Thermal X-rays & proper motion in RX J1713.7-3946

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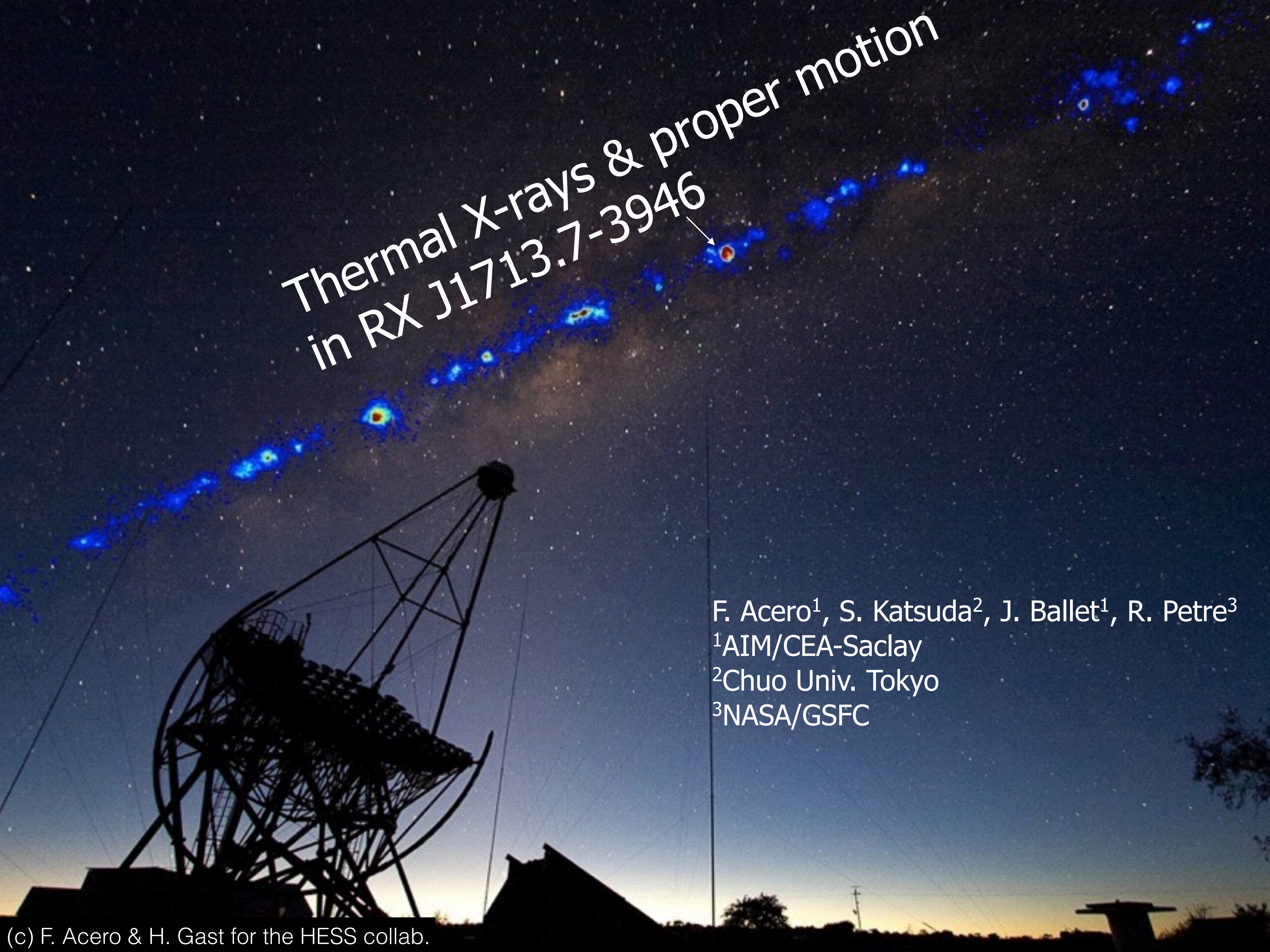
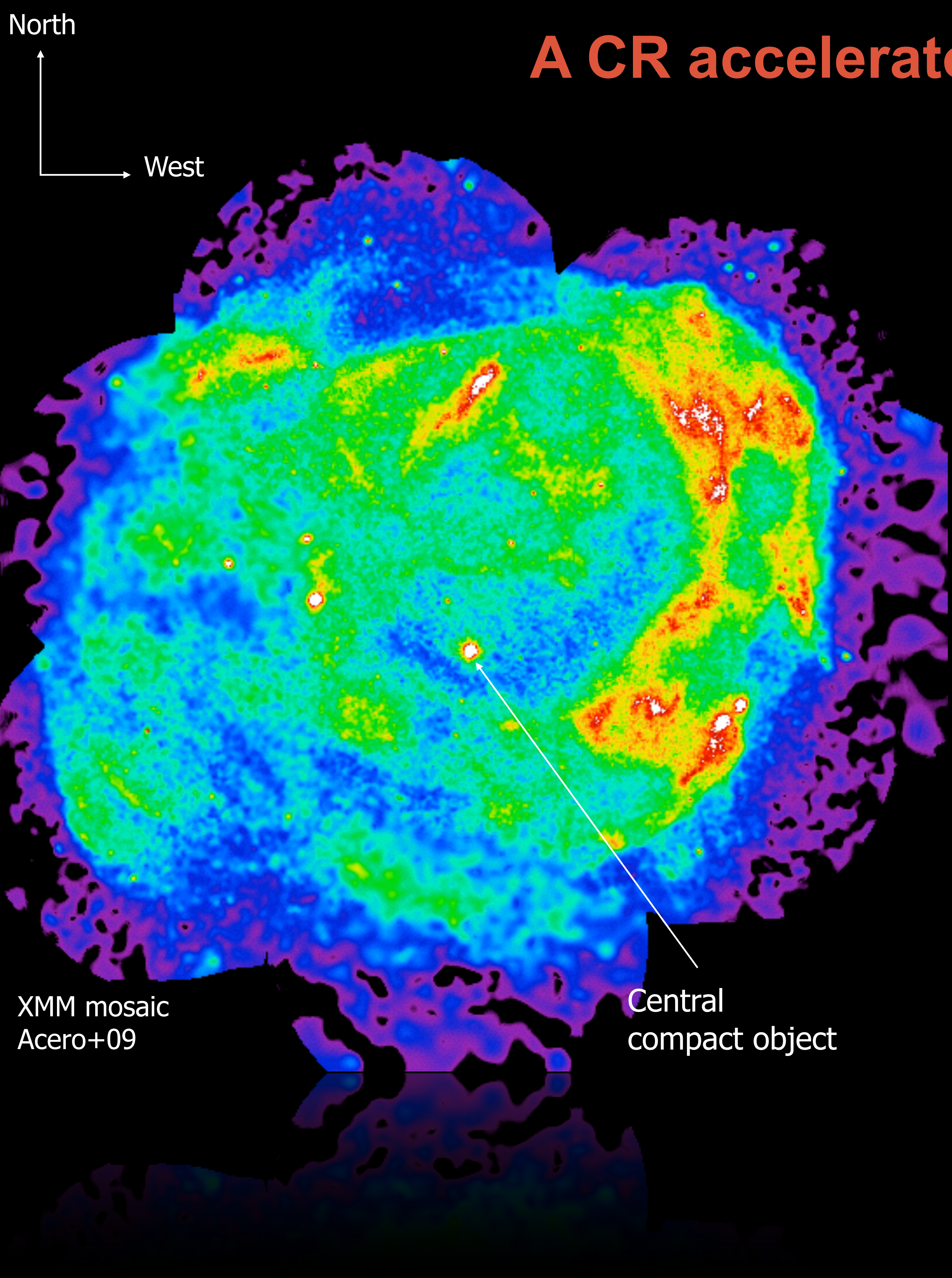


(c) F. Acero & H. Gast for the HESS collab.

A CR accelerator prototype



What we know:

- CC supernova
- Synch dominated X-rays
- interacting with clouds in the NW
- from interaction d ~ 1 kpc

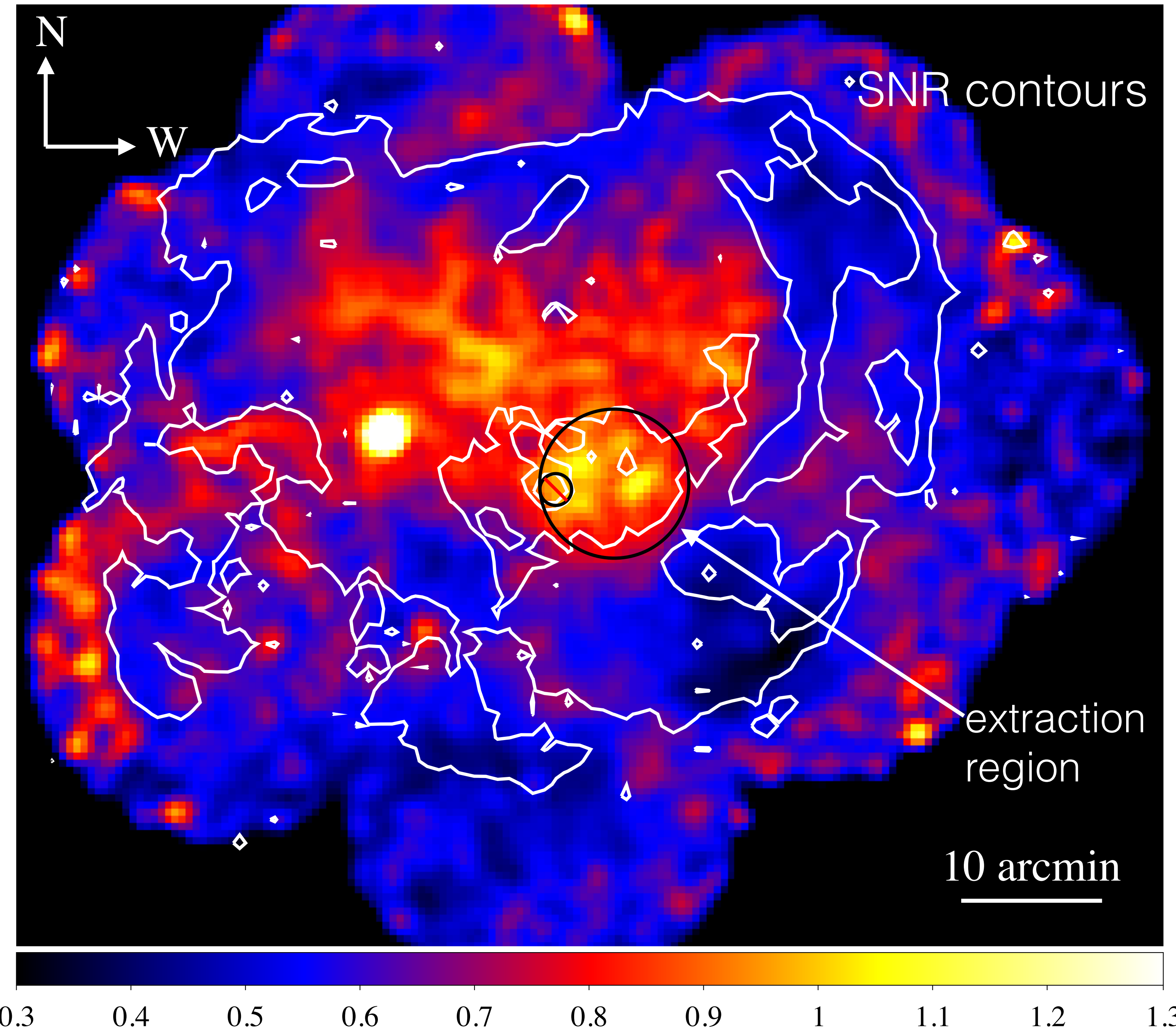
- Brightest SNR in TeV

Don't know:

- age (SN 393 debated)
- progenitor type/mass ?
- ambient density, V_{shock}

proper motion → Hα
proper motion → X-rays motion
ambient density, V_{shock} → Thermal X-rays

