Star Formation throughout the Galaxy

An independent determination of the Galactic Star Formation Rate

Thomas Robitaille
Harvard-Smithsonian Center for Astrophysics

Barbara Whitney
Space Science Institute
The GLIMPSE & MIPSGAL surveys

Ed Churchwell et al.  Sean Carey et al.

• GLIMPSE/MIPSGAL I
  ➤ 220 sq deg
  ➤ 31/49 million sources (IRAC)

• GLIMPSE/MIPSGAL II
  ➤ 54 sq deg
  ➤ 18/23 million sources (IRAC)
GLIMPSE YSO census

GLIMPSE I/II Catalog (~50 million sources)

Robitaille et al (2008)
GLIMPSE YSO census

GLIMPSE I/II Catalog (~50 million sources)

Brightness selection

Robitaille et al (2008)
GLIMPSE YSO census

GLIMPSE I/II Catalog (~50 million sources) → Brightness selection → Mid-IR color selection

Robitaille et al (2008)
GLIMPSE YSO census

GLIMPSE I/II Catalog (~50 million sources) → Brightness selection → Mid-IR color selection → Genuine red sources (~18,000)

Robitaille et al (2008)
GLIMPSE YSO census

GLIMPSE I/II Catalog (~50 million sources)

Brightness selection

Mid-IR color selection

Genuine red sources (~18,000)

YSOs (~11,000)  AGBs (~7,000)

Robitaille et al (2008)
THE INFRARED MILKY WAY: GLIMPSE (3.6–8.0 microns)
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(3.6–8.0 microns)

Galactic Latitude [degrees]

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Determining the Galactic Star Formation Rate
Determining the Galactic Star Formation Rate

- Construct a population synthesis model of the Galaxy
Determining the Galactic Star Formation Rate

- Construct a population synthesis model of the Galaxy
- Apply identical selection criteria than for R08 catalog
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- Construct a population synthesis model of the Galaxy
- Apply identical selection criteria than for R08 catalog
- Adjust SFR until total number of sources agrees
- Preliminary results! no attempt to fit anything other than the number of sources (yet)
Sample \((x, y, z)\)

Compute \((d, Av)\)

Spatial distribution of SF

Dust distribution & opacities
Sample \((x, y, z)\) → Spatial distribution of SF

Compute \((d, A_v)\) → Dust distribution & opacities

Sample masses → Initial Mass Function
Sample (x, y, z) → Spatial distribution of SF
Compute (d, Av) → Dust distribution & opacities
Sample masses → Initial Mass Function
Sample ages → Star Formation History
Sample (x, y, z) → Spatial distribution of SF

Compute (d, Av) → Dust distribution & opacities

Sample masses → Initial Mass Function

Sample ages → Star Formation History

Check if (l,b) in GLIMPSE → Survey coverage

Find magnitudes → SED models

Scale to (d, Av)
Sample \((x, y, z)\) → Spatial distribution of SF → Dust distribution & opacities

Compute \((d, Av)\) → Initial Mass Function → Star Formation History

Sample masses → Survey coverage → SED models

Sample ages →

Check if \((l, b)\) in GLIMPSE → Scale to \((d, Av)\)

Find magnitudes → Selection criteria

Select ‘observed’ sources
Spatial distributions of SF and dust
Spatial distributions of SF and dust

Spatial SFR (no absolute scaling)

Boissier & Prantzos (1999)
Spatial distributions of SF and dust

Spatial SFR (no absolute scaling)

\[ \Psi(R) \propto (\Sigma_{H_2} + \Sigma_{HI})^{1.5} R^{-1} \]

Dust distribution (absolutely scaled)

Misiriotis et al. (2006)

Boissier & Prantzos (1999)
Spatial distributions of SF and dust

Spatial SFR
(no absolute scaling)

\[ \Psi(R) \propto (\Sigma_{H_2} + \Sigma_{HI})^{1.5} R^{-1} \]

Dust distribution
(absolute scaled)

Use Kim et al (1994) model, modified to match
Indebetouw et al. (2005) IRAC Av law

Misiriotis et al. (2006)

Opacities

Boissier & Prantzos (1999)
Initial Mass Function & SF history
Initial Mass Function & SF history

Spatial SFR
(no absolute scaling)

Kroupa (2001)
Initial Mass Function & SF history

Spatial SFR
(no absolute scaling)

Star Formation History
(no absolute scaling)

Assume constant from $10^3$ to $10^7$ yr ago

Kroupa (2001)
SED Models

SED Models

SED Models

SED Models

Mass function

Total number: $7 \times 10^7$

'Observed' number: $1.1 \times 10^4$ (0.02%)

Total mass: $1.06 \times 10^7 M_{\text{Sun}}$

'Observed' mass: $7.63 \times 10^4 M_{\text{Sun}}$ (0.7%)
Spatial Distribution
Colors/Magnitudes

Observed (Robitaille et al, 2008)

This model
Results

- Required \(70,000,000\) YSOs to ‘observe’ \(11,606\)
- Star formation rate: \(1.7 \, M_{\text{sun}}/\text{yr}\)
- Previous values:
  - O stars: \(5 \, M_{\text{sun}}/\text{yr}\) (Smith, Biermann, and Mezger, 1978)
  - Gamma rays from \(^{26}\text{Al}\): \(4 \, M_{\text{sun}}/\text{yr}\) (Diehl et al, 2006)
  - FIR emission from COBE data: \(2.7 \, M_{\text{sun}}/\text{yr}\) (Misiriotis et al, 2006)
  - Free-free emission from WMAP data: \(1.3 \, M_{\text{sun}}/\text{yr}\) (Murray & Rahman, preprint)
Future work

• Estimate SFR uncertainty from input uncertainties
• Use better models for SF and dust distribution (warp, spiral arms, etc.)
• Use fainter sources in GLIMPSE I/II
• Use GLIMPSE 360 data to constrain outer Galaxy
• Use deeper surveys (e.g. UKIDSS GPS)