INTERSTELLAR MEDIUM

- Stefano Bovino -

Introduction

General properties of the ISM

- Large range in temperature & density

  $T \sim 10\text{-}10^6$ K $n \sim 10^{-3}$ - 10^6 cm^{-3}

- Even dense regions are “ultra-high vacuum” difficult to reproduce in Lab

  Lab UHV: 10^{-10} Torr ($n \sim 4 \times 10^6$ cm^{-3})

- Multiphase / multicomponent medium (processes interconnected in feedback loops)

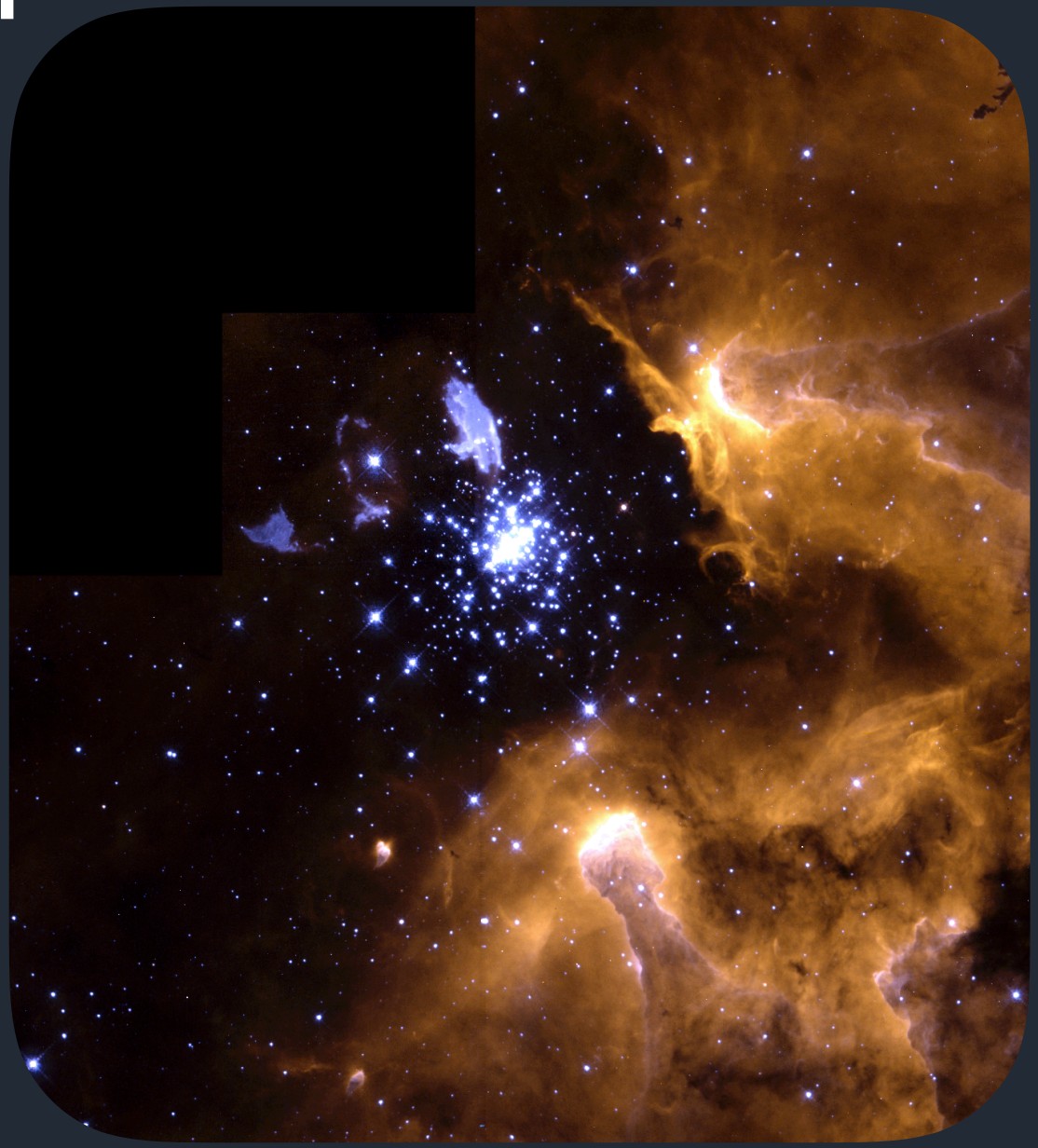
- Far from equilibrium and steady state (low density means long timescales to reach equilibrium)