Why can we detect thermal X-rays today

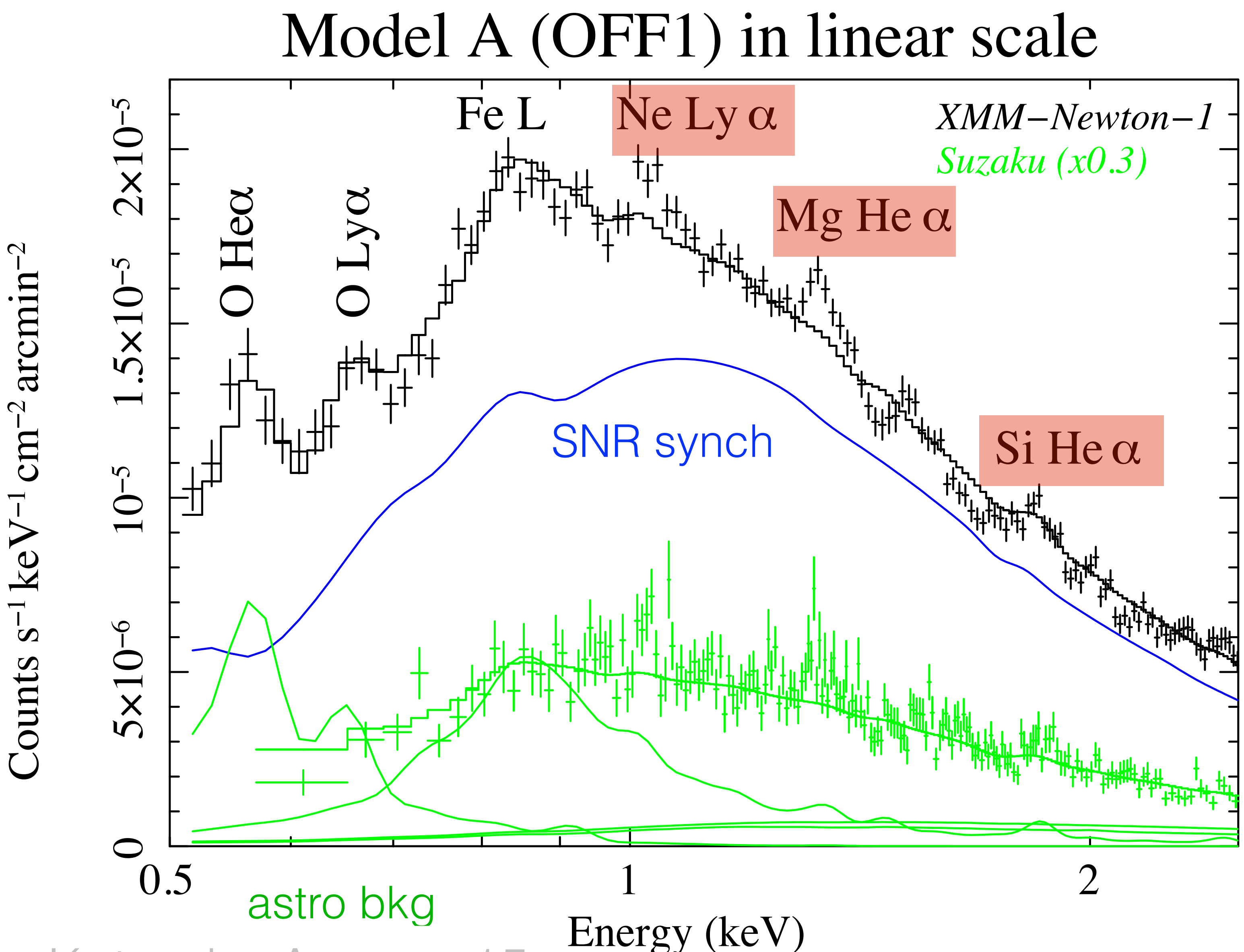


Softness map = 0.5-1.5/1.5-8 keV

Katsuda, Acero +15

- **Optimize where to look: lowest N_H and/or thermal contribution in the center region**
- **70 ks dedicated Suzaku observation**
- **+230 ks XMM exposure for CCO pulsation search**
- **Bkg spectrum is very important: using 2x40 ks OFF Suzaku pointings**

Pure power-law model



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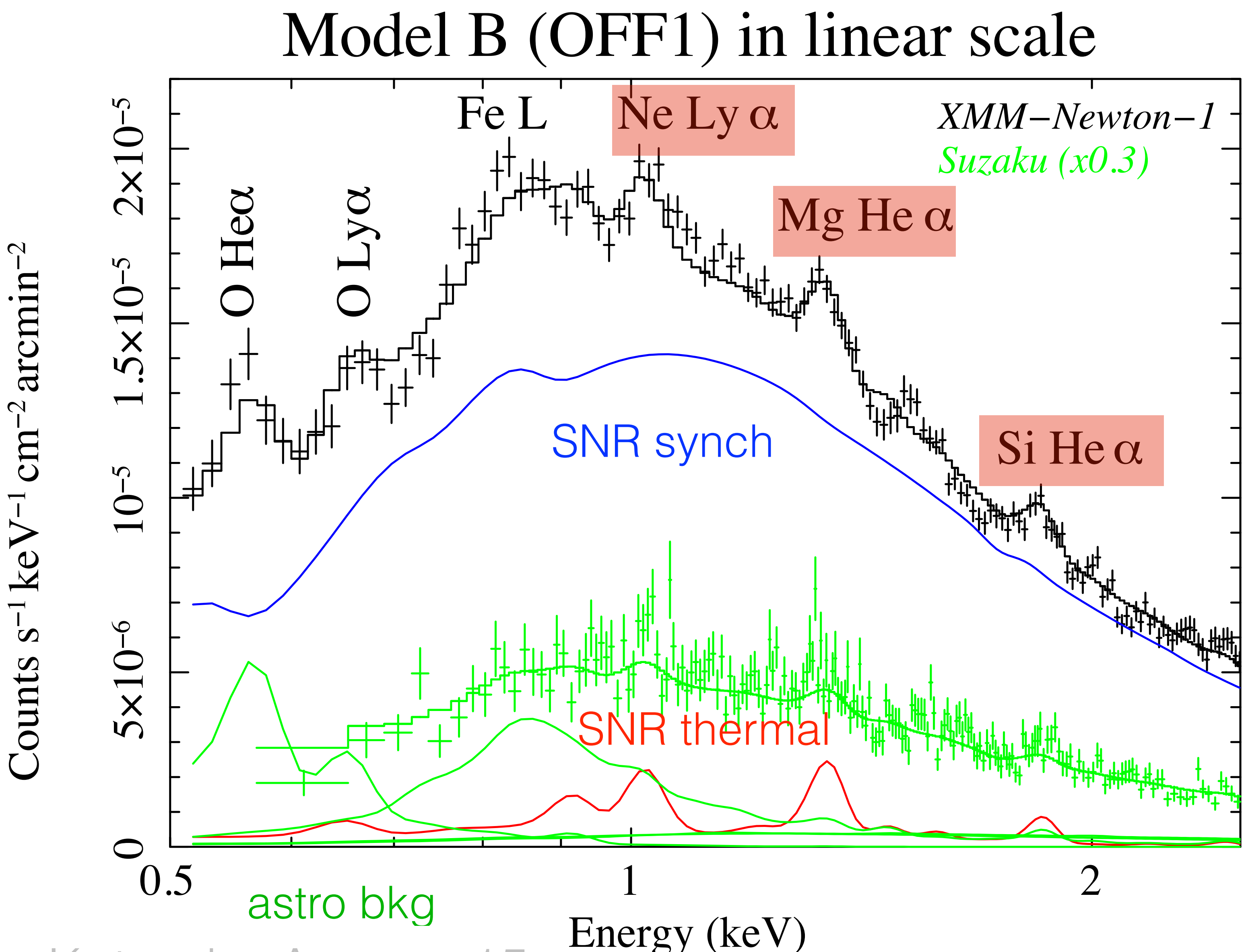
Clear detection in XMM

Hints of emission line in Suzaku

Power-law model + thermal



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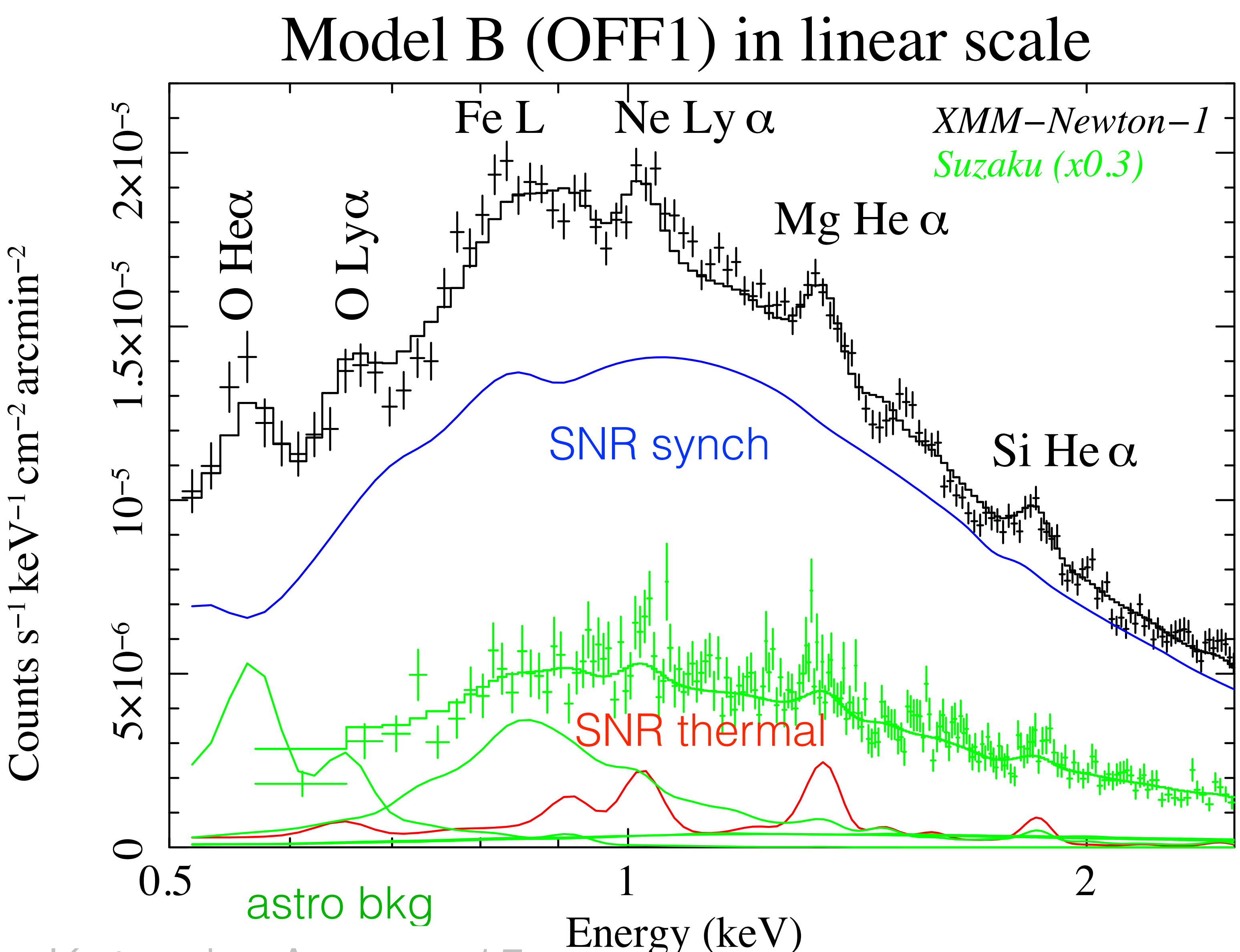

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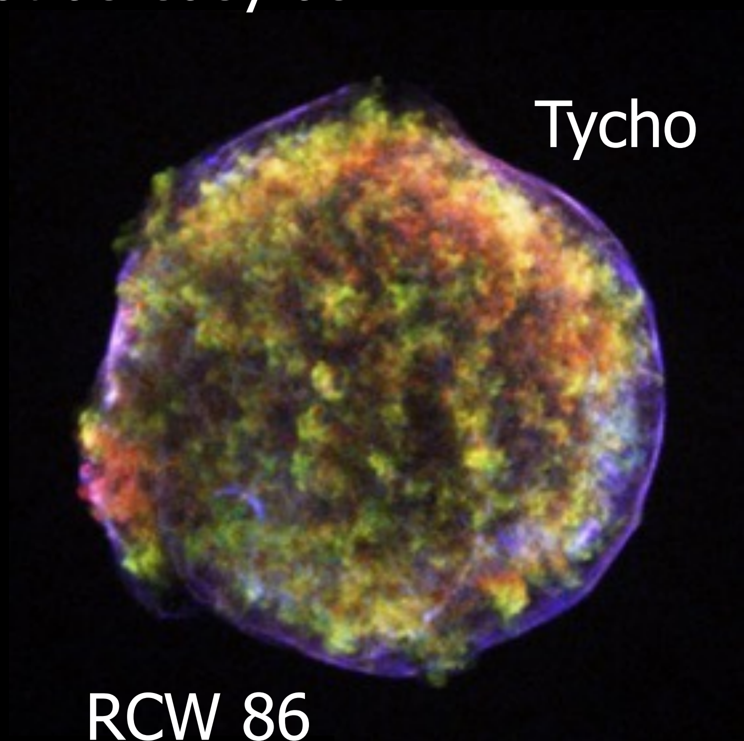
	best-fit
kT_e - keV	0.57 (+0.26 -0.06)
$\log(n_e t)$ cm^{-3} s	11.61 (+0.16 -0.15)
Ne	3.3 (+4.3 -0.7)
Mg	7.0 (+11. -4.4)
Si	5.4 (+4.7 -1.6)
Fe	<0.5

