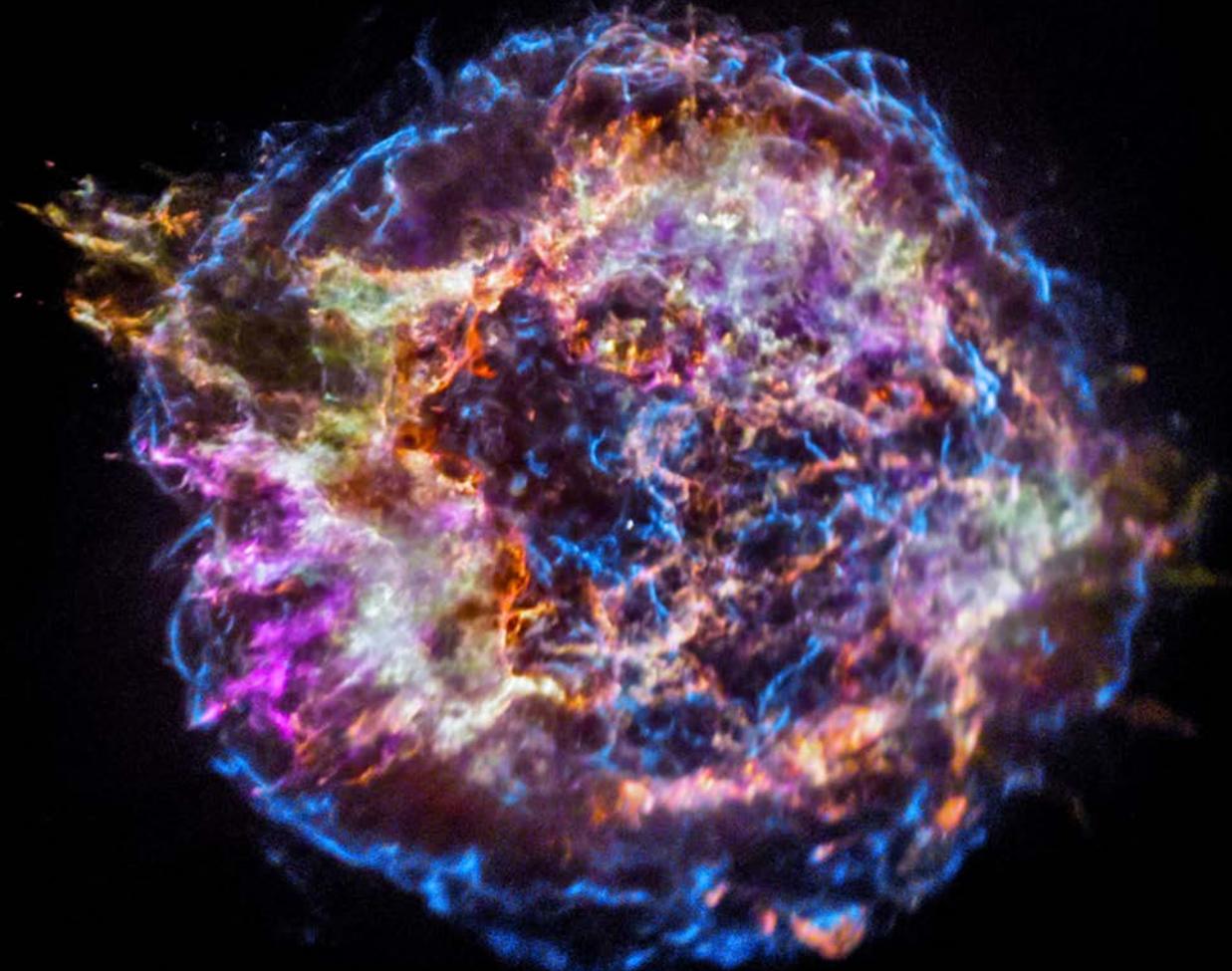


# THE EXPANSION AND WIDTH OF THE SYNCHROTRON FILAMENTS ASSOCIATED WITH THE FORWARD SHOCK OF CAS A



snr ii - an odyssey in space after stellar death – 2019  
daniel castro (cfa)

# COLLABORATORS

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jacco vink (uva)

pat slane (cfa)

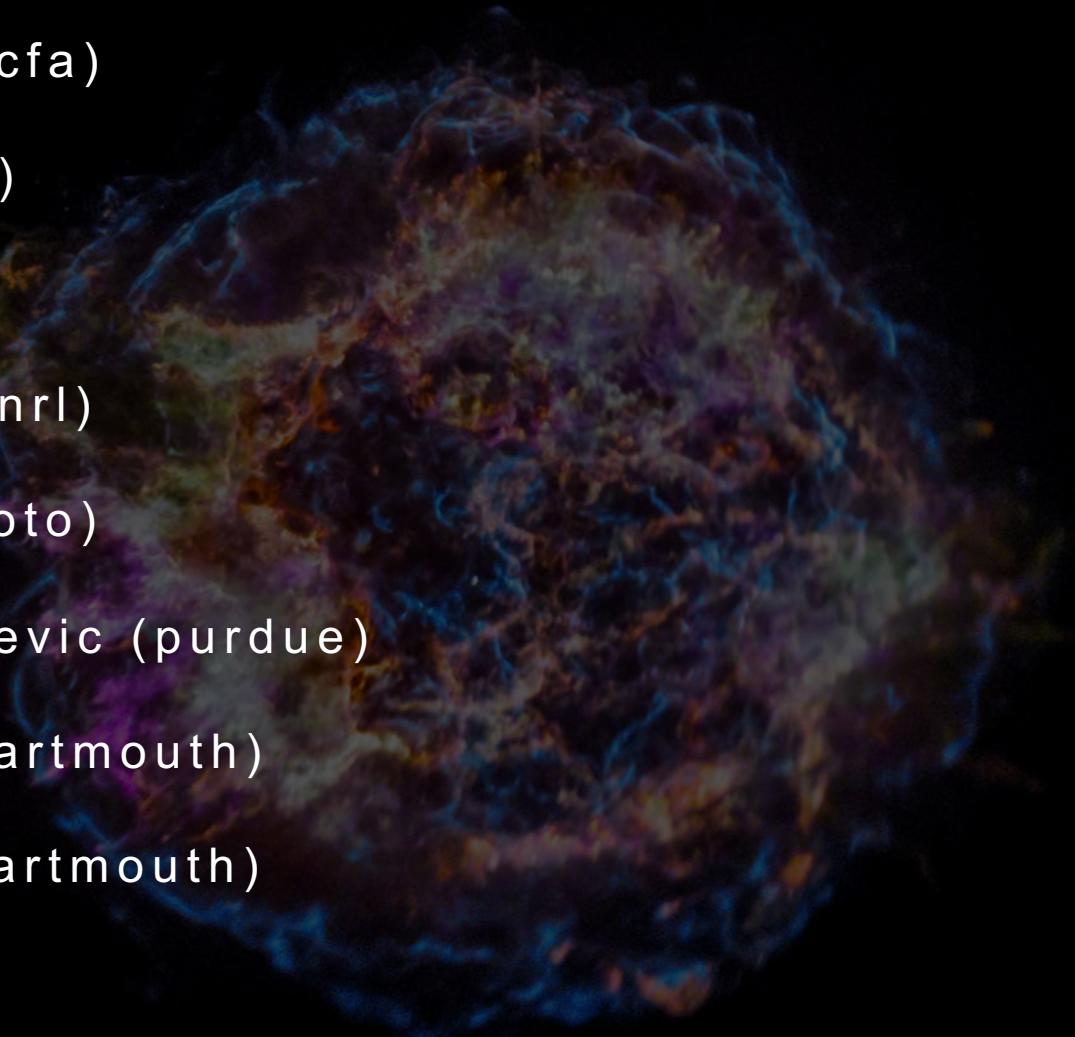
martin laming (nrl)

herman lee (kyoto)

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# OUTLINE

why should you care about the connection between SNRs and cosmic rays?

what evidence is there that SNRs accelerate cosmic rays?

what can we learn from a multiyear study of cas a with chandra?

