Tracing the MW spiral arms with ^{26}Al:

the role of novae in the 2D distribution of ^{26}Al

Arianna Vasini - University of Insubria, Como
In collaboration with Prof. F. Matteucci & E. Spitoni - University of Trieste
arianna.vasini@inaf.it

NIC 2025

UNIVERSITÀ DEGLI STUDI DELL'INSUBRIA

COMO LAKE CENTER FOR ASTROPHYSICS

European Research Council
Established by the European Commission

Outline

Introduction: ^{26}Al in astrophysics

- What do we want to do?
- Why?

2D Chemical Evolution Model: Spitoni+19, 23, Vasini+22,+24

- Parameters and assumptions
- 2D results: SFR, novae and ^{26}Al

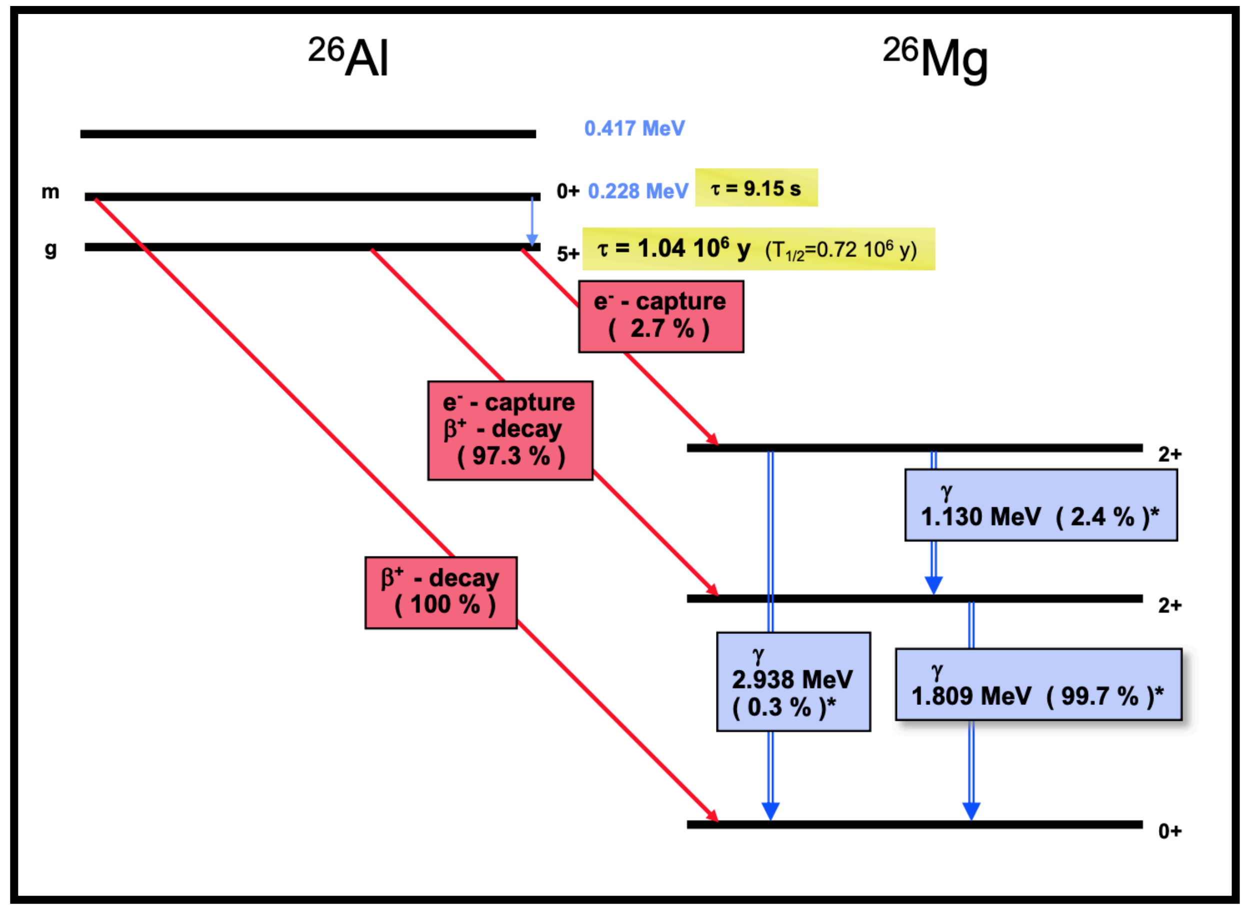
Conclusions

Chemical evolution of SLR isotopes: ^{26}Al

Nuclear and astrophysical properties

^{26}Al

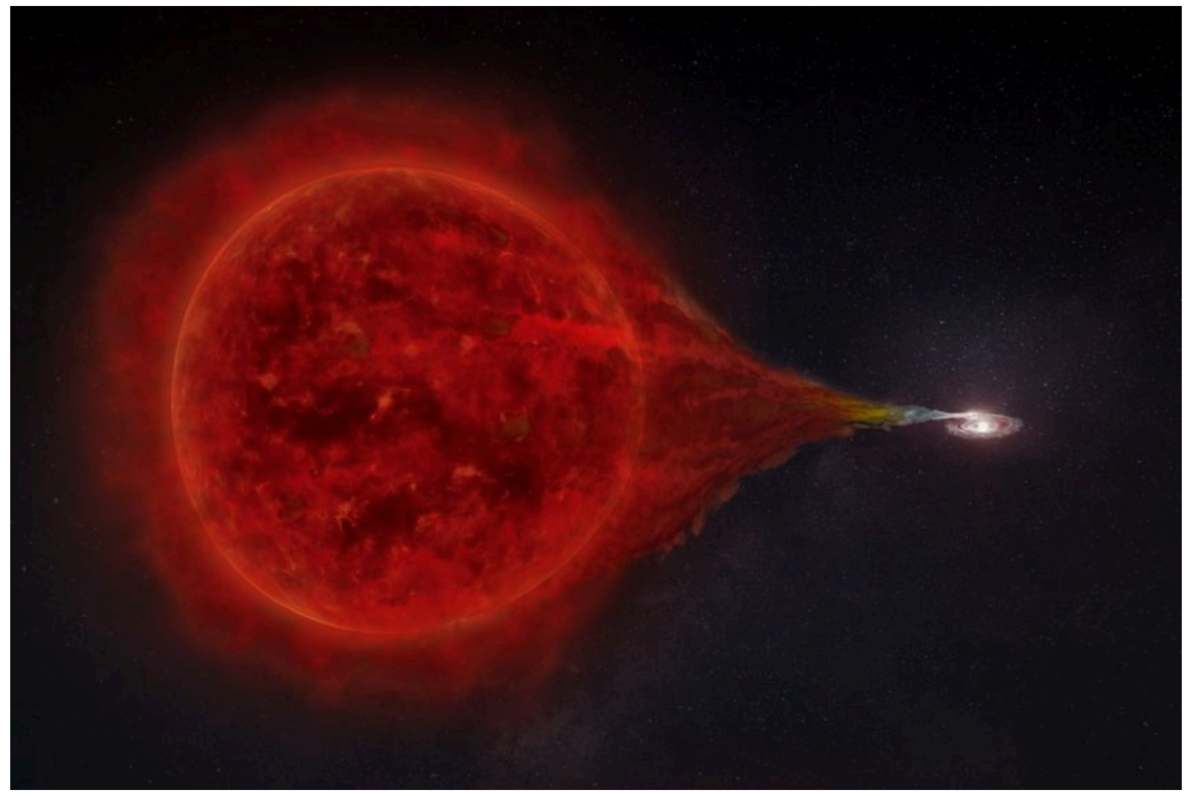
$\tau_{26Al} \sim 1.05\ Myr$



^{26}Al main production sites:

Massive stars

Nova systems(?)



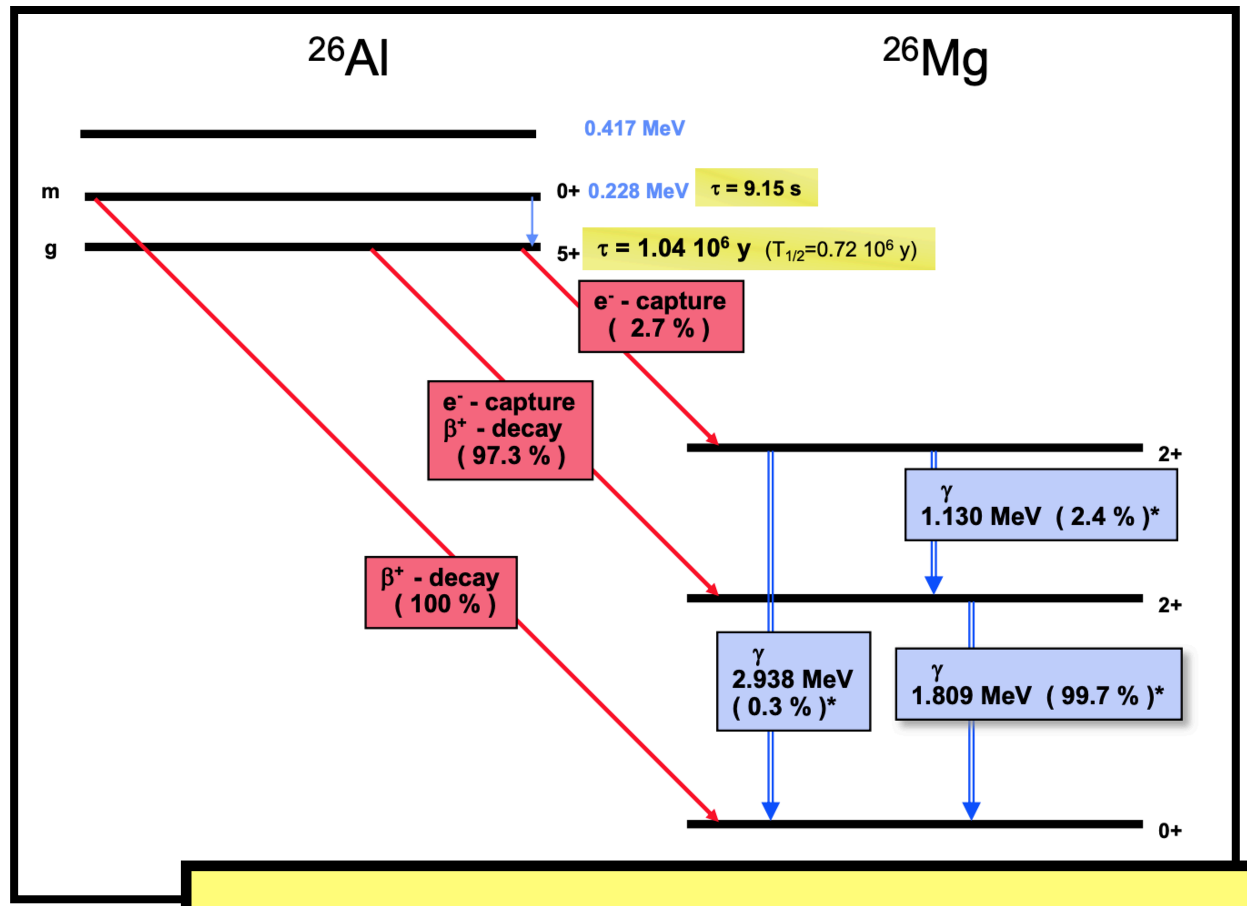
- Novae are WD that accrete matter from a companion
- An explosion is triggered but the nova doesn't die
- The matter accretion continues until a new explosion
- Novae can experience up to 10^4 explosions during their lifetime

Chemical evolution of SLR isotopes: ^{26}Al

Nuclear and astrophysical properties

^{26}Al

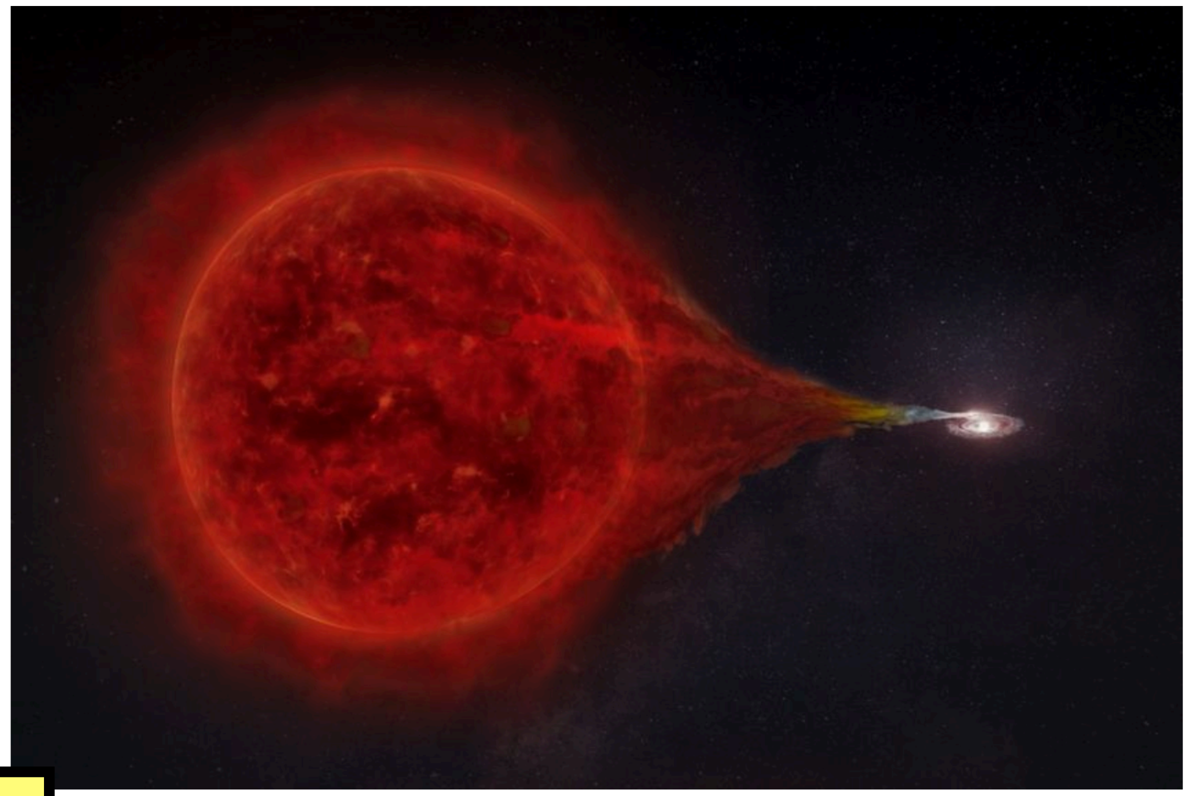
$\tau_{26Al} \sim 1.05\ Myr$



^{26}Al main production sites:

Massive stars

Nova systems(?)



