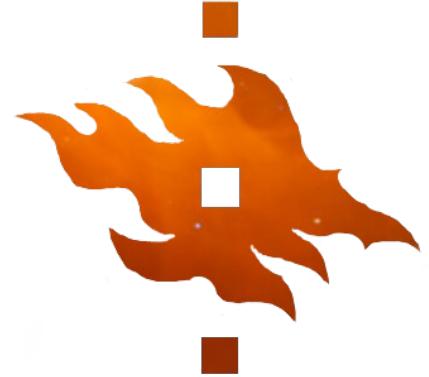


The multiscale interstellar medium from massive molecular clouds to cold cores

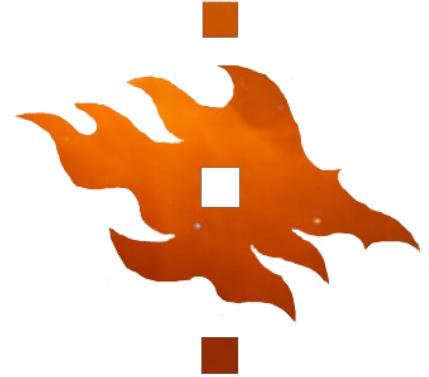
Emma Mannfors
Lectio Praecursoria
30.1.2026





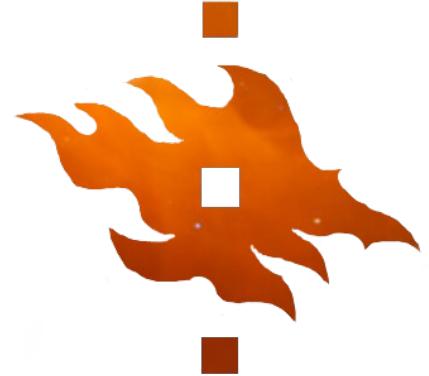
Add QR code/tinyurl link to thesis
Add QR code/tinyurl link to English translation of
lektio

https://github.com/EmmaMannfors/Mannfors_PhD



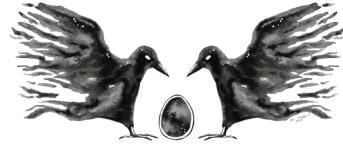
Contents

- A story (of baby stars)
- The ISM
 - Properties
 - How they affect the rest of astronomy
- The Galaxy
- Observations
 - The wavelengths
 - Telescopes
 - How signals travel in space
- Summary of my work



Units

- 1 parsec (pc)
= 3.26 lightyears
= 3.09×10^{16} m
(1 billion = 10^9)
- 0 K = -273.15 °C

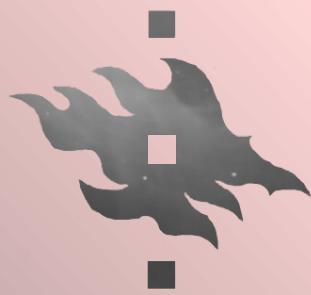


ISM = Interstellar medium
 = Tähtienvälinen aine
 (= space clouds)

