When Clouds Collide

The Hot Interstellar Medium in the Large Magellanic Cloud

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Introduction

Introduction

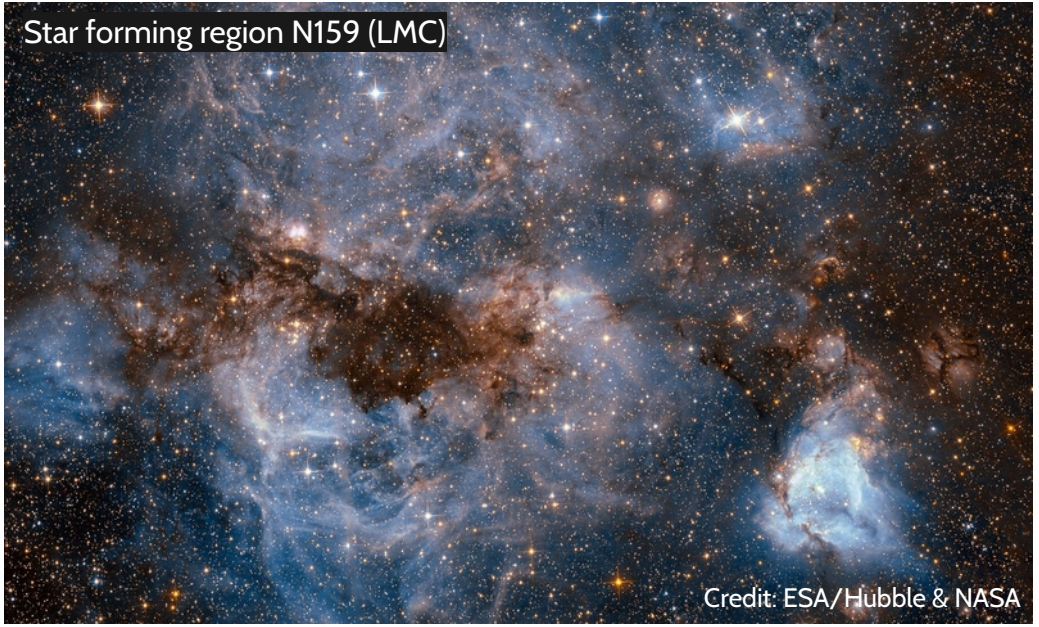
Cold phase

- Dense, fills only a small volume
- T < 100K
- Molecular clouds, dust, atomic hydrogen
- Molecular clouds are birth-sites for stars
- Observable in radio (HI), sub-mm/radio (molecules), infrared (dust)

Introduction

Warm phase

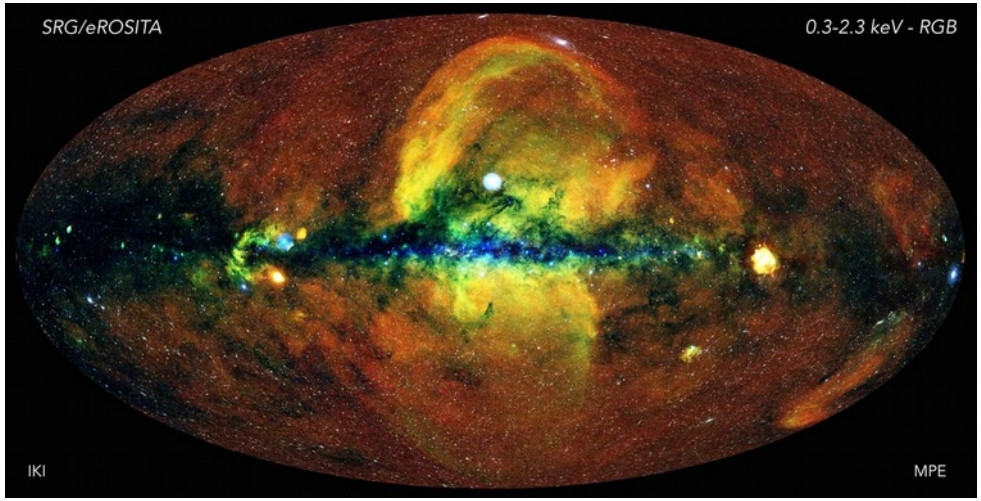
- T ~ 10^3-10^4 K, fills large fraction of ISM
- Intercloud medium
- Warm neutral hydrogen
- Partially ionized regions
  - Massive stars ionize their surroundings with intense UV radiation
- Observable with line emission (e.g., Hα)



Introduction

Hot Phase

- T ~ 10^6-10^7 K, fills large fraction of ISM
- “Unstable” phase
  - But: long cooling times
- Heated by stellar winds of massive stars and supernova remnants (SNRs)
- Thermal plasma, detectable in X-rays

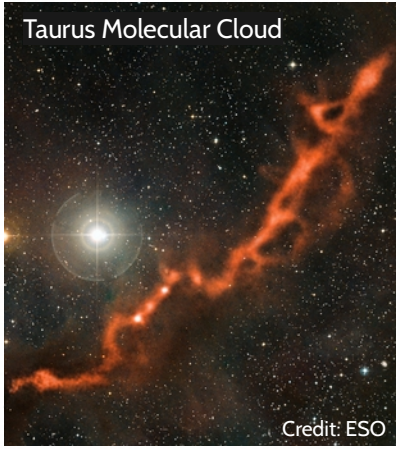


Introduction

The three phases of the interstellar medium (ISM) McKee & Ostriker (1977)

