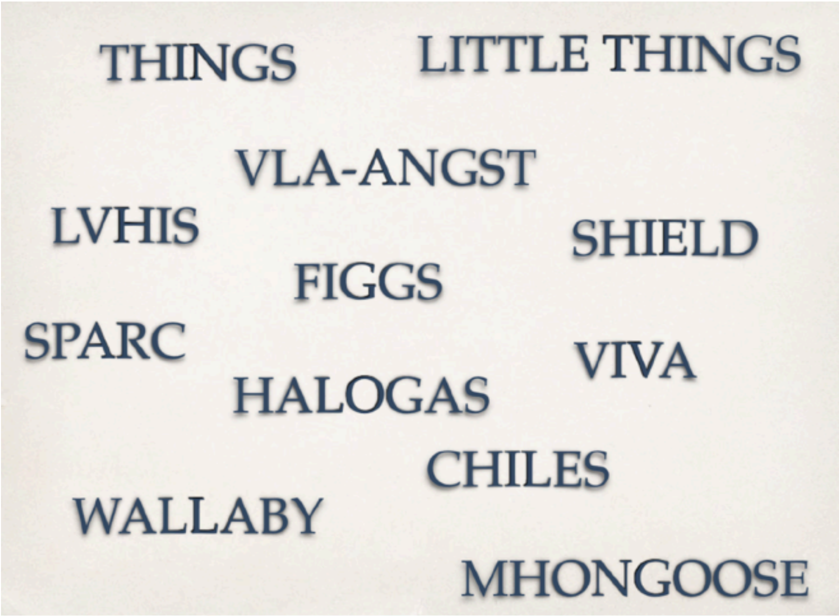
FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG

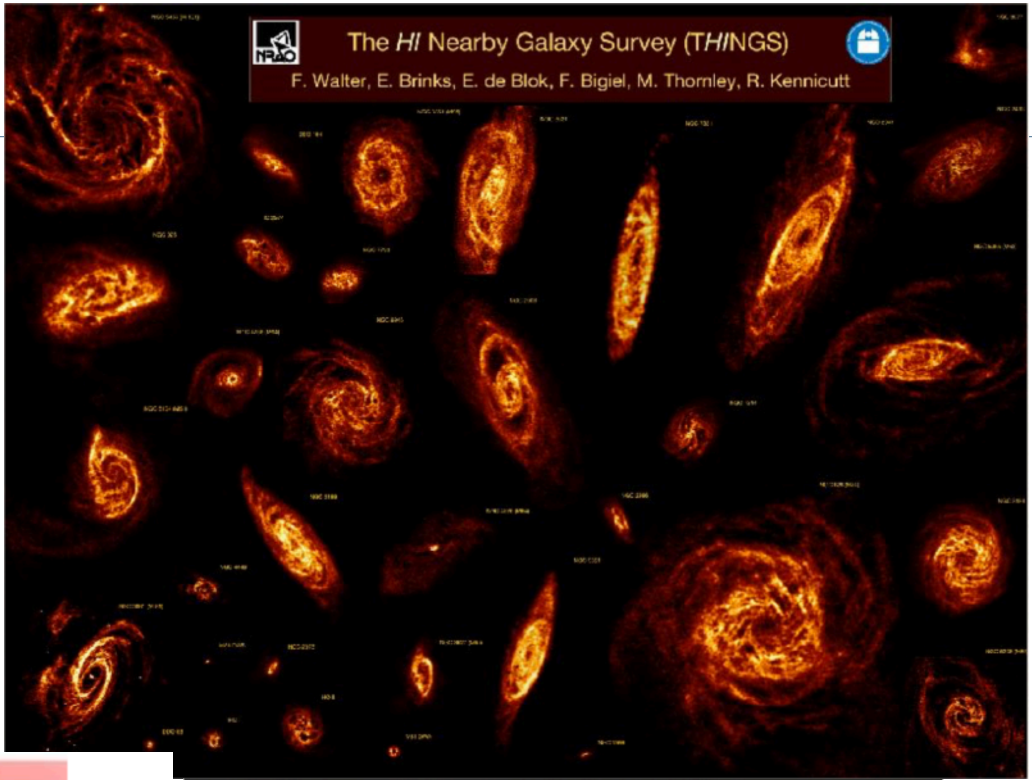
Interstellar Medium in the Nearby Universe

