



清华大学天文系  
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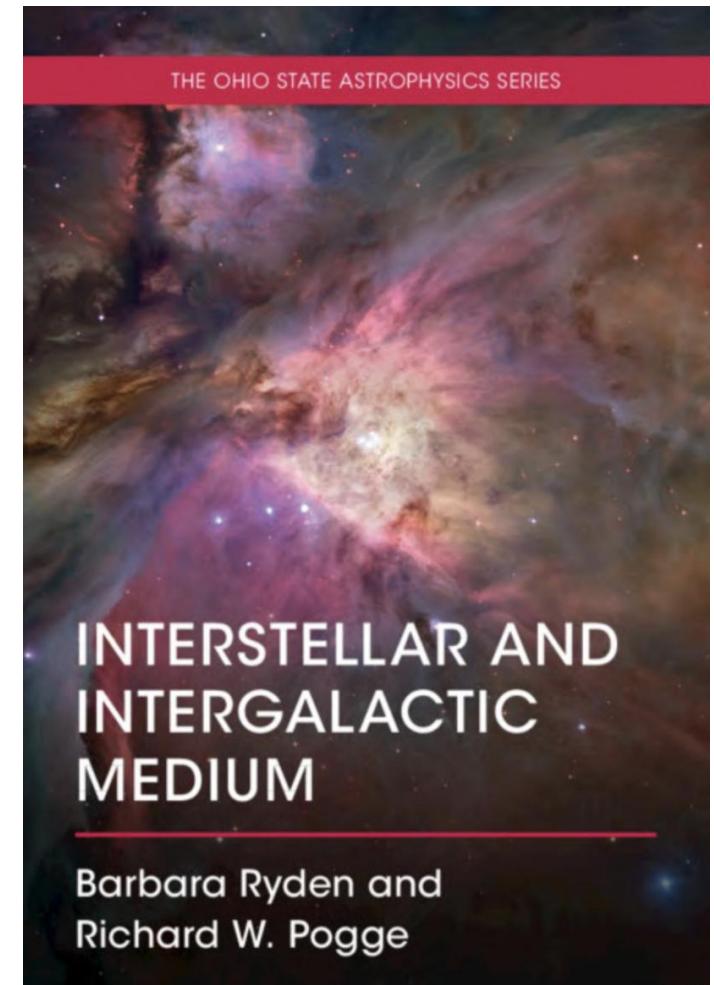
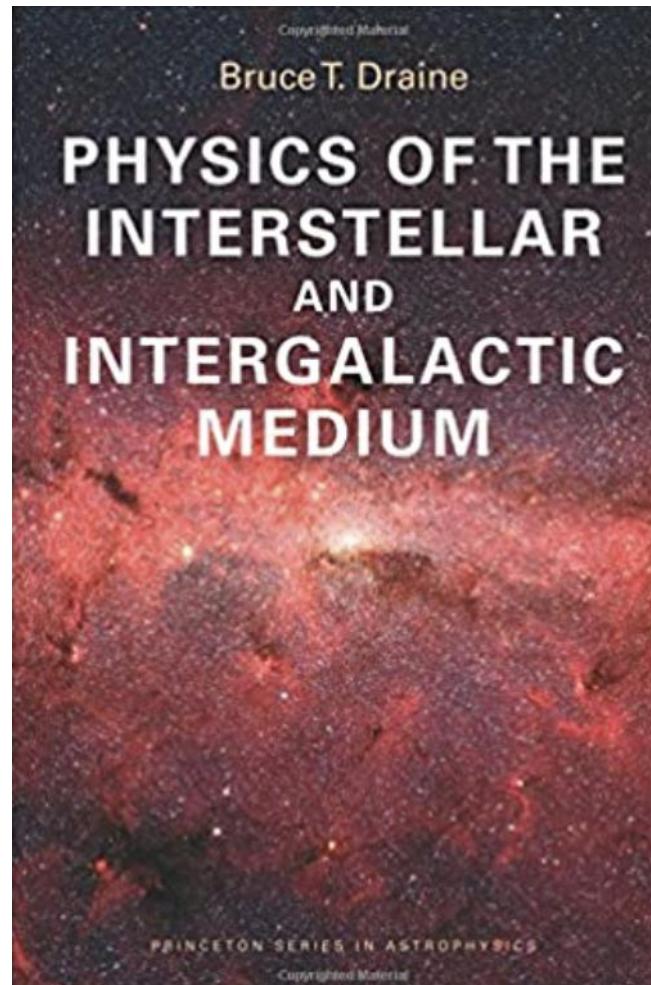
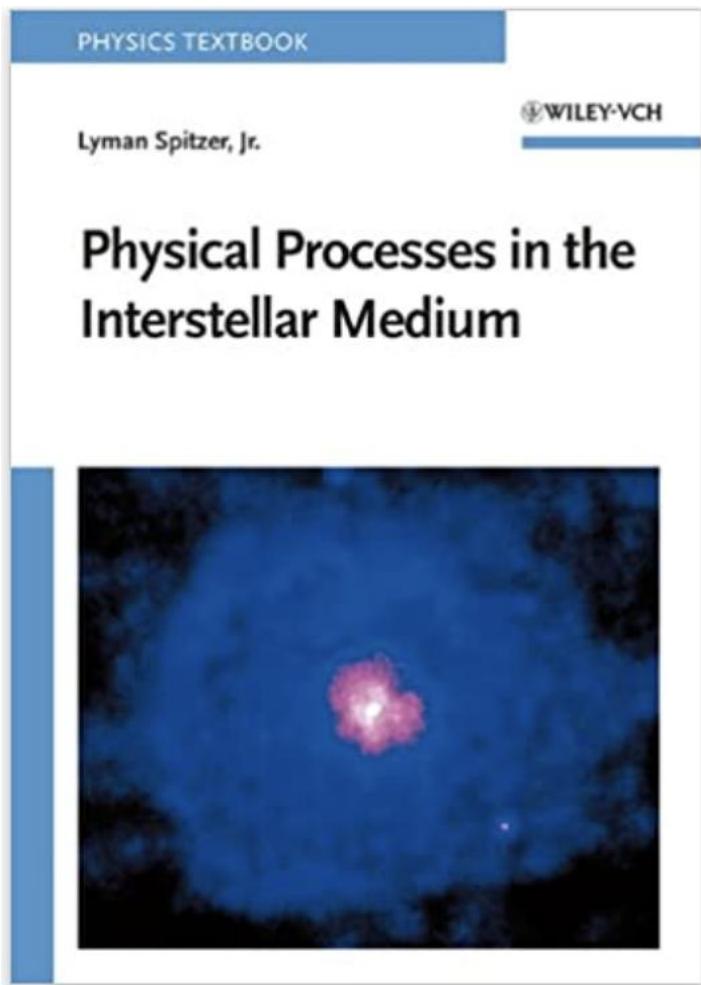
# Physics of the Interstellar Medium