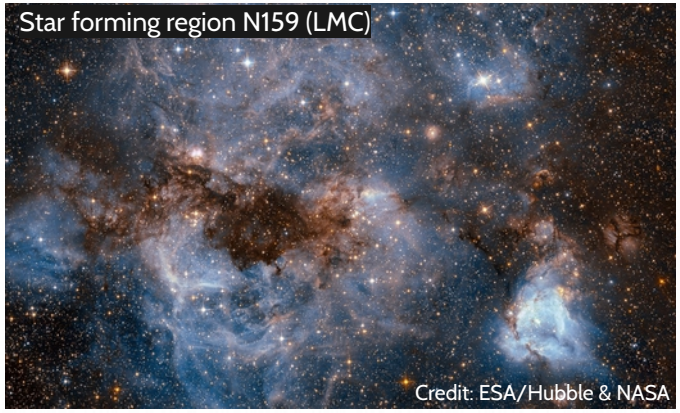
Cold phase

- T < 100K
- Molecular clouds, cold HI, dust
- Star forming regions



Warm phase

- T ~ 10^3-10^4 K
- Intercloud medium
- Photoionized regions



Hot phase

- T > 10^6 K
- X-ray emitting plasma
- Heated by massive stars and SNRs

Introduction

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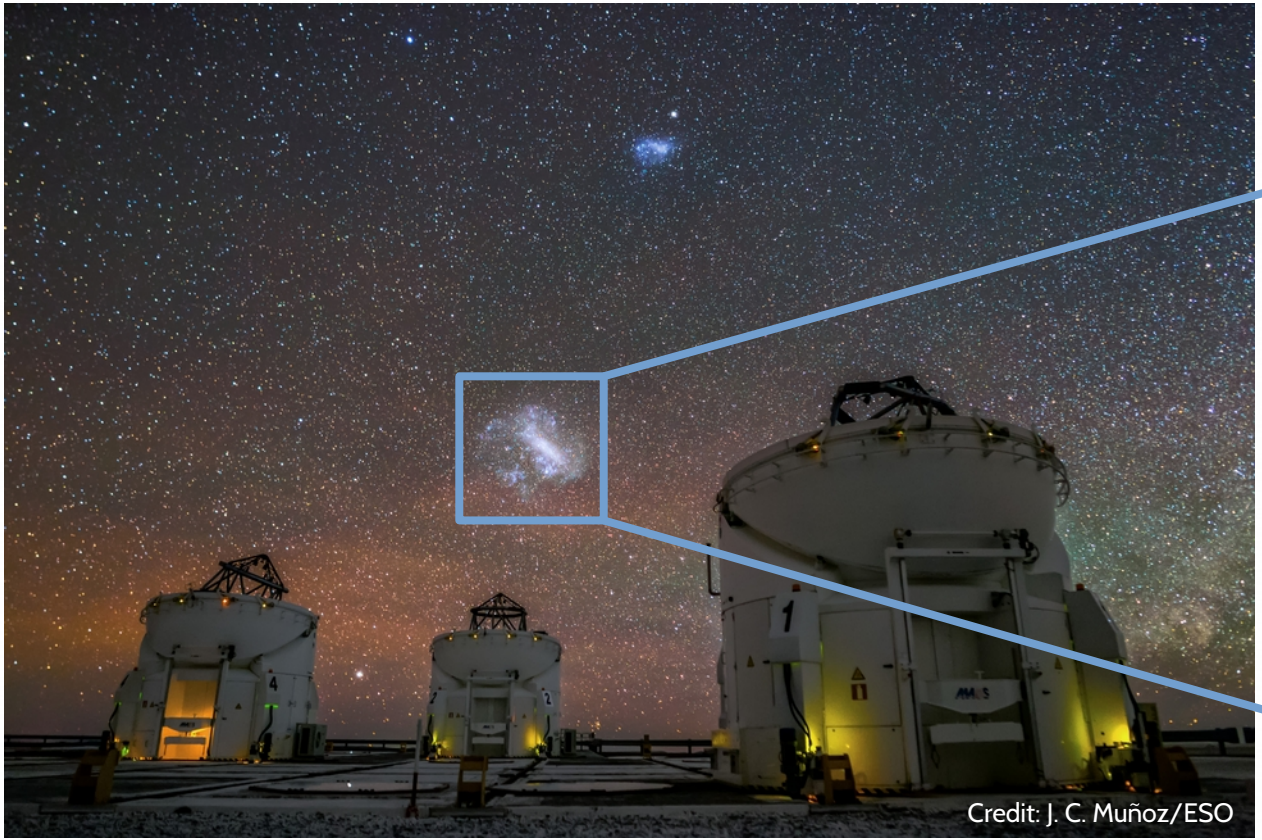

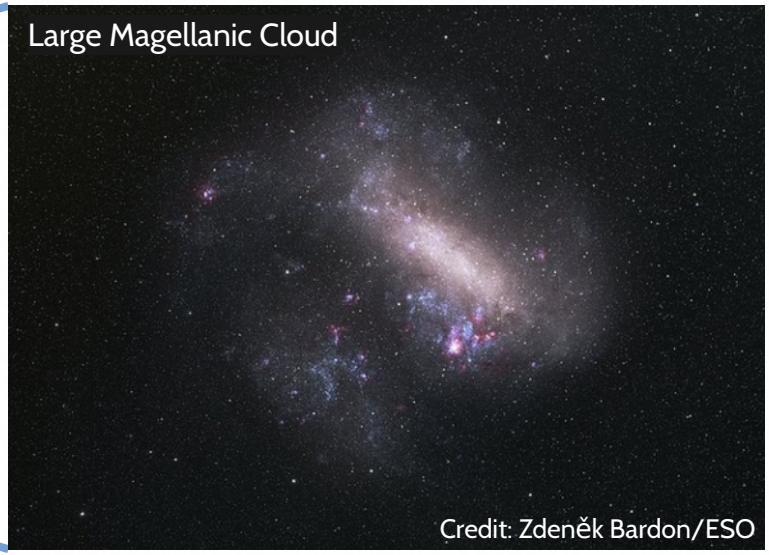

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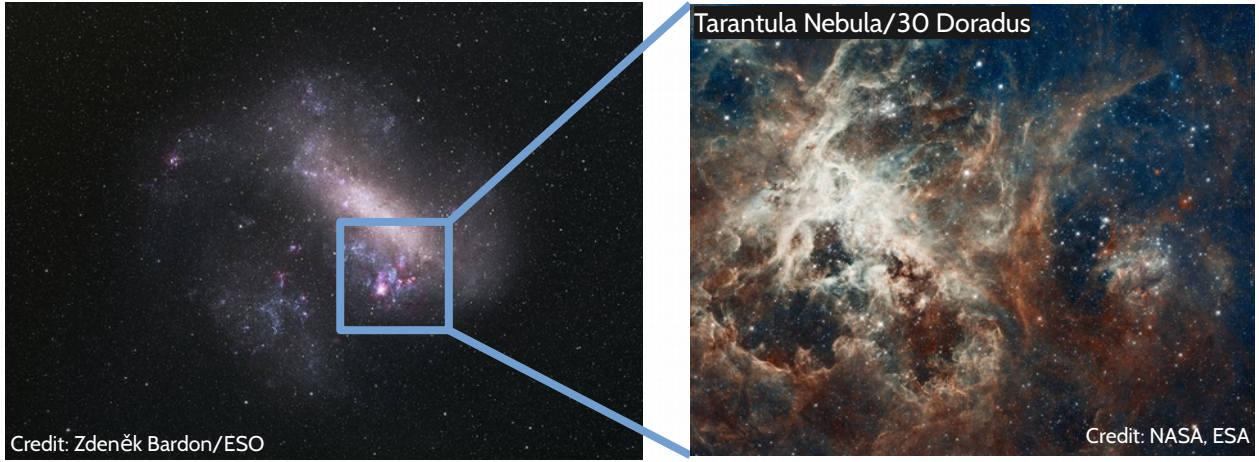