- Novae
- An ex
- The m
- Novae … fetime

→ **tracers of active star formation regions**

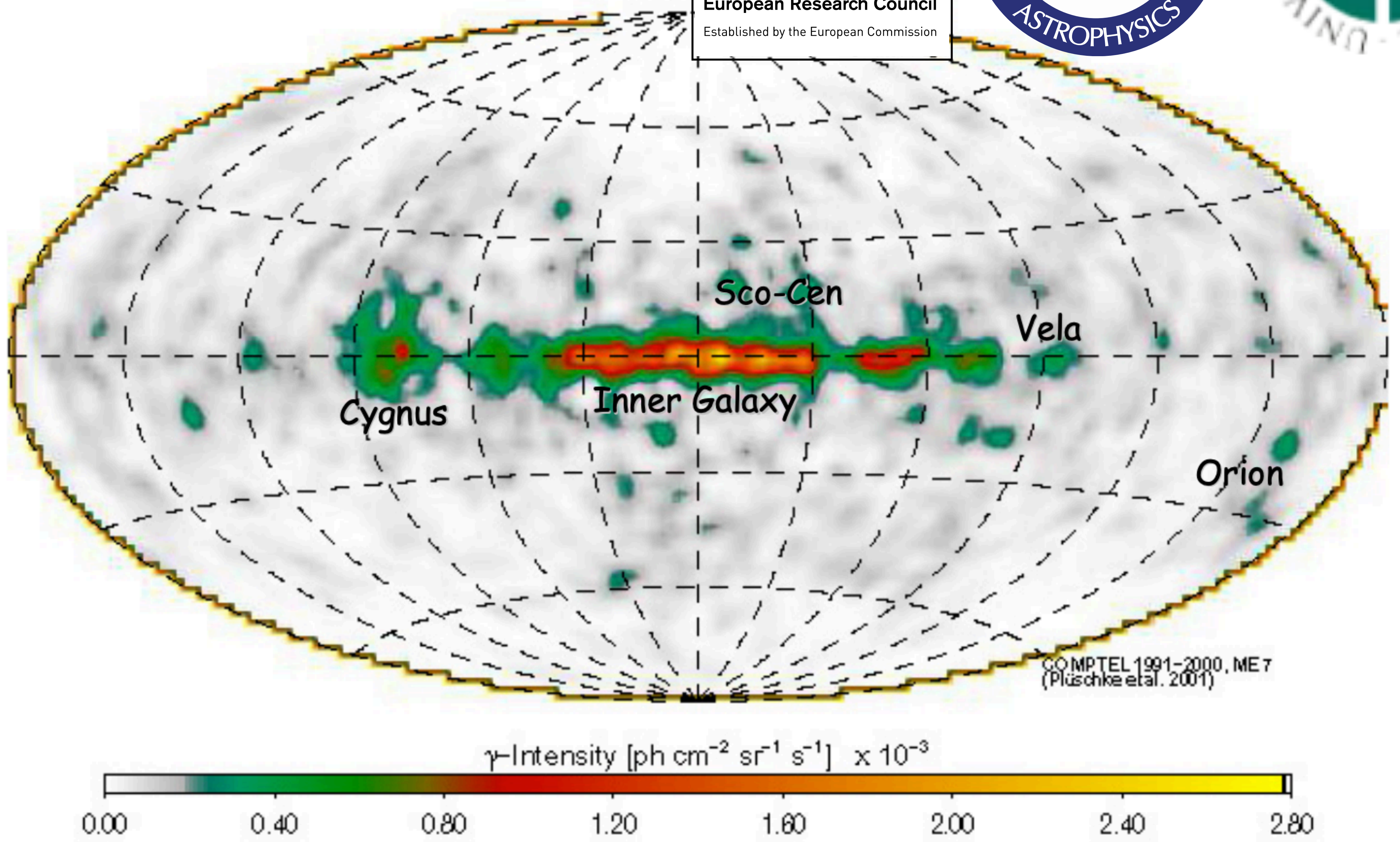
^{26}Al & ^{60}Fe observations

COMPTEL, INTEGRAL and COSI

***COMP**ton **TEL**escope*

(COMPTEL, Schönefelder+84):

- **1.5 - 2 $M_\odot$ of ^{26}Al** within 5 kpc from the Galactic centre



Diehl+05

^{26}Al & ^{60}Fe observations

COMPTEL, INTEGRAL and COSI

***COMP**ton **TEL**escope*

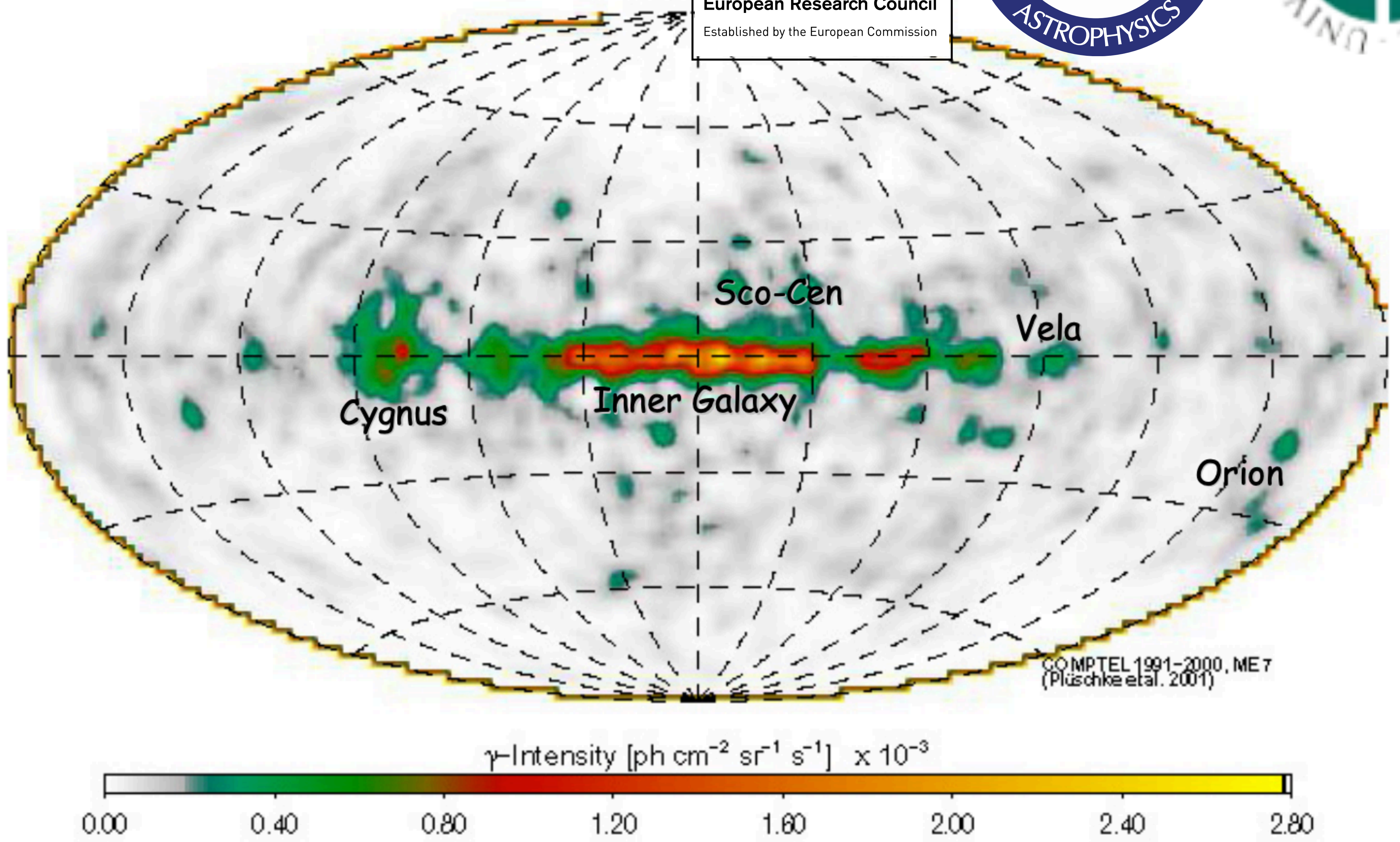
(COMPTEL, Schönefelder+84):

- **1.5 - 2 $M_\odot$ of ^{26}Al** within 5 kpc from the Galactic centre

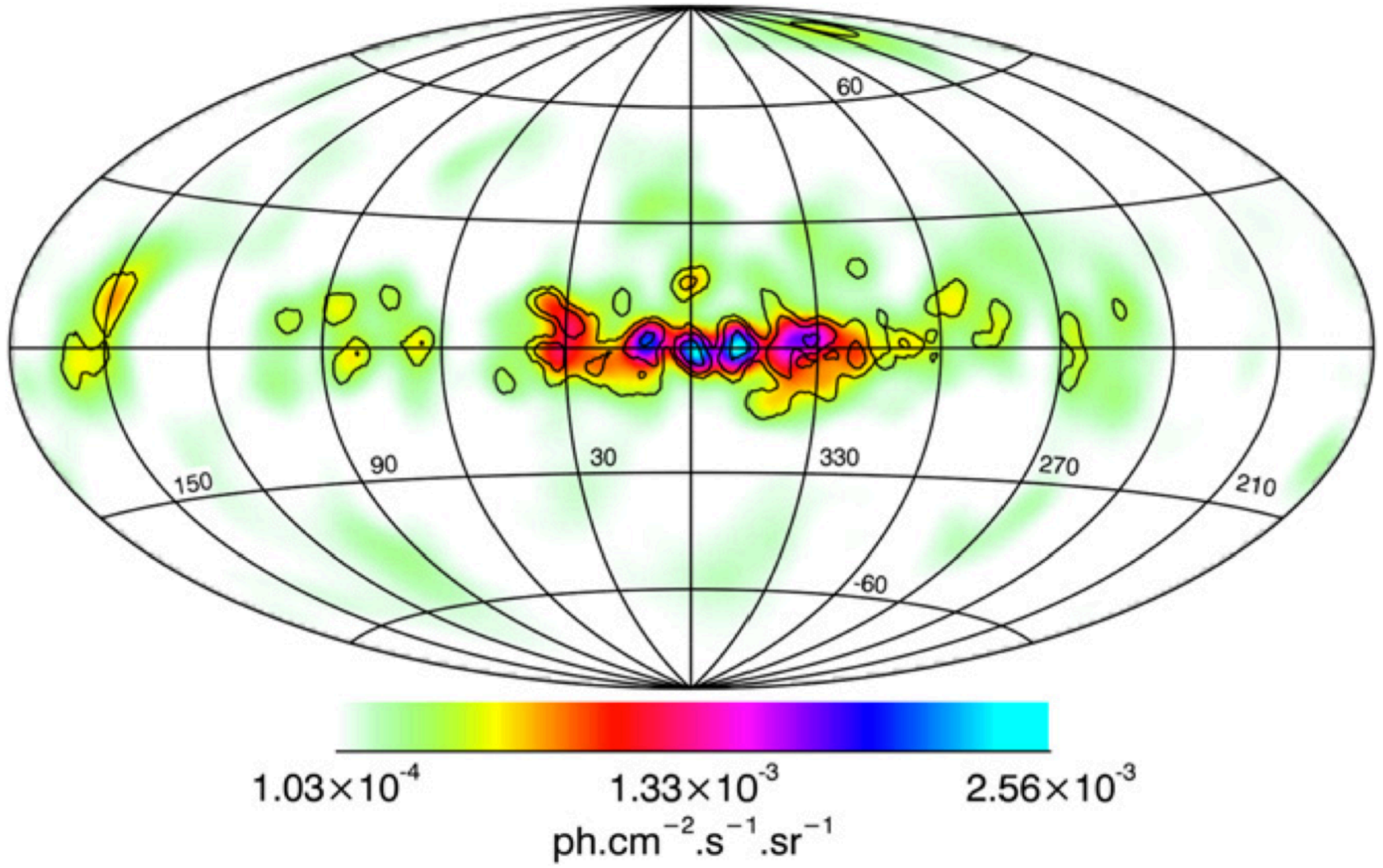
***INTE**rnational **G**amma-**R**ay **A**strophysics **L**aboratory*

(INTEGRAL, Winkler94):

- **1.7 - 2 $M_\odot$ of ^{26}Al** within 5 kpc from the Galactic centre
- **1-6 $M_\odot$ of ^{60}Fe** within 5 kpc from the Galactic centre



Diehl+05



Bouchet+15

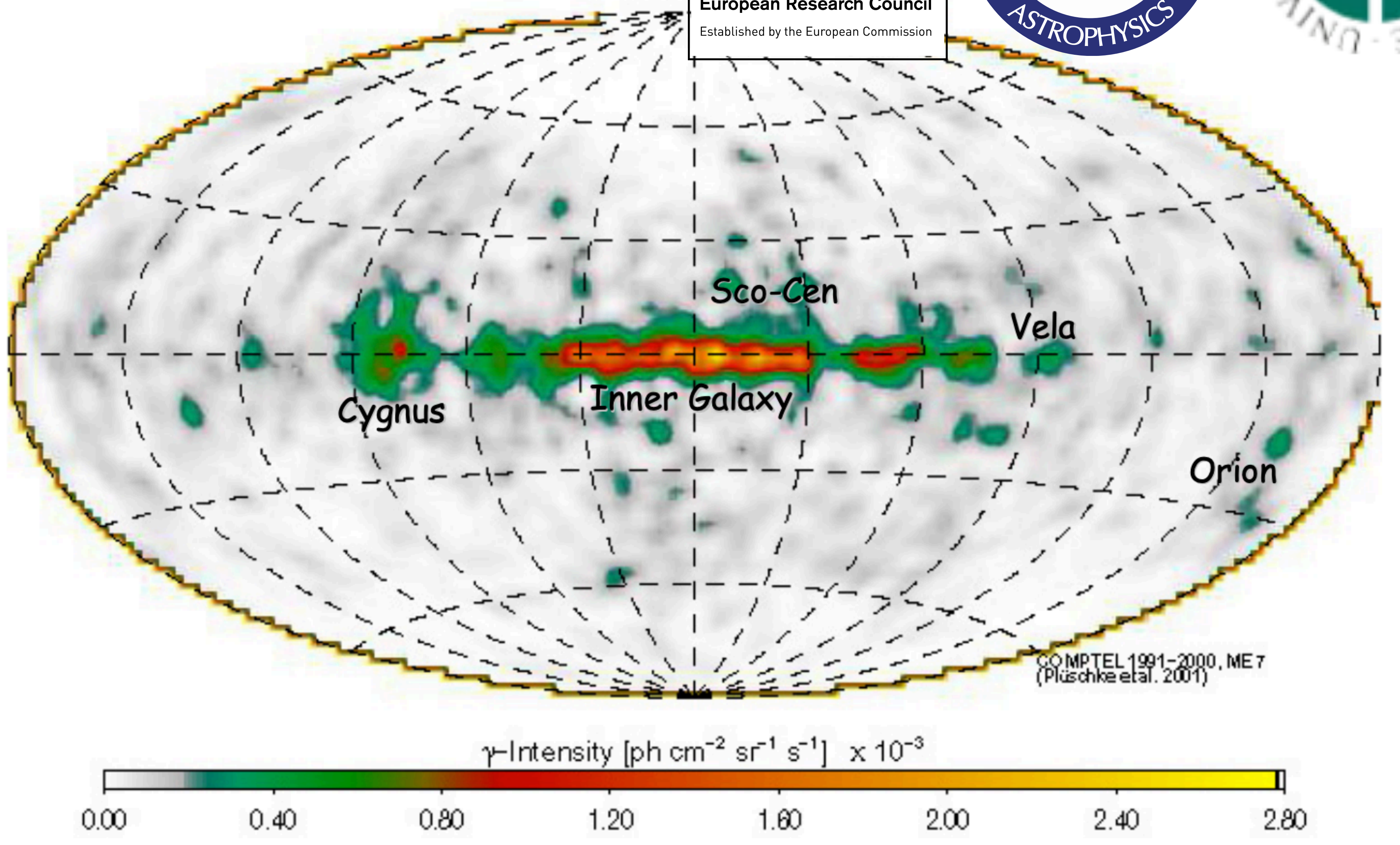
^{26}Al & ^{60}Fe observations

COMPTEL, INTEGRAL and COSI

***COMP**ton **TEL**escope*

(COMPTEL, Schönefelder+84):

