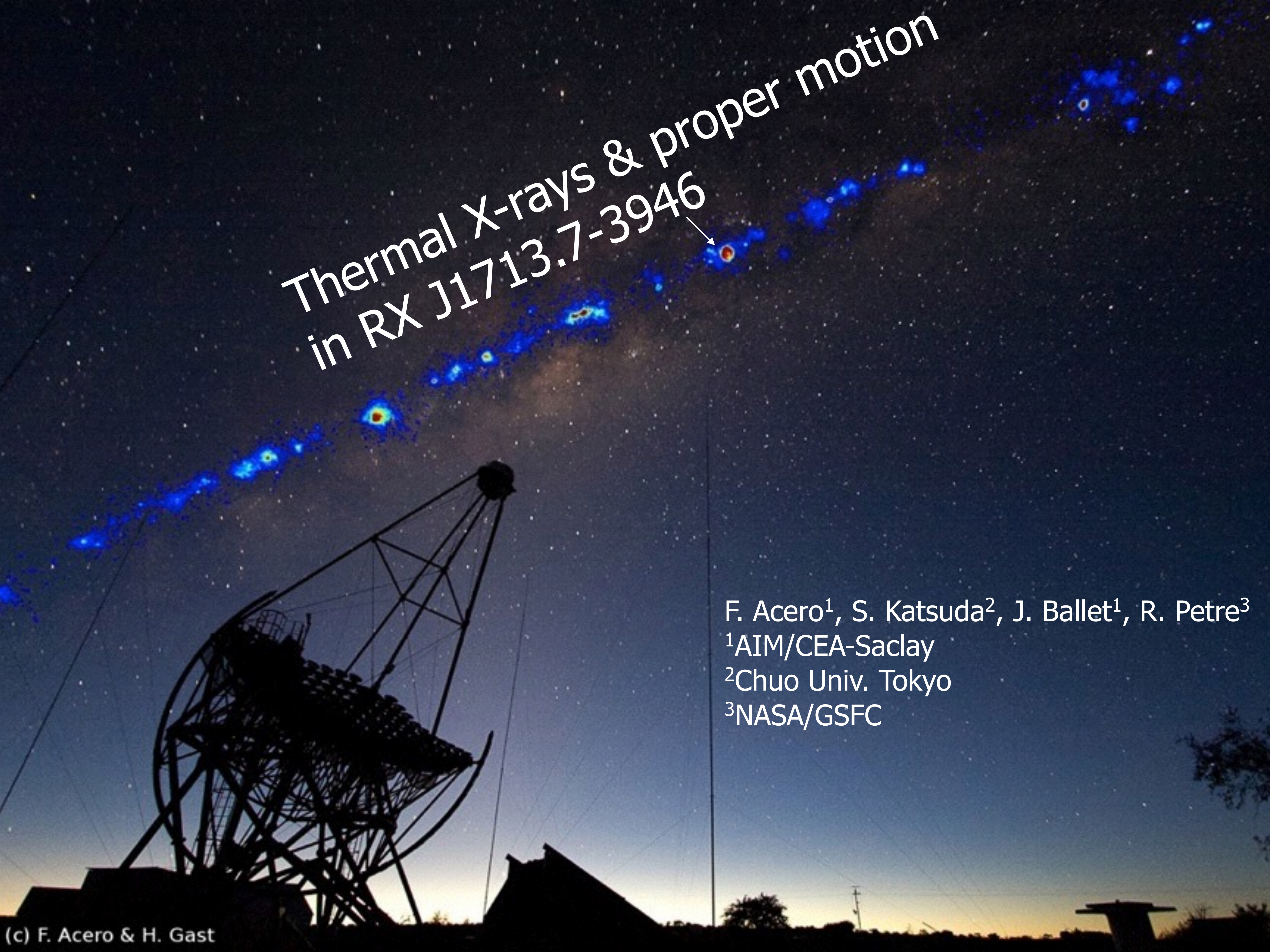
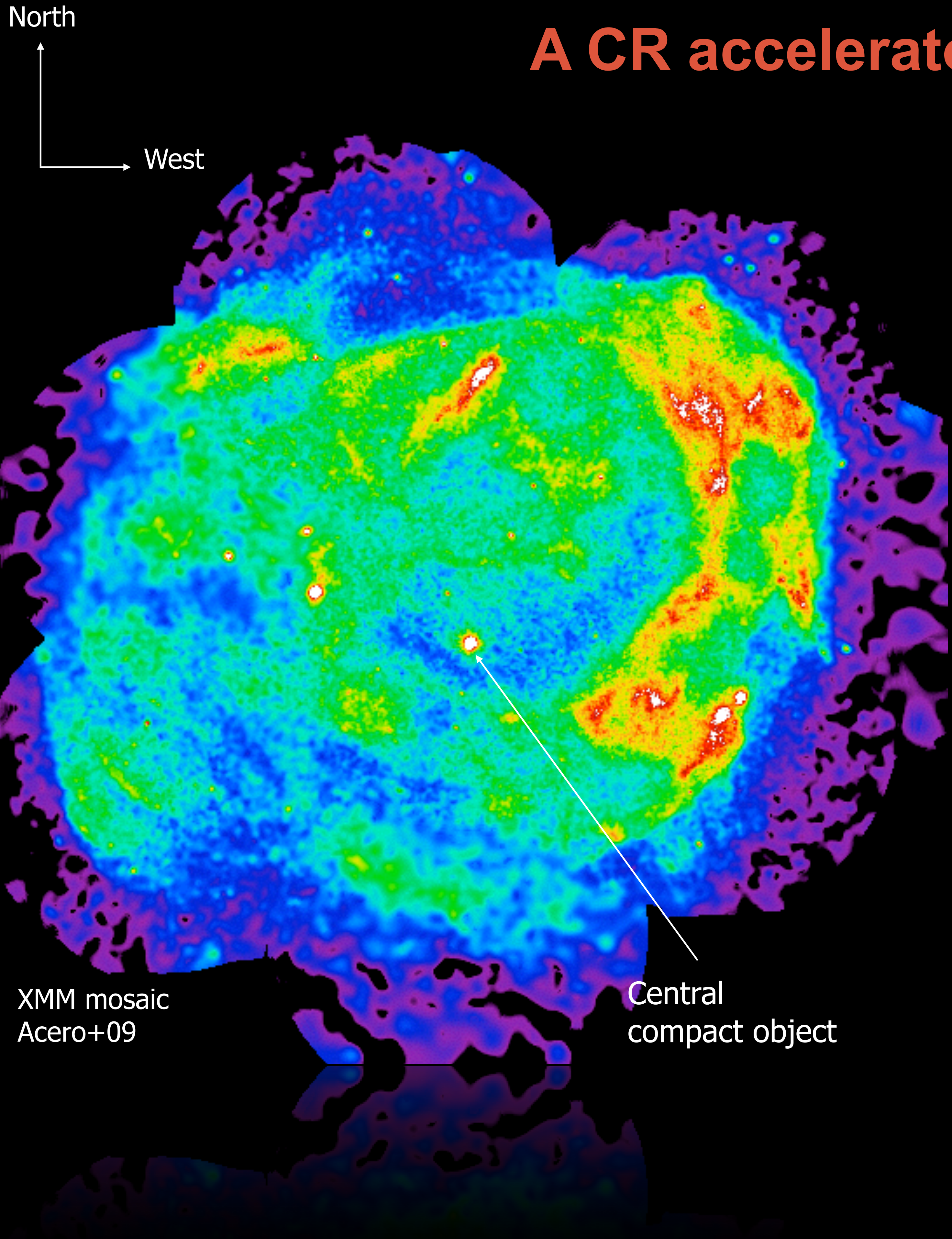
Thermal X-rays & proper motion in RX J1713.7-3946