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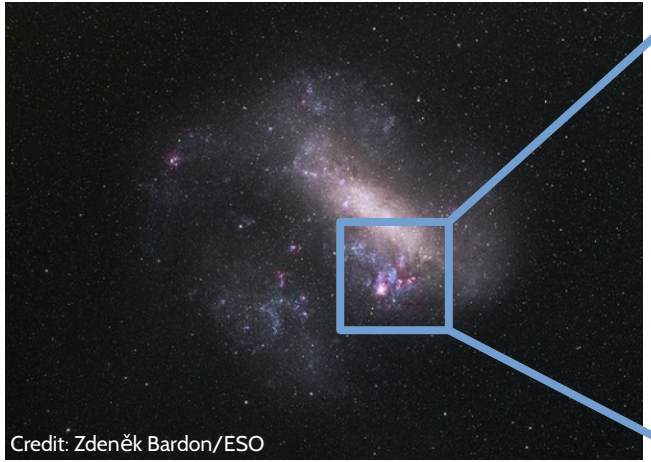
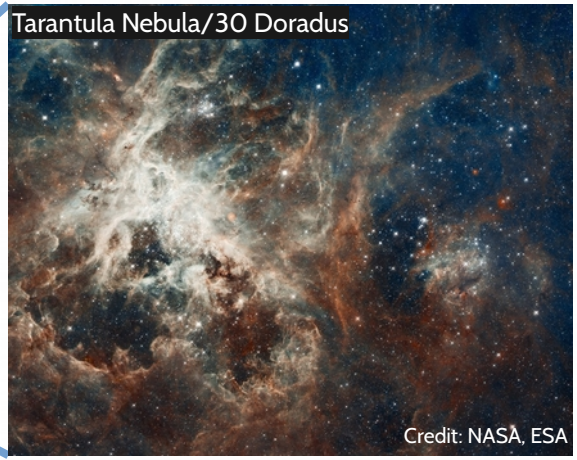
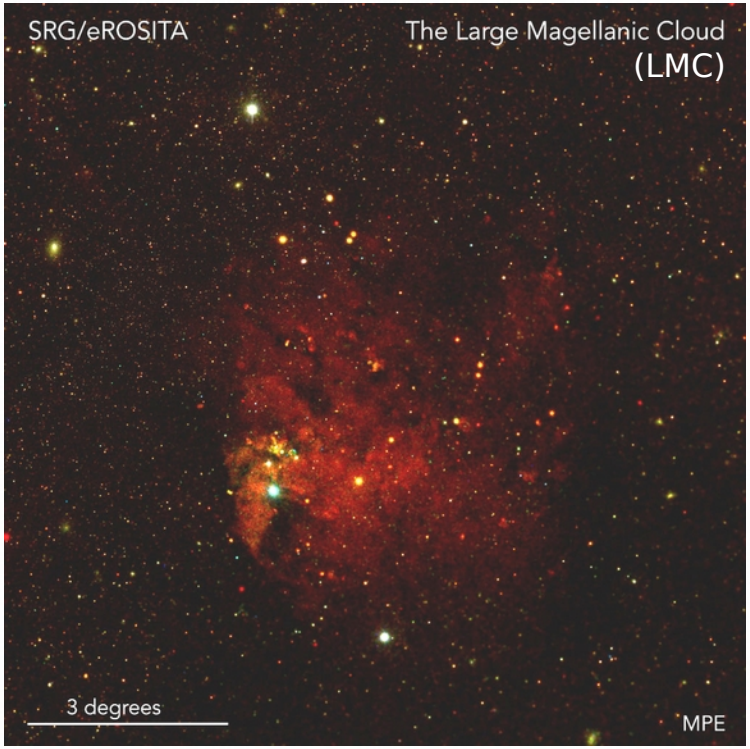
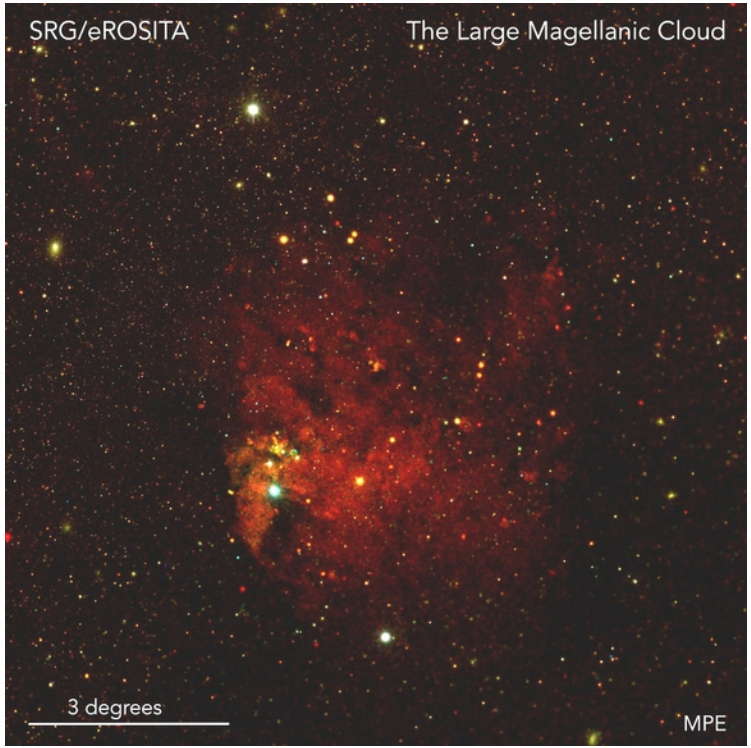




