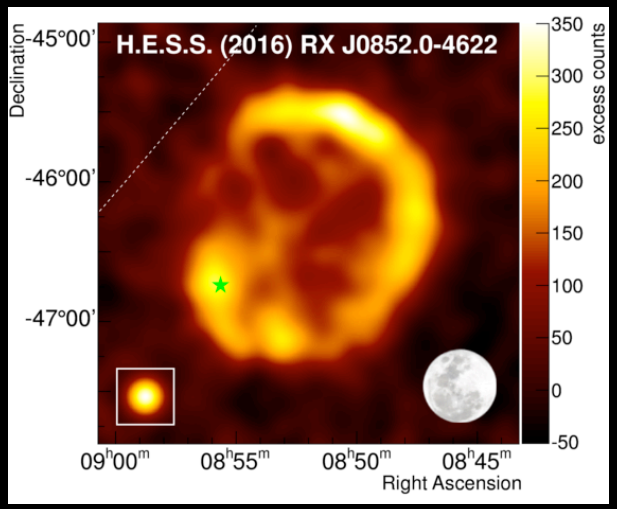
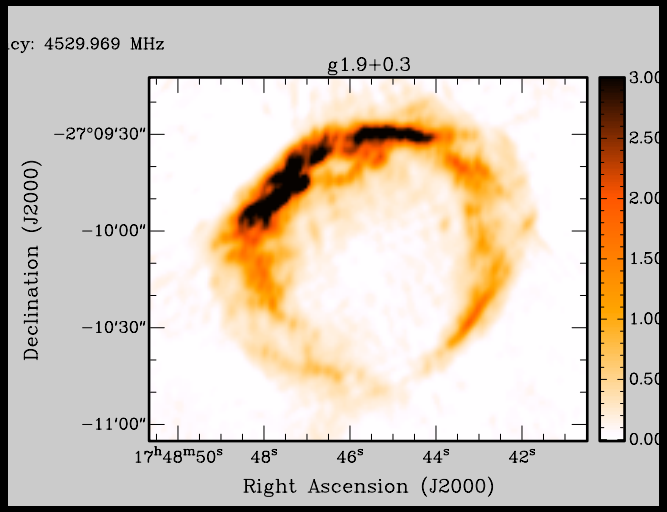
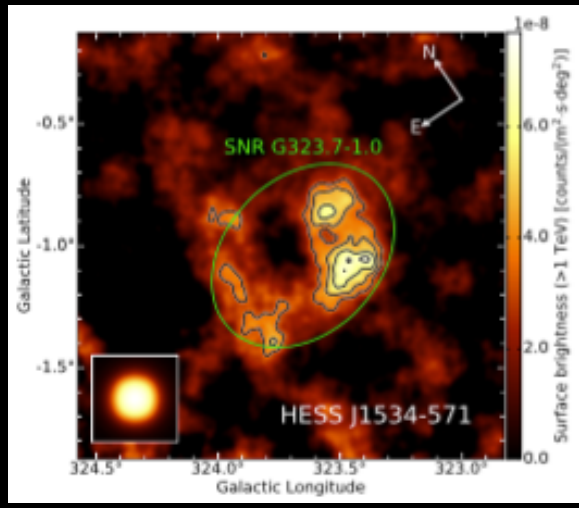
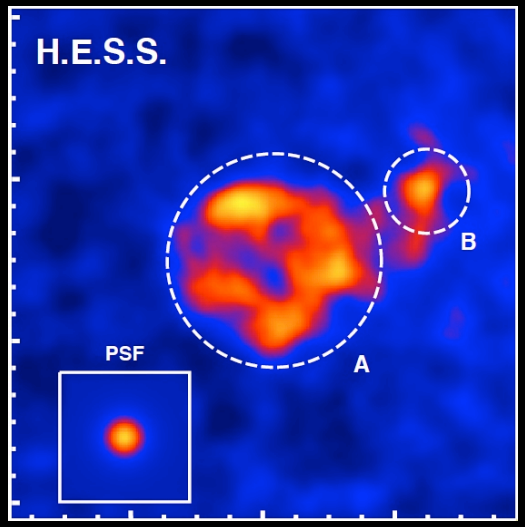
Searching for molecular gas bombarded by cosmic rays near supernova remnants

