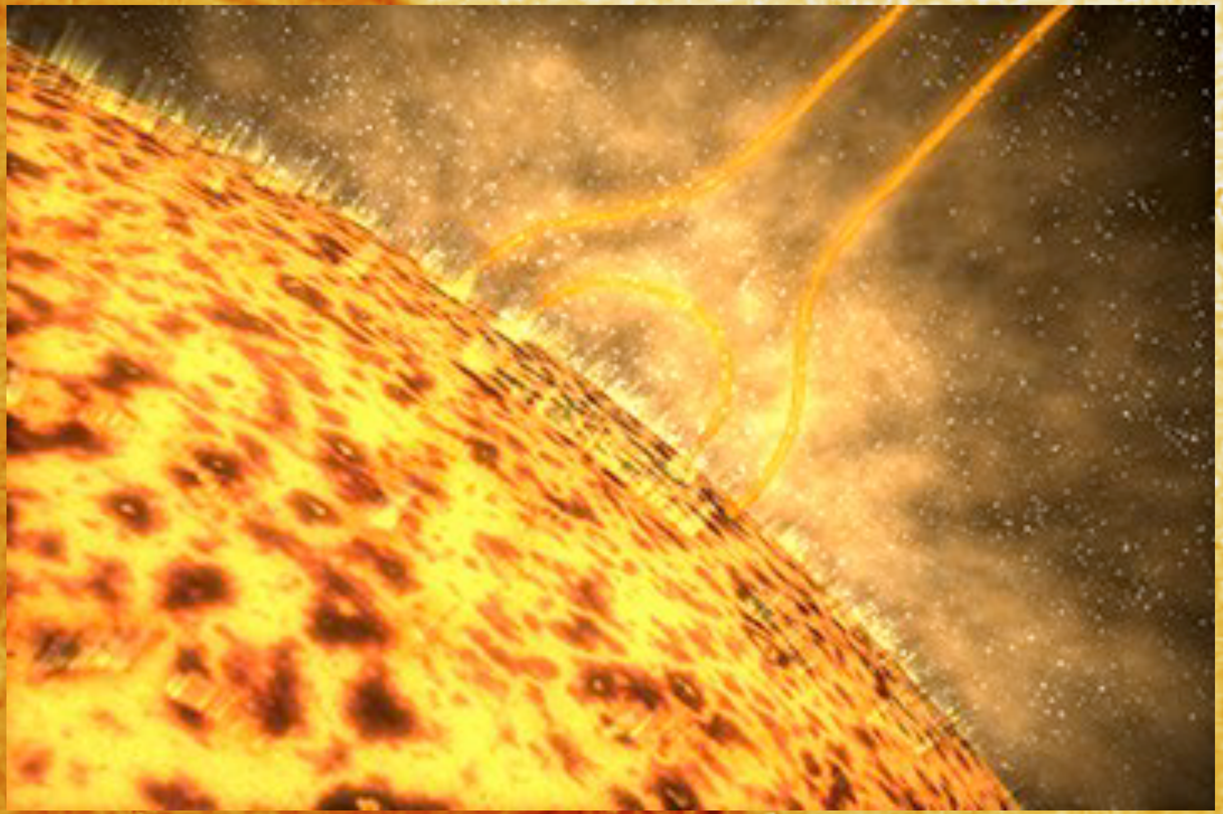
Observing Strategy





XMS 2 ks from a coronal flare; 200 ks each on about 5 stars based on flare statistics, total of 1 Ms