- **Given abundances, thermal emission is likely ejecta related**
- **Lack of Fe => compatible with CC supernova**
- **Mg/Ne, Si/Ne, and Fe/Ne ratios indicate $M_{progenitor}$ < 20 M_o**

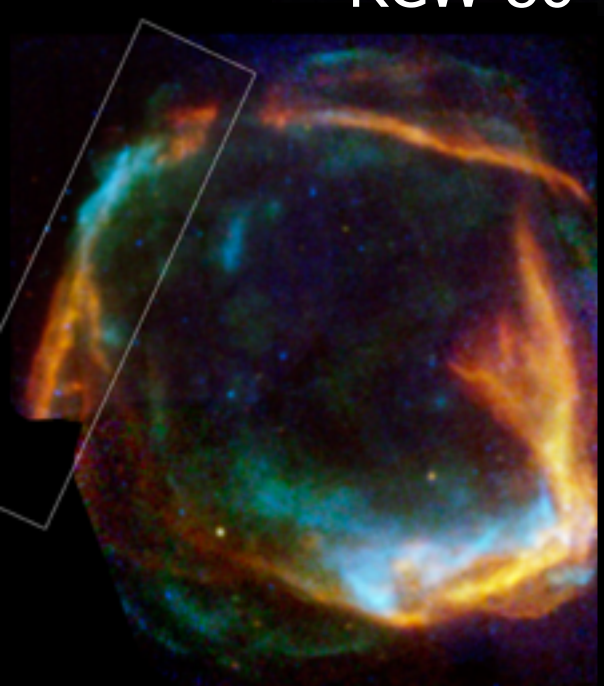
How to constrain ambient medium: Filament proper motion

Filament structures in RXJ … ?
Not as easy as in:

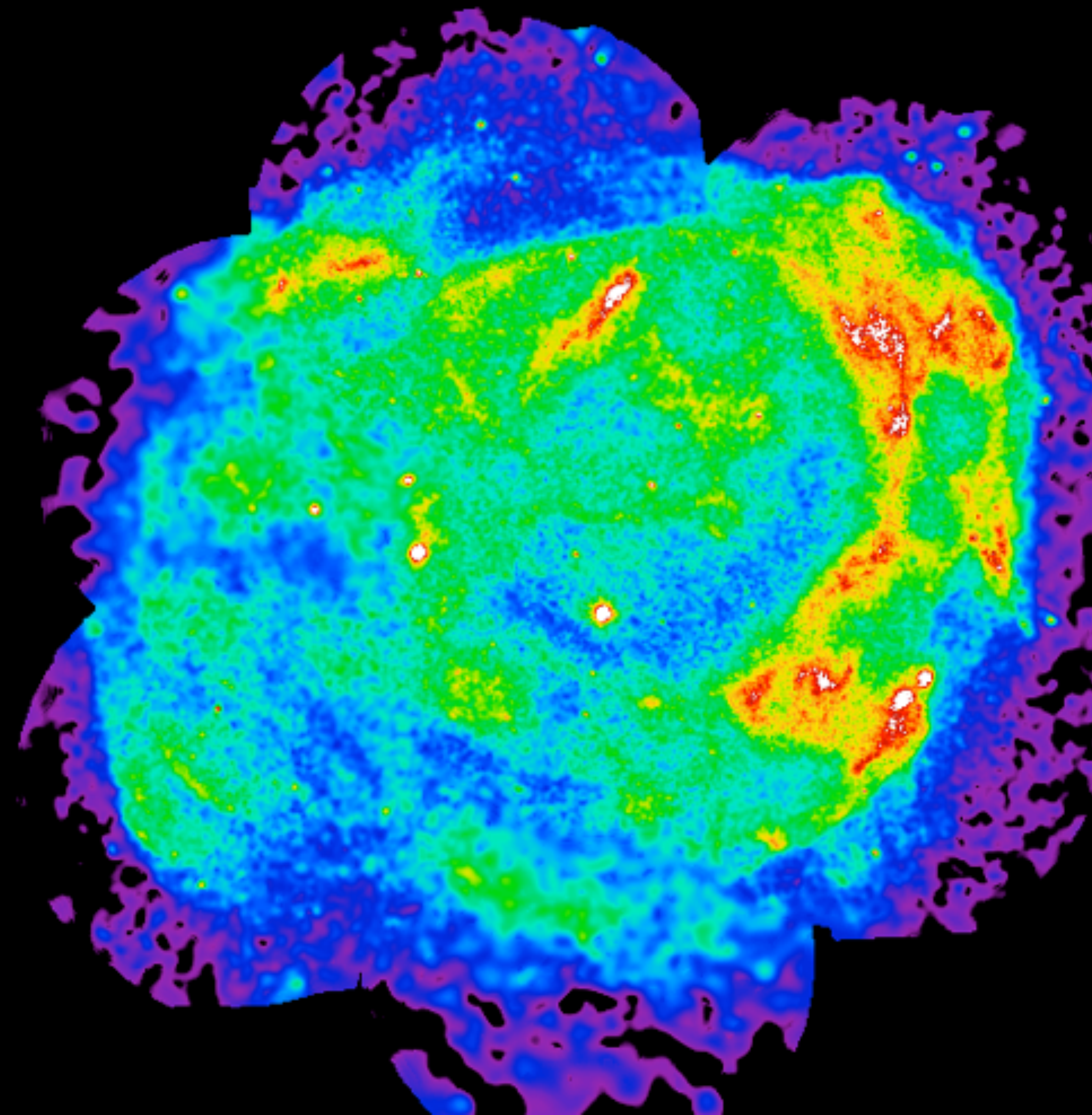


Tycho

RCW 86



SN 1006



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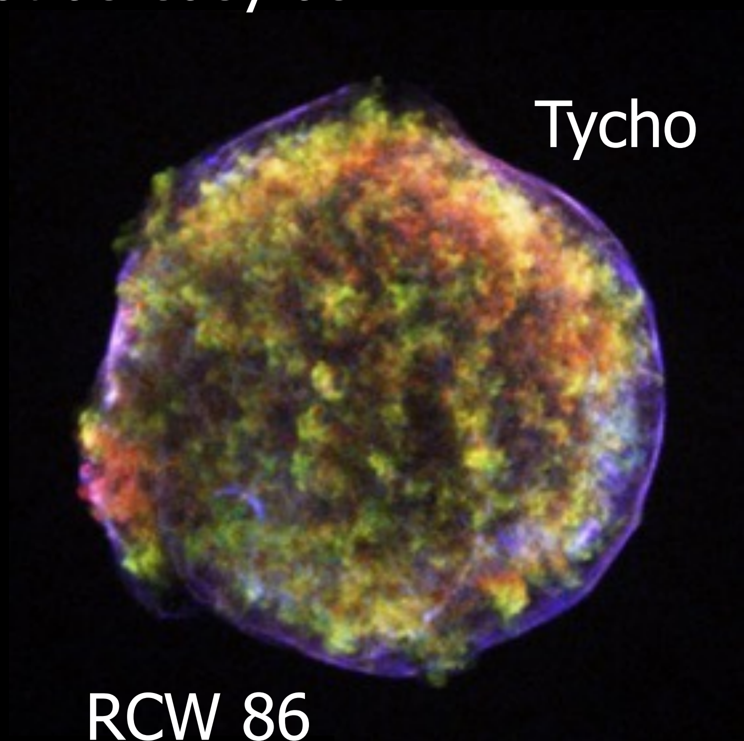

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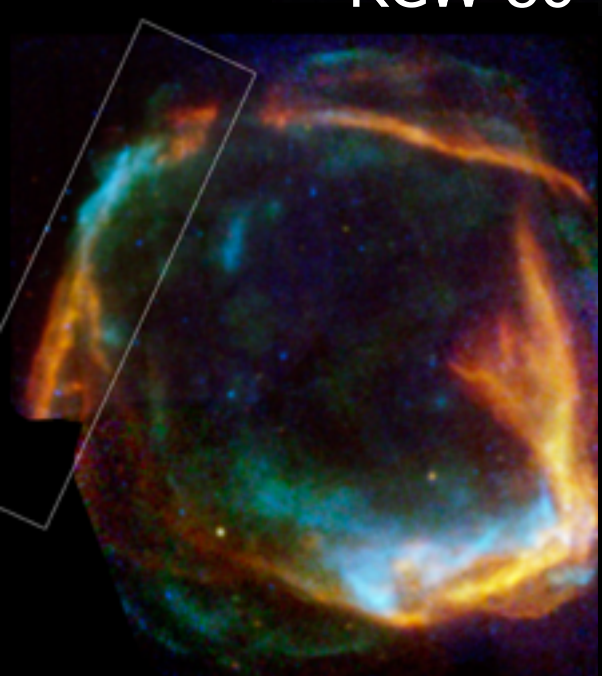

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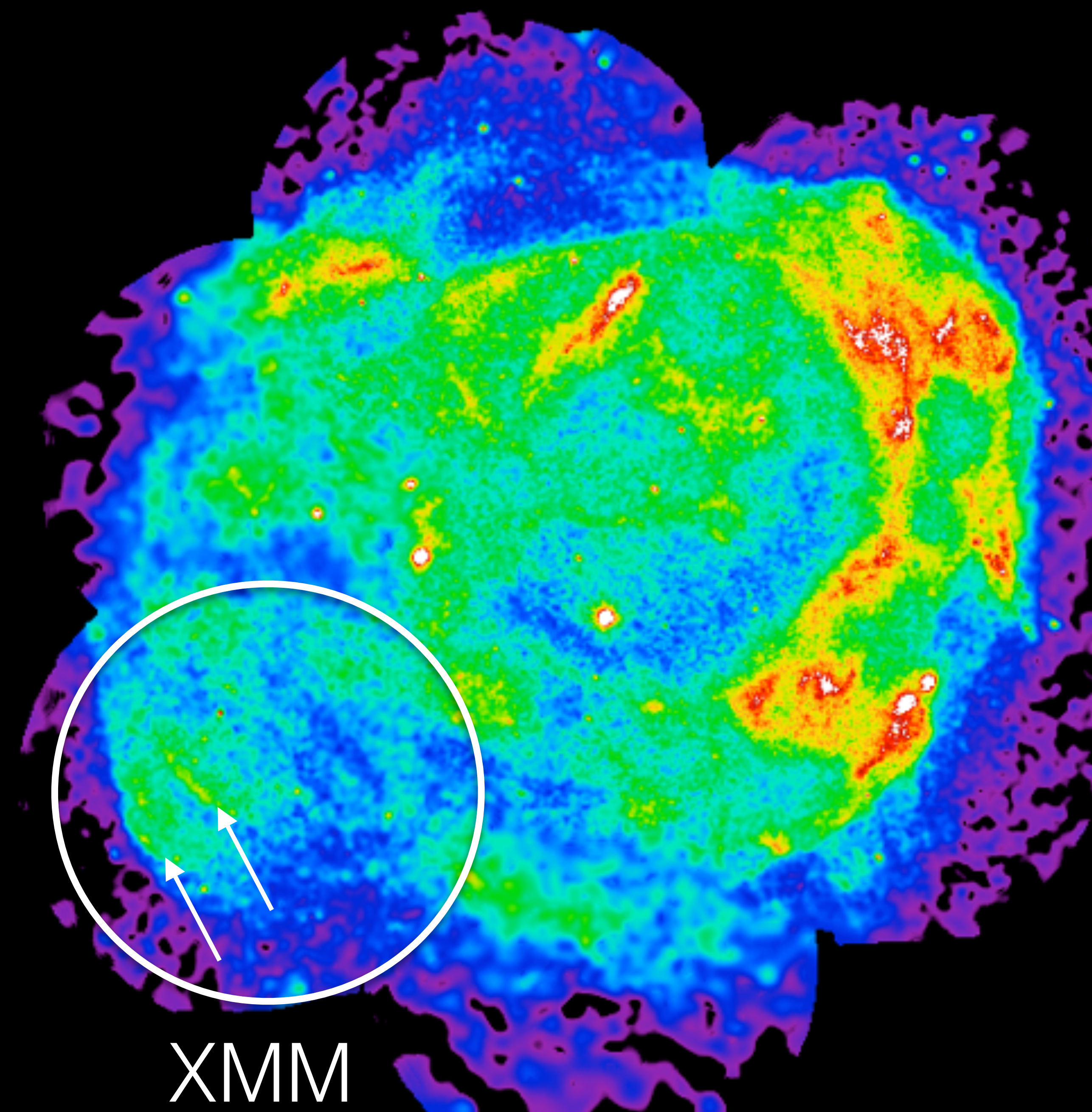
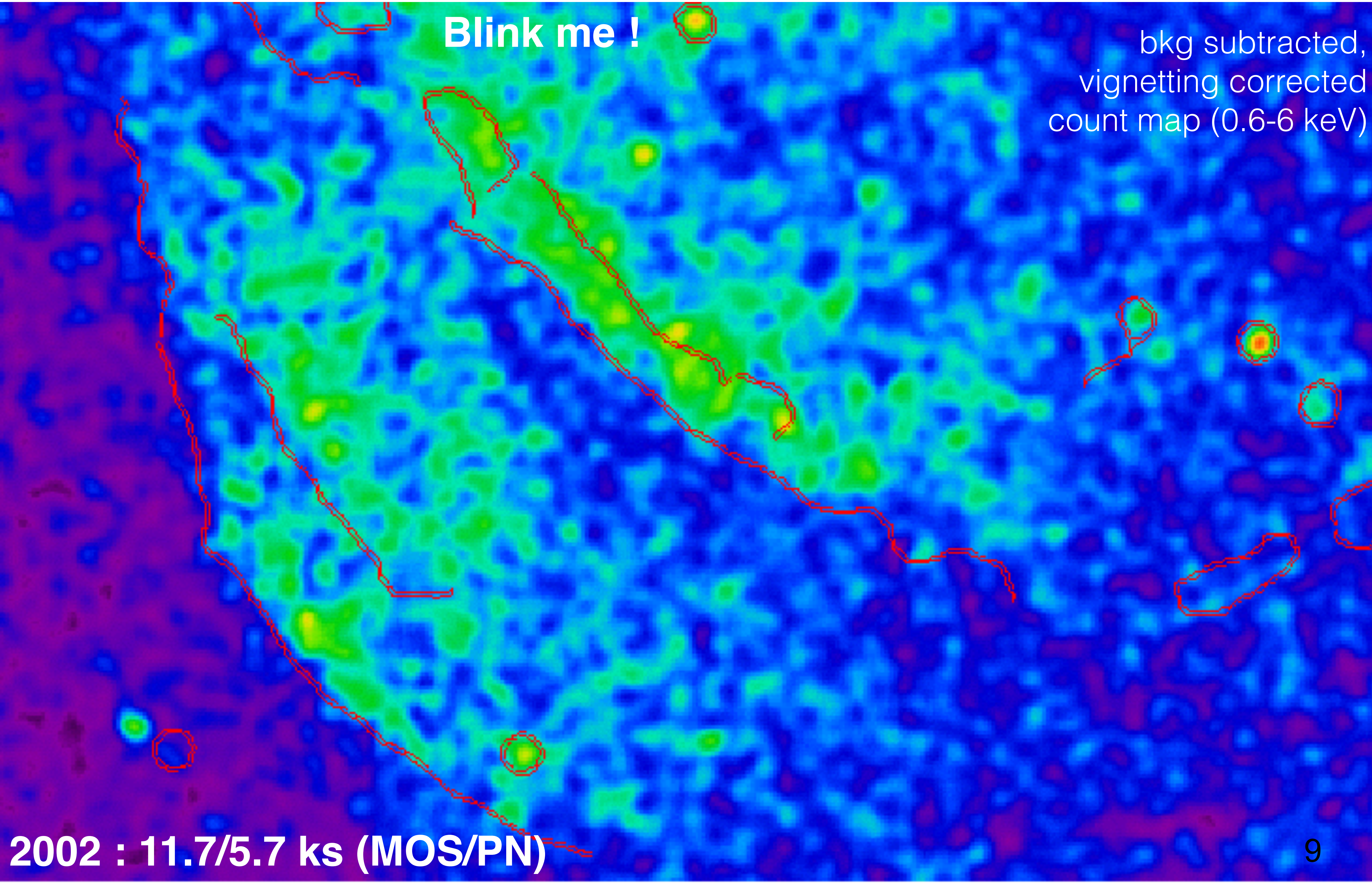