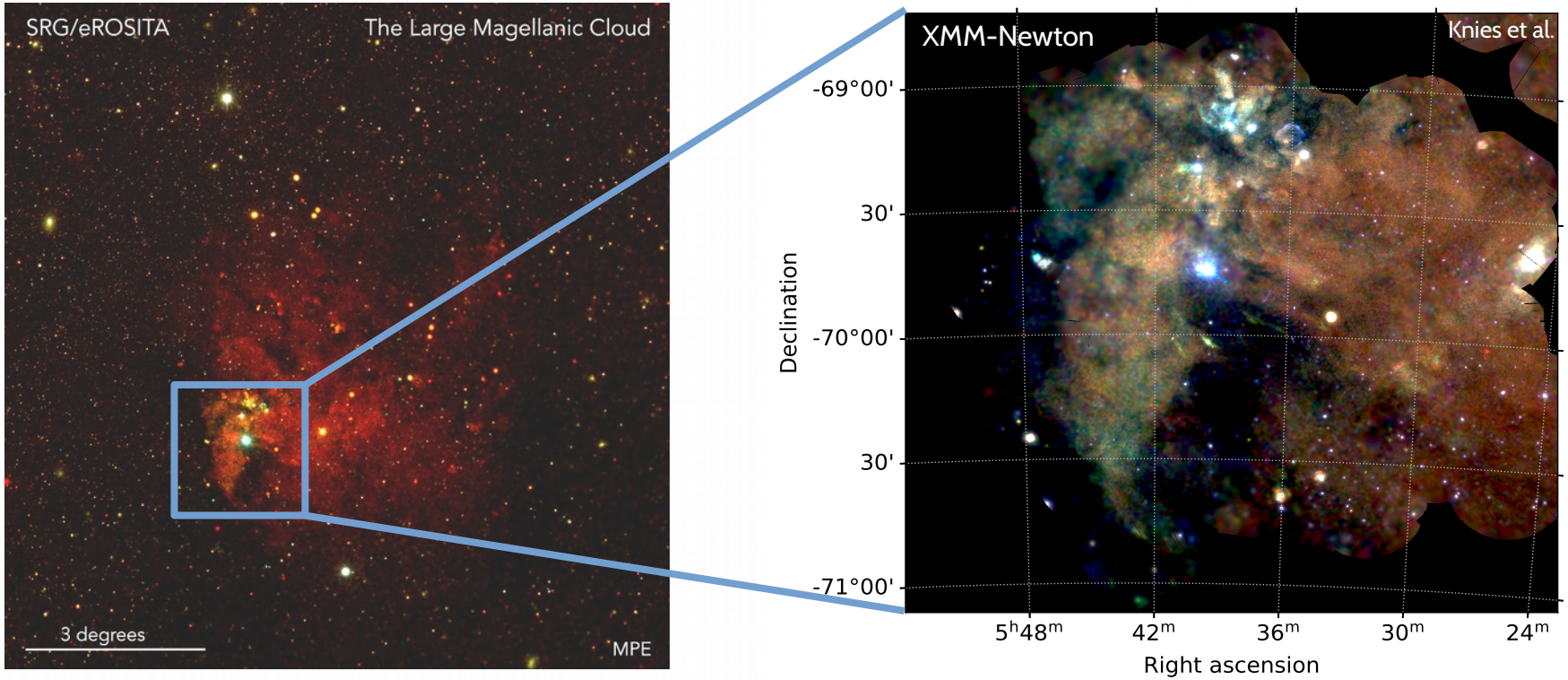


The Hot ISM in the LMC

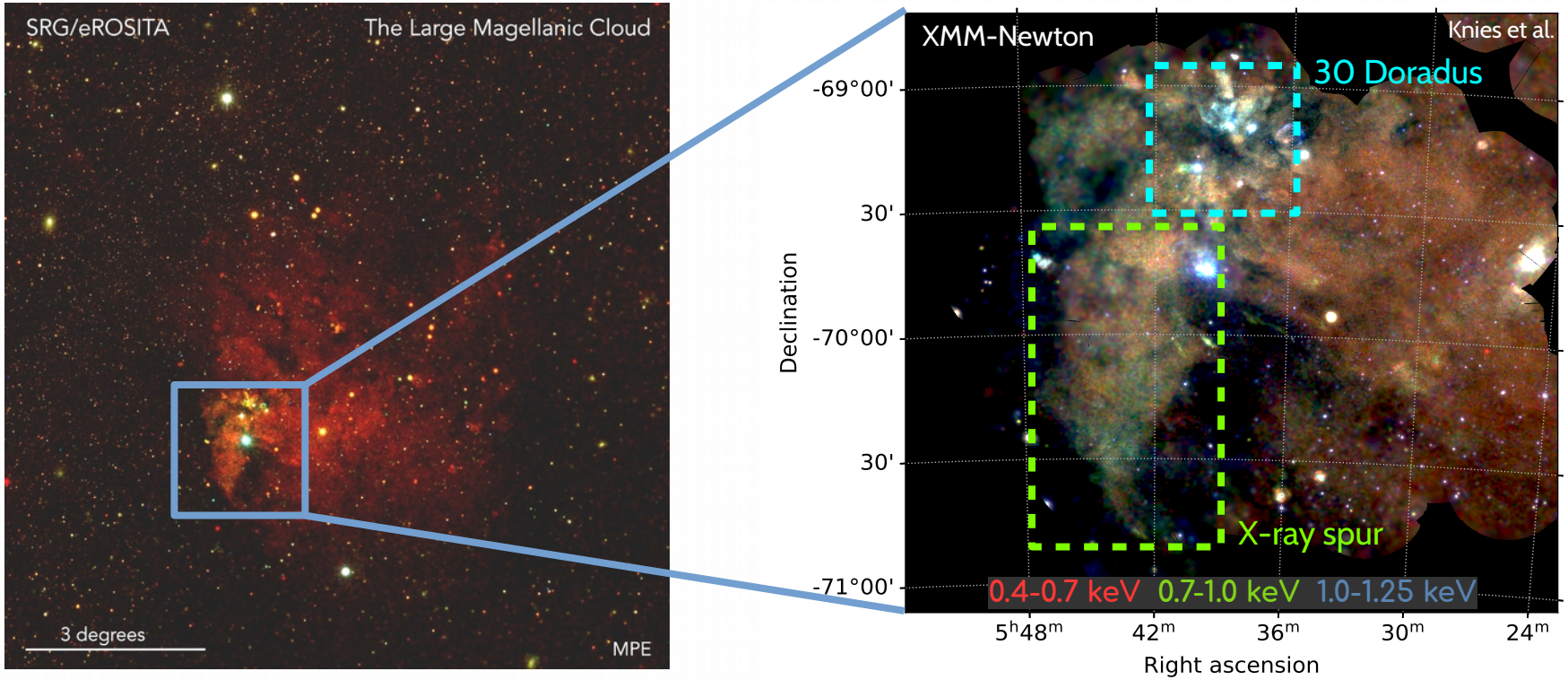
Overview



Overview


SRG/eROSITA
The Large Magellanic Cloud
3 degrees
MPE
XMM-Newton
Knies et al.
-69°00'
30'
-70°00'
30'
-71°00'
Declination
5h48m
42m
36m
30m
24m
Right ascension

