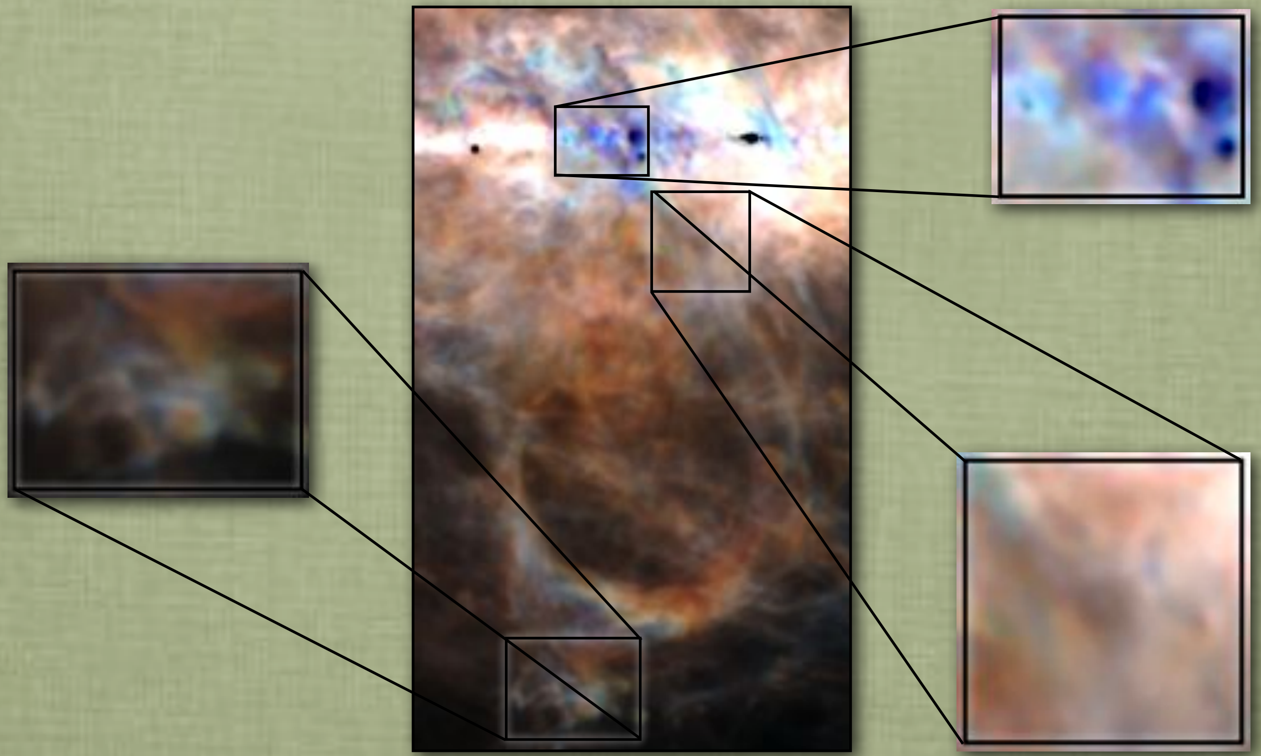

Galactic Supershells and GSH 006-15+7

Vanessa A. Moss

Parkes 50th Symposium

3rd November 2011

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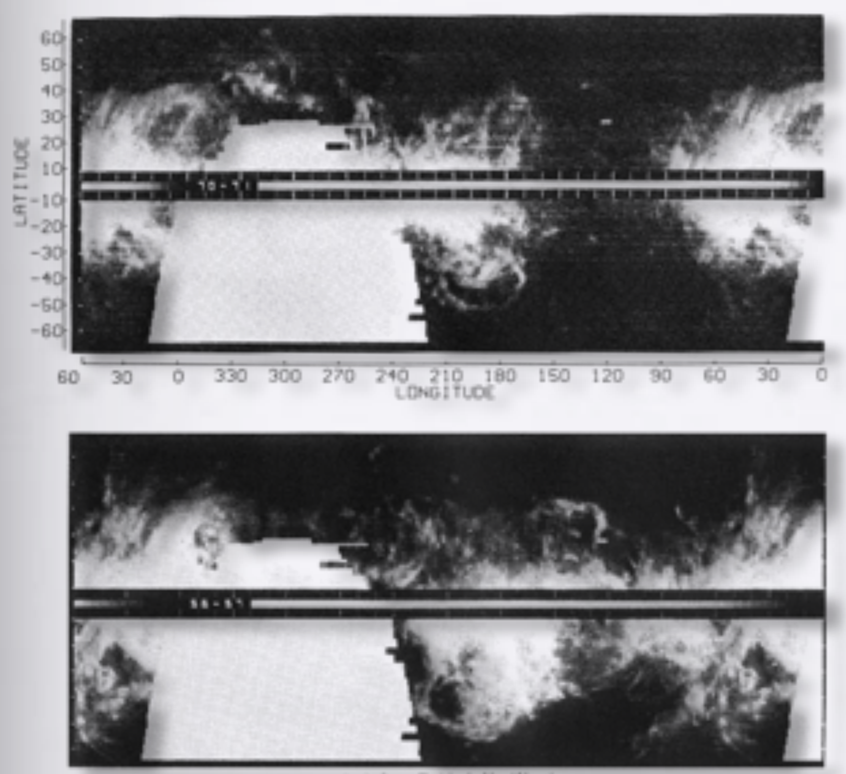
Early history of supershells

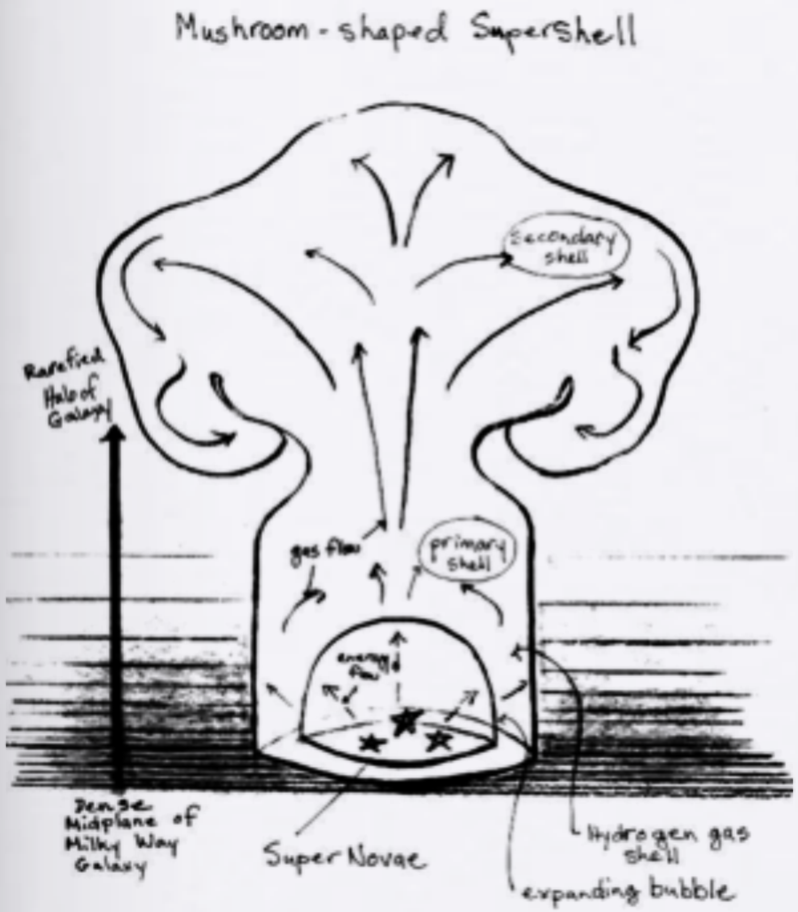
The discovery of HI 'holes'



Heiles (1976)

- Expanding structures in HI were first seen by Heiles (1976) in the Hat Creek survey, who suggested these were expanding HI shells
- These 'holes' in neutral hydrogen were then catalogued by Heiles (1979), followed by Hu (1981), Heiles (1984) and McClure-Griffiths et al. (2002) in the south
- Note the absence of the southern hemisphere

Early interpretations of supershells



http://www.ucalgary.ca/ras/node/221

- Heiles (1976) offered two models
  - a) *"An interstellar bubble blown by a stellar wind?"* (not enough energy)
  - b) *"An old supernova explosion?"* (some energy agreement)
- Heiles (1979) deemed them `supershells', based on their size and energy requirements
- It was clear from early on that the biggest supershells could *not* be produced by a single supernova