# WHY?

origin

$\gamma$ -ray background

particle acceleration

snr evolution

cr feedback



# EVIDENCE

shock structure

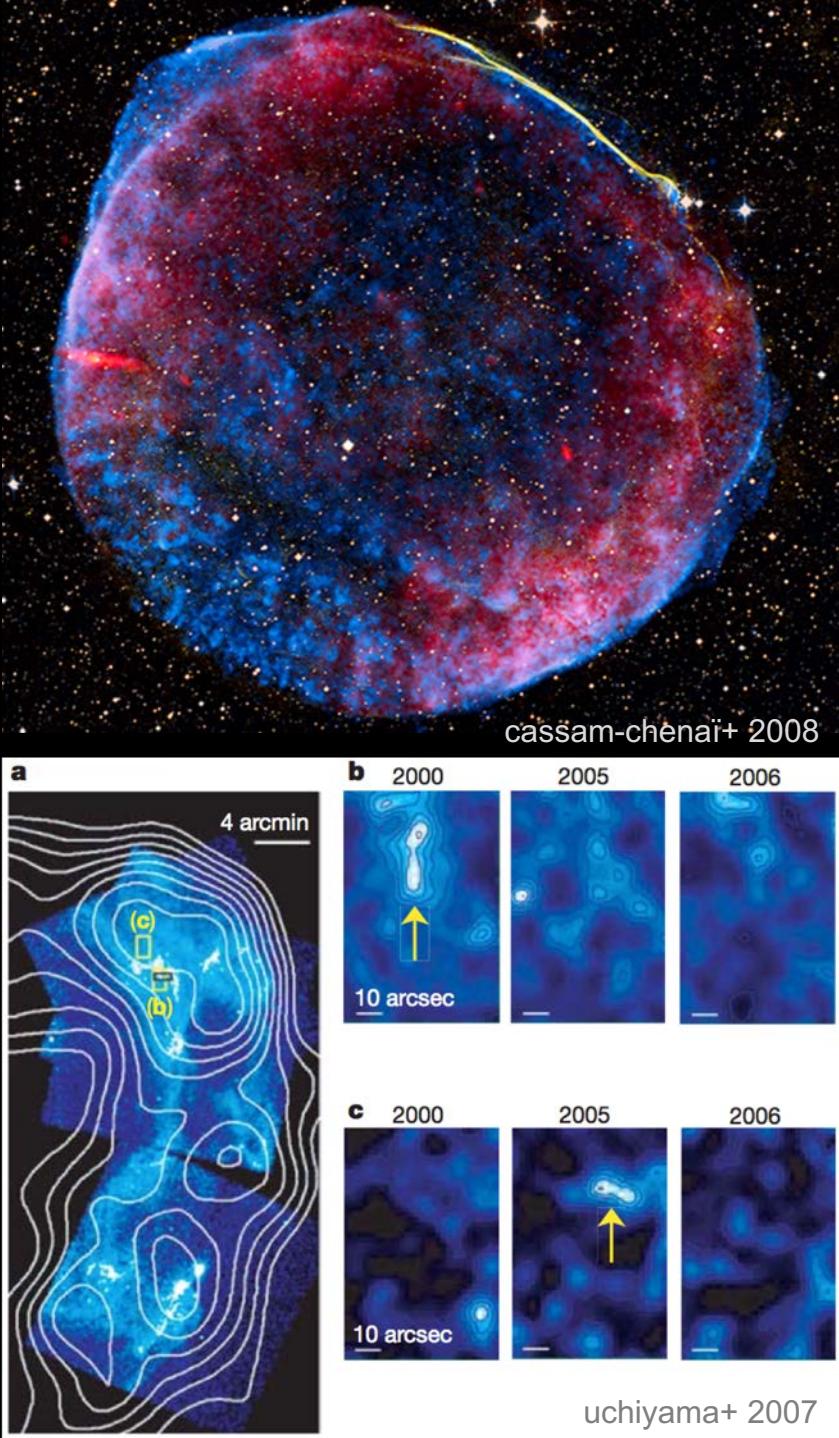
non-thermal x-rays

- synchrotron emission
- mfa

$\gamma$ -ray emission

leptonic vs hadronic

$$t_{\text{sync}} \sim 1.5 \left( \frac{B}{\text{mG}} \right)^{-1.5} \left( \frac{\epsilon}{\text{keV}} \right)^{-0.5} \text{ year}$$



# CAS A – NONTHERMAL RIMS

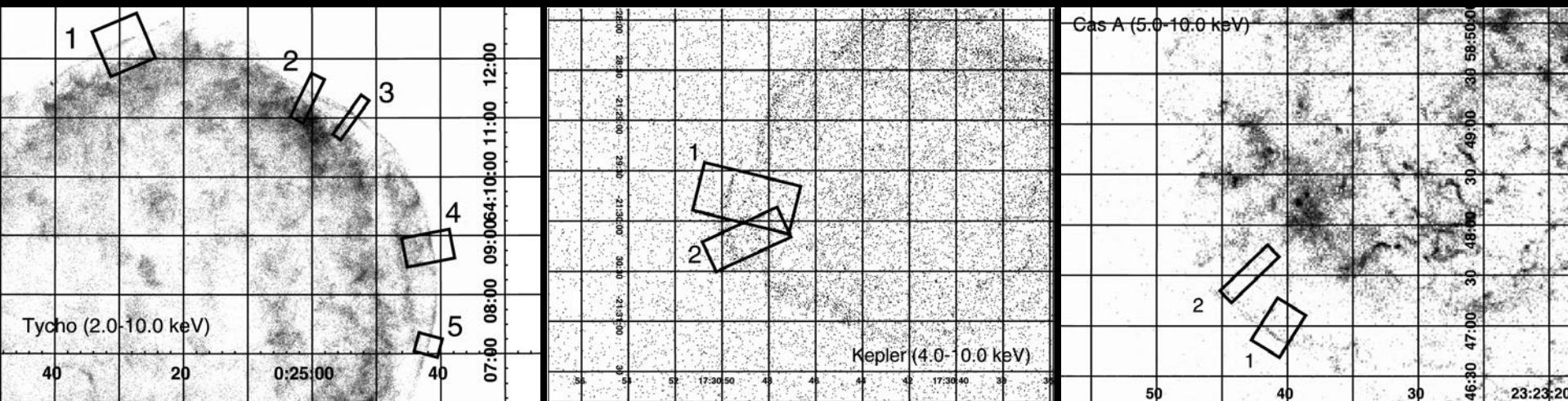
motivation for this work

study the connection between shock characteristics and particle acceleration

# CAS A - NONTHERMAL RIMS

magnetic field amplification - evidence

- rapid variability of nonthermal x-ray emission from bright filaments in SNRs
- thin X-ray filaments



bamba et al. 2005

# CAS A - NONTHERMAL RIMS

the data

20 years of chandra  
observations

largest total exposure -> 2004  
165 ks - pi hwang

ObsID	Year	Exposure [ks]
114	2000	50
1952	2002	50
4634		
4635		
4636		
4637		
4638	2004	165
4639		
5196		
5319		
5320		
9117		
9773	2007	50
10935		
12020	2009	46
10936		
13177	2010	49
14229	2012	49
14480	2013	49
14481	2014	49
14482	2015	49
18344		
19903	2016	50
19604	2017	50
19605	2018	49

# CAS A – NONTHERMAL RIMS

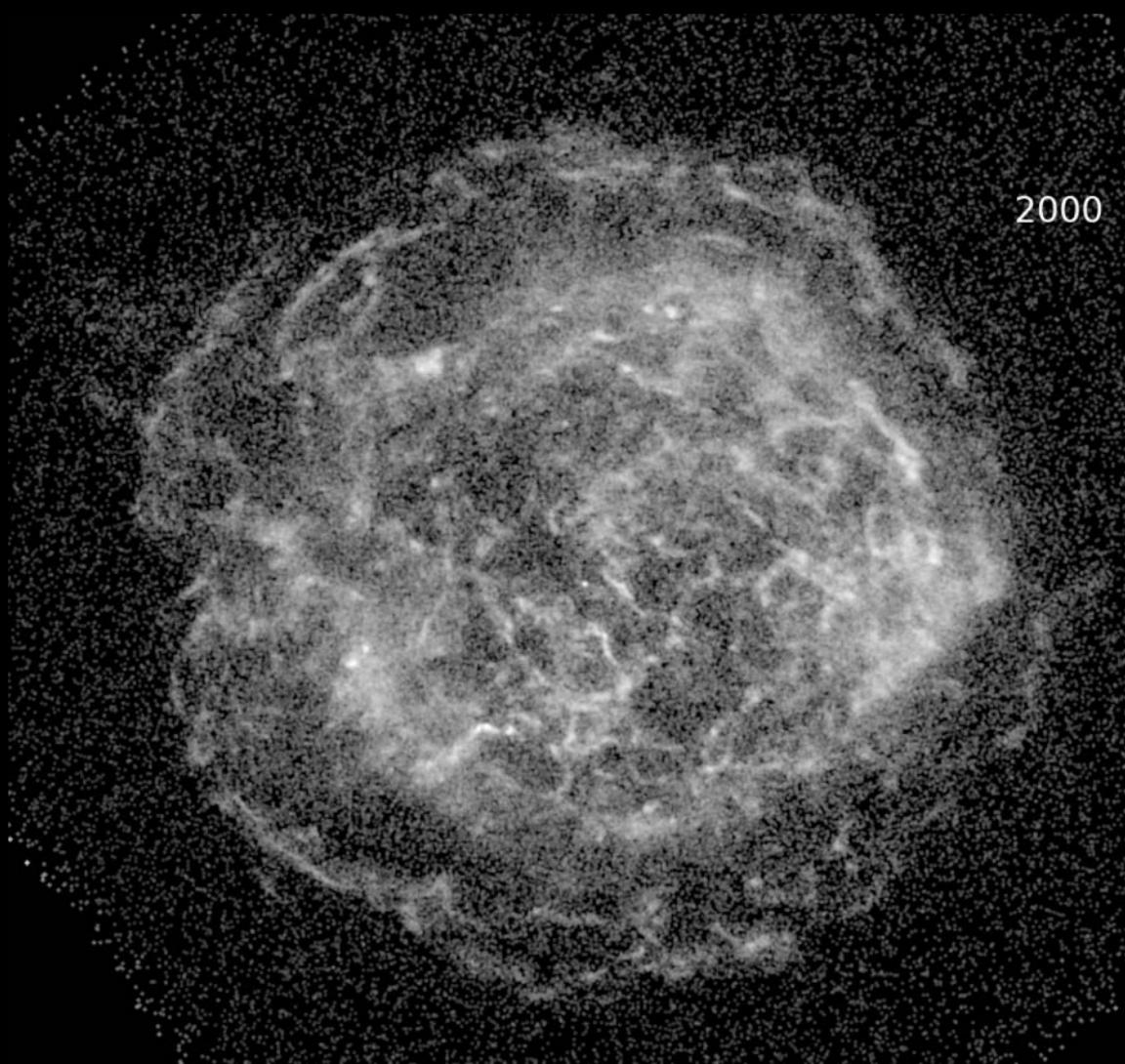
the method

energy 4.2 - 6 keV

radial profile -  
exposure corrected  
count rate  
(1 pix wide steps)

cco used for  
“registering”