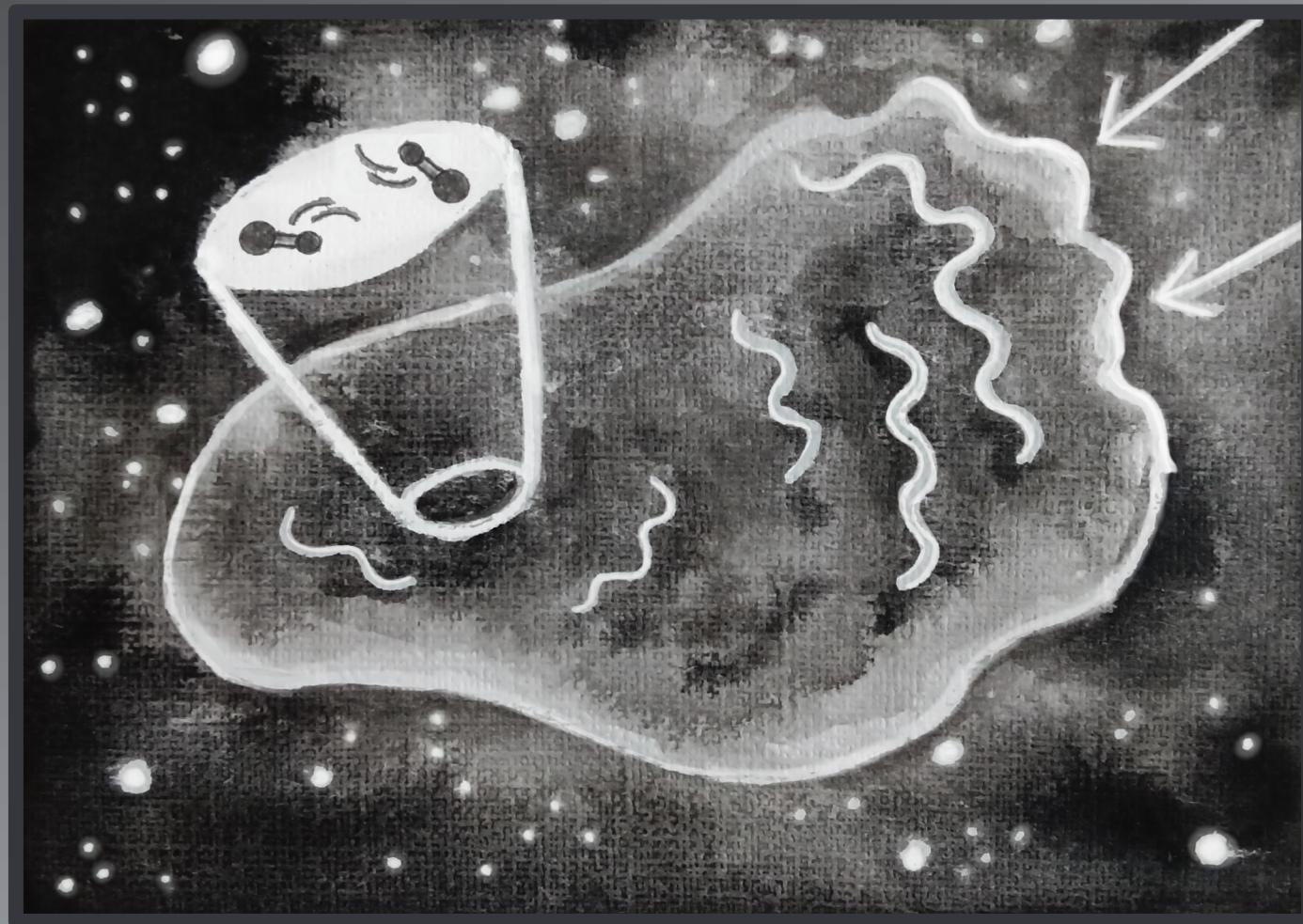


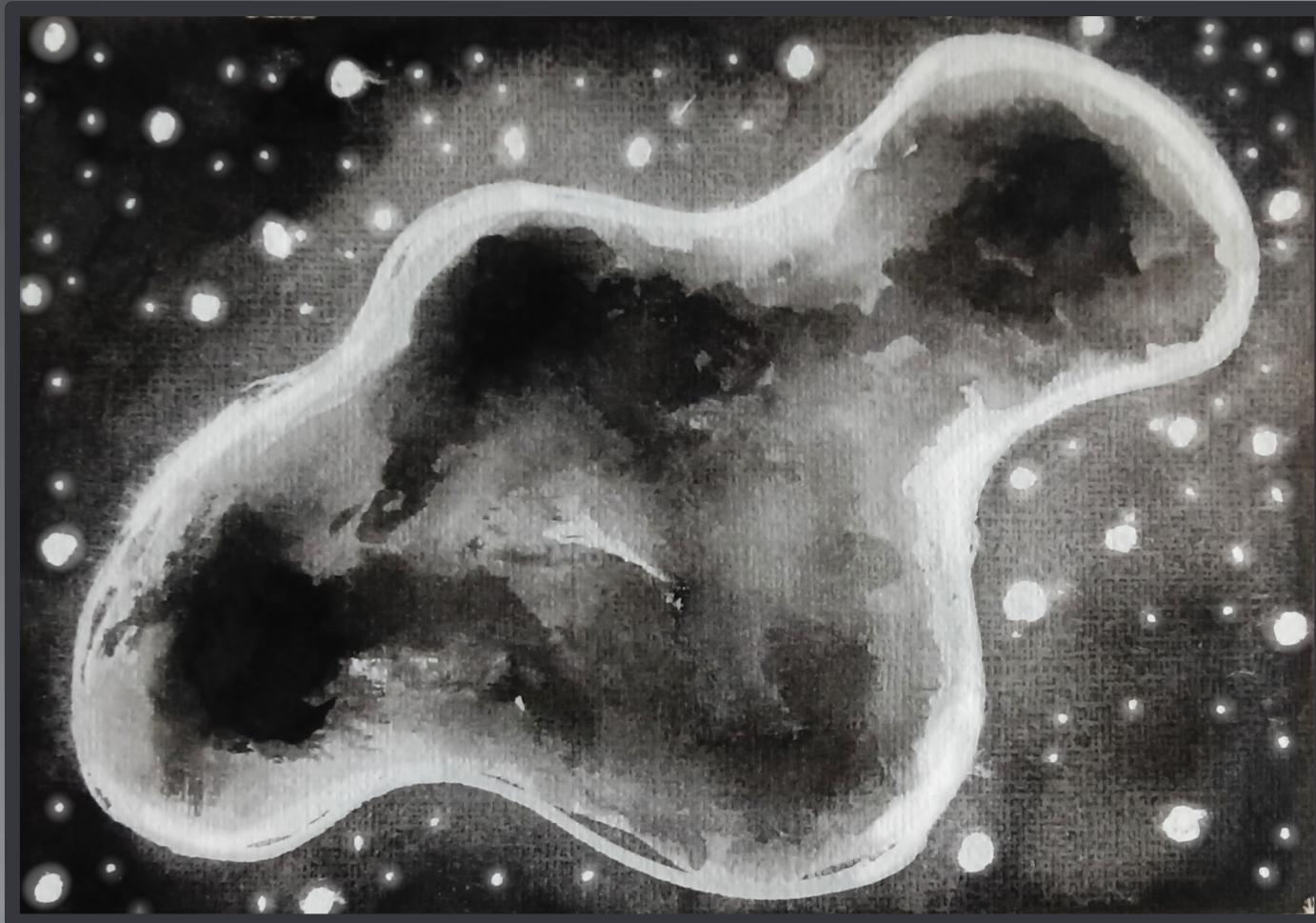
Illustrations: E. Mannfors

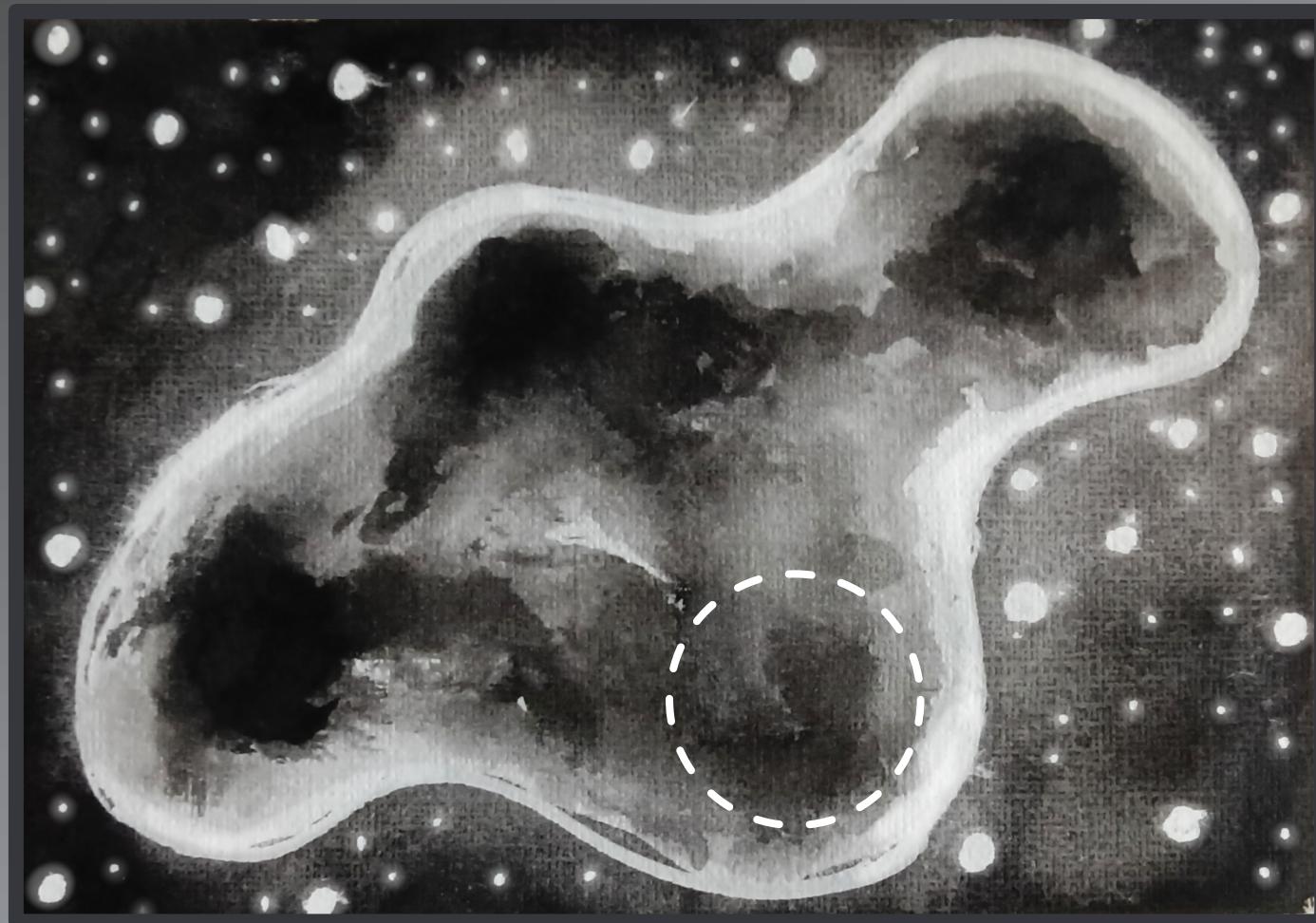


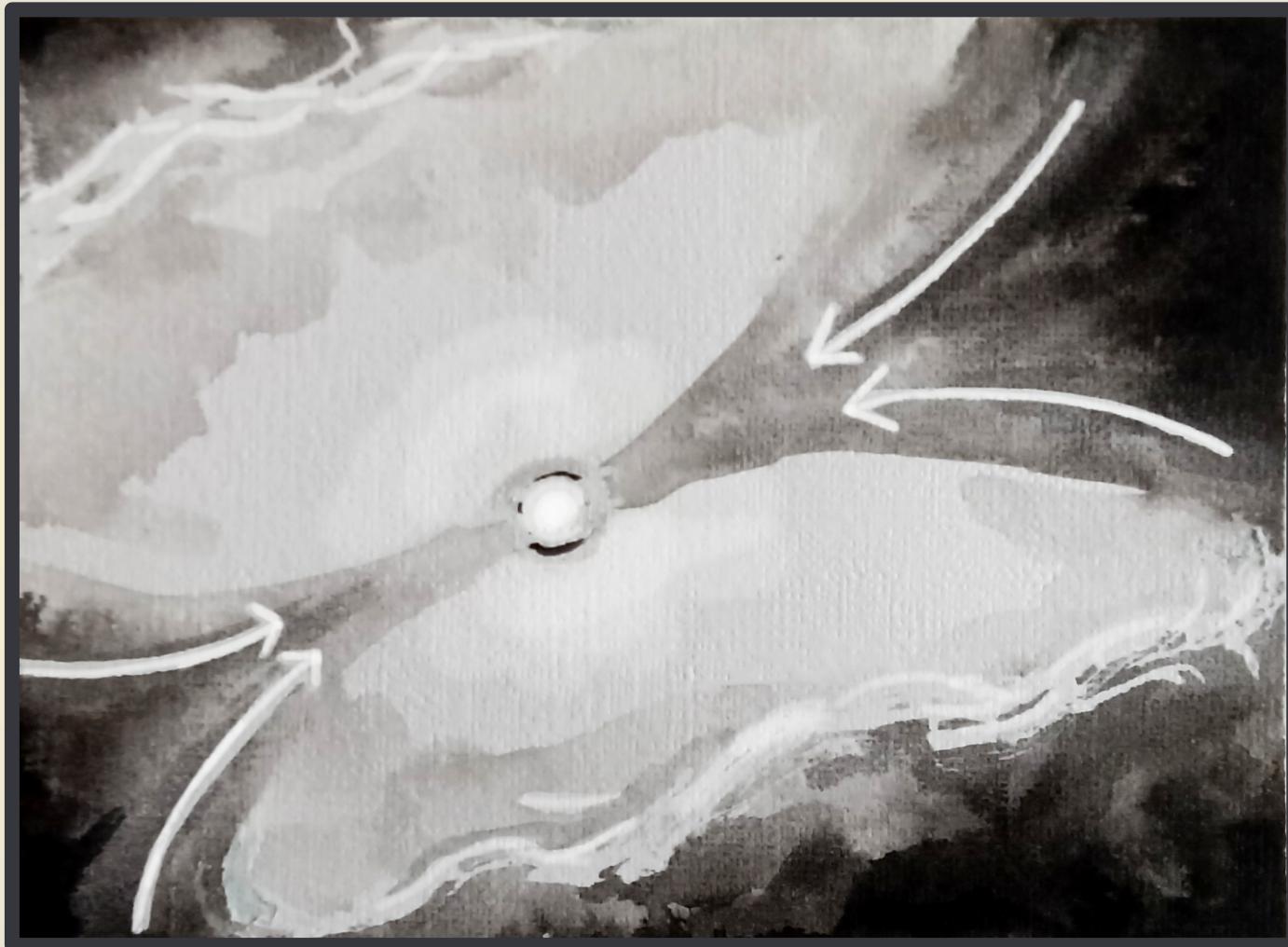


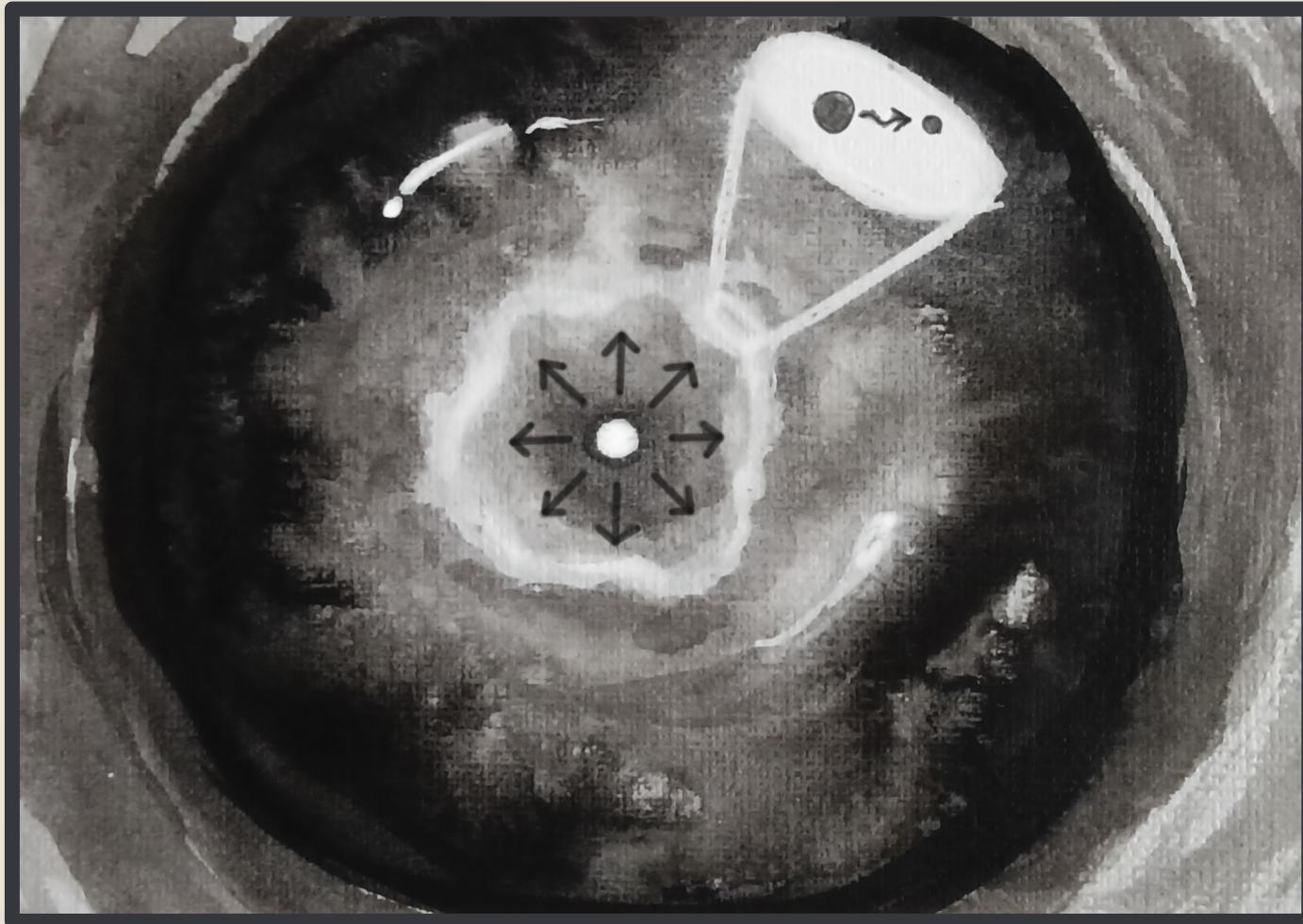


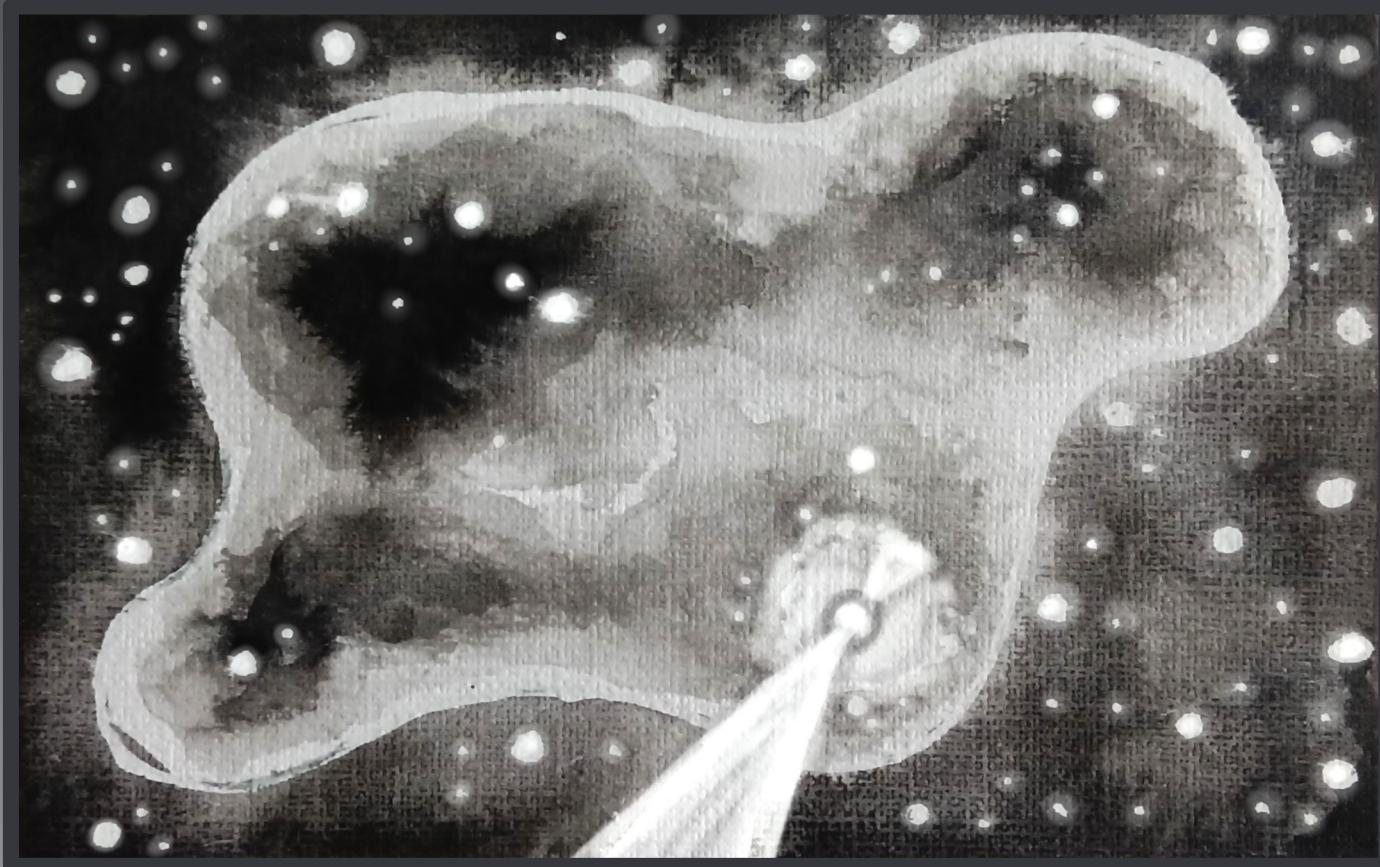




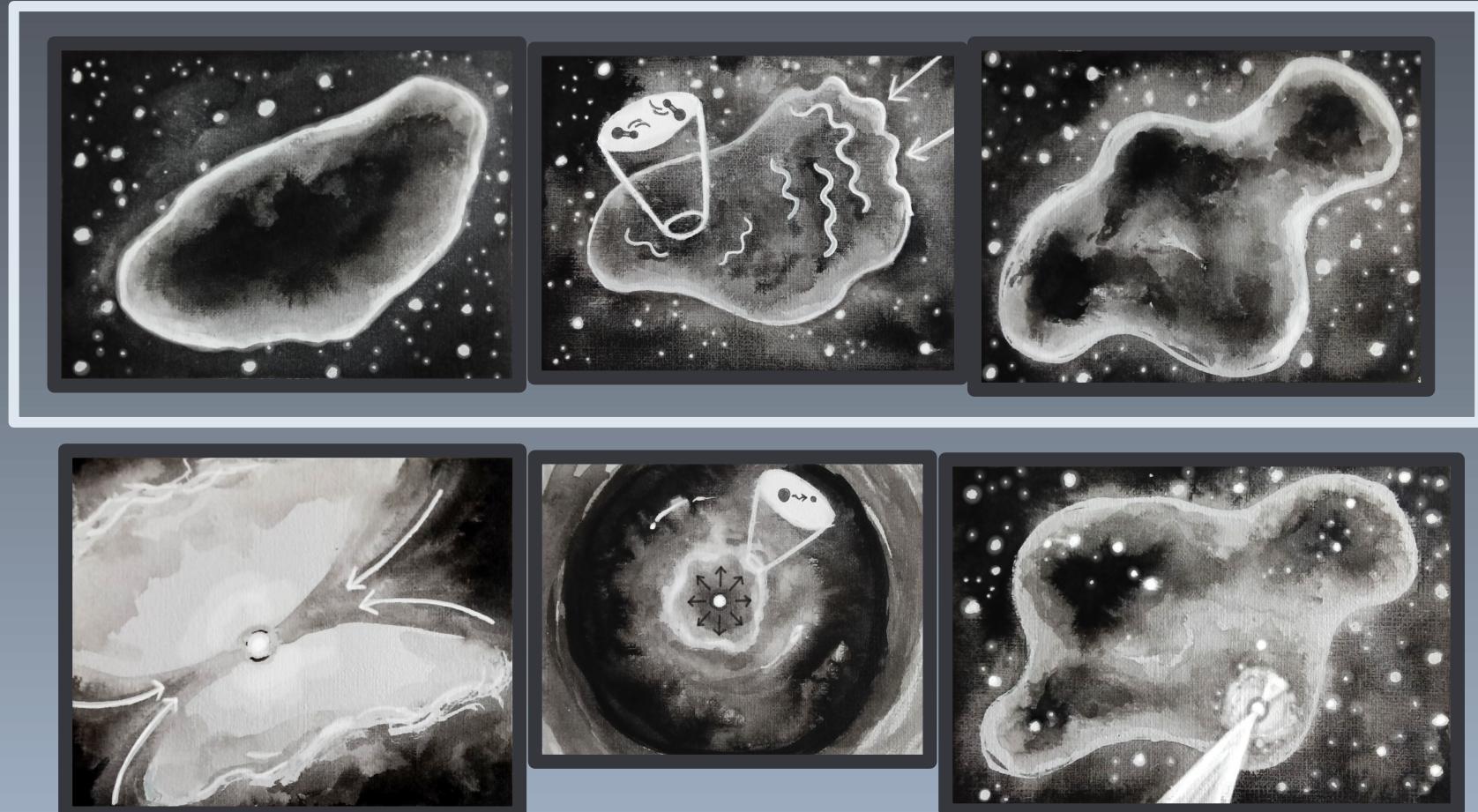








My thesis

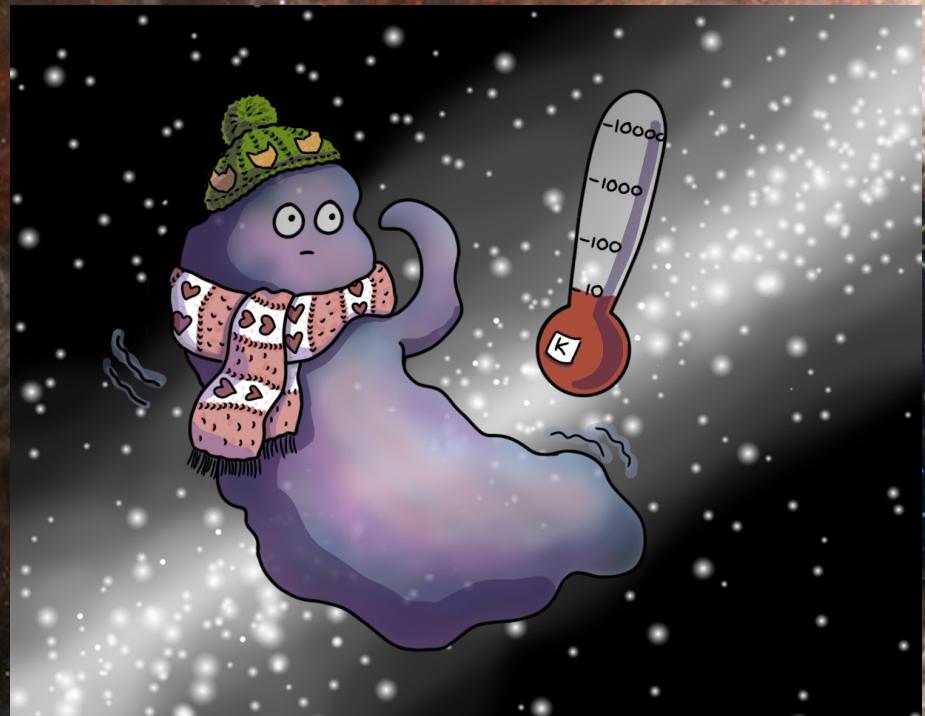


Illustrations: E. Mannfors



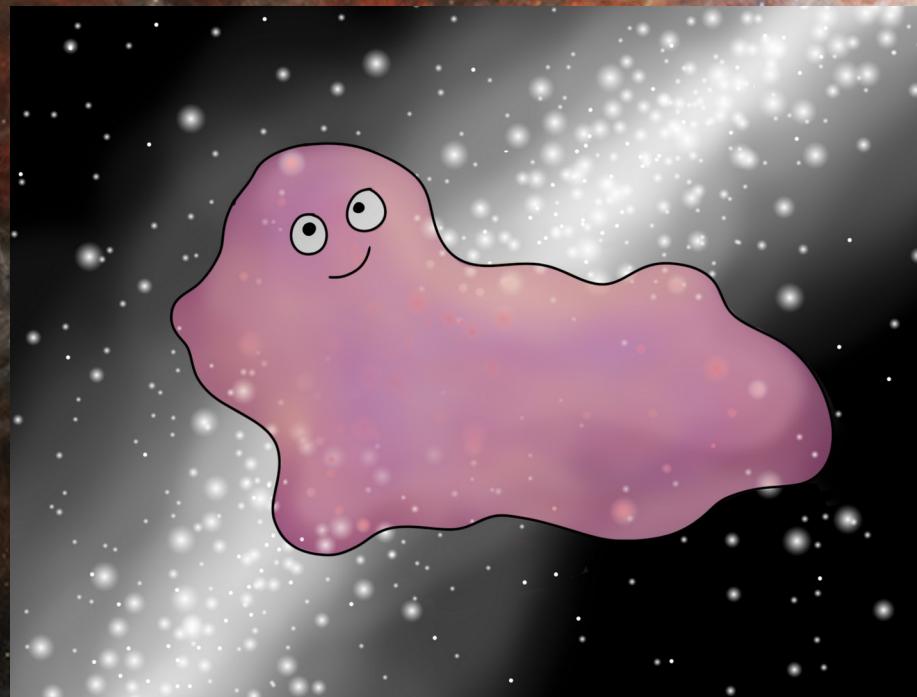
What are space clouds?

Basics of the (COLD) ISM



- Cold [10 - 100 K (-260 to -160°C)]

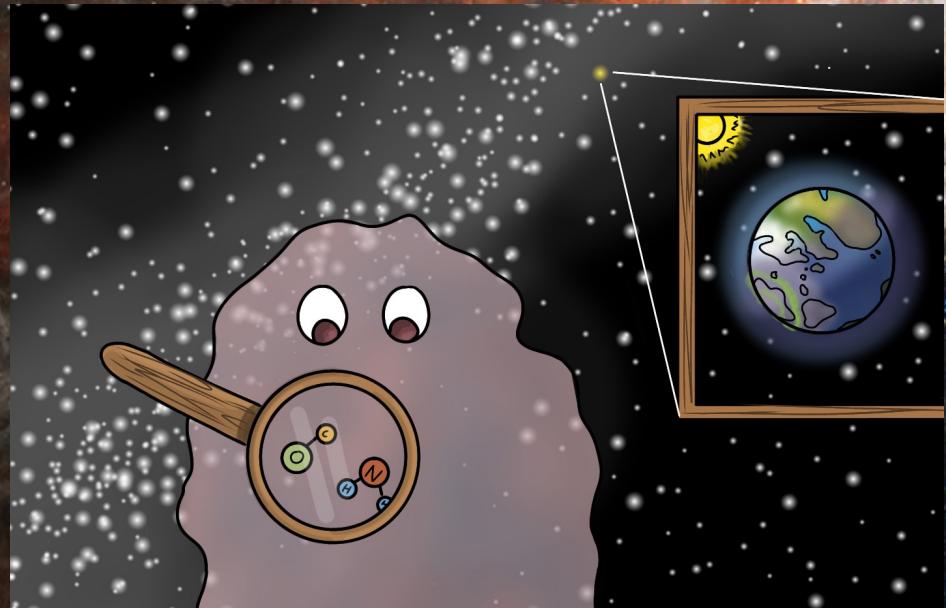
Basics of the (COLD) ISM



- Cold [10 - 100 K (-260 to -160°C)]
- Dense (for space)
 - 10^3 - 10^6 atoms / cm 2
 - Earth: $\sim 10^{22}$ H atoms / cm 2
 - ($T = 0^\circ\text{C}$, $P = 100 \text{ kPa}$)

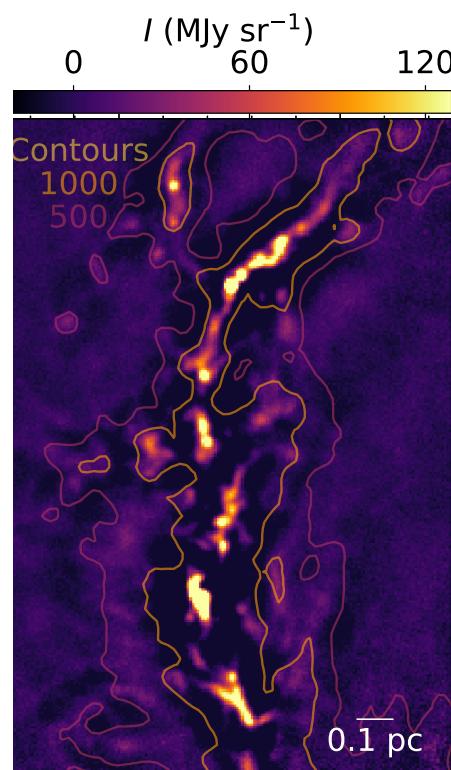
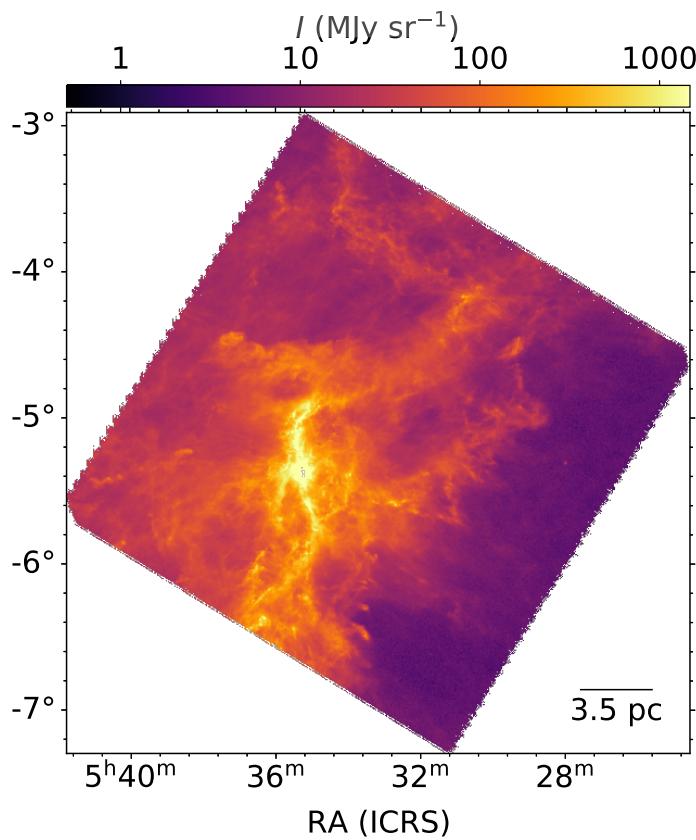
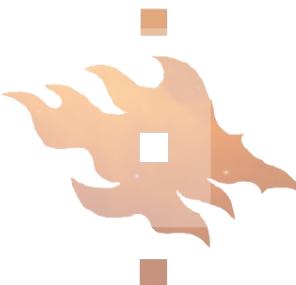