Early interpretations of supershells

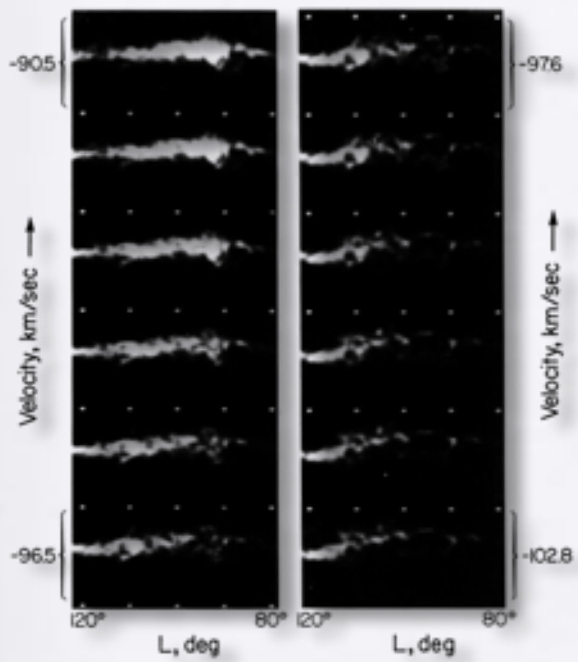
The number of shells visible in the complete set of photographs is large. Nearly every H I density concentration appears to be part of a large arc and therefore an expanding shell in the present interpretation.

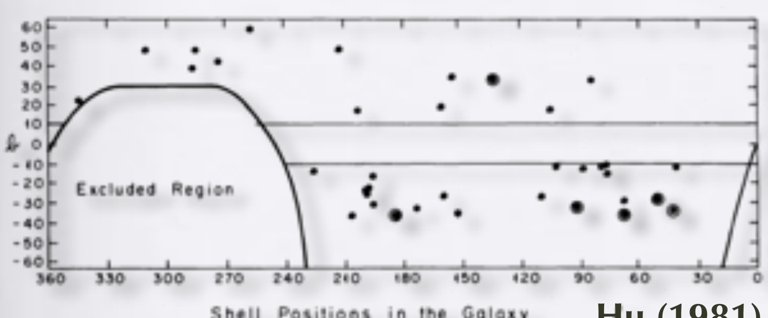
Alternatively, or in addition, it is not unlikely for a supernova to be located inside a cavity created by previous supernovae—particularly since Type II supernovae result from young stars which tend to be formed in clusters.

Surveys of supershells

Northern hemisphere surveys for Galactic supershells

Heiles (1979)



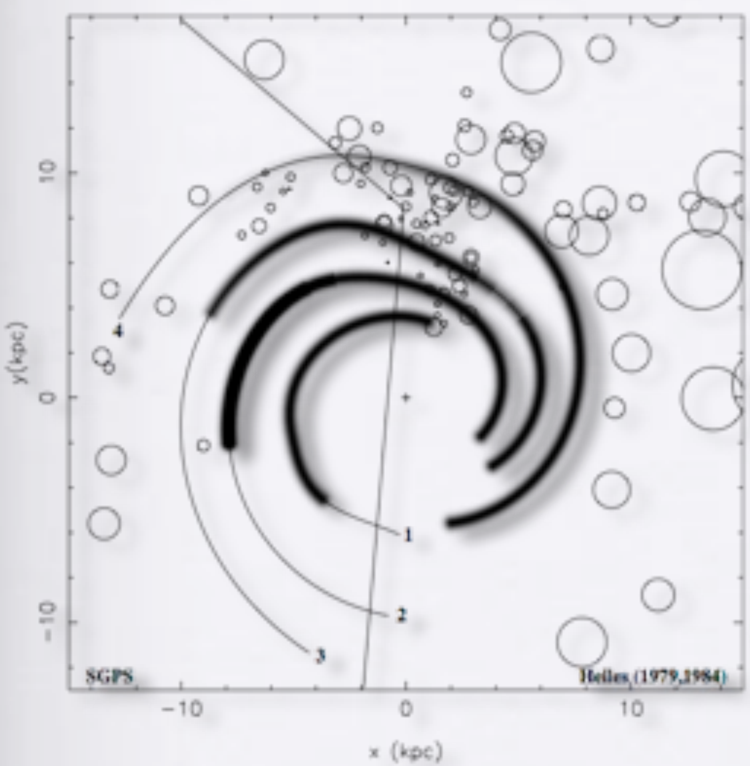


Hu (1981)

- Much work in this field is done on individual interesting objects
- First catalogues produced by the discoverer of supershells - Heiles (1979), Heiles (1984)
- Another catalogue produced by Hu (1981) - this traced a high latitude population uncorrelated with OB stars
- Ehlerova & Palous (2005): an automated search for supershells revealed hundreds (?) more

Southern hemisphere surveys for Galactic supershells

McClure-Griffiths (2002)



- The only catalogue of Galactic supershells in the southern hemisphere is McClure-Griffiths et al. (2002), which contains 19 supershells found with Parkes data (from SGPS)
- The lines on the map divide the southern/northern hemispheres

The important role of Parkes

- Southern Galactic surveys for supershells have depended on Parkes data: SGPS, GASS
- The Parkes multibeam receiver played a key role in being able to survey the sky at high speed
- Thanks to Parkes/GASS, the entire HI southern sky is now available
- Significance of surveys - SGPS/HIPASS/GASS are still being used for new science discoveries