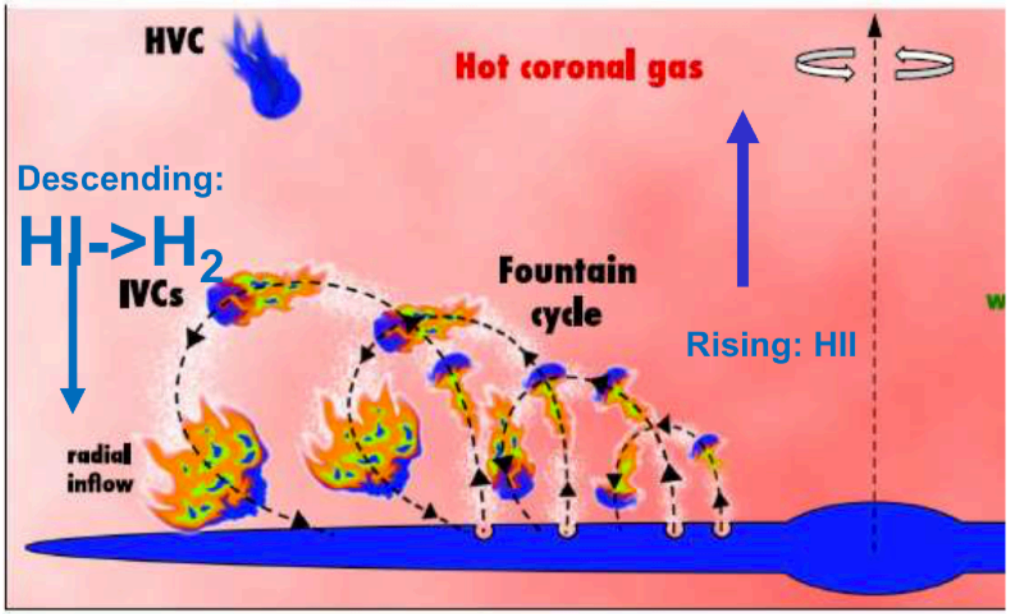
A workshop on interstellar matter, light, and magnetic fields in our Milky Way and nearby galaxies.
A biased summary

Manami Sasaki

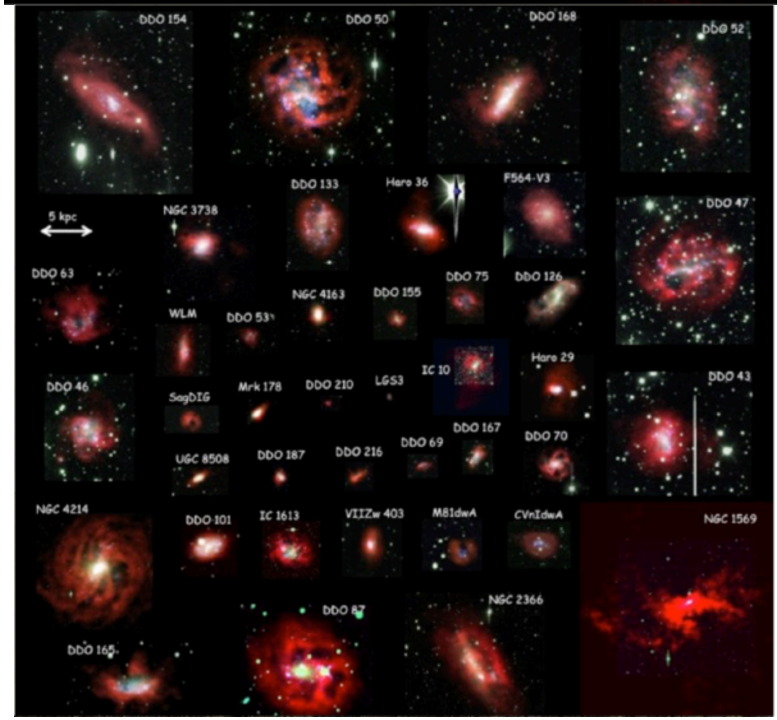
HI gas







Marasco, Marinacci & Fraternali 2013, MNRAS 443, 1634



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HI gas

HI in galaxies:

- Low density HI, flat surface density distribution.
- Dust is well mixed in HI.
- Star formation rate follows radial distribution of H_2 up to $r/r_{25} = 0.6$, then constant up to $r/r_{25} = 0.8$. Stochastic SF.
- Rotation curve measurements.
- HI holes: porous ISM.

Velocity dispersion in the disk caused by SF.

Schmidt-Kennicutt relation Σ_{SFR} proportional to Σ_{gas}^N, $N \approx 1$.

Galactic fountain and IVCs:

- H gas moves up as HII and falls back down as HI cloud: IVC.
- IVCs can only be studied in MW due to small size.
- ~1000 IVC known.