Nigel Maxted
ISM Meeting, Bamberg
March 2018









Vela Jr

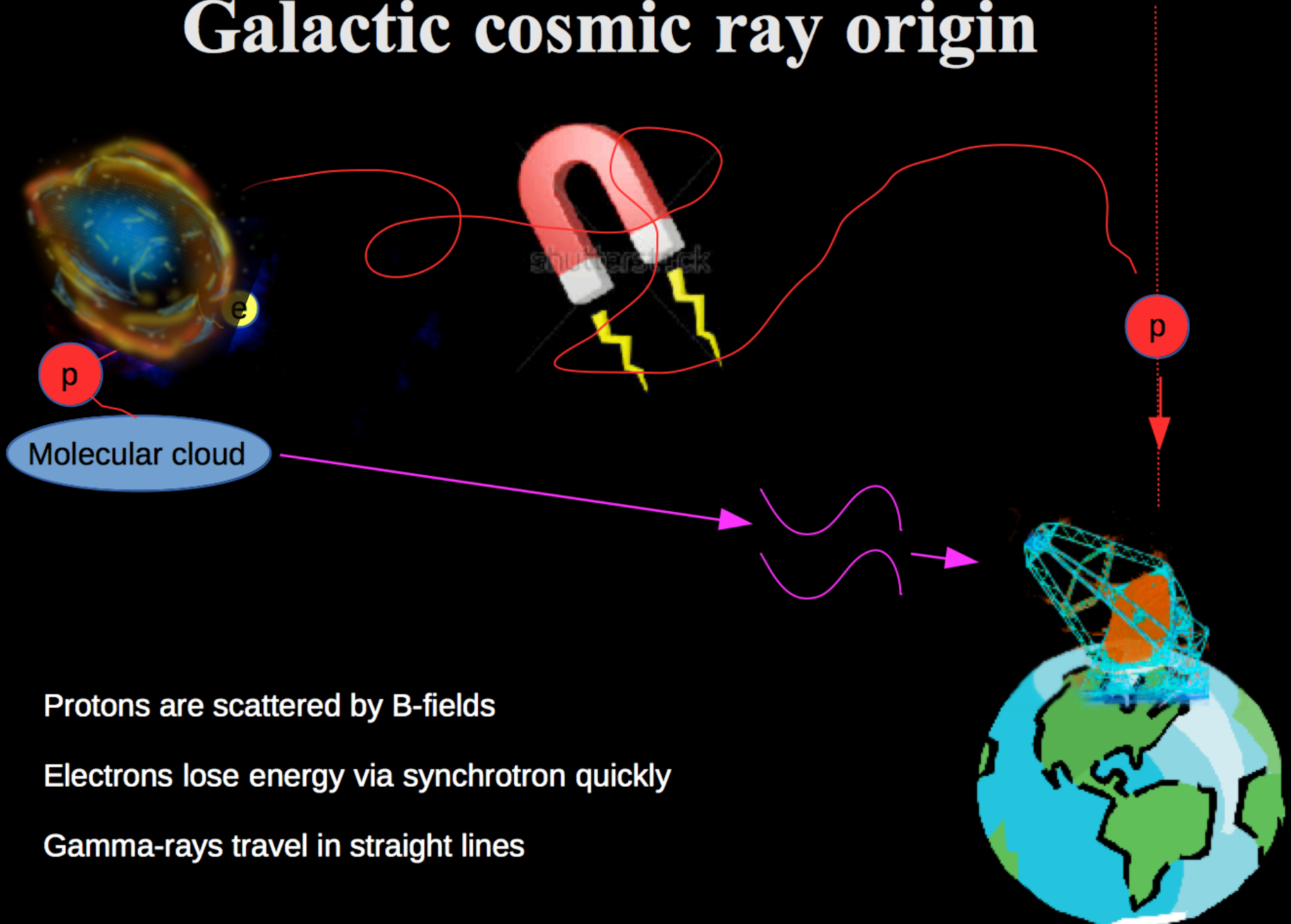
G1.9+0.3

HESS J1534-571

HESS J1731-347

Some notes on recent multi-wavelength studies of interesting Galactic SNRs

Galactic cosmic ray origin



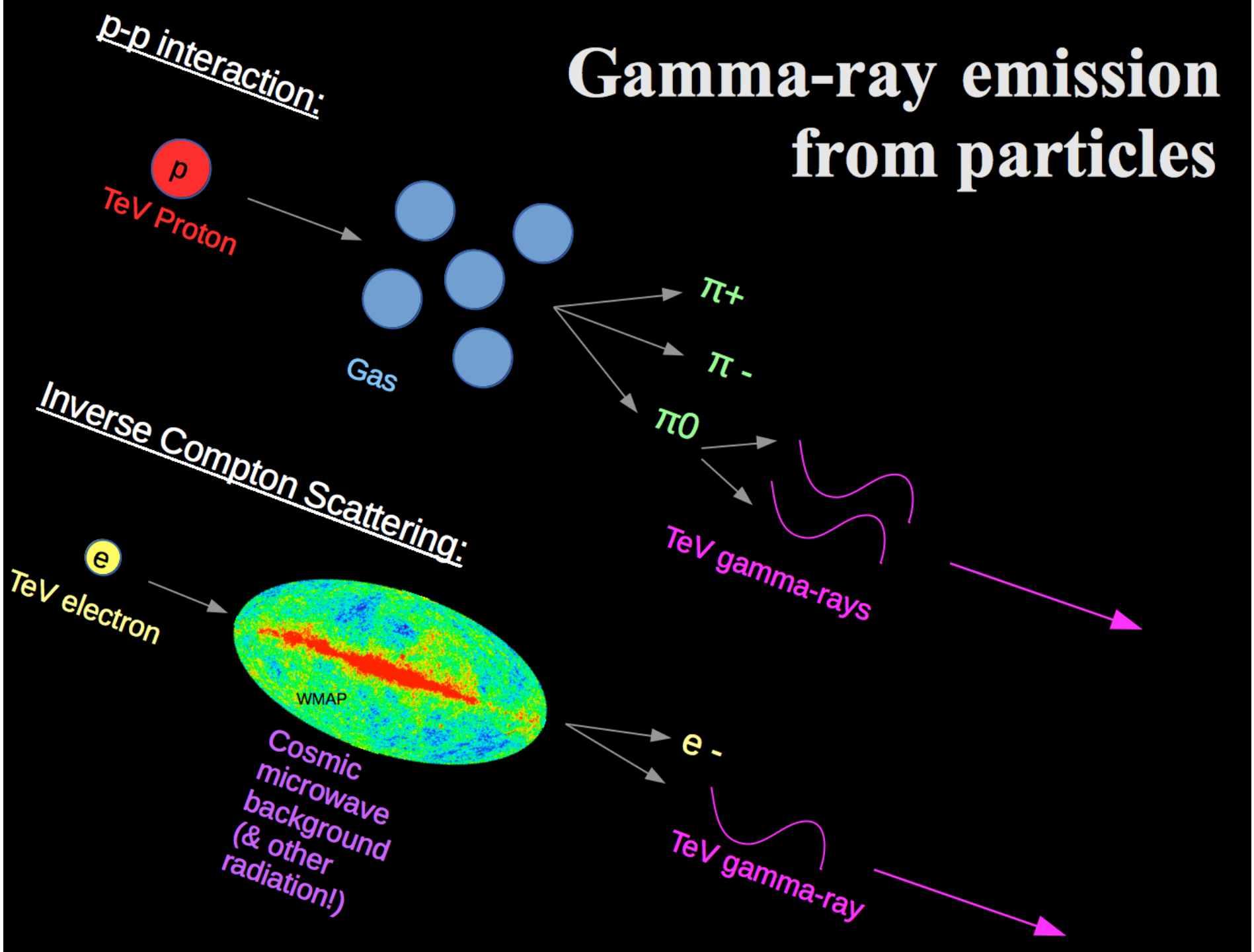
Protons are scattered by B-fields

Electrons lose energy via synchrotron quickly

Gamma-rays travel in straight lines

Gamma-ray emission from particles

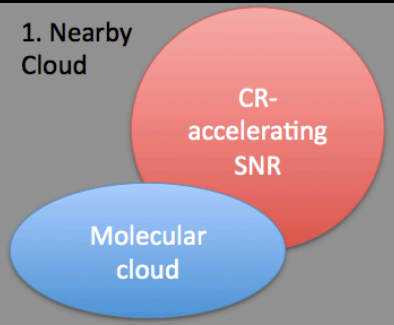
p-p interaction:



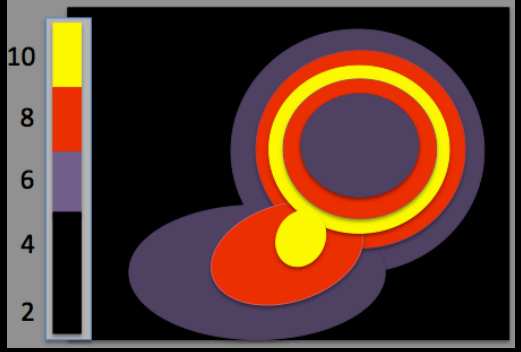
Inverse Compton Scattering:

Looking for CR sources with gamma-ray astronomy

1. Nearby Cloud



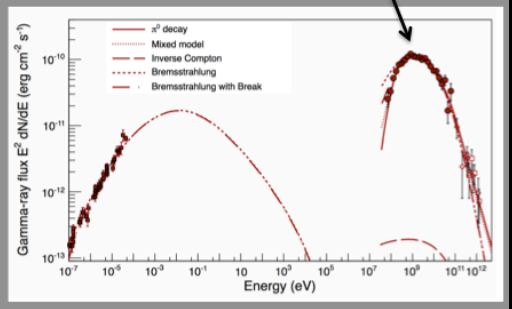
TeV gamma-ray significance



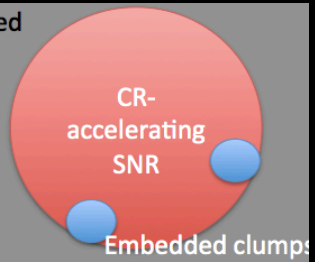
2. Pion bumps

Bump feature indicates clear cosmic-ray interactions...

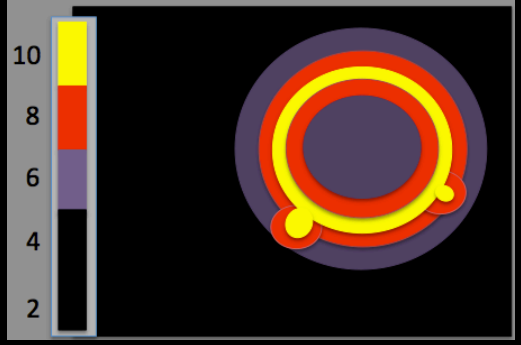
(e.g. In W44 and IC443, Ackemann et al 2013)



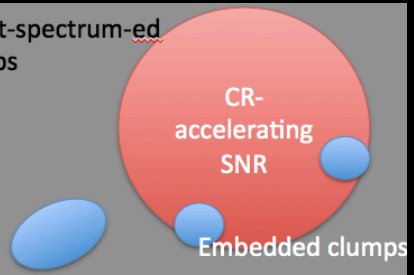
3. Embedded clumps



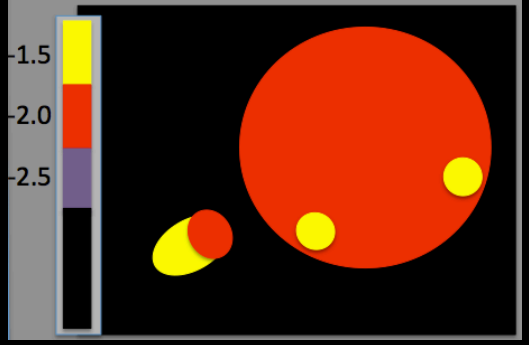
TeV gamma-ray significance



4. Flat-spectrum-ed clumps

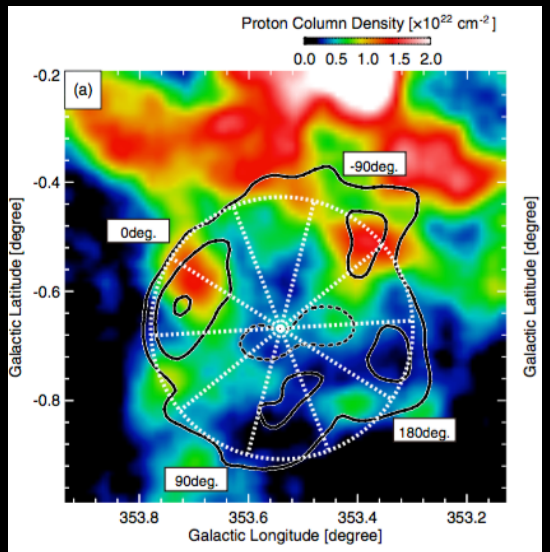


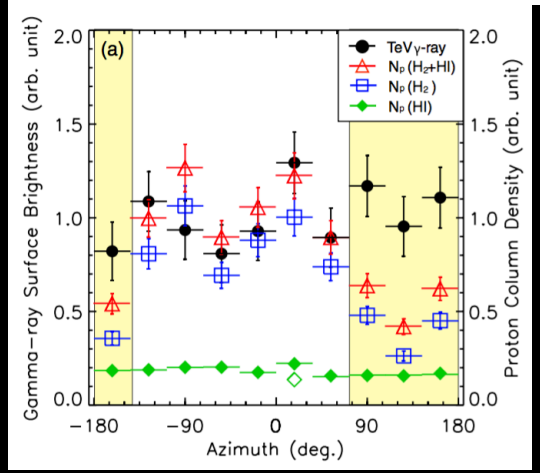
Gamma-ray spectral index (F ~ A E ^ a)



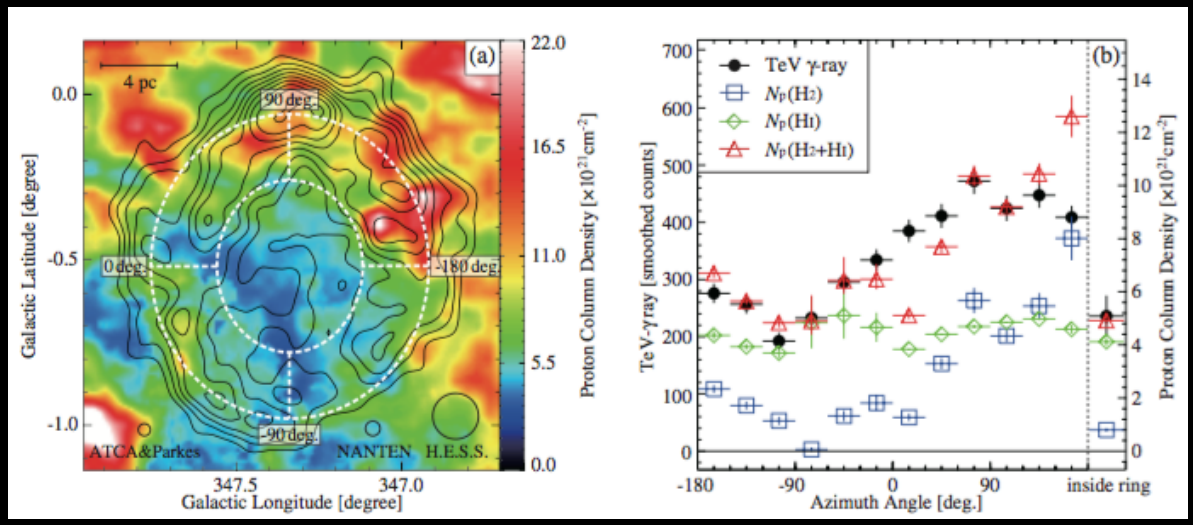
Gamma-ray/proton density correspondence

HESS J1731-347 for 5.2-6 kpc distance (Fukuda et al 2014)