F. Acero[1], S. Katsuda[2], J. Ballet[1], R. Petre[3]
[1]AIM/CEA-Saclay
[2]Chuo Univ. Tokyo
[3]NASA/GSFC



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}

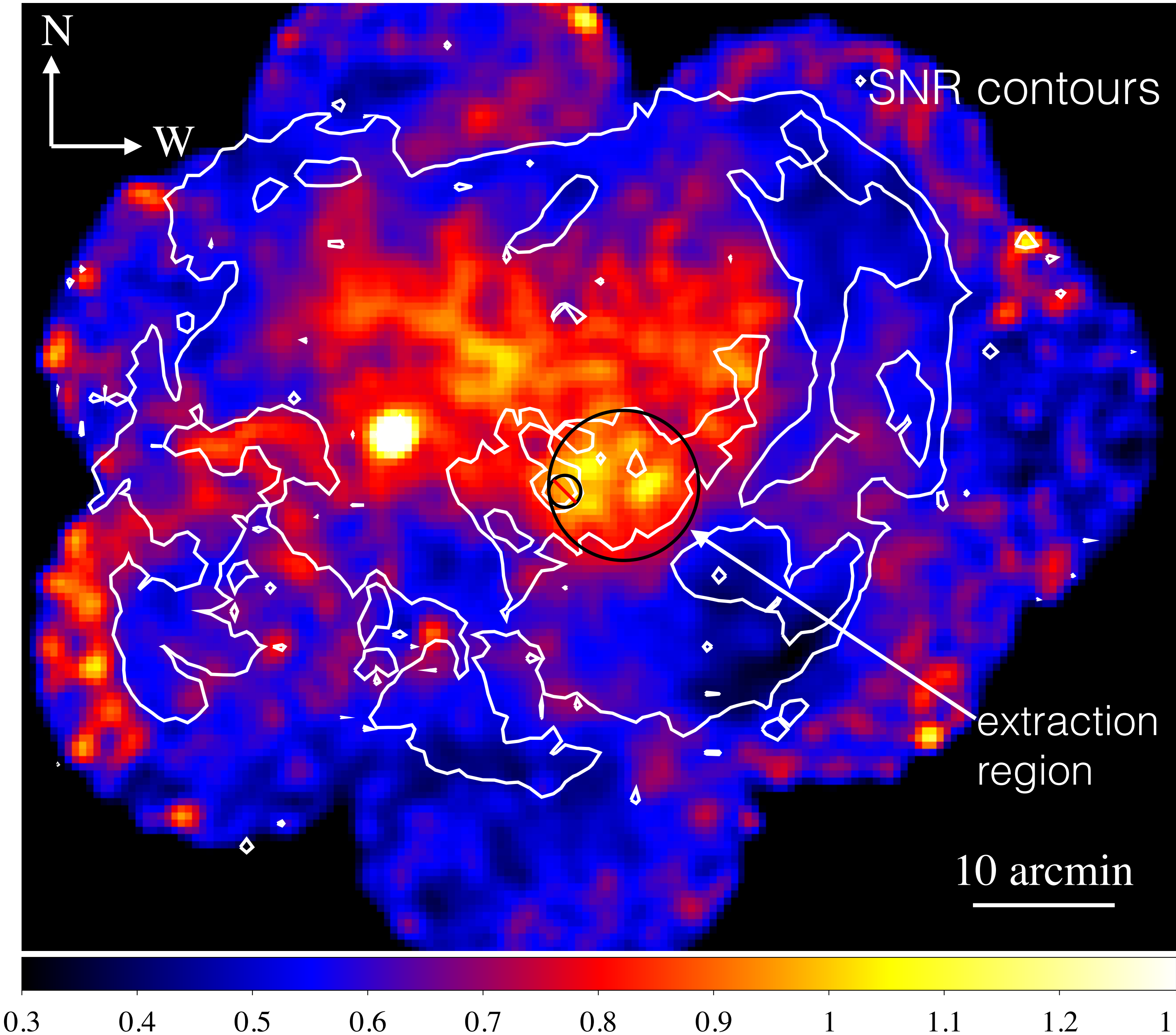
proper motion → Hα

proper motion → X-rays motion

Thermal X-rays

Why can we detect thermal X-rays today

- **Optimize where to look: lowest absorption 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**
- **Softness map indicates low N_H and/or thermal contribution**