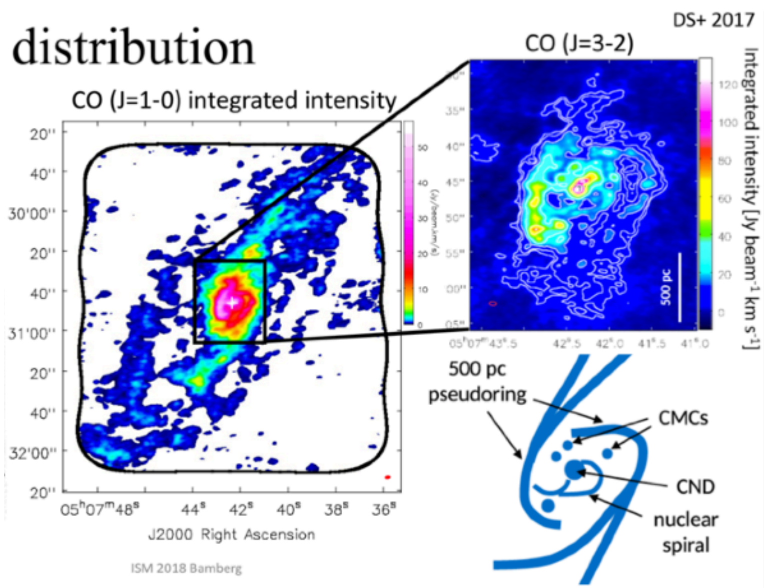
Molecular gas/clouds

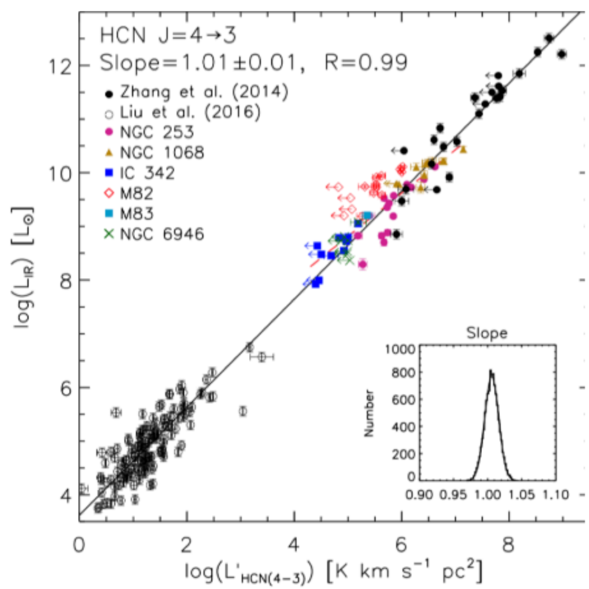
Starburst galaxy NGC1808:

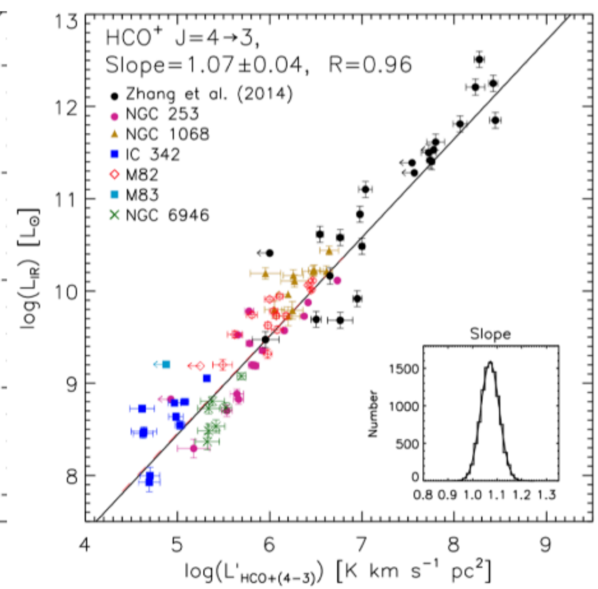
- Giant molecular clouds move toward the galactic center region and feed starburst.
- Dust and gas outflows observed.
- Outflow velocity higher in the outer parts: acceleration or decrease in ejection velocity.

HCN, CS, HCO^+ as tracers of dense cores in galaxies.

Linear correlation L_{IR} vs L_{HCN} from MW cores up to galaxies.