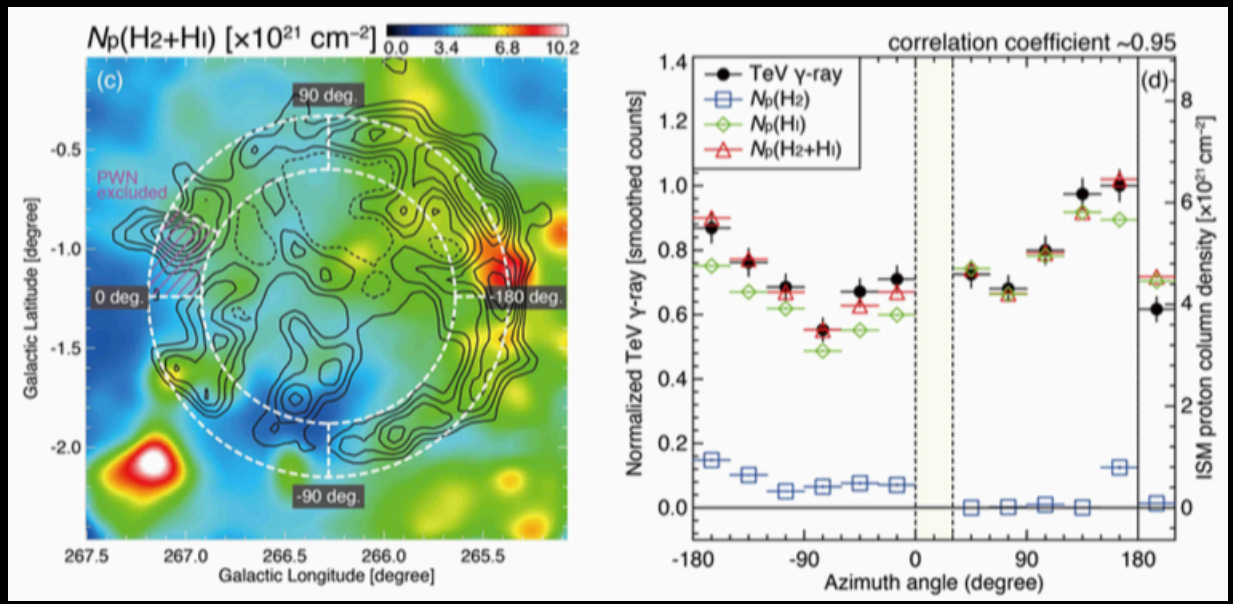




RX J1713.7-3946 (Fukui et al 2012)

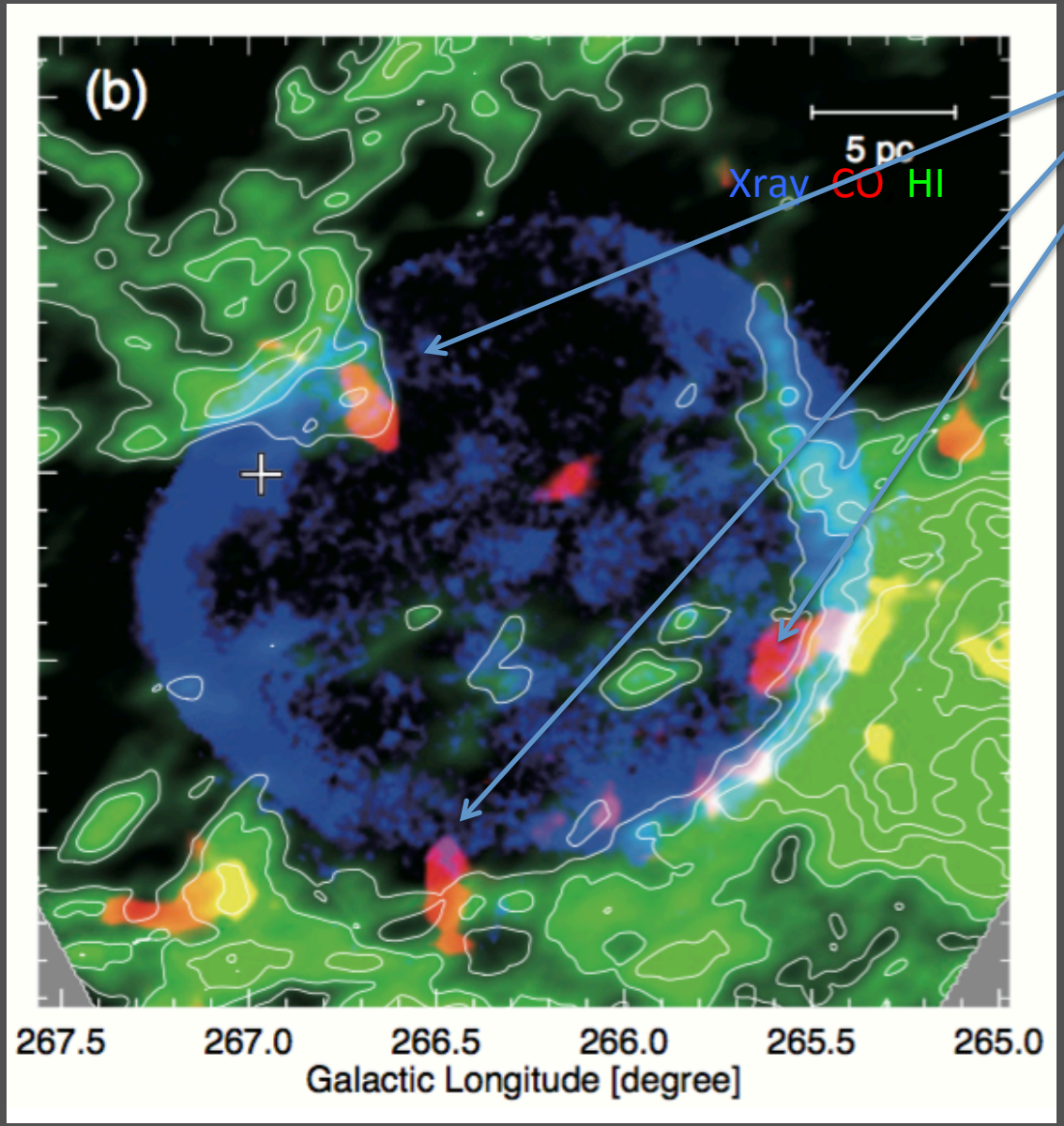


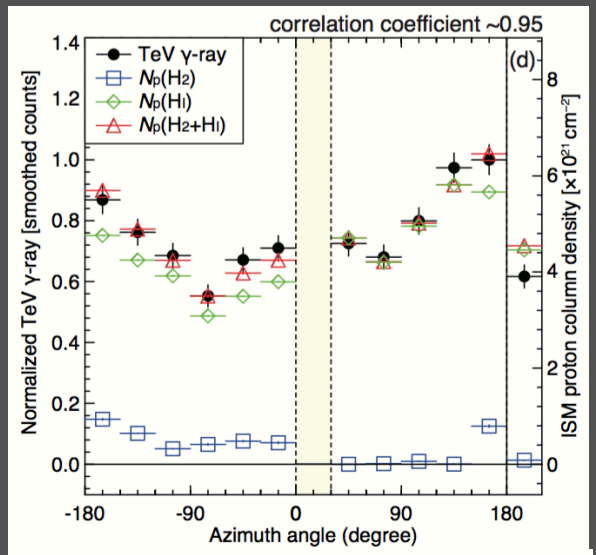
Vela Jr (Fukui et al 2017)