Overview


SRG/eROSITA
The Large Magellanic Cloud
3 degrees
MPE
XMM-Newton
Knies et al.
30 Doradus
X-ray spur
0.4-0.7 keV
0.7-1.0 keV
1.0-1.25 keV
-69°00'
30'
-70°00'
30'
-71°00'
Declination
5h48m
42m
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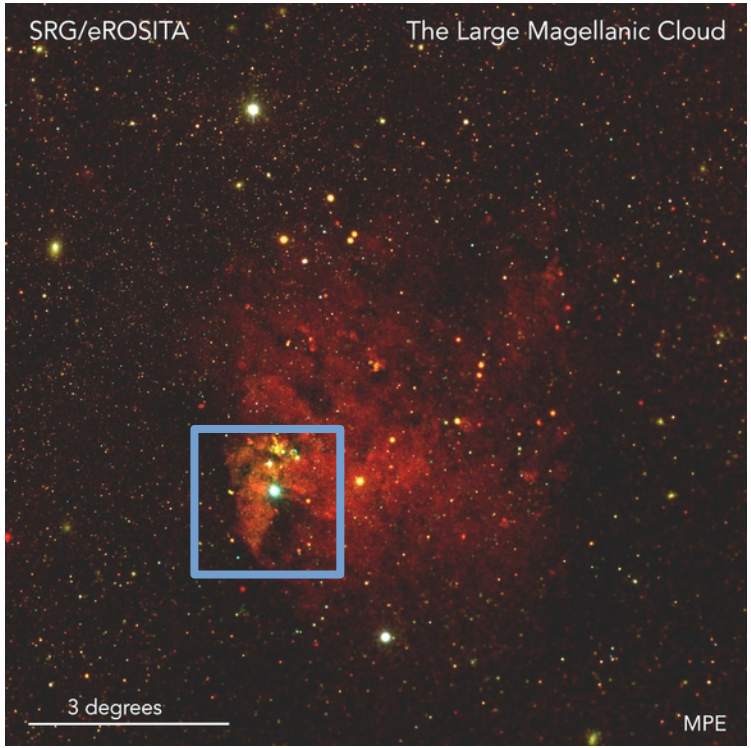
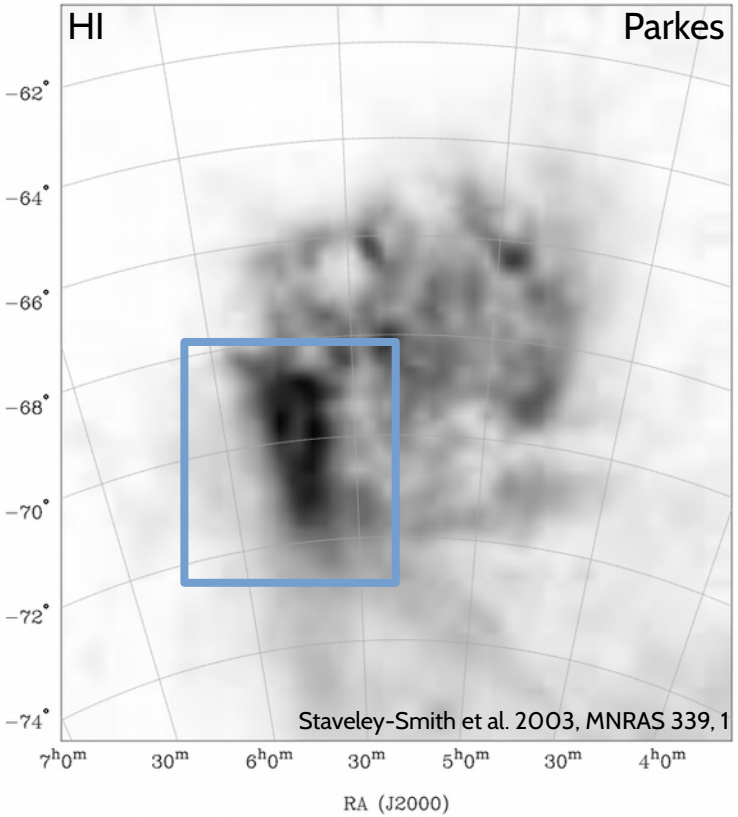
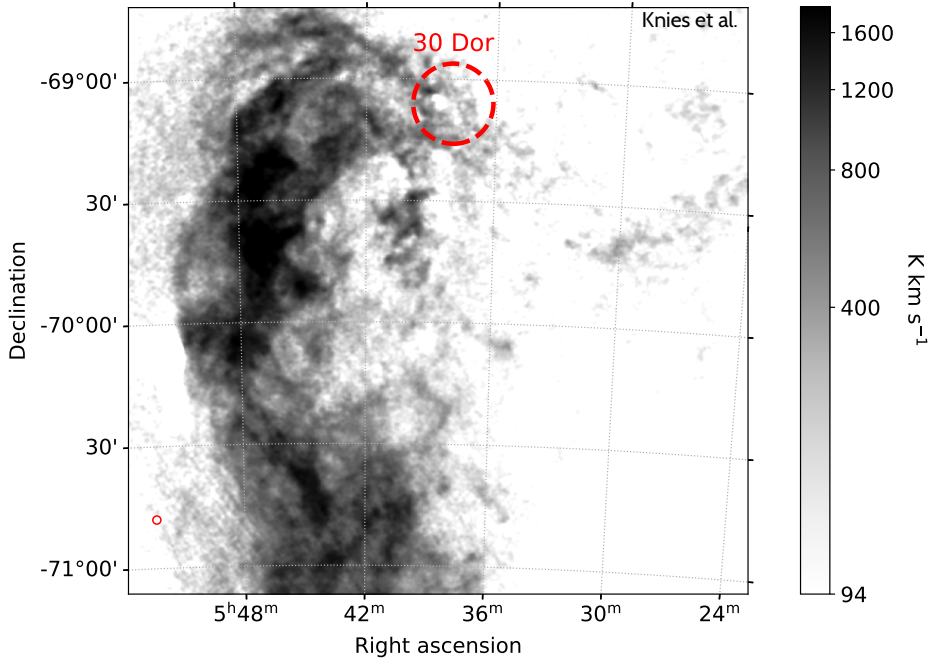
Overview

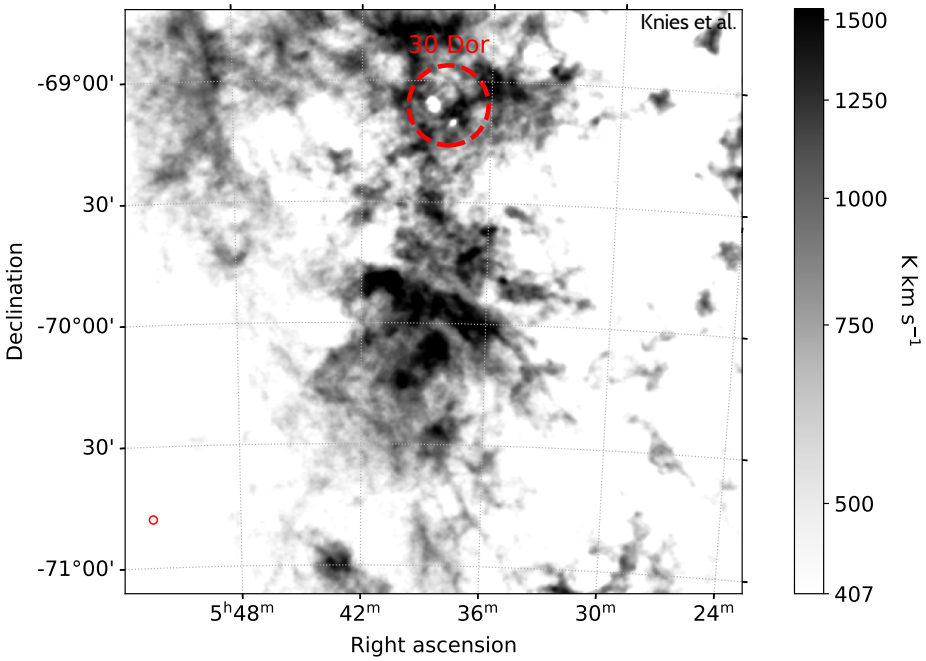

SRG/eROSITA
The Large Magellanic Cloud
3 degrees
MPE


HI
Parkes
−62°
−64°
−66°
−68°
−70°
−72°
−74°
7h0m
30m
6h0m
30m
5h0m
30m
4h0m
RA (J2000)
Staveley-Smith et al. 2003, MNRAS 339, 1