analyzed 15 different  
rims



# CAS A – NONTHERMAL RIMS

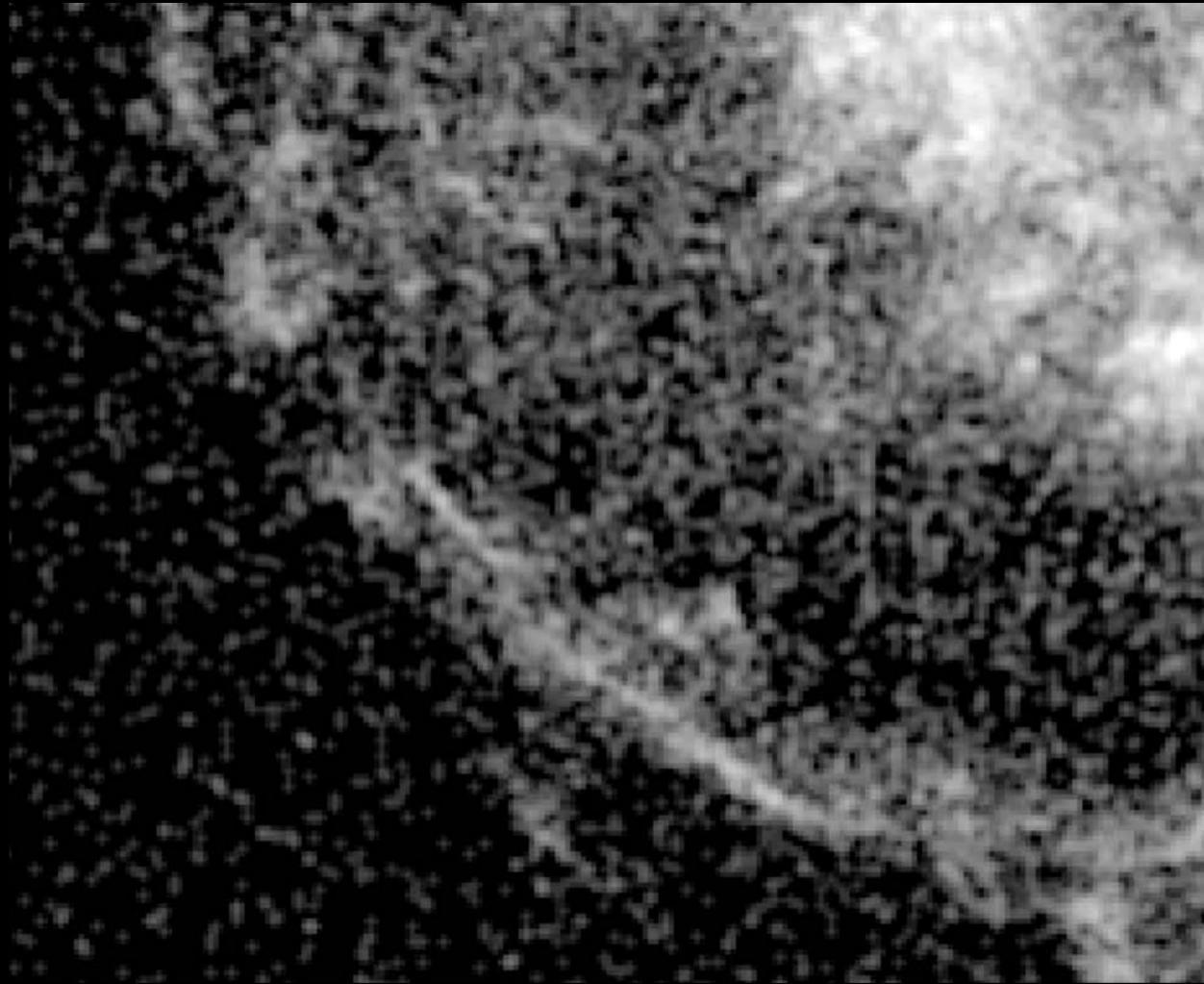
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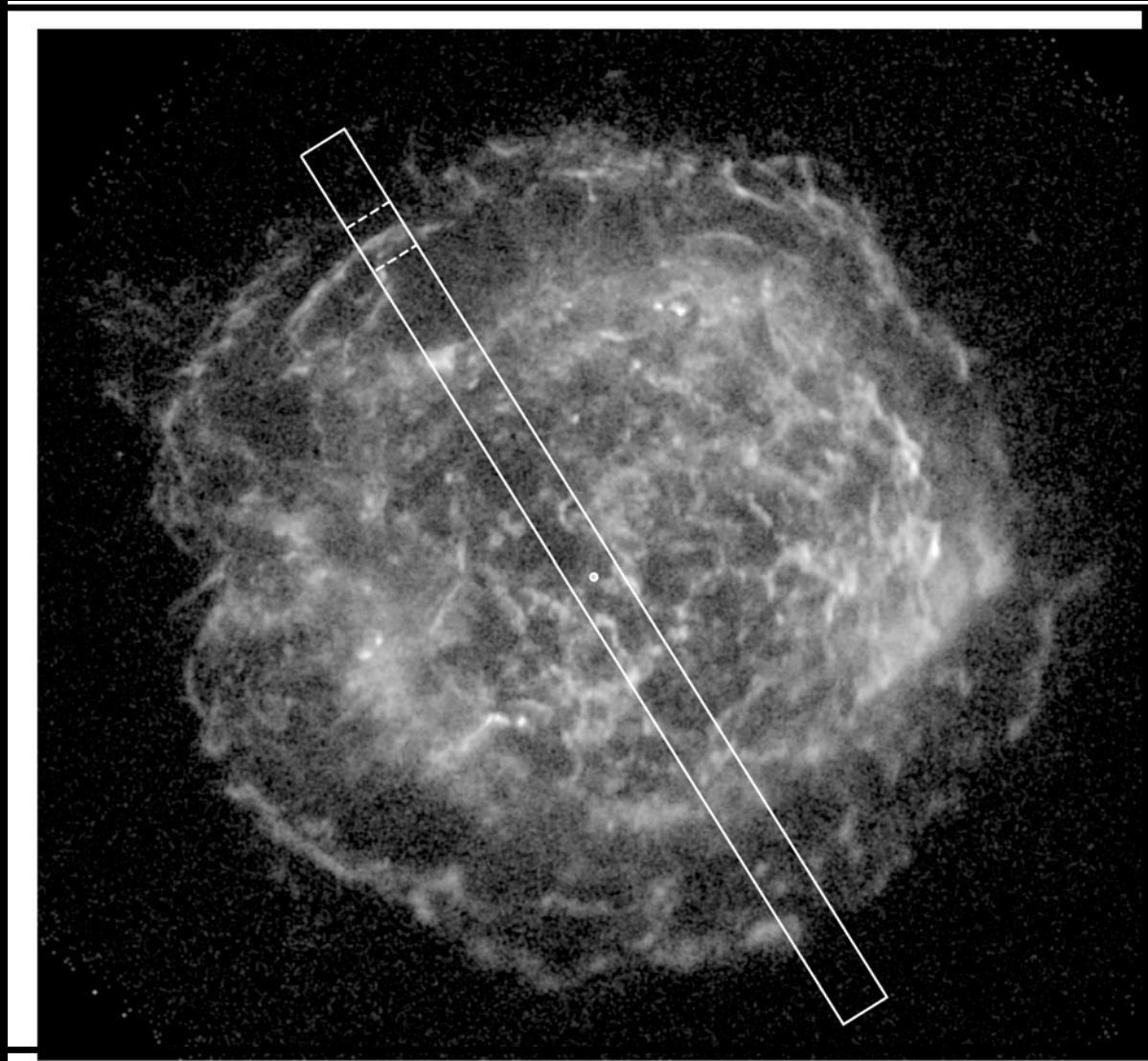
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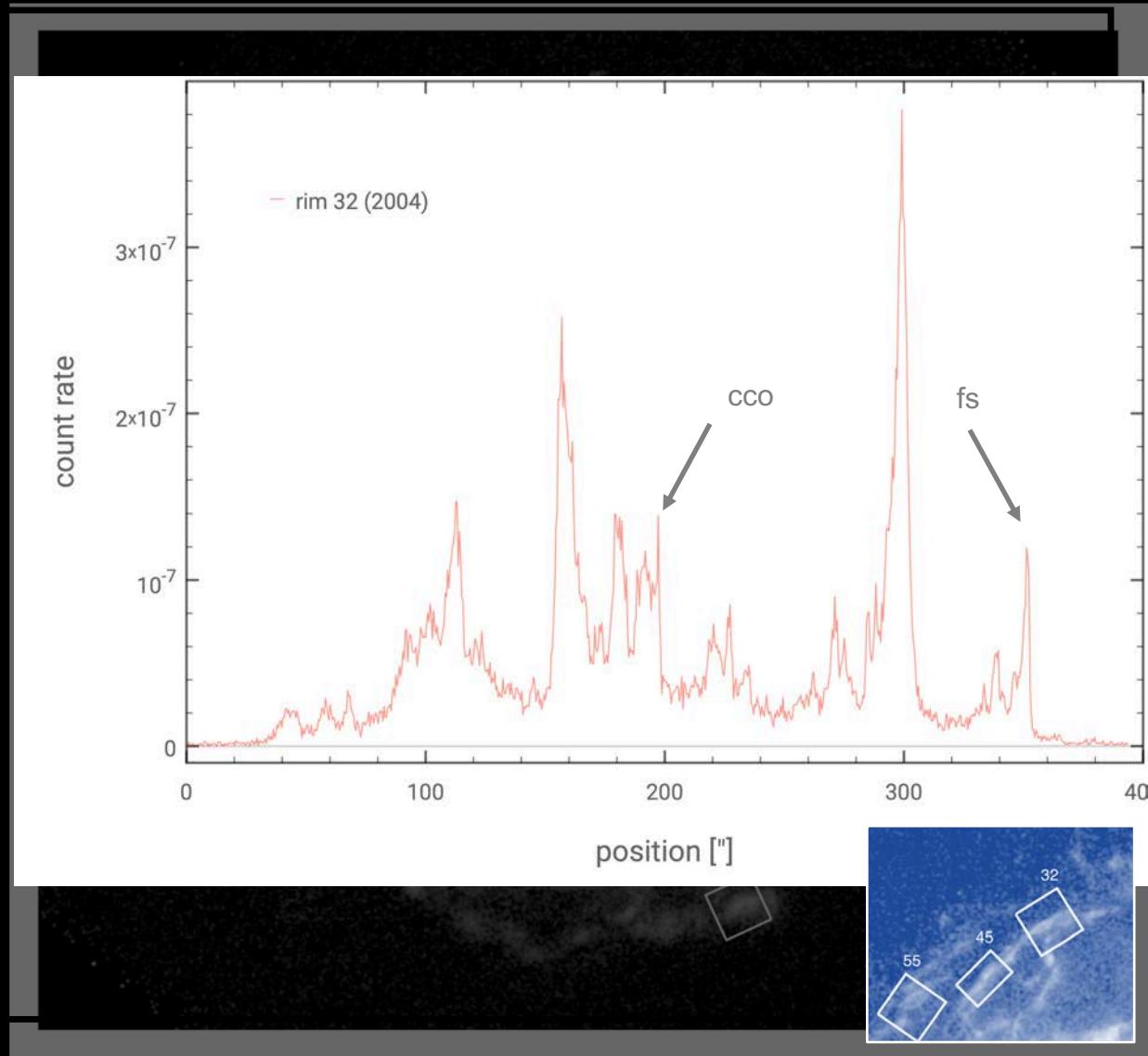