Basics of the (COLD) ISM

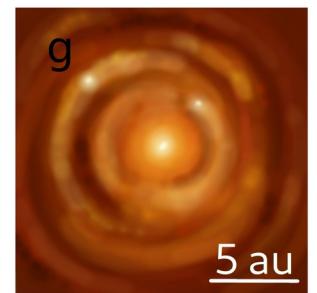


- Cold [10 - 100 K (-260 to -160°C)]
- Dense (for space)
 - 10^3 - 10^6 atoms / cm²
 - Earth: $\sim 10^{22}$ H atoms / cm²
 - ($T = 0^\circ\text{C}$, $P = 100 \text{ kPa}$)
- Components:
 - Gas
 - Atoms: H, He, metals
 - Molecules: > 100 species
 - H², CO
 - Dust
 - ~1% by mass
 - Ice around silicate core
-

Scales and structure

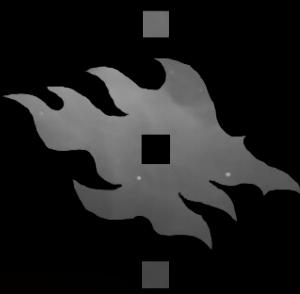


- Filaments:
 - Long, thin clouds
- Clumps & Cores:
 - Spherical, <1 pc in size



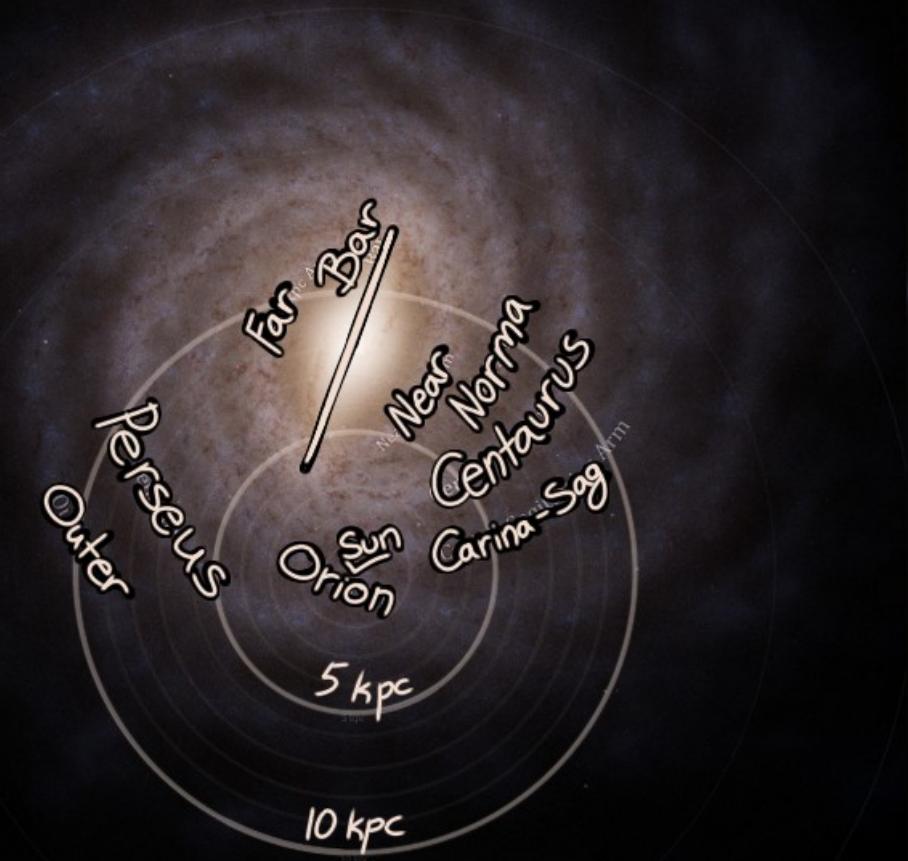


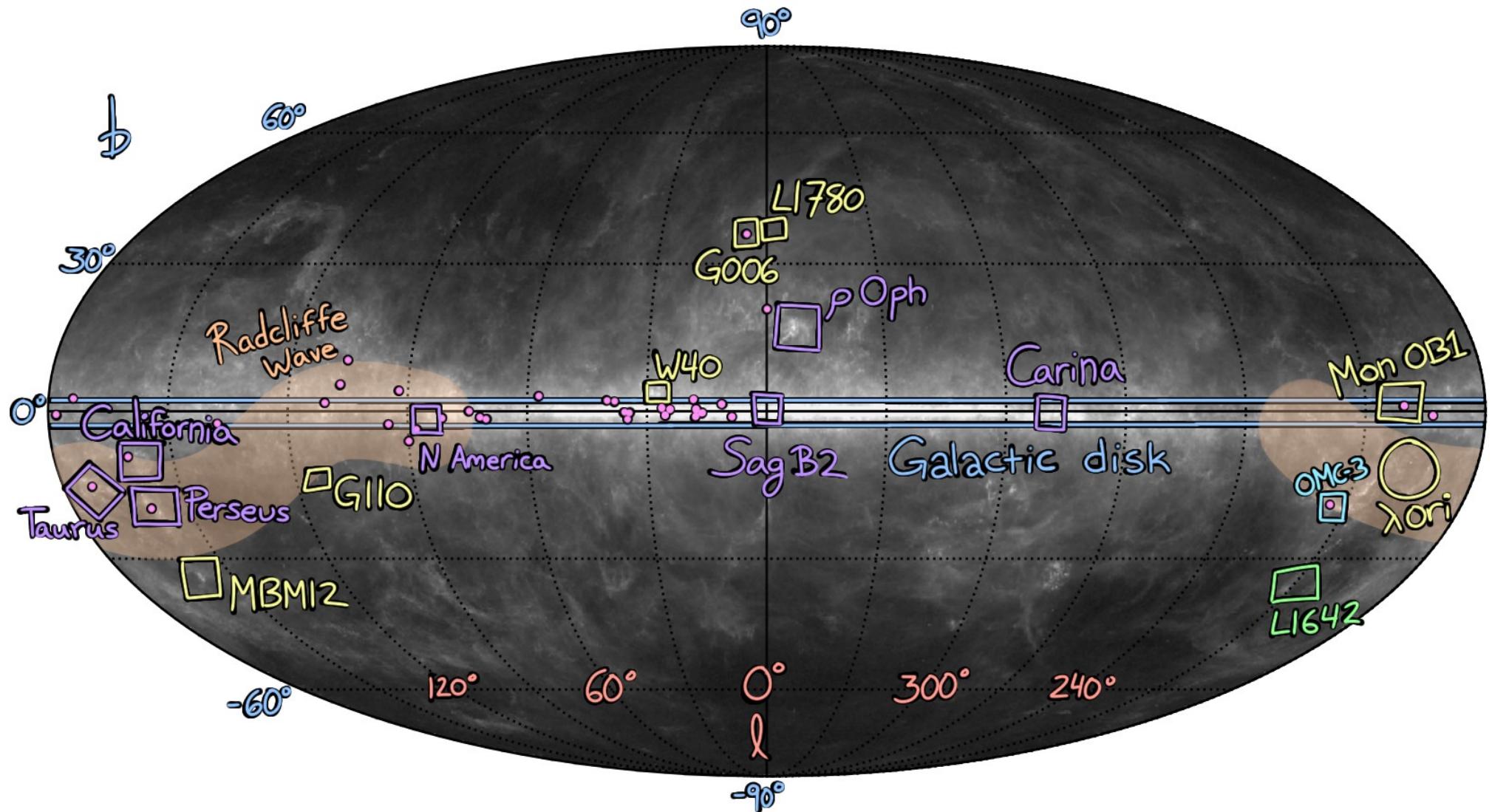
Our galaxy



Sagittarius
Dwarf Galaxy

~ 20 kpc







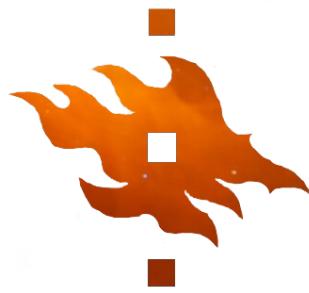
Observing



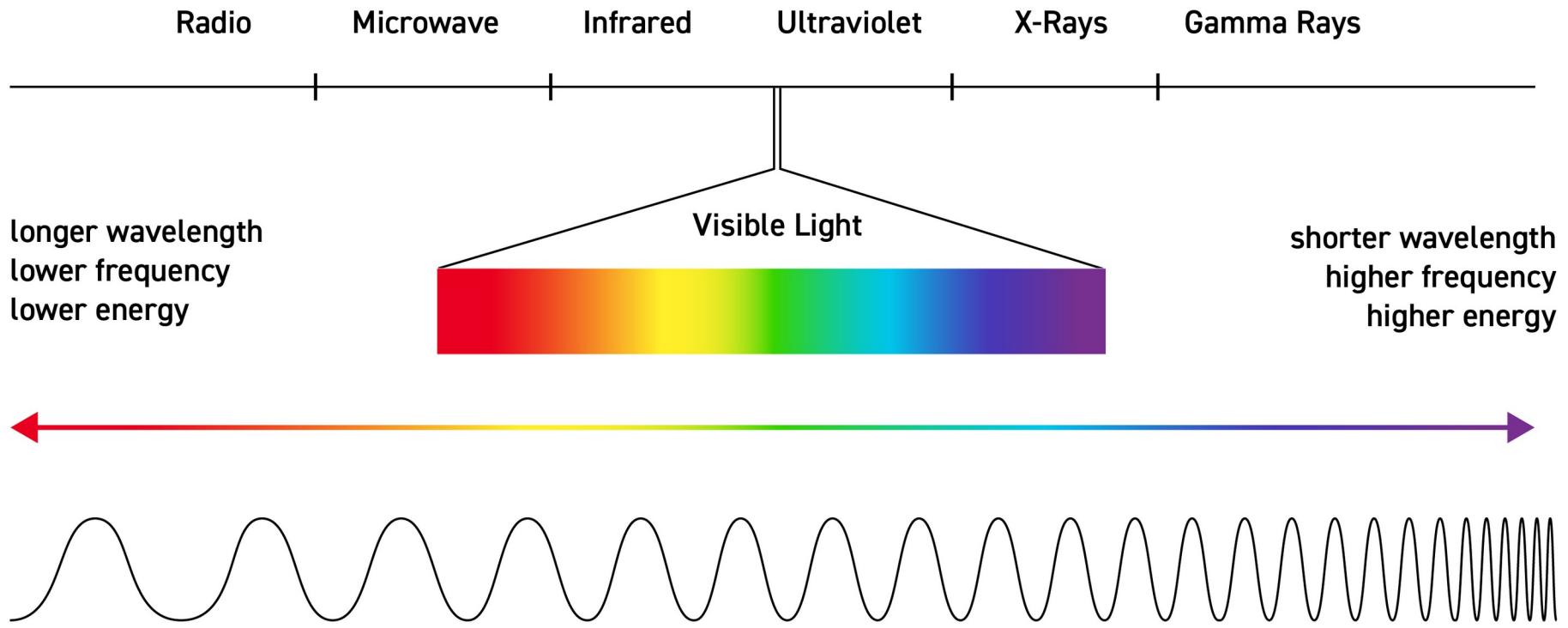
30/1/2026

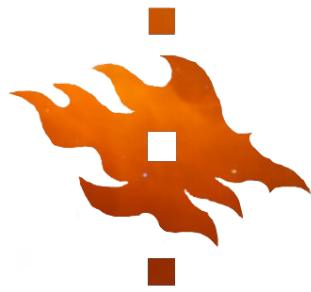
24

Credit: ESO/S. Guisard <https://www.eso.org/public/images/potw1217a/>

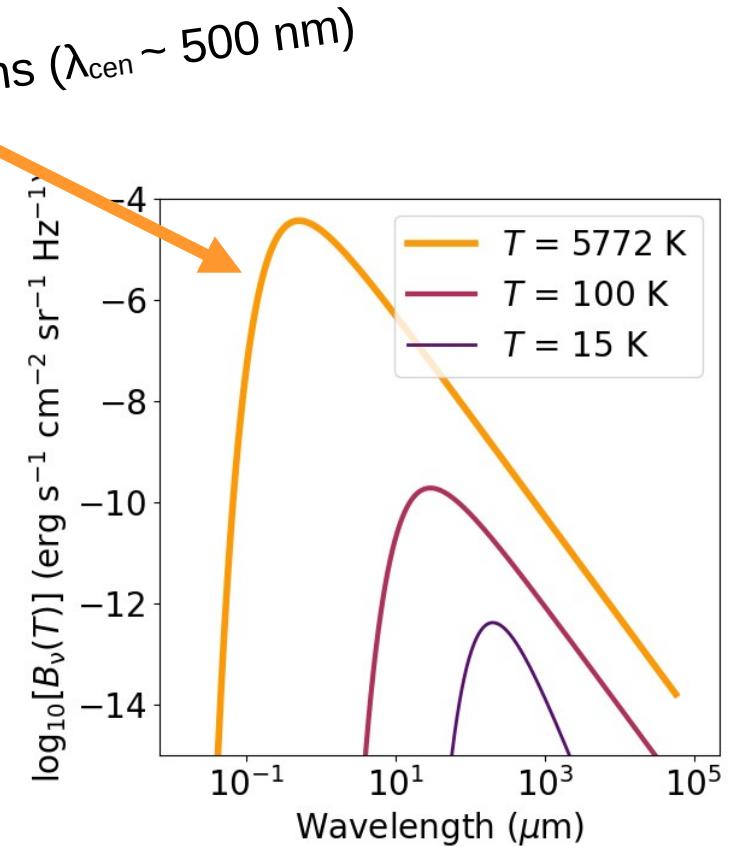


Wavelengths

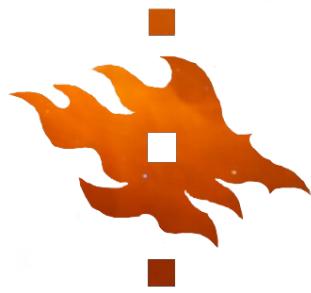




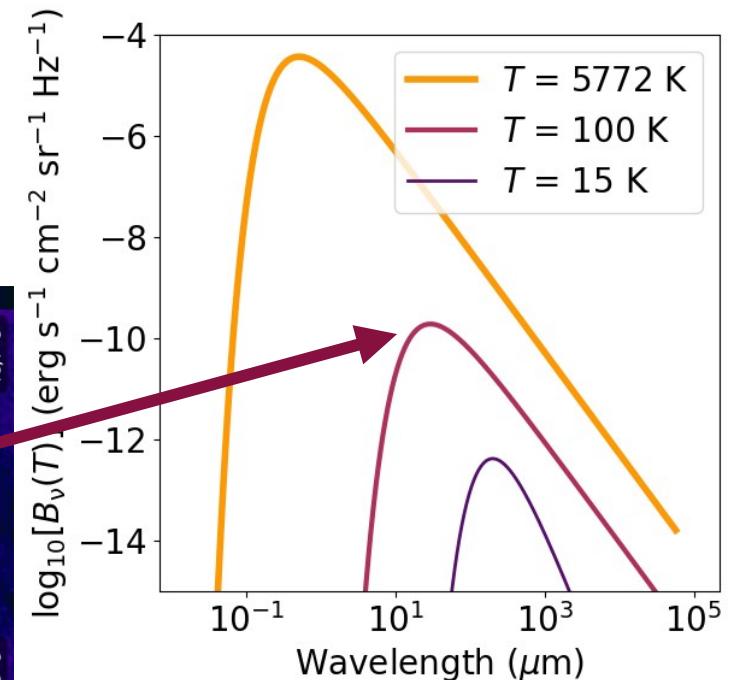
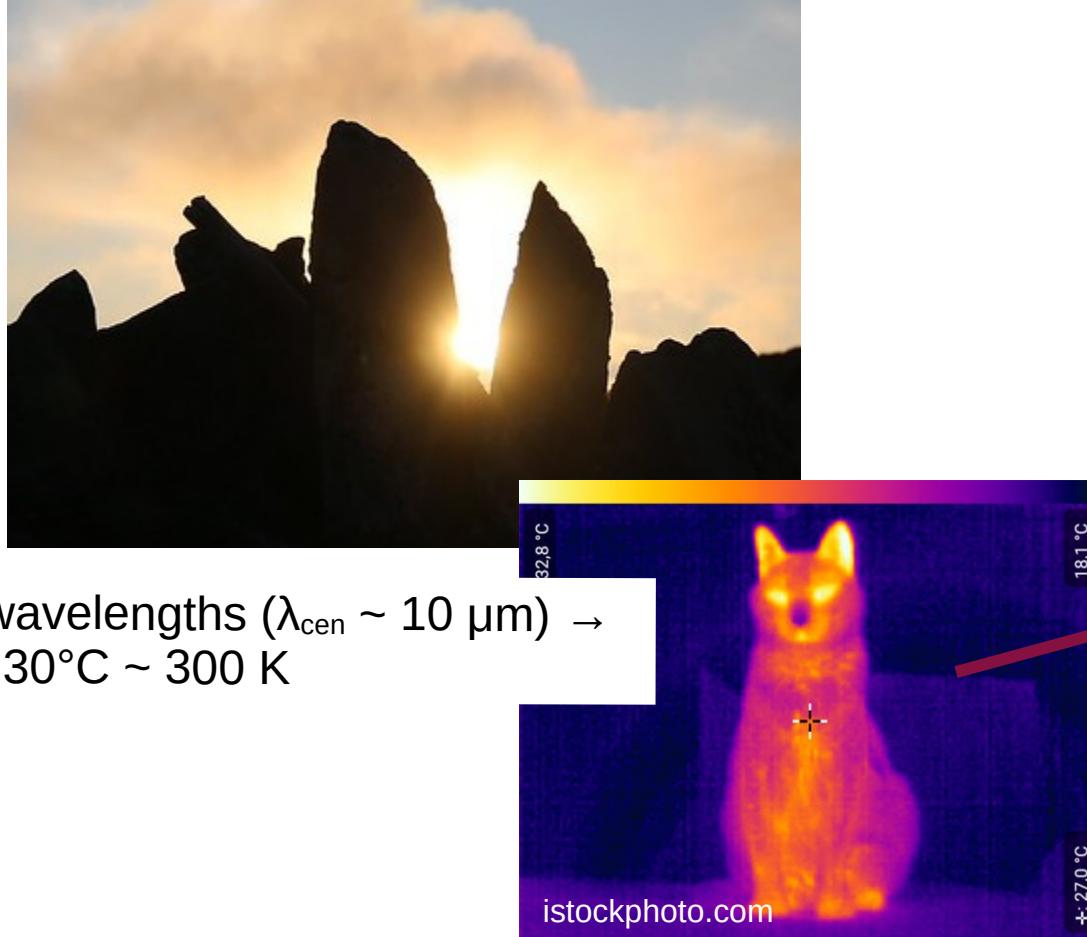
Blackbody spectrum