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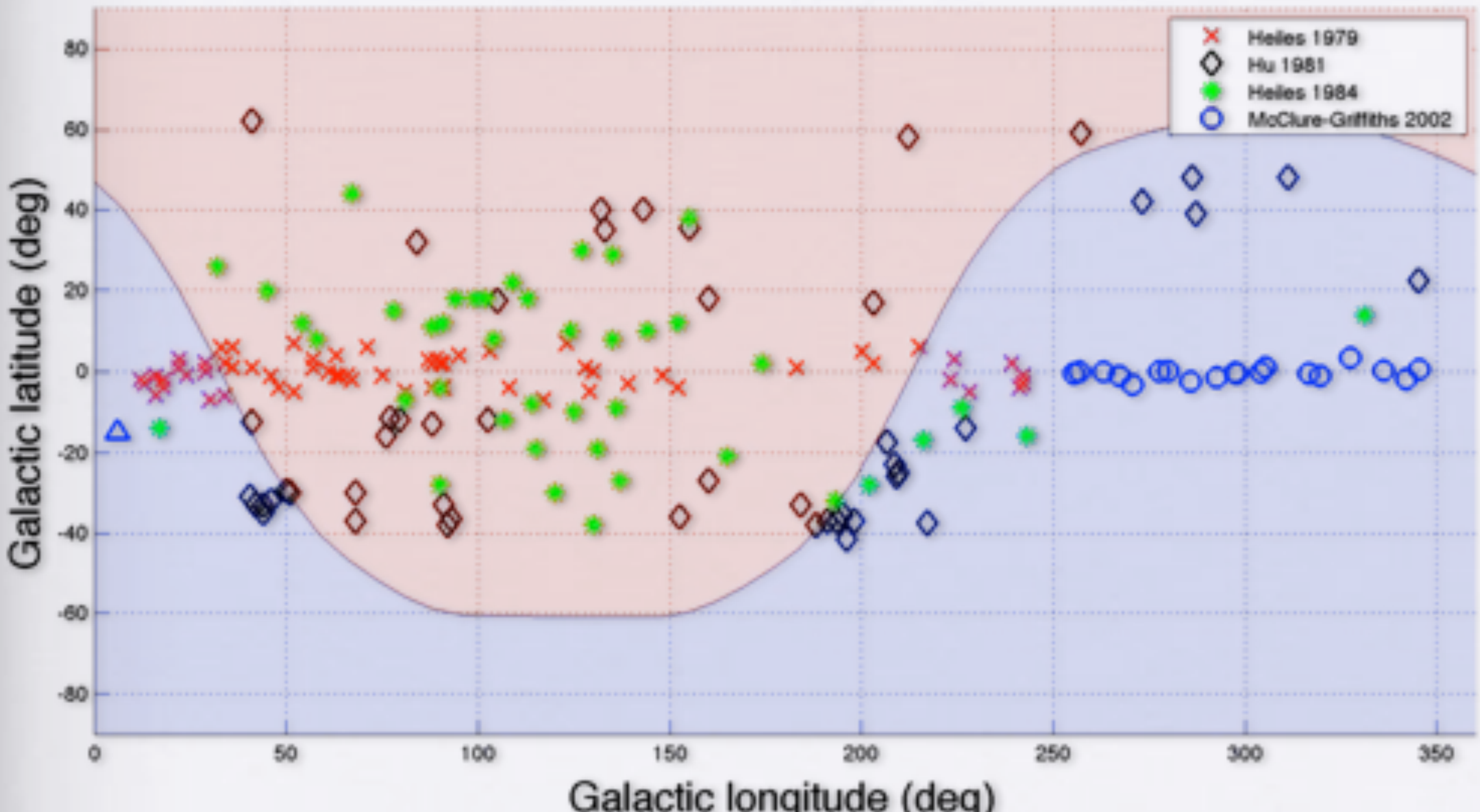
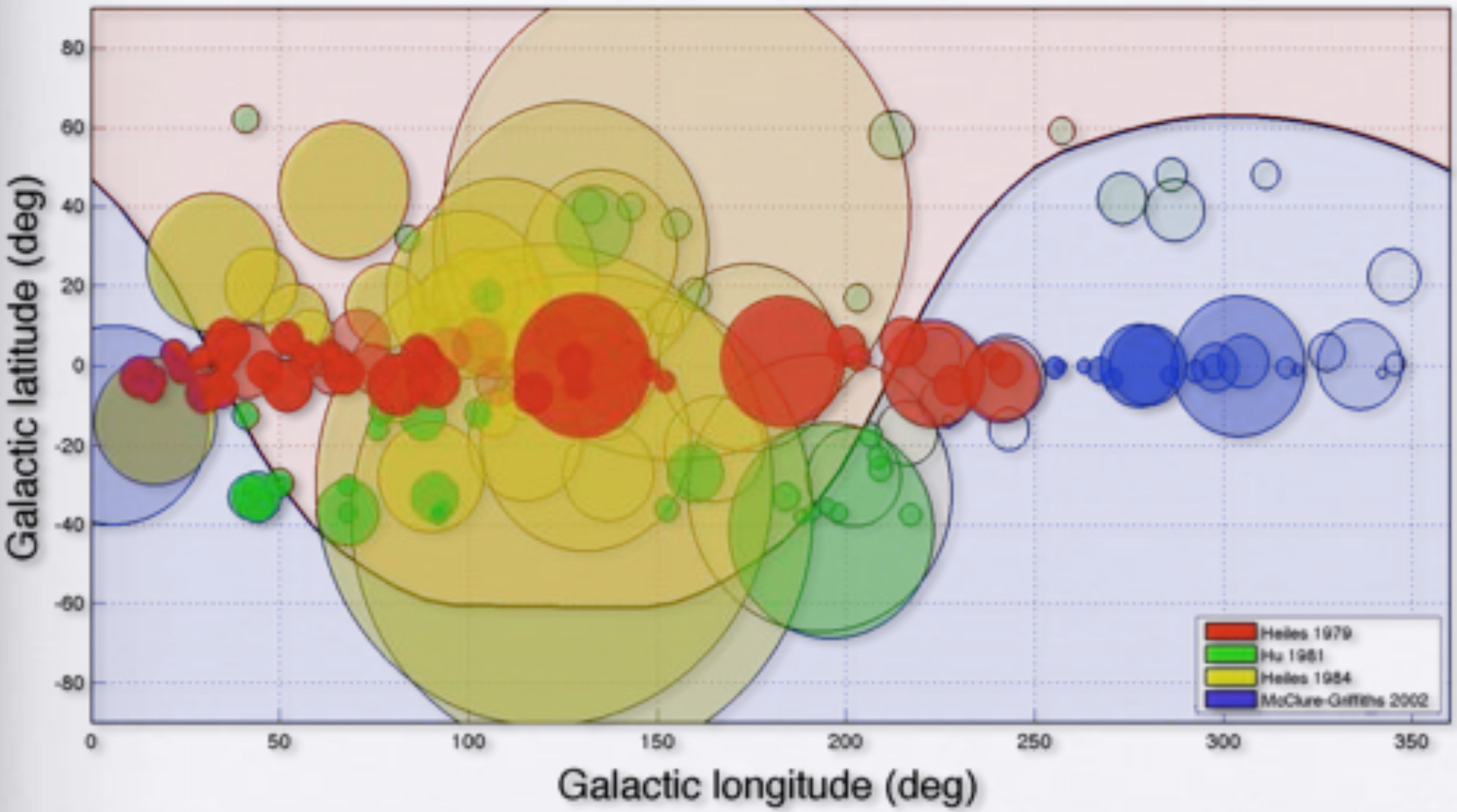
Distribution of Galactic supershells



Distribution of Galactic supershells



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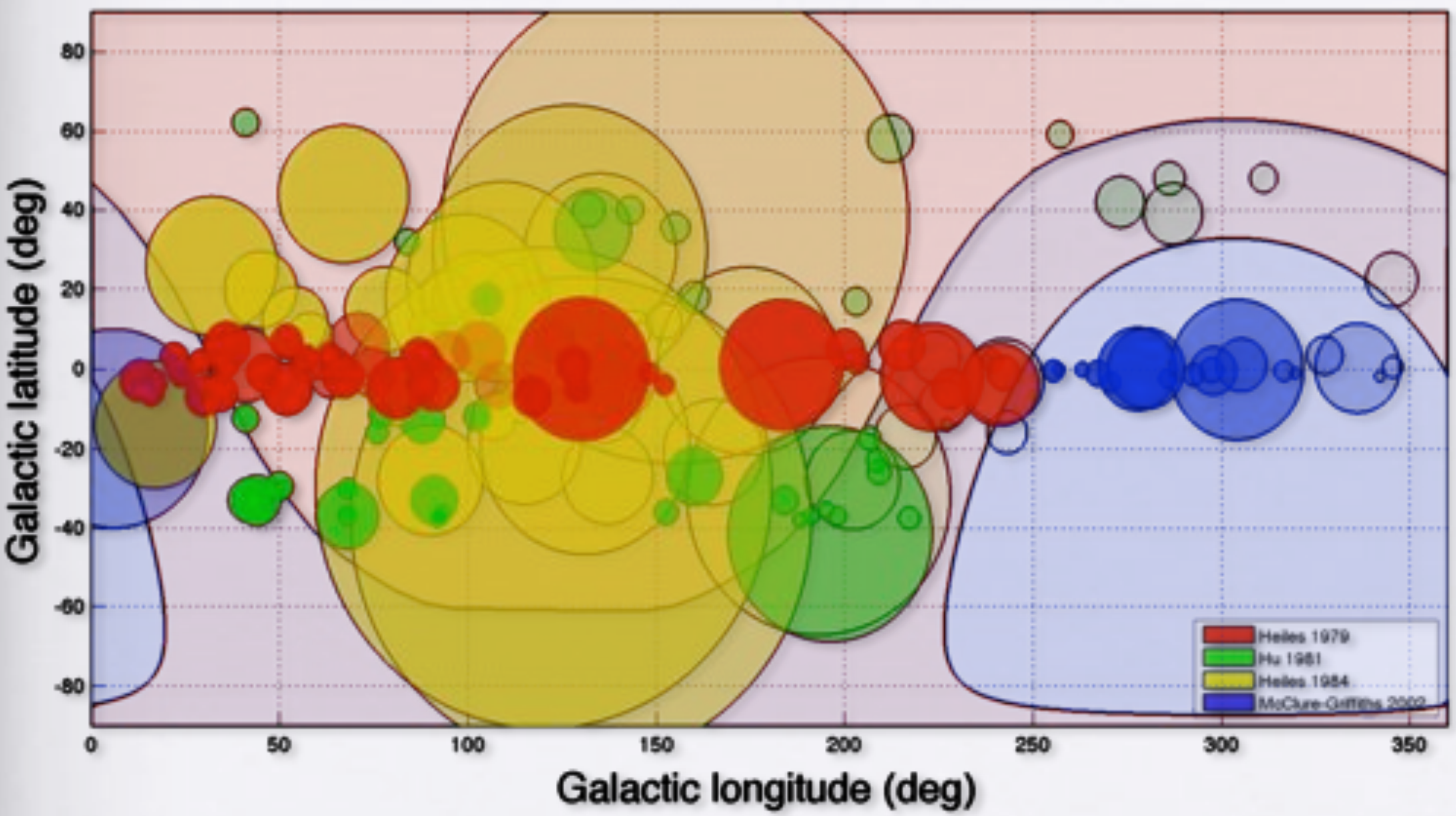