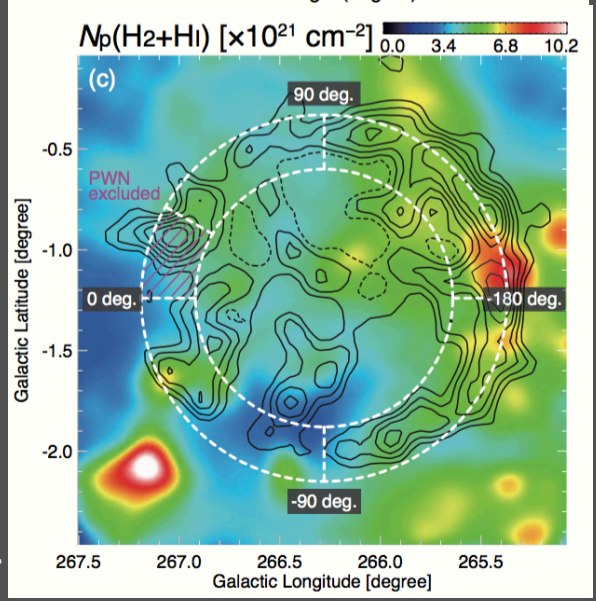


Vela Jr

Molecular clumps

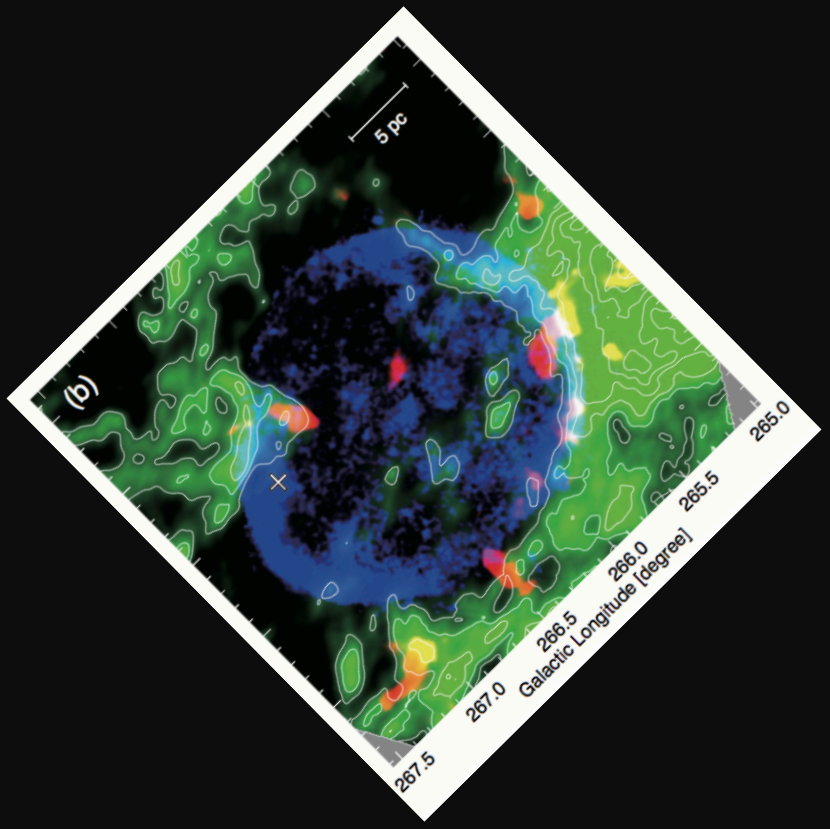


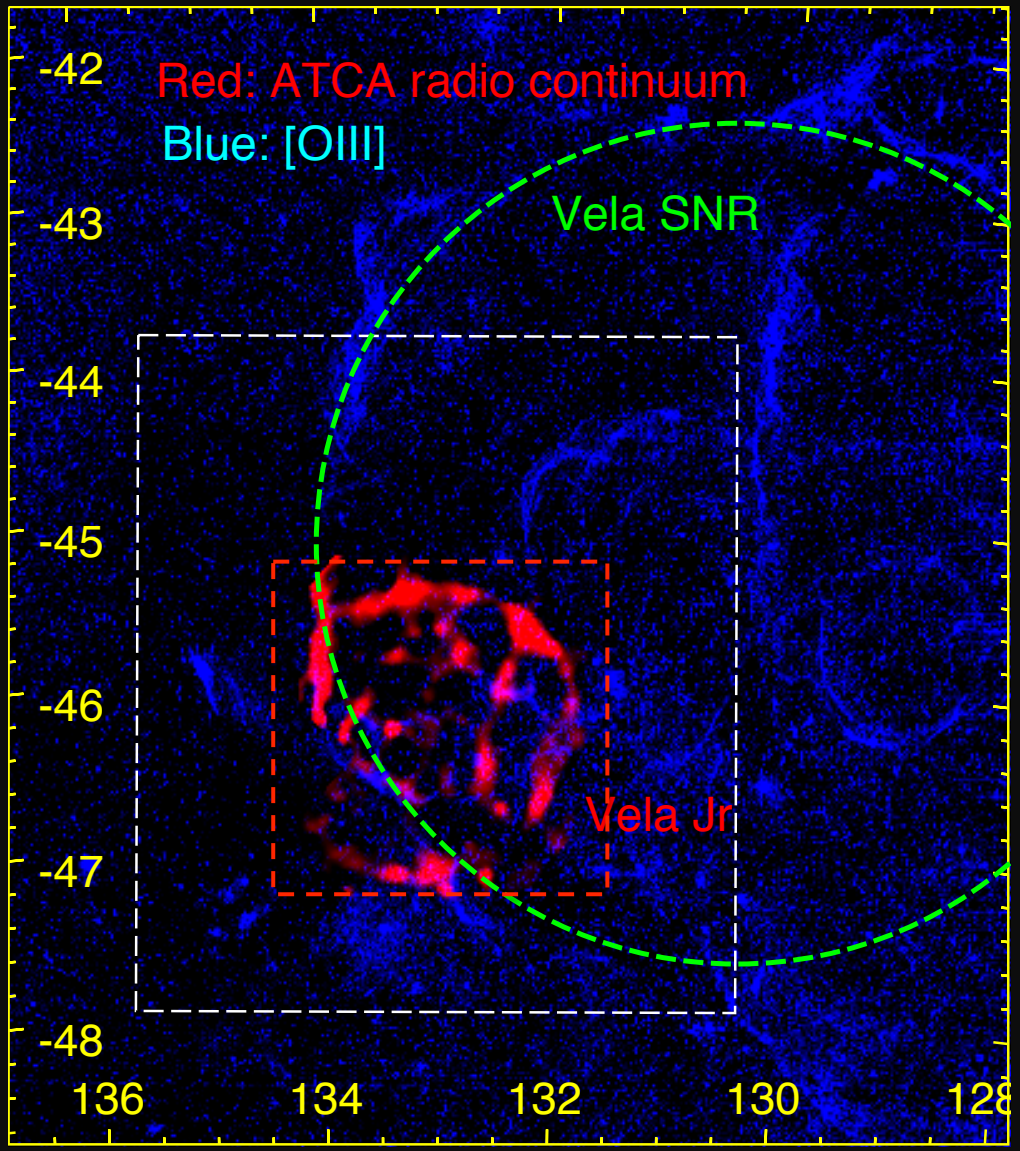




Fukui, Sano et al 2017 found the probable Vela Jr association.

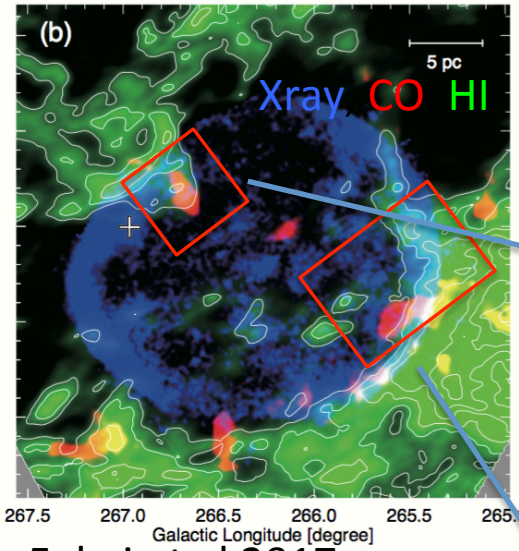
Vela Jr





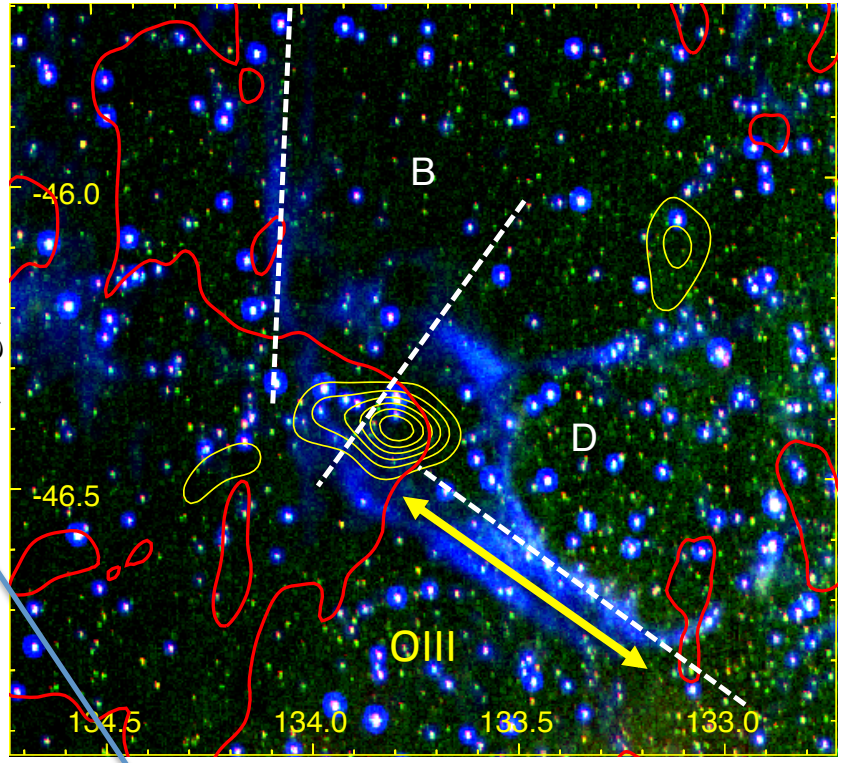
Maxted, Filipovic et al, under review

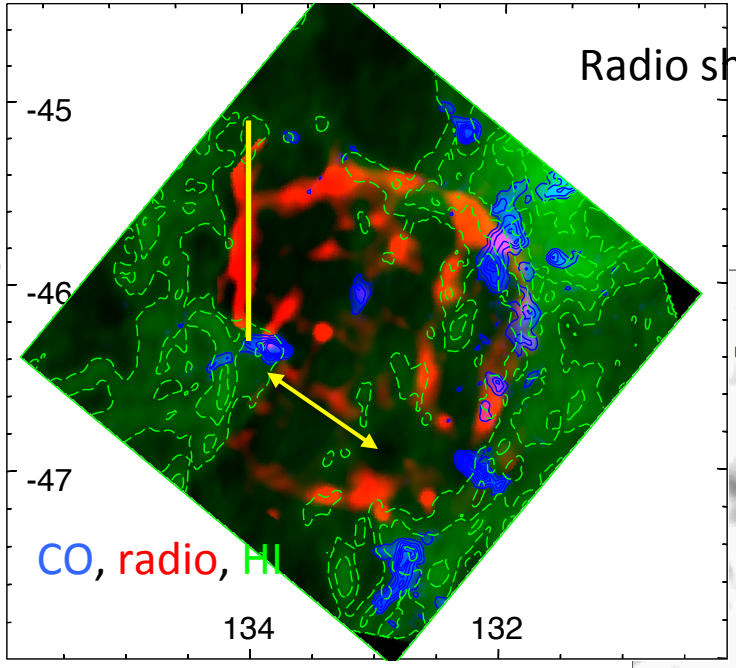
Vela Jr

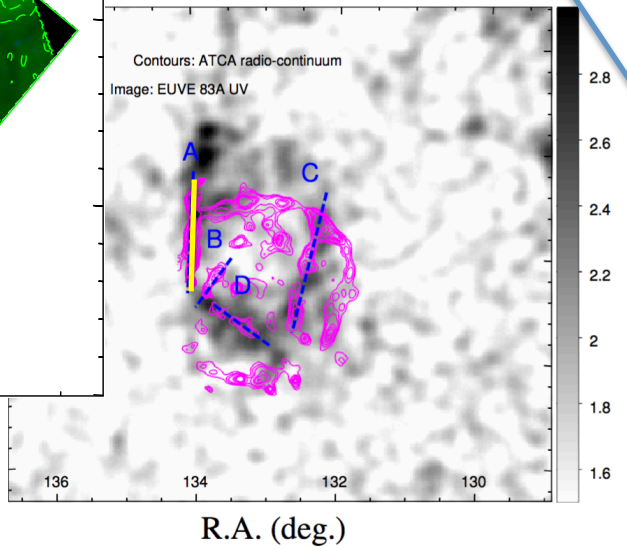


Fukui et al 2017

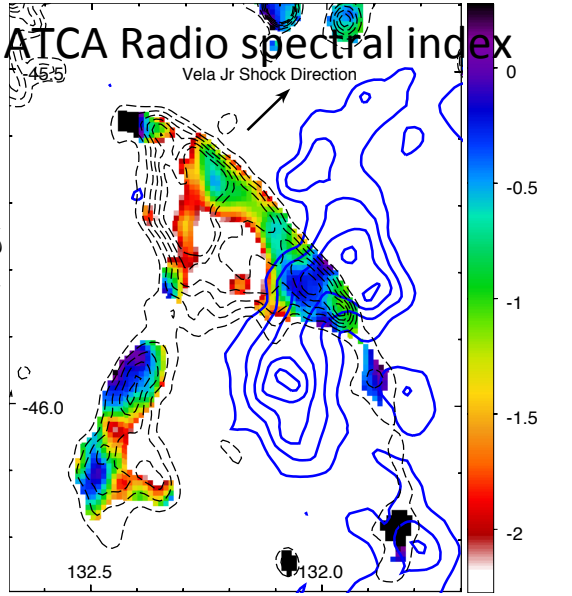
OIII emission around Vela Jr-associated clump