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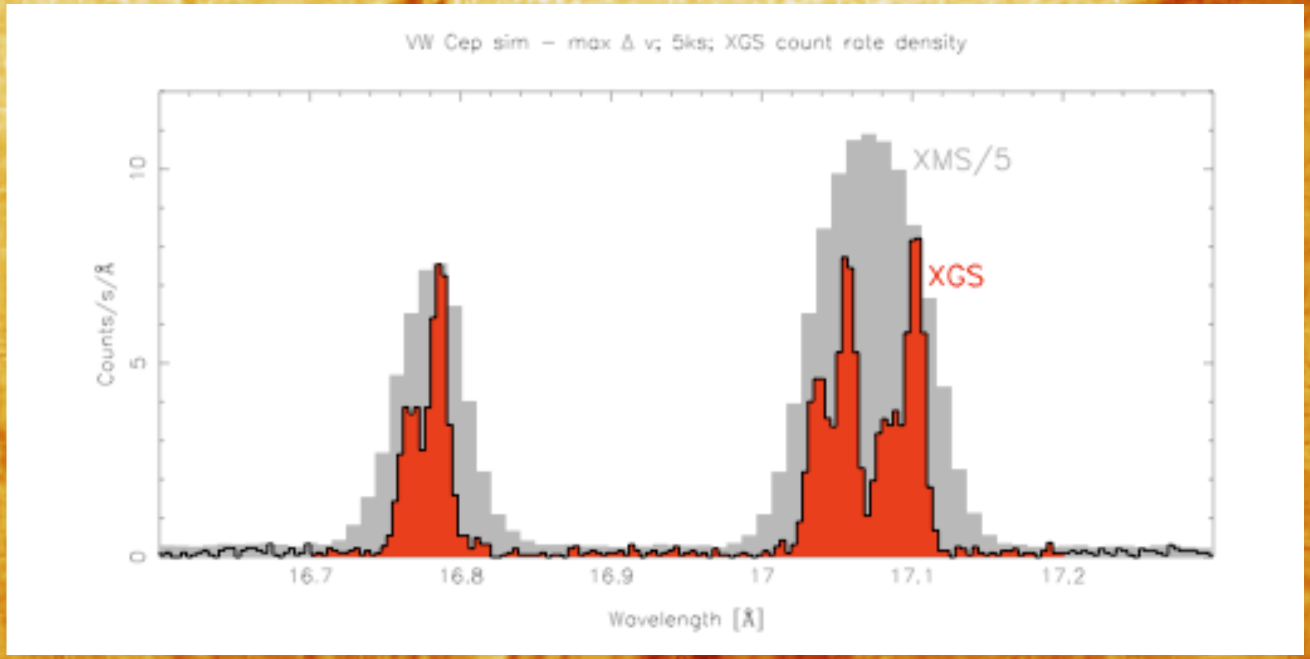