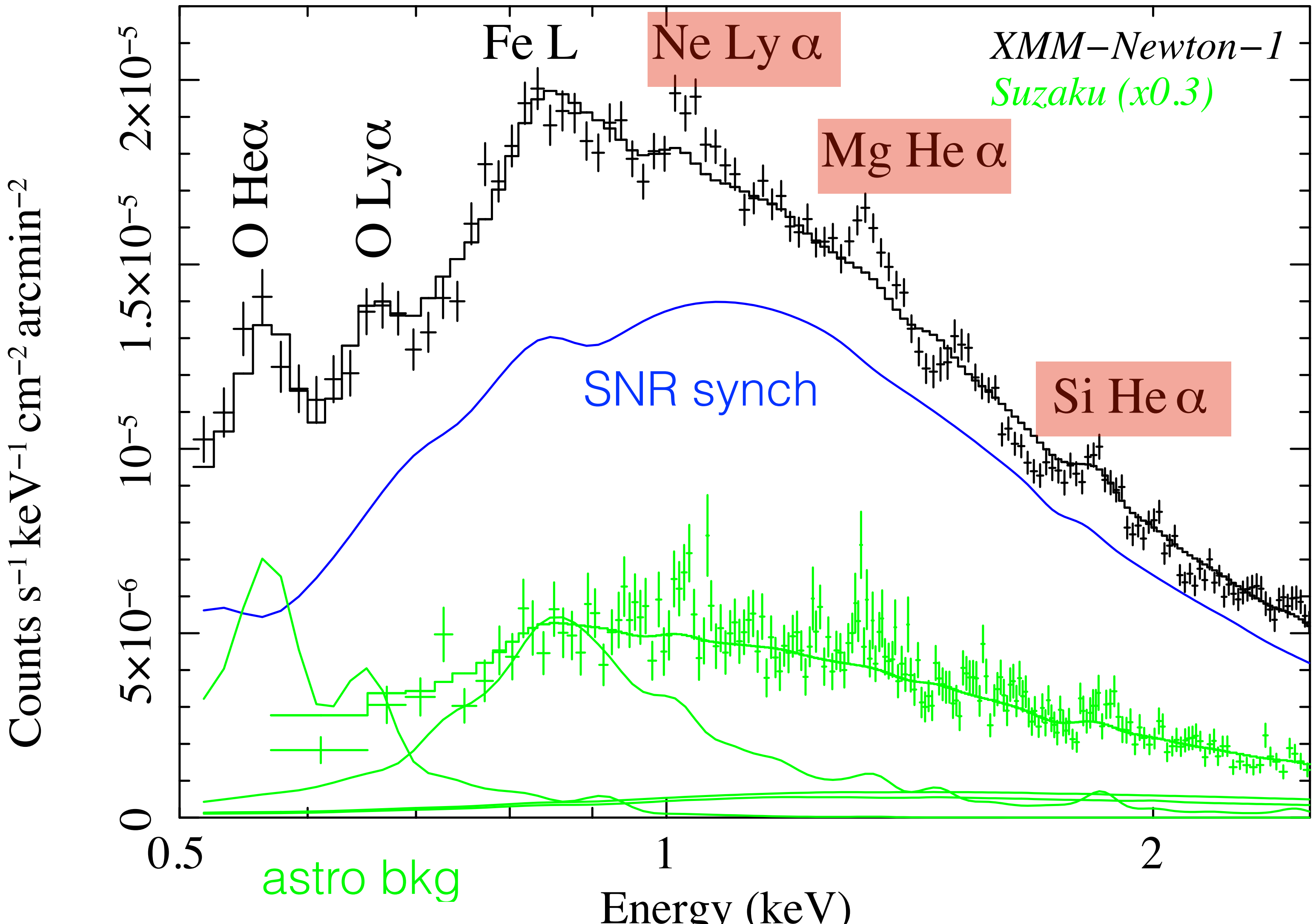


Softness map = 0.5-1.5/1.5-8 keV

Katsuda+15

Pure power-law model

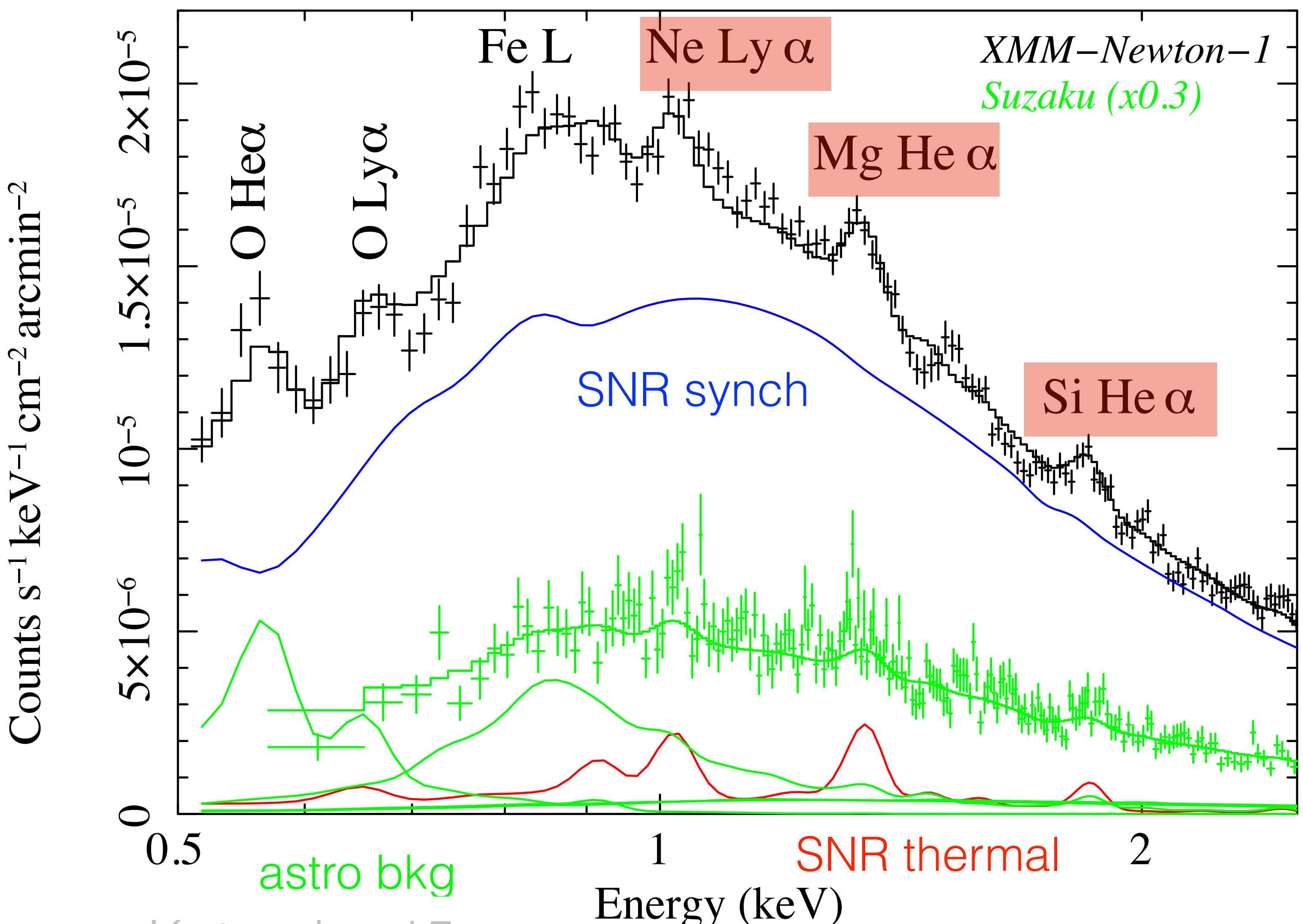
Model A (OFF1) in linear scale



Katsuda+15

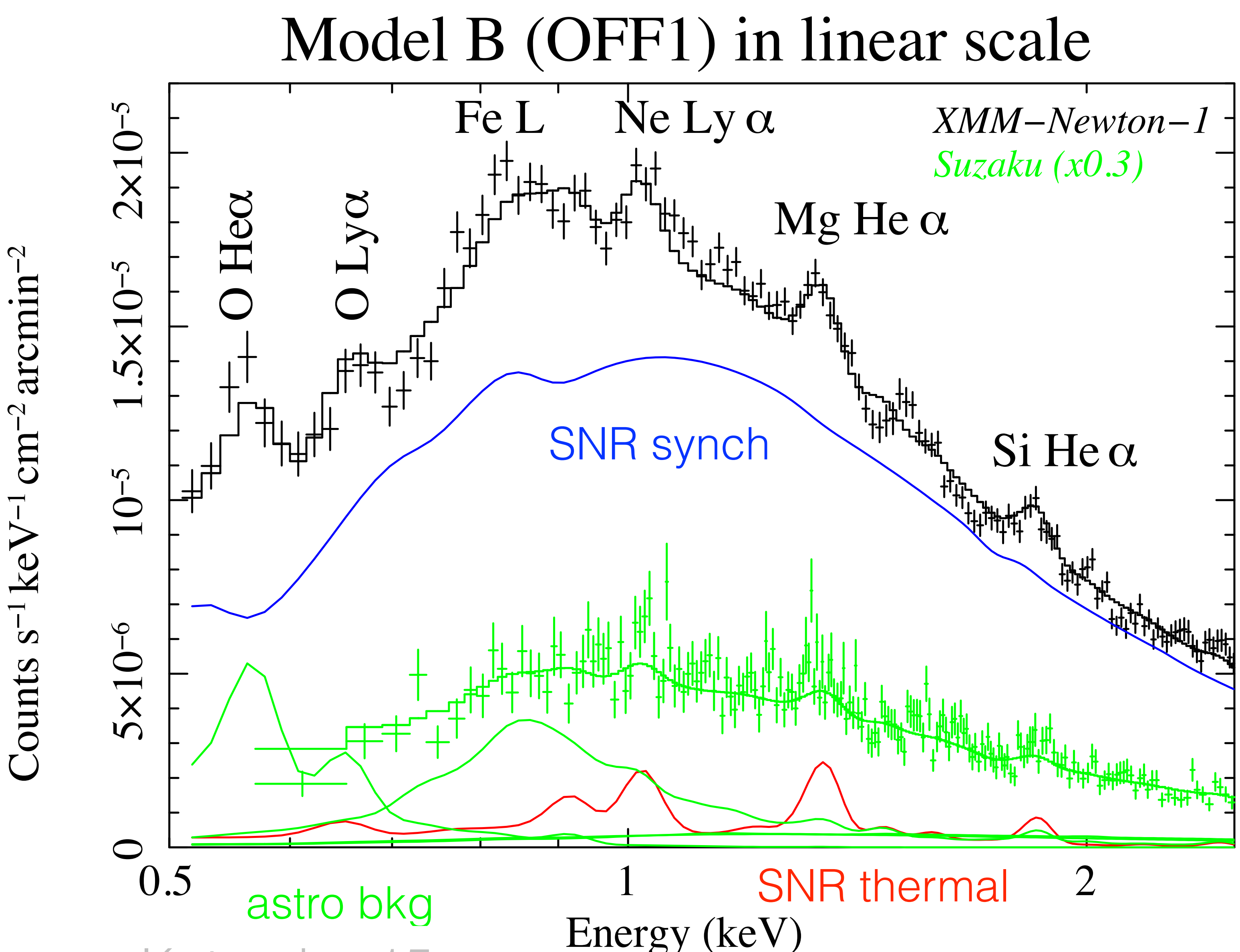
Power-law model + thermal

Model B (OFF1) in linear scale



Katsuda+15

Power-law model + thermal



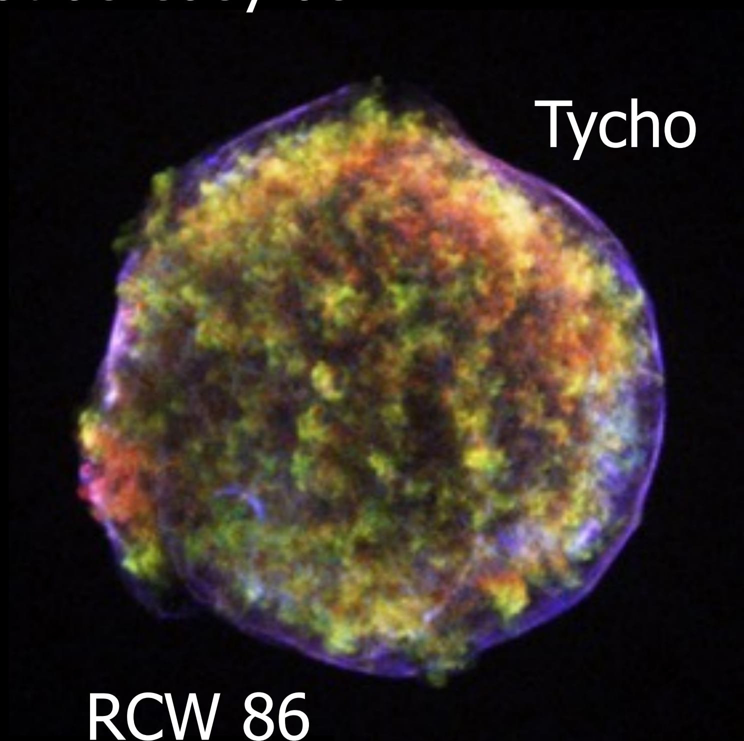
Katsuda+15

	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**

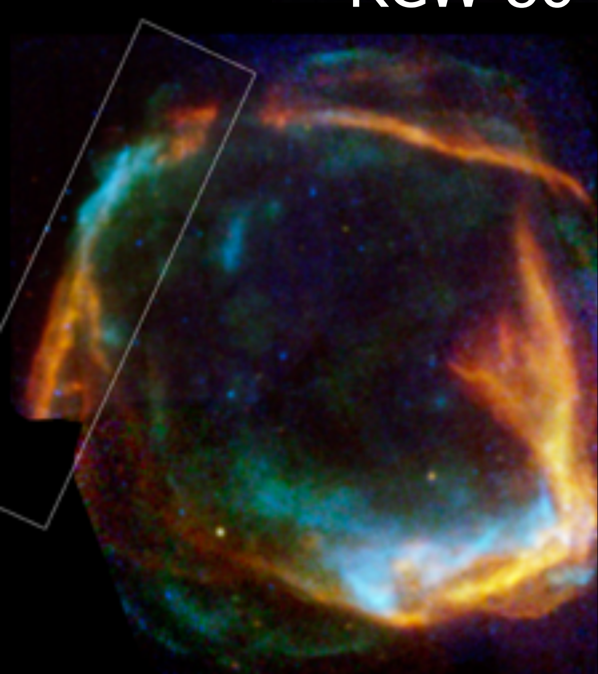
How to constrain ambient medium: Filament proper motion