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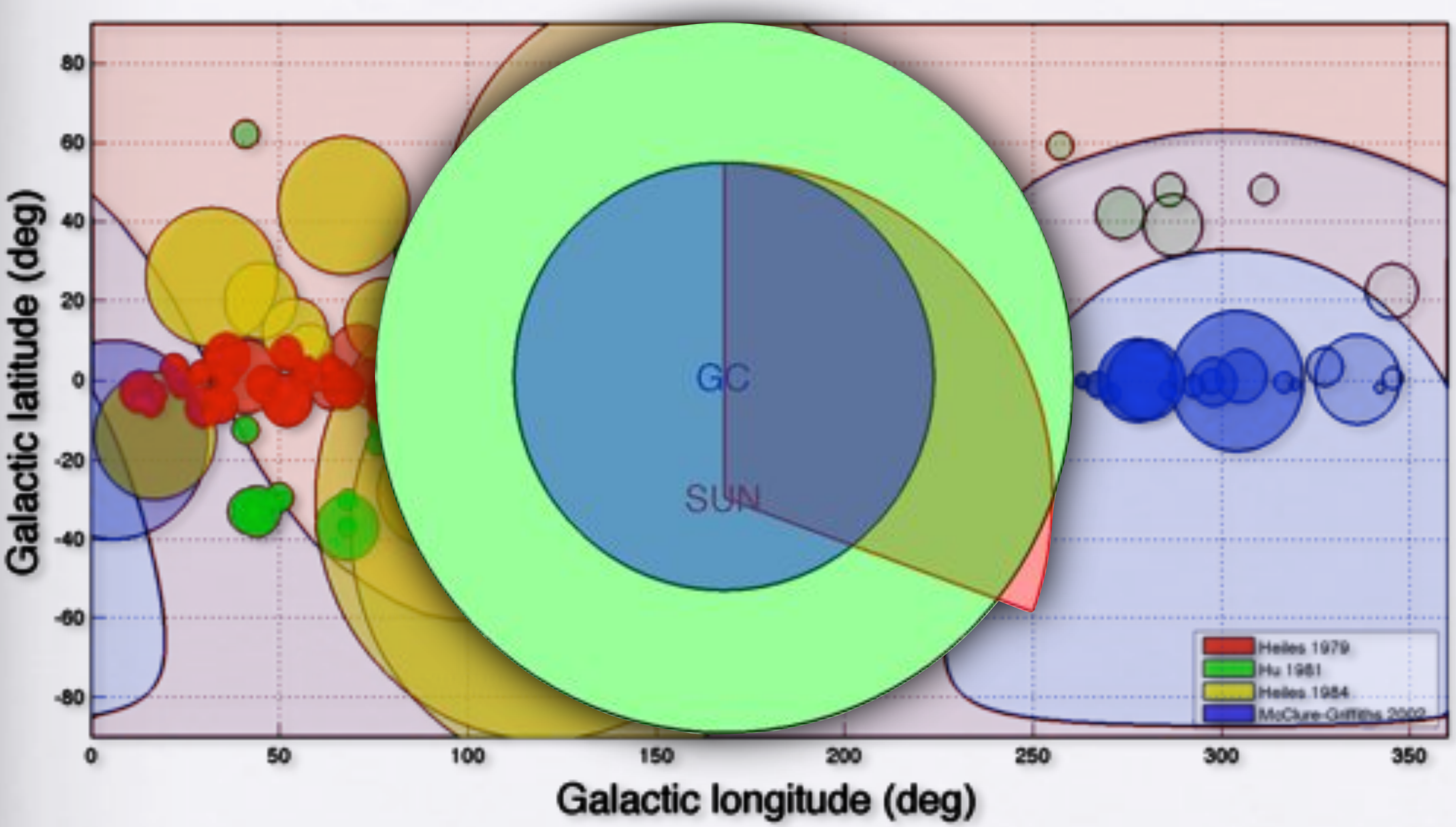
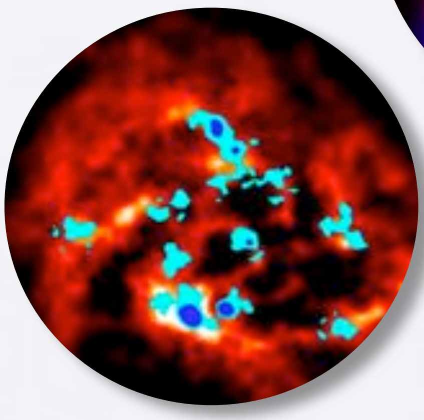


Supershells and superbubbles in other galaxies

- Supershells have also been discovered in other galaxies, mostly in the Local Group
- Henize (1956), Davies et al. (1976), Meaburn (1980): HI bubbles observed in the Magellanic system in optical/Hα
- Brinks & Bajaja (1986): ~140 HI holes found in M31, some also correlated with OB associations
- Also found in NGC 891, 1313, 3079, 4631, 5775, etc...

N44 (LMC)

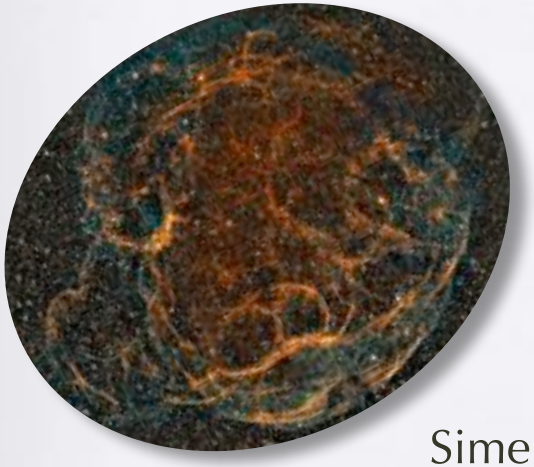


HI/CO map of IC 10
UHerts/THINGS

Life cycle of a supershell

Supernovae and supernova remnants

Crab nebula
http://apod.nasa.gov/apod/ap991122.html



Simeis 147
http://apod.nasa.gov/apod/ap090131.html

- The physical processes that drive supershell expansion are similar to high-mass stars and SNRs: stellar winds of high-mass stars and shock expansion of SNe
- Because of this, SN theory is commonly applied to or expanded for supershells

OB associations and high-mass stars

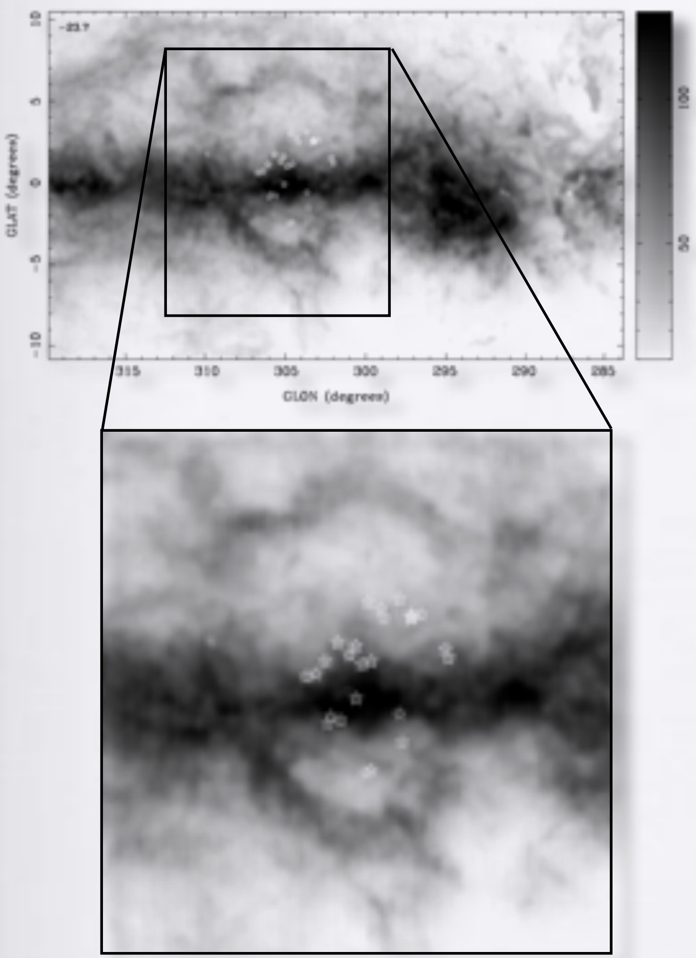
OB cluster in NGC 3603

http://www.eso.org/public/images/eso9946a/

- OB associations are collections of high-mass stars, greater than 8 solar masses, which have likely formed from the same parental molecular cloud
- These allow the transition from supernova theory to supershell theory,with multiple supernovae (SNe) in a “small” region