2002: 11 ks
2015: 64 ks

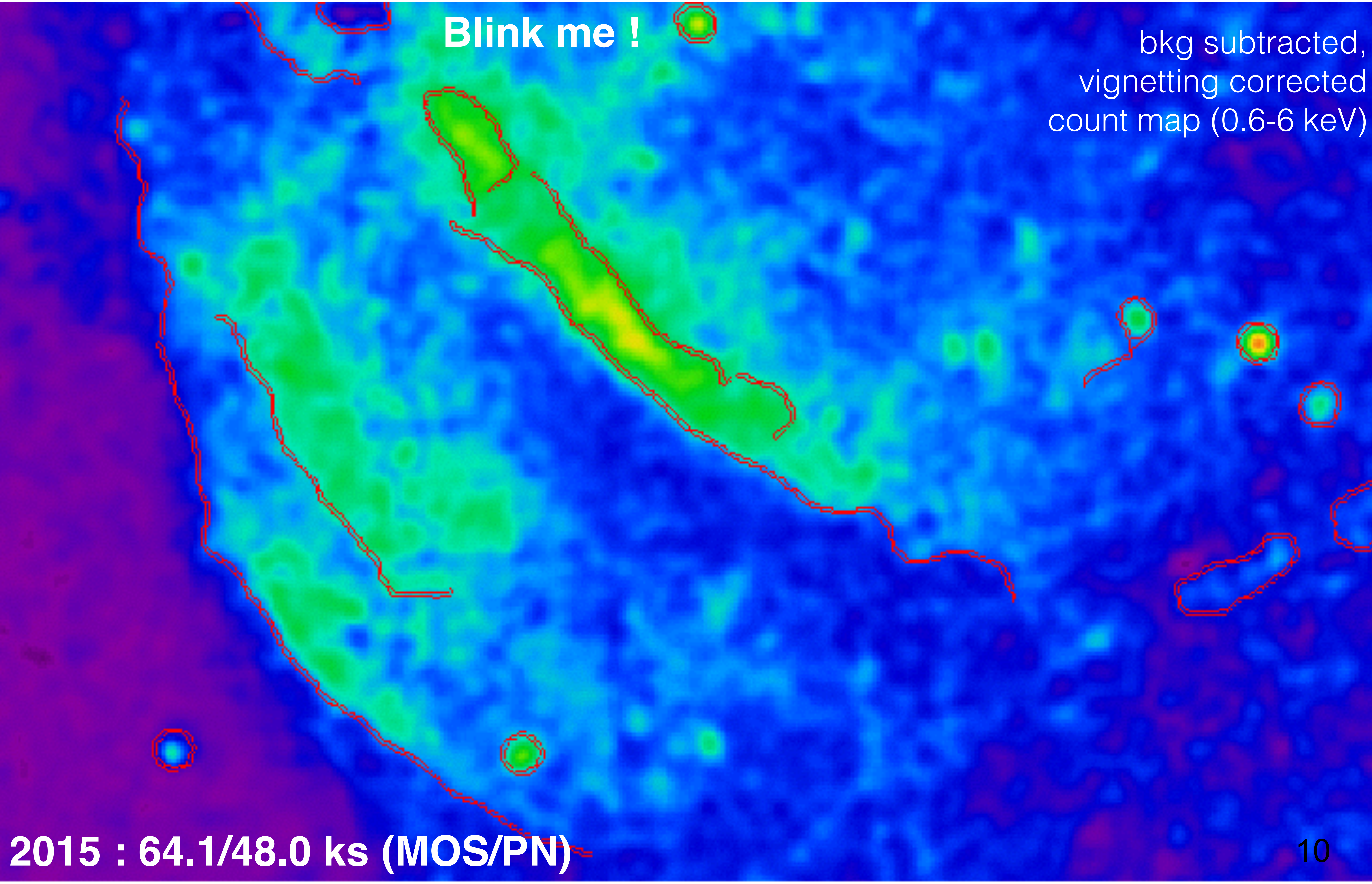
2002 image
2015 edges

X-ray proper motion in the SE

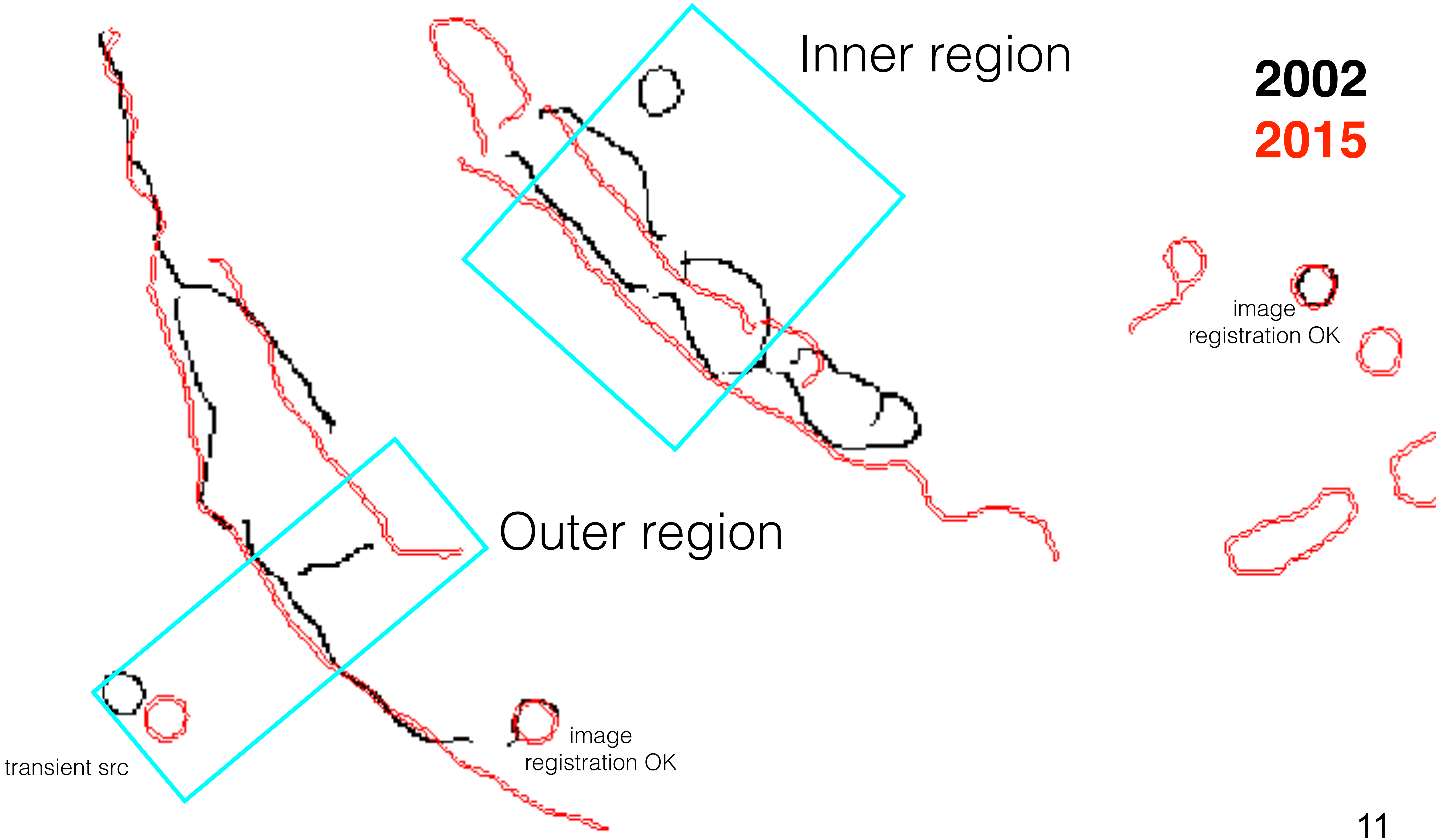


2015 image
2015 edges

X-ray proper motion in the SE



Edge detection for region definition



Method

- **Profiles with MOS at 2''/bin from event lists**

- **Not using chi2 (in some bins Cts<25) but Cash statistics (Cstat)**

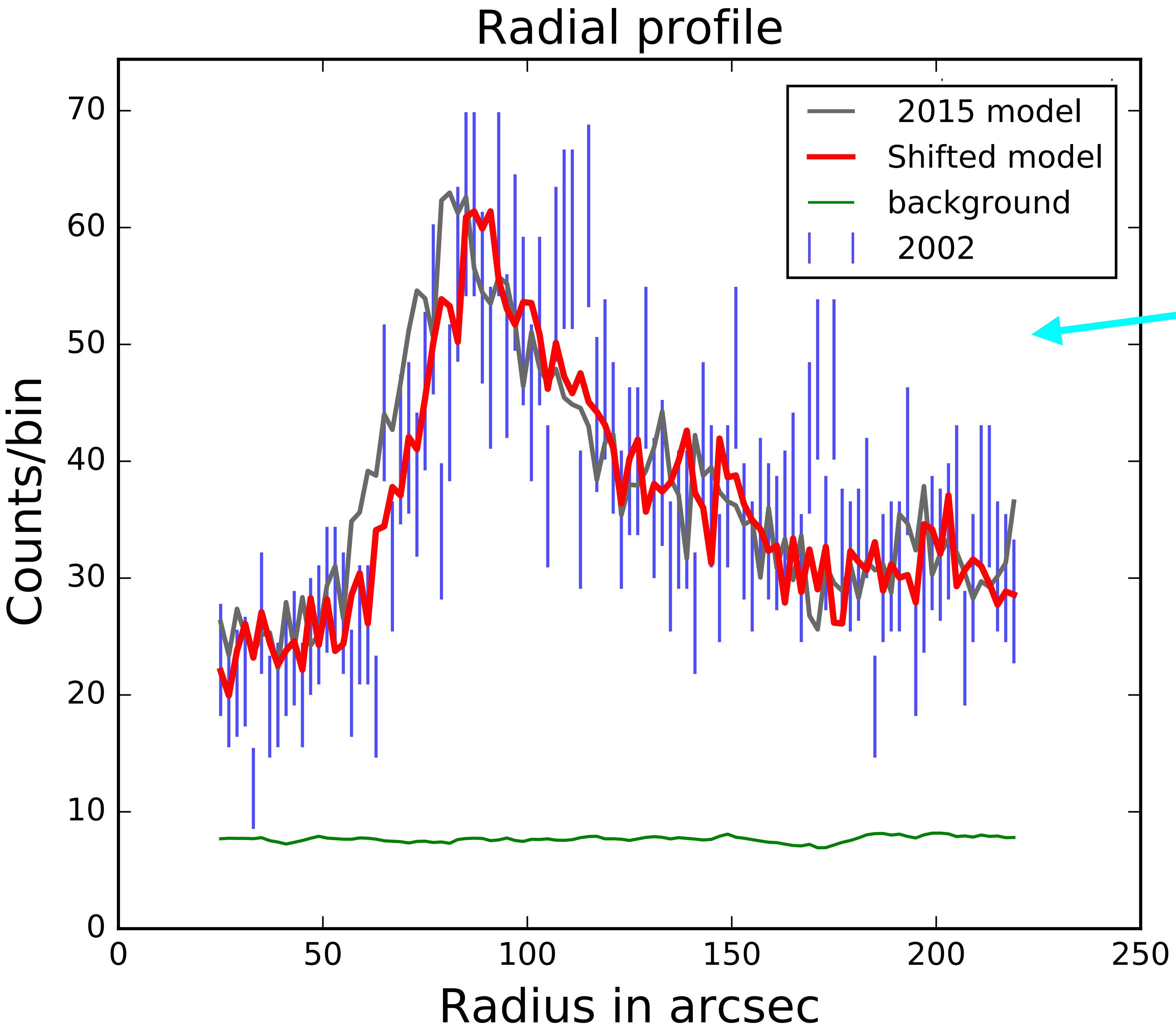
$$C = 2\sum_{i=1}^{N} M_{\rm i} - S_{\rm i} + S_{\rm i}(ln(S_{\rm i}) - ln(M_{\rm i}))$$

  - **S_i is the 2002 profile observed**