Overview



Low velocity component

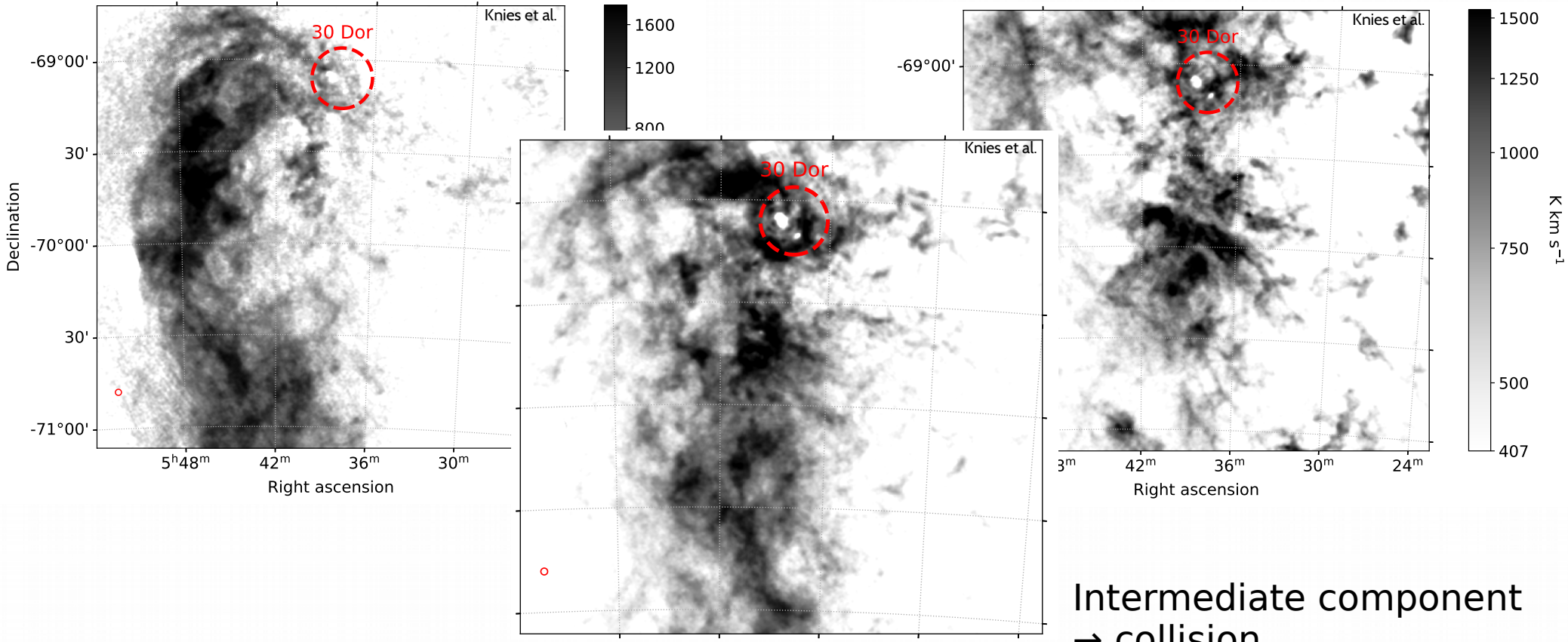


Disk component

HI (ATCA+Parkes)

More details: Fukui et al. (2017), Tsuge et al. (2019)

Overview



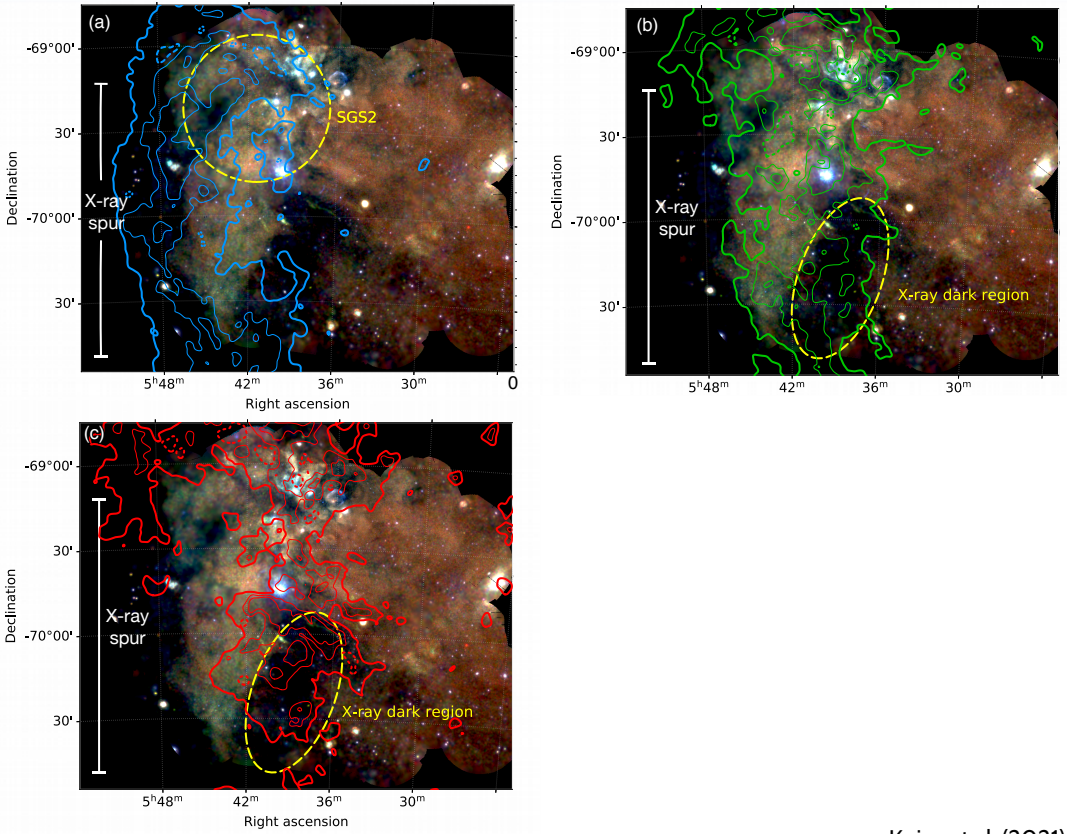
Intermediate component
→ collision

Colliding Clouds

Massive Cloud-Cloud Collision

- Gas from the SMC (blue) colliding with the LMC disk (red) with Δv ~ 50-100 km/s
- Collision traced by intermediate velocity component (green)
- Overlap with 30 Doradus and X-ray spur
- Most likely triggered *massive star formation* in 30 Doradus

(Fukui et al. 2017)



Contours: HI Radio (ATCA+Parkes)

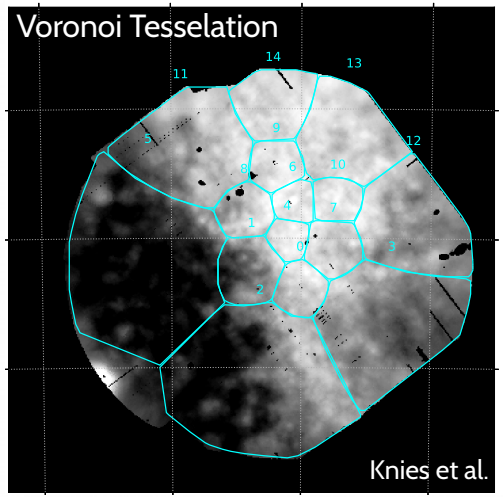
Knies et al. (2021)