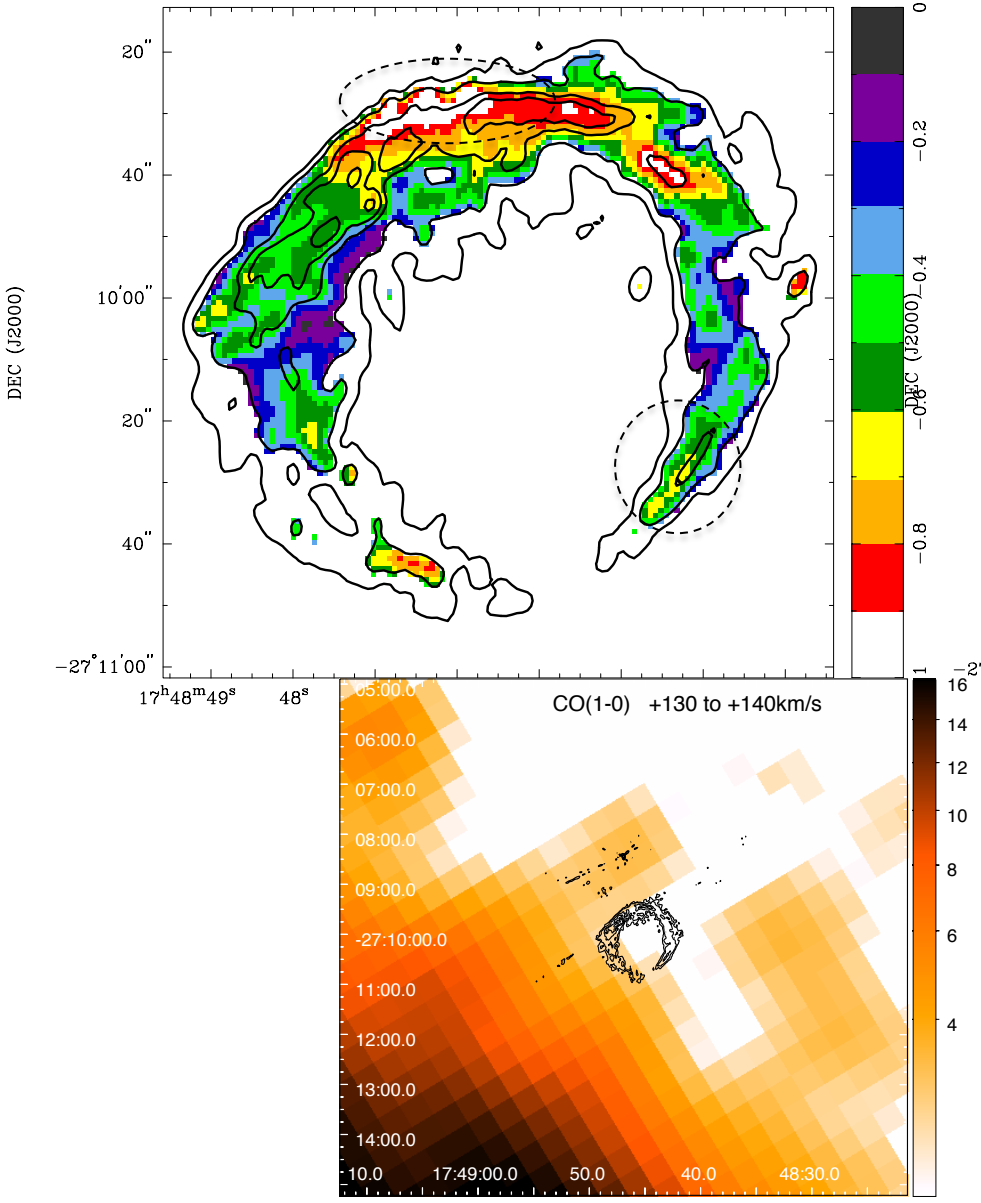


ATCA Radio spectral index



Maxted, Filipovic et al, revisions

Spectral steepening – G1.9+0.3

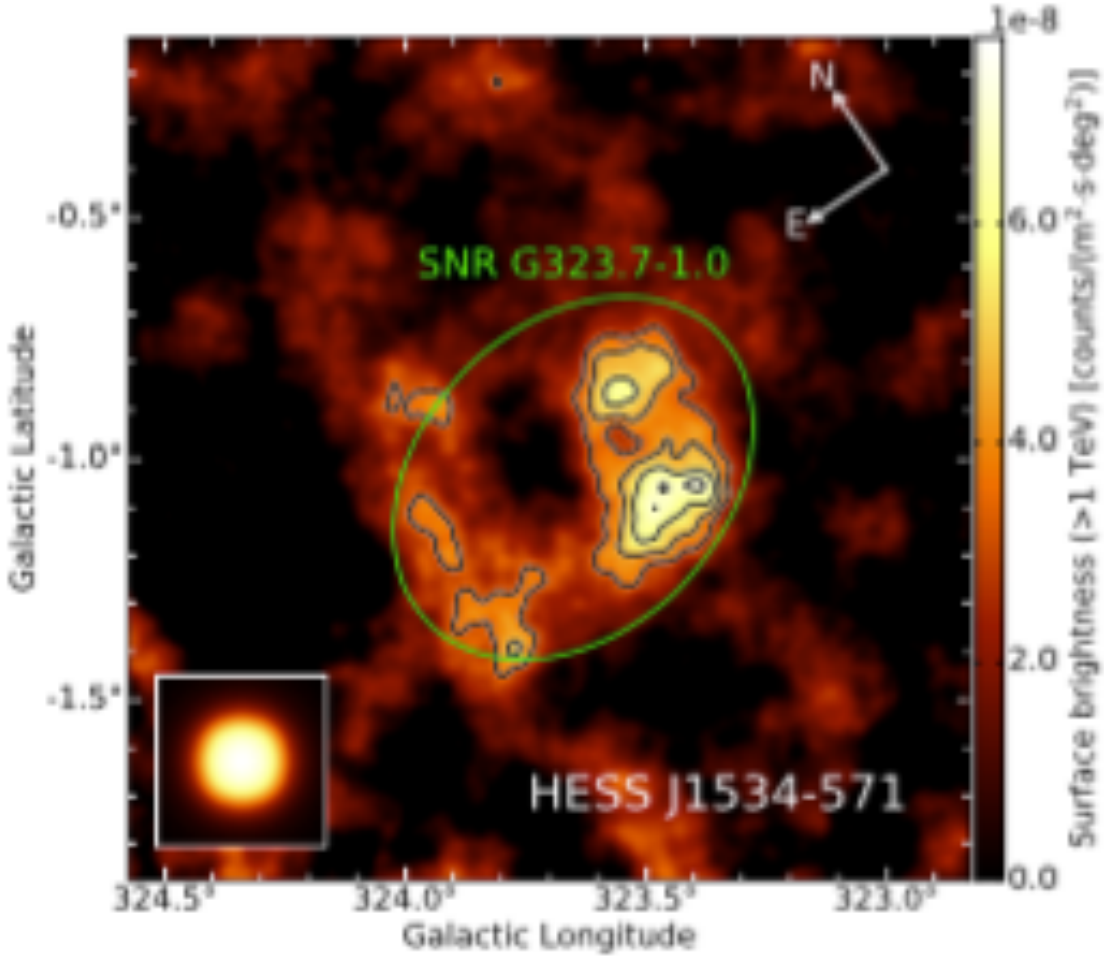


K. Luken, in prep.

The Milky Way's youngest SNR (~100 years)

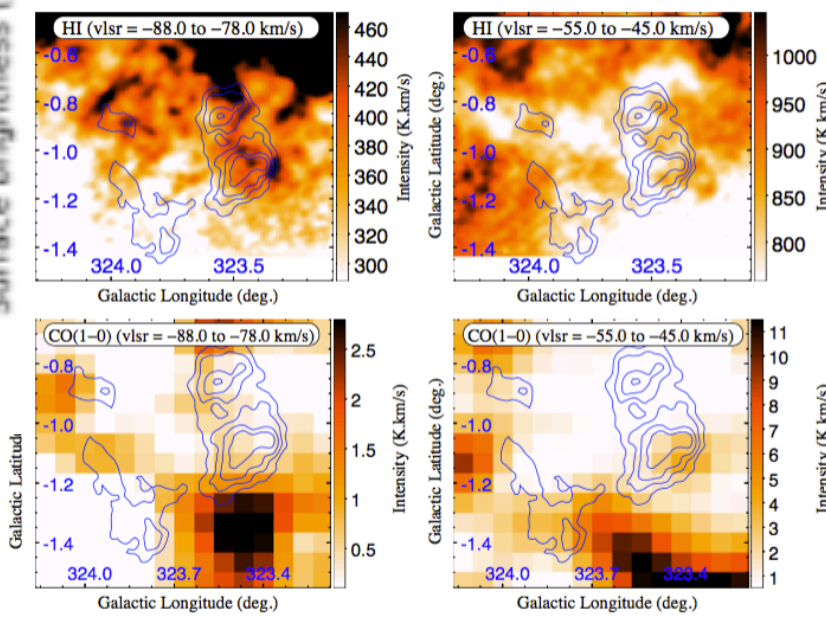
Signs of interaction, including brightening (?) → more to come

SNR HESS J1534-571



Discovered as SNR candidate (G323.7-1.0) at 843MHz by Green et al 2014

Confirmed by HESS to have a TeV shell counterpart.