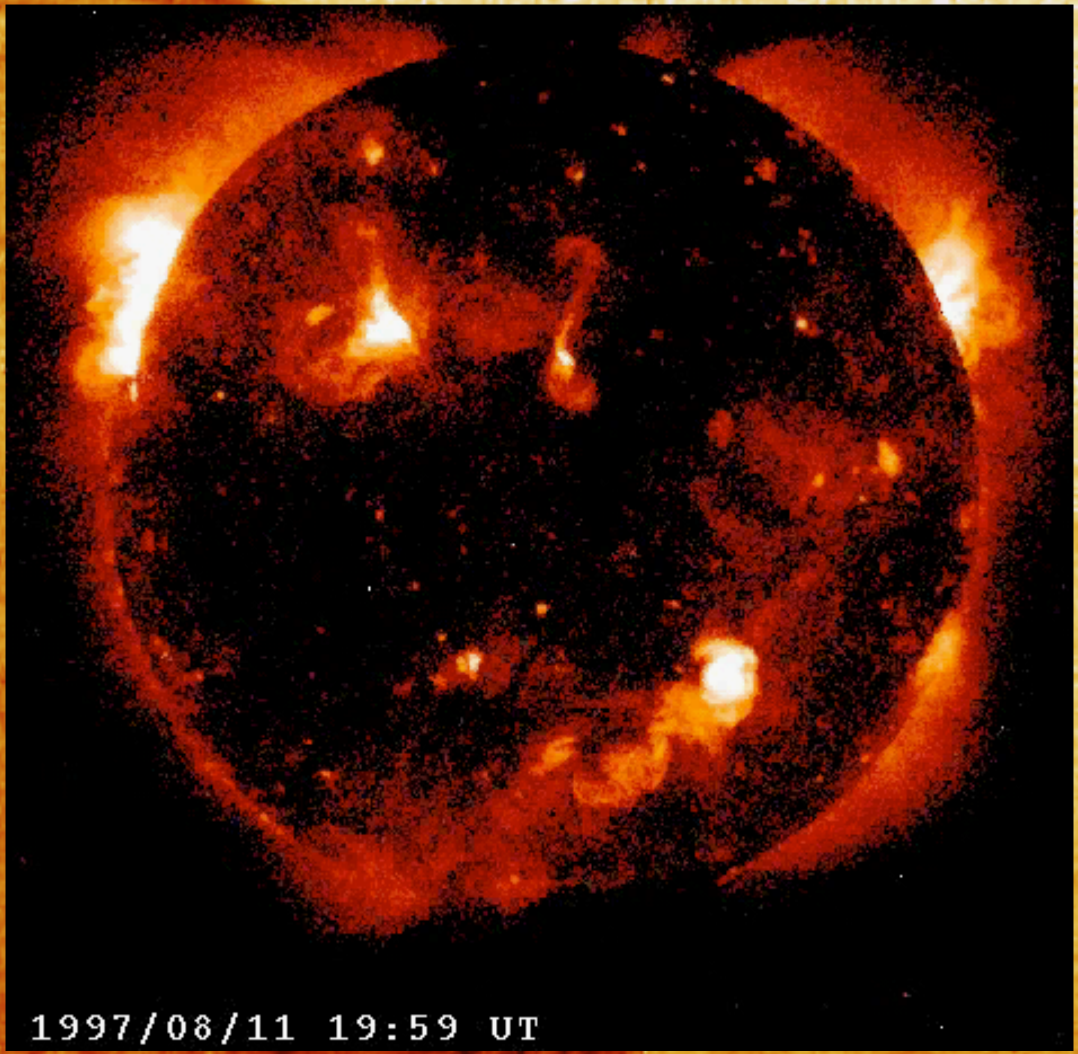

XGS observations needed: 10 binaries, 2 orbital/rotation periods per binary (200ks) for total of 2 Ms

X-ray Doppler imaging: separate contributions of binaries determine T, VEM, n_e, A, l_x as a function of orbital/rotational phase

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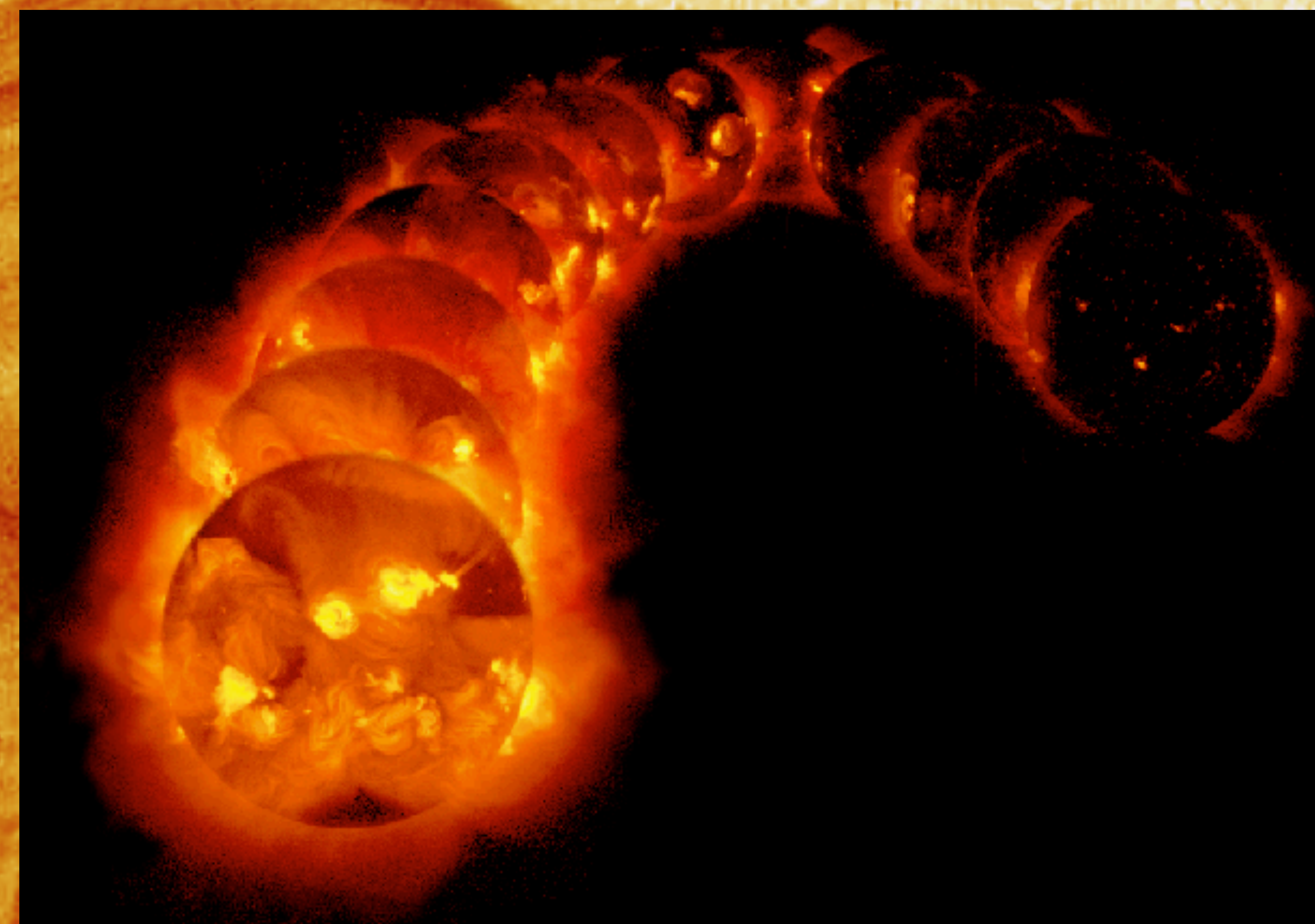