Young supershells: GSH 305+01-24

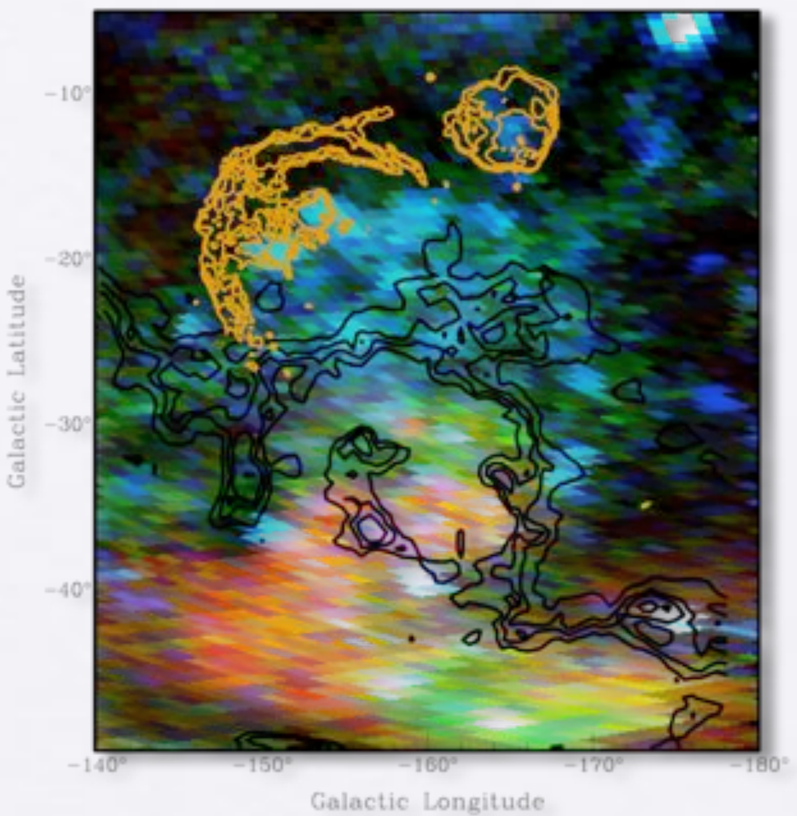
McClure-Griffiths (2001)



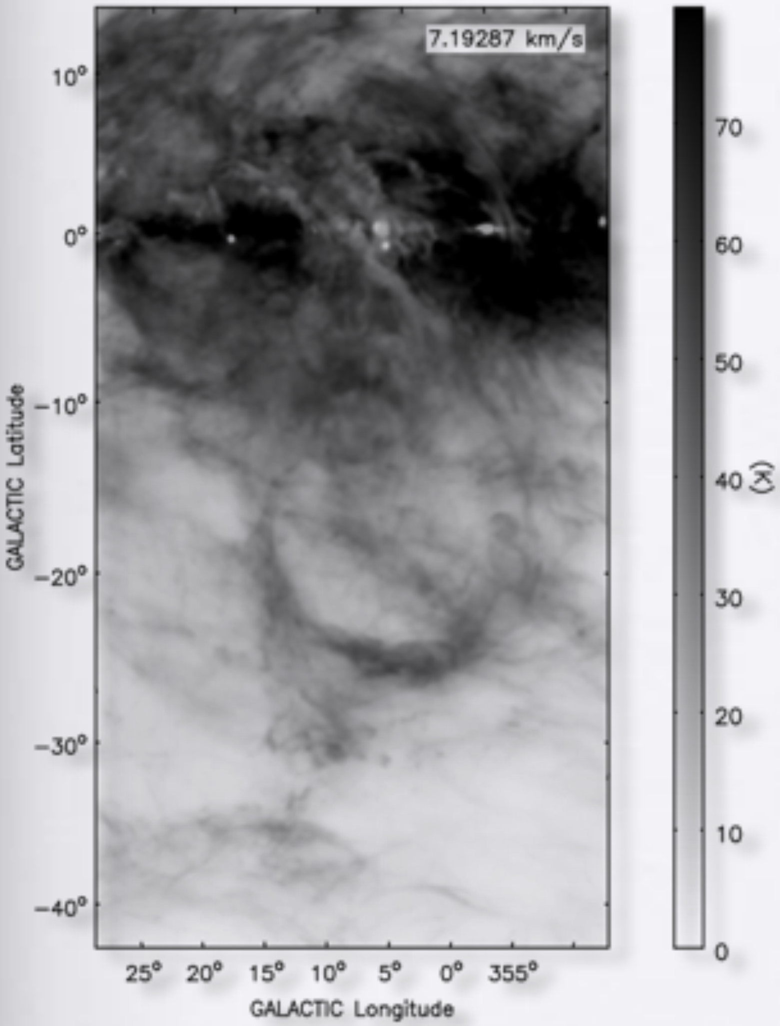
- McClure-Griffiths et al. (2001): New HI supershell discovered behind the Coalsack Nebula (2.2 kpc, with ~360 pc diameter)
- Energy arguments (Weaver et al. 1977) show that the formation of this supershell can be accounted for by the winds of Cen OB 1
- This OB association contains 21 stars with the earliest being O9 and including a Wolf-Rayet star

Young supershells: Orion-Eridanus superbubble

- Reynolds & Ogden (1979): evidence of an expanding shell associated with Orion OB1 (age of ~2 Myr, diameter ~280 pc at a distance of ~460 pc)
- Heiles et al. (1999): Orion-Eridanus superbubble contains HI, X-ray, infrared and Hα
- Lee & Chen (2009): triggered star formation observed in the walls surrounding Orion-Eridanus

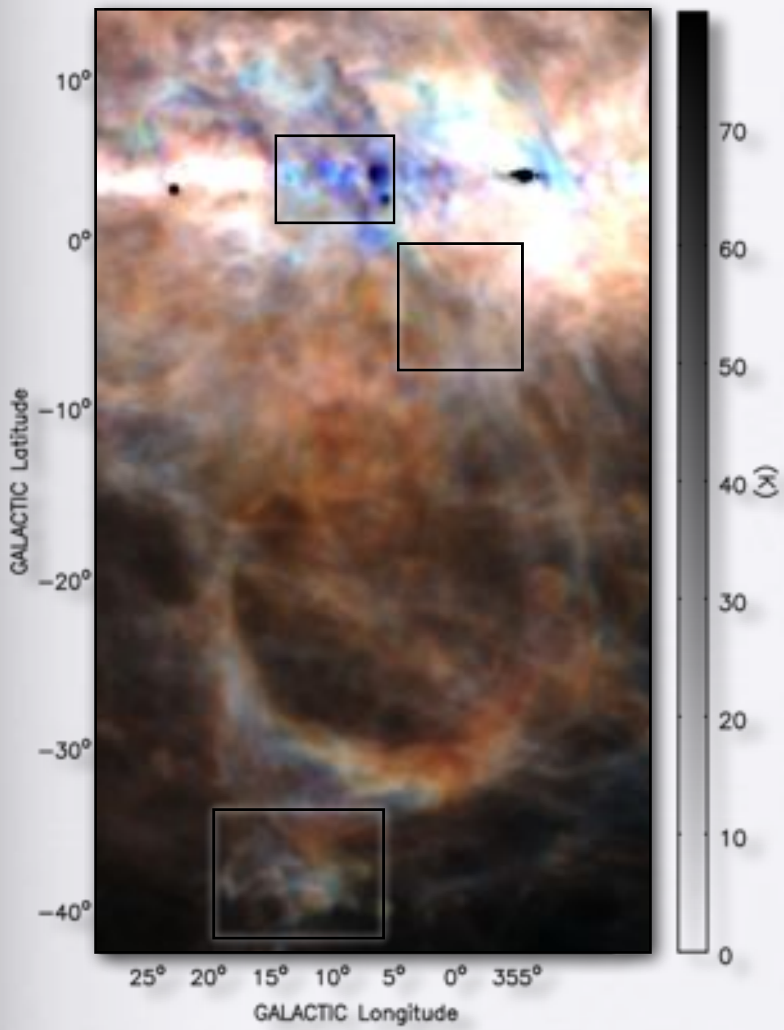


Old supershells: GSH 006-15+7



- Newly discovered supershell in the Galactic All Sky Survey data (Moss, McClure-Griffiths & Braun, 2011, in review)
- A nearby (~1-2 kpc), large (~800 pc off the Galactic plane), old (10-20 Myr) supershell
- GSH 006-15+7 is a case study in HI self-absorption, supershell powering sources and possible fragmentation at high-latitude
- A player in disk-halo interaction?