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

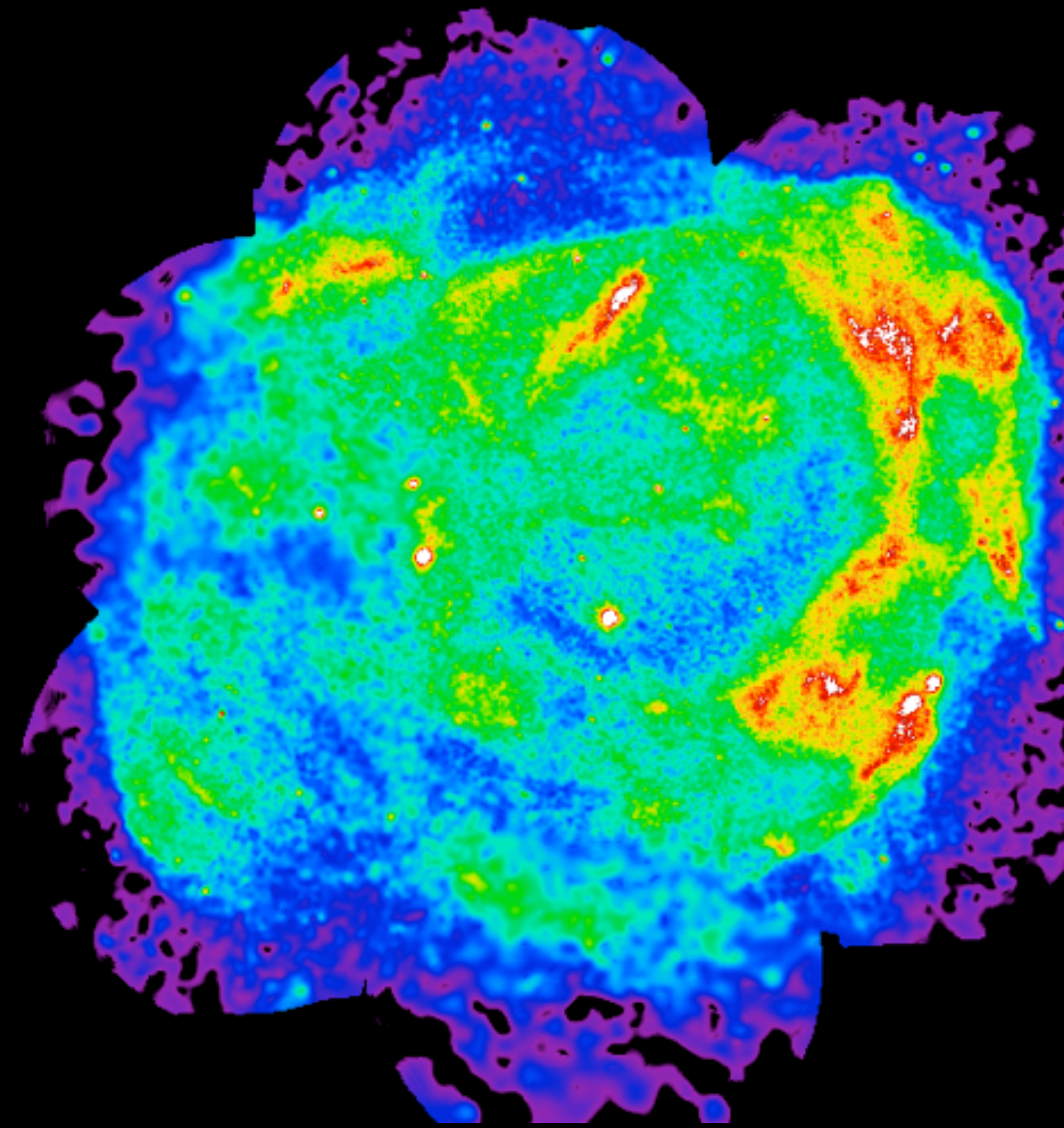


Tycho

RCW 86



SN 1006



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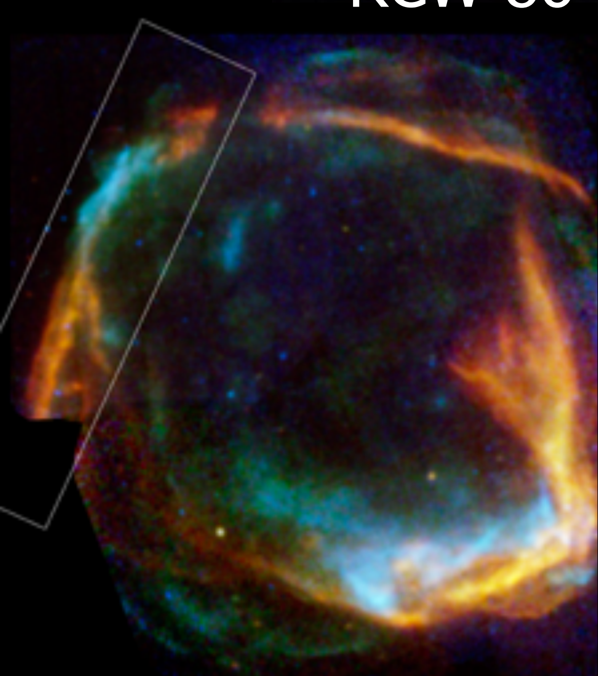
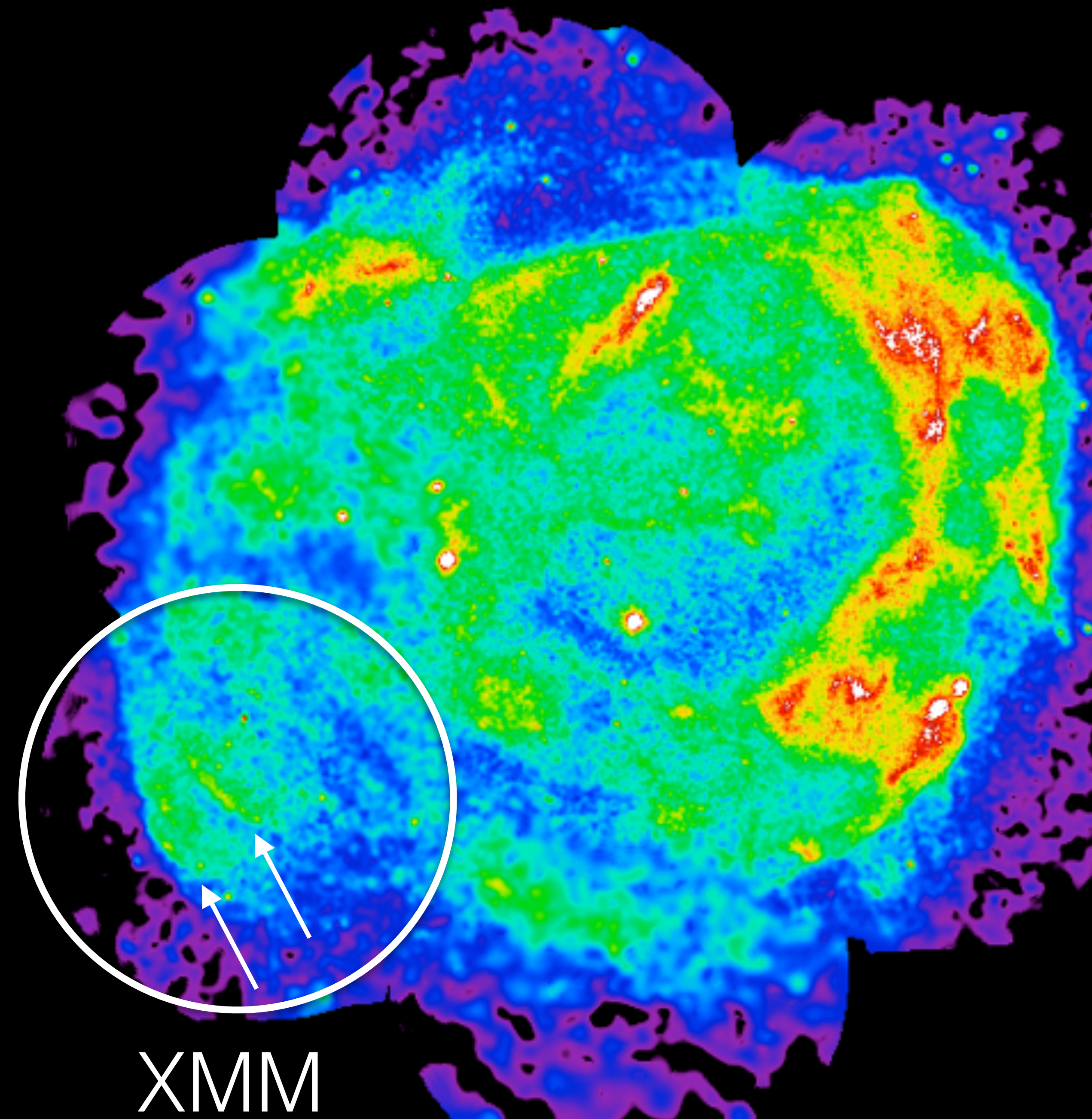