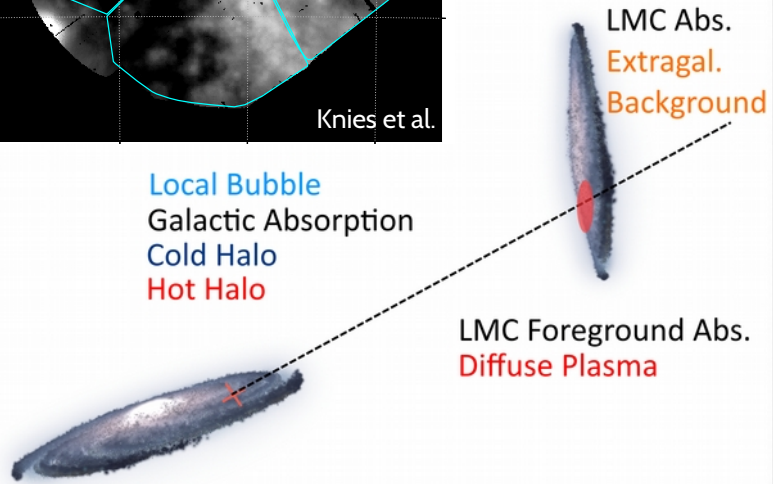
Spectral Analysis

Large scale spectral analysis (XMM-Newton)

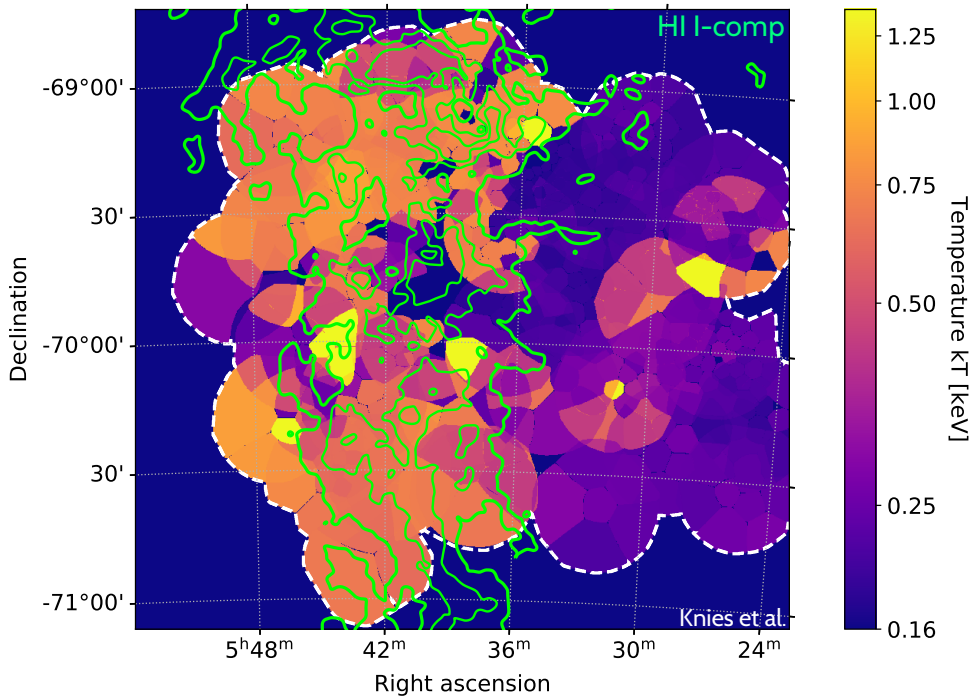
- Spatial binning with Voronoi tesselation
- Background carefully modeled
- Source emission: combination of two thermal plasma models at different temperatures *kT*