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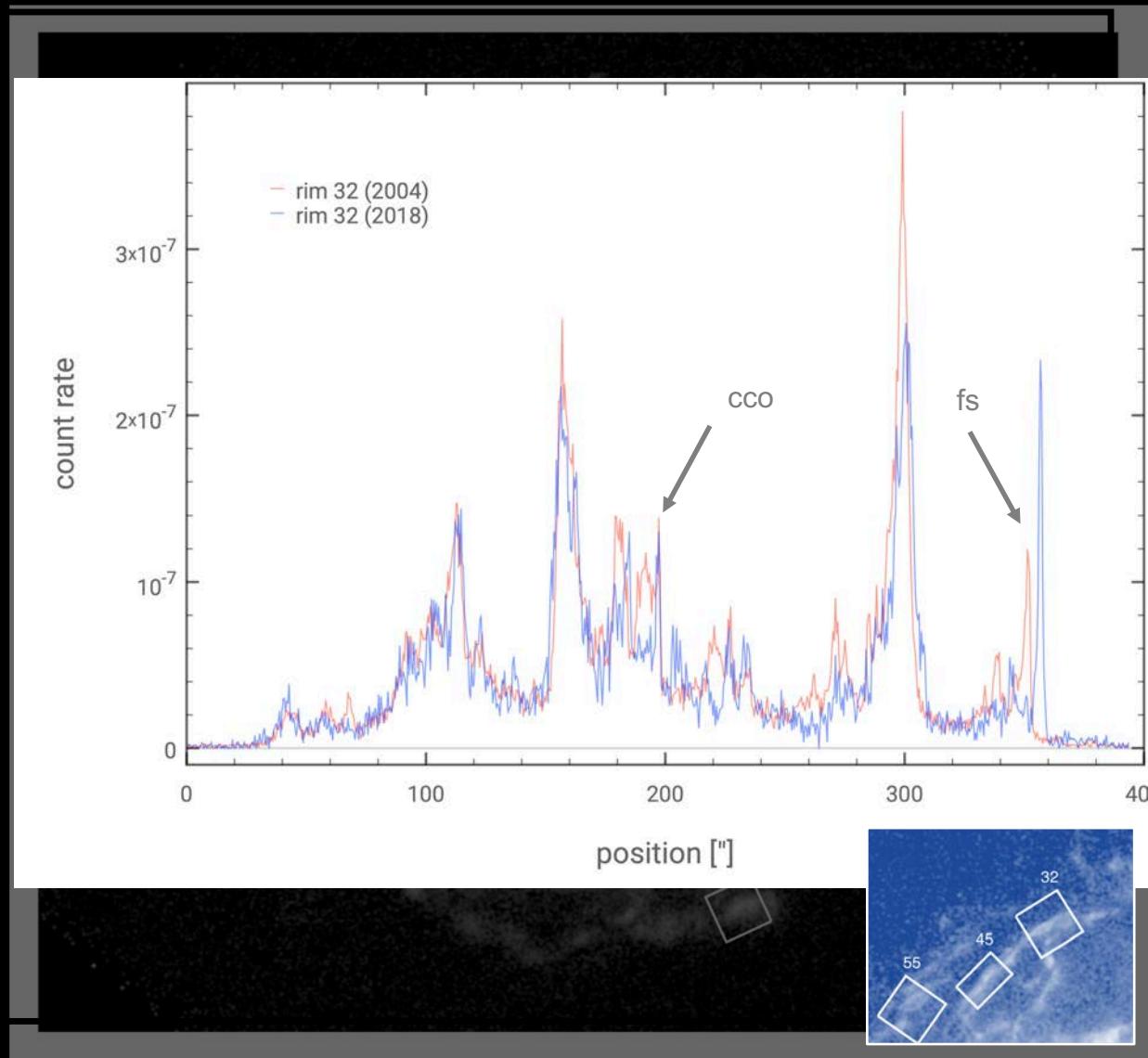
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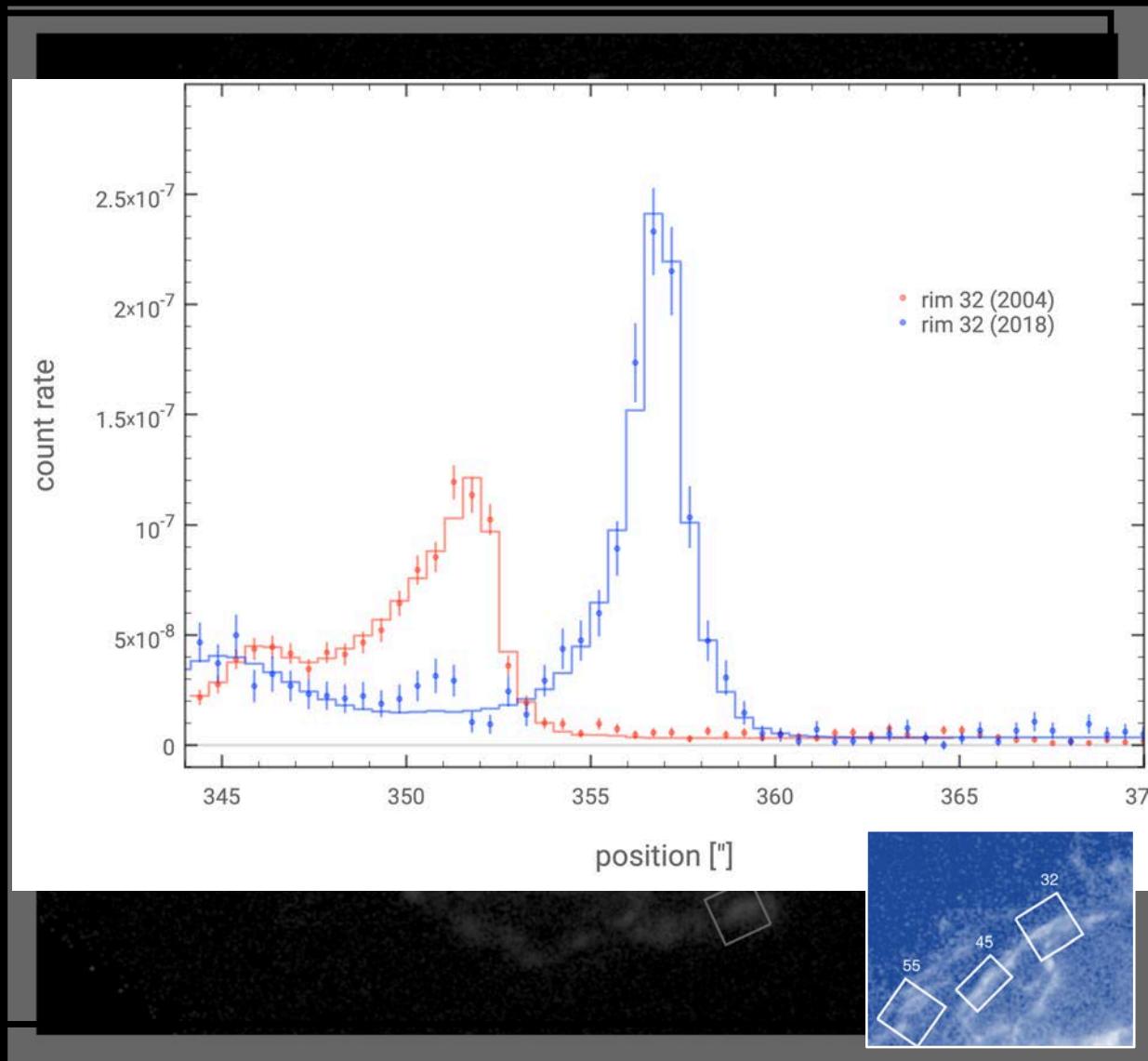
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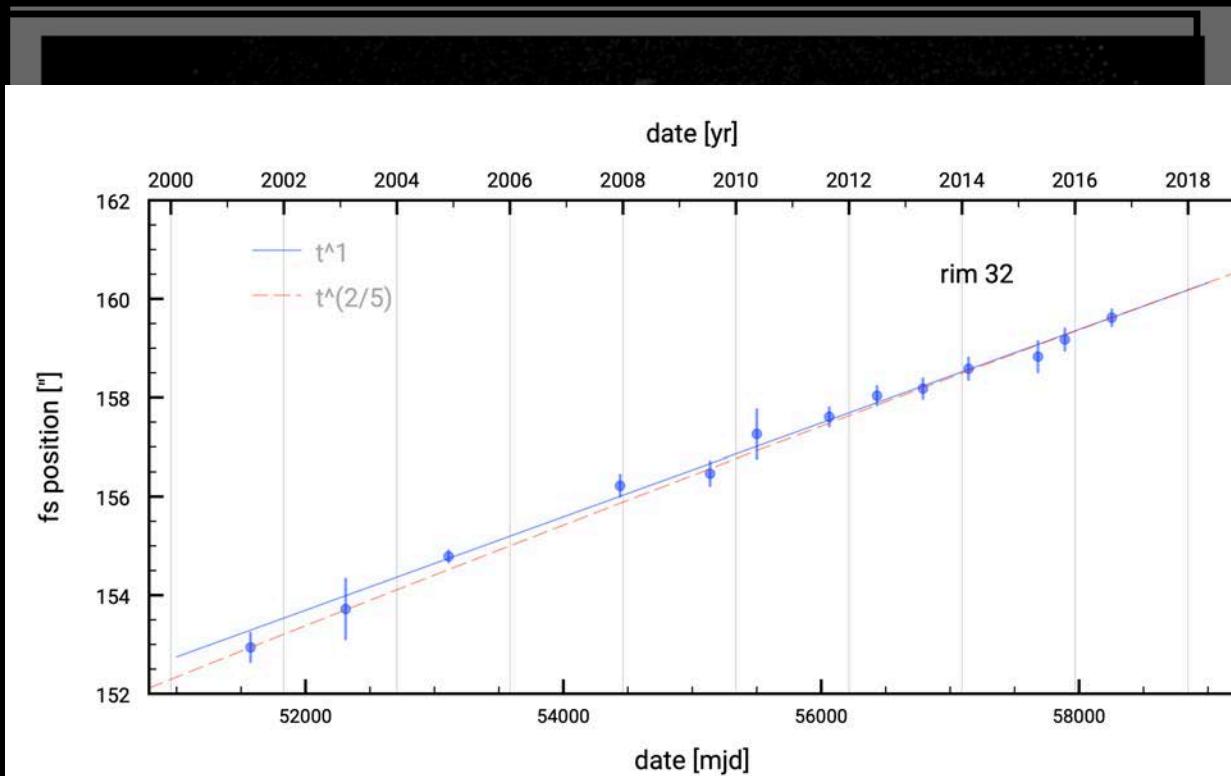