Abdalla et al 2018 (see Gerd's talk)

Nigel I. Maxted[1,2*], C. Braiding[1], G. F. Wong[1,2], G. P. Rowell[3], M. G. Burton[1,4], M. D. Filipovic[2], Q. Roper[2], F. Voisin[3], D. Urosevic[5,6], B. Vukotic[7], M. Z. Pavlovic[5], H. Sano[8] and Y. Fukui[8]
[5]Department of Astronomy Faculty of Mathematics, University of Belgrade Studentski trg 16, 11000 Belgrade, Serbia
[6]Isaac Newton Institute of Chile Yugoslavia Branch, Serbia
[7]Astronomical Observatory, Volgina 7, 11060 Belgrade 38, Serbia

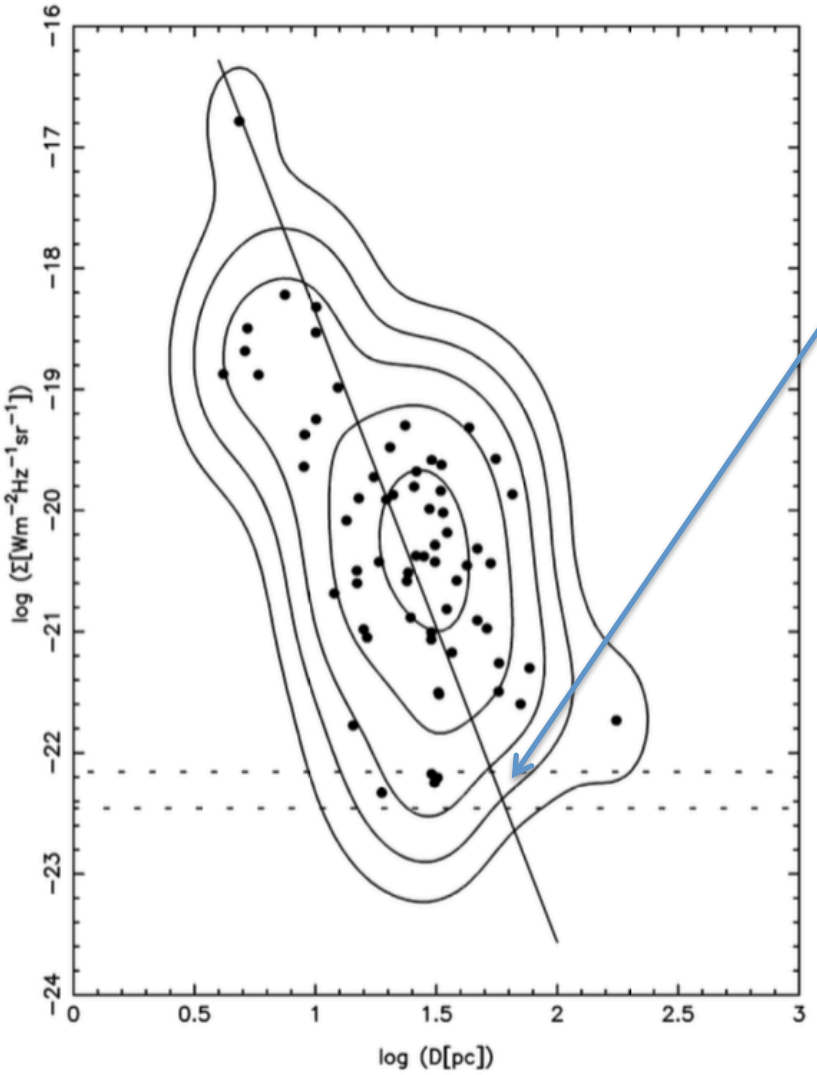
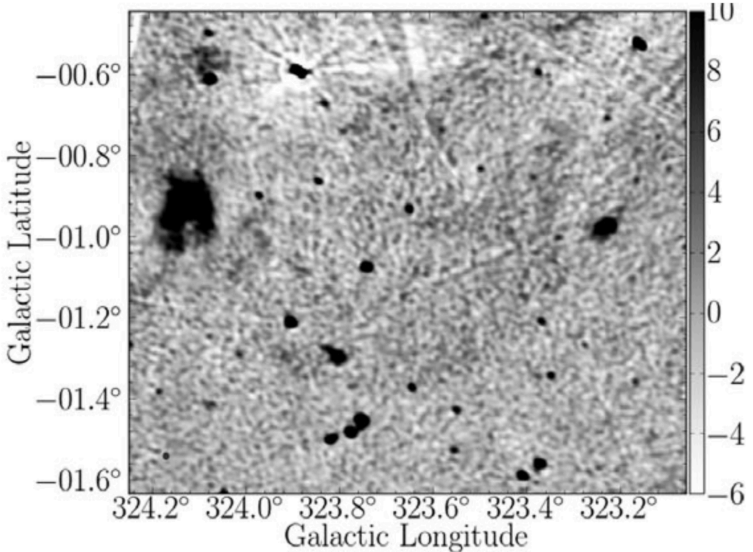


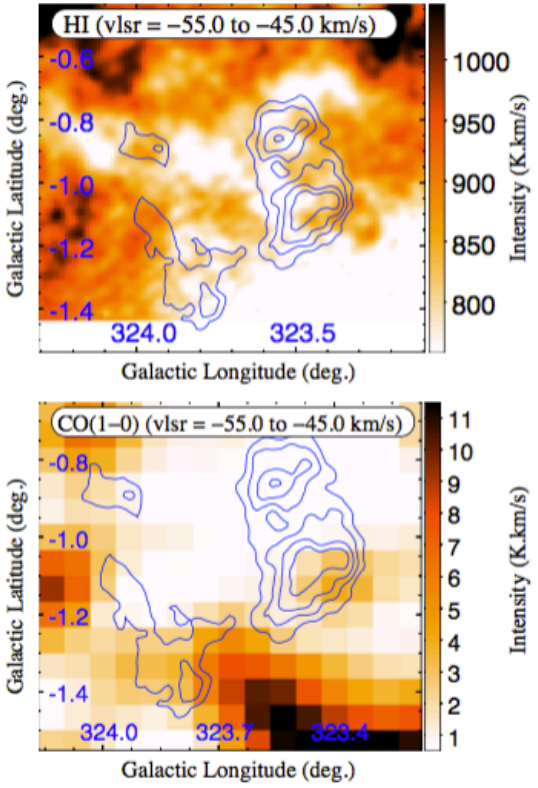
Figure 7. The Probability Density Function of the 1 GHz radio flux of 65 SNRs (from Pavlovic et al. 2014). The contour levels are at 0.02, 0.05, 0.1, 0.2 and 0.4. The solid line is the best fit from Pavlovic et al. while the dashed lines are the 1 GHz flux bounds (Σ) extrapolated from the HESS J1534−571 MOST 843 MHz flux (Green et al. 2014).

HESS J1534-571

Sigma-D distances based on 2 different methods that use the probability distribution of known-diameter SNRs yield:
~4.5 +/-2.5 kpc
~2.5 +3-1.5 kpc