λ = wavelength; T = temperature



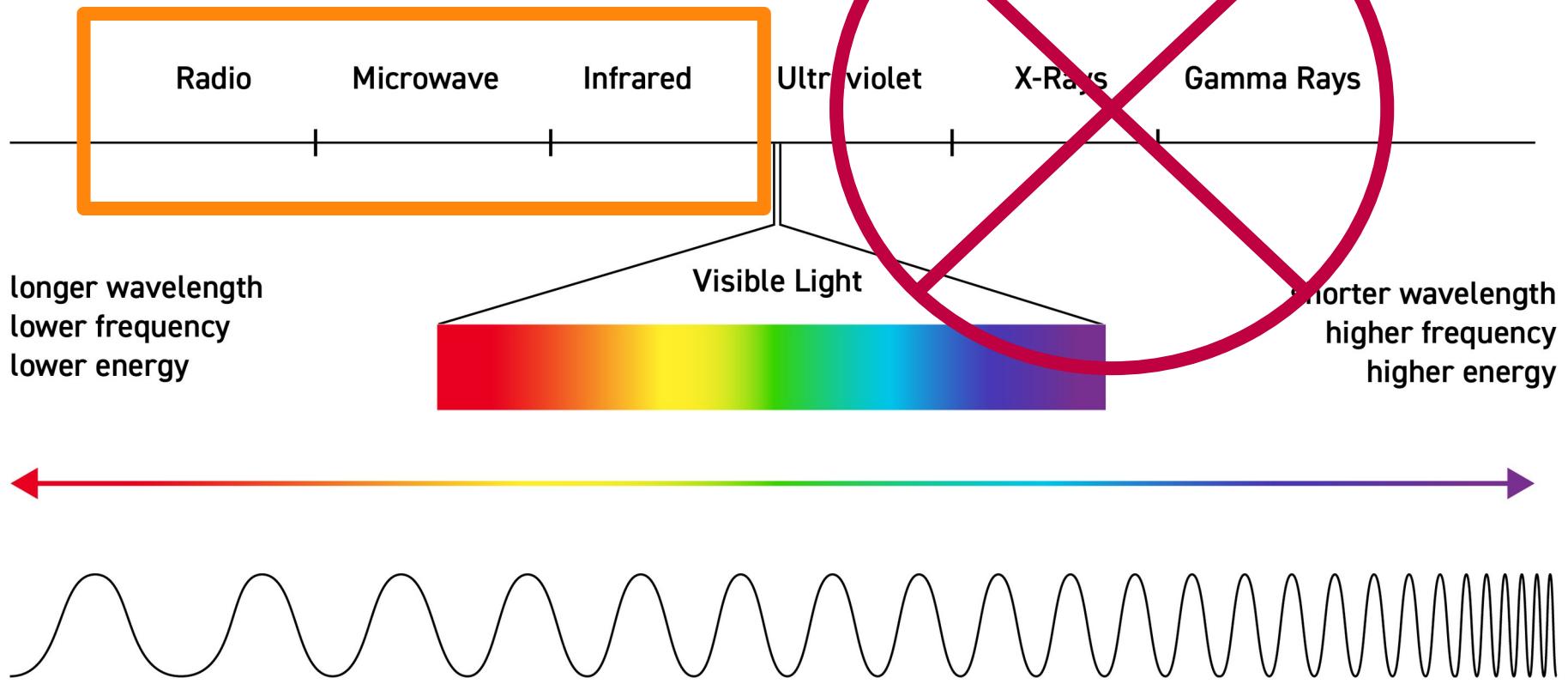
Blackbody spectrum



λ = wavelength; T = temperature



Wavelengths

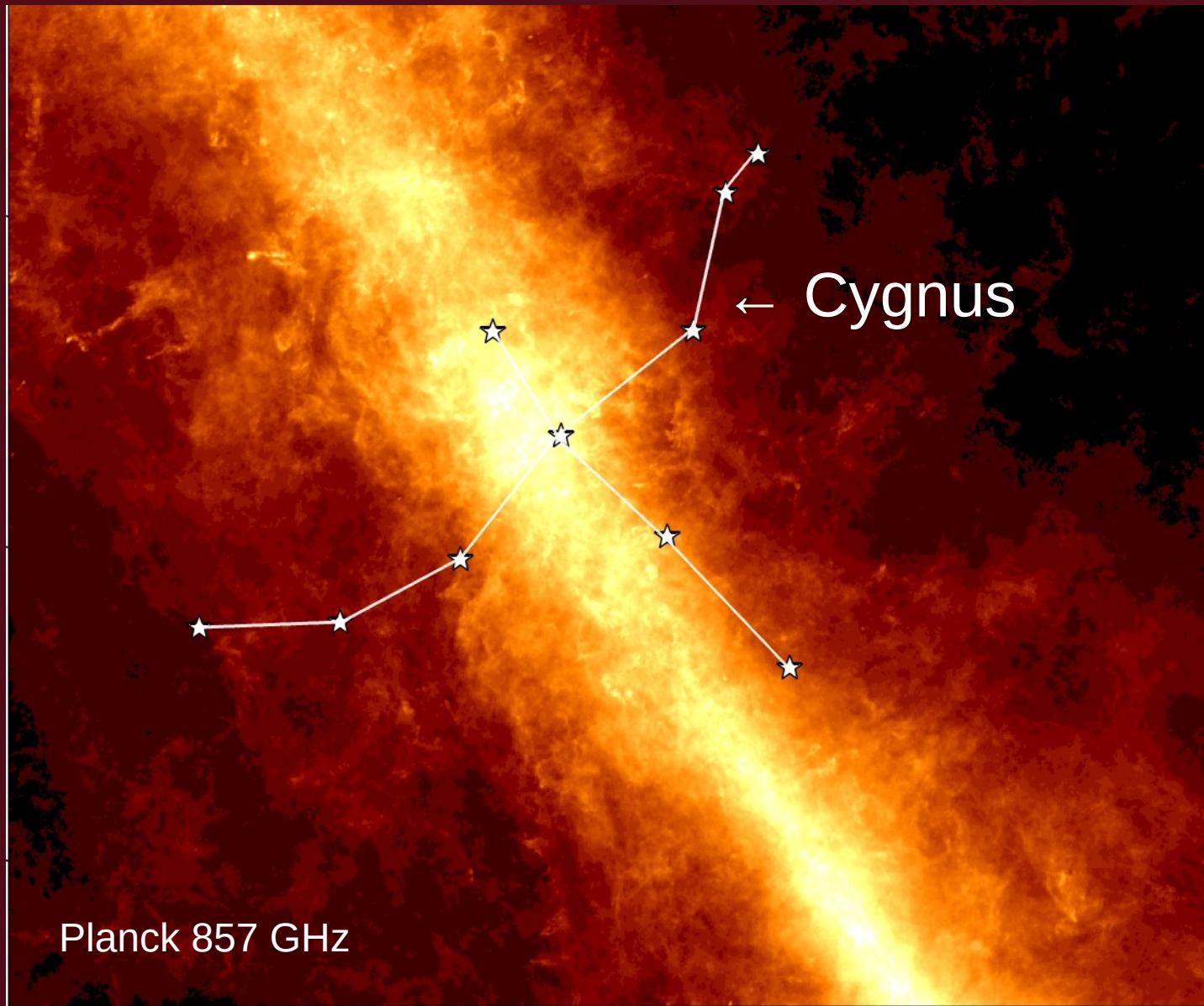
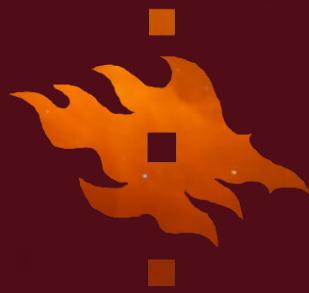


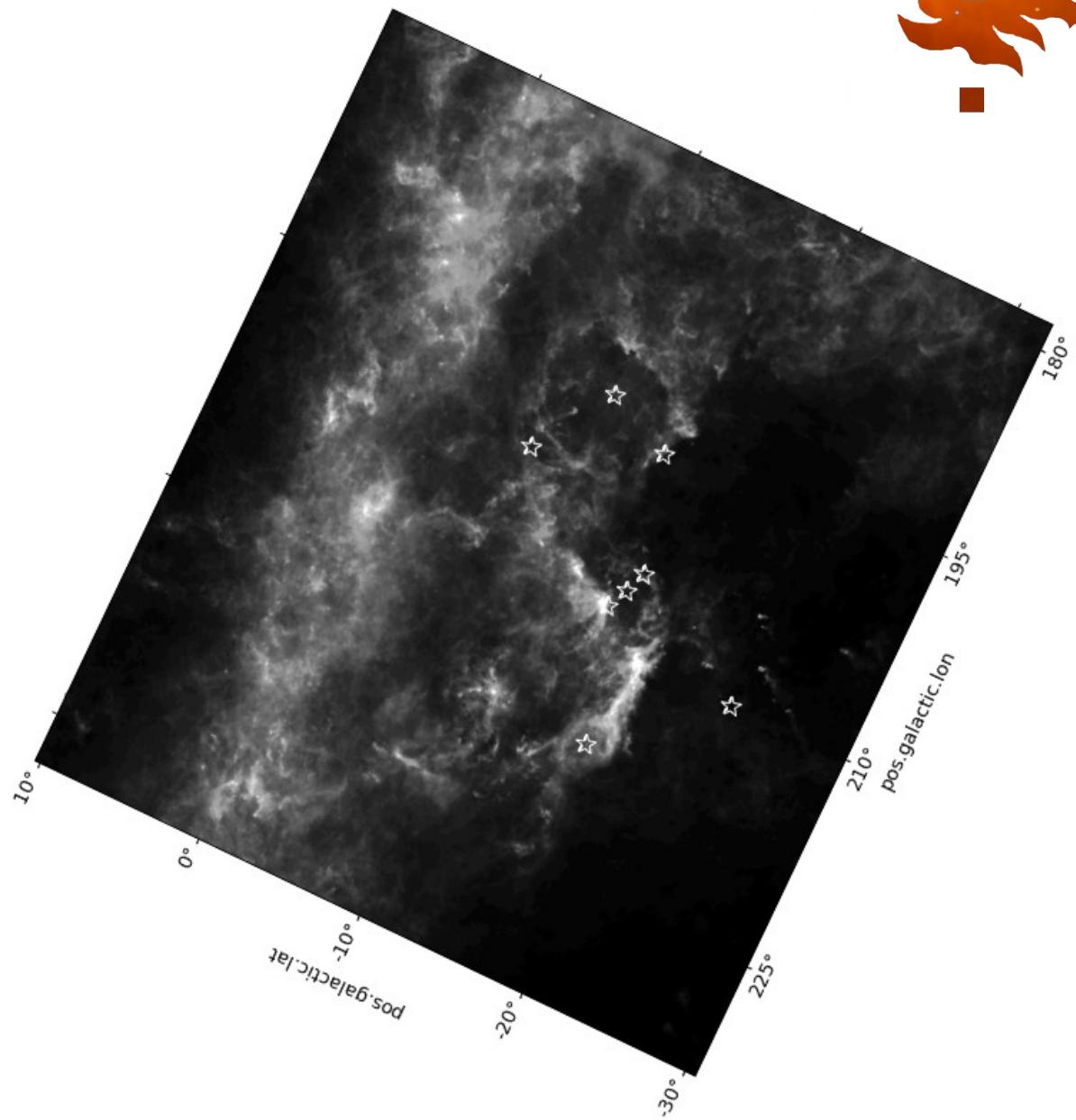


30/1/2026

Longyearbyen, Svalbard
Dec. 26, 2019
~12:00 noon
Exp: 15 sec
F/5.0
24.0 mm
ISO 1600
Photo: EM

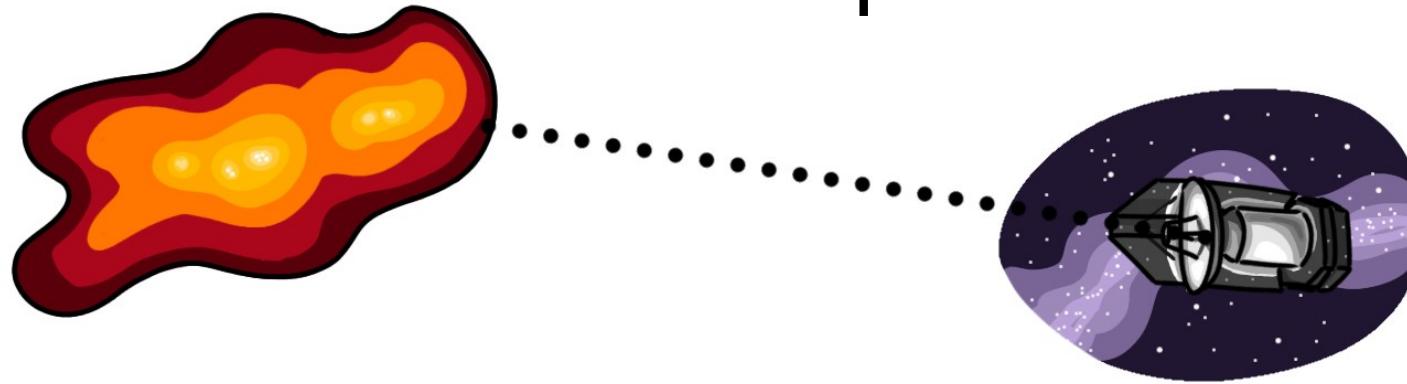
29







Telescopes



$$\text{Resolution} \rightarrow \theta = \frac{\lambda}{D}$$

Wavelength

Diameter of dish

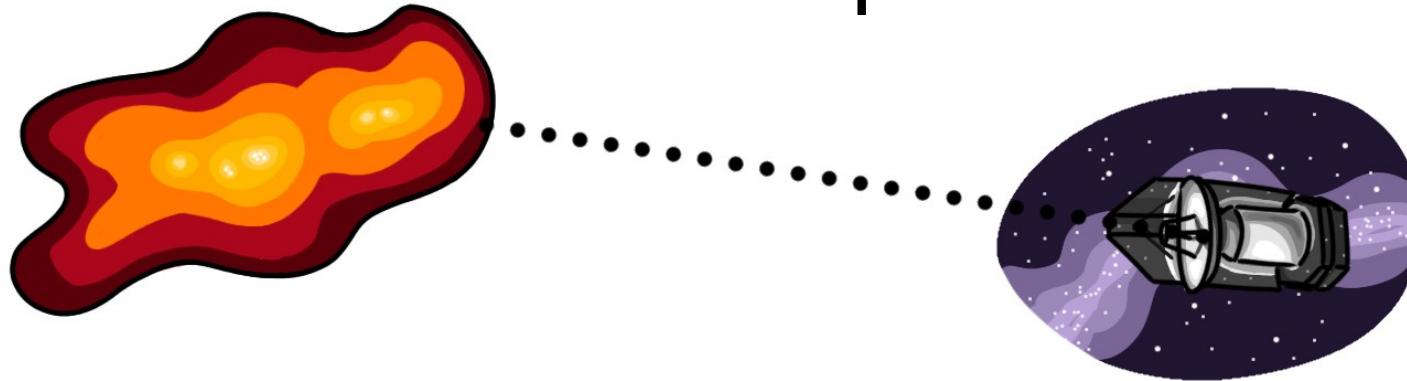
Longer wavelength
=> lower resolution

Larger dish
=> higher resolution

Illustrations: E.M.



Telescopes



Space based:

- + No atmosphere
- + Less light pollution

- Expensive
- High-risk & difficult or impossible repairs
- High environmental impact of launches
- Space weather, micrometeorites, etc.
- Size limit



Telescopes



Ground based:

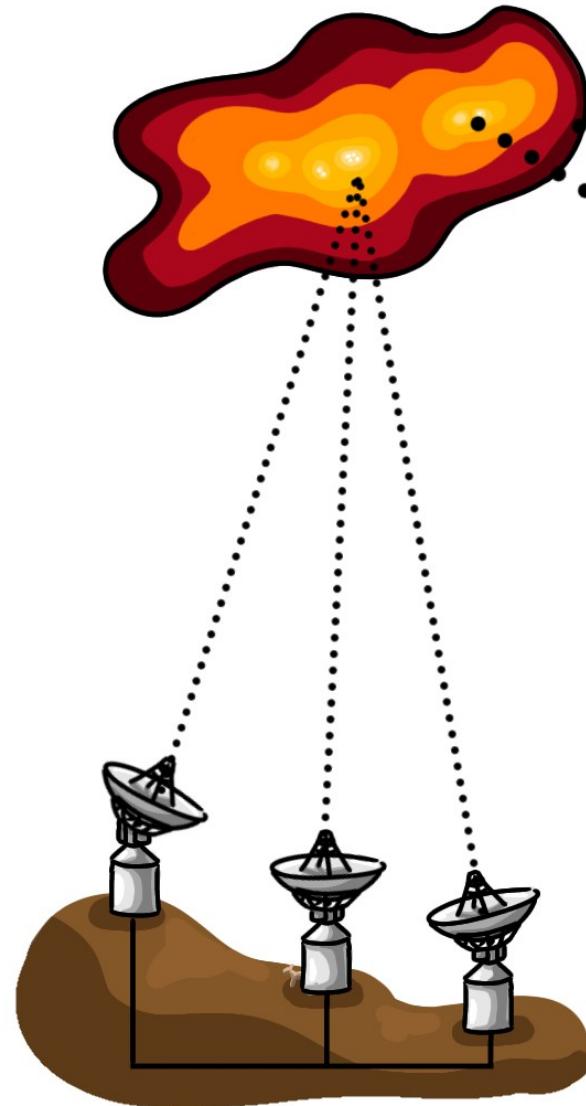
- + Easier to build, (can have) lower cost
- + Greater availability, easier access

- Atmosphere
- High environmental impact
- Good places to build telescopes tend to be sacred places (e.g. Mauna Kea in Hawai'i)