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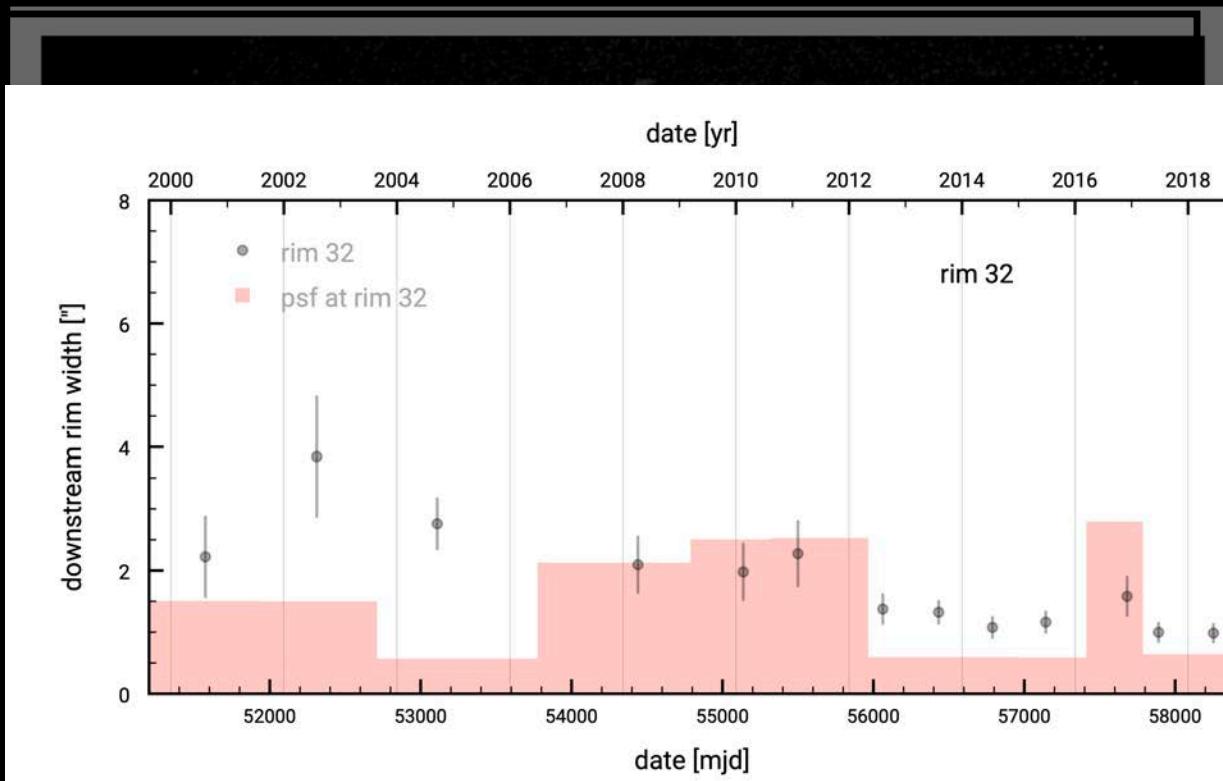
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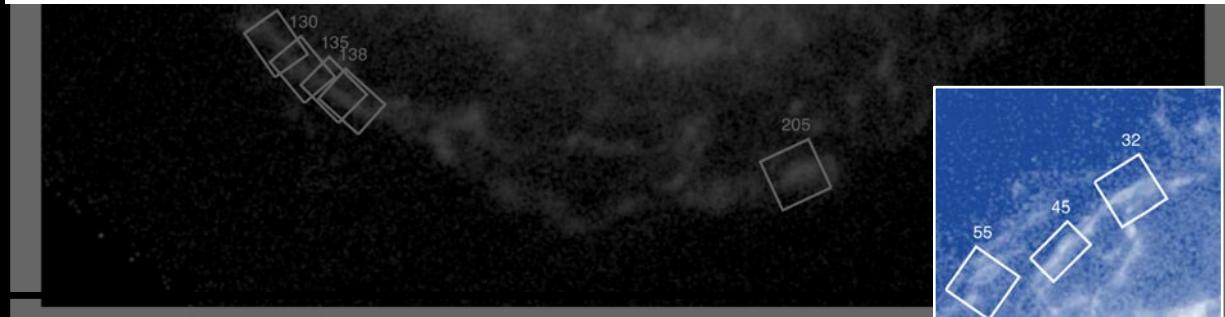
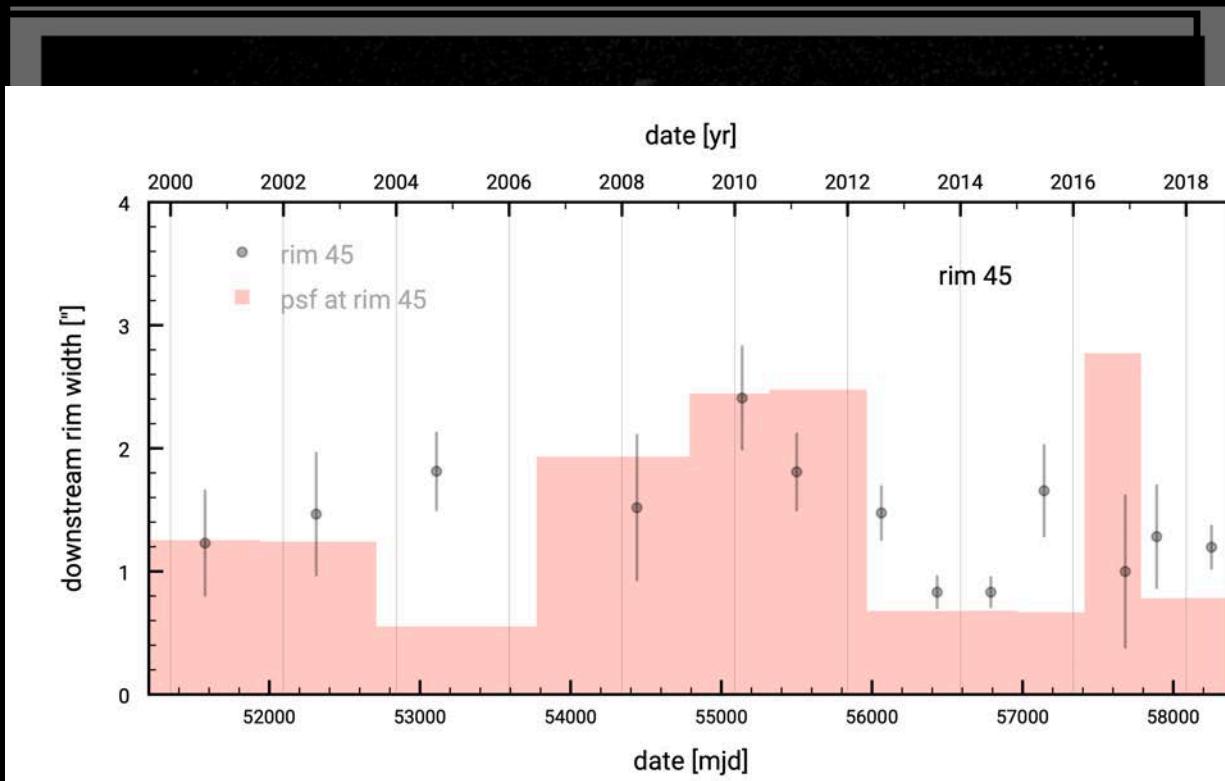