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## Reference books



## Phases of the ISM (on the order of temperature)

- Coronal gas (HIM)
  - HII gas (WIM)
  - Warm HI gas (WNM)
  - Cold HI gas (CNM)
  - Molecular gas
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- I'm using Antennae galaxies, an interacting system, as an example to demonstrate the ISM in different phases.

# Phases of the ISM (on the order of temperature)

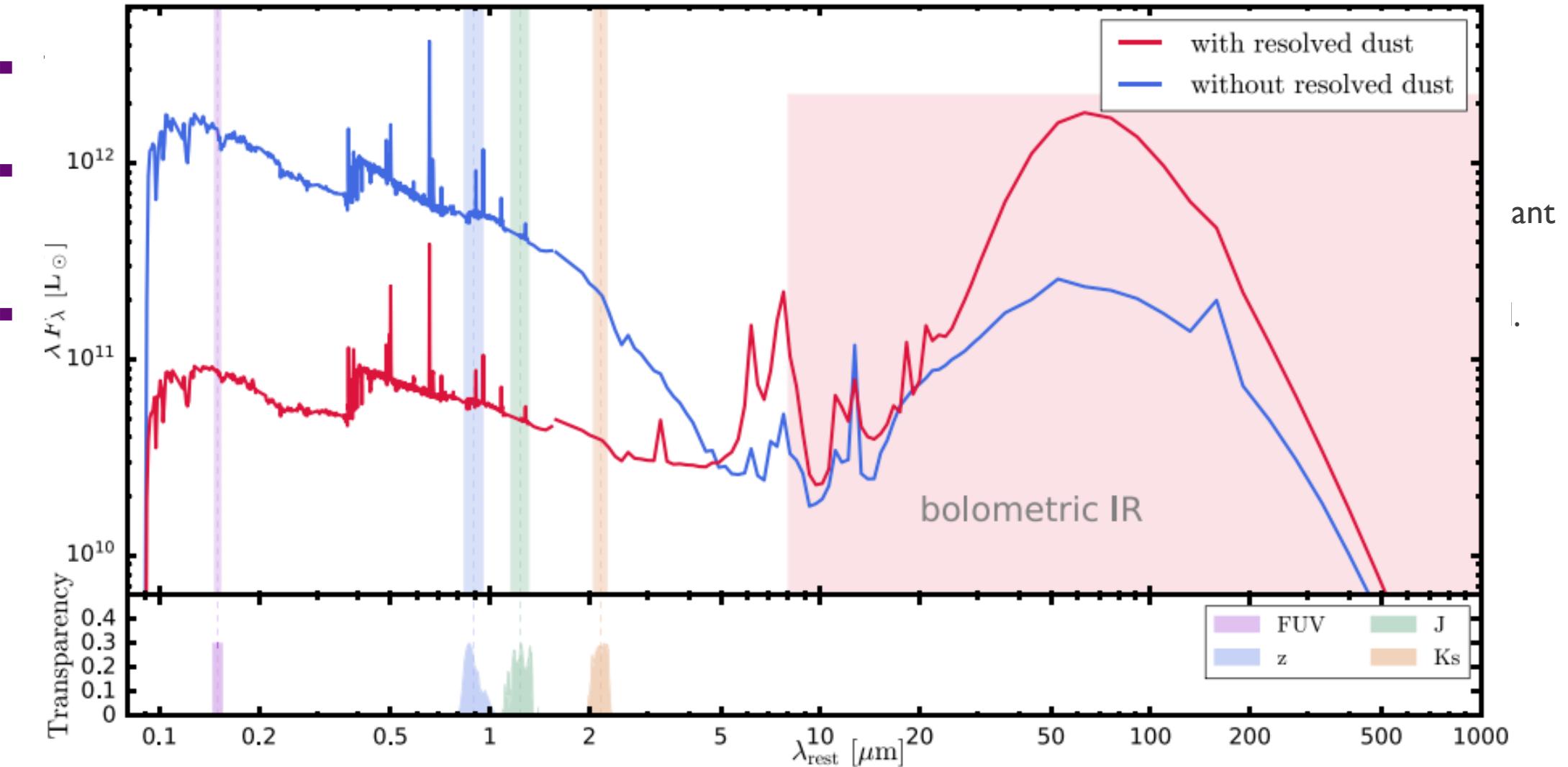
Phase	$T$ (K)	$n_H$ (cm $^{-3}$ )	Comments
Coronal gas (HIM) $f_V \approx 0.5?$ $\langle n_H \rangle f_V \approx 0.002 \text{ cm}^{-3}$ ( $f_V$ ≡ volume filling factor)	$\gtrsim 10^{5.5}$	$\sim 0.004$	Shock-heated Collisionally ionized Either expanding or in pressure equilibrium Cooling by: ◊ Adiabatic expansion ◊ X ray emission Observed by: • UV and x ray emission • Radio synchrotron emission
H II gas $f_V \approx 0.1$ $\langle n_H \rangle f_V \approx 0.02 \text{ cm}^{-3}$	$10^4$	$0.3 - 10^4$	Heating by photoelectrons from H, He Photoionized Either expanding or in pressure equilibrium Cooling by: ◊ Optical line emission ◊ Free-free emission ◊ Fine-structure line emission Observed by: • Optical line emission • Thermal radio continuum