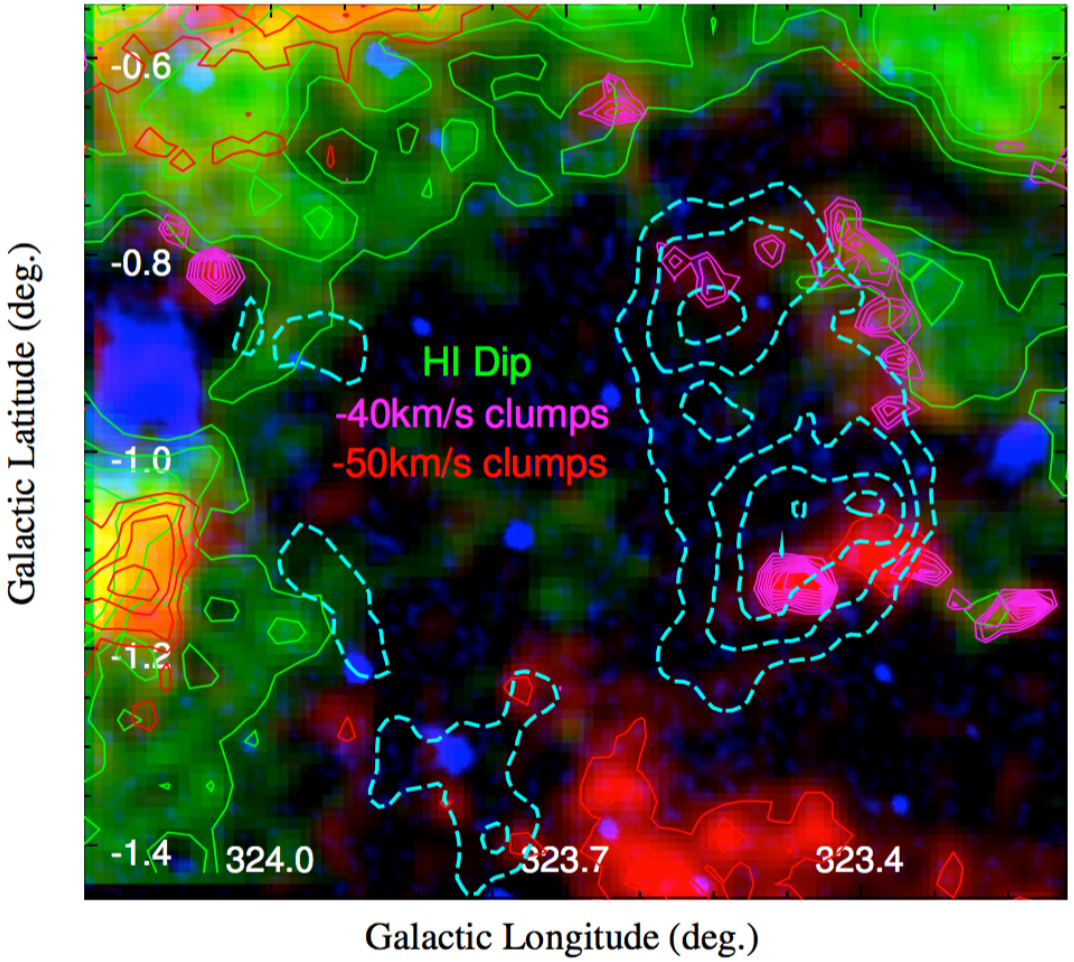


A new shell type supernova remnant, HESS J1534-571



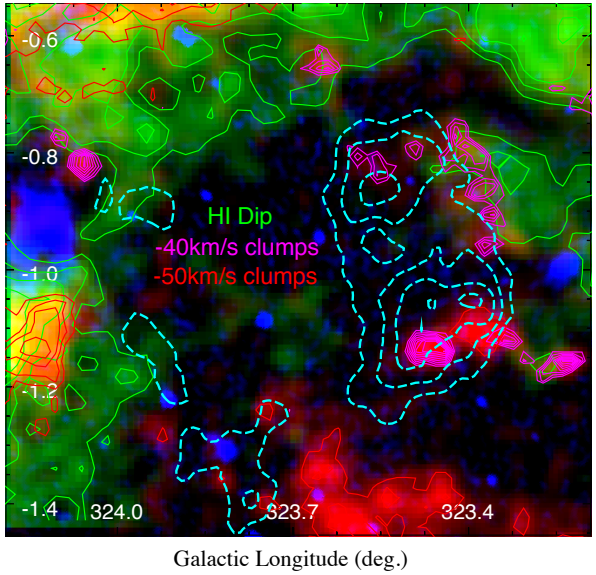
Have we found the SNR distance through a gas association?

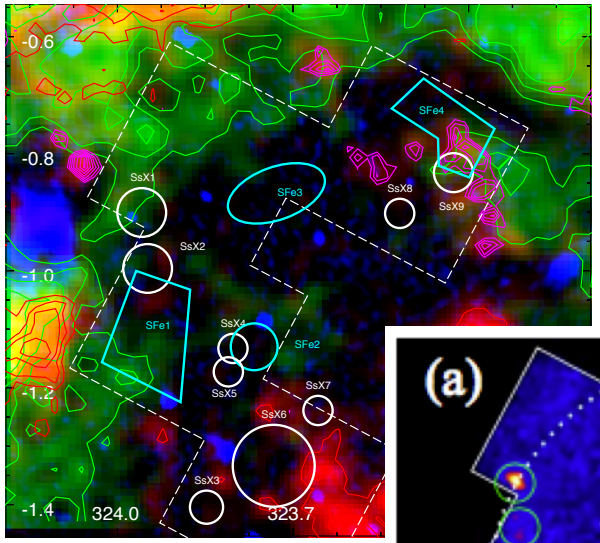
If so, core-collapse?



Maxted et al, submitted

HESS J1534-571



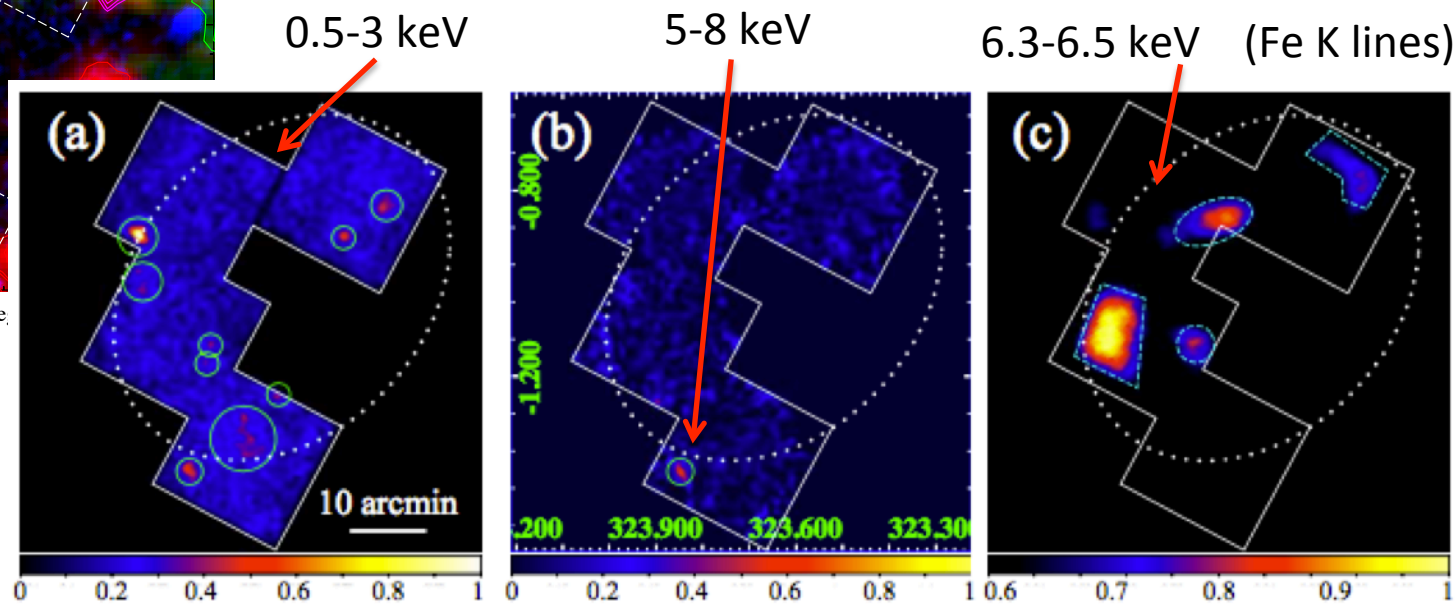


HI cavity at ~3.5 kpc (Maxted et al, submitted)

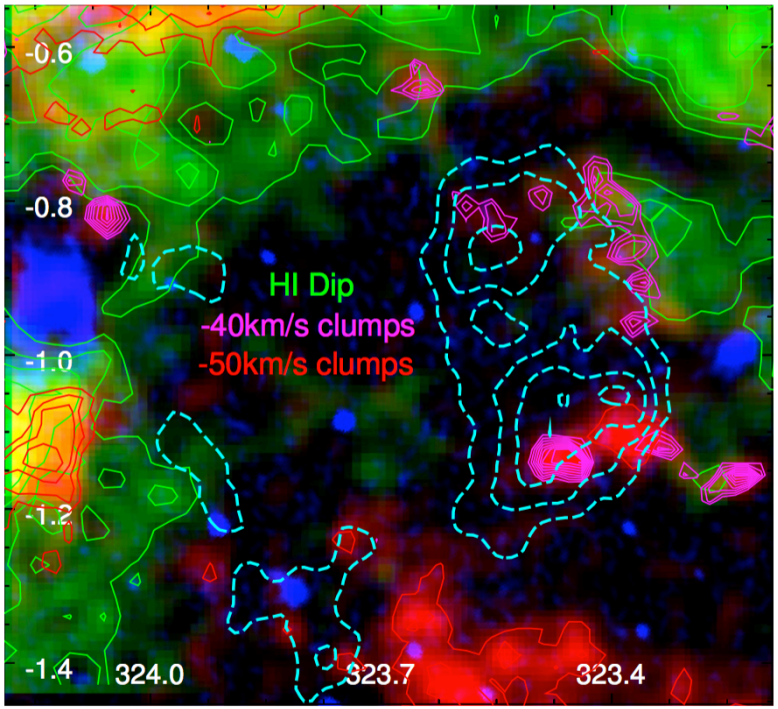
Leptonic modelling, inferred infrared photon density
→ 4-5 kpc (Araya et al 2017)

X-ray absorption favours, 6+/-2 kpc (Saji et al 2017)

Scaled Sigma-D → ~5 kpc (Abdalla et al 2018)
Our Sigma-D analysis → ~4.5 +/-2.5 kpc, ~2.5 +3-1.5 kpc



Saji et al 2017



HESS J1534-571

Assuming a distance of 3.5 kpc,

age ~ 8-24 kyr

(modelling with Leahy & Williams 2017 assuming 0.5e51erg, 0.01-0.1/cm^3, uniform ISM)

SNR	d^a (kpc)	D^a (pc)	Age^a (yr)	Molecular Mass^a ($M_\odot$)	Γ_γ	$L_{\gamma,1-10\,TeV}$ (10^{33} erg s^{-1})
RX J0852.0−4622	0.75	26	$\sim 10^3$	$\sim 1\times10^3$	1.81	5.7
RX J1713.7−3946	1.0	20	1.6×10^3	9×10^3	2.06	7.2
HESS J1731−347	3.2	30	$\sim 2.5\times10^3$	5×10^4	2.32	8.5
	5.2	49	"	$4\text{-}5\times10^4$		22.4
HESS J1534−571	1.2	17	[b,e] $1.3\text{-}5.5\times10^3$	$1.7\text{-}5.0\times10^3$		1.1
	3.5	49	[c,e] $8\text{-}24\times10^3$	$0.9\text{-}2.2\times10^4$	2.51	9.6
	7.2	100	[d,e] $>32\times10^3$	$1.4\text{-}4.2\times10^5$		40.4

HESS J1534-571 alongside Type II TeV shell SNRs

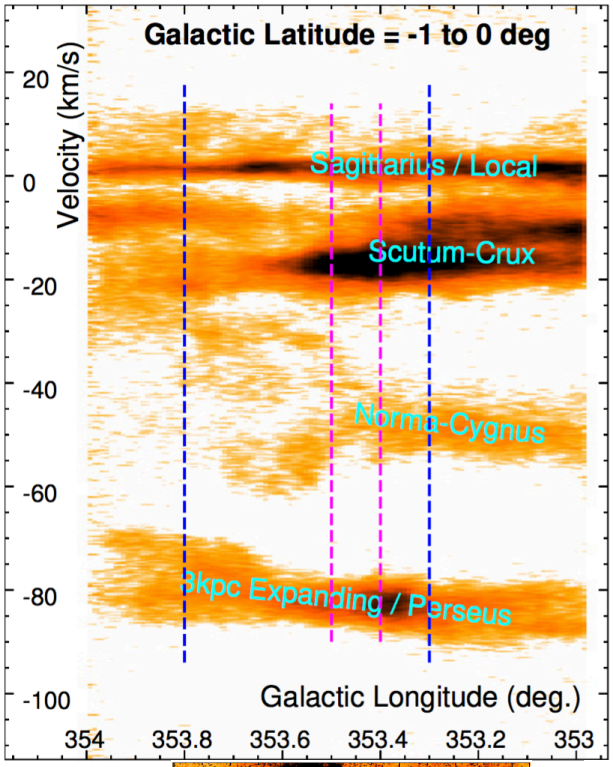
(Maxted et al, submitted)