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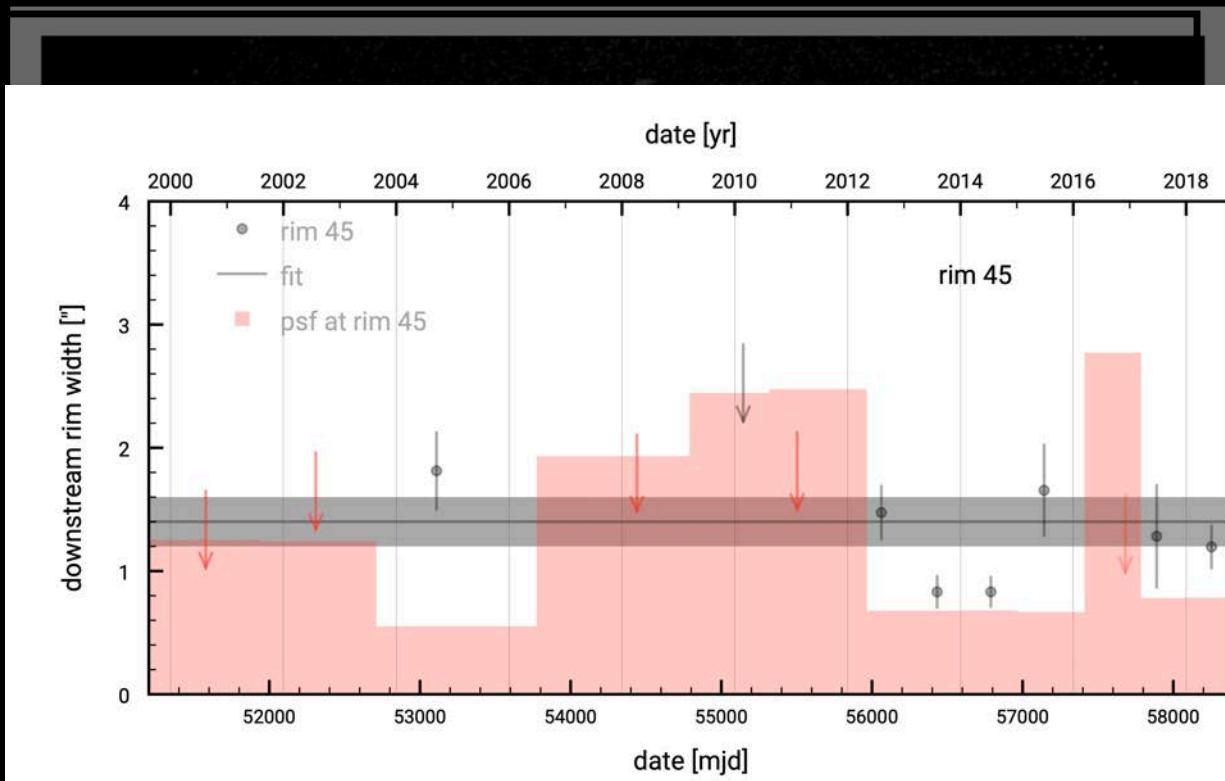
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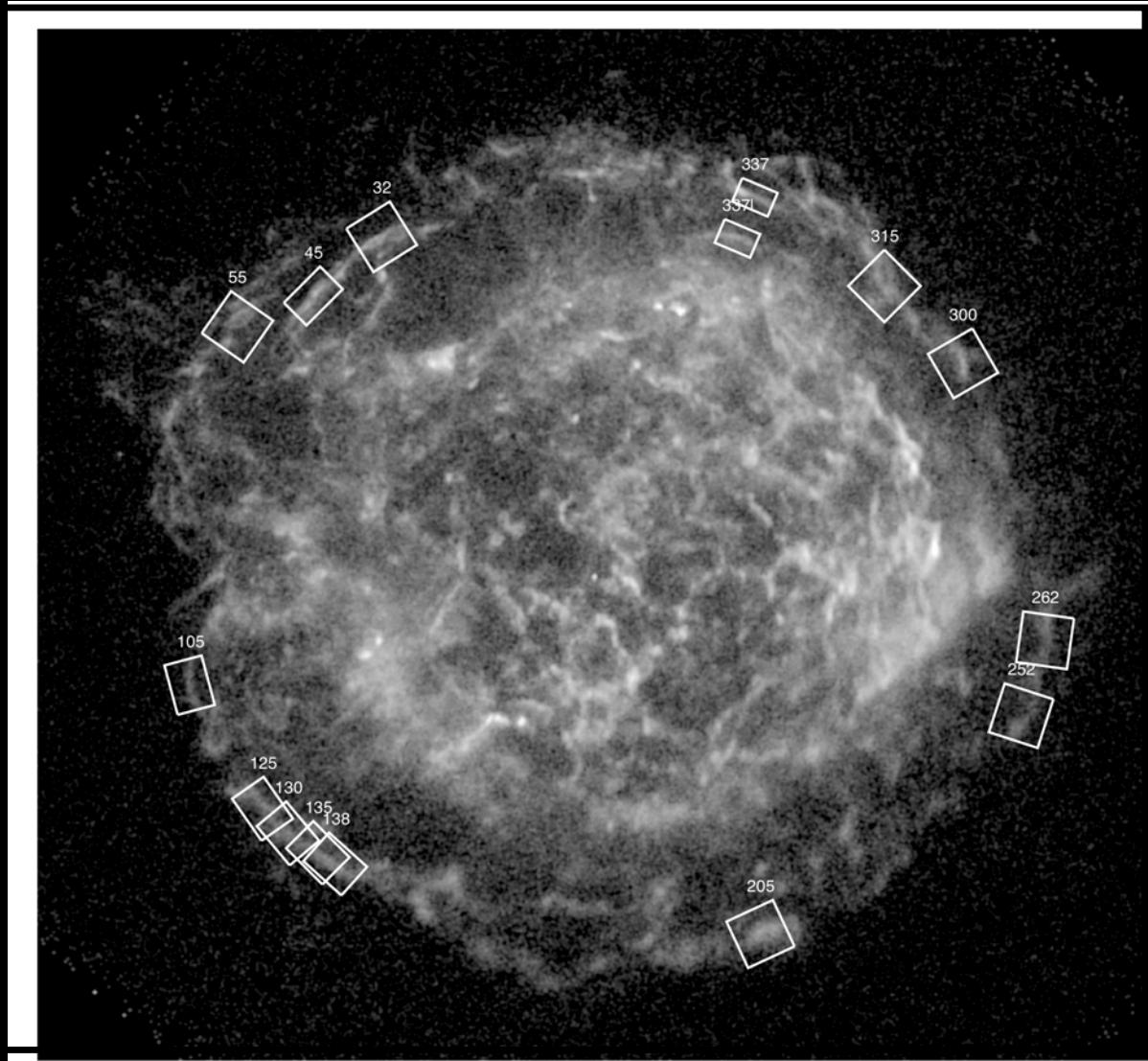
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# CAS A – NONTHERMAL RIMS