  → *cold+hot component*

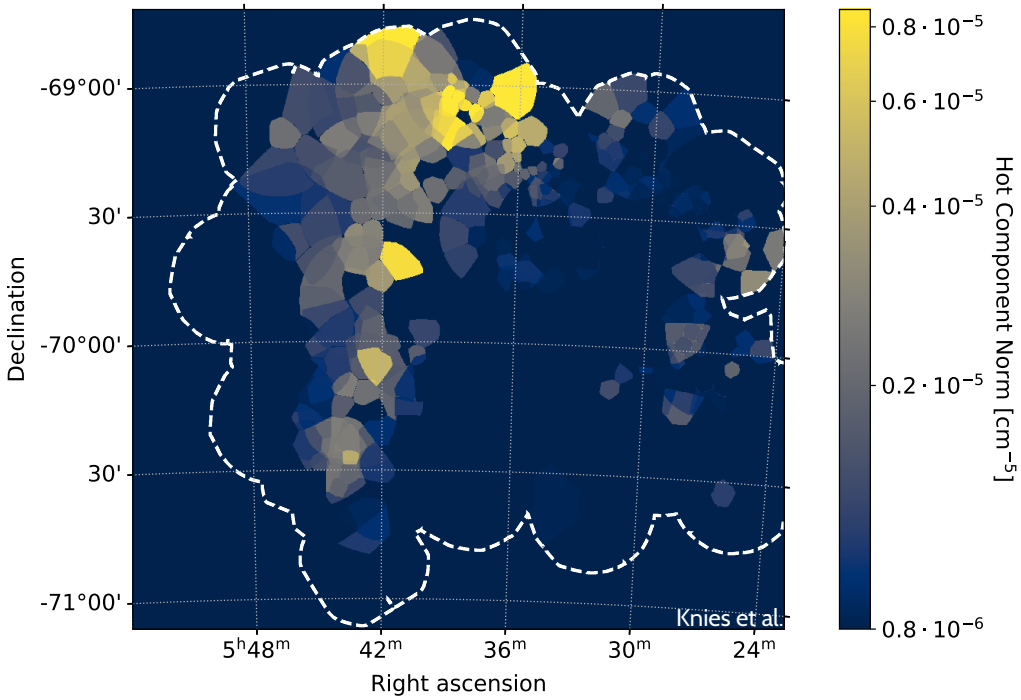




Results

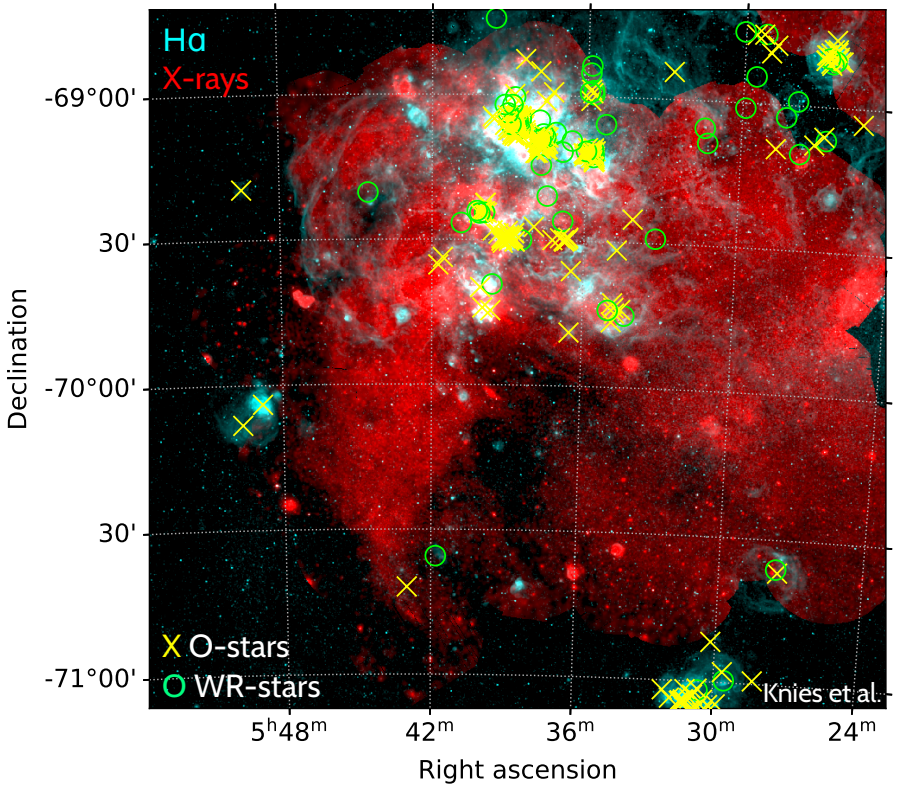


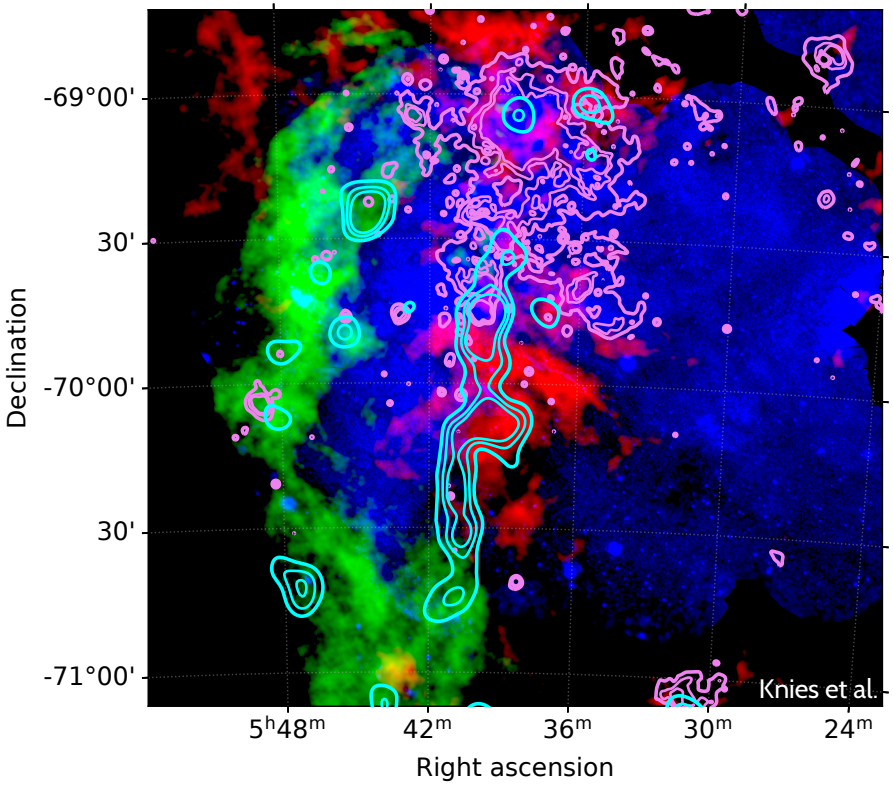
“Average” Temperature Map



Hot Component Emission Strength

Multi-Wavelength View





Collision Scenario

Stellar Synthesis simulations show large energy discrepancy in X-ray spur → Heated by the collision?

Knies et al. (2021)

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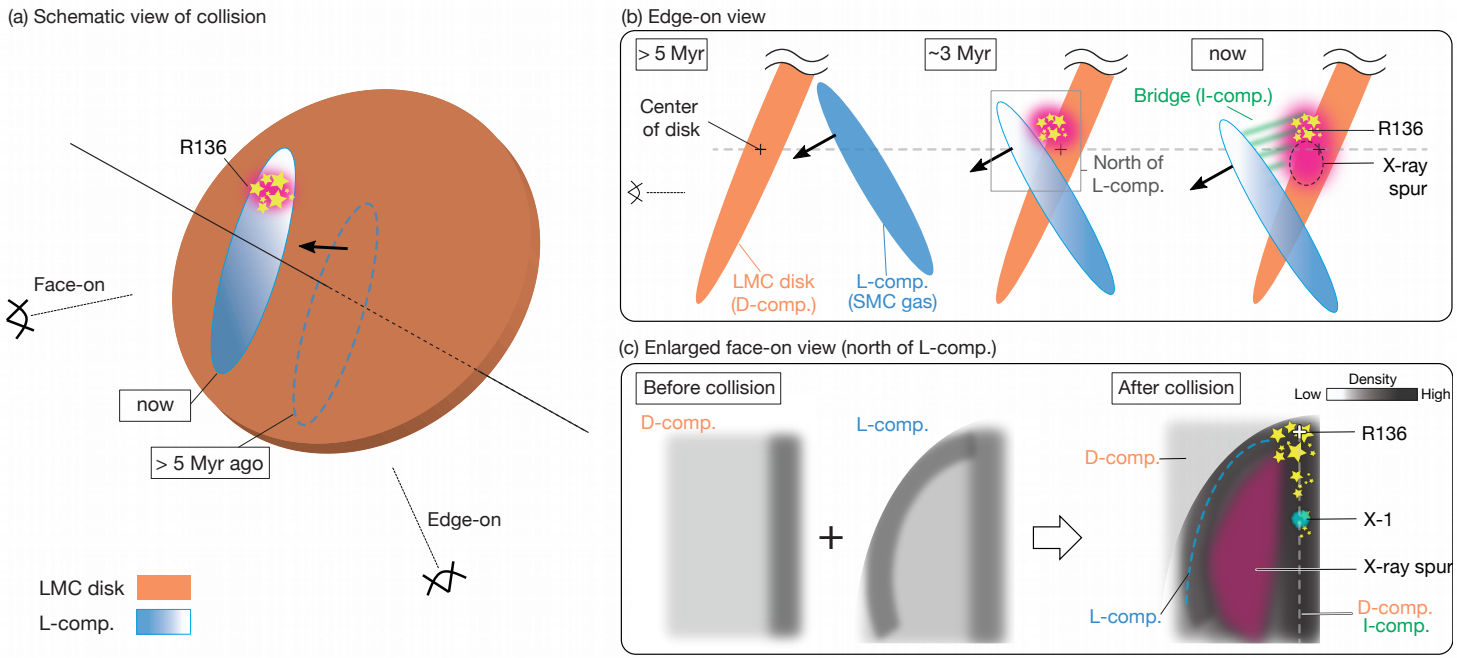

Knies et al. (2021)

Summary & Outlook

- Large scale collision of SMC gas and LMC disk, triggered star formation in 30 Doradus
- Large scale spectral analysis shows enhanced plasma temperatures where collision takes place
- Stellar energy input not sufficient to explain plasma in the X-ray spur
- Collision most likely caused additional heating and compression at the spur, future star forming region
- With *eROSITA* this study can be extended to the whole LMC