- **1.5 - 2 $M_\odot$ of ^{26}Al** within 5 kpc from the Galactic centre



Diehl+05

***INTE**rnational **G**amma-**R**ay **A**strophysics **L**aboratory*

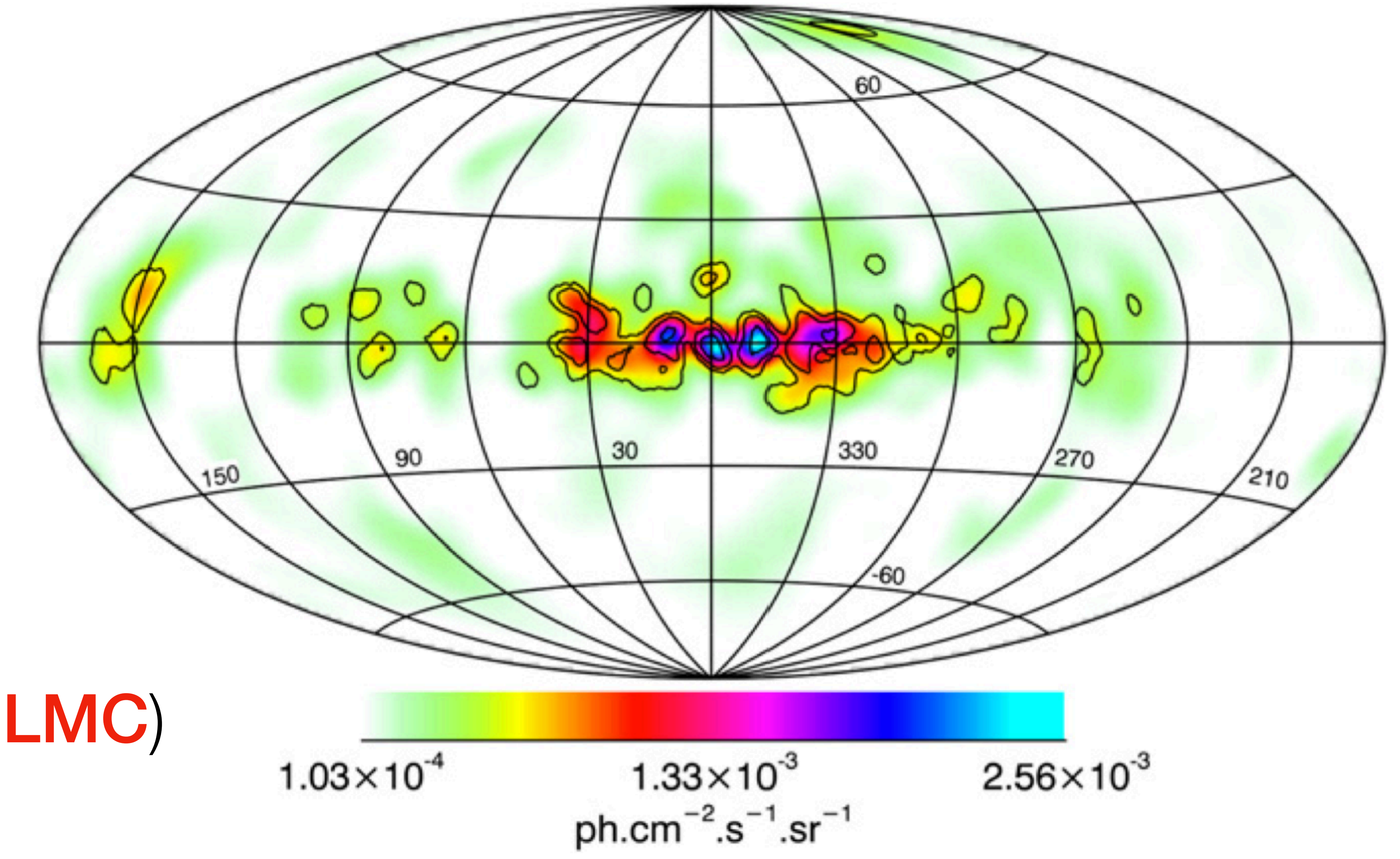
(INTEGRAL, Winkler94):

- **1.7 - 2 $M_\odot$ of ^{26}Al** within 5 kpc from the Galactic centre
- **1-6 $M_\odot$ of ^{60}Fe** within 5 kpc from the Galactic centre

***CO**mpton **S**pectrometer and **I**mager*

(COSI, Tomsick+ 2019):

- will detect the ^{26}Al in each ring around the Galactic center;
- will be able to observe **outside of the Milky Way** (observations of the **LMC**)



Bouchet+15

Aim: what do we want to do?

We want to study in a more detailed way the distribution of ^{26}Al in the Milky Way

Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

Royal Astronomical Society

MNRAS **517,** 4256–4264 (2022) https://doi.org/10.1093/mnras/stac2981
Advance Access publication 2022 October 21

Chemical evolution of ^{26}Al and ^{60}Fe in the Milky Way

A. Vasini,[1,2★] F. Matteucci[1,2,3] and E. Spitoni[4,5,6]

[1]*Dipartimento di Fisica, Sezione di Astronomia, Università di Trieste, via G.B. Tiepolo 11, I-34131 Trieste, Italy*
[2]*INAF Osservatorio Astronomico di Trieste, via G.B. Tiepolo 11, I-34131 Trieste, Italy*
[3]*INFN Sezione di Trieste, via Valerio 2, I-34134 Trieste, Italy*
[4]*Universitè Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Bd de l'Observatoire, CS 34229, F-06304 Nice Cedex 4, France*
[5]*Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Konkoly Thege Miklós út 15-17, H-1121 Budapest, Hungary*
[6]*Stellar Astrophysics Centre, Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, DK-8000 Aarhus C, Denmark*

Accepted 2022 May 19. Received 2022 May 19; in original form 2022 April 1

Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Vasini+22:
Chemical Evolution model with 1D approximation

Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Vasini+22:
Chemical Evolution model with 1D approximation

Aim: what do we want to do?

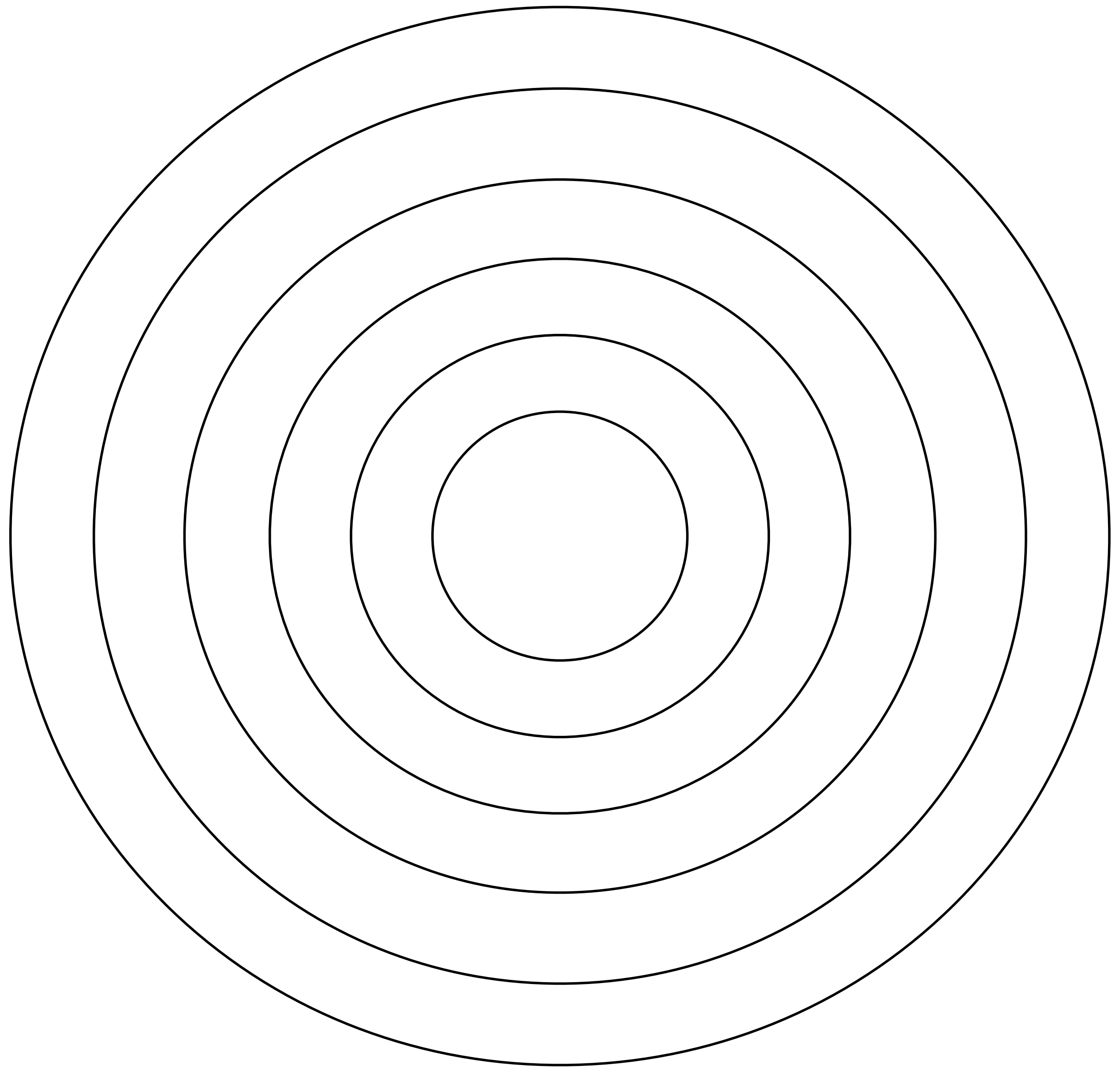
We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al

Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

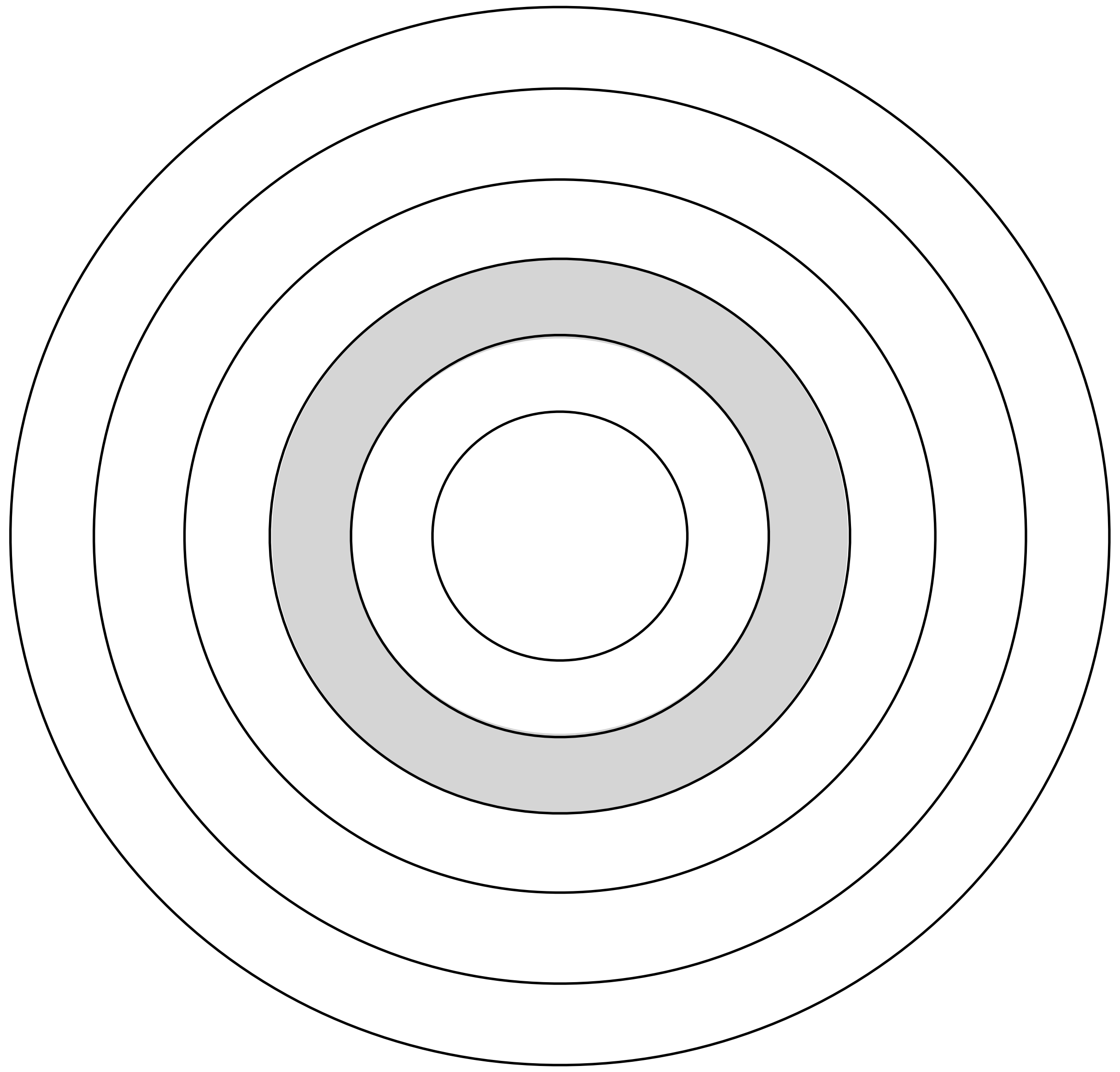
Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al



Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

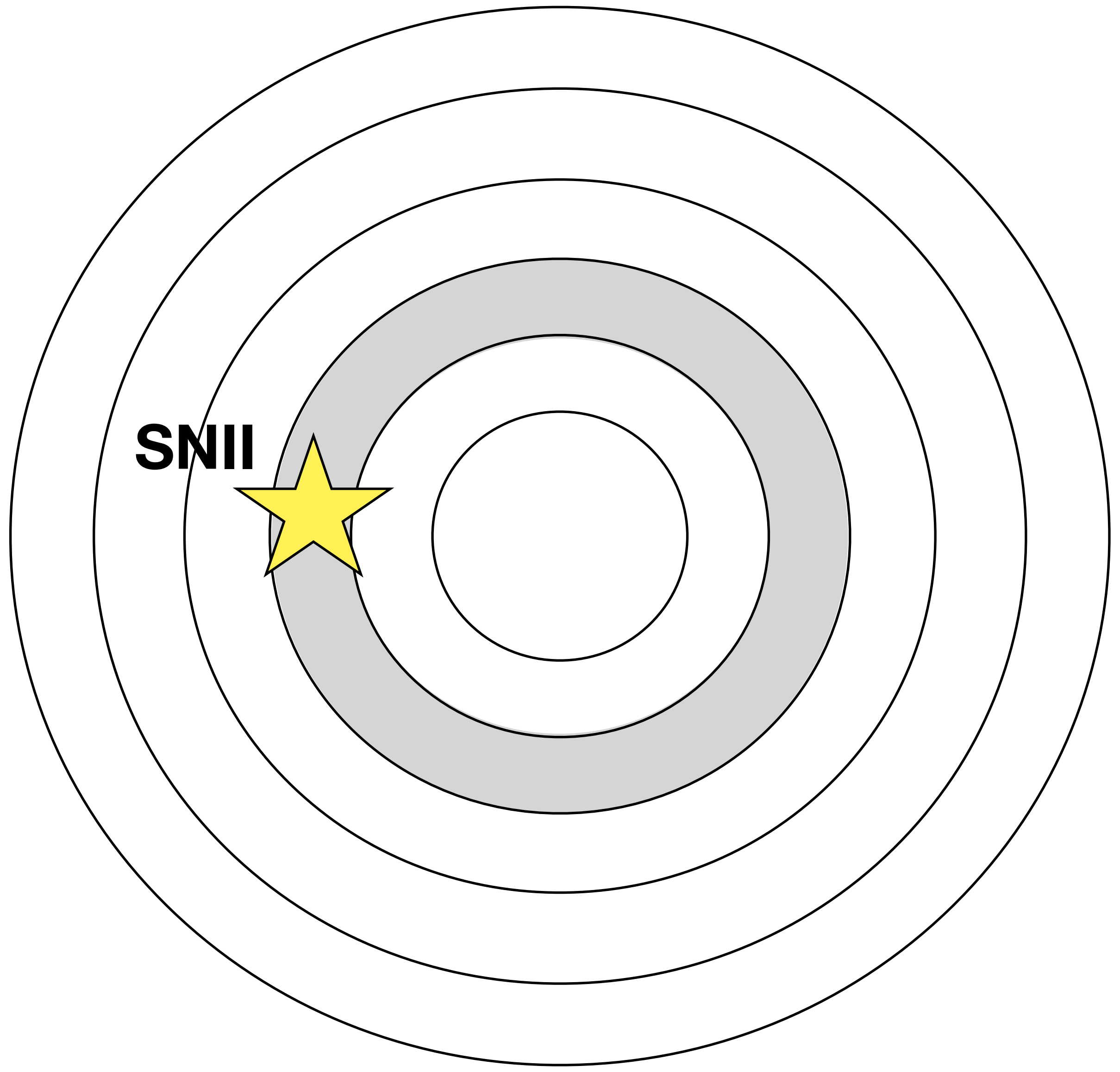
Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al



Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

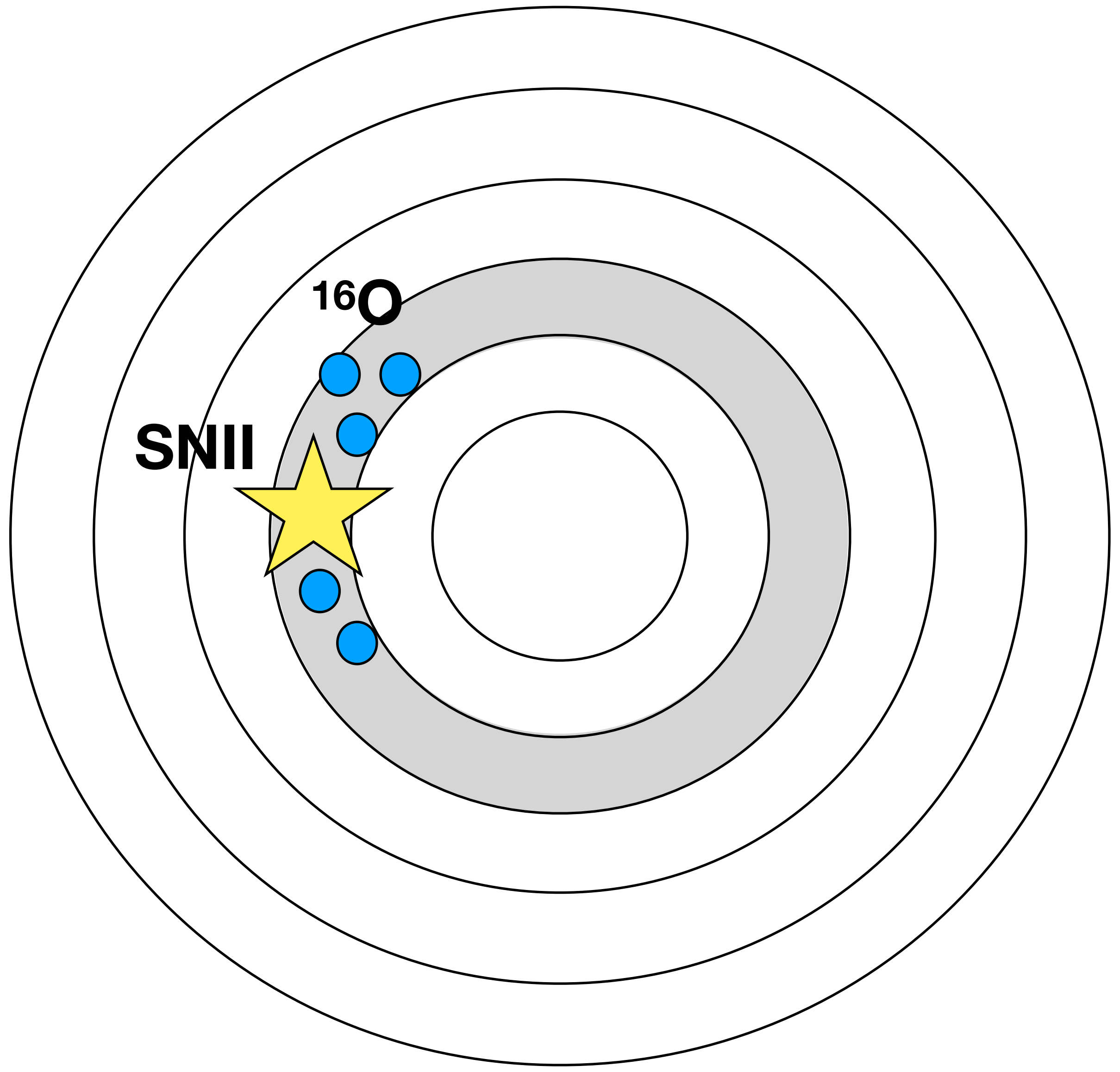
Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al



Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

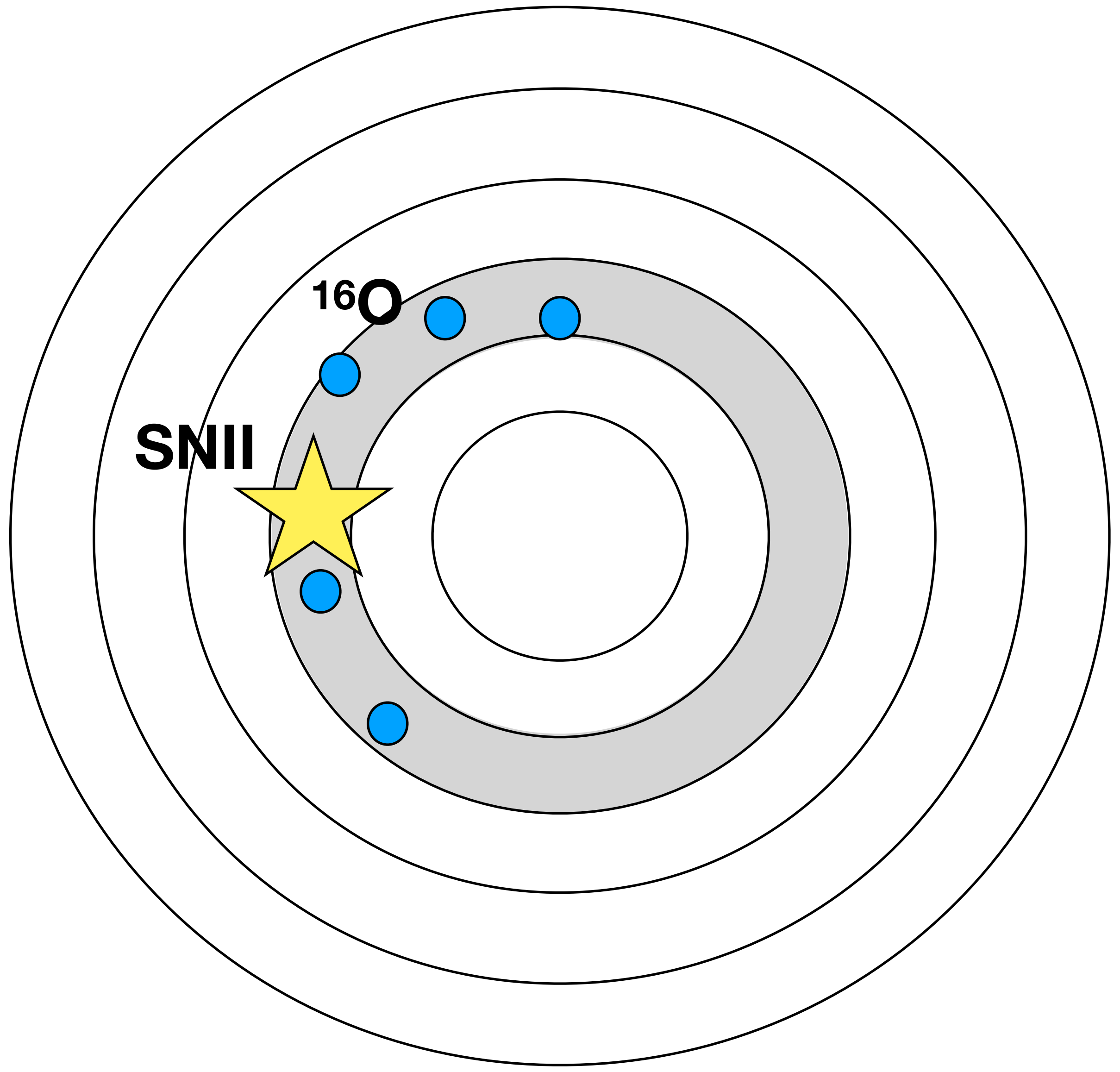
Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al



Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

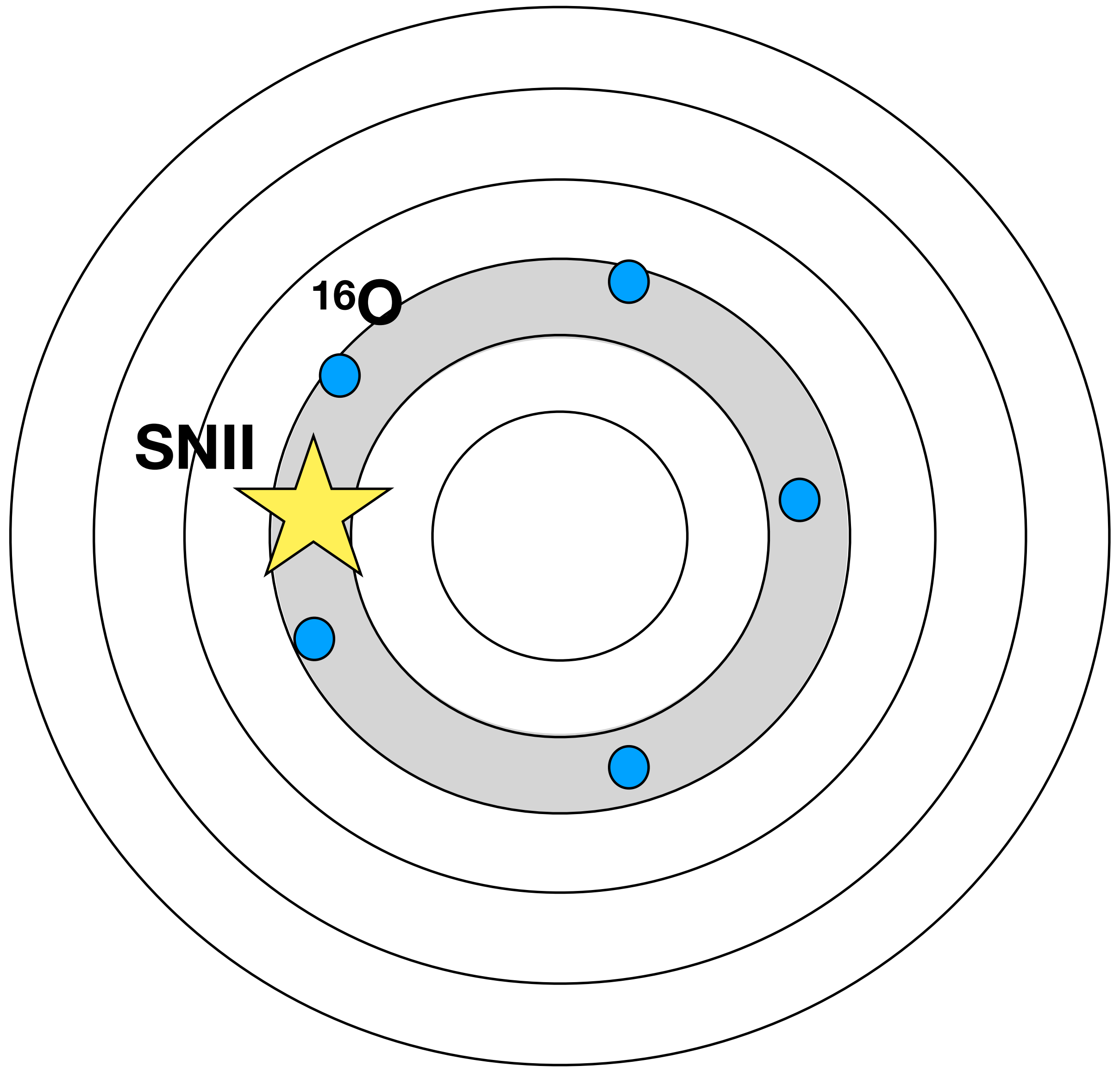
Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al



Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

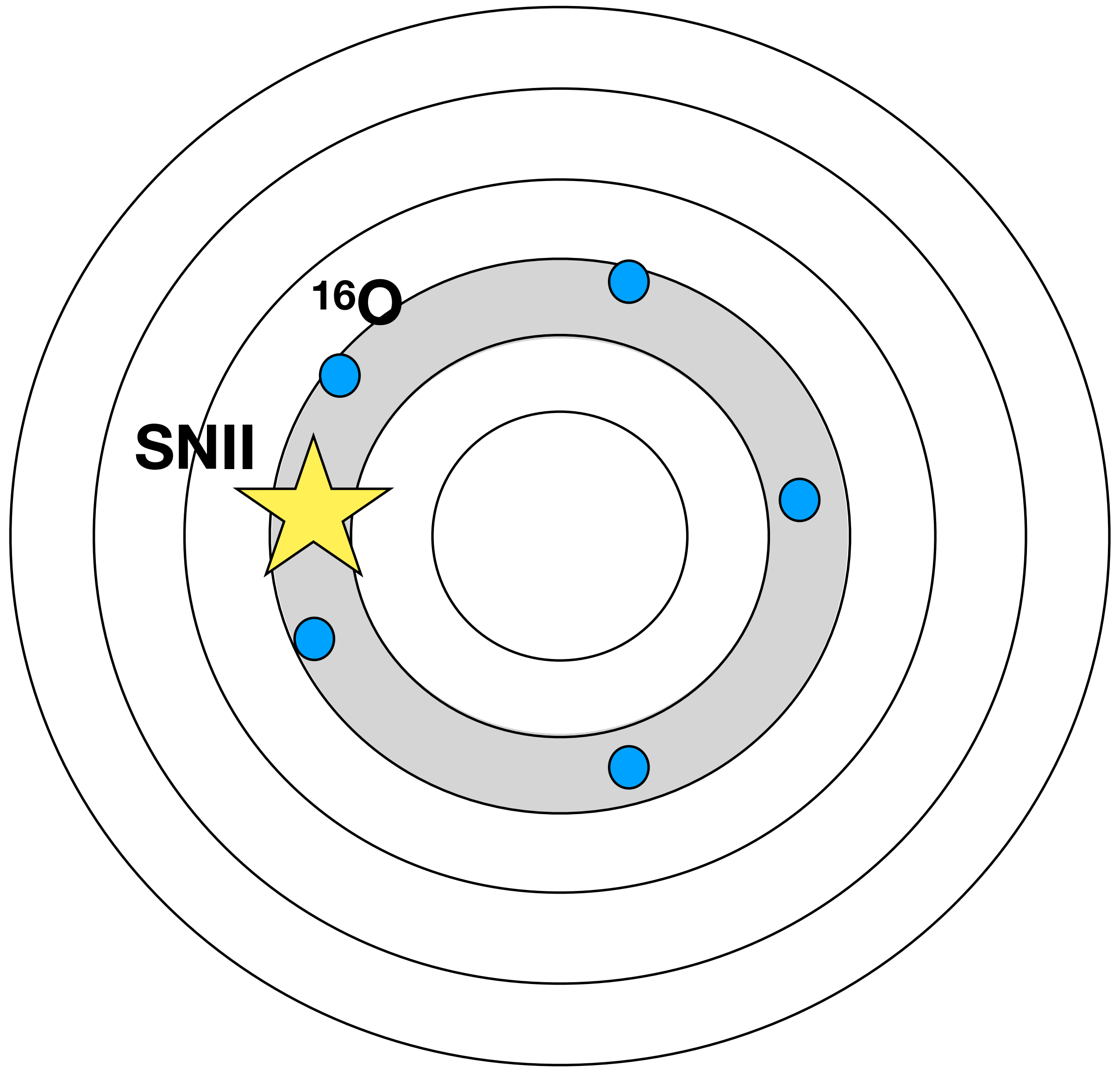
Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al