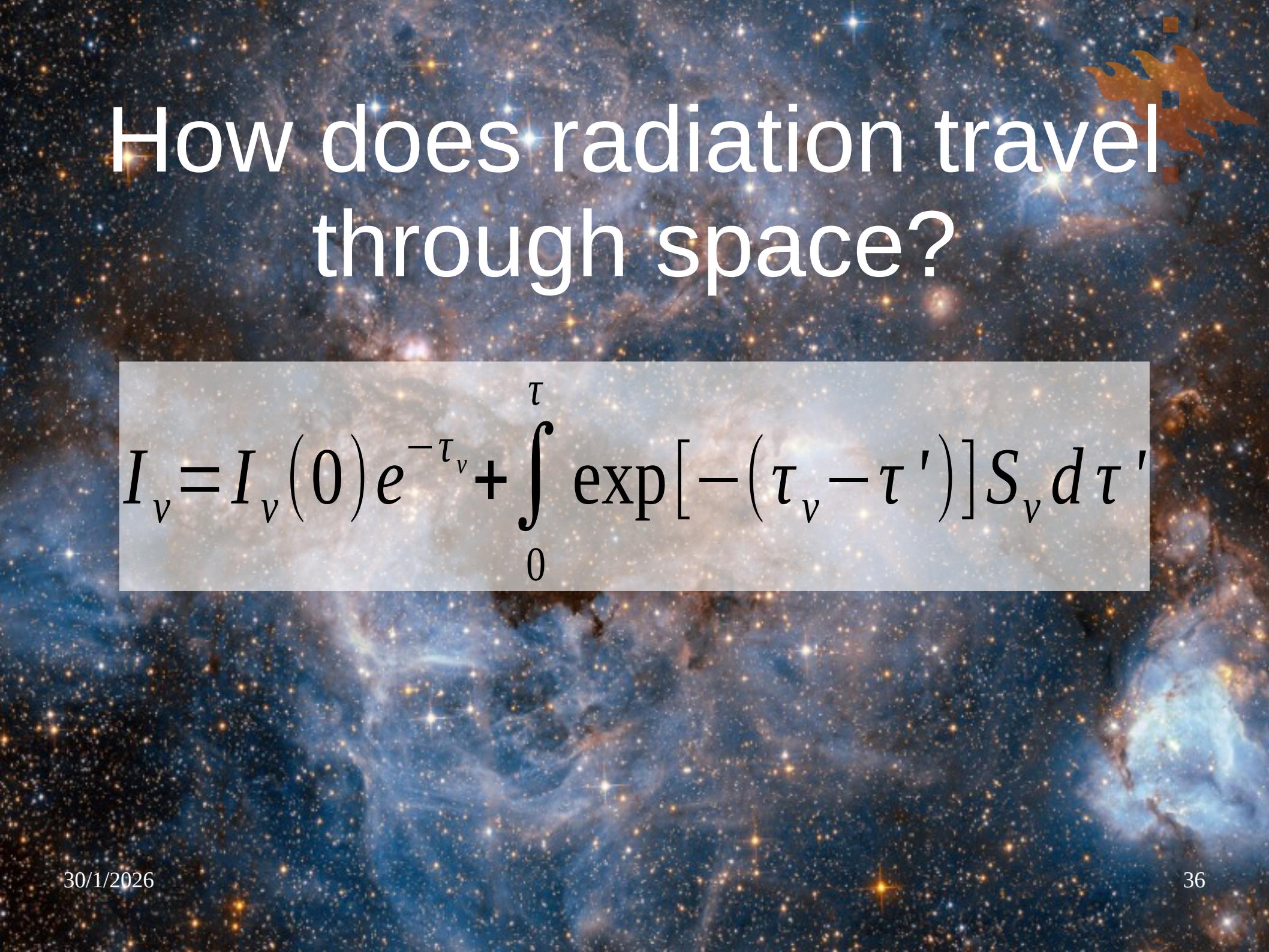
Telescopes



Interferometry:
+ Incredible
resolution due to
long baseline



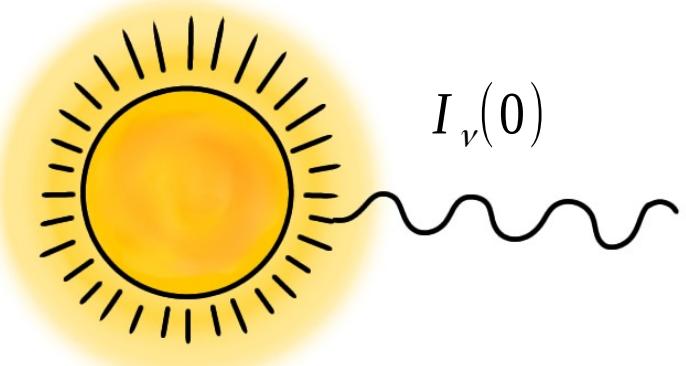
Illustrations: E.M.



How does radiation travel through space?

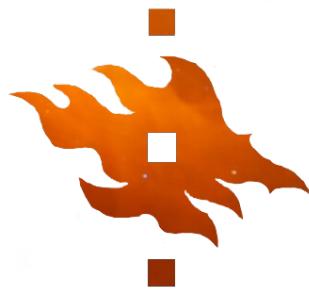
$$I_v = I_v(0) e^{-\tau_v} + \int_0^{\tau} \exp[-(\tau_v - \tau')] S_v d\tau'$$

Radiative transfer

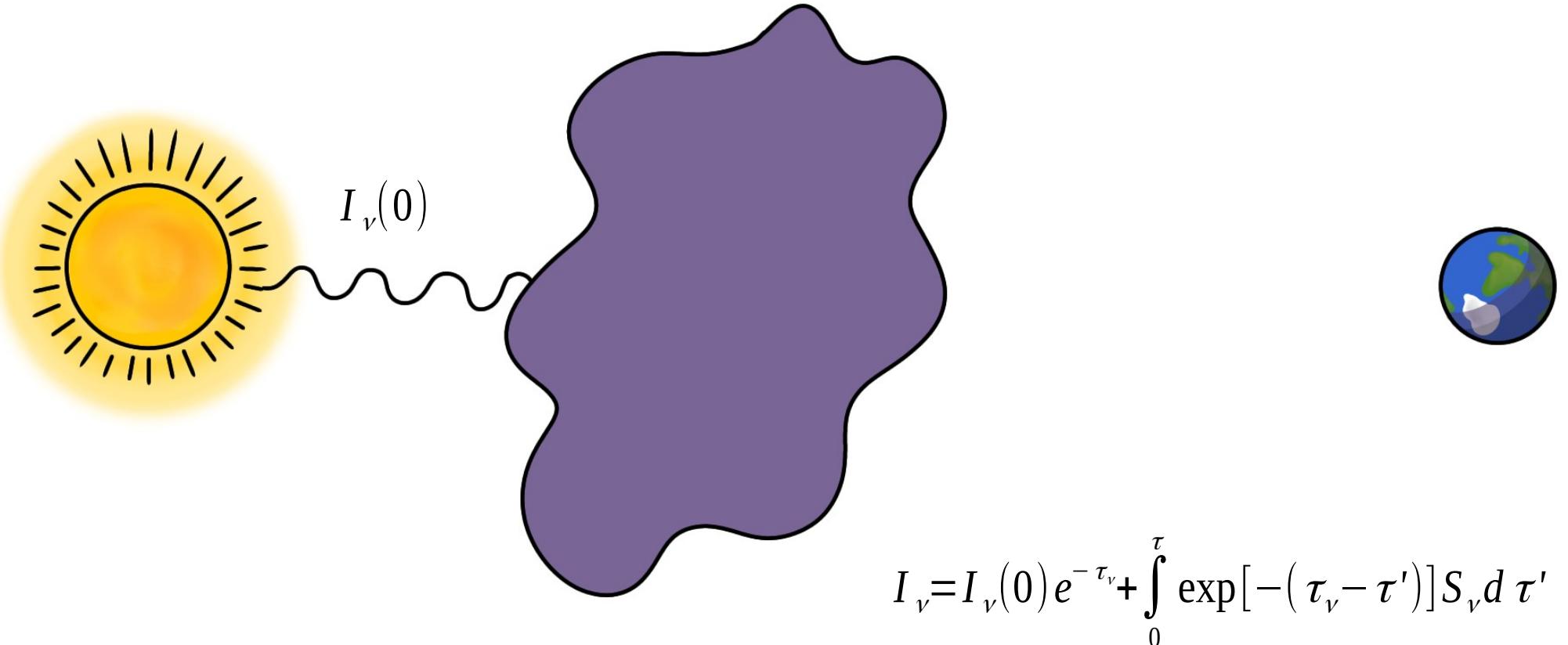


$$I_\nu = I_\nu(0) e^{-\tau_\nu} + \int_0^\tau \exp[-(\tau_\nu - \tau')] S_\nu d\tau'$$

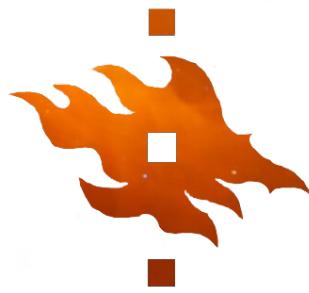
Illustrations: E.M.



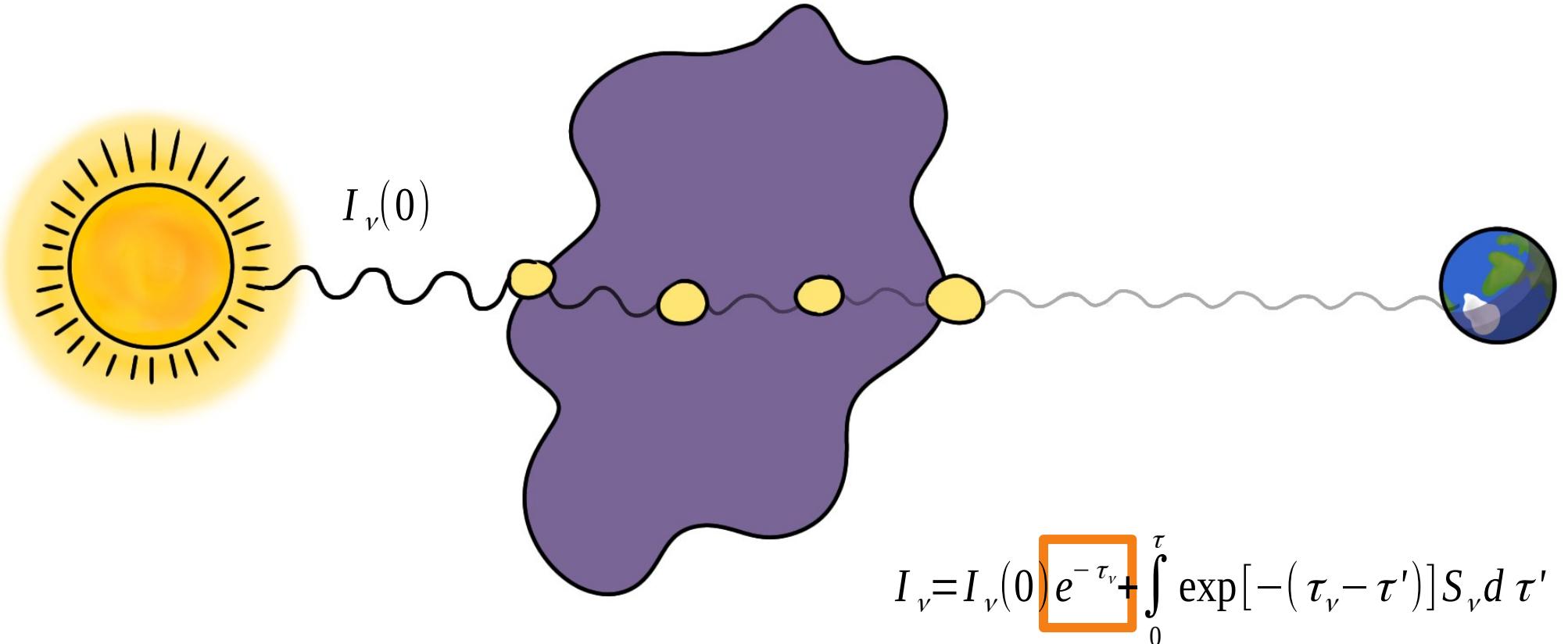
Radiative transfer



Illustrations: E.M.



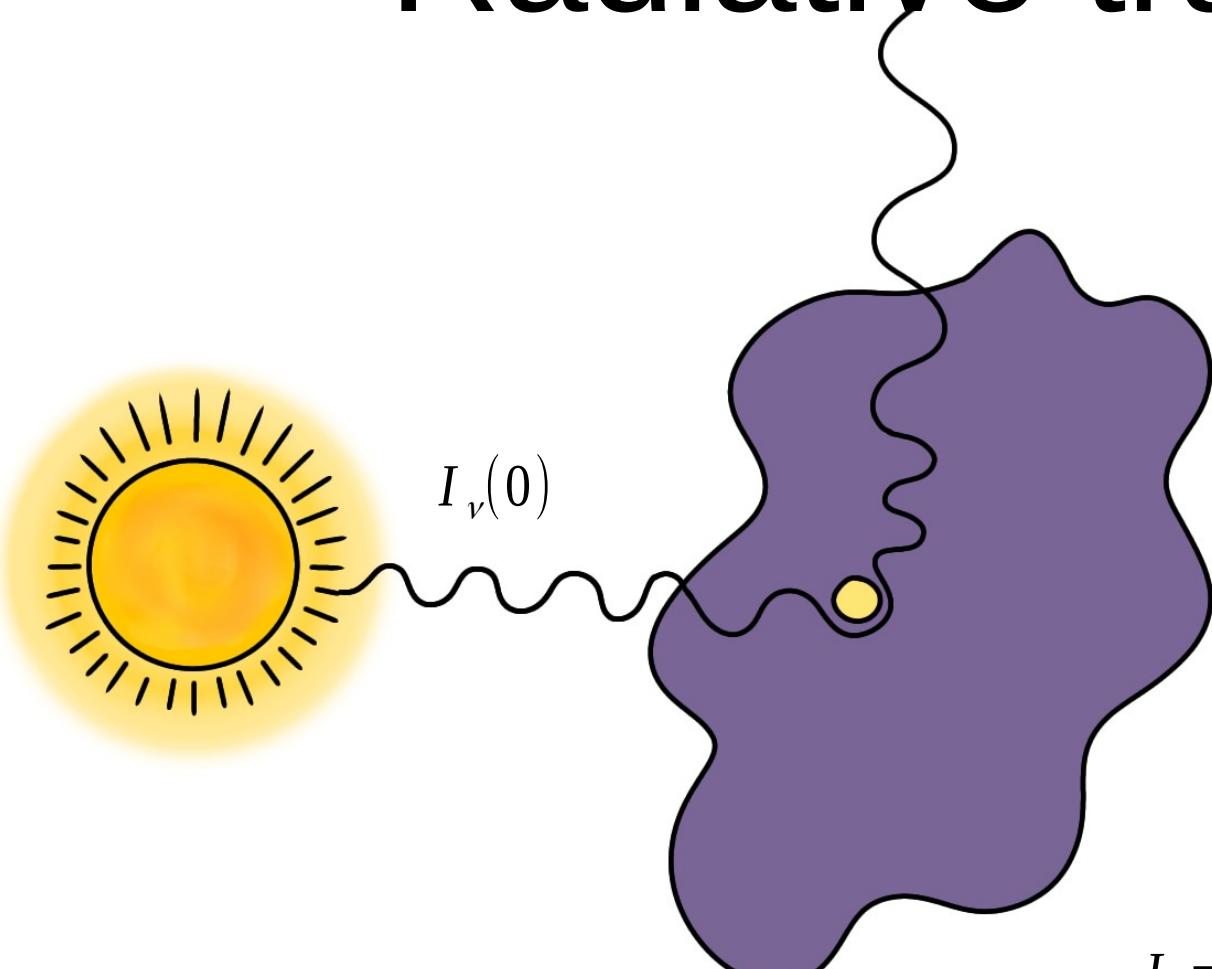
Radiative transfer



Illustrations: E.M.



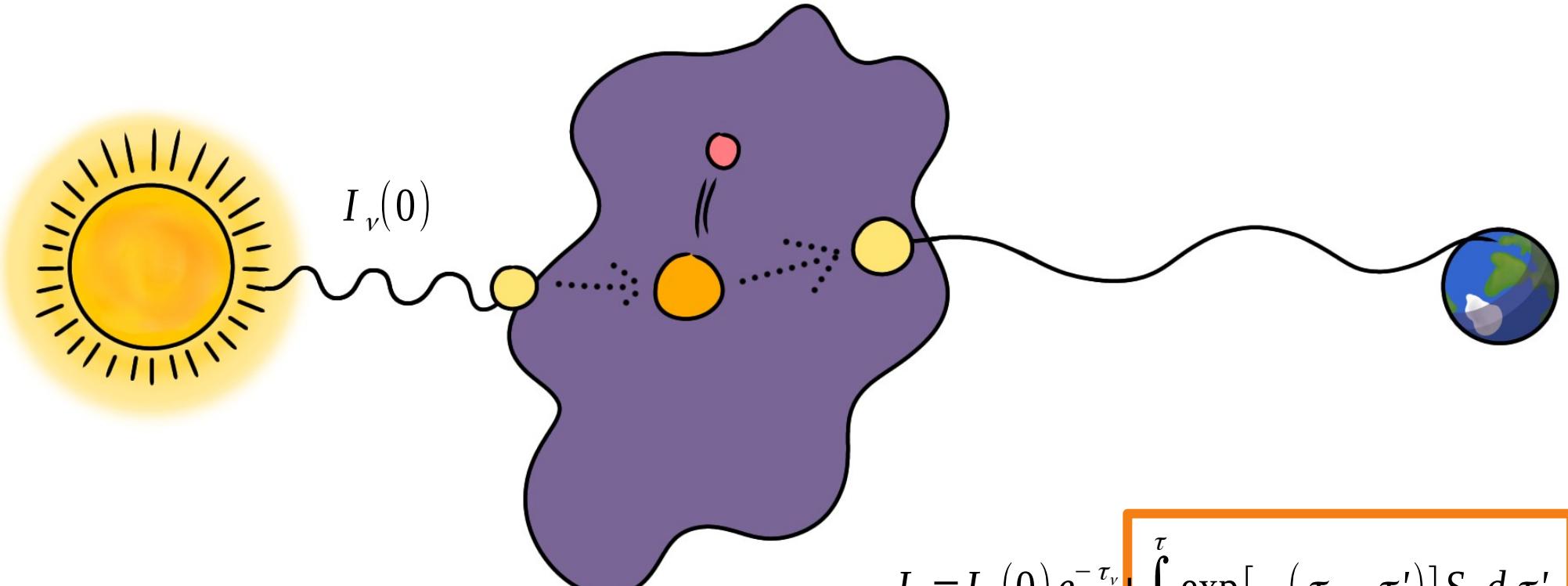
Radiative transfer



$$I_\nu = I_\nu(0) e^{-\tau_\nu} + \int_0^\tau \exp[-(\tau_\nu - \tau')] S_\nu d\tau'$$

Illustrations: E.M.