  - **M_i a model predicting counts based on the 2015 profile (deepest obs)**

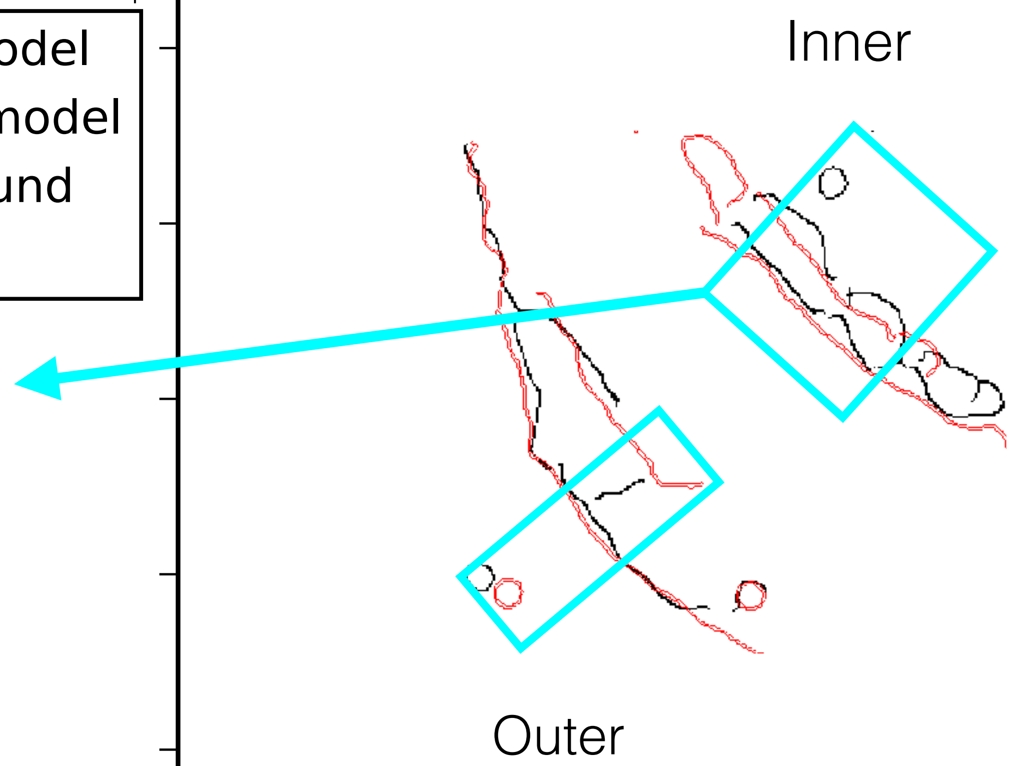
$$M = (Shift(F^{mod}_{src}) * Amp + F_{cst}) * Exp^{obs} + C^{obs}_{bkg}$$

F^{mod}_{src} ↑ 2015; Exp^{obs} ↑ 2002; C^{obs}_{bkg} ↑ 2002

Results

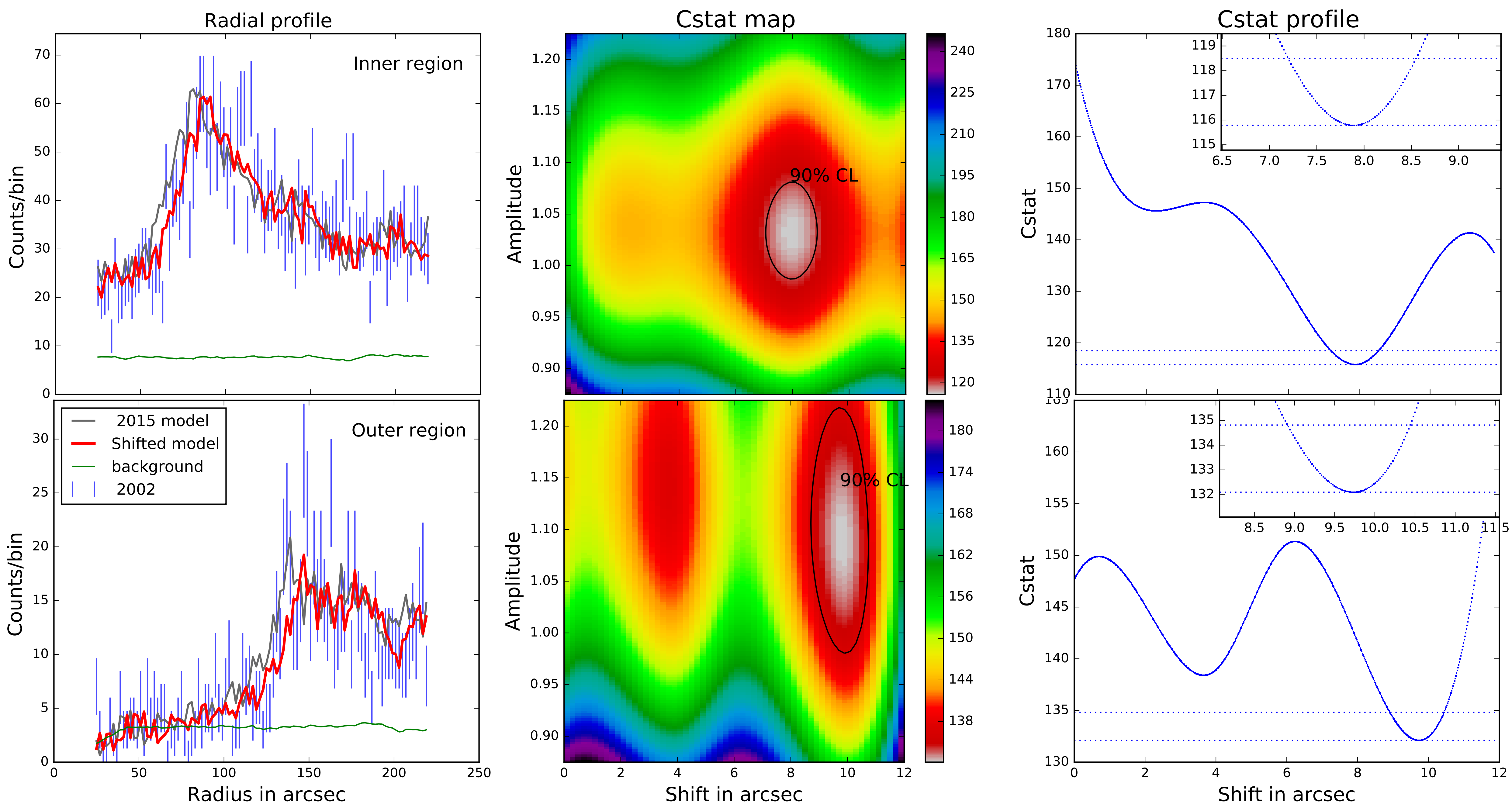


Radial profile
2015 model
Shifted model
background
2002
Counts/bin
Radius in arcsec
0
10
20
30
40
50
60
70
0
50
100
150
200
250



Inner
Outer

Results

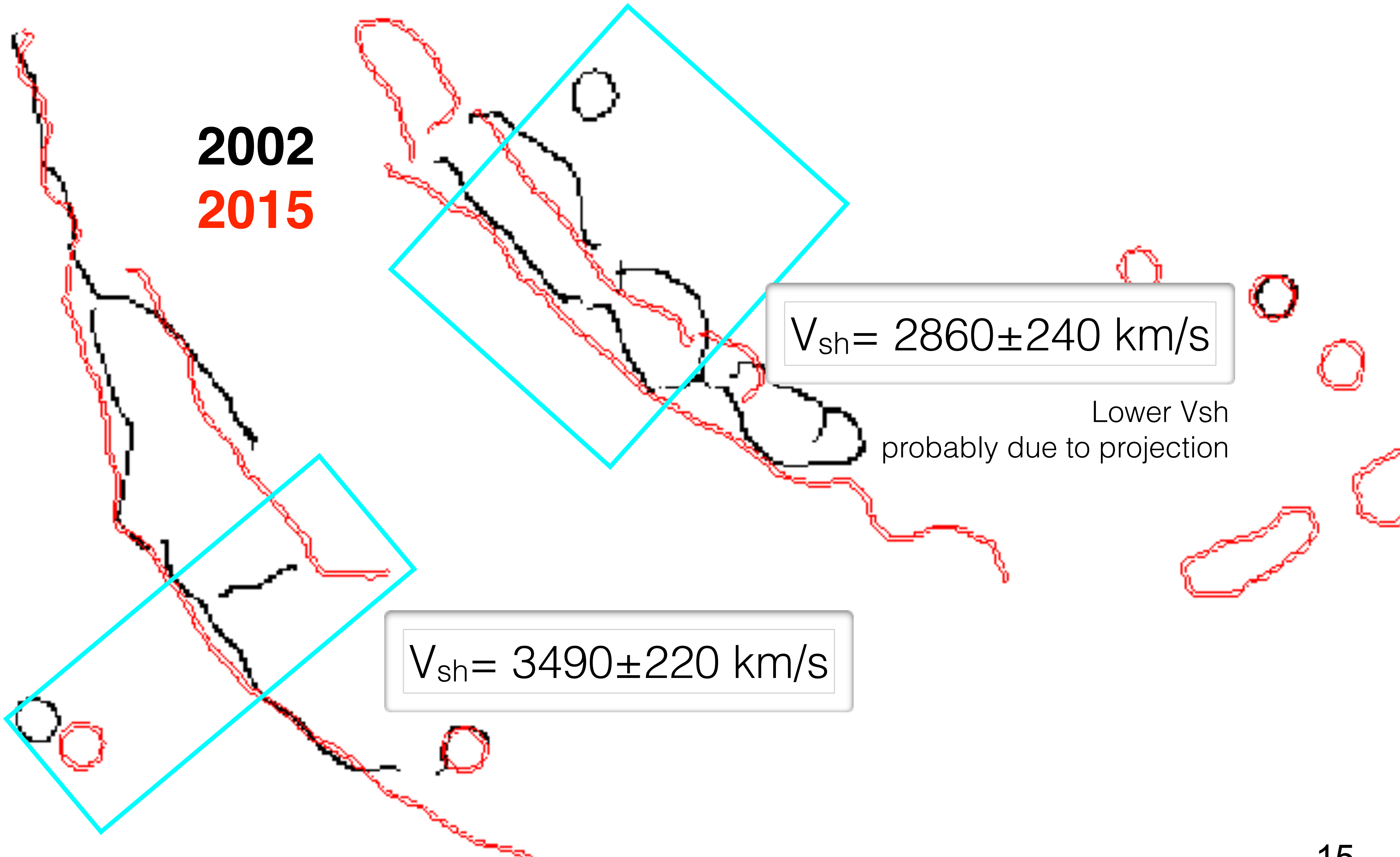


No fitting procedure but computing the Cstat for each point of the grid in the Shift-Amplitude space