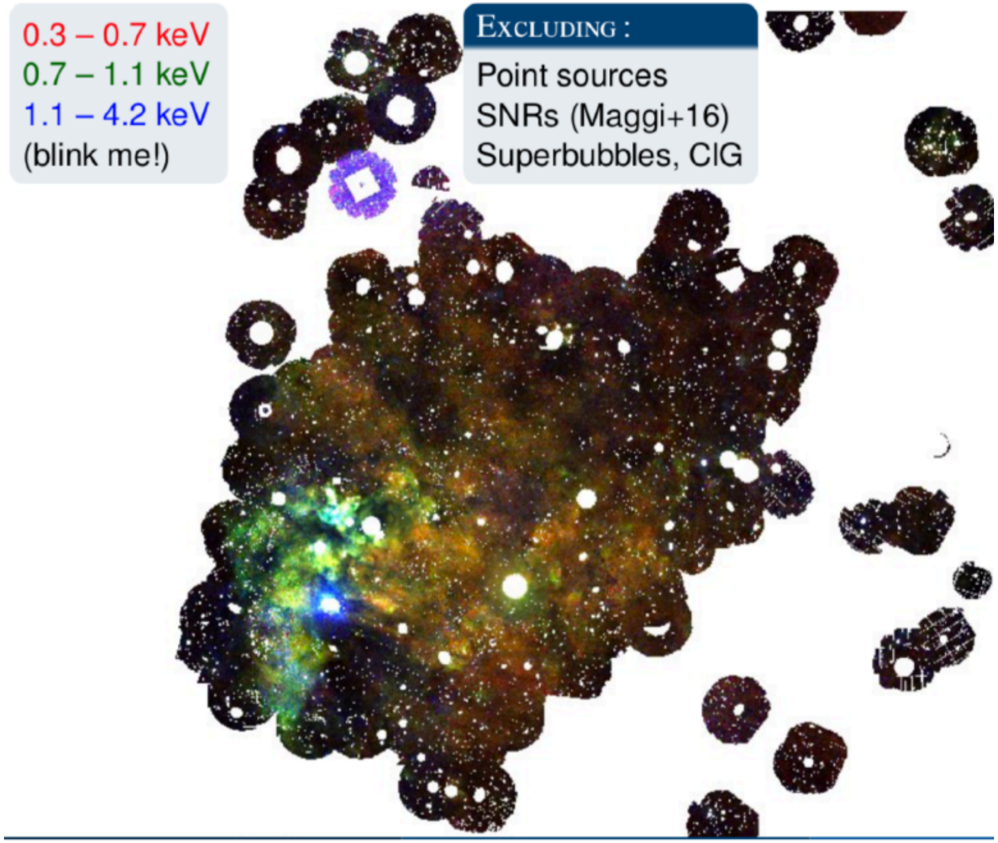




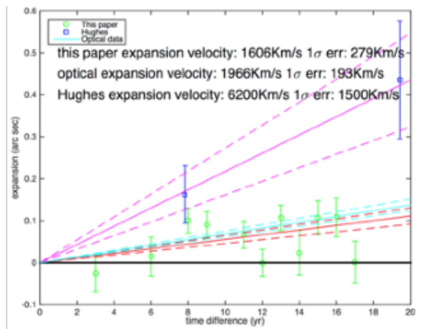


Interstellar hot plasma

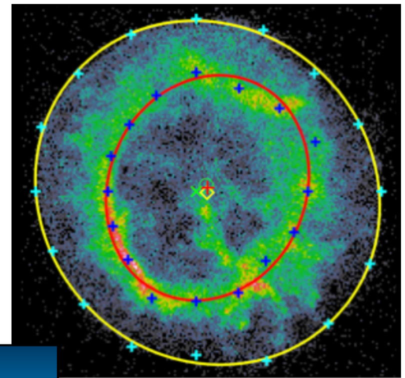
- Assumption of collisional ionization equilibrium for interstellar plasma is wrong.
- Non-equilibrium ionization.
- Time-dependent dynamical and thermal simulations of the interstellar plasma.
- Take into account the atomic history of the plasma, a variable adiabatic parameter, and non-thermal electron/ particle distribution functions.
- 3D MHD simulation. Calculate spectum.