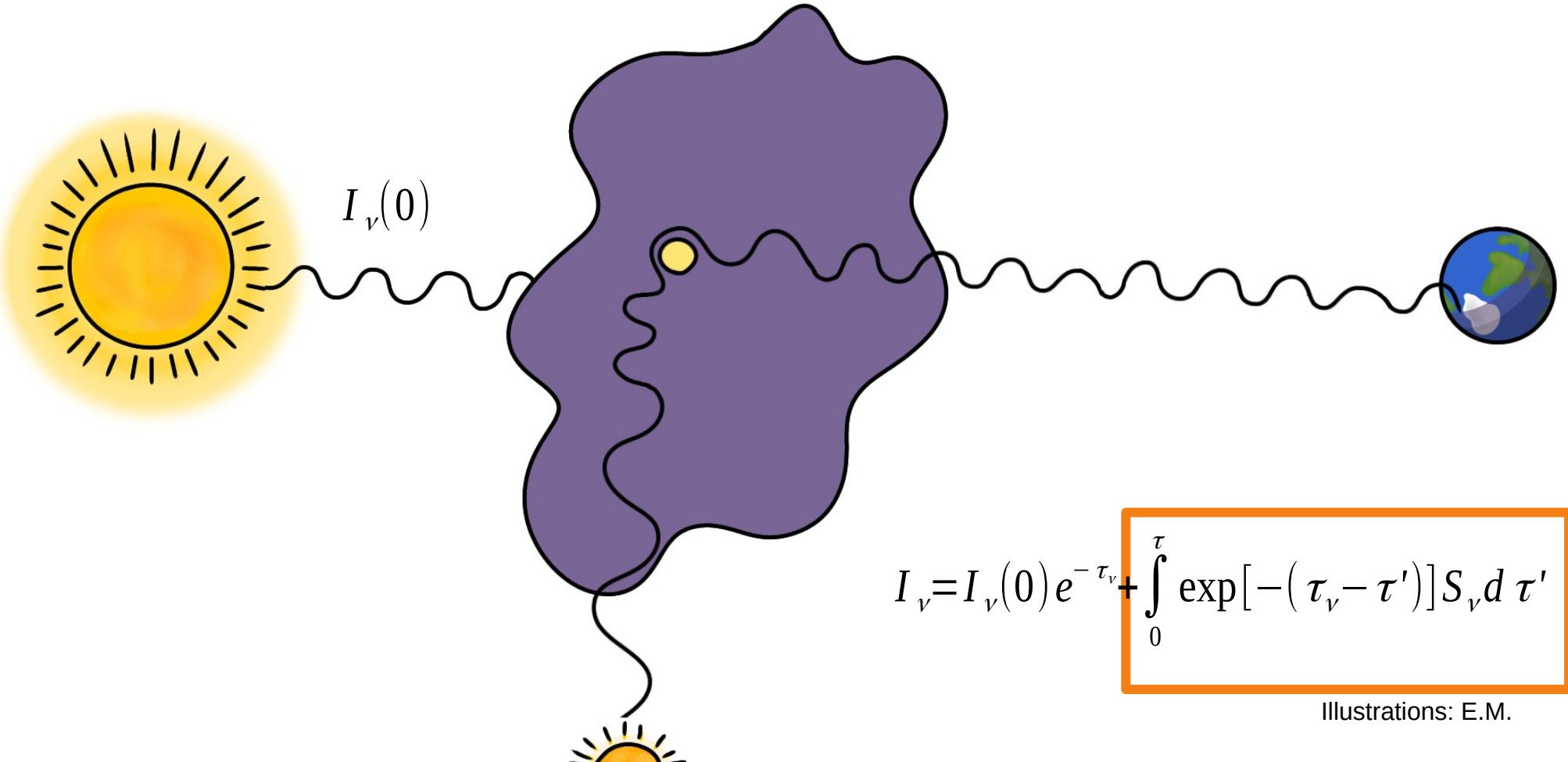
Radiative transfer



$$I_\nu = I_\nu(0) e^{-\tau_\nu} + \int_0^\tau \exp[-(\tau_\nu - \tau')] S_\nu d\tau'$$

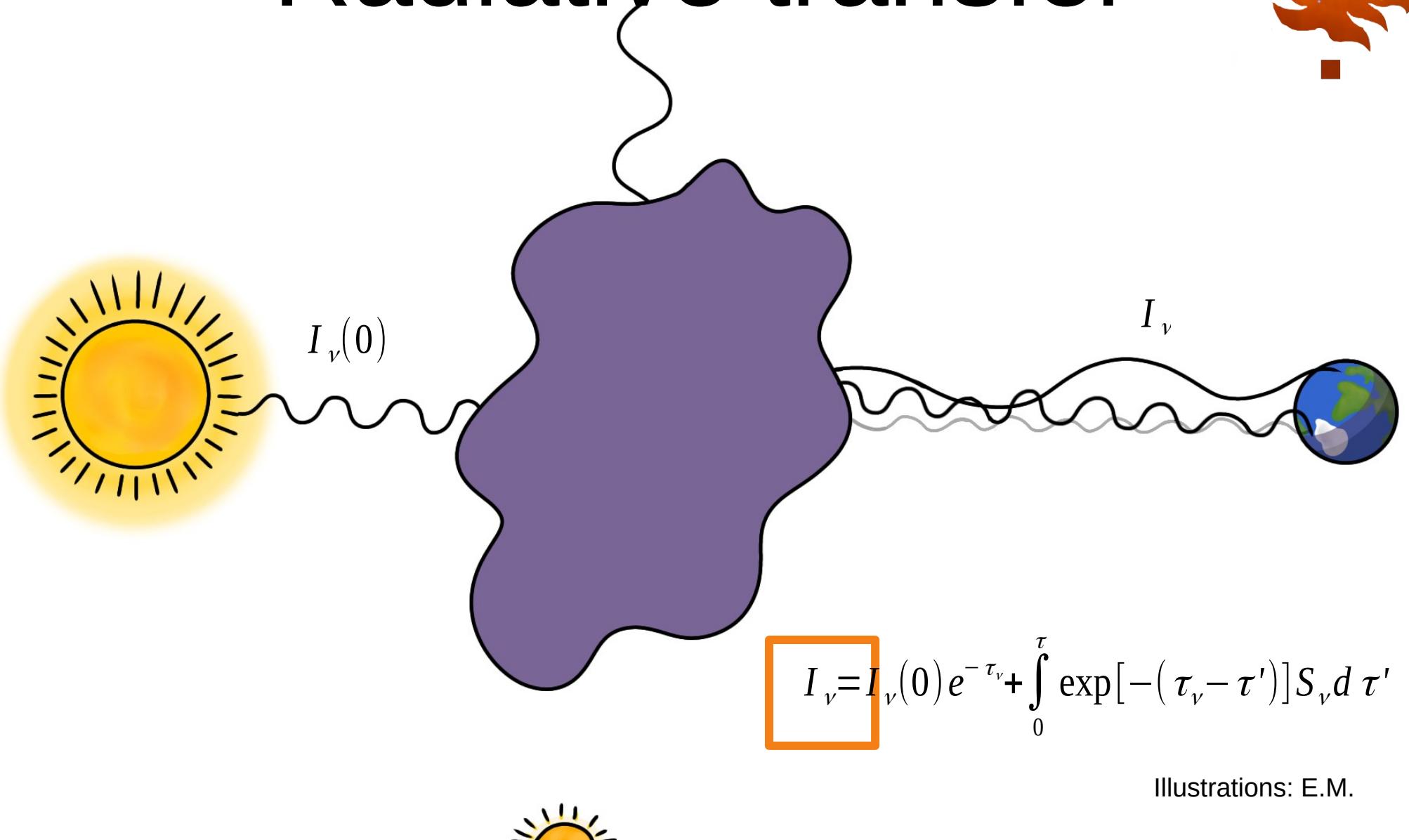
Illustrations: E.M.

Radiative transfer



Illustrations: E.M.

Radiative transfer



Illustrations: E.M.



Astronomy is easy and our
observations are great



English

Korean

The telescope is
broken

망원경이 고장 났어

Astronomy is easy and our
observations are great



English

Korean

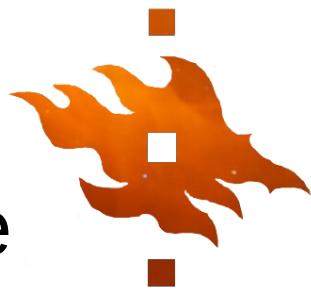
The telescope is
broken

망원경이 고장 났어

Astronomer: Some causes of error in our observations can

Some issues

- I. Noise
 - I. Atmosphere
 - II. Instrumental noise
- II. Resolution
- III. Line-of-sight confusion
- IV. ~~(The telescope broke)~~
 - Instrumental errors
- V. Modeling, astrochemistry,
other physical errors
- VI.



Publication image



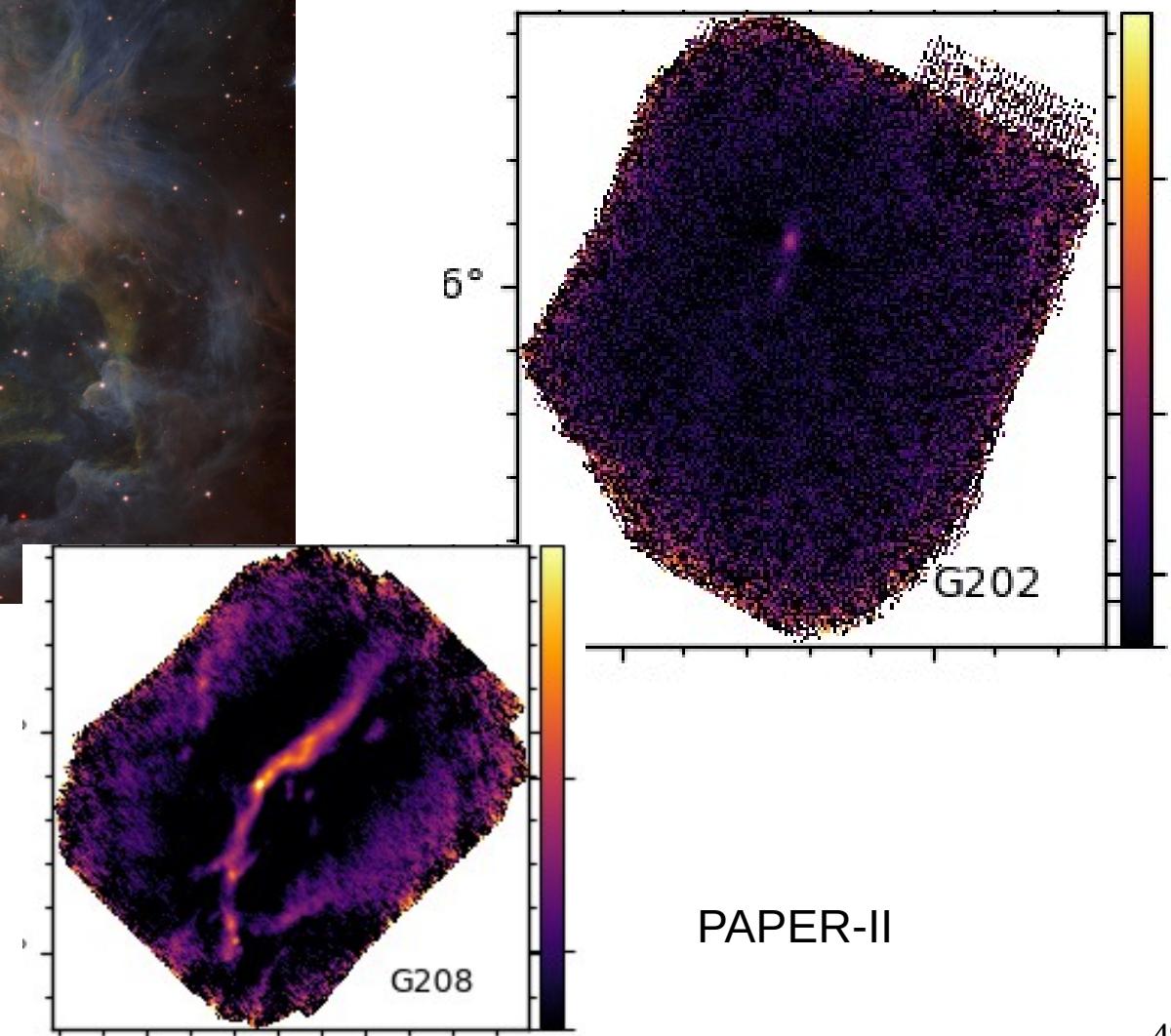
Credit: ESO/G. Beccari
Orion nebula and cluster with the VLT
<https://www.eso.org/public/images/eso1723a/>



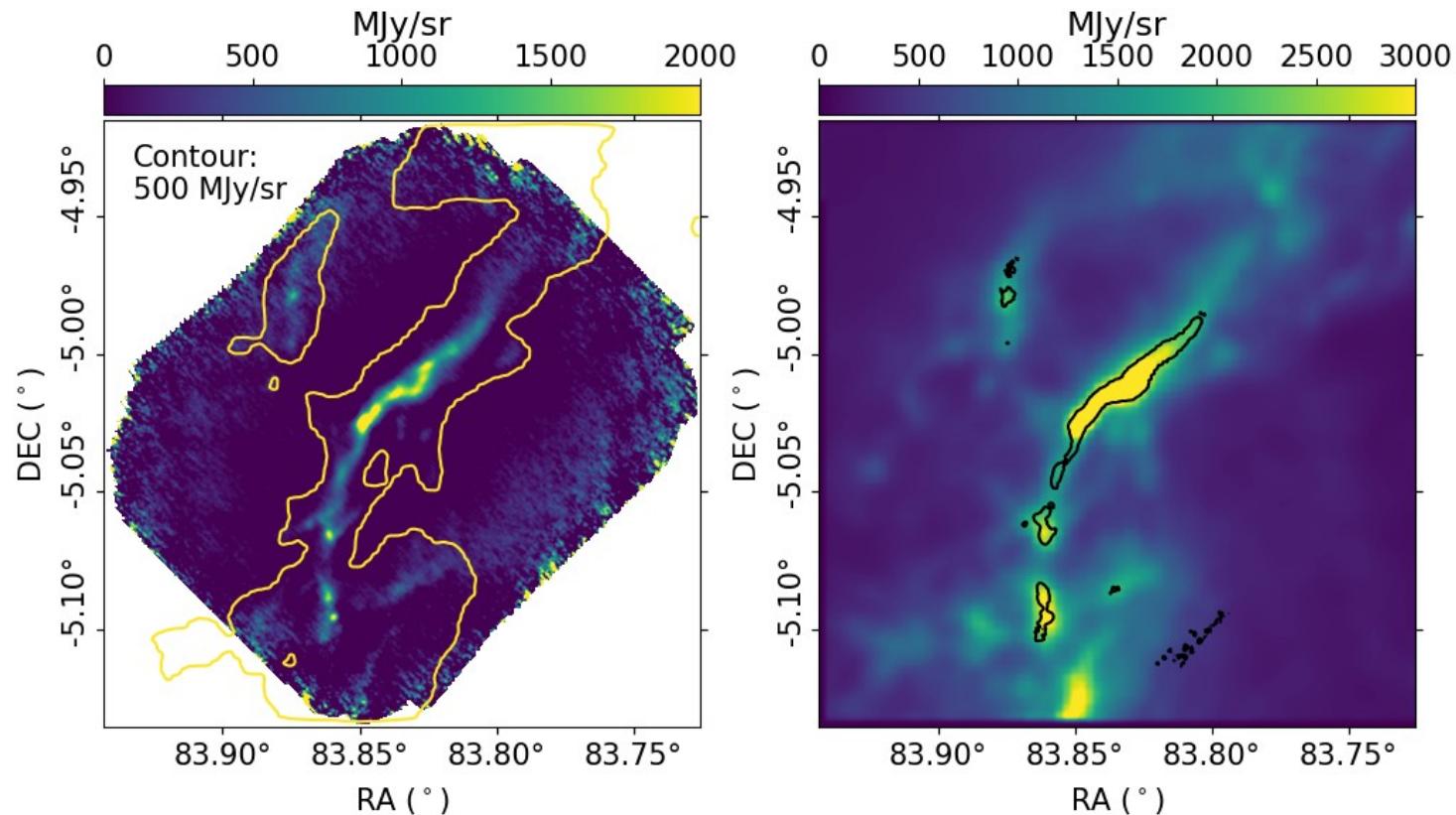
Normal data :')



Credit: ESO/G. Beccari
Orion nebula and cluster with the VLT
<https://www.eso.org/public/images/eso1723a/>



Removal of atmospheric noise



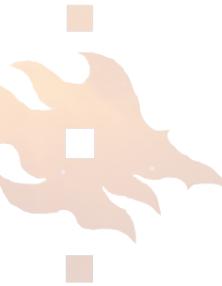
especially PAPER-II, PAPER-V

Low



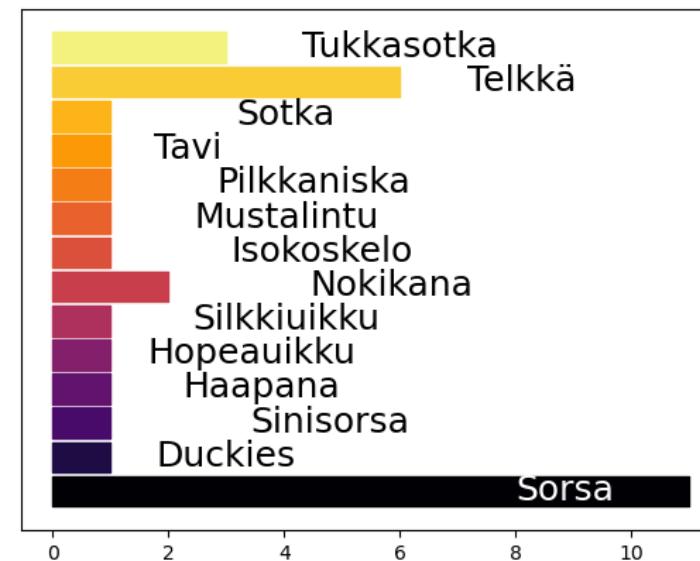
Credit: CONCERTO team/A. Beelen, ESO
<https://www.eso.org/public/images/ann21010d/>

High



Resolution

Crab nebula
 $d = 6000$ light years



Low



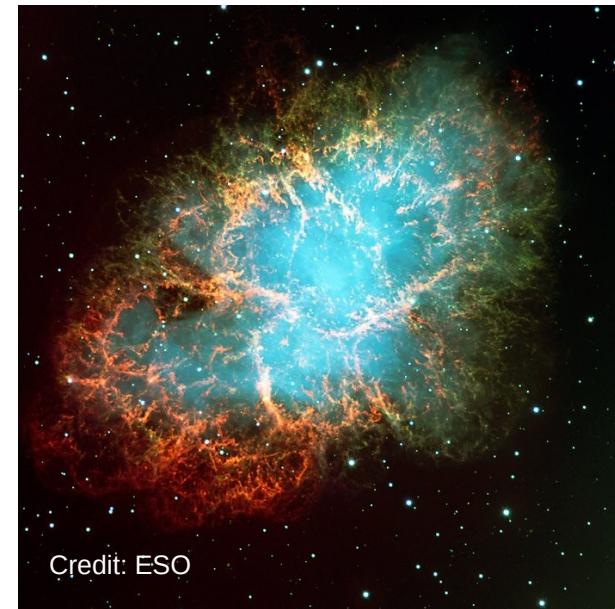
Credit: CONCERTO team/A. Beelen, ESO
<https://www.eso.org/public/images/ann21010d/>