Warm HI (WNM) $f_V \approx 0.4$ $n_H f_V \approx 0.2 \text{ cm}^{-3}$	$\sim 5000$	0.6	Heating by photoelectrons from dust Ionization by starlight, cosmic rays Pressure equilibrium Cooling by: ◊ Optical line emission ◊ Fine structure line emission Observed by: • HI 21 cm emission, absorption • Optical, UV absorption lines

Cool HI (CNM) $f_V \approx 0.01$ $n_H f_V \approx 0.3 \text{ cm}^{-3}$	$\sim 100$	30	Heating by photoelectrons from dust Ionization by starlight, cosmic rays Cooling by: ◊ Fine structure line emission Observed by: • HI 21-cm emission, absorption • Optical, UV absorption lines
Diffuse H <sub>2</sub> $f_V \approx 0.001$ $n_H f_V \approx 0.1 \text{ cm}^{-3}$	$\sim 50 \text{ K}$	$\sim 100$	Heating by photoelectrons from dust Ionization by starlight, cosmic rays Cooling by: ◊ Fine structure line emission Observed by: • HI 21-cm emission, absorption • CO 2.6-mm emission • optical, UV absorption lines
Dense H <sub>2</sub> $f_V \approx 10^{-4}$ $\langle n_H \rangle f_V \approx 0.2 \text{ cm}^{-3}$	$10 - 50$	$10^3 - 10^6$	Heating by photoelectrons from dust Ionization and heating by cosmic rays Self-gravitating: $p > p(\text{ambient ISM})$ Cooling by: ◊ CO line emission ◊ CI fine structure line emission Observed by: • CO 2.6-mm emission • dust FIR emission
Cool stellar outflows	$50 - 10^3$	$1 - 10^6$	Observed by: • Optical, UV absorption lines • Dust IR emission • HI, CO, OH radio emission