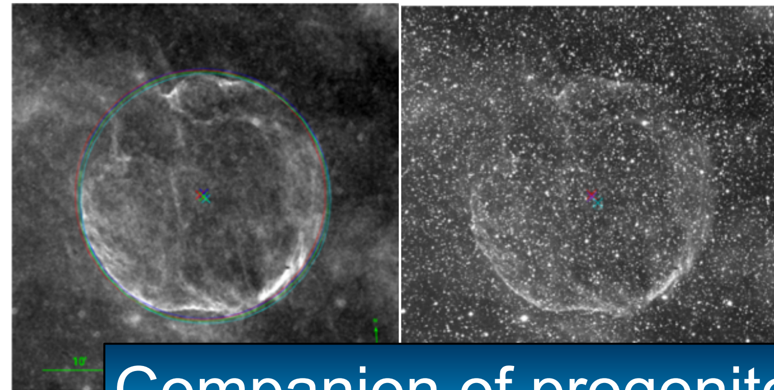
Supernova remnants



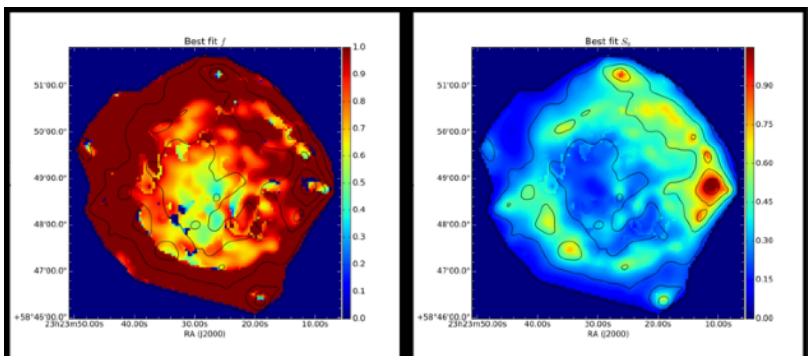
Expansion



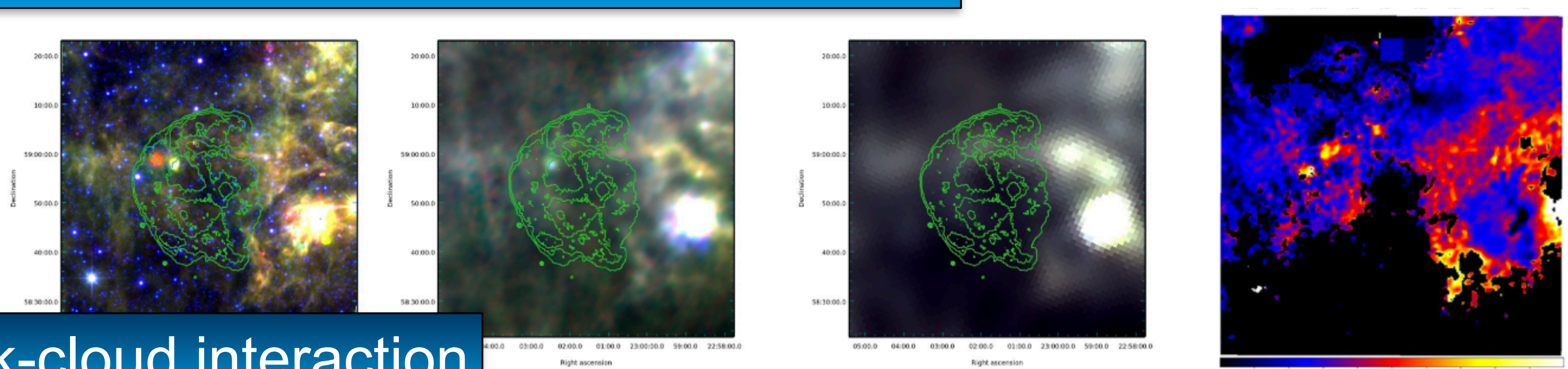
Companion of progenitor



Free-free absorption by unshocked ejecta



New SNRs



Shock-cloud interaction

160, 140, 90 µm

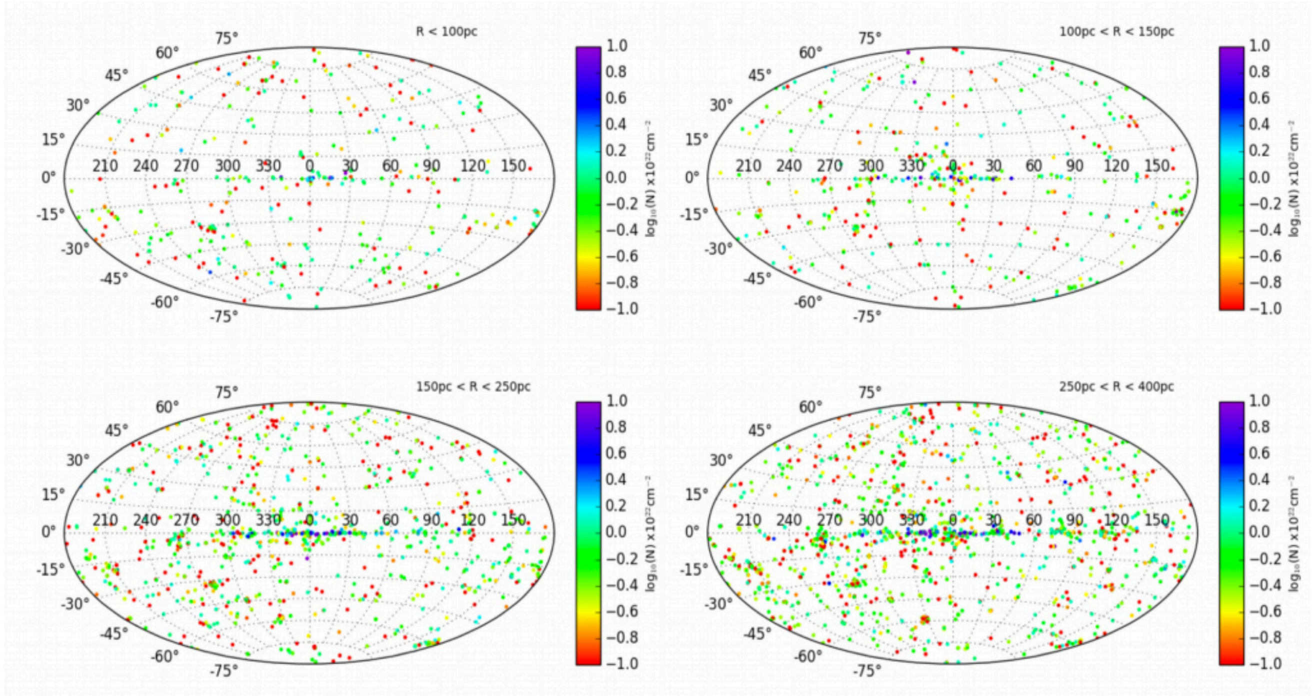
Planck 850, 550, 350 µm

Absorption by ISM

Photo-absorption of X-rays

- LMXBs and Blazars. Novae: higher statistics.
- Neutral and partially ionised atoms of, e.g., O, Ne.
- Three components: 10 000 K - 1 900 000 K.
- X-rays with Gaia results: 3D map of the ISM.