SN 1006

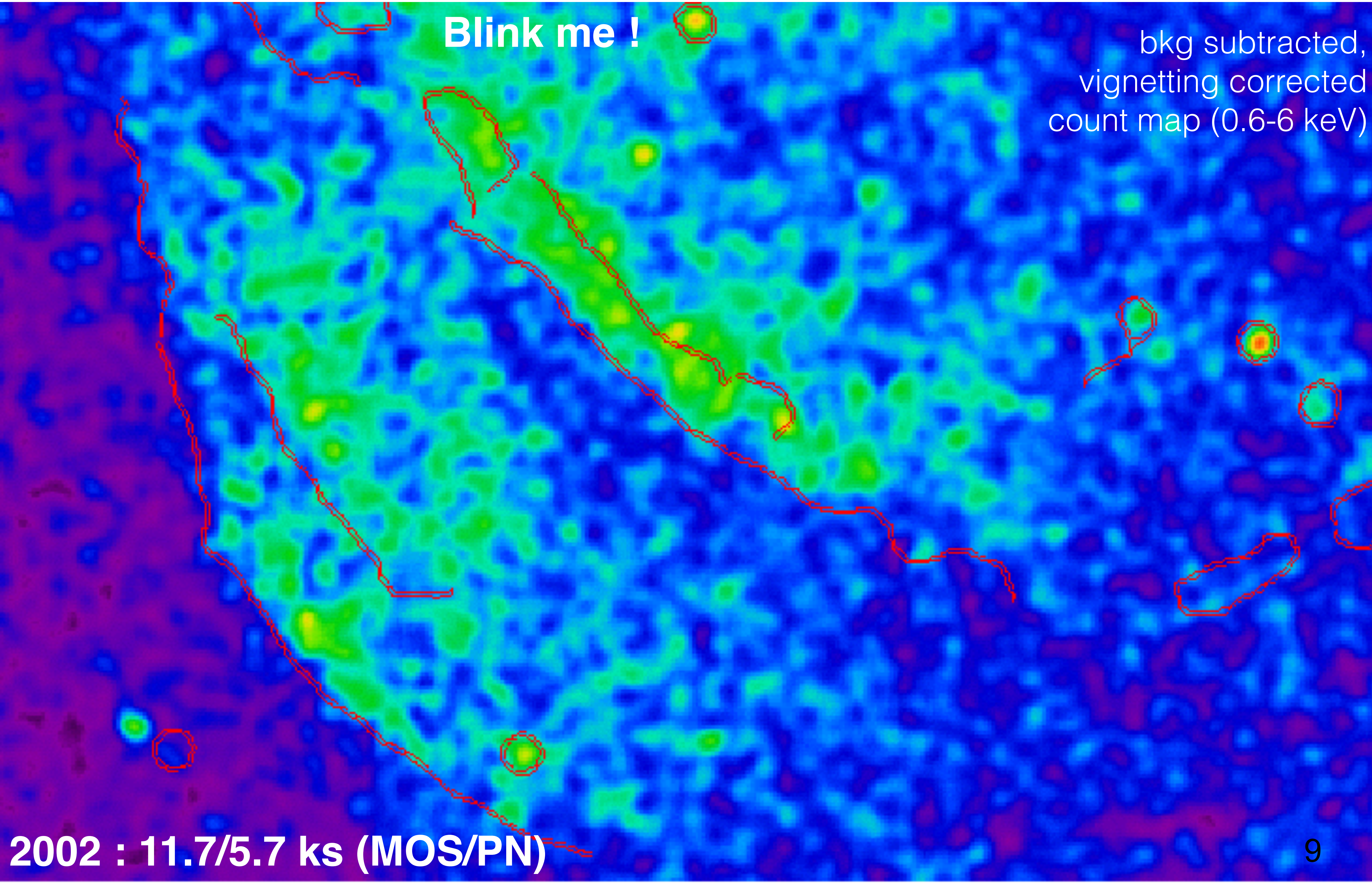


XMM

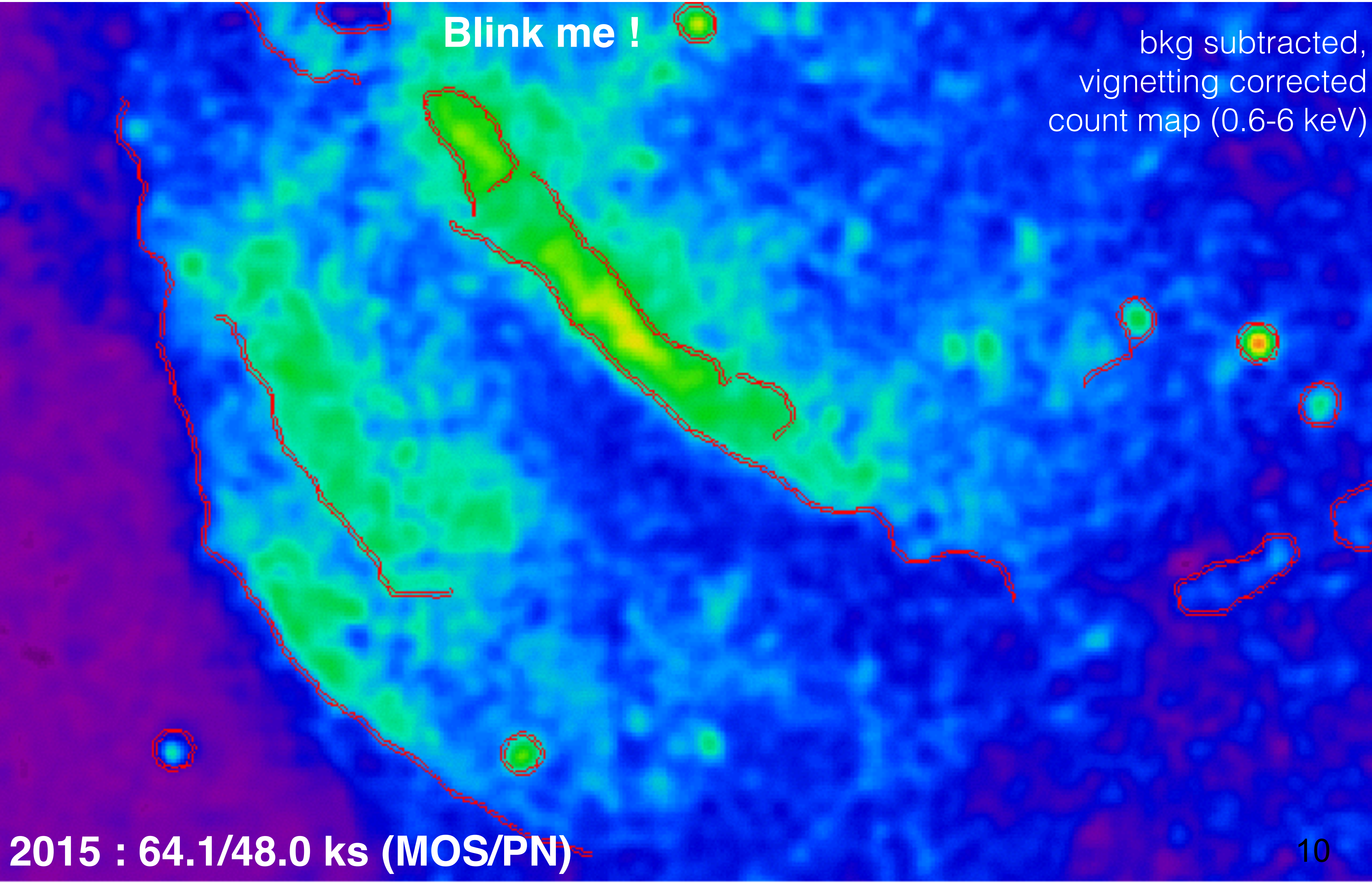
2002: 11 ks

2015: 64 ks

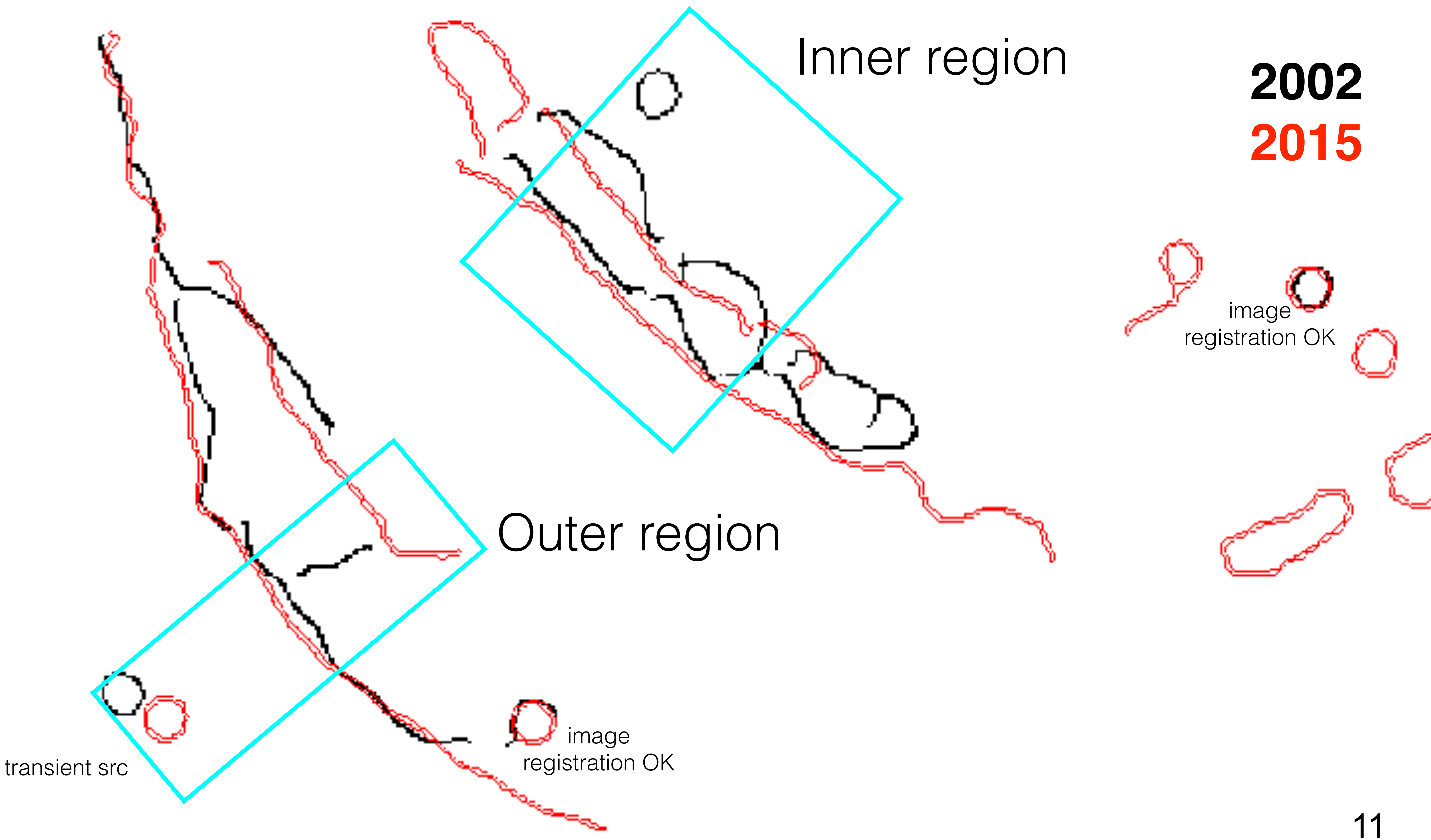
X-ray proper motion in the SE



X-ray proper motion in the SE



Edges detection for region definition



Method

- **Using a maximum likelihood function as estimator:**
  - **not using chi2 as for some bins Cts<25**
  - **Computes the max Likelihood estimator Cash statistics (Cstat)**

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

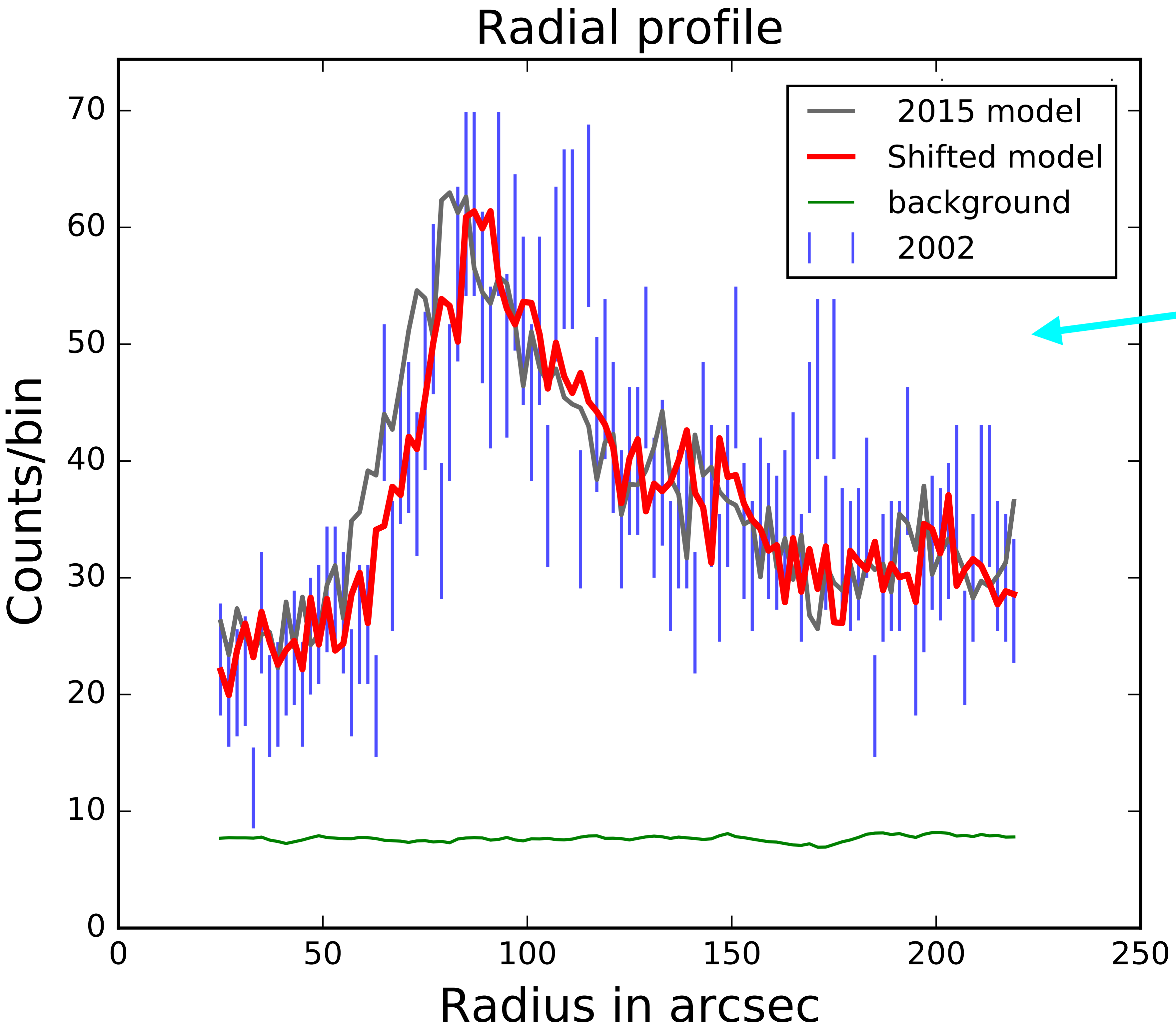
- **where S_i are the observed counts and M_i the predicted counts**