## Energy partition in the local ISM

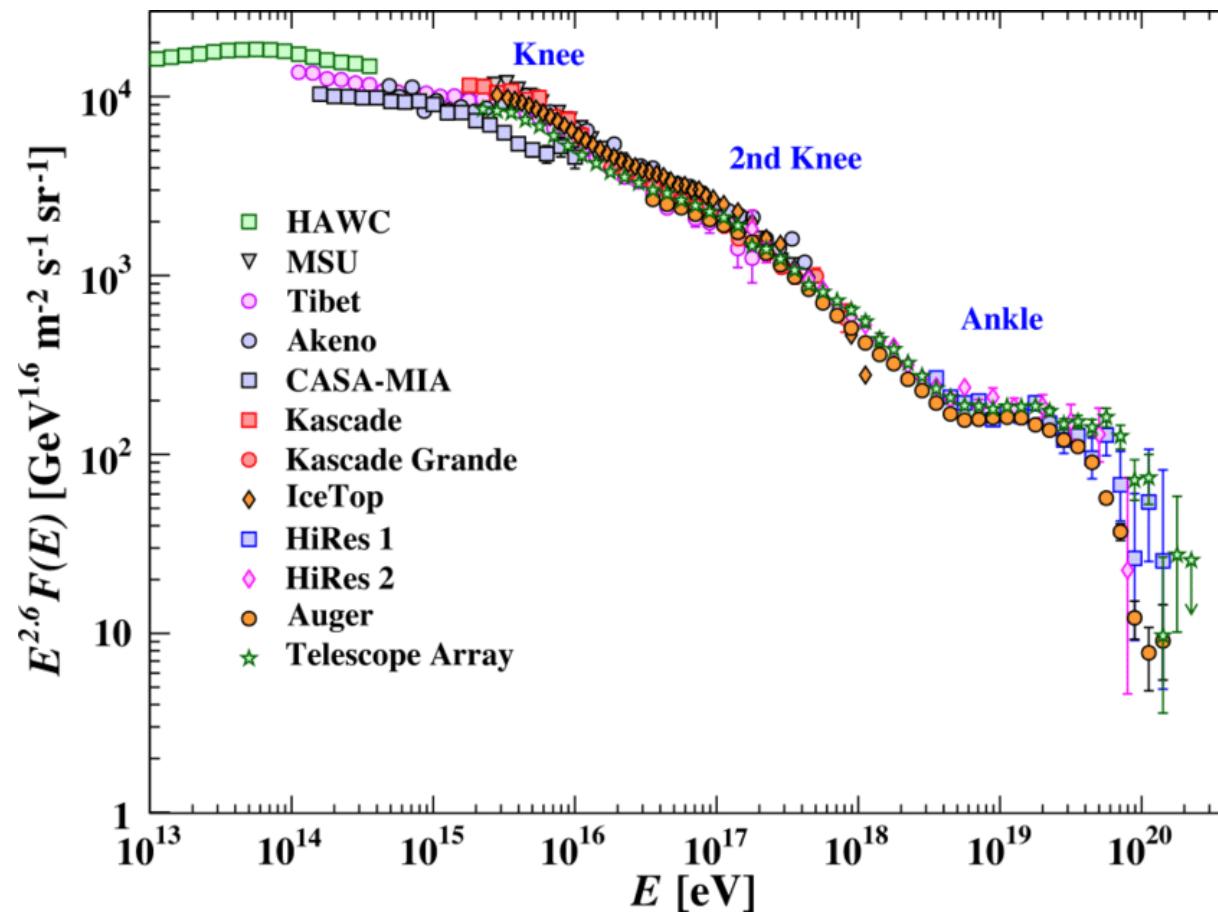
Component		$u(\text{eV cm}^{-3})$	Note
Cosmic microwave background	( $T_{\text{CMB}} = 2.725 \text{ K}$ )	0.265	<i>a</i>
Far-infrared radiation from dust		0.31	<i>b</i>
Starlight ( $h\nu < 13.6 \text{ eV}$ )		0.54	<i>c</i>
Thermal kinetic energy $(3/2)nkT$		0.49	<i>d</i>
Turbulent kinetic energy $(1/2)\rho v^2$		0.22	<i>e</i>
Magnetic energy $B^2/8\pi$		0.89	<i>f</i>
Cosmic rays		1.39	<i>g</i>