Resolution

High



Crab nebula
 $d = 6000$ light years



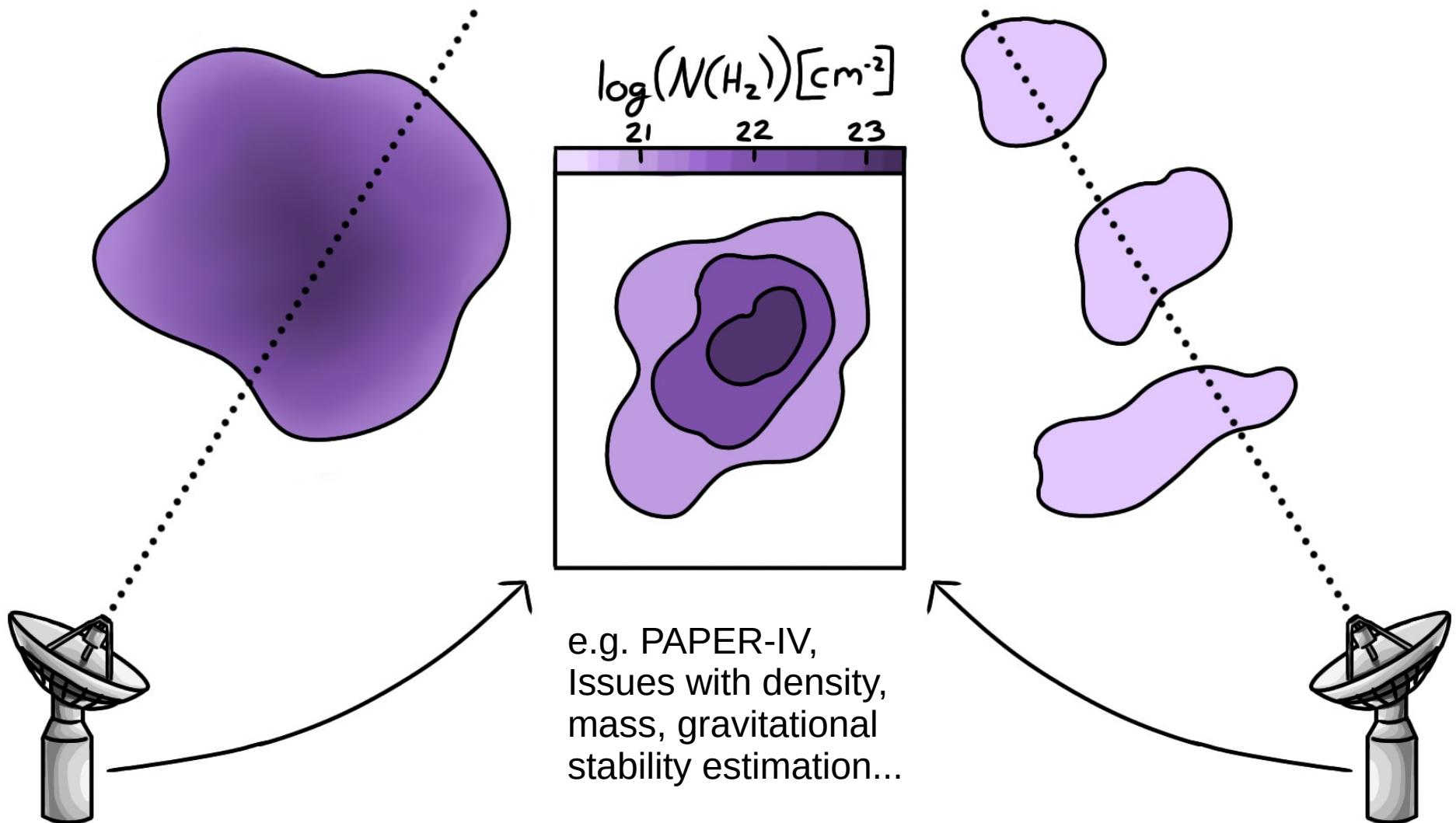
Credit: ESO



Tukkasotka ! →
(3+1 correct)



Line-of-sight





Summary of my work



Summary of papers

PAPER-I	PAPER-II	PAPER-III	PAPER-IV	PAPER-V
<ul style="list-style-type: none">- Catalog of cores in 52 dense MCs- Do properties show correlation with e.g. SF status, location in the Galaxy, etc?	<ul style="list-style-type: none">- Study of the main filament in OMC-3 with <i>Herschel</i> and ArTeMiS- Determine properties of this filament.- Do the properties change based on observing method?	<ul style="list-style-type: none">- Three dense clouds in the L Ori bubble observed in 12CO & 13CO- How does the cloud evolve in a high-feedback environment?	<ul style="list-style-type: none">- Simulated observations of high-mass filament- How does the proposed ngVLA telescope recover properties of the filament?	<ul style="list-style-type: none">- Dense filament segments in OMC-3, including MIR Spitzer data.- How do properties of this filament change based on observing method?

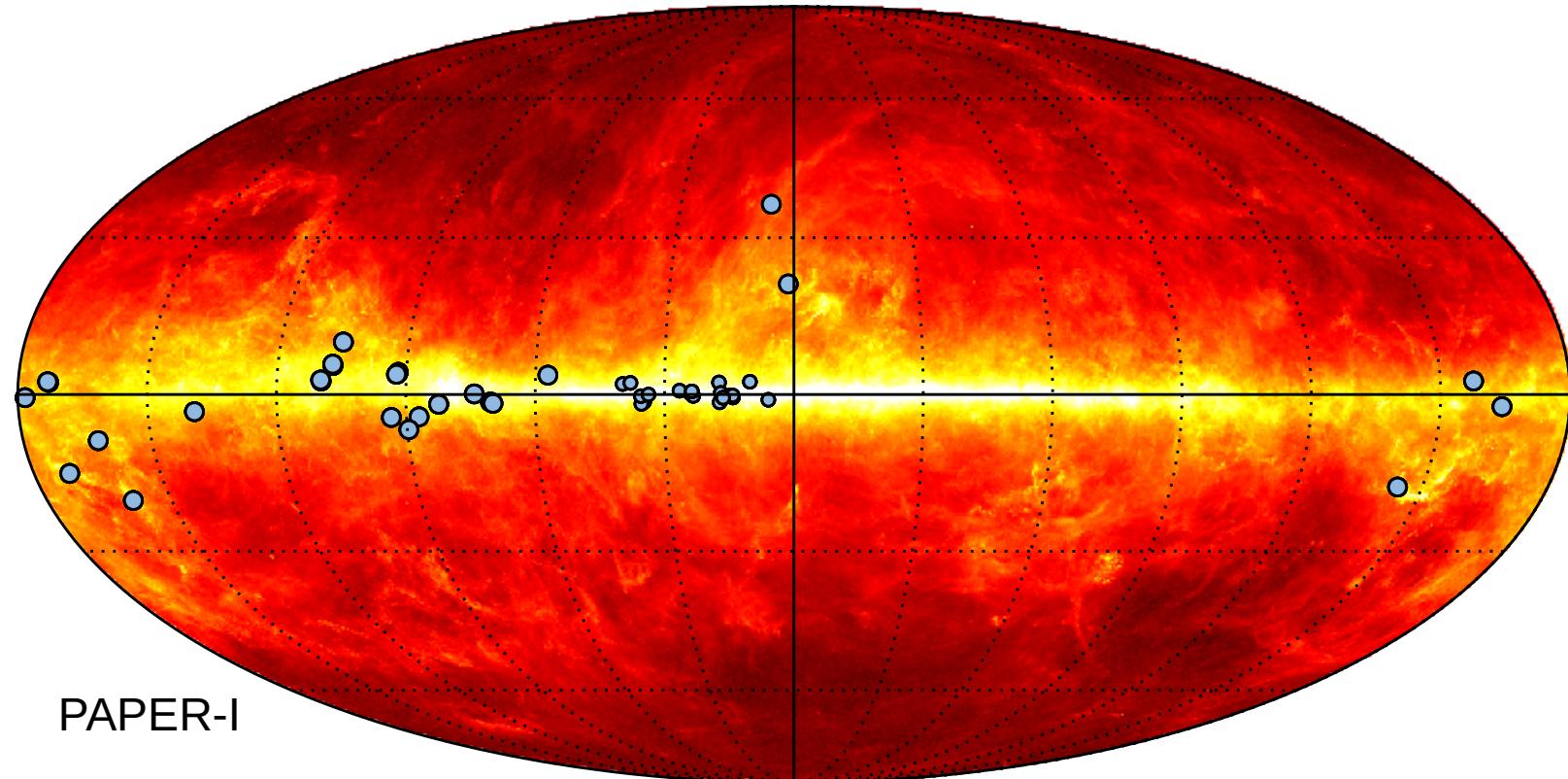


Main results

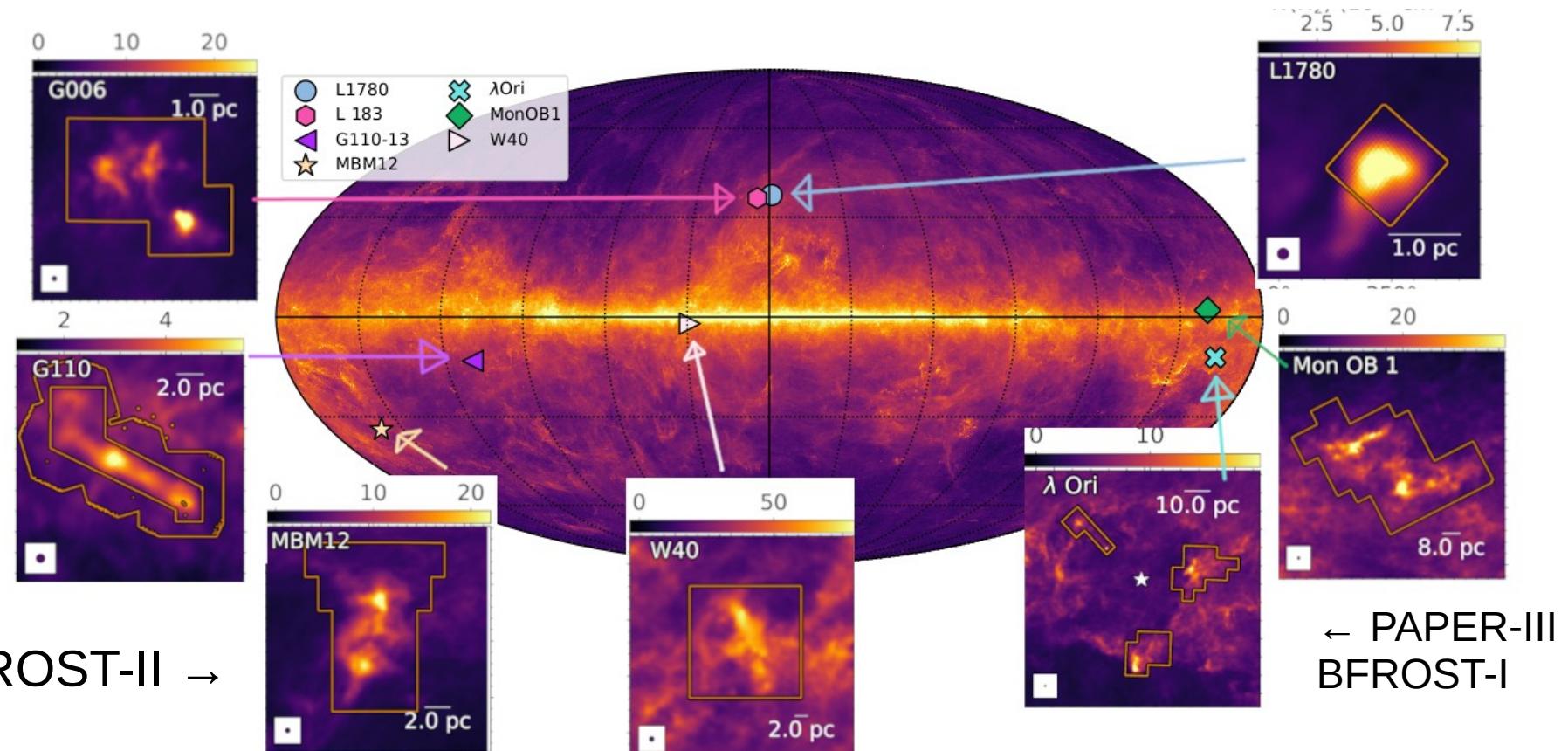


1. Creation of catalogs usable by the astronomical community

Creation of catalogs usable by the astronomical community – GCC



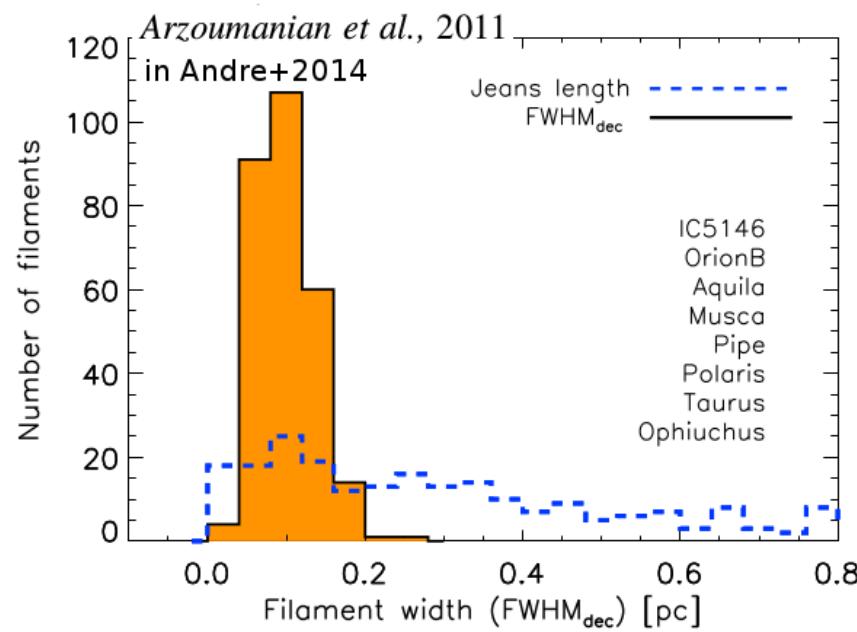
Creation of catalogs usable by the astronomical community – BFROST