Old supershells: GSH 006-15+7



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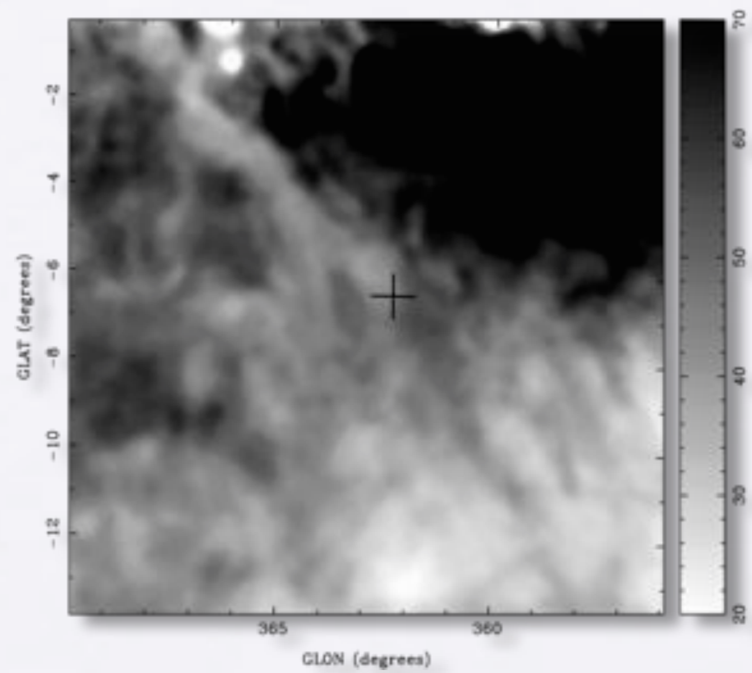
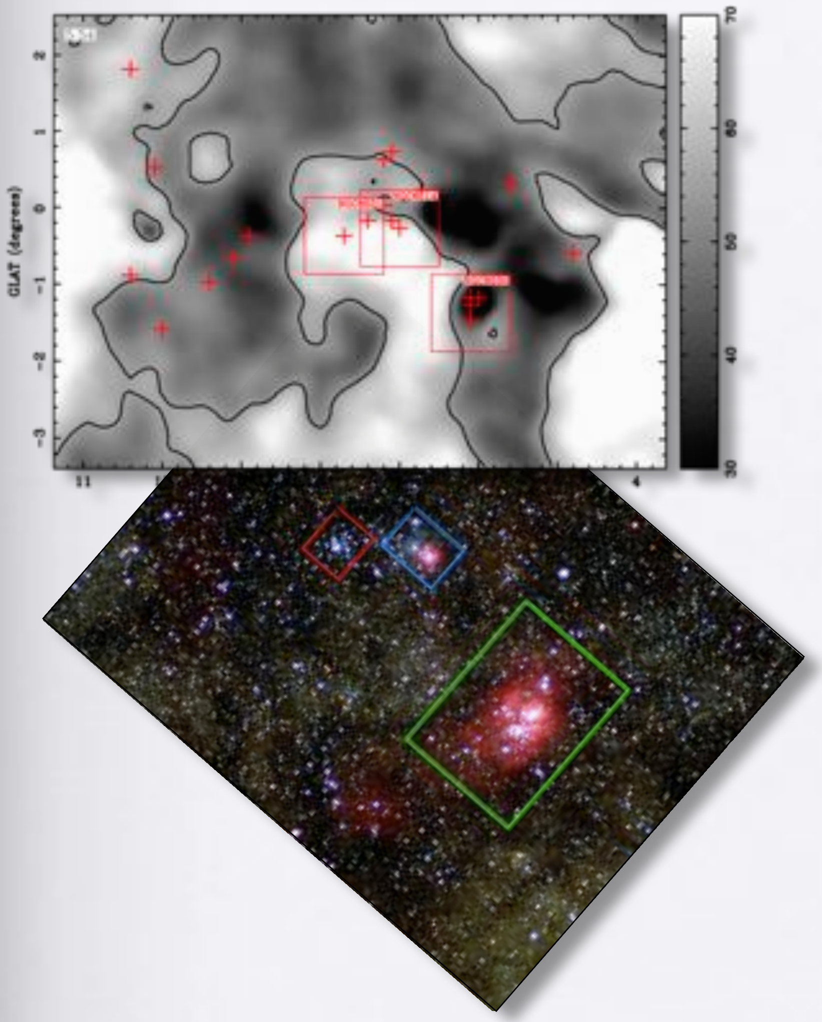
GSH 006-15+7: What does HISA tell us about mass?

- Column density mass estimates are used for supershells - under the assumption of negligible optical depth
- HISA proves that optical depth is not zero, so we can revise a mass estimate based on absorption
- We find that the spin temperature is ~40 K, which indicates an optical depth of ~3 and a mass of ~3-5 x 10^6 solar masses



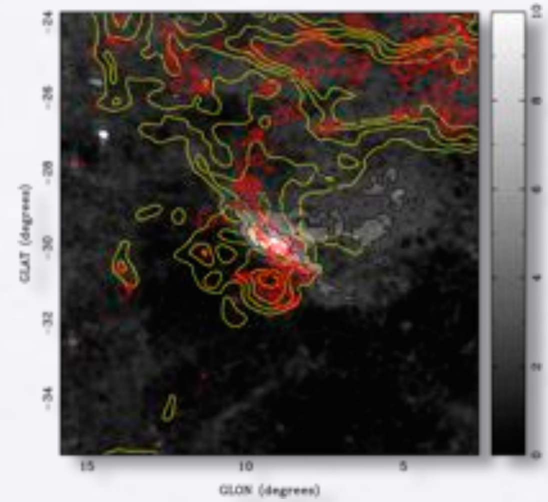
GSH 006-15+7: Traces of a powering source region

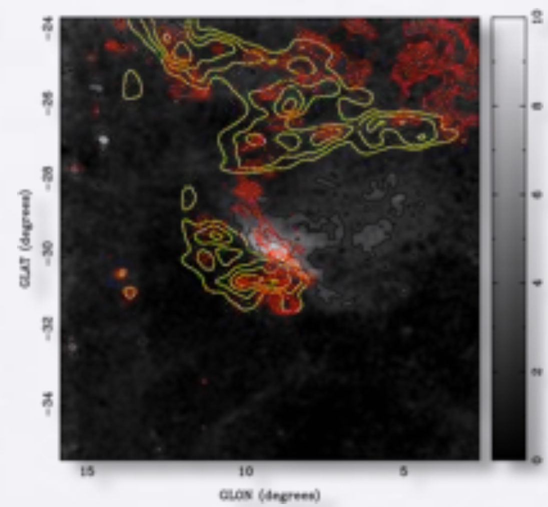


- Candidate powering sources: Sagittarius OB 1 and open clusters NGC 6514, 6530, 6531
- Stellar winds: with the stellar type, we can integrate for total energy output due to winds
- Initial mass function: estimate number of stars already gone SN, and their wind/supernova energy
- 3 x 10^{51} (winds) + 4 x 10^{51} (SNe) ~ 10^{52} ergs (rough formation energy of GSH 006-15+7)

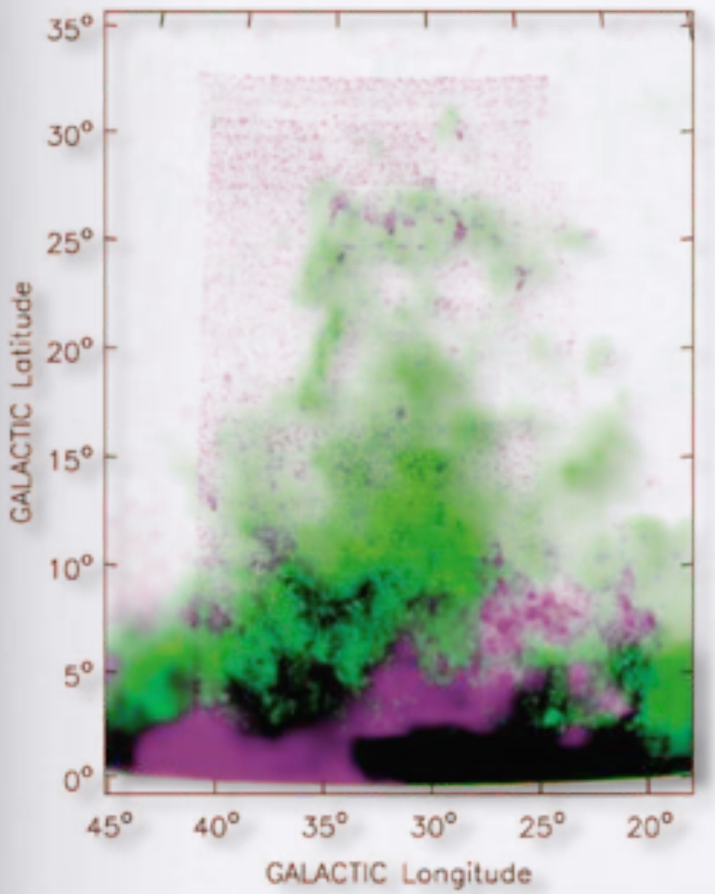
GSH 006-15+7: Possible evidence of blowout