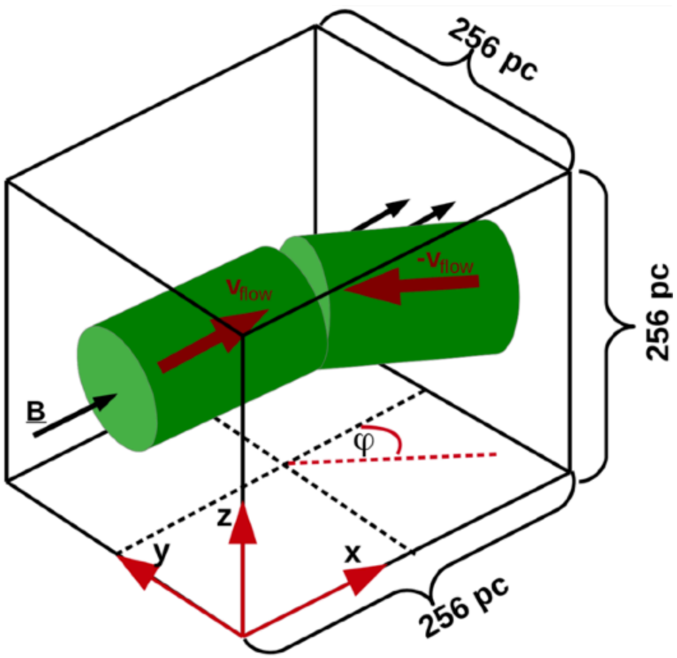
DIBs in star light.



Gatuzz+18c (submitted)

Star formation

- Stars formed in the densest cores. Observed as dark globules.
- Mass distribution of molecular clouds follows a power law, most of the mass is in big clouds.
- Stellar feedback (stellar radiation, SNe): change chemical abundances, dynamics.
- Resolution of ~0.1 pc in simulations necessary for study sub-structures.
- Magnetic fields slow down cloud evolution and star formation.
- Flux loss by ambipolar diffusion with turbulence not high enough.
- Model oblique colliding flow of gas.
- Parker instability results in molecular cloud formation in disk.



Star formation

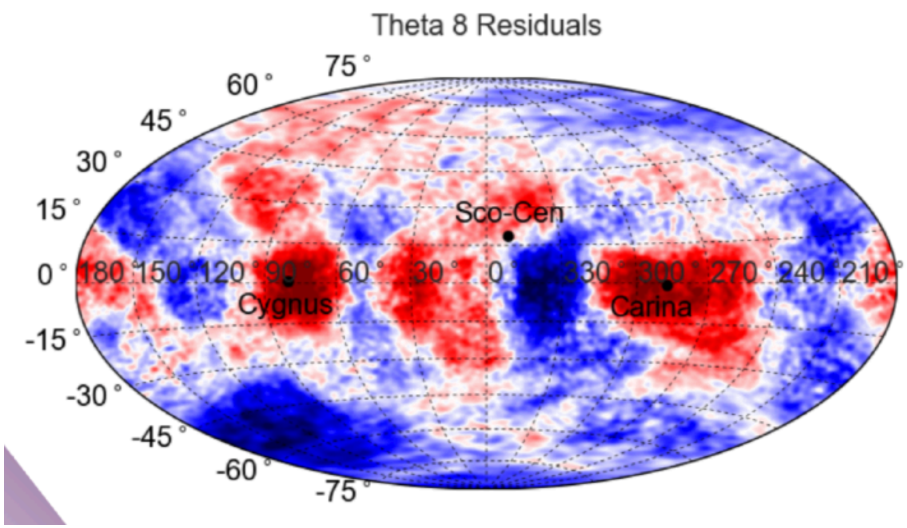
- Cloud-cloud collision results in formation of massive stars, in particular, O stars.
- In almost all star forming regions in Sagittarius Arm and other bright star forming regions or super-star clusters.
- 10 - 50 km/s velocity required for high-mass star formation.
- Clouds experience collisions several times in their life time. Larger giant molecular clouds collide more often.
- Collision changes mass distribution of cores.
- Observations: 2 components in HI, with bridge. Small clouds + large clouds with complementary structures.

Feedback

Star formation tracer: [CII]

- Excited by UV photons of stars.
- Contamination of AGN: study low-redshift galaxies with AGN and large extent.

Bow shocks around massive stars.



^{26}Al from nucleosynthesis in stellar winds and supernovae. Compare emission derived from stellar population synthesis modelling with observed emission.

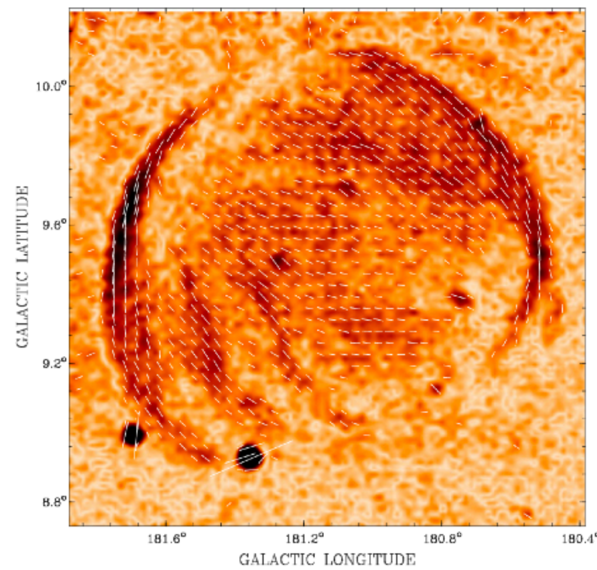
Positron annihilation at 511 keV + continuum (11 yrs with INTEGRAL/SPI), related to warm ISM.