the results

rim	width ["]	width uncertainty ["]	velocity ["/yr]	velocity uncertainty ["/yr]	velocity [km/s]	velocity uncertainty [km/s]
32	1.0	0.2	0.35	0.02	5600	300
45	1.4	0.2	0.29	0.02	4600	300
<b>55</b>	<b>4.6</b>	<b>0.6</b>	<b>0.24</b>	<b>0.05</b>	<b>3900</b>	<b>900</b>
105	1.5	0.4	0.37	0.03	6000	500
125	2.2	0.5	0.36	0.03	5900	500
130	4.3	0.4	0.3	0.1	6000	2000
135	2.4	0.6	0.37	0.03	6000	500
138	2.4	0.6	0.38	0.03	6100	500
205	1.7	0.2	0.33	0.02	5300	400
<b>252</b>	<b>2.7</b>	<b>0.2</b>	<b>0.44</b>	<b>0.04</b>	<b>7100</b>	<b>700</b>
262	2.2	0.2	0.39	0.04	6300	700
300	2.7	0.4	0.41	0.03	6700	500
315	5.1	0.5	0.42	0.05	6900	800
337	1.1	0.1	0.26	0.02	4200	300
337I	2.9	0.5	0.30	0.03	4800	500

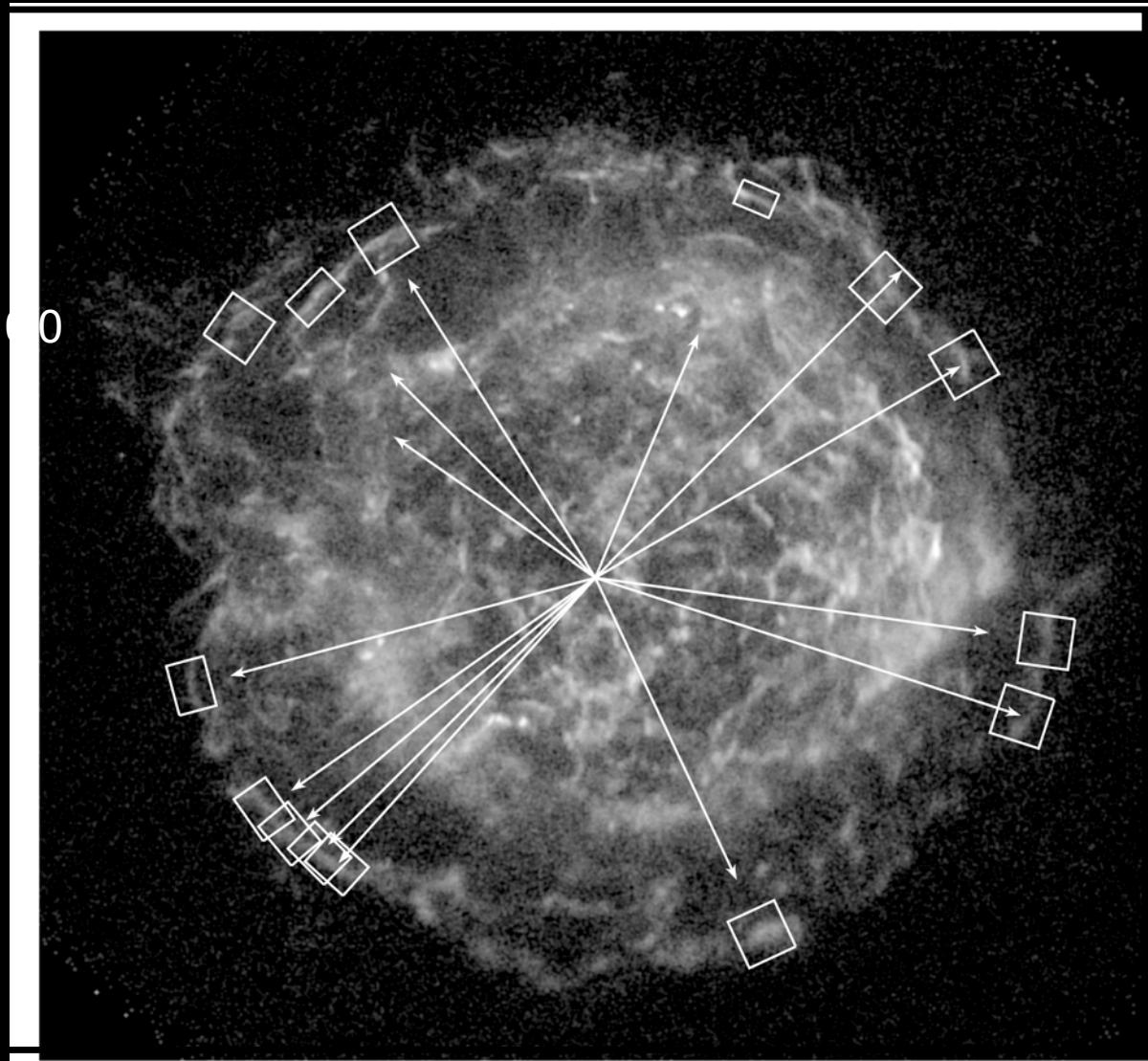
# CAS A - NONTHERMAL RIMS

the results

rim velocities ranges  
between ~4000 and 7000

slowest rims in the NE

fastest in the W



# CAS A – NONTHERMAL RIMS

the results

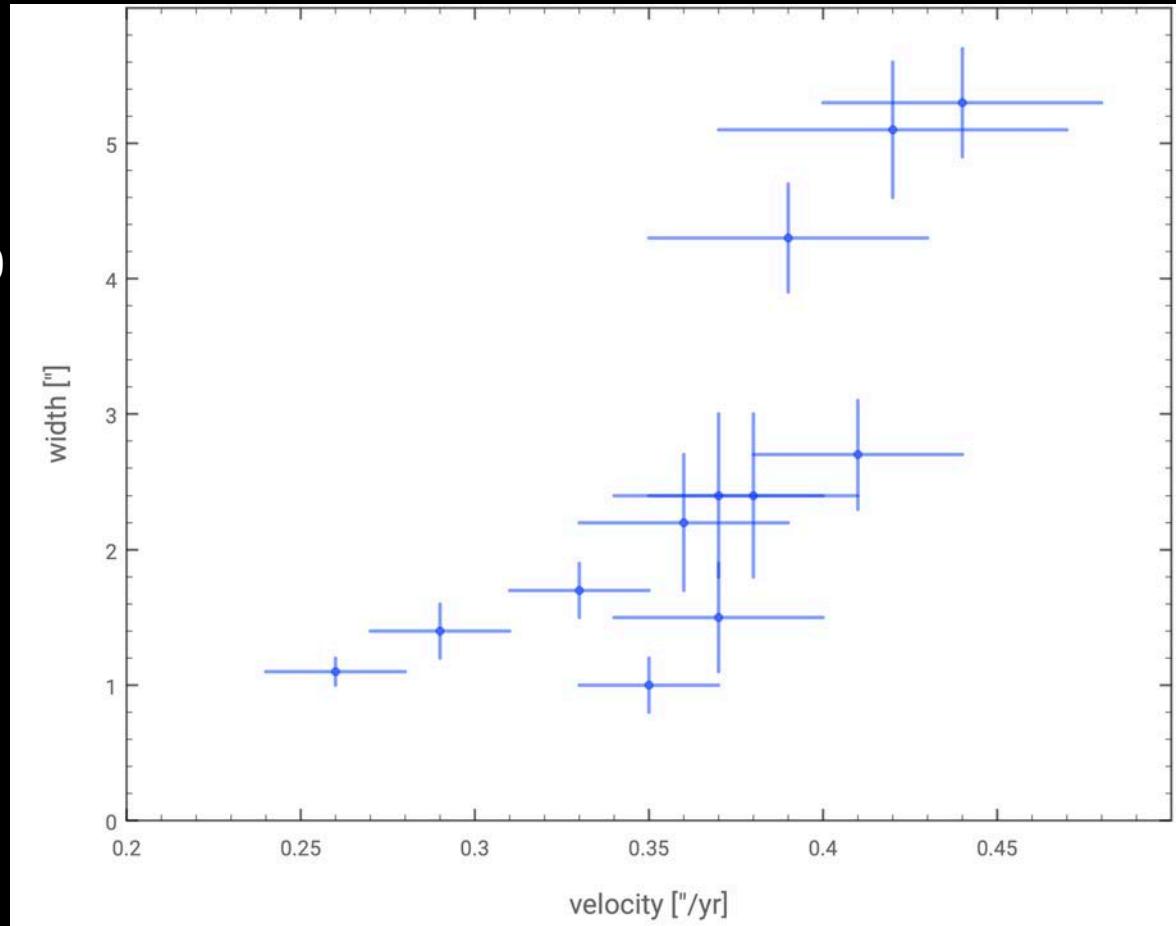
rim velocities ranges  
between  $\sim 4000$  and 7000