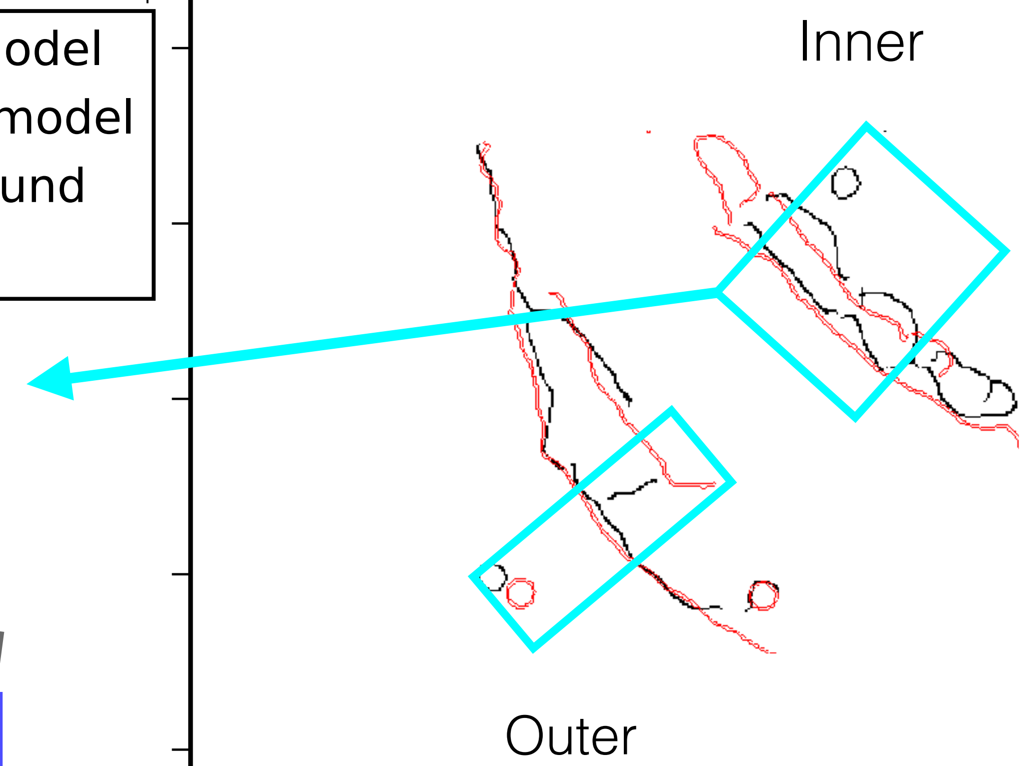
- **Our study: S_i is the 2002 profile and M_i a model predicting counts based on the 2015 obs**

- **As the 2015 exposure is much deeper, using this observation to produce a model**

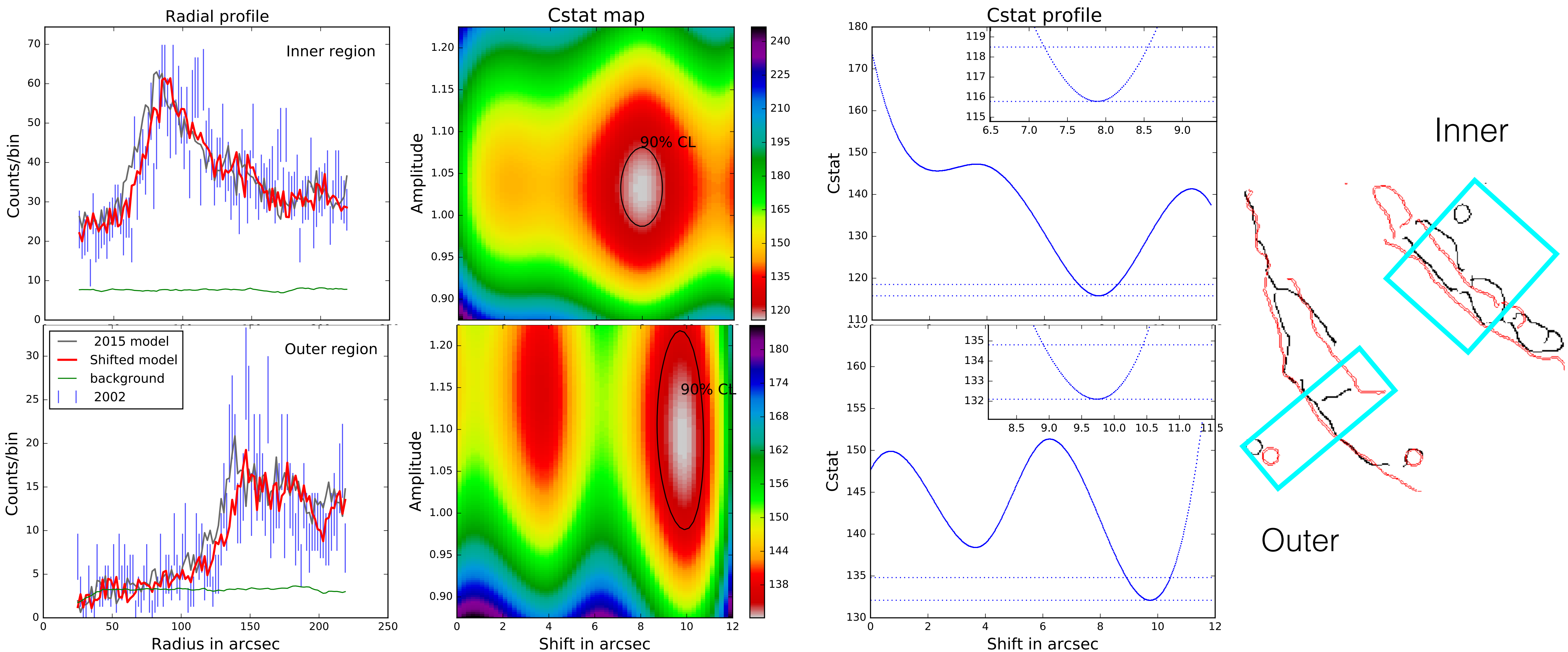
$$M = (Shift(\underbrace{F_{src}^{mod}}_{2015}) * Amp + F_{cst}) * \underbrace{Exp^{obs}}_{2002} + \underbrace{C_{bkg}^{obs}}_{2002}$$

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

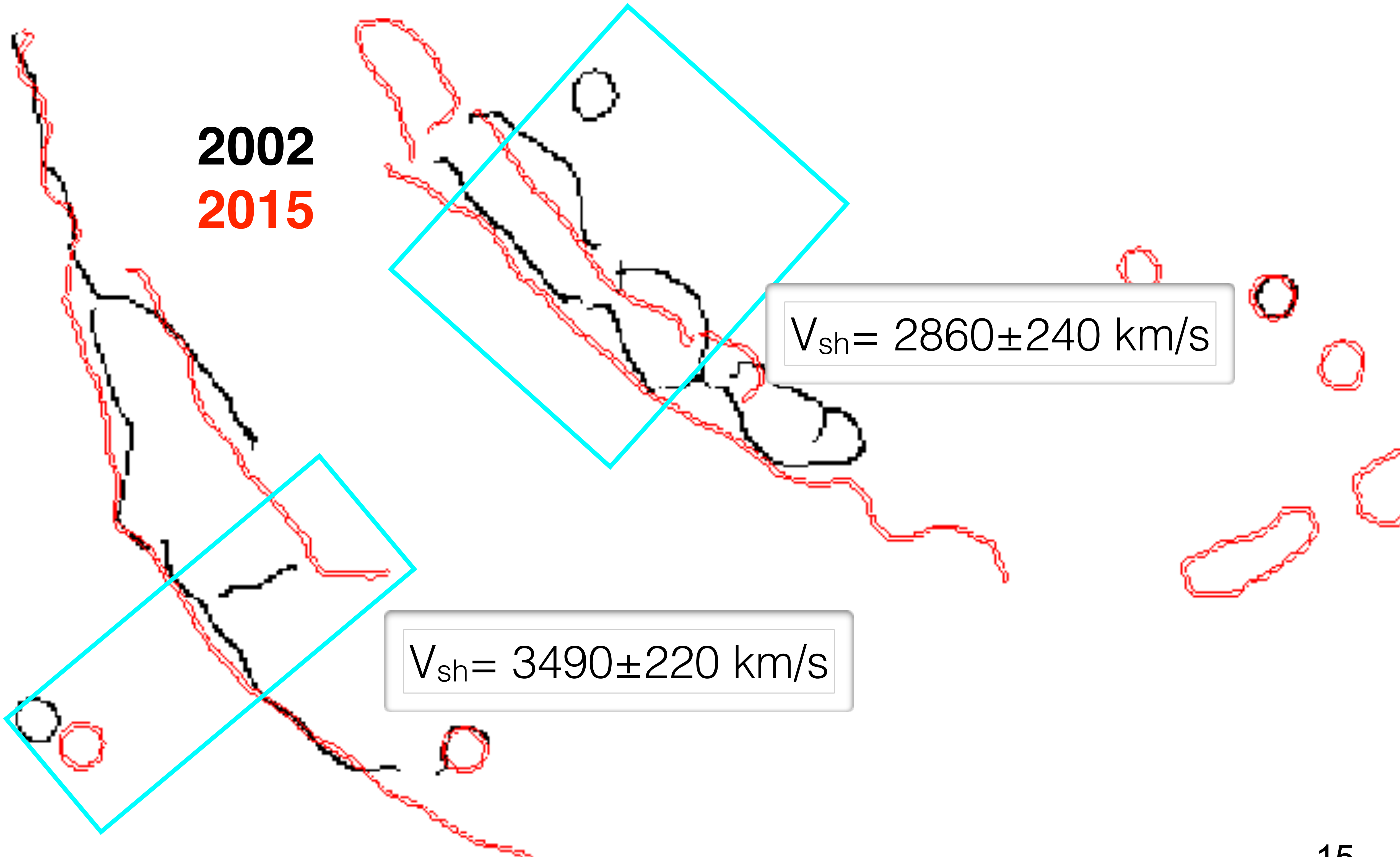


No fitting procedure but computing the Cstat for each point of the grid in the Shift-Amplitude space