Computing Cstat for integer values of Shift and then interpolating

Derived shifts of the order of 8-10” in 13 years (0.6/0.7 ”/yr)

Results: V_{sh} at 1 kpc



SNR age

- **Simple evolution solution:**
  - **$R_{shock} \sim t^m$ and $V_{shock} \sim m * t^{m-1}$**
    where m is the expansion parameter
    $T_{snr} = m*R/V = m * \underbrace{\theta/\dot{\theta}}$
    observable parameter

- **In a stellar wind (as in CC supernova):**

  - **0.86 > m > 0.66 (s=2, n=9)**
    ejecta phase Sedov phase
  - **2330 yrs > T_{snr} > 1810 yrs**

- **Age estimate independent of the distance !**
  => Not compatible with SN393

Estimating M_{ejecta}

- **Use evolution equations* to find Age and ρ_0 that match observed θ, $\dot{\theta}$:**
  - **Age and $\rho_0 = f(M_{ejecta}, E_{SN}, \text{distance})$**
  - **Value for M_{ej} ?**
  - **M_{ej} related to wind density (Mass loss)**

- **Shock in a stellar wind and currently near the border of the cavity:**

$$M_{progenitor} = M_{loss} + M_{neutronstar} + M_{ejecta}$$

14 M_o	**$M_{swept\text{-}up}$** $= f(\rho_0)$	**1.4 M_o**	**M_{ej}**

$$M_{ejecta} = f(\rho_0)$$

*** TrueLove&McKee + Hwang&Laming**

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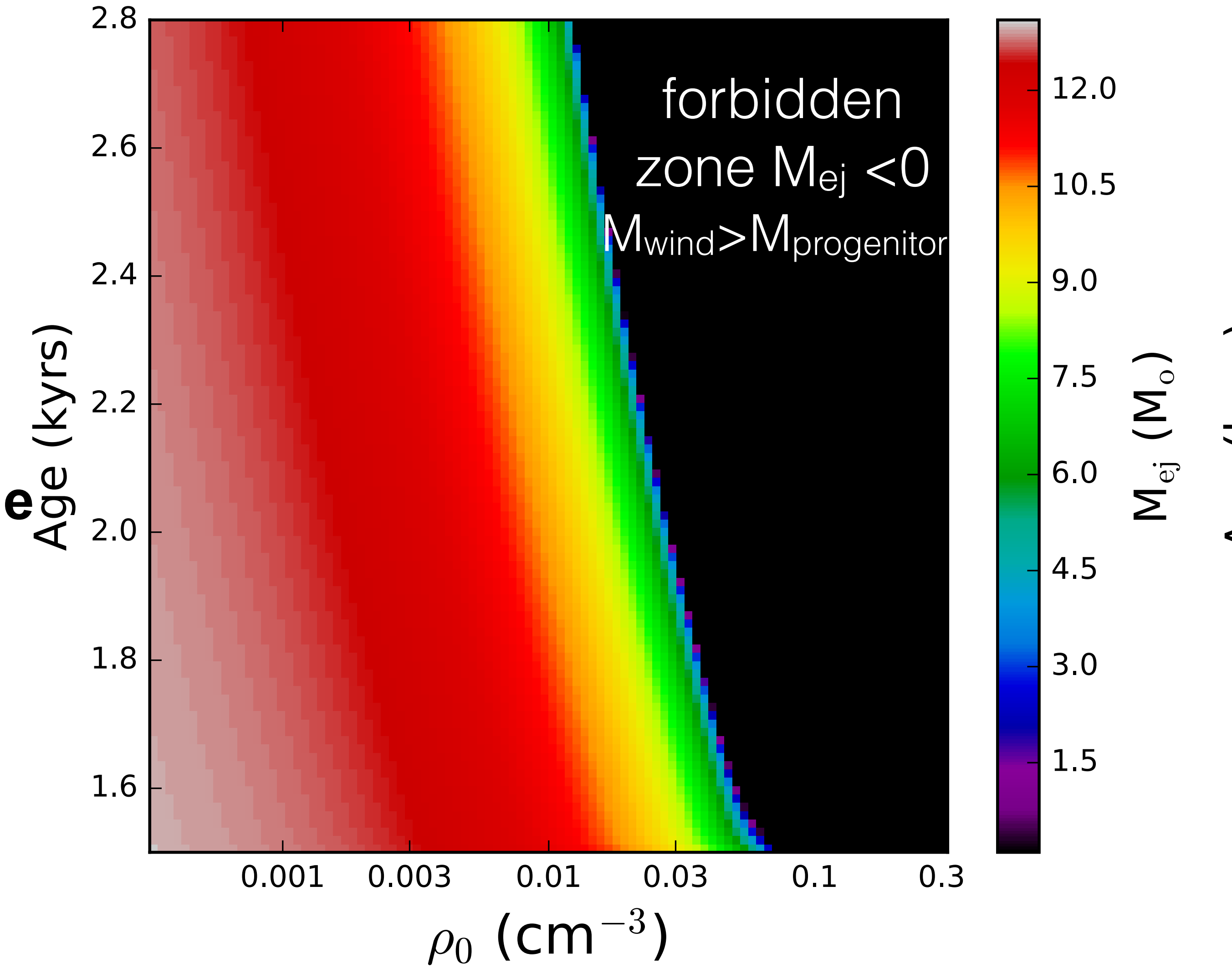

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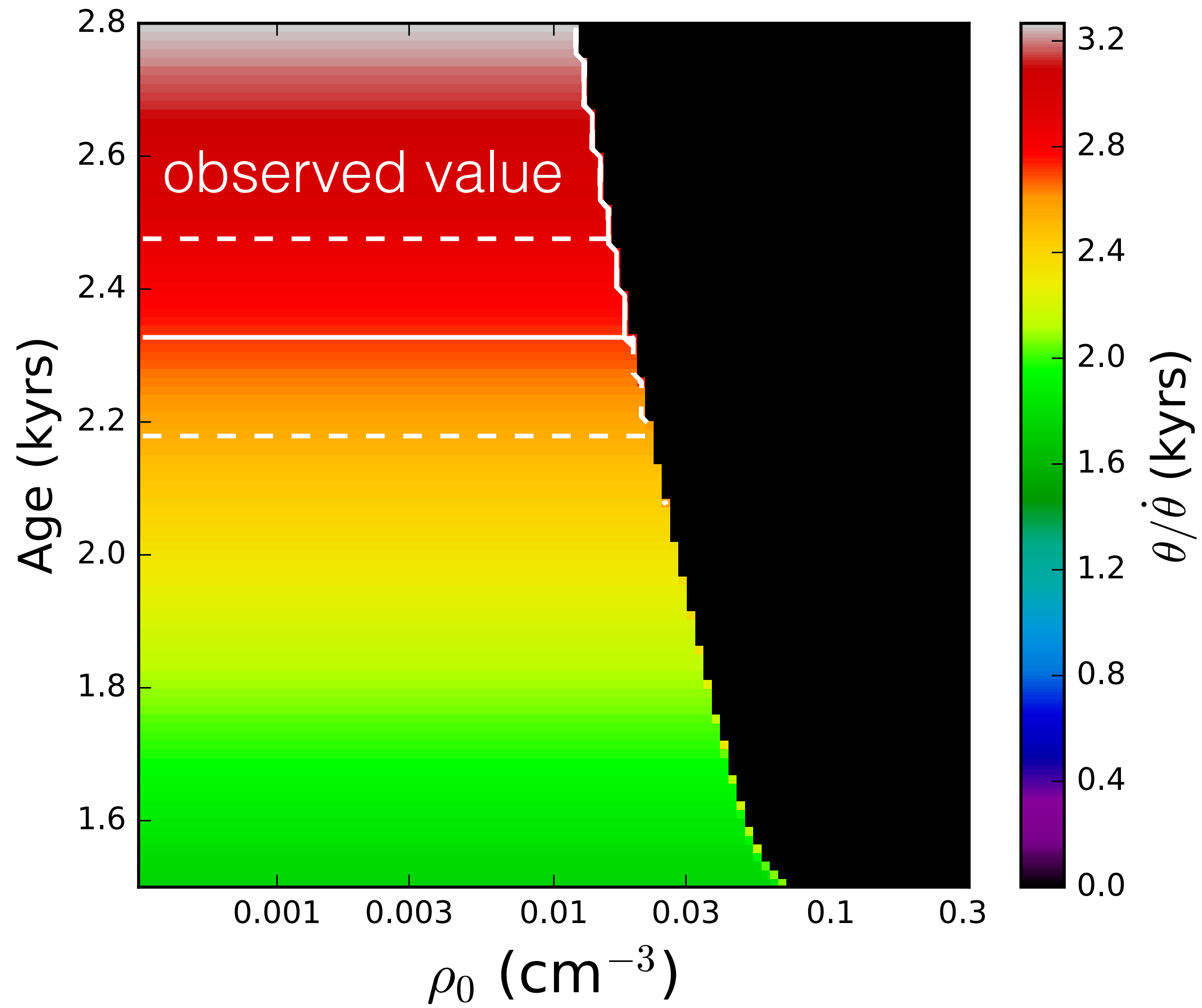
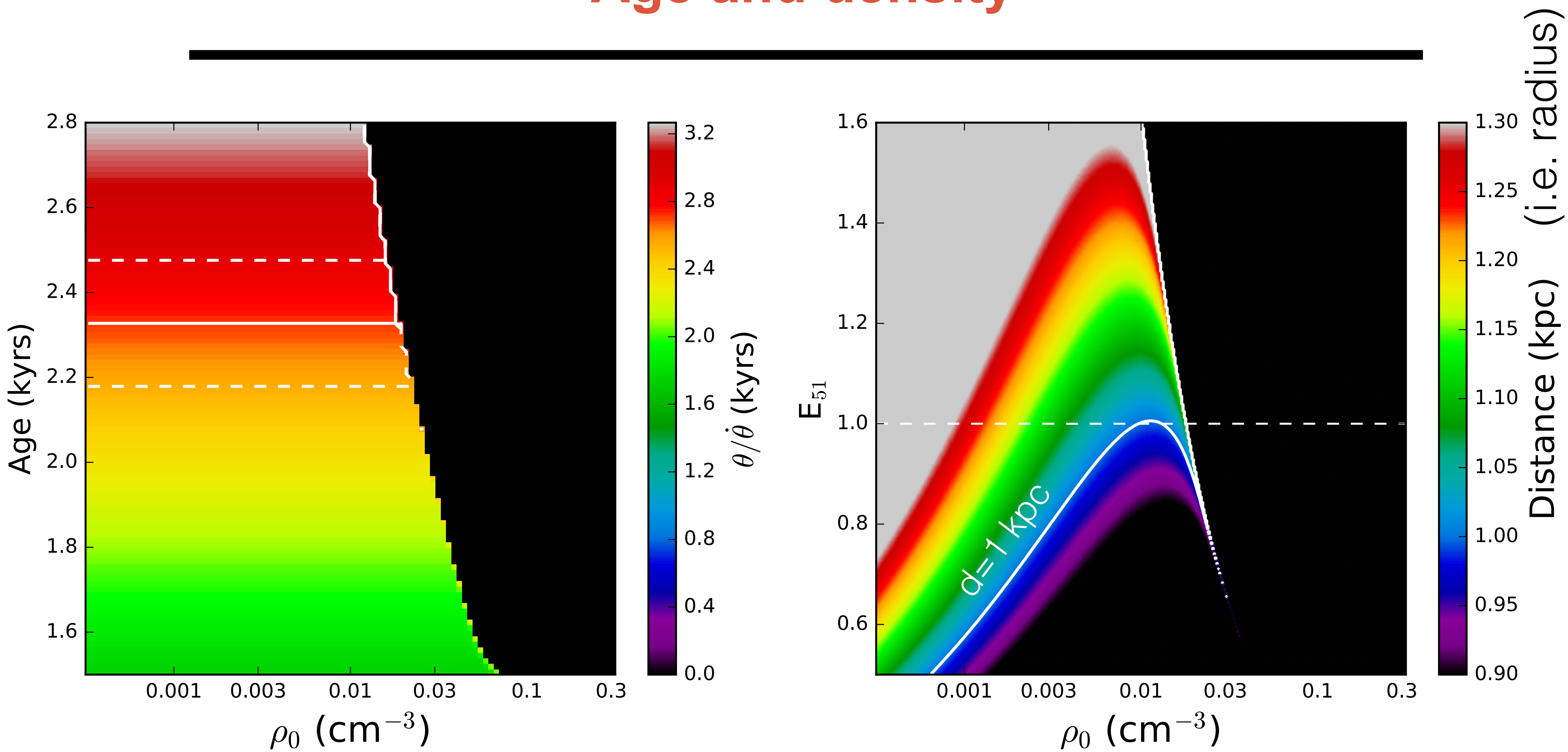
Age and density



- **With this M_{ej} prescription, can compute predicted $\theta/\dot{\theta}$ for different age/ρ:**
  - **T_{SNR} = 2330 ± 150 yrs**

Age and density



- **For a given Age, M_{ej}, explore density dependence on dist, E_{51}**
  - **for d = 1 kpc and E=10^{51} ergs => ρ_0 = 0.01 cm^{-3}**
- **For such density, $M_{sweptup}$ = 4 M_o and M_{ej} = 9 M_o (ejecta phase)**

Conclusions

* Progenitor type/mass ?   * Age (SN 393 debated) ?   * Ambient density, V_{shock} ?