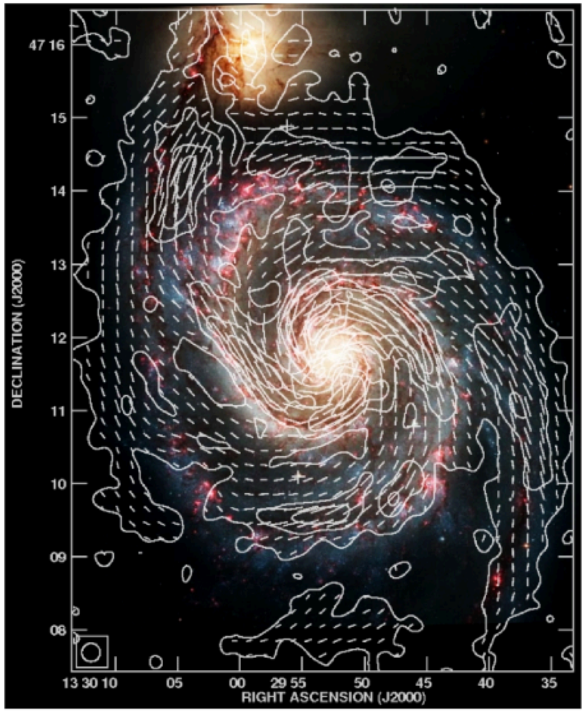
Ultraluminous X-ray sources:

- Compact objects accrete gas and eject as jets. Most likely intermediate mass black holes.
- S26 in NGC7793: radio lobes surrounded by Halpha nebula.

Magnetic fields

- Radio observations: polarisation of star light, thermal dust emission, Zeeman splitting, Faraday rotation measure. Dust grains as polarising filter.
- Milky Way: 1 - 2 μG. field reversal in the disk.
- Rotation measure ~ HI column density (ionisation fraction of WNM). Magnetic field tied to WNM.
- Shape of SNRs depends on the interstellar magnetic field. Measure magnetic fields in the Galaxy.
- Polarisation gradient: measure depolarisation, magnetic field turbulence.
- Energy densities of radiation, magnetic fields, cosmic rays, dynamics are in equilibrium.
- Radio continuum: electrons. Effects of cosmic rays important.





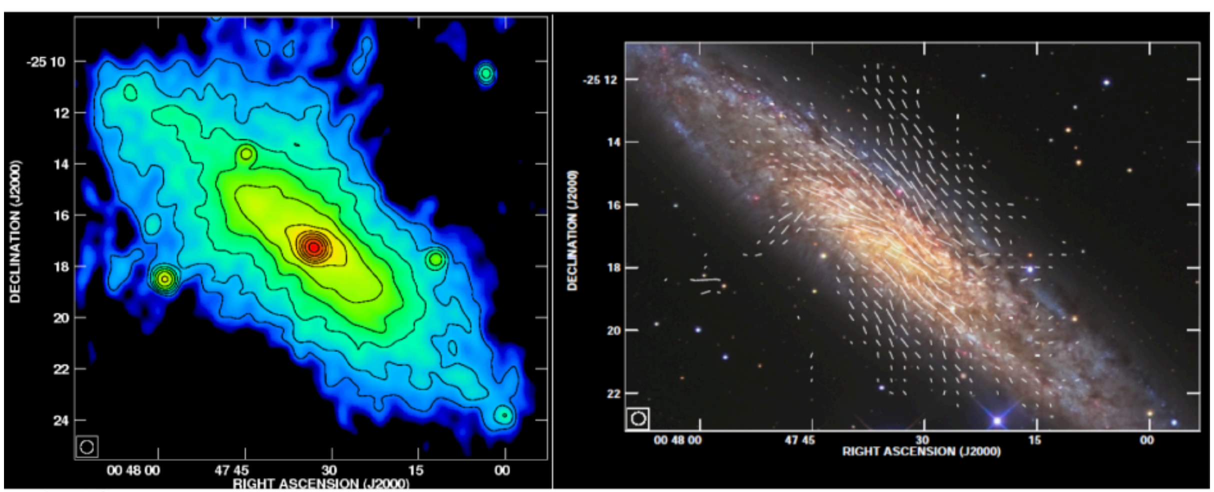
Magnetic fields

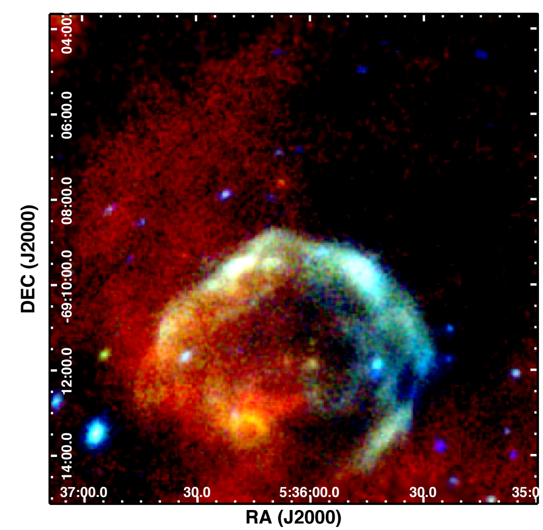
Nearby face-on galaxies: magnetic fields follow spiral arms.