slowest rims in the NE

fastest in the W

width seems to be  
proportional to velocity

filament width might be  
decreasing in some rims



# CAS A – NONTHERMAL RIMS

## the results

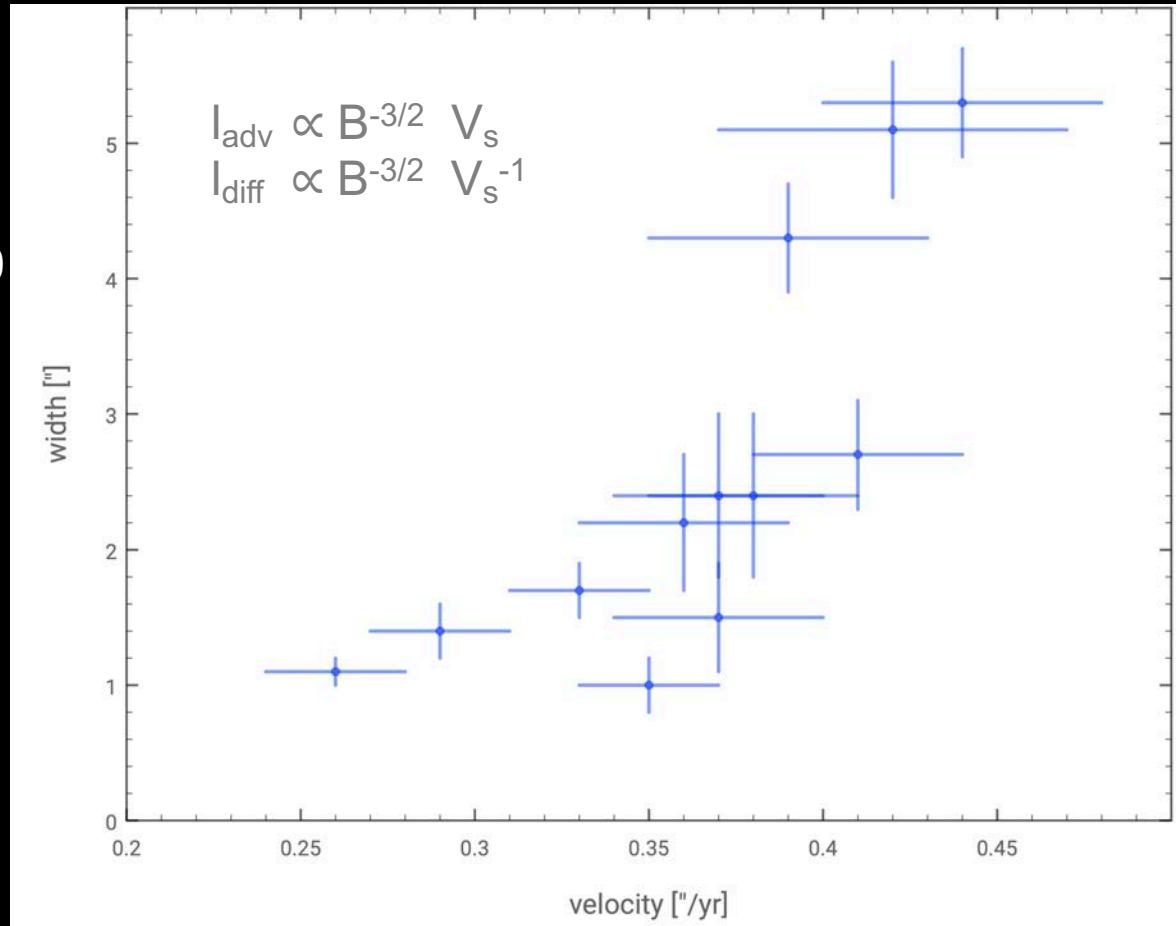
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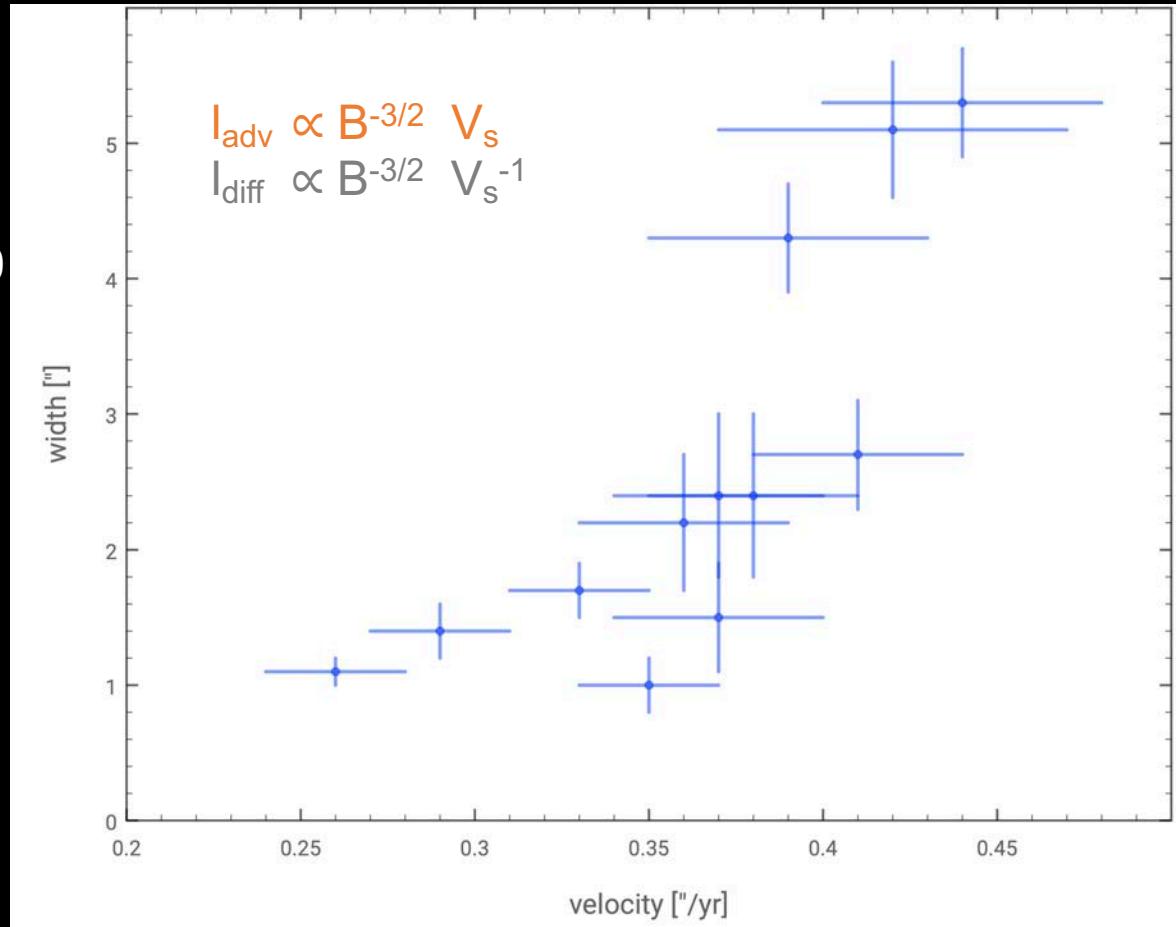
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# CAS A – NONTHERMAL RIMS

## takeaways

- large variations in the forward shock velocity of cas a
- the width of the synchrotron filaments in cas a seems to be correlated to the velocity of the rims -> advection?

## more cavalier statement

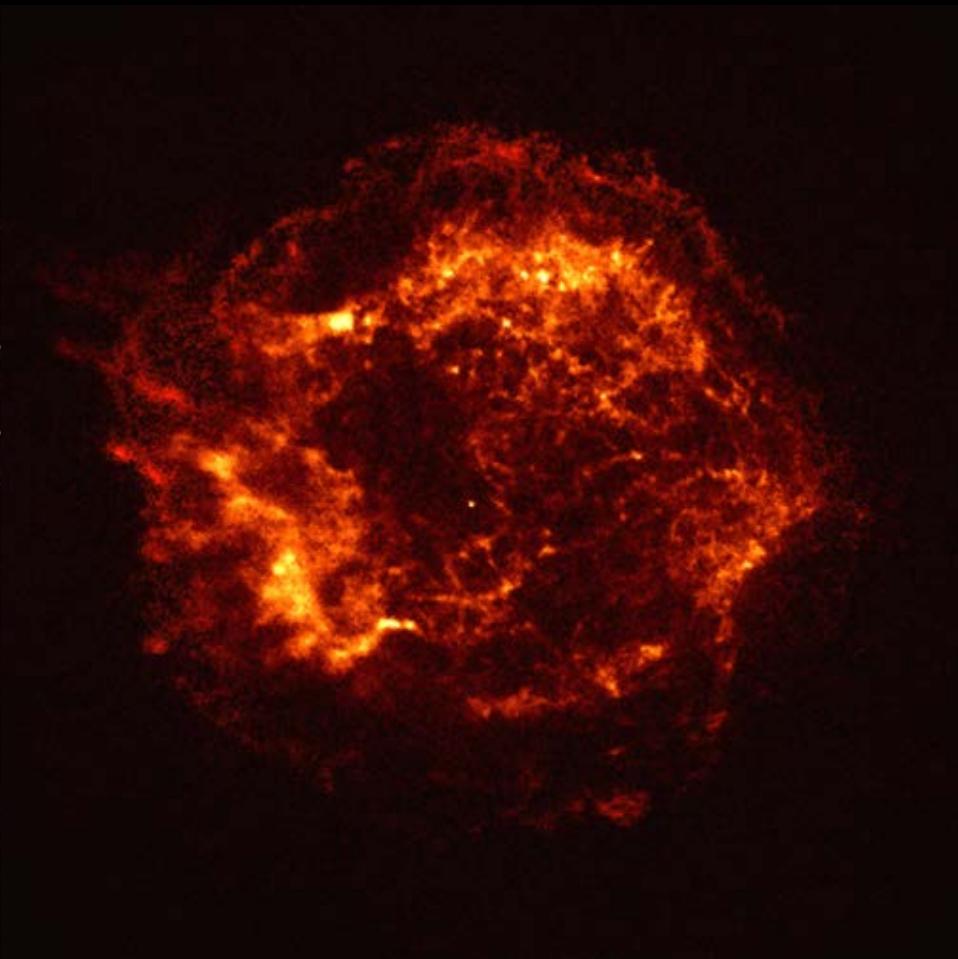
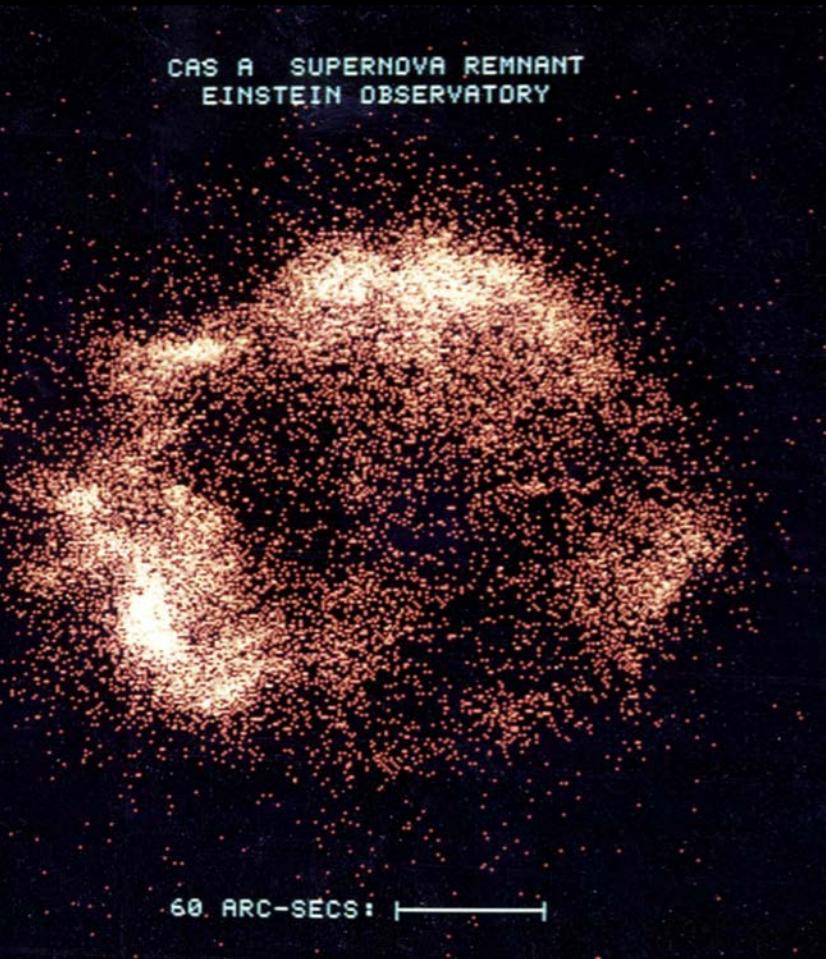
- some rims might show evidence of narrowing in width

# CHANDRA | THE FIRST 20 YEARS



# DOING ASTROPHYSICS WITH CHANDRA

the remnants of exploding stars...





more info at [cxc.cfa.harvard.edu](http://cxc.cfa.harvard.edu)

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