↓

First thermal X-rays

↓

Ejecta emission

$M_{progenitor} < 20 M_{o}$

Note :

ejecta emission. No shocked ambient medium found so far.

↓ ↓

First shock speed ~ 3500 km/s

↓

Age ~2300 ±150 yrs

(not SN 393)

↓

very low density cavity

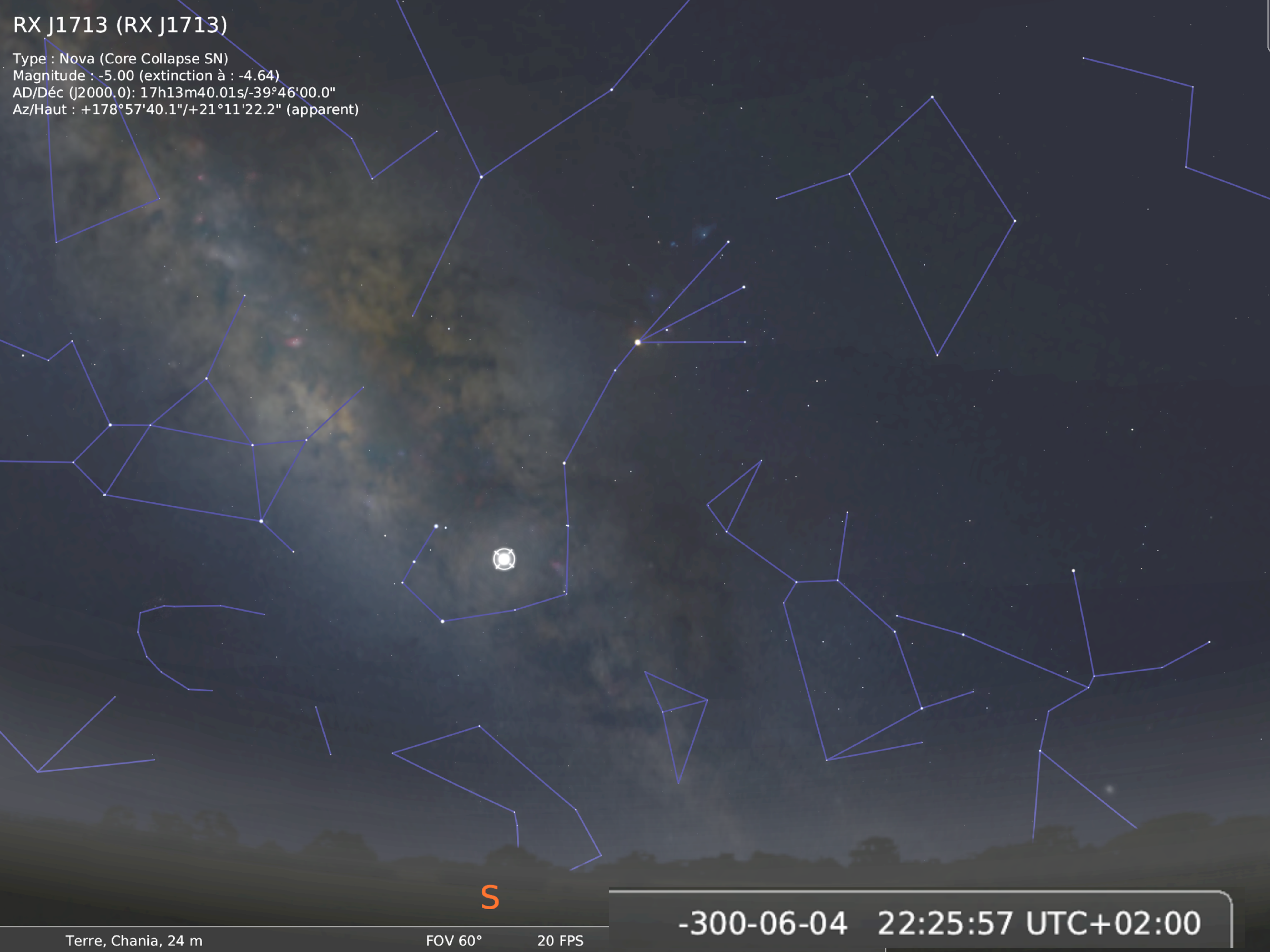
$\rho_0 = 10^{-2}$ cm^{-3}

Caveats :

not the density in the bright NW region

Katsuda, Acero et al. ‘15

Acero, Katsuda, et al. in prep


RX J1713 (RX J1713)
Type : Nova (Core Collapse SN)
Magnitude : -5.00 (extinction à : -4.64)
AD/Déc (J2000.0): 17h13m40.01s/-39°46'00.0"
Az/Haut : +178°57'40.1"/+21°11'22.2" (apparent)
S
Terre, Chania, 24 m
FOV 60°
20 FPS
-300-06-04 22:25:57 UTC+02:00

Back up

Estimating M_{ejecta}

- **Use evolution equations* to match θ, $\dot{\theta}$:**
  - **Age and $\rho_0 = f(M_{ejecta}, E_{SN}, \text{distance})$**
  - **Value for M_{ej} ?**
  - **Wind density (Mass loss) related to M_{ej}**

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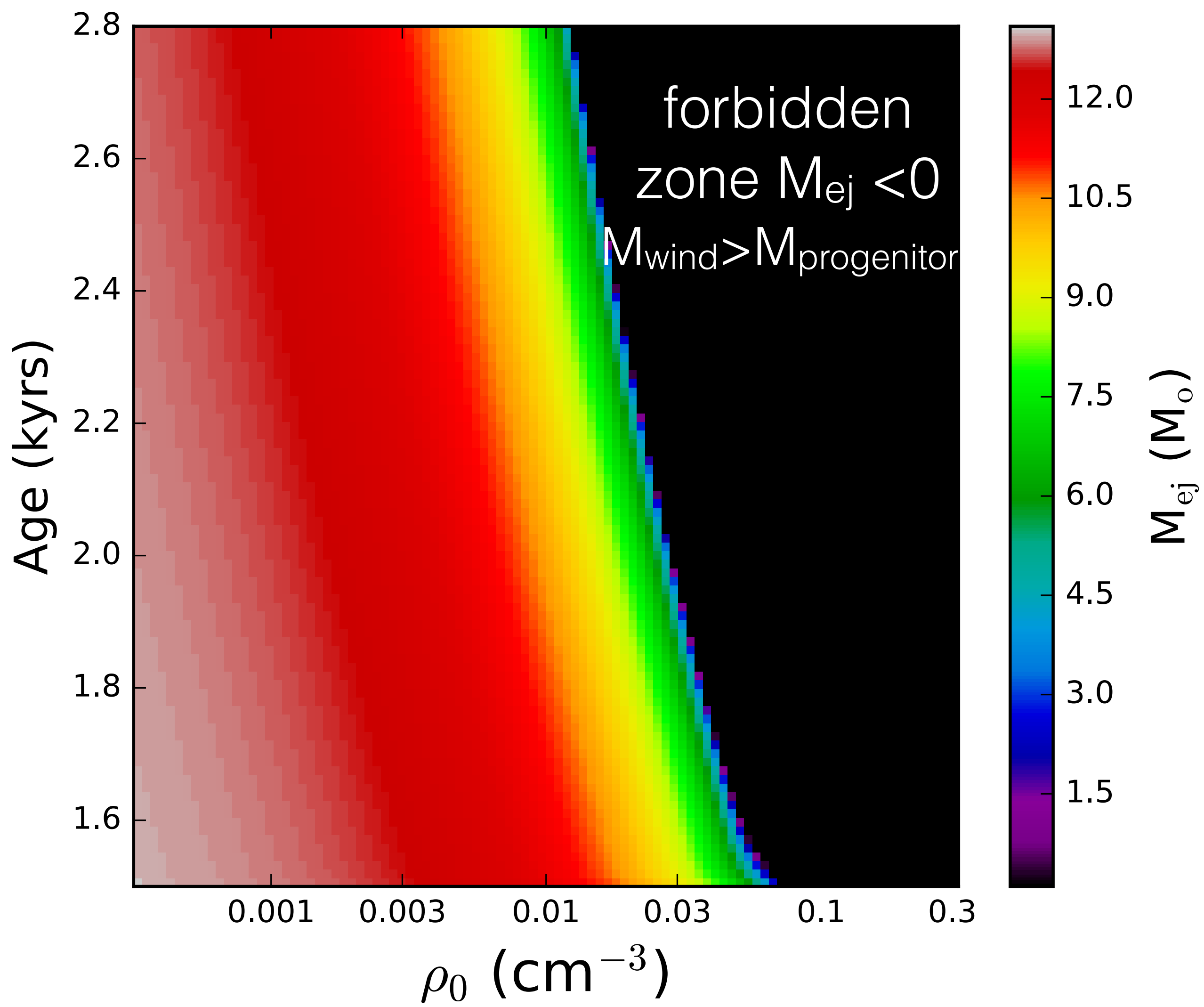


For a given rho, M_{ej}(from rho) what's the required age to reach current R_{sh}