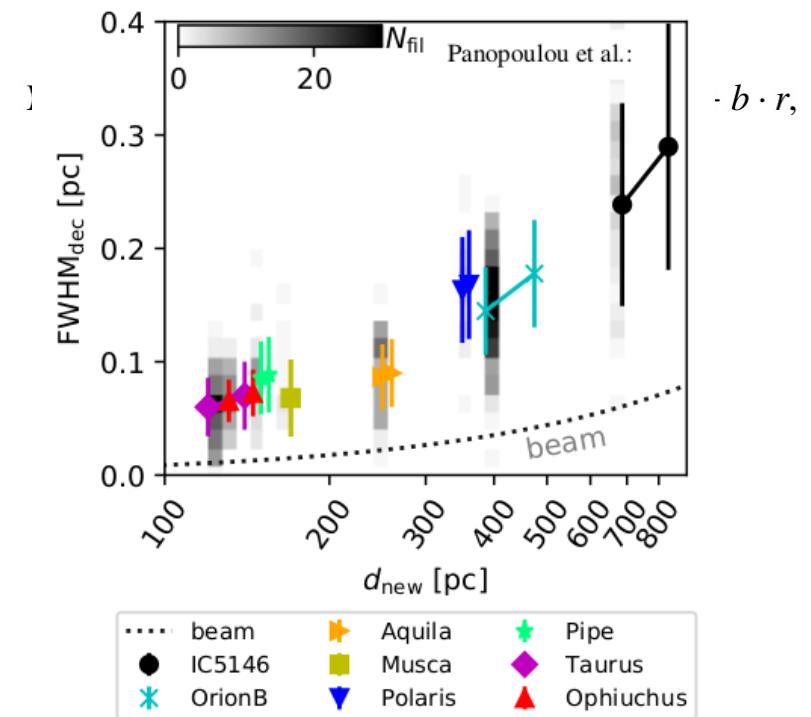


2. Observational parameters affect our results

Observational parameters affect our results – 0.1 pc filament width



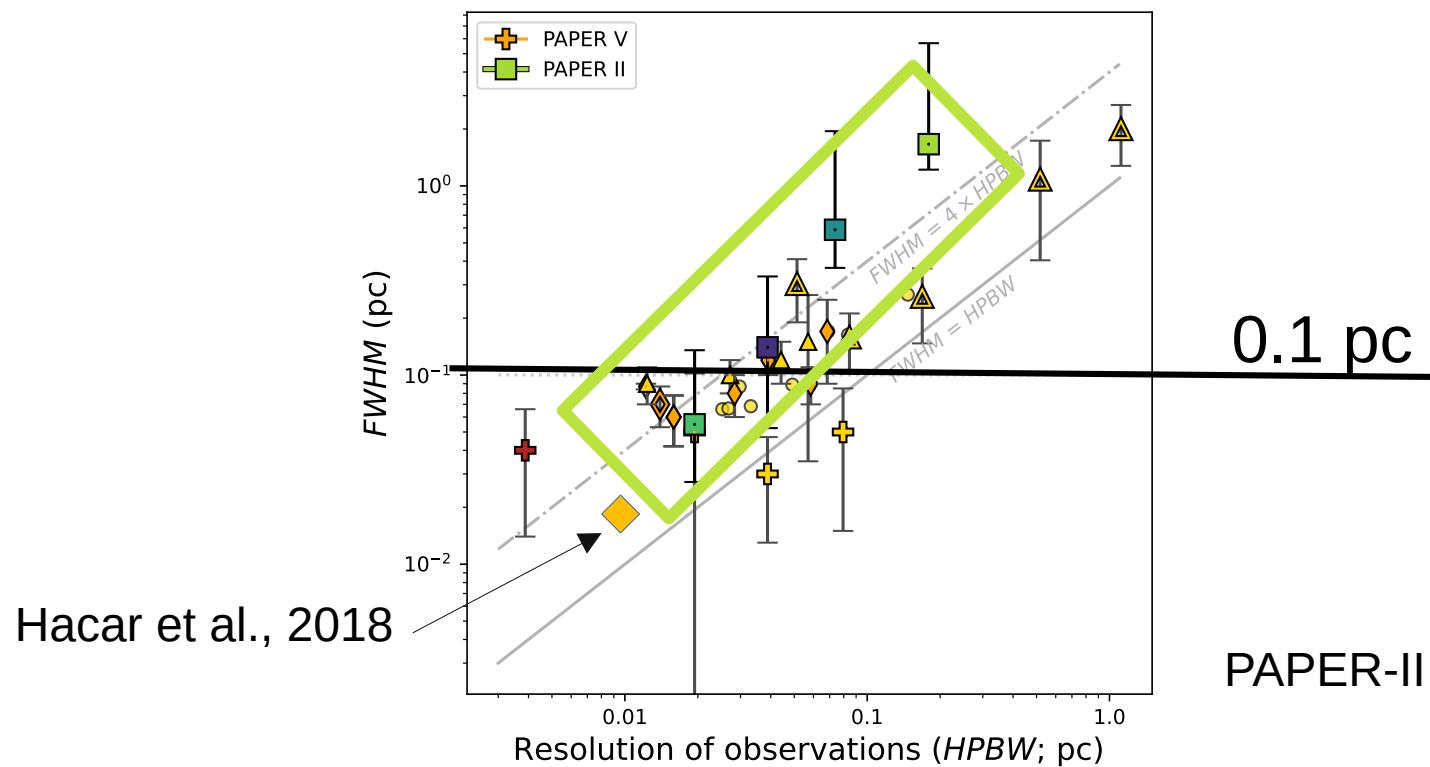
Arzoumanian et al., 2011



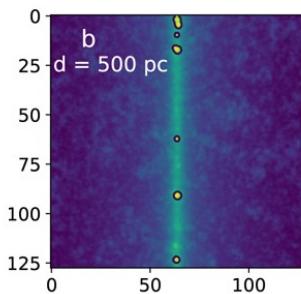
Panopoulou et al., 2021



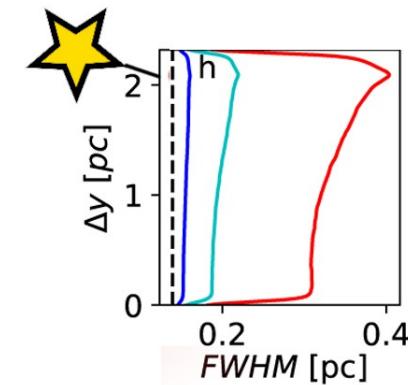
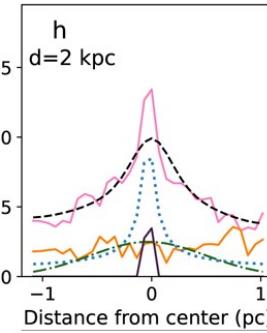
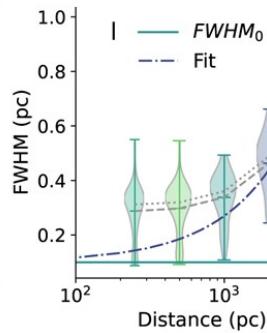
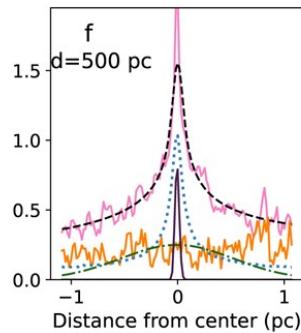
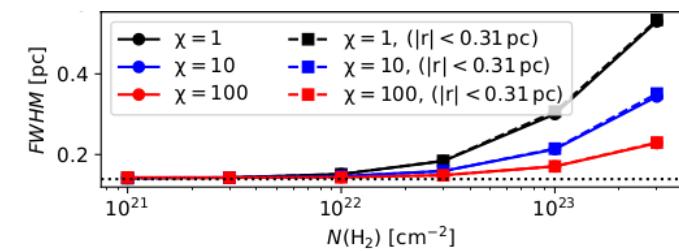
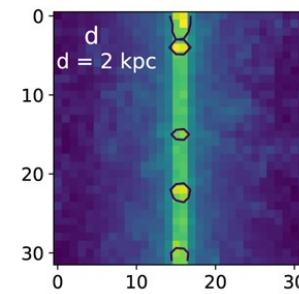
Observational parameters affect our results – 0.1 pc filament width



Observational parameters affect our results – 0.1 pc filament width

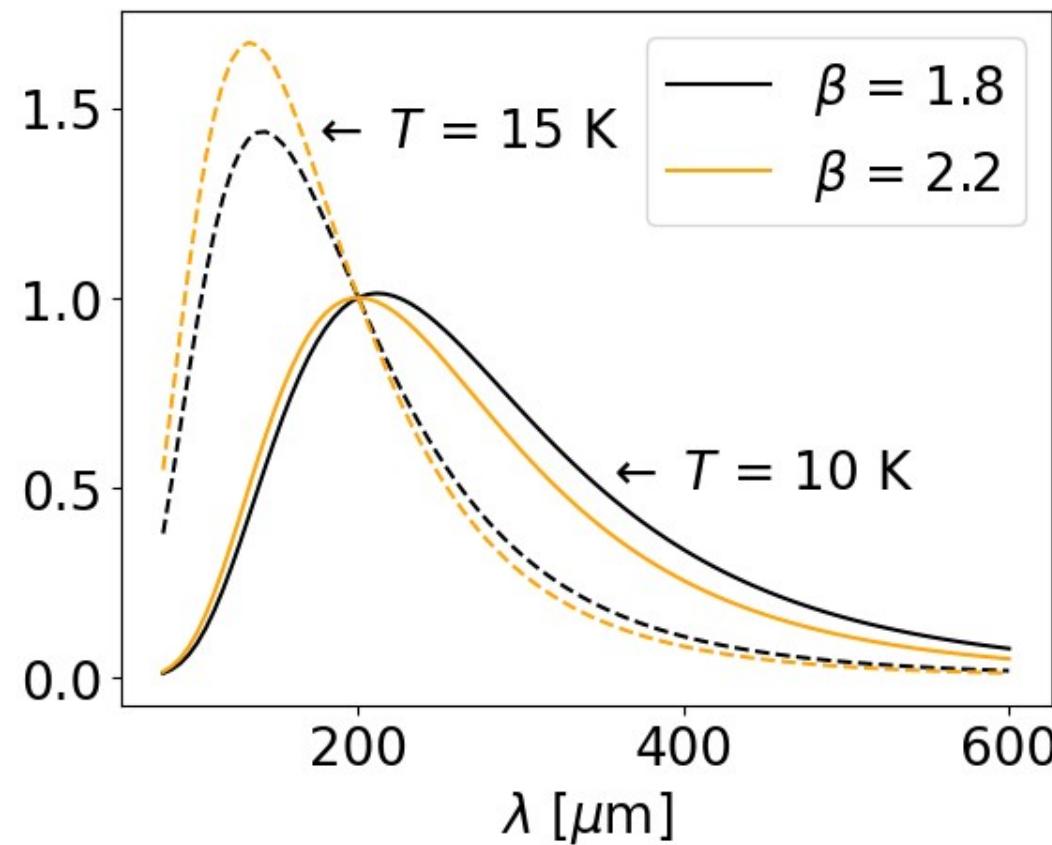


PAPER II

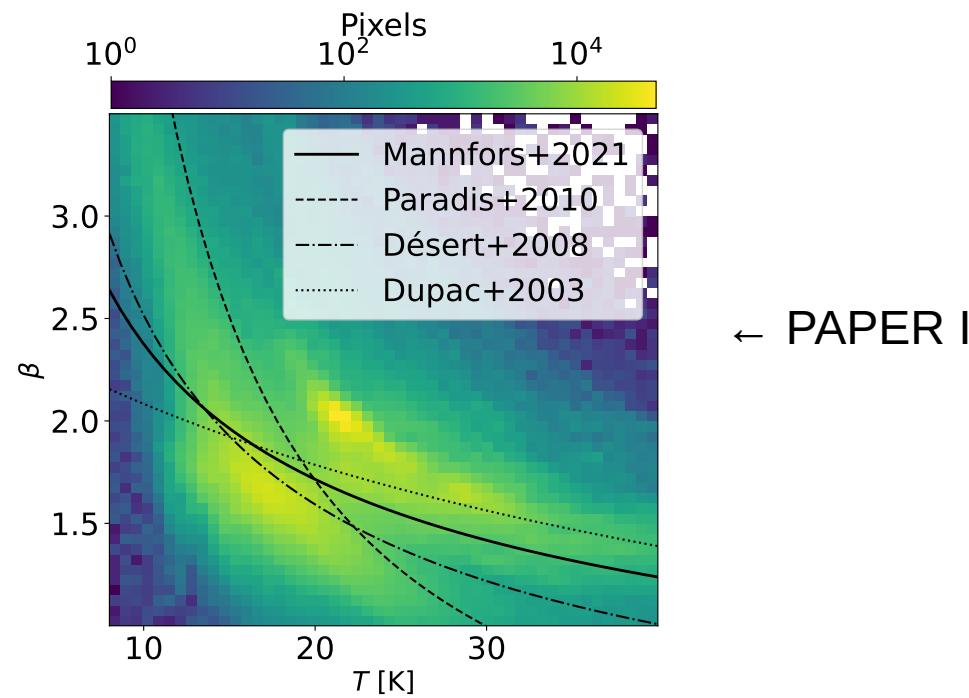


PAPER-V

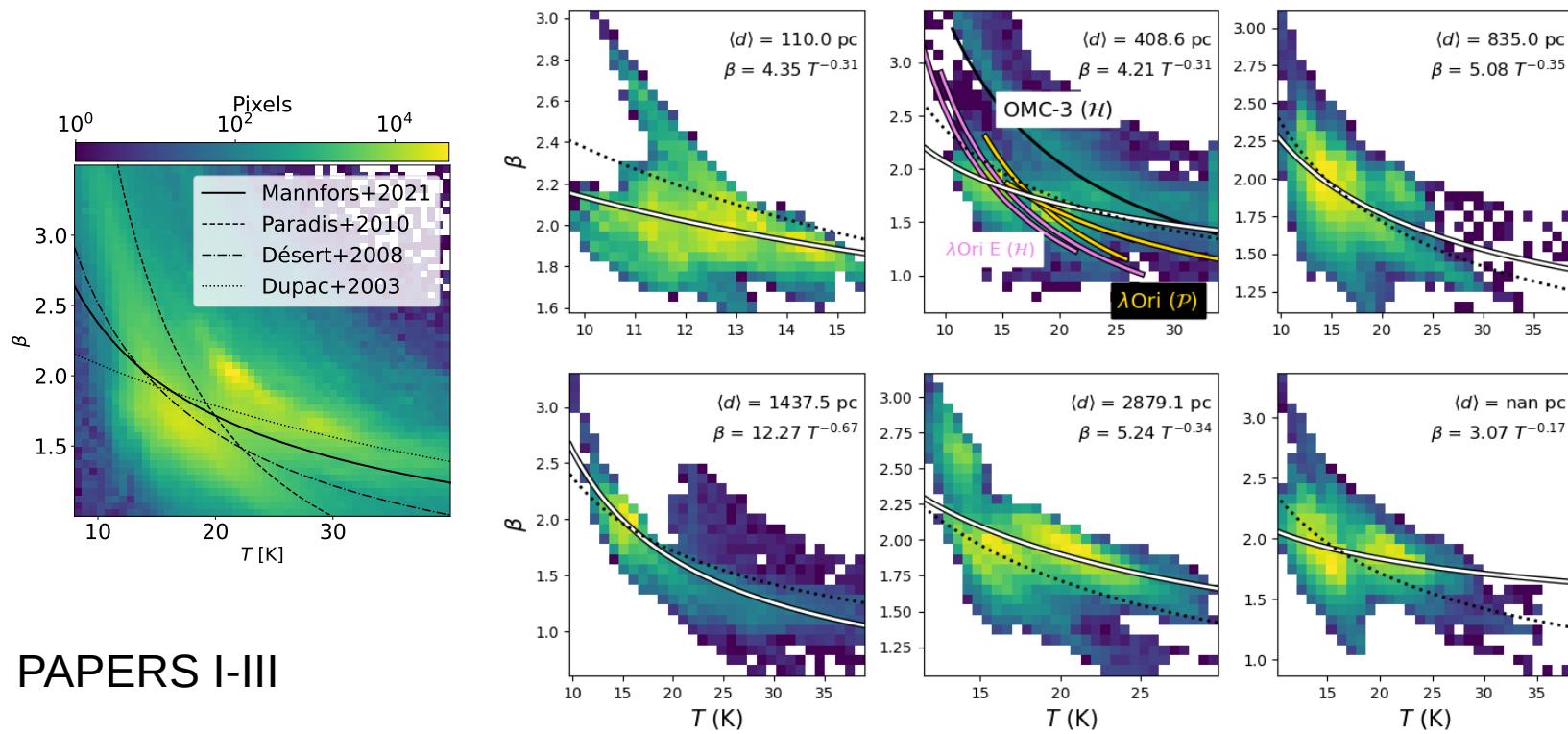
Observational parameters affect our results – T- β anticorrelation



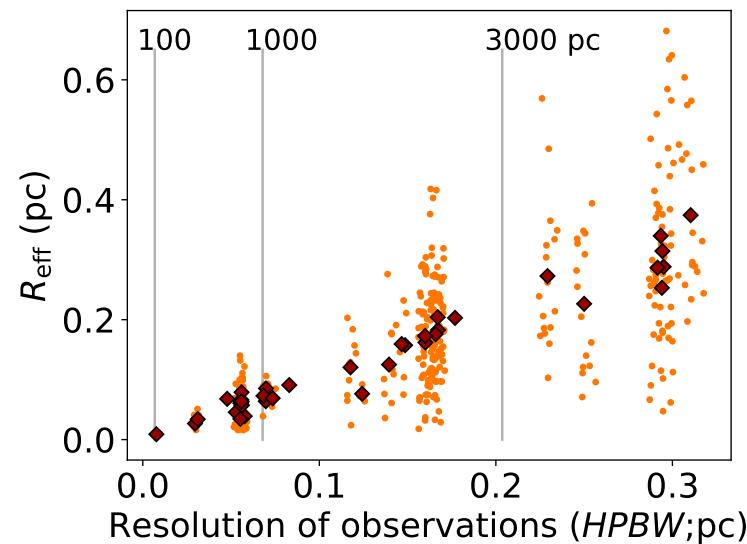
Observational parameters affect our results – T- β anticorrelation



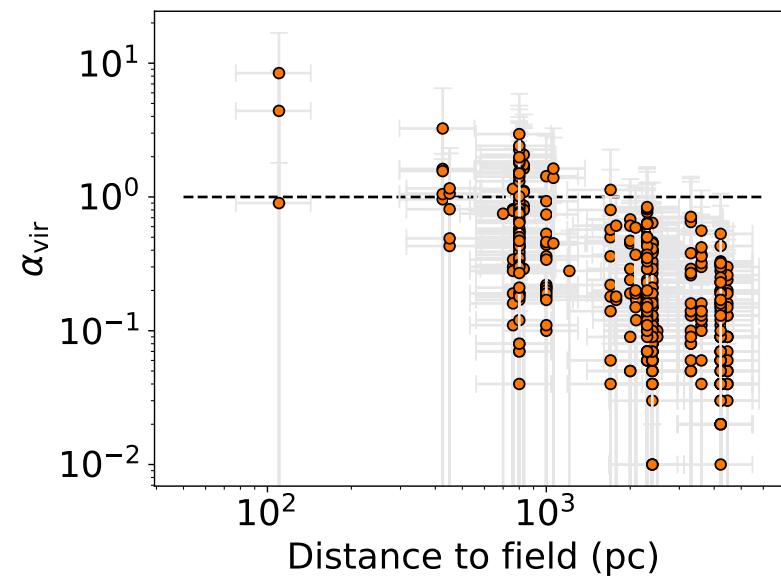
Observational parameters affect our results – T- β anticorrelation



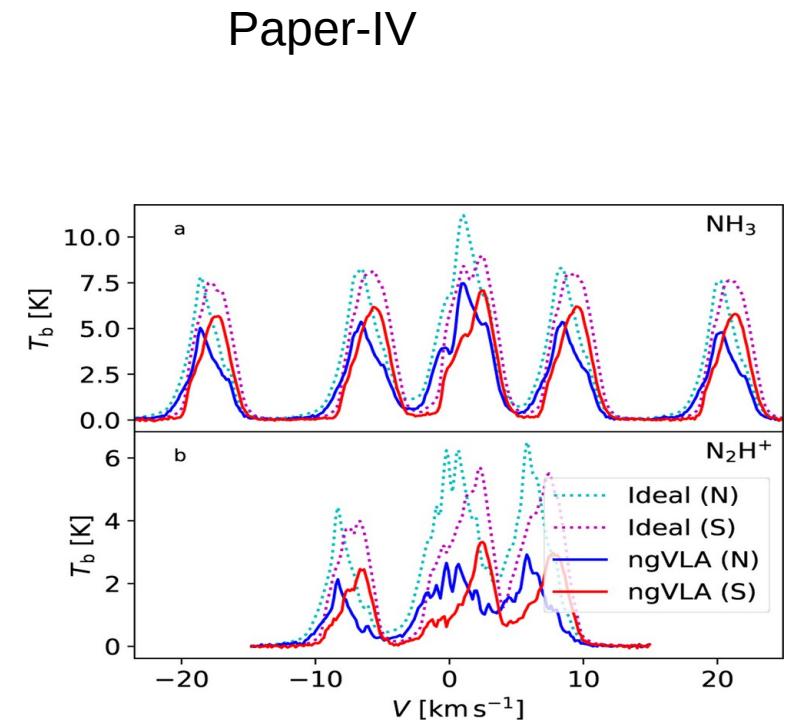
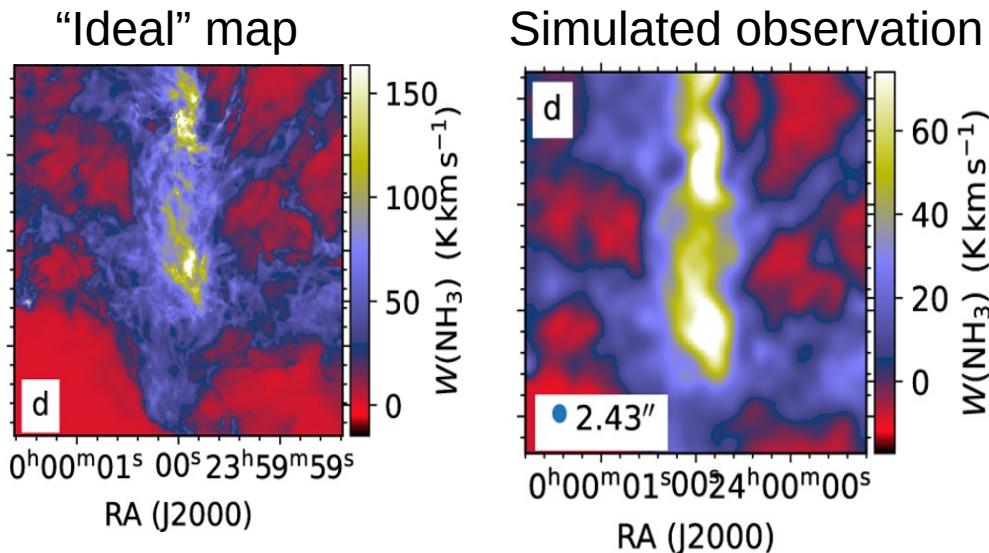
Observational parameters affect our results – Distance dependence



PAPER I



Observational parameters affect our results – ngVLA study





Future prospects

- JWST and ALMA imaging of clouds
 - Same cloud at multiple resolutions
 - Deep study of one cloud
- More sophisticated modeling of clouds
 - e.g. multi-temperature components of MBB fitting
 - Multi-dust-species
- A greater understanding of *what* causes error & our assumptions