Computing Cstat for integer values of Shift and then interpolating

Asymmetric uncertainties derived from likelihood profile (right panel)

Results



SNR age

- **Simple evolution solution:**

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

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

  - $0.86 > m > 0.66$
  ejecta phase **Sedov phase**

  - $2330 \text{ yrs} > T_{snr} > 1810 \text{ yrs}$

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

Age and density

- Using evolution equations* for given θ, $\dot{\theta}$:
  - Age and ρ_0 = f(M_{ejecta}, E_{SN}, distance)

- In a stellar wind and shock near the border of the cavity:

Star **Supernova remnant**

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

14 M_o $M_{swept\text{-}up}$ 1.4 M_o M_{ej}

$= f(\rho_0)$

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

* TrueLove&McKee + Hwang&Laming

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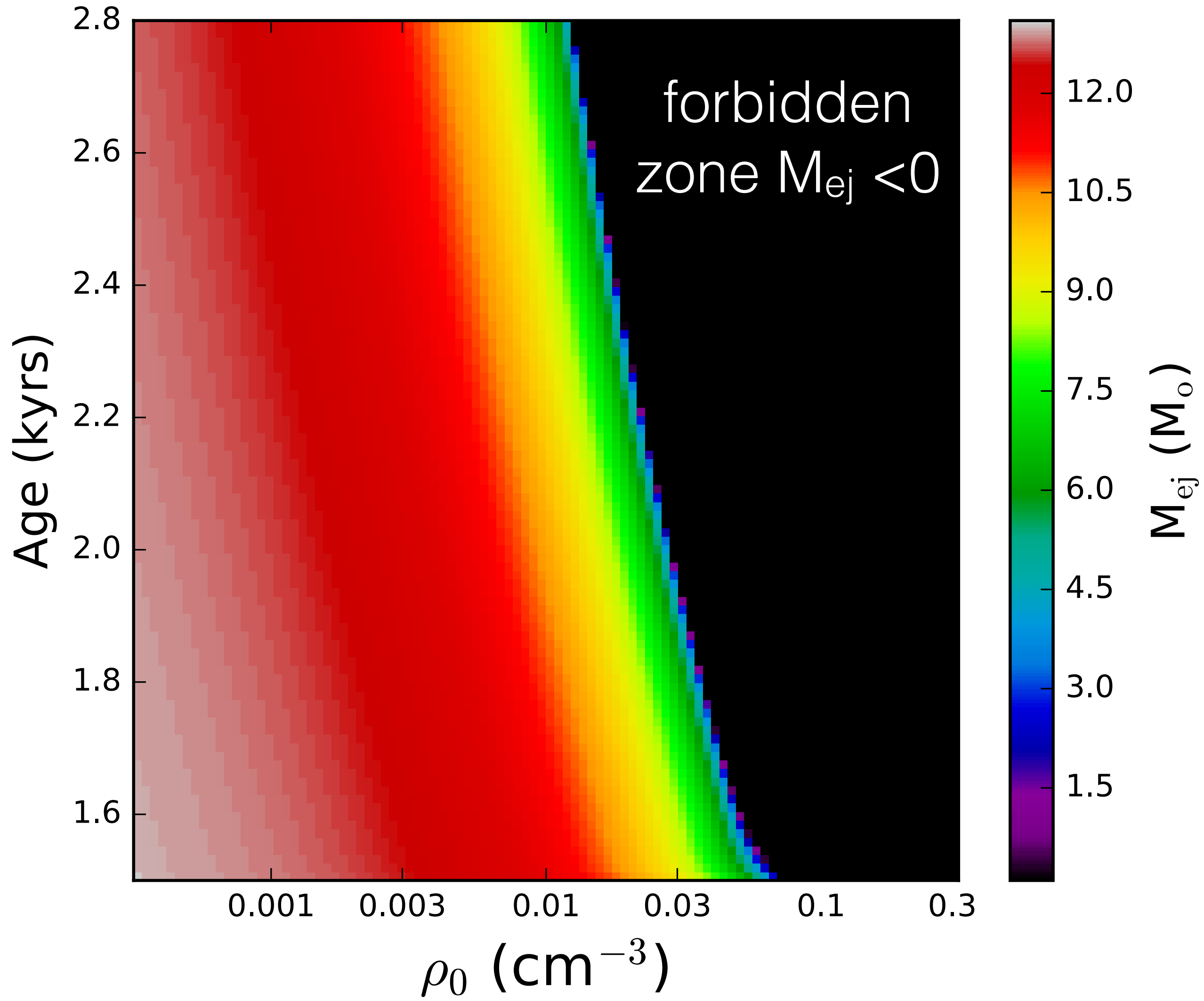

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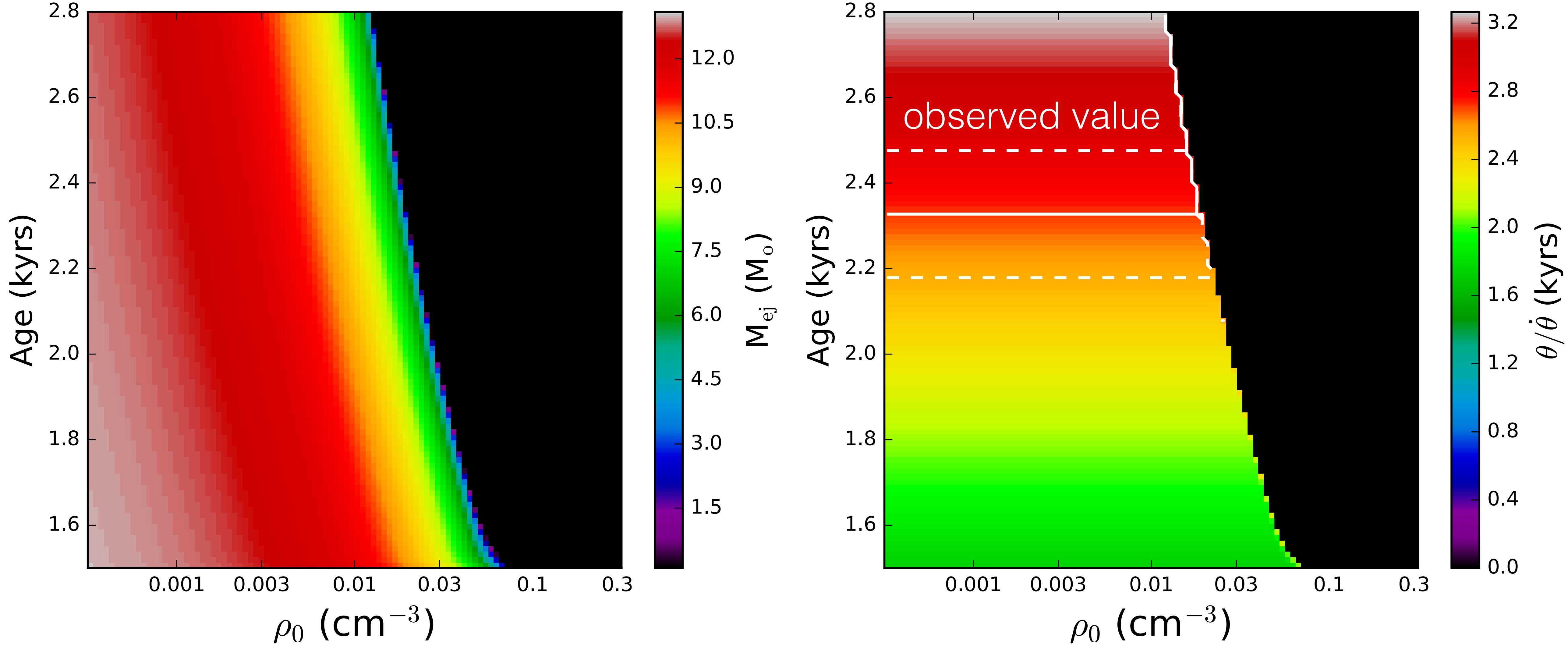
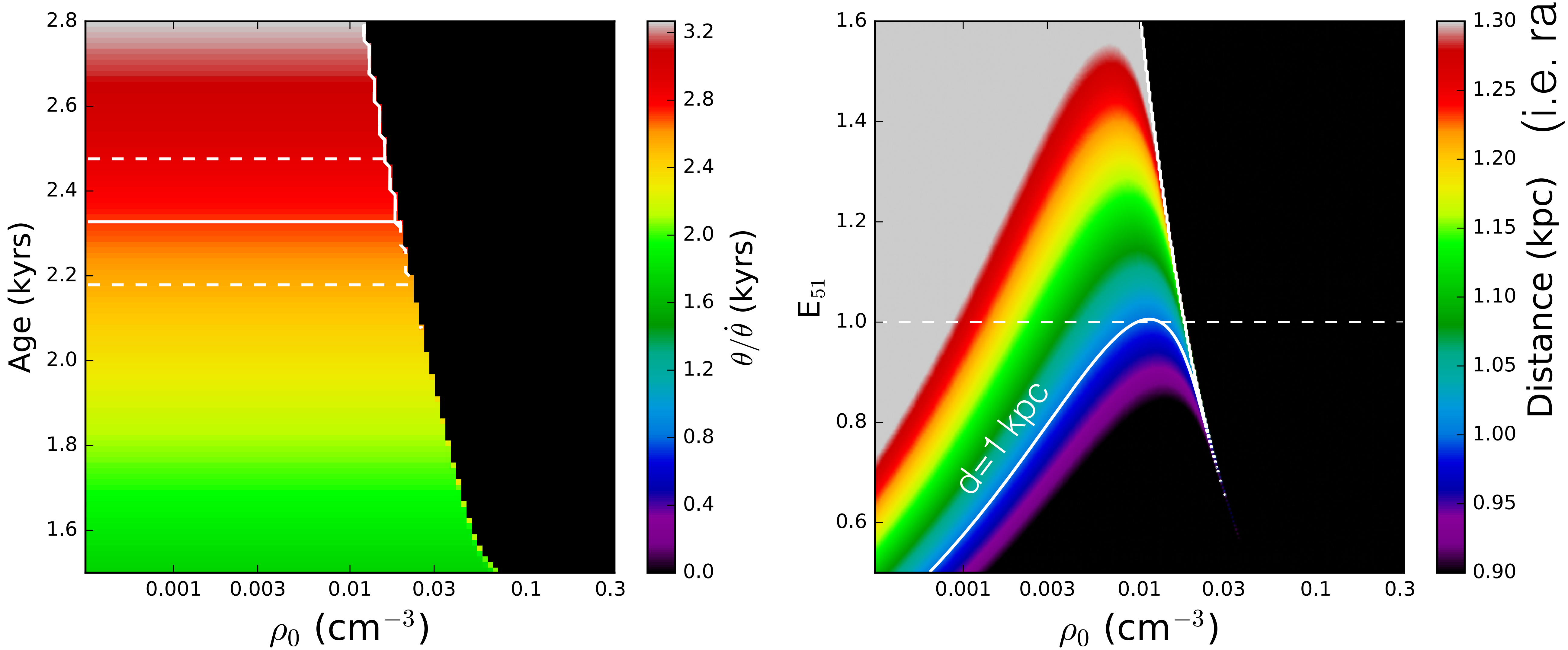
Age and density