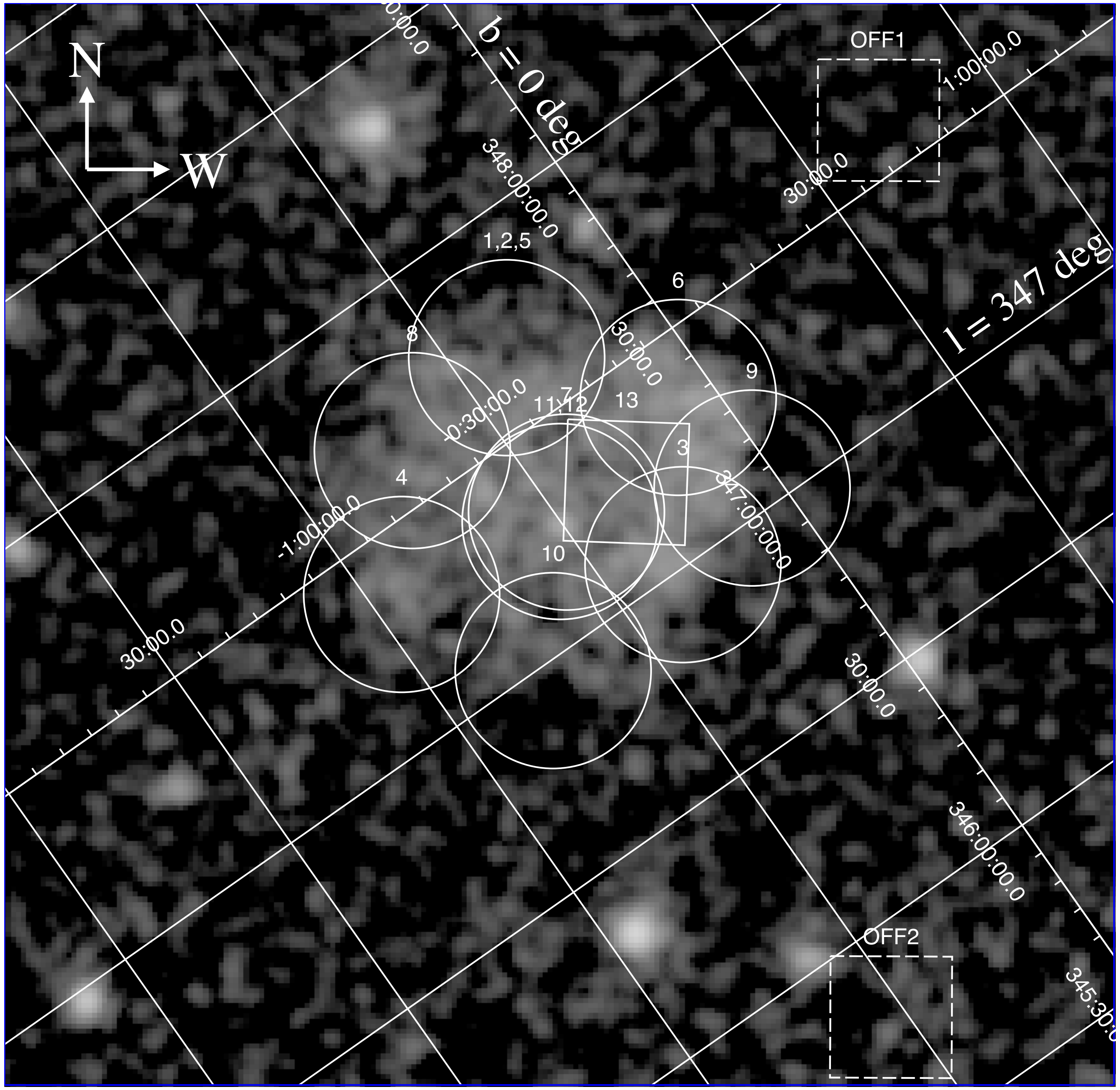
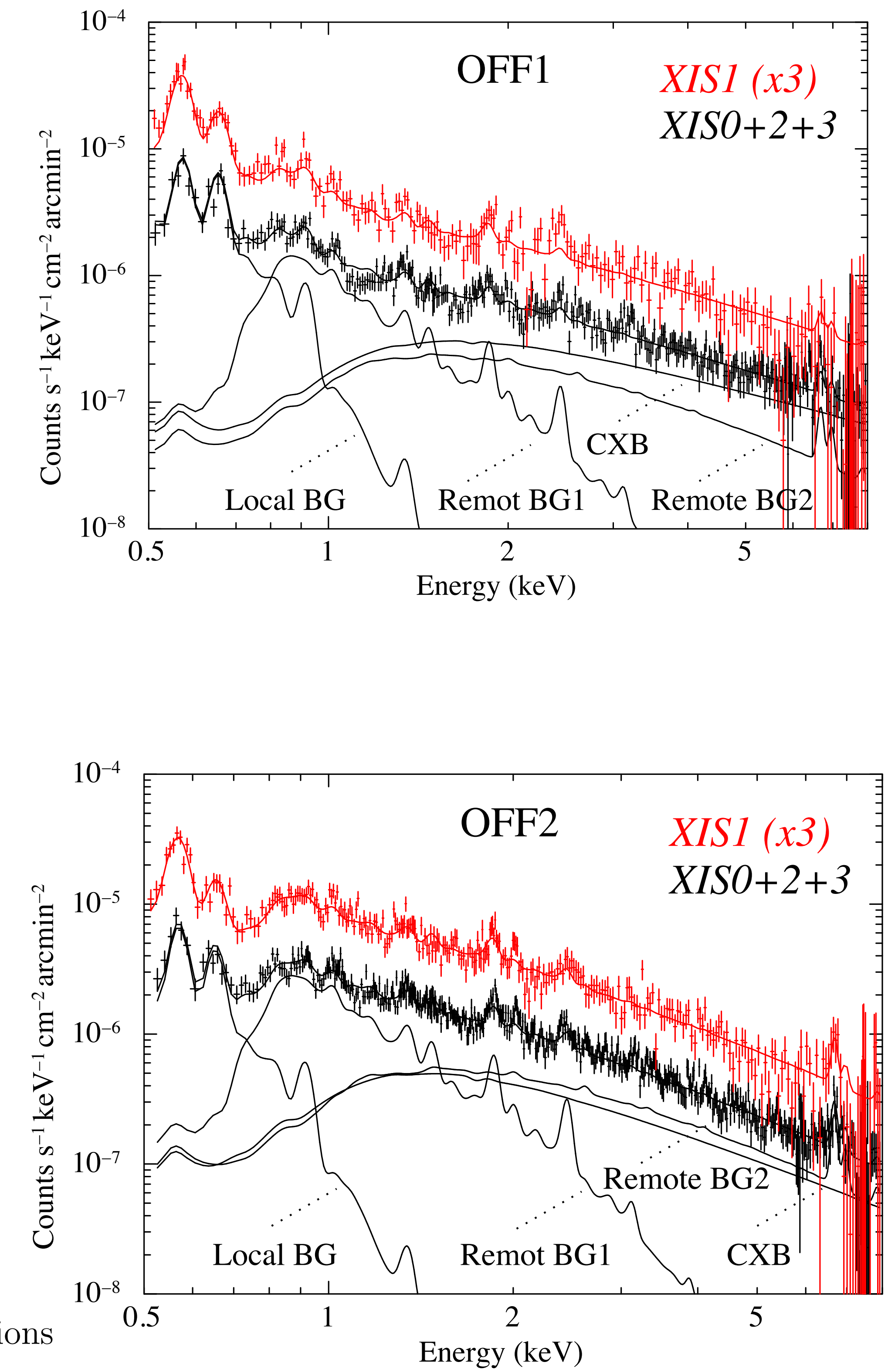


Fig. 1.— The fields of view of the *XMM-Newton* (circle) and *Suzaku* (box) observations listed in Table 1 overlaied on the *ROSAT* all-sky survey image. Position IDs in Table 1 are labelled just outside individual fields of view. The image is binned by 45″, and has been smoothed with a Gaussian kernel of $1\sigma = 135''$.



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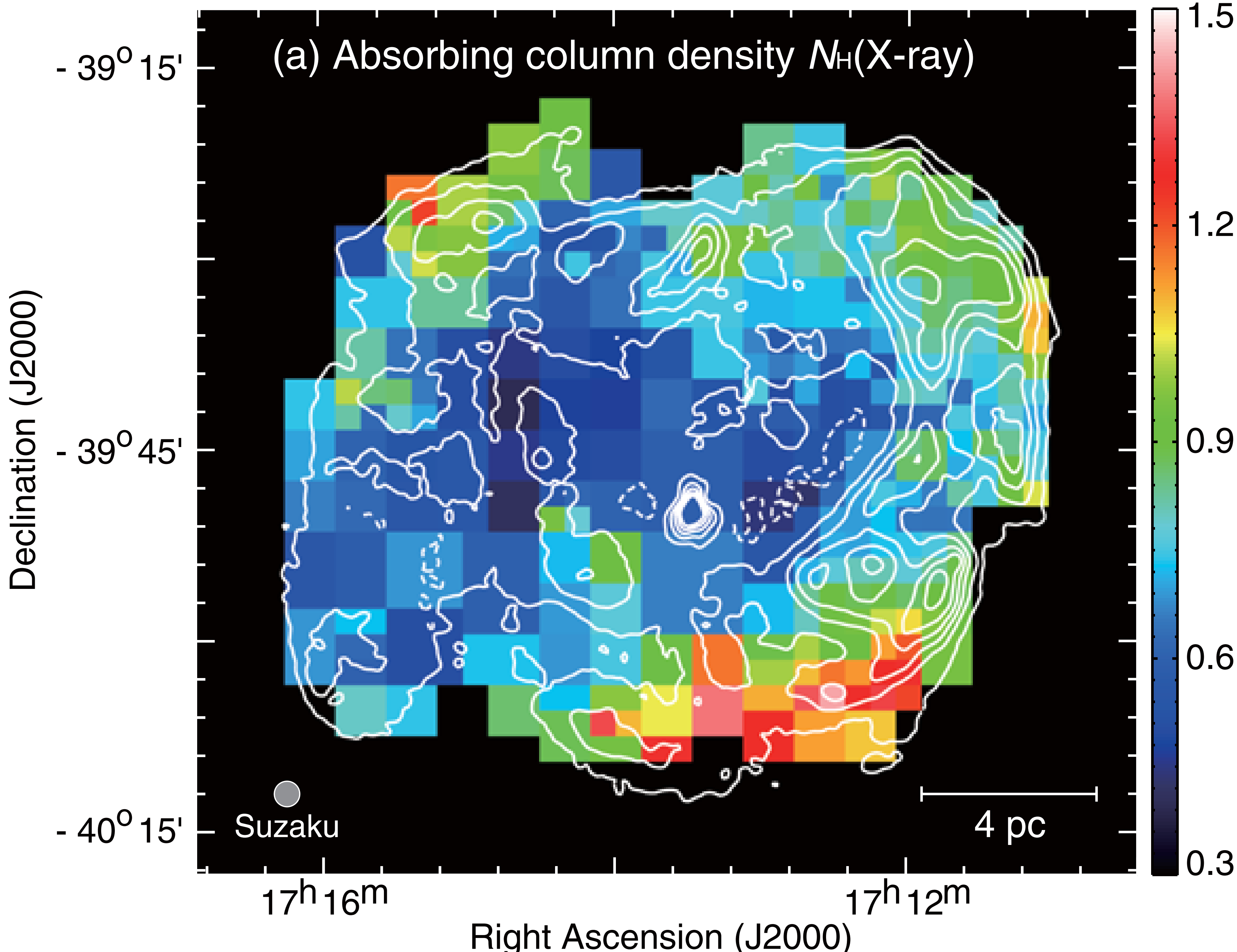
Absorption map

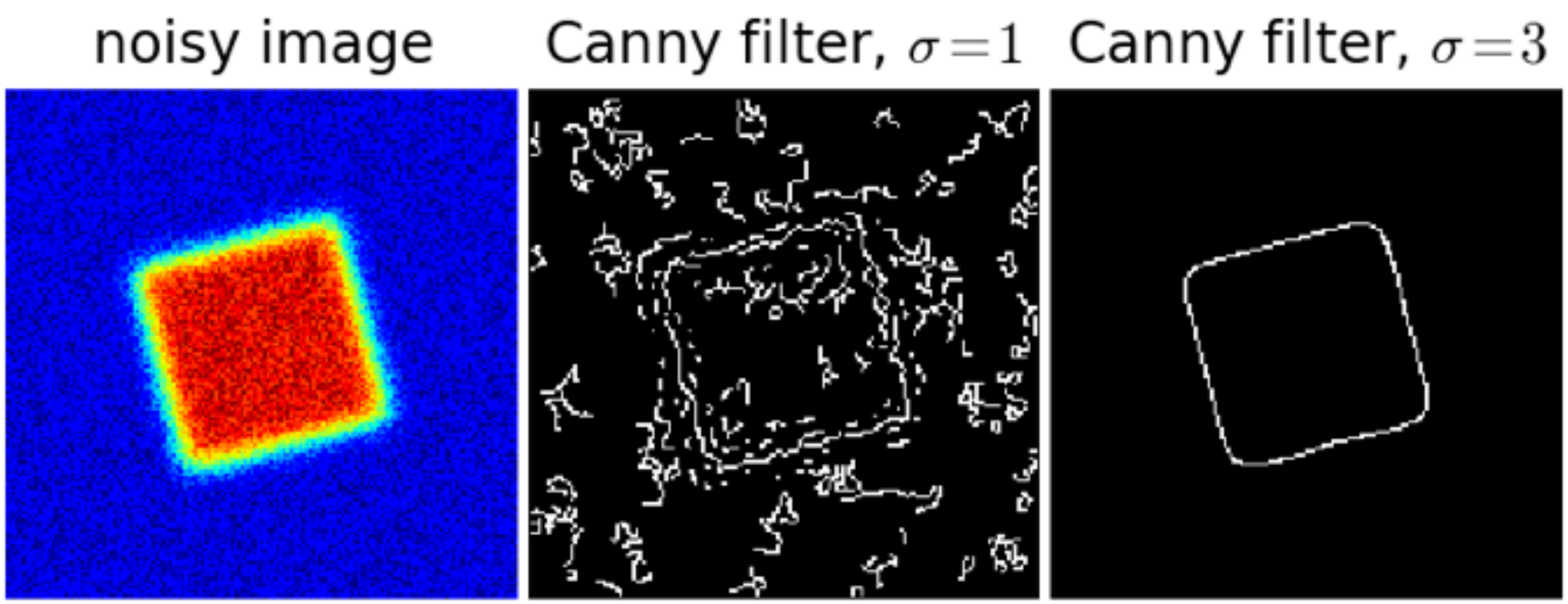


Sano+15

Edges detection for region definition

- **Need to detect the edges of the shock to choose regions for radial profile. In particular the rotation angle of the box**
- **Used and edge detection algorithm (used in image processing)**
- **Stable edge detection, 1 parameter to play with. Works well in noisy images**

The Process of Canny edge detection algorithm can be broken down to 5 different steps:
-Apply Gaussian filter to smooth the image in order to remove the noise
-Find the intensity gradients of the image
-Apply non-maximum suppression to get rid of spurious response to edge detection
-Apply double threshold to determine potential edges
-Track edge by hysteresis: Finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.



Example from
http://scikit-image.org/docs/dev/auto_examples/plot_canny.html