Edge-on galaxies:

- Higher scale height of radio emission in the outer parts. Lower magnetic fields, therefore, synchrotron life time of electrons longer.
- Study cosmic ray transport. Wind velocity depends on mass.
- X-shaped magnetic field structures (kpc scale, quadrupole) in the halo. Cosmic ray driven wind.

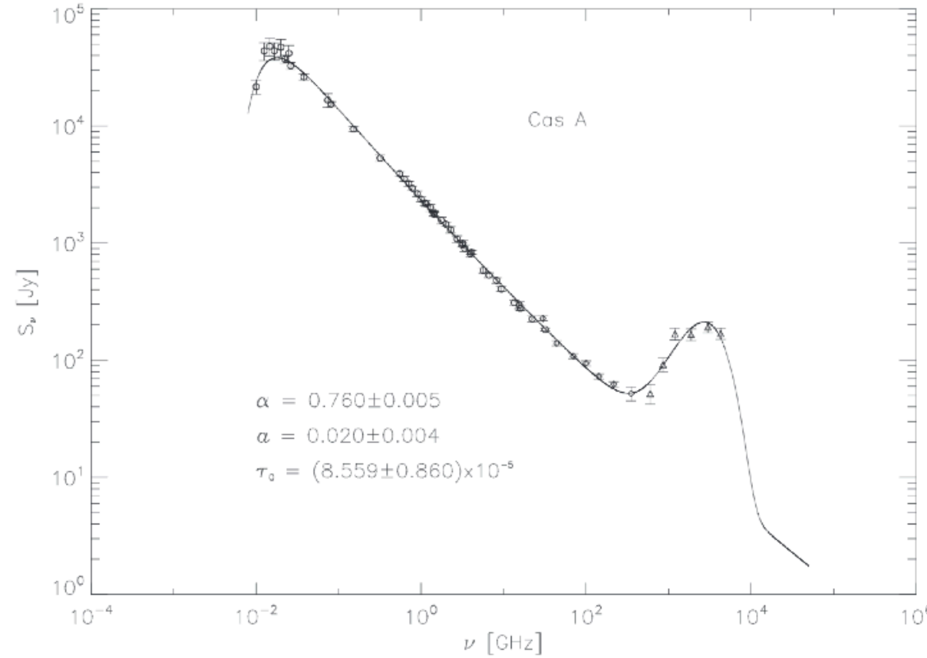
High energies: superbubble 30 Doradus C with non-thermal X-rays and TeV emission. Magnetic field from width of Synchrotron filaments: ~10 μG.

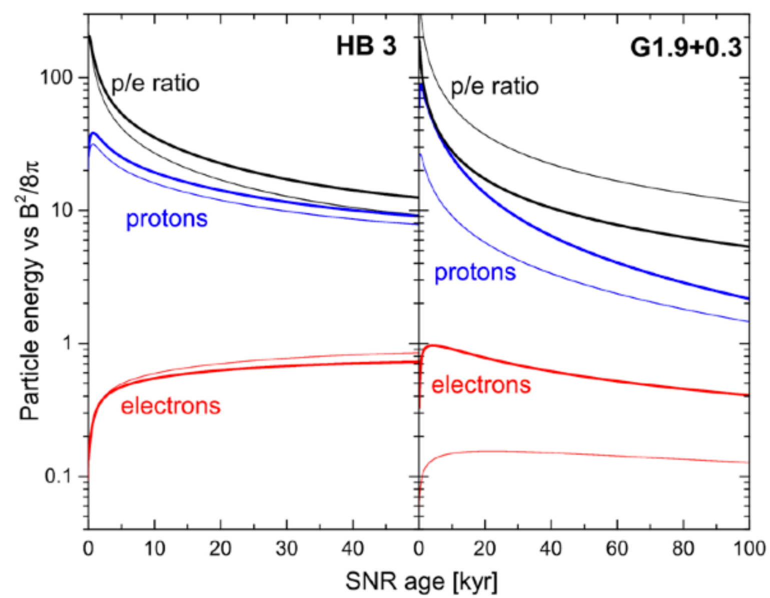




Particle acceleration in SNRs

- Particle acceleration in SNRs: DSA. Power-law energy distribution of cosmic rays. 2nd-order Fermi acceleration: turbulence down-stream.
- Curved spectra: non-linear effects of particle acceleration with Sychrotron losses.
- Evolution of radio flux: change in B-field or electron population? Model time evolution of radio flux of SNRs using 3D HD evolution and CR acceleration and MFA.
- Equipartition between magnetic fields and cosmic rays.





Particle acceleration in SNRs

TeV emission from:

- SNRs with non-thermal X-ray emission, no thermal emission.
- Mixed-morphology SNRs.

Search for Pevatrons. Proton emission > 10 TeV.

SNRs near molecular clouds: π^0 decay.

Study of escape of CRs and propagation in ISM.

Shock interaction with high-density clumps in molecular gas: enhanced magnetic fields.

Spatial correlation between TeV and HI.

Hadronic model (F_{TeV} proportional to gas density).