# Non-thermal components of the ISM: dusts

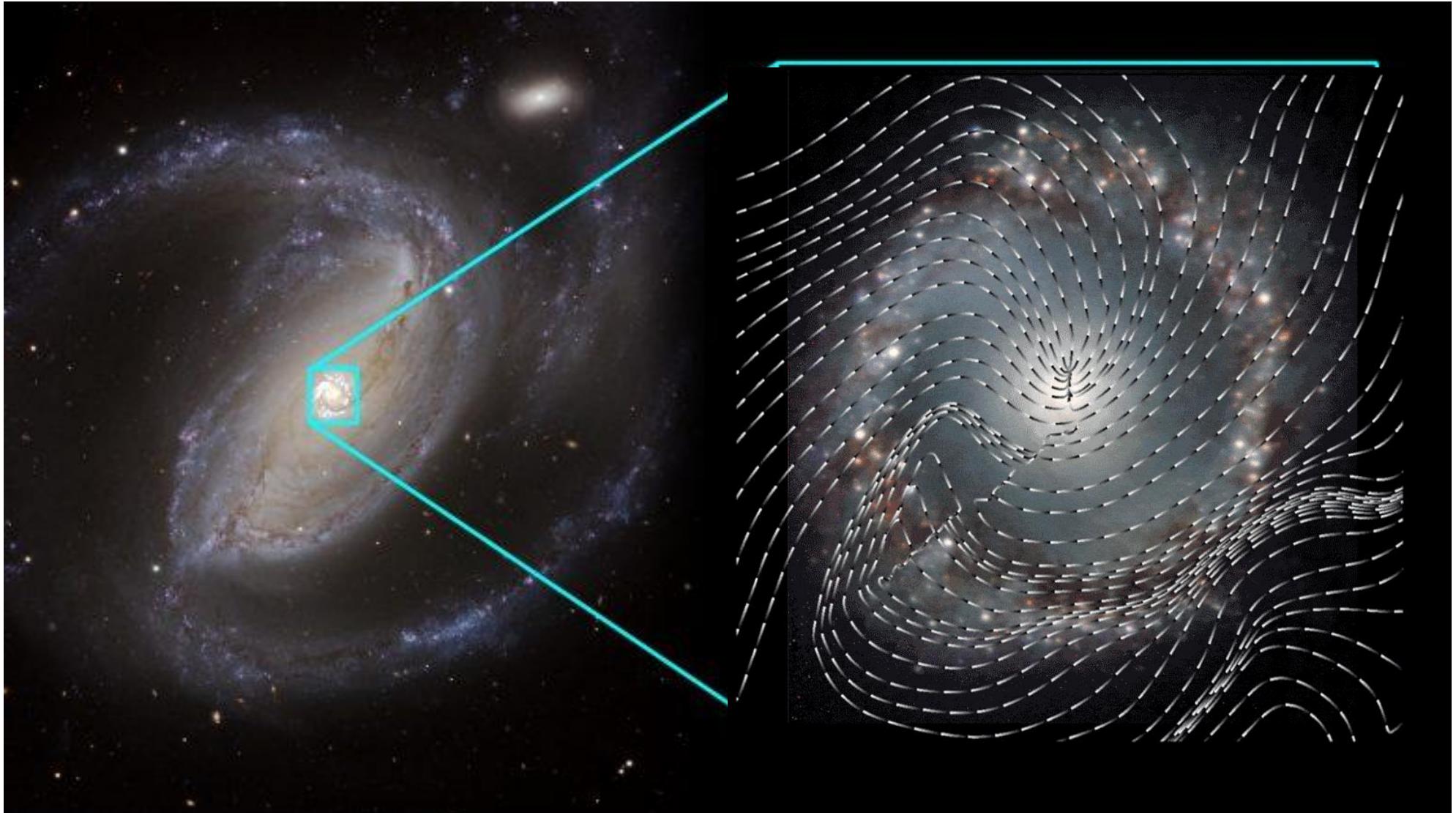


# Non-thermal components of the ISM: cosmic rays

- Relativistic particles with energy that can reach the energy of macroscopic objects!



## Non-thermal components of the ISM: magnetic fields



# Baryonic cycles in the galaxies