- We see correlation between HI, IR and Hα at high latitudes
- Image: HI shell (yellow contours) and 100 μm dust emission (red contours) overlaid on Finkbeiner Hα map
- The correlation we see between HI and IR suggests that the shell is beginning to fragment
- Can we explain the presence of the Hα feature? *Maybe...*





Old supershells: Ophiuchus superbubble

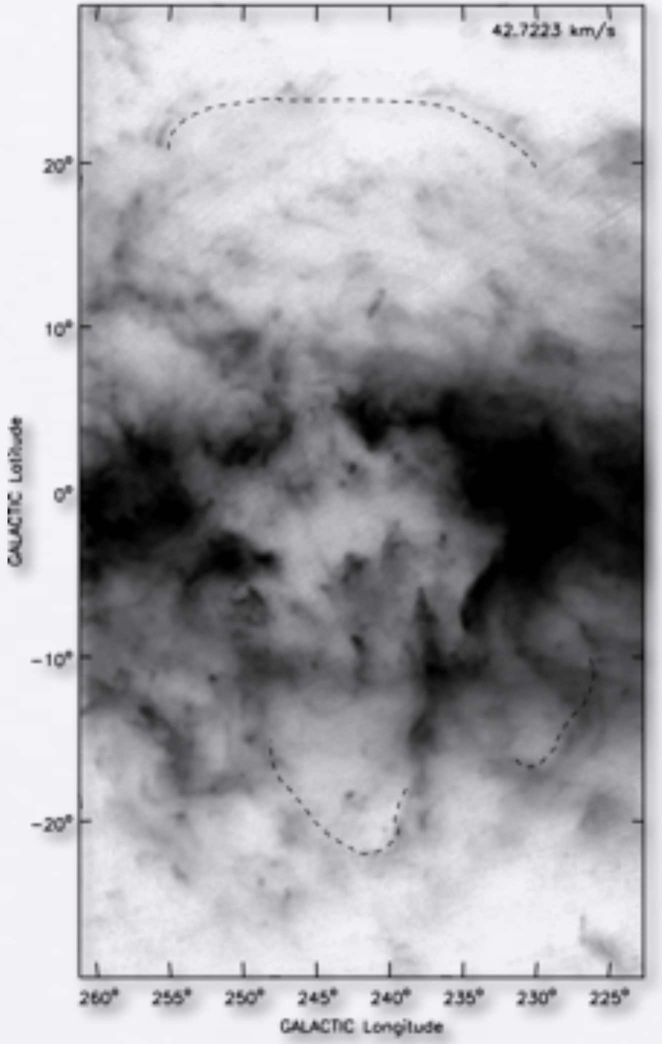


Pidopryhora & Lockman (2007)

- Pidopryhora & Lockman (2007): discovery of a giant supershell at a distance of 7 kpc
- 10^6 solar masses with a peak height of 3.4 kpc off the plane (whiskers reaching 1kpc!)
- Correlation between Hα (green) and the shell (purple) - described as a "coherent structure of gigantic proportions"
- Evidence for co-rotation of plume with Galactic gravitational field based on CO velocities

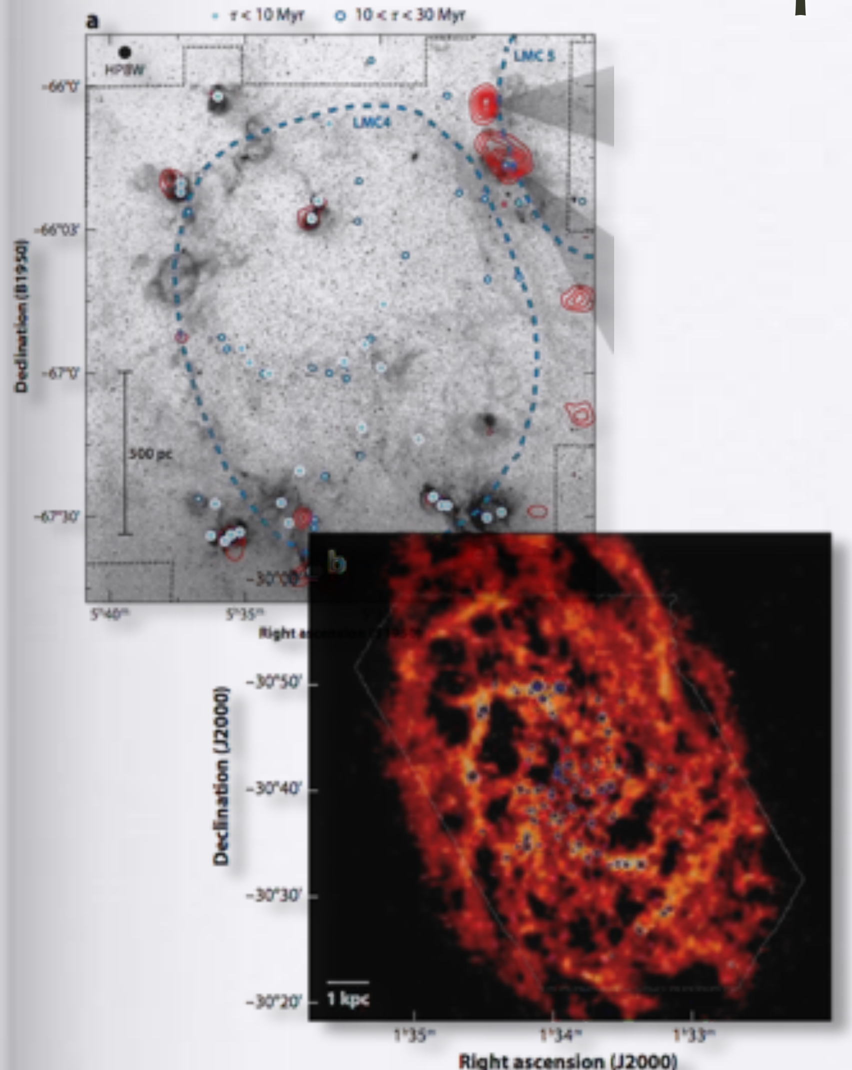
Chimneys: GSH 242-03+37

- McClure-Griffiths et al. (2006): there is evidence for chimney breakout in GSH 242-03+37
- One of the largest HI supershells (radius > 500 pc) and formation energy of the order of 10^{53} ergs
- Chimney structures capped with filaments and HI clumps
- Suggestive evidence for triggered star formation in the walls of the shell, with late O stars



McClure-Griffiths (2006)

Molecular cloud formation in supershell walls

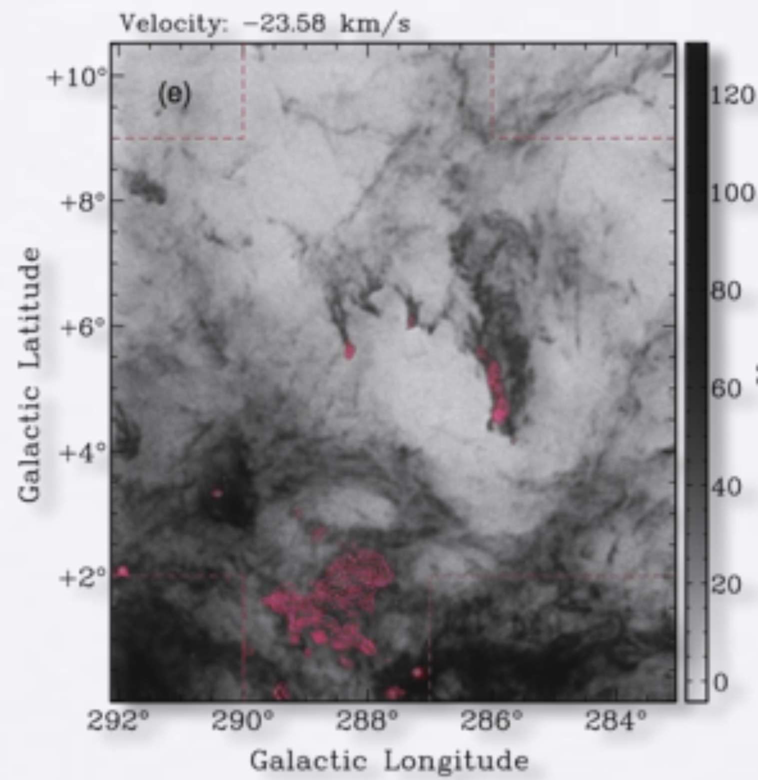


Fukui & Kawamura (2010)