  Complex processes & Challenging physics

General properties of the ISM

- Most of the ISM space is filled with hot, diffuse (very thin) atomic hydrogen gas.
- Embedded within this we have deep dense clouds of molecular hydrogen
- MCs fills most of the mass but not much of volume

Giant galactic nebula NGC 3603

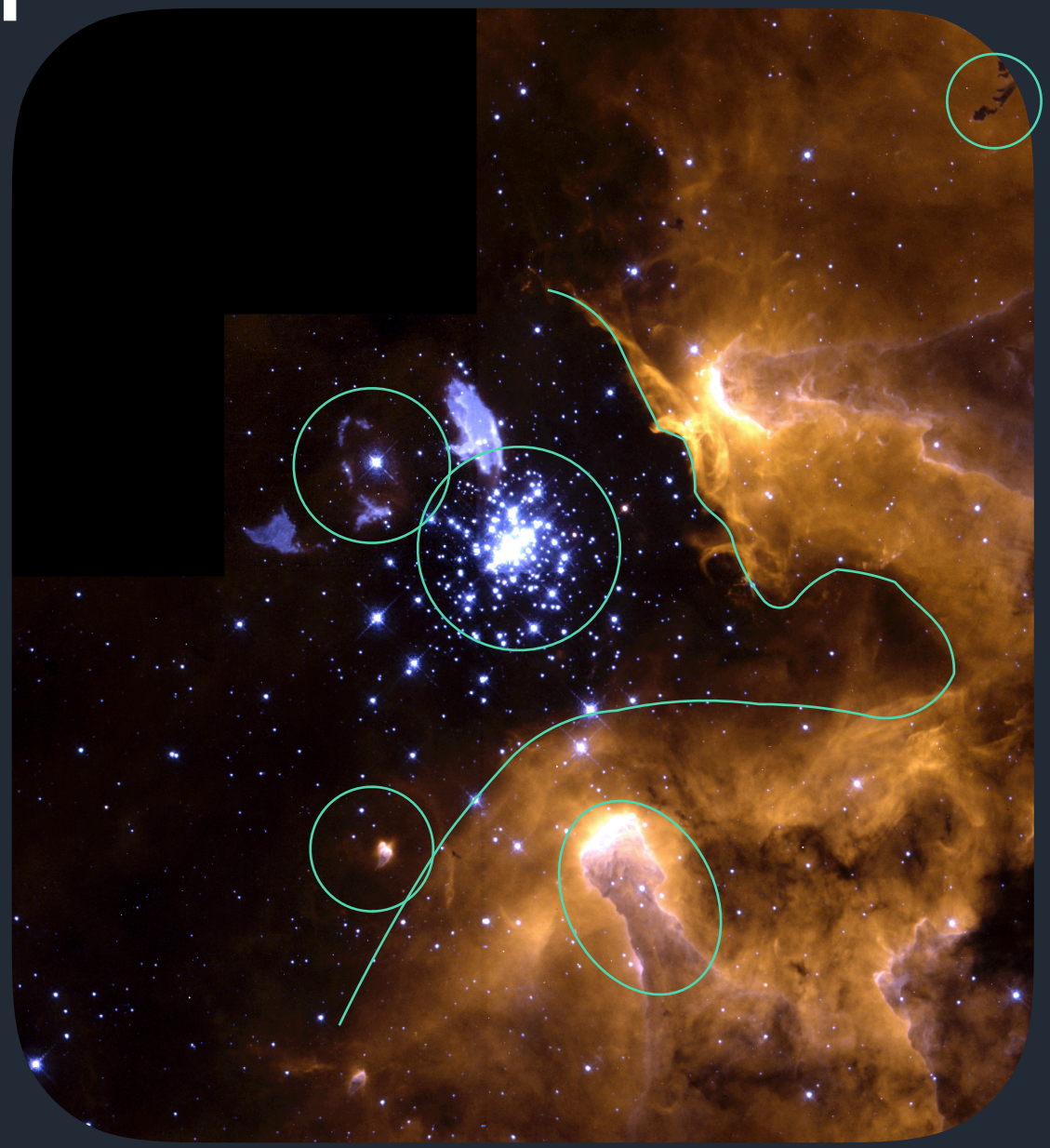


Credit: Wolfgang Brandner (JPL/IPAC), Eva K. Grebel (Univ. Washington), You-Hua Chu (Univ. Illinois Urbana-Champaign), and NASA