Probing the local environment of the supernova remnant HESS J1731−347 with CO and CS observations

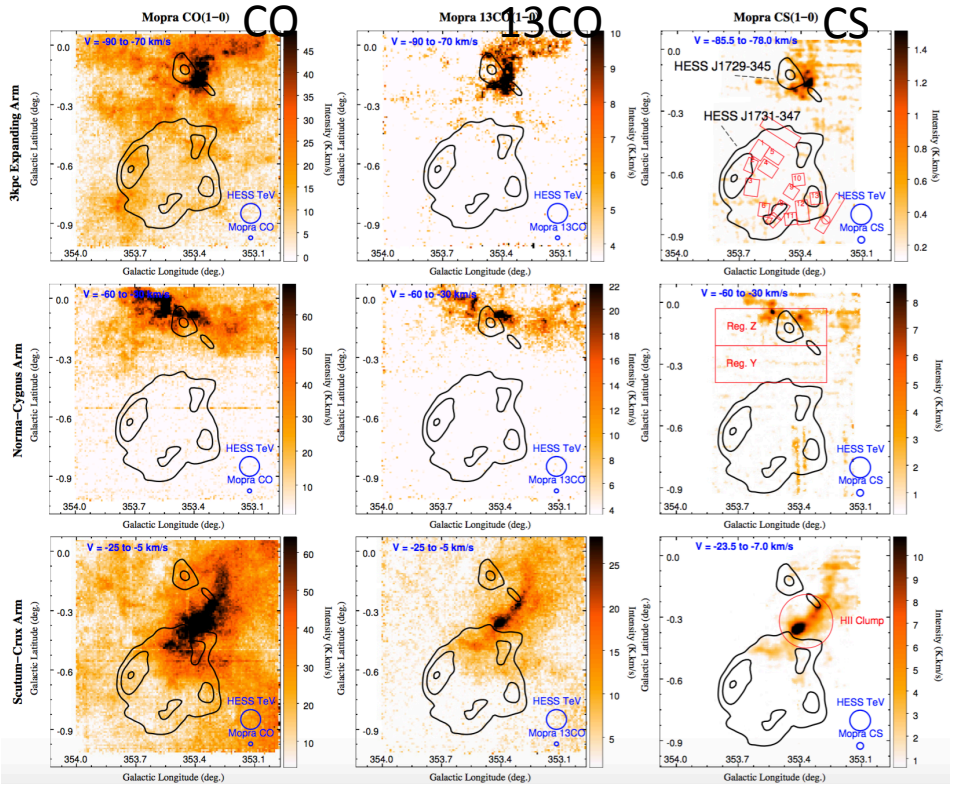
*New dense gas morphology

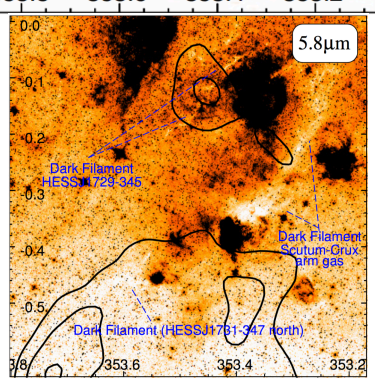
*Infrared and radio correspondences

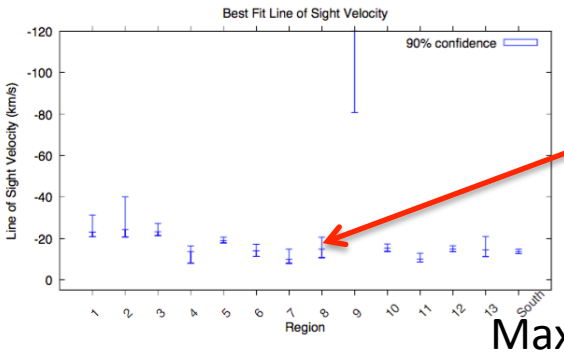
*New X-ray absorption distance estimate

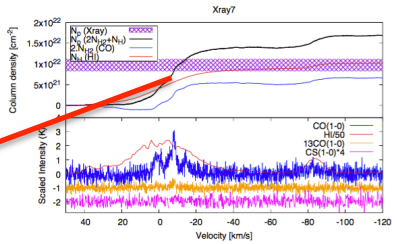


CO 13CO CS



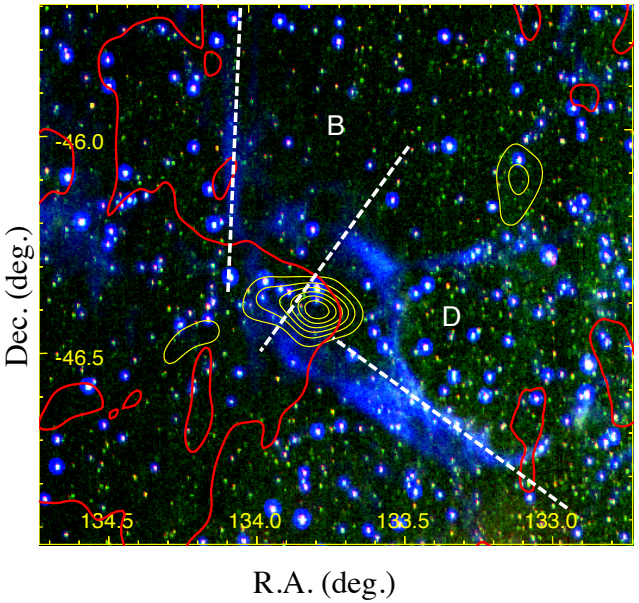




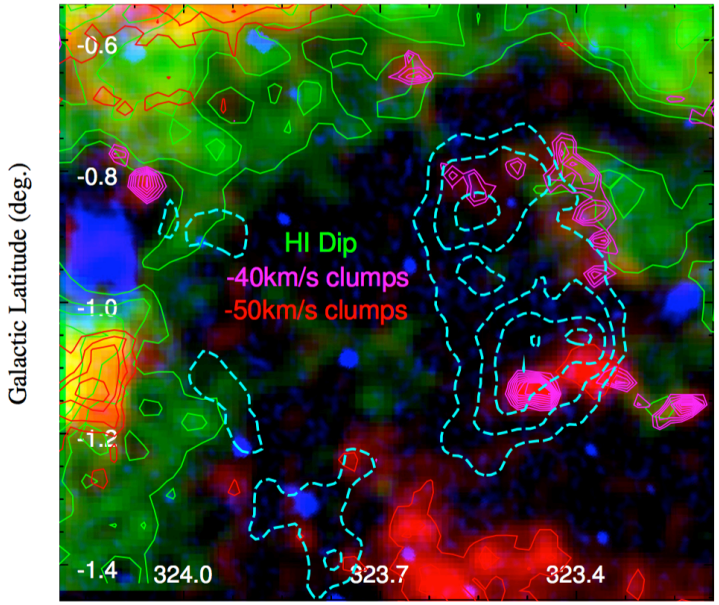


Maxted et al, 2018, MNRAS

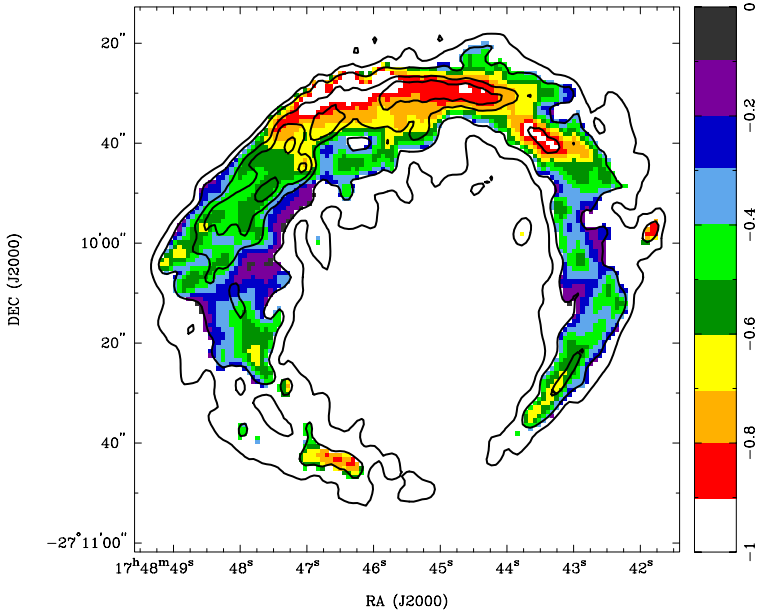
Thank you



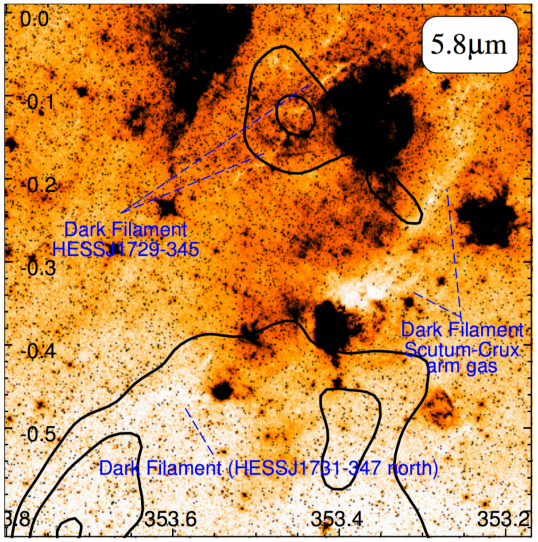
Vela Jr



HESS J1534-571



G1.9+0.5



HESS J1731-347