- McCray & Kafatos (1987): expanding supershells sweep up gas in their walls, leading to overdensities in HI and possible collapse into molecular clouds
- Fukui & Kawamura (2010): extragalactic evidence for molecular clouds associated with evacuated HI regions

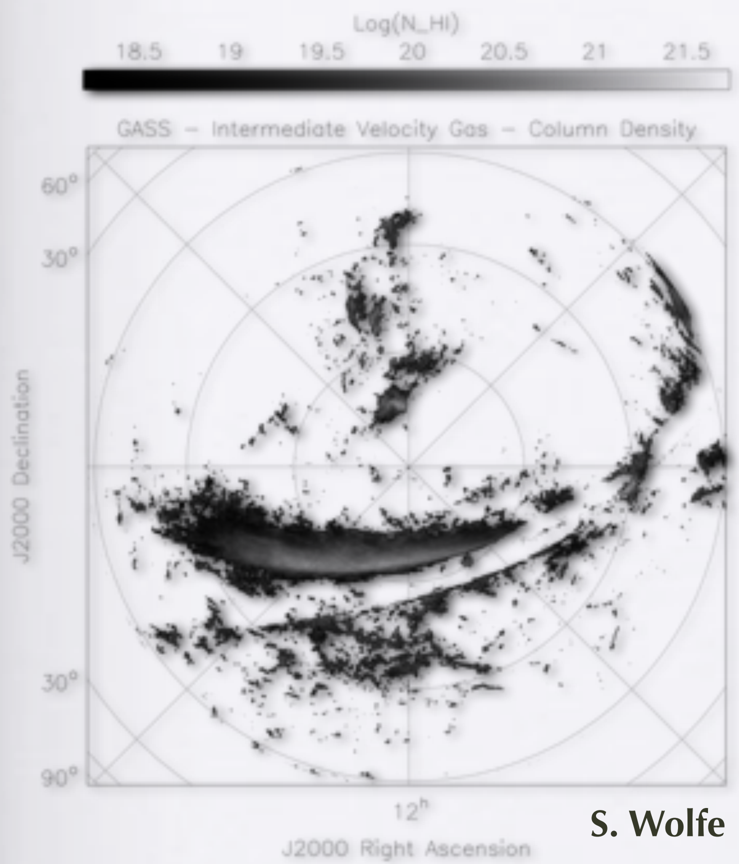
Molecular cloud formation: Carina Flare supershell

- GSH 287+04-17: `Carina Flare' supershell, found in CO by Fukui et al. (1999), HI shell discovered in SGPS by Dawson et al. (2008) - plot from Dawson et al. (2011)
- Largest CO clouds have estimated masses of up to 2000 solar masses with signs of active star formation
- A CNM-rich supershell with a twist: is the molecular gas formed in-situ from the swept-up HI, or is this supershell interaction with pre-existing molecular clouds?



Dawson et al (2011)

Low/intermediate velocity clouds in the halo



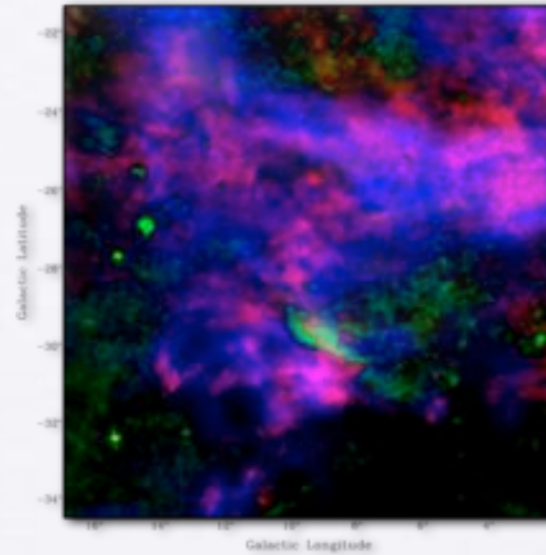
S. Wolfe

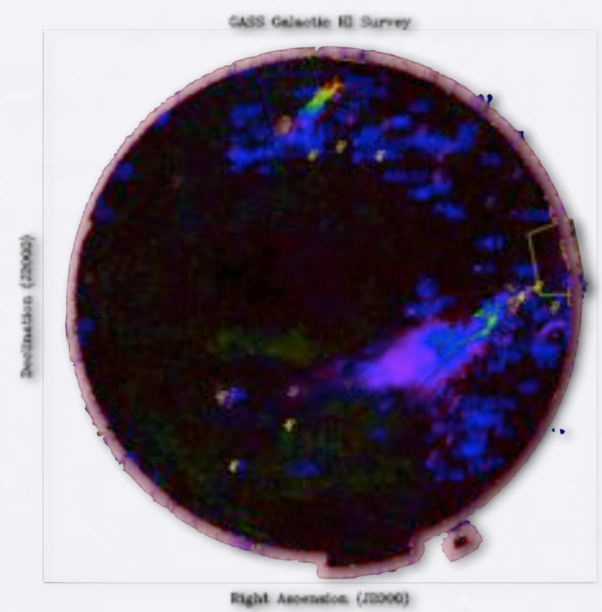
- We can explain a lot of the high velocity sky, but the low and intermediate velocity sky is still somewhat mysterious
- This map (Spencer Wolfe) is the intermediate velocity GASS sky
- Ford et al. (2008, 2010): correlation between spiral arm activity and HI halo clouds (3:1)
- How can we distinguish clearly at low velocity between Galactic and extragalactic material?

Future work/ conclusions

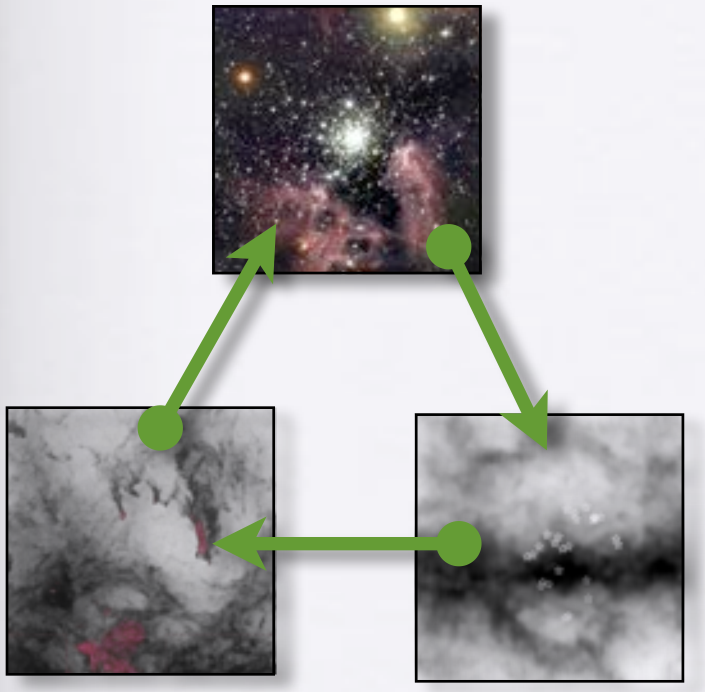
Future work using Parkes

- The presence of Hα near the supershell and what it tells us
- GASS HVC catalogue: the first step towards cataloguing the Galactic halo from GASS
- Extending the GASS HVC catalogue to the intermediate velocity sky, and low velocity
- Southern catalogue of supershells from entire GASS data set?





Conclusions



- Supershells are an integral part of the Galactic ecosystem from their birth in OB associations to their ends as halo fragments and molecular clouds
- Data obtained with the Parkes telescope has been pivotal to understanding the life cycle of a supershell
- Check back in the near future for more results filling in the life cycle gaps using Parkes data!

Thanks for listening!