General properties of the ISM

- Cluster of bright hot blue stars
- Photodissociation region
- Pillars of glowing hydrogen
- Dark cloud
- Supergiant star Sher 25
- Protoplanetary disc

Giant galactic nebula NGC 3603



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Different phases

- H is the most abundant element (> 90% of nuclei)
- Ionized atomic hydrogen (H^+ or H II) “H-two”

  WIM/HIM/HII T up to ~ 10^5 K n_e ~ 0.1 - 10^4 cm^{-3}

- Neutral atomic hydrogen (H^0 or H I) “H-one”

  CNM/WNM T ~ 100-8000 K n ~ 0.5-40 cm^{-3}

- Molecular hydrogen (H2)

  GMC/DC T ~ 10-20 K n ~ 10^2-10^4 cm^{-3}

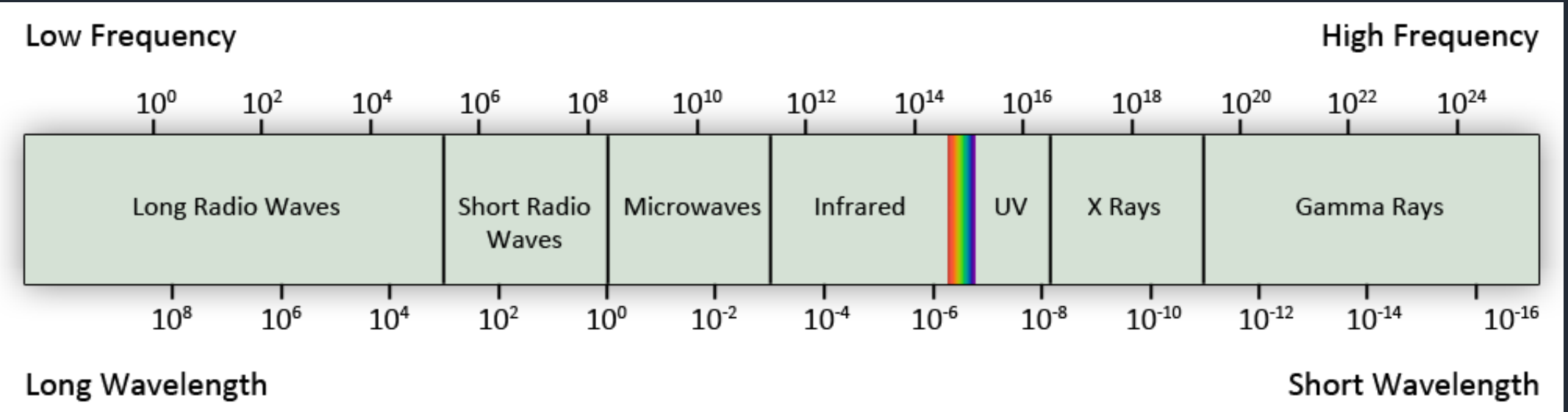
- These regions are usually separated by thin transition zones

Different phases: simple three-phase model

Phase		Density cm^{-3}	Temperature K	Total mass $M_\odot$
Atomic (H I)	Cold	$\simeq$ 25	$\simeq$ 100	1.5×10^9
	Warm	$\simeq$ 0.25	$\simeq$ 8 000	1.5×10^9
Molecular (H_2)		$\geq$ 1 000	$\leq$ 100	10^9?
Ionized	H II regions	$\simeq 1 - 10^4$	$\simeq$ 10 000	5×10^7
	Diffuse	$\simeq$ 0.03	$\simeq$ 8 000	10^9
	Hot	$\simeq 6 \times 10^{-3}$	$\simeq 5 \times 10^5$	10^8?

Observing the ISM

- Most of the gas in galaxies is relatively cool and, since a typical wavelength is inversely proportional to temperature it is only observable in *emission* in bands outside of the visible
- Large volume of gas are hot, and require short wavelength observations (UV & X-rays) with satellite observatories.



Past, present, future

- Last half-century the ISM has been intensively studied
- Planck - Herschel provided a multi-wavelength view of the ISM
- ALMA will give fuel for decades
- Wide range of conditions leads to the formation of very different structures
- Different in distribution, volume, morphology, relevant physical processes