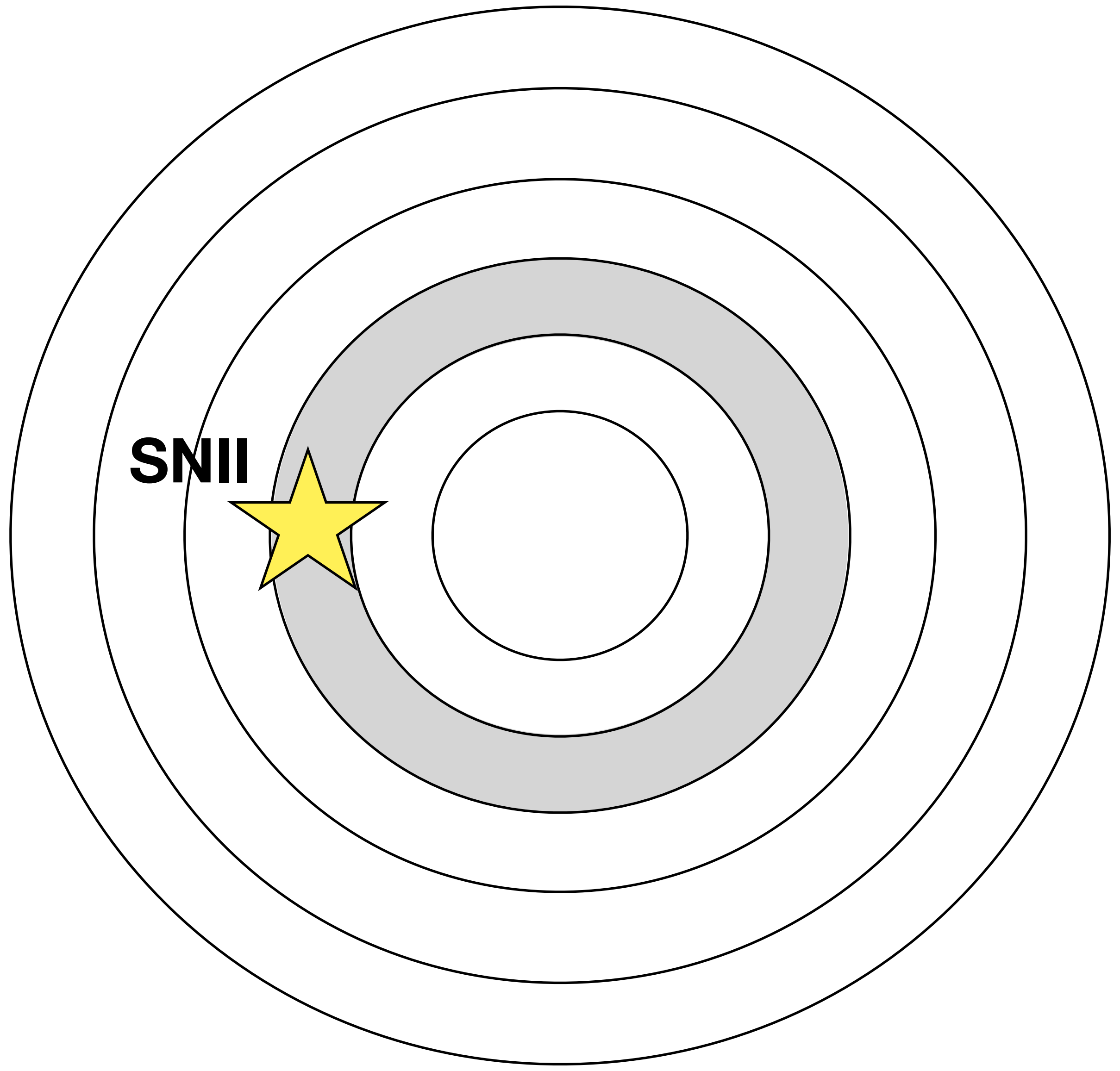


Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al

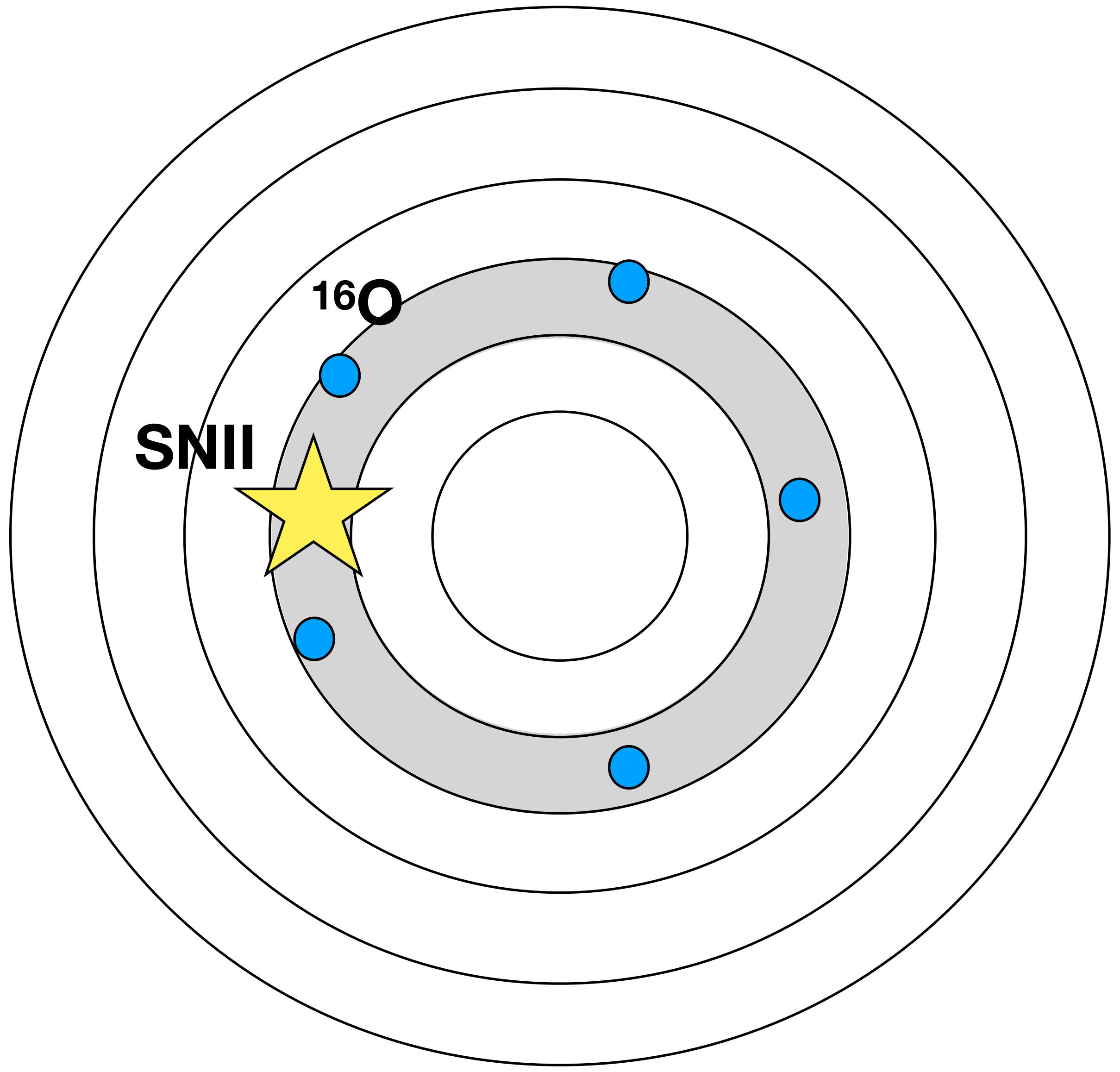


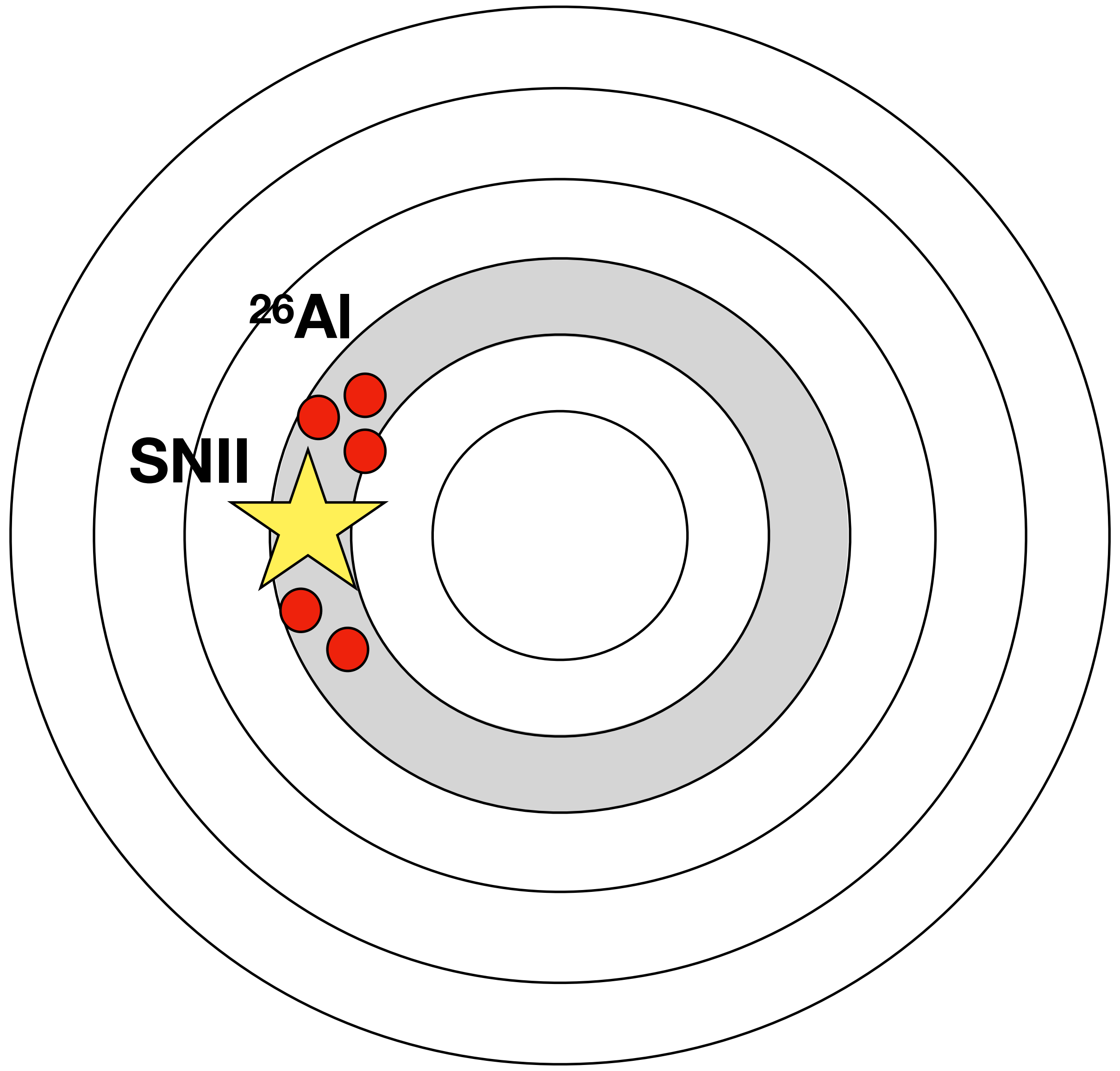


Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al

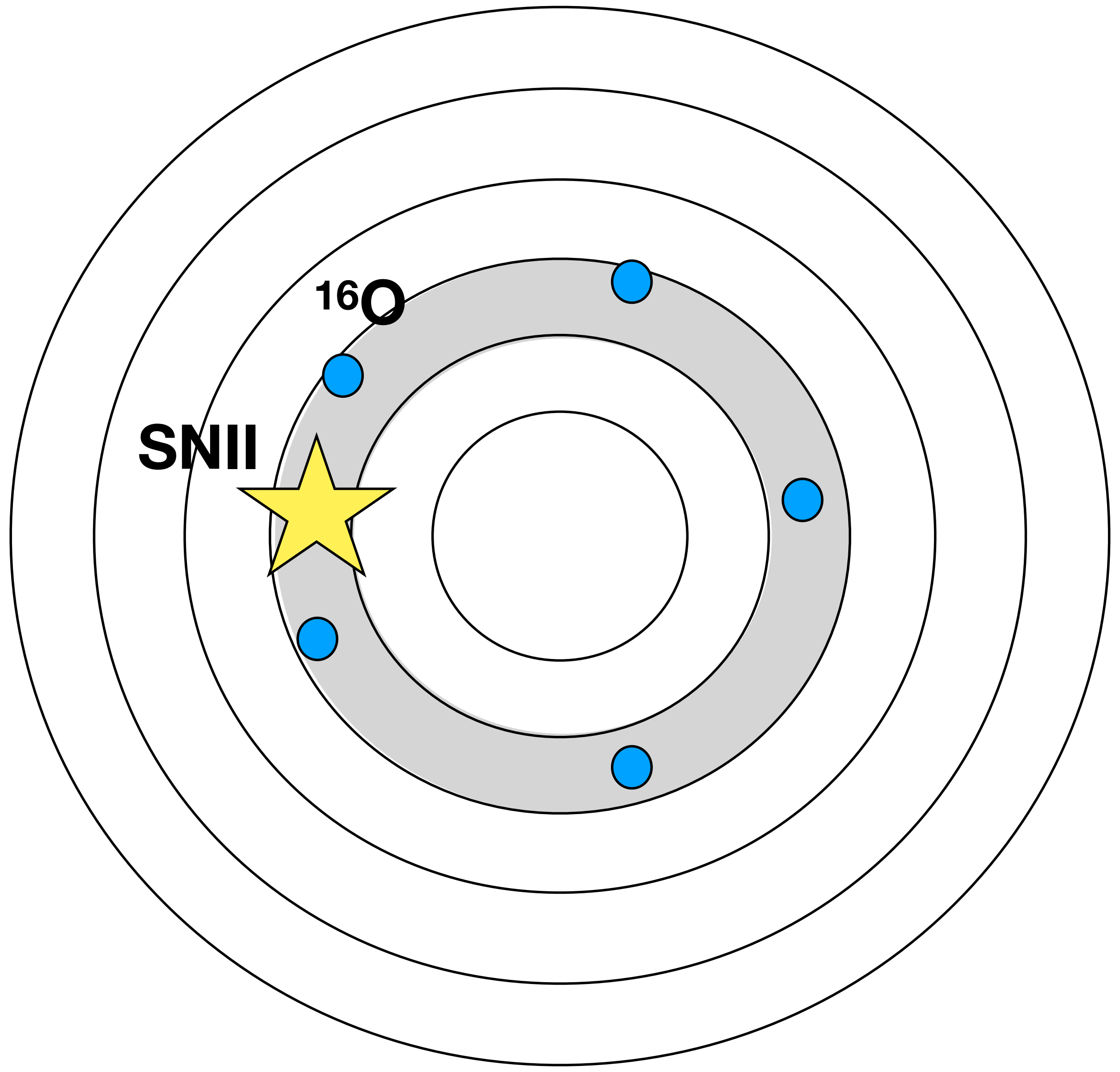


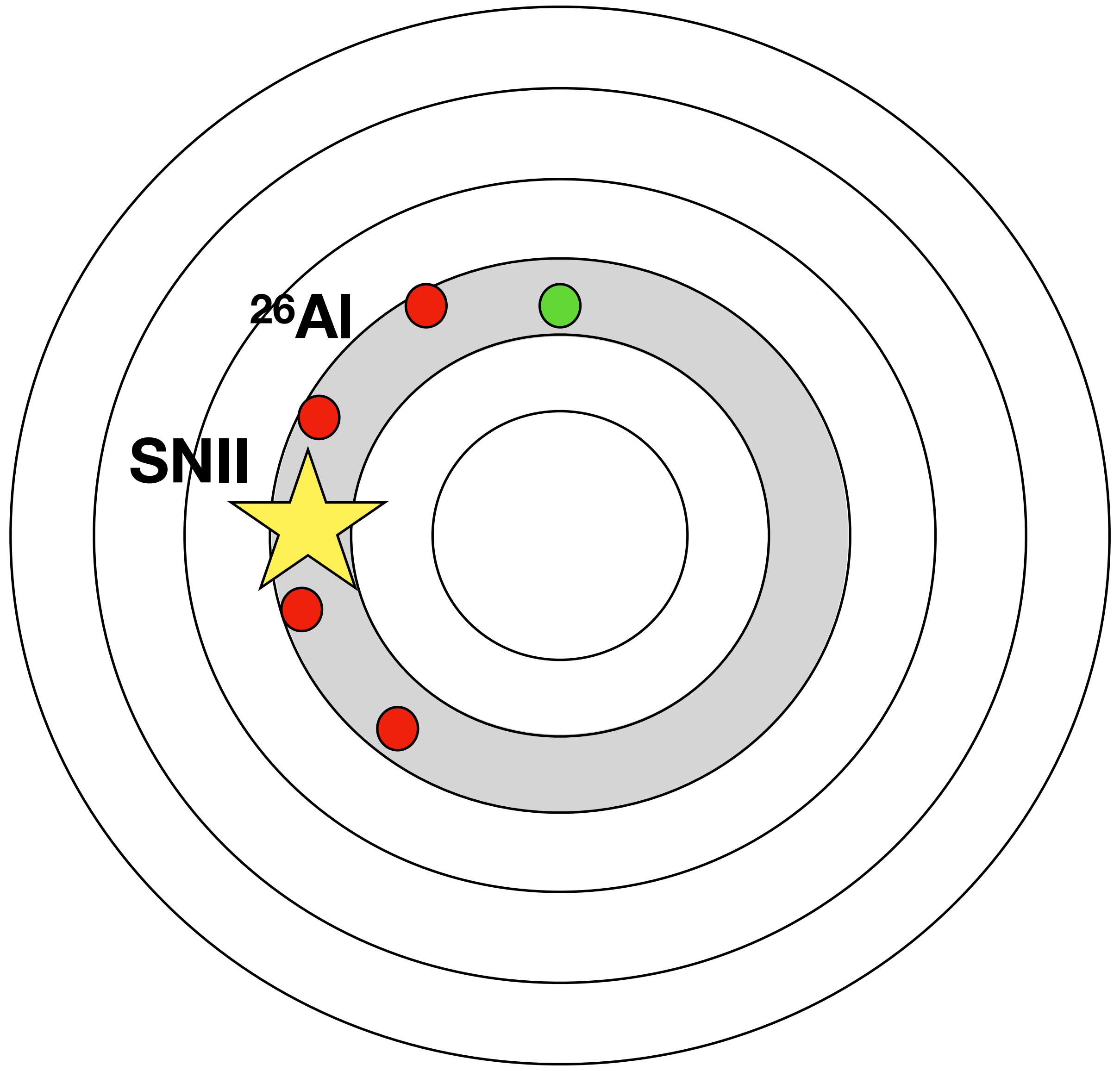


Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al

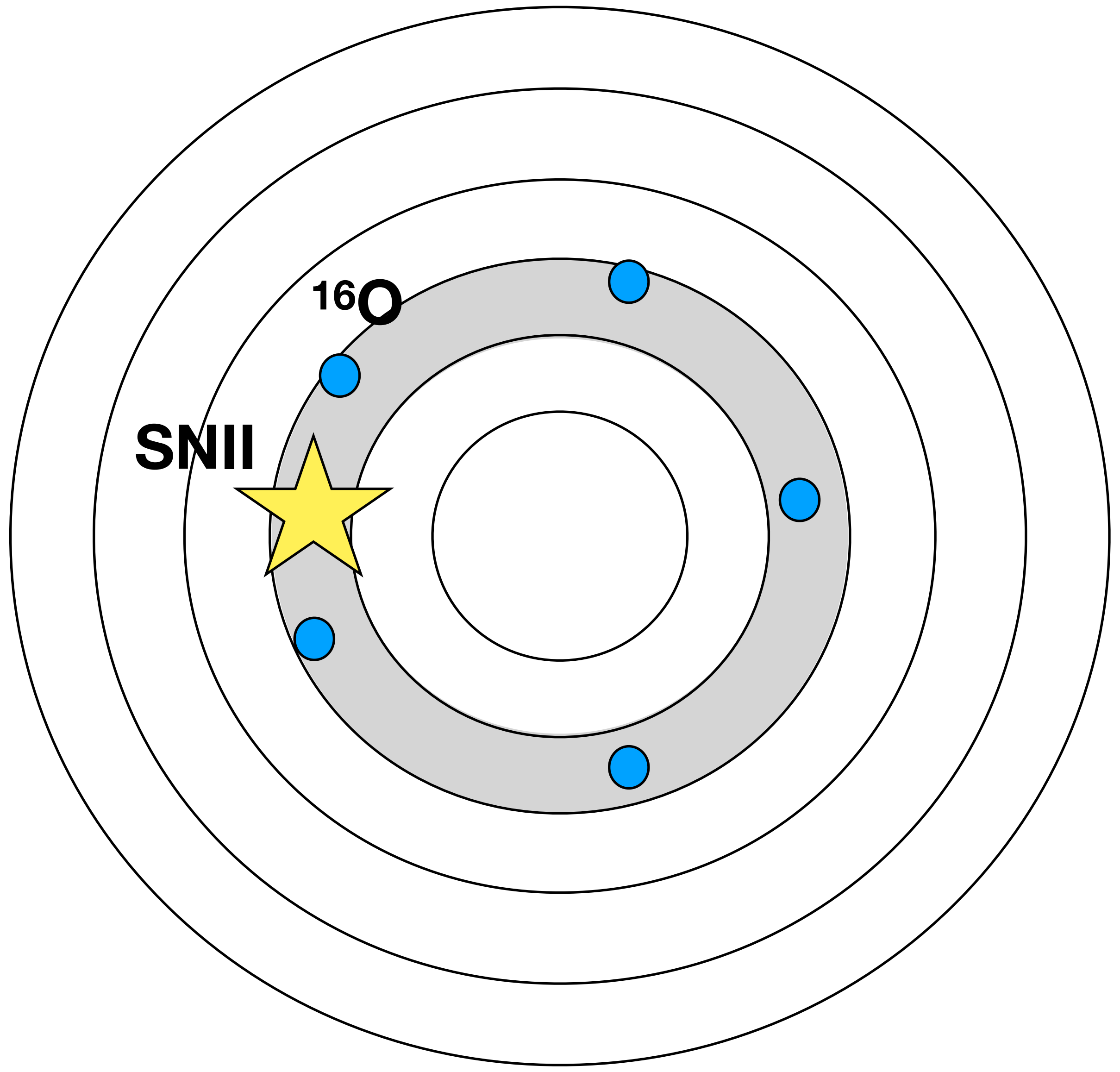


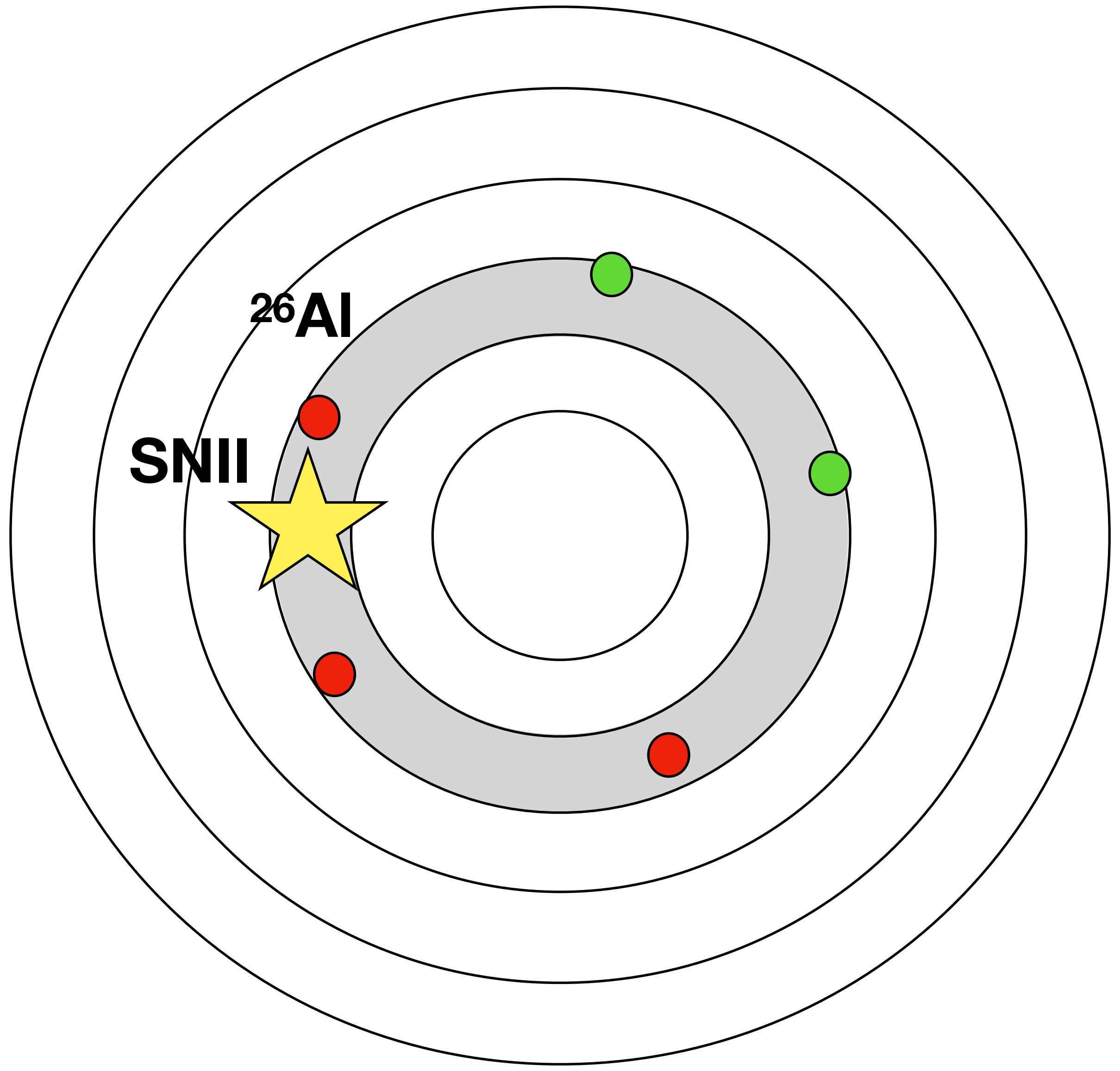


Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al

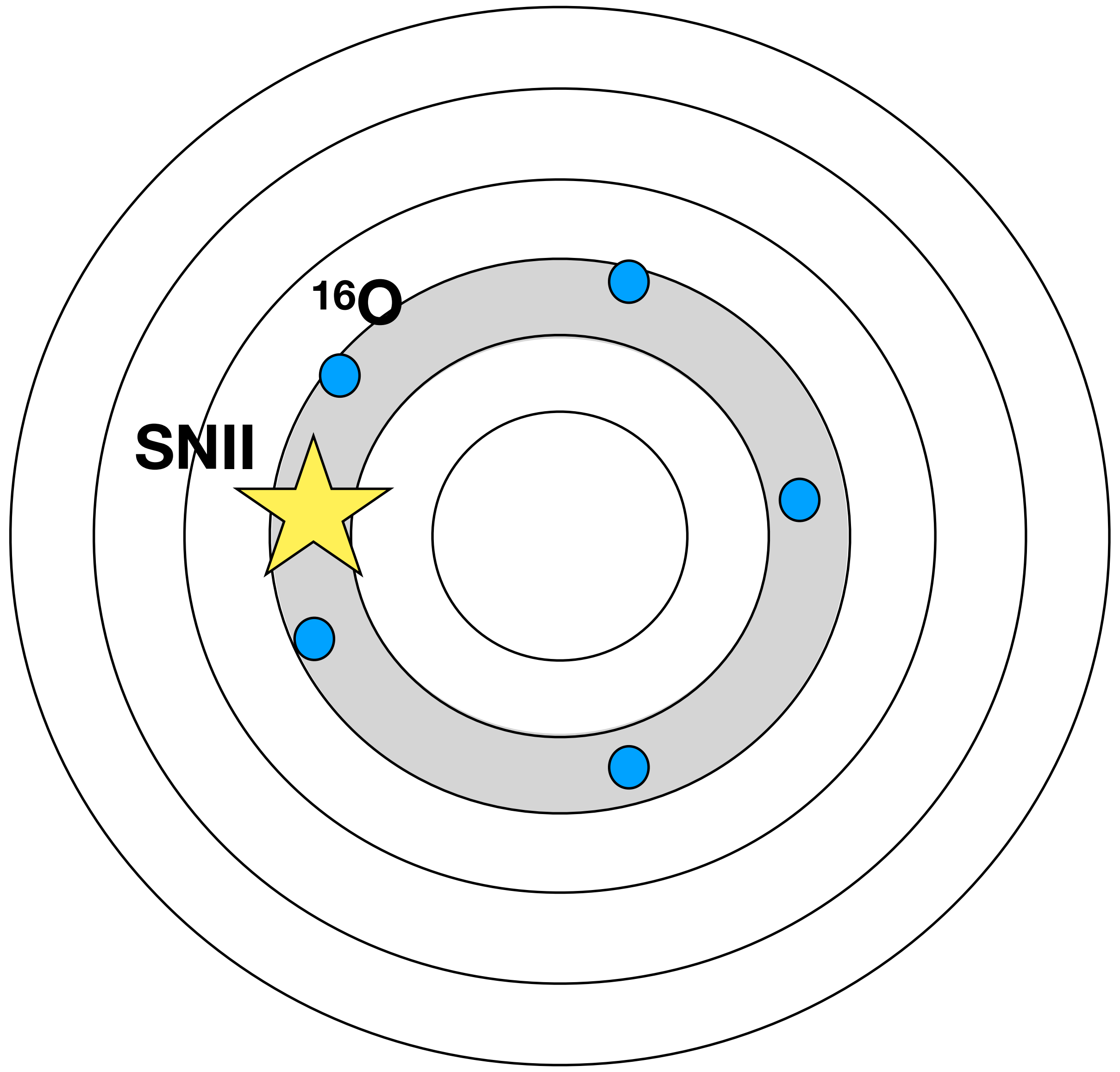


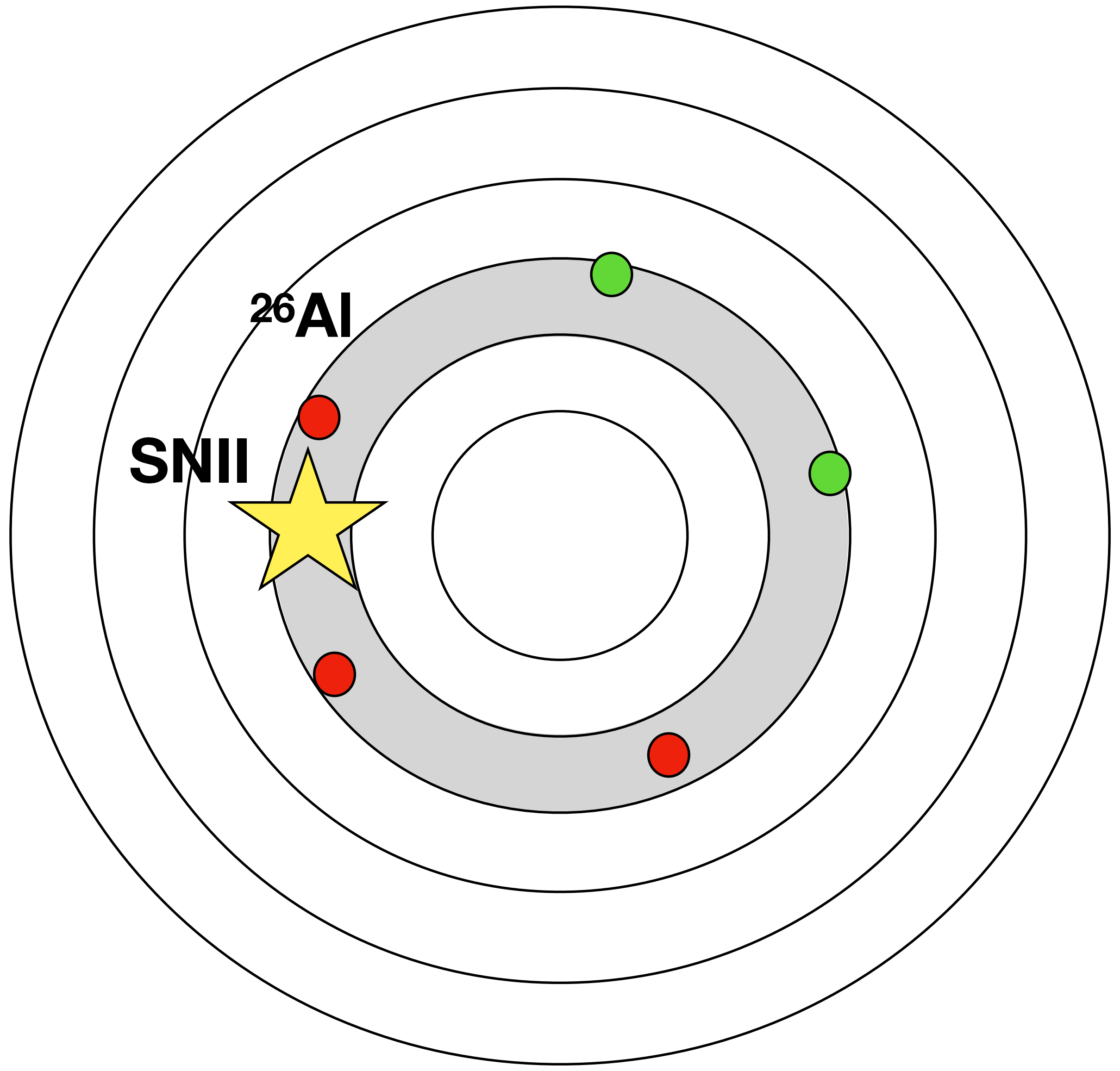


Aim: what do we want to do?

We want to study in a **more detailed way** the distribution of ^{26}Al in the Milky Way

Vasini+22:
Chemical Evolution model with 1D approximation → The scenario is too simplistic for ^{26}Al





→ homogeneous mixing does not hold for Short Lived Radioisotopes: 2D model needed

Aim: why?

Spitoni+2019,+2023: 2D model can trace the alpha-element abundance oscillations in an annulus

Aim: why?

Spitoni+2019,+2023: 2D model can trace the alpha-element abundance oscillations in an annulus

→ How much the results of Vasini+2022 about ^{26}Al are affected by the choice of 1D over 2D model?

Aim: why?

Spitoni+2019,+2023: 2D model can trace the alpha-element abundance oscillations in an annulus

⟶ How much the results of Vasini+2022 about ^{26}Al are affected by the choice of 1D over 2D model?

Massive stars are not the only astronomical production site of ^{26}Al

Nova systems contribute too:
- delay for the formation of the white dwarf
- delay for the cooling time

⟶ Nova systems do not trace the SFR

Aim: why?

Spitoni+2019,+2023: 2D model can trace the alpha-element abundance oscillations in an annulus

⟶ How much the results of Vasini+2022 about ^{26}Al are affected by the choice of 1D over 2D model?

Massive stars are not the only astronomical production site of ^{26}Al

Nova systems contribute too:
- delay for the formation of the white dwarf
- delay for the cooling time

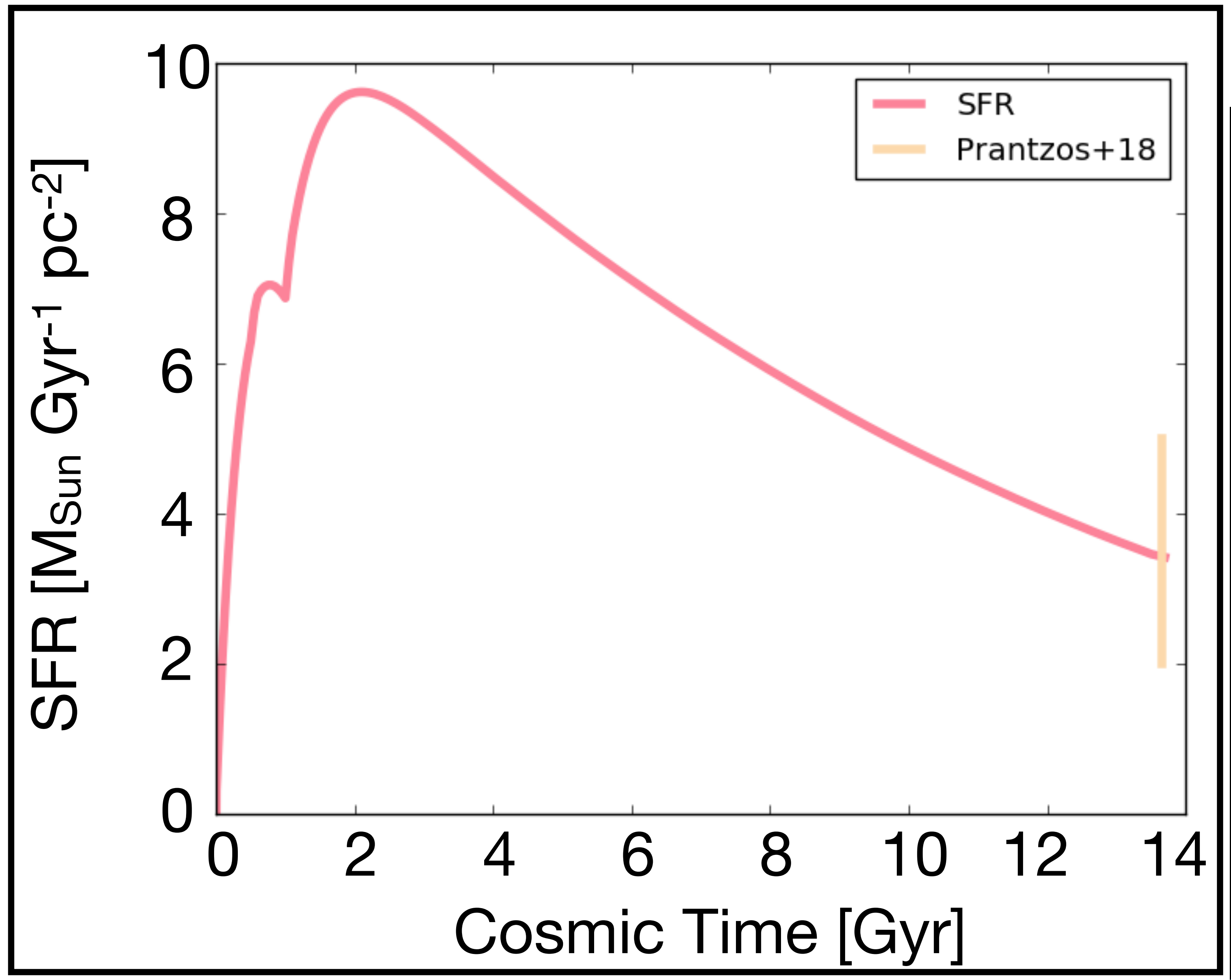
⟶ Nova systems do not trace the SFR

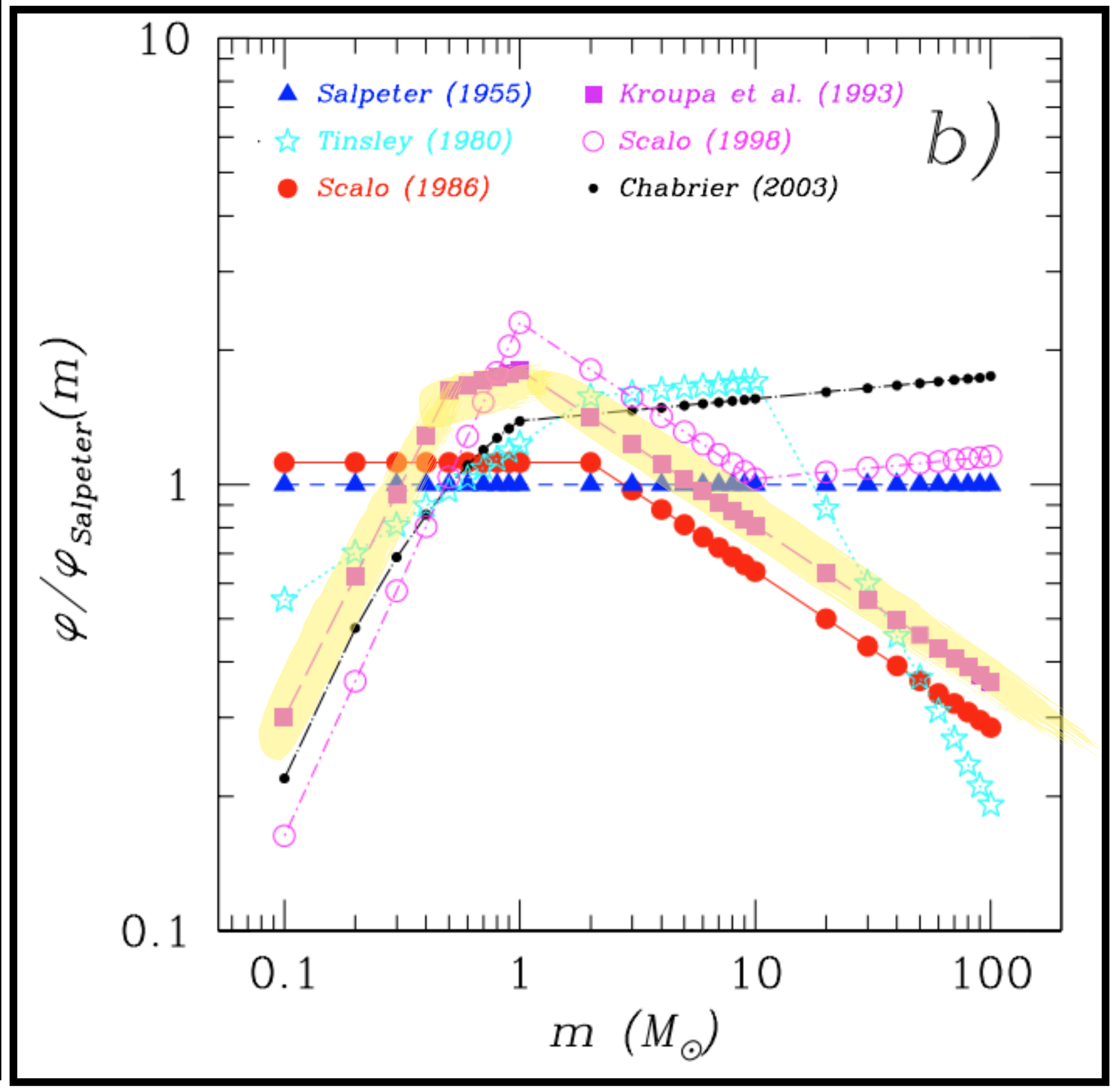
⟶ How much the nova contribution affect the precision of the ^{26}Al SFR tracing?

Model: prescriptions from Vasini+22 and Spitoni+23

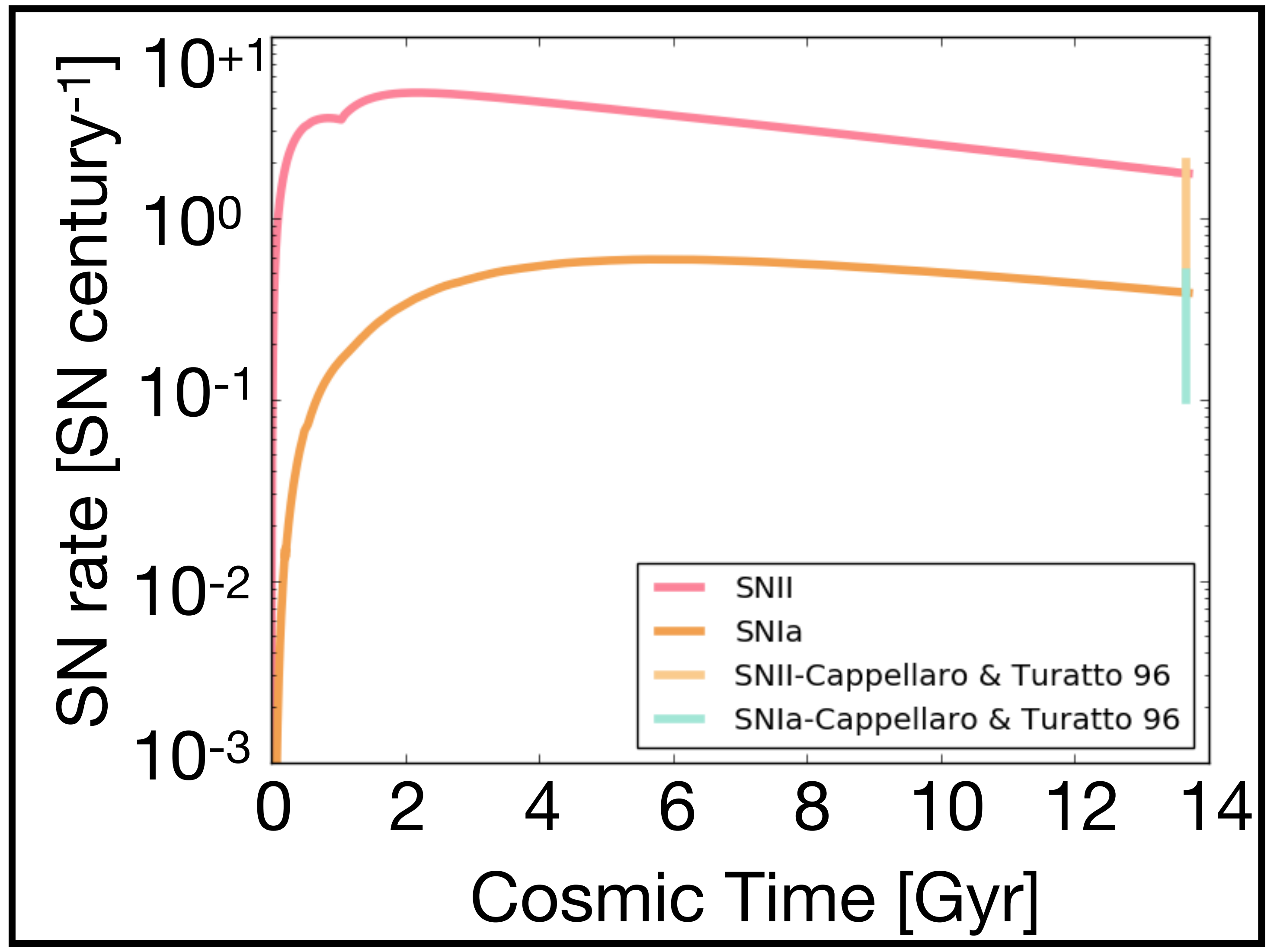
From Vasini+22:

- Schmidt - Kennicutt SFR + two infall law
- Kroupa+93 IMF
- Pollution from → Supernovae II,Ib,Ic
  Producers of ^{26}Al
  → Supernovae Ia
  (Matteucci & Greggio 86)
  → Novae
  (D'antona & Matteucci 91)
  Producers of ^{26}Al





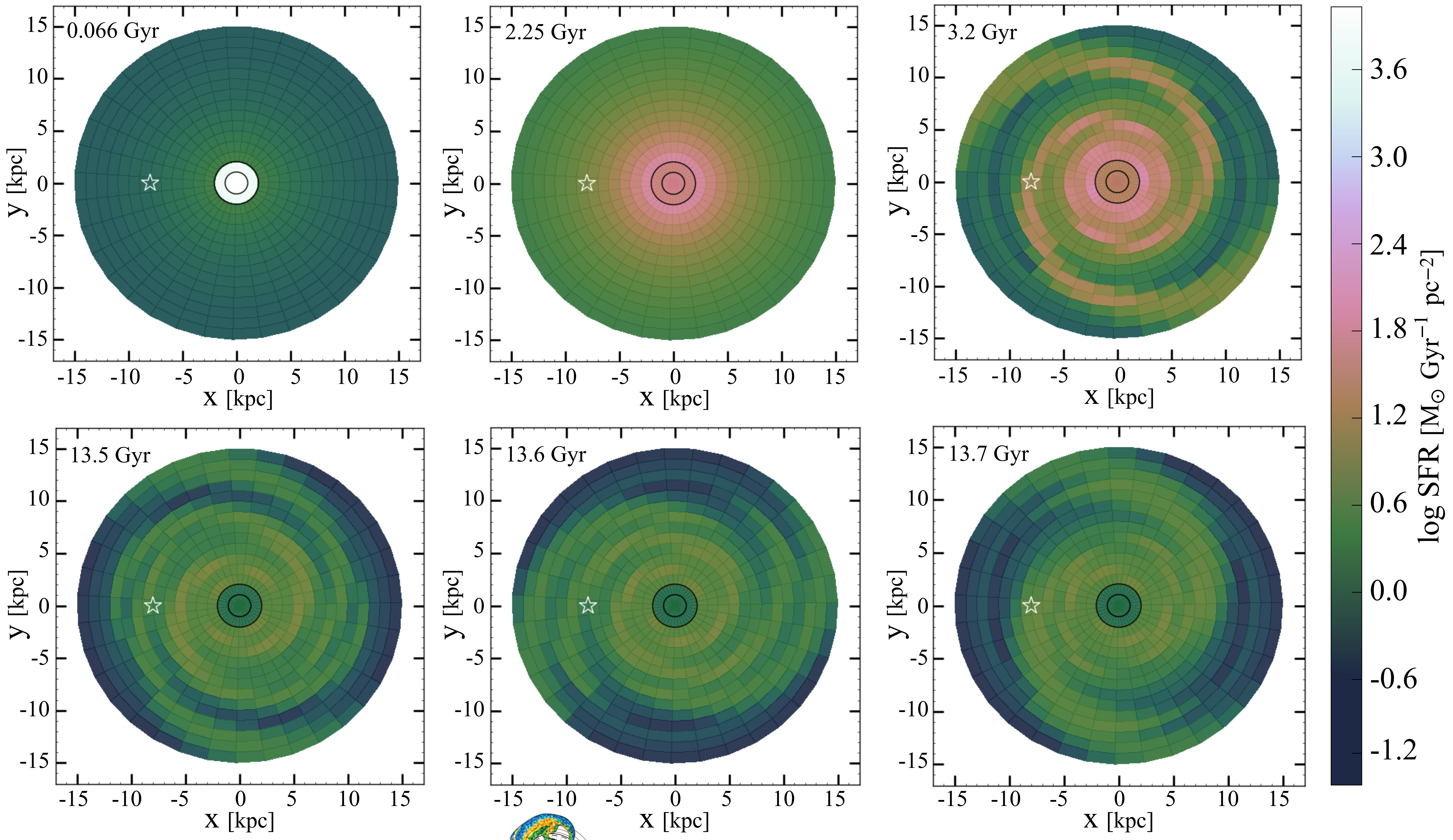
Romano+05



Chemical evolution of ^{26}Al: 2D MW

Vasini, Spitoni, Matteucci, Cescutti & Della Valle 2024

SFR from
2D model
by *Spitoni+19,+23*:

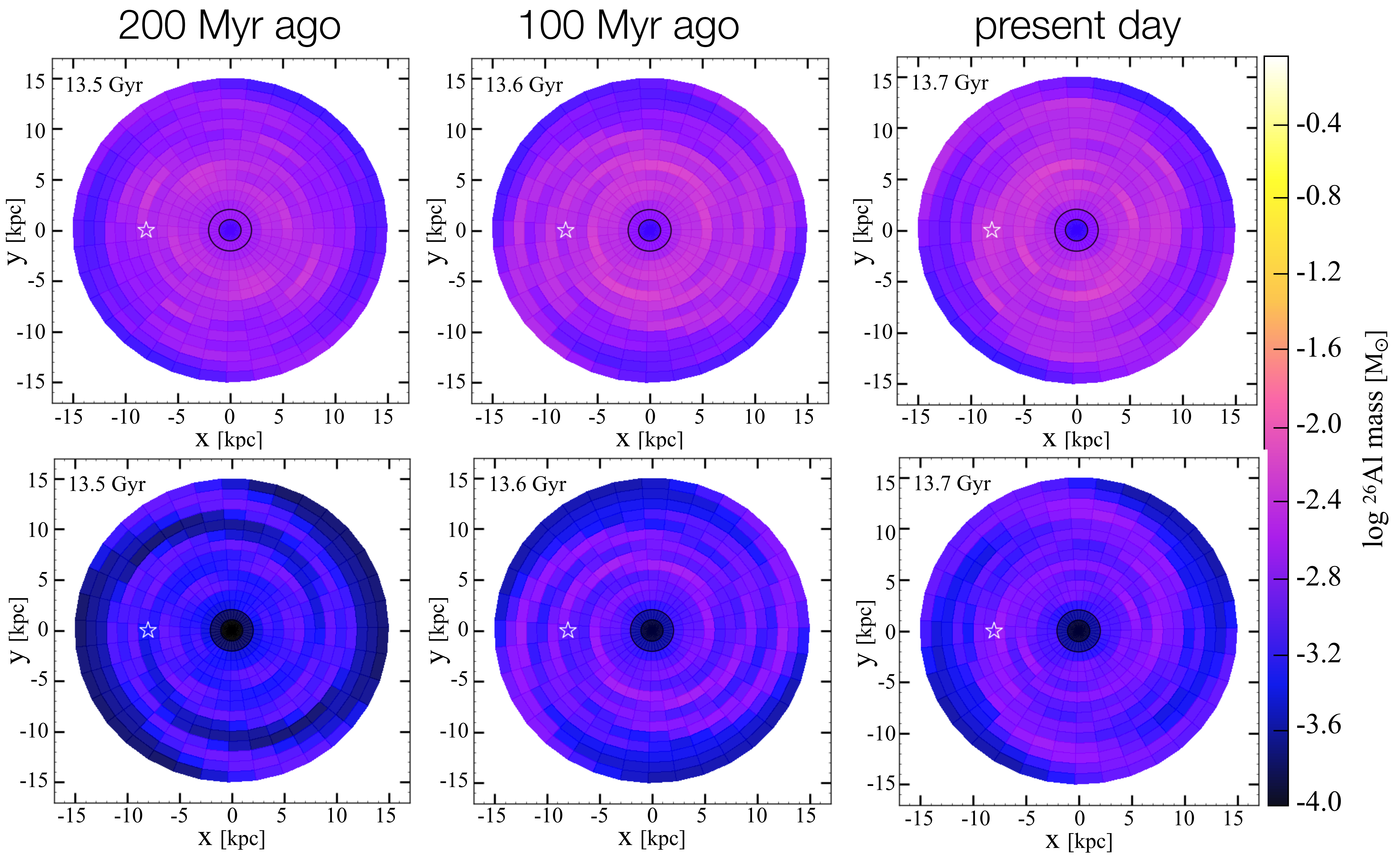


Chemical evolution of ^{26}Al: 2D MW

Vasini, Spitoni, Matteucci, Cescutti & Della Valle 2024

^{26}Al producers:
massive stars + nove

^{26}Al producers:
massive stars

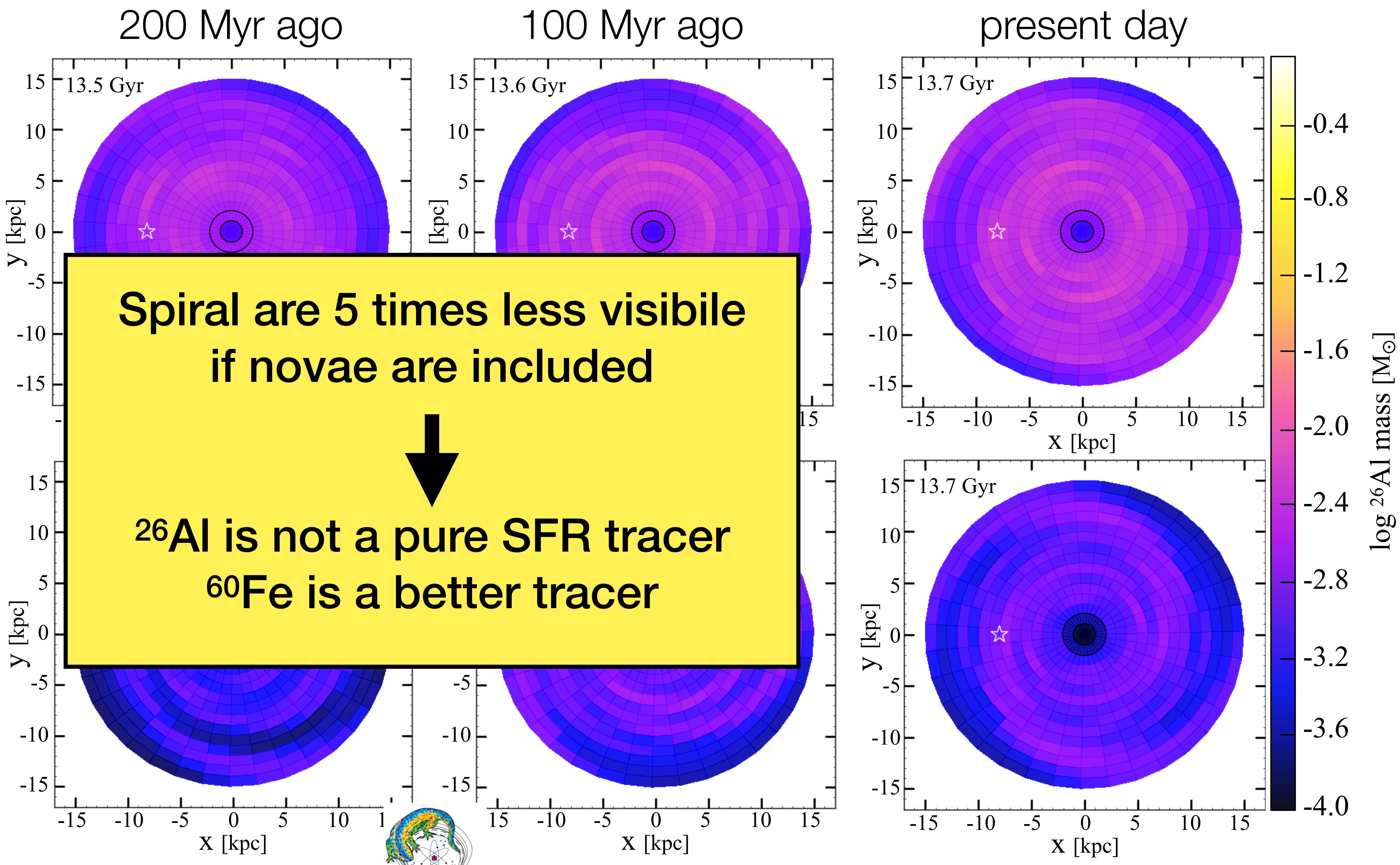


Chemical evolution of ^{26}Al: 2D MW

Vasini, Spitoni, Matteucci, Cescutti & Della Valle 2024

^{26}Al producers:
massive stars + nove

^{26}Al producers:
massive stars



Spiral are 5 times less visibile if novae are included

^{26}Al is not a pure SFR tracer
^{60}Fe is a better tracer

Chemical evolution of ^{26}Al: 2D MW

Vasini, Spitoni, Matteucci, Cescutti & Della Valle 2024

^{26}Al producers:
massive stars + nove → $1.028\ M_\odot$

^{26}Al producers:
massive stars → $0.265\ M_\odot$

vs $2\ M_\odot$ observed

↓

theoretical ^{26}Al is too low

Chemical evolution of ^{26}Al: 2D MW

Vasini, Spitoni, Matteucci, Cescutti & Della Valle 2024

European Research Council
Established by the European Commission

COMO LAKE CENTER FOR ASTROPHYSICS

UNIVERSITAS STUDIORUM INSUBRIAE

^{26}Al producers:
massive stars + nove → $1.028\ M_\odot$

^{26}Al producers:
massive stars → $0.265\ M_\odot$

vs $2\ M_\odot$ observed

↓

theoretical ^{26}Al is too low

two different nova populations:

disc novae (regular novae)

bulge novae (Enhanced nucleosynthesis x10 disc novae)

↓

$2.88\ M_\odot$

Chemical evolution of ^{26}Al: 2D MW

Vasini, Spitoni, Matteucci, Cescutti & Della Valle 2024

^{26}Al producers:
massive stars + nove

$1.028\ M_\odot$

^{26}Al producers:
massive stars

0.2

vs $2\ M_\odot$

two different nova populations:

bulge novae
(Enhanced nucleosynthesis
x10 disc novae)

$2.88\ M_\odot$

If bulge novae eject up to x10 more matter than a disc nova

we reproduce the observations

theoretical ^{26}Al is too low

Conclusions

Chemical evolution + INTEGRAL data ⟶ **constraints on the ^{26}Al production**

Milky Way 1D (Vasini+22):

- Only by including production from novae we can reproduce the observations ⟶ **novae are ^{26}Al sources**

Milky Way 2D (Vasini+24):

- 1D models have limitations ⟶ we developed a 2D model
- novae smooth out the spiral arm pattern ⟶ **^{26}Al is not a pure SFR tracers, ^{60}Fe traces it better**
- we cannot reproduce the observations ⟶ **increased production by bulge novae** (already observed)