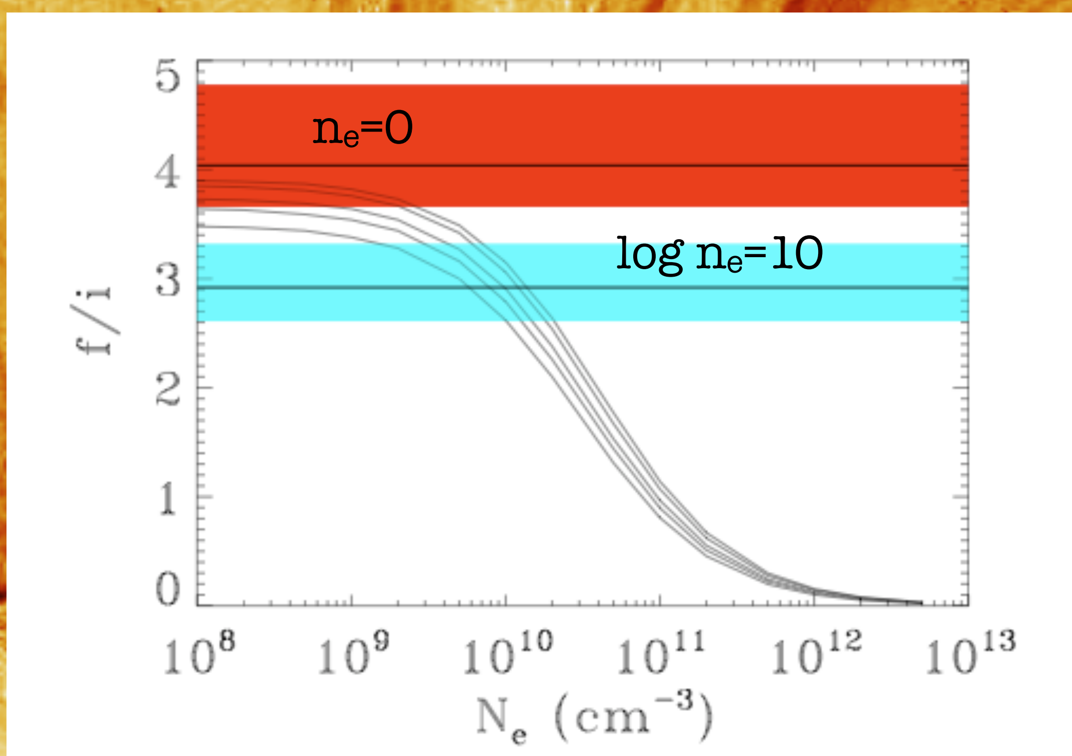

using XMS, constrain n_e from O VII f/i for a solar minimum star (L_x=2x10^{26} erg s^{-1}) at 5 pc in 50 ks; 20 stars in 1 Ms to span L_x, T_x, fB

comment on . . .

- angular resolution (15”⇒5”)
  - good enough for isolated objects, makes confusion in crowded regions (e.g. LMC, SMC) difficult
- collecting area + spectral resolution
  - increase in XMS A_{eff} at low energies good
  - increase A_{eff}, $d\lambda/\lambda$ for XGS?
- HXD
  - good for hard X-ray flux from stellar flares, colliding wind binaries