- With M_{ej} prescription, can compute predicted $\theta/\dot{\theta}$ in evolution model
- For the range of allowed wind density, SNR is still in ejecta phase:
  - 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**

Conclusions

Don't know:

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

First thermal X-rays

Ejecta emission
$M_{progenitor} < 20 M_o$

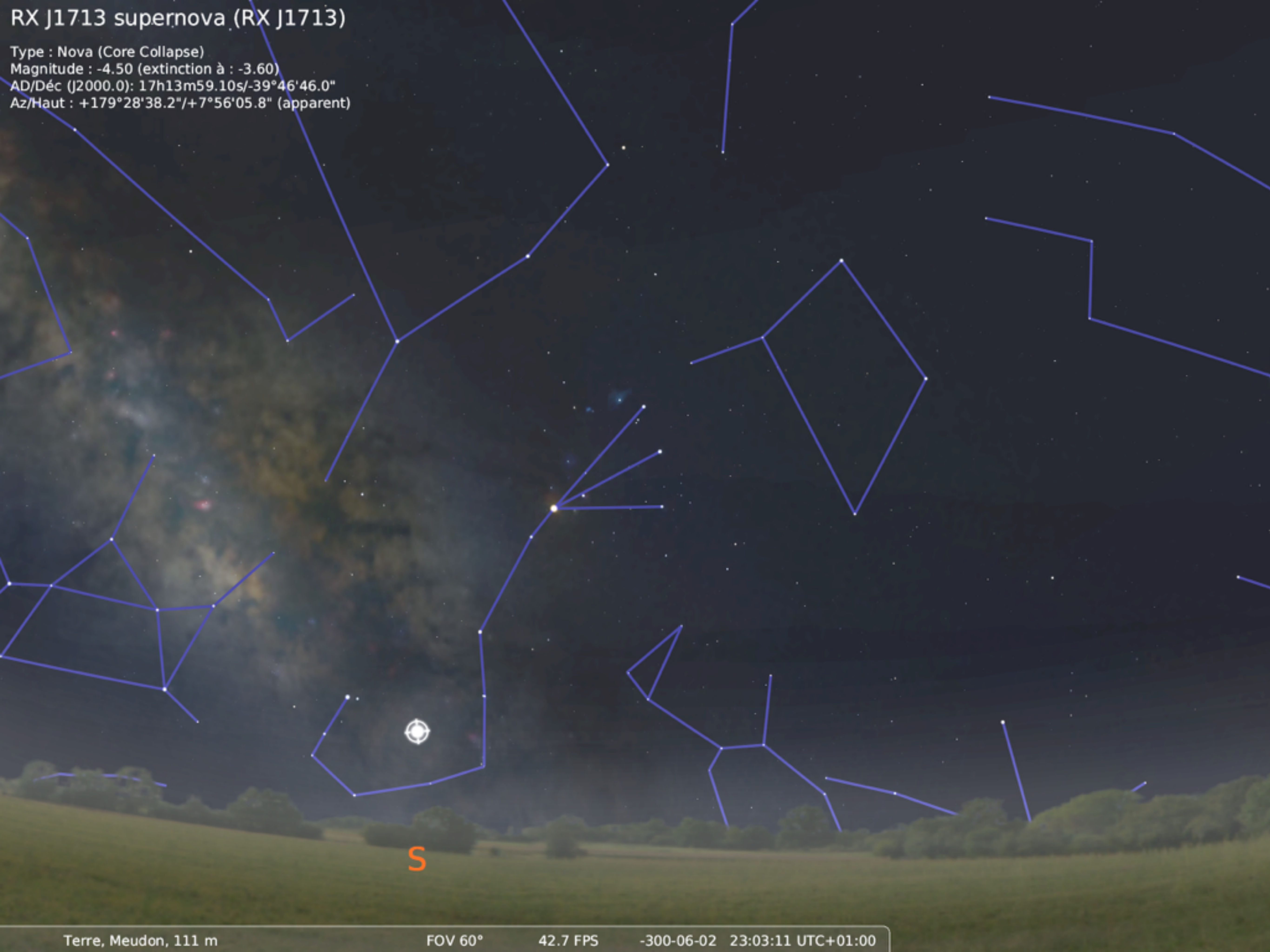
First shock speed ~ 3500 km/s

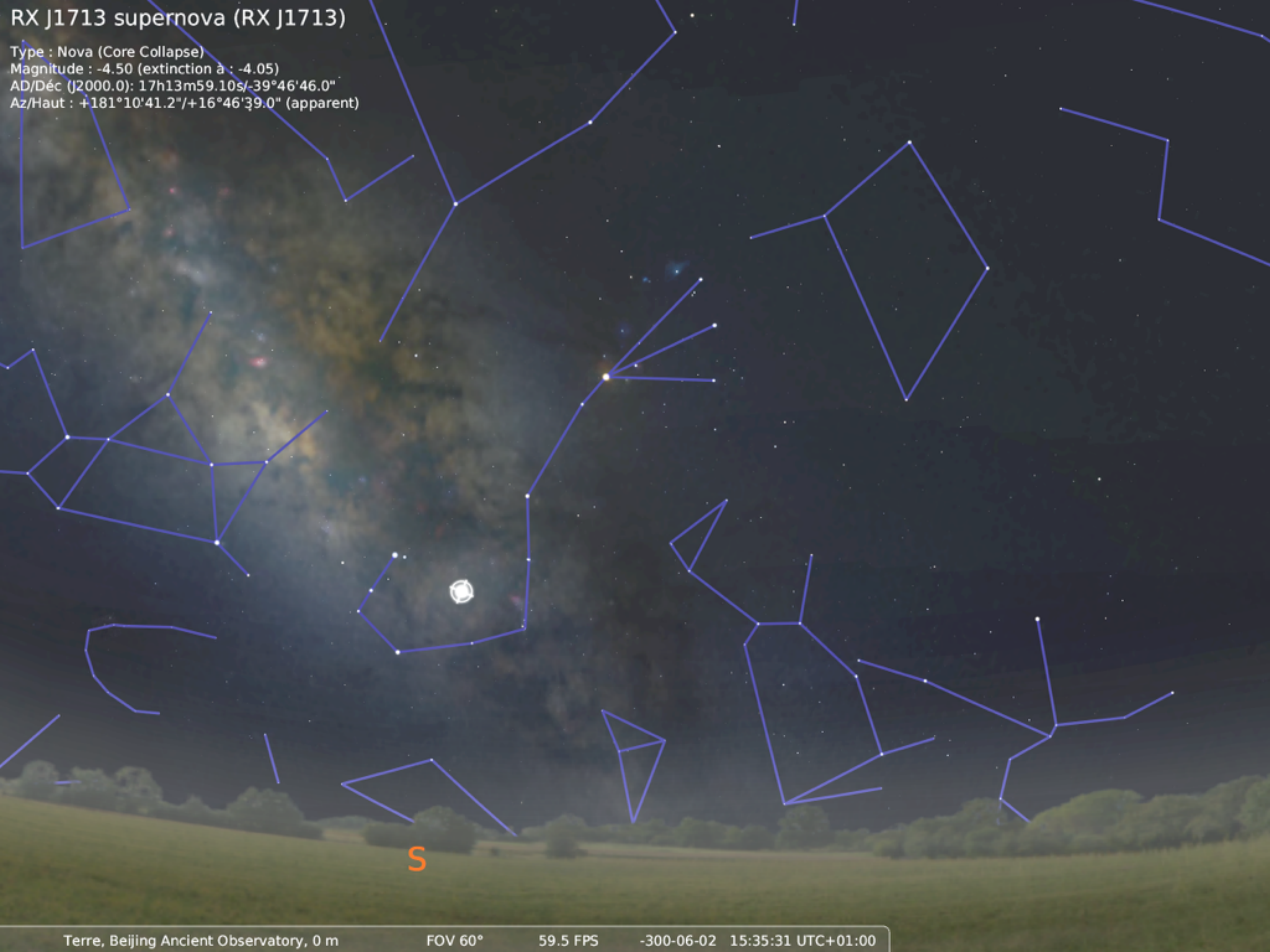
Age ~2300 ±150 yrs
(not SN 393)

very low cavity density
$\rho_0 = 10^{-2}$ cm^{-3}

Caveats :

not the density in the bright NW region


RX J1713 supernova (RX J1713)
Type : Nova (Core Collapse)
Magnitude : -4.50 (extinction à : -3.60)
AD/Déc (J2000.0): 17h13m59.10s/-39°46'46.0"
Az/Haut : +179°28'38.2"/+7°56'05.8" (apparent)
S
Terre, Meudon, 111 m
FOV 60°
42.7 FPS
-300-06-02 23:03:11 UTC+01:00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AD/Déc (J2000.0): 17h13m59.10s/-39°46'46.0"
Az/Haut : +181°10'41.2"/+16°46'39.0" (apparent)
S
Terre, Beijing Ancient Observatory, 0 m
FOV 60°
59.5 FPS
-300-06-02 15:35:31 UTC+01:00