Insights from synthetic star-forming regions:
Star-formation rates, gas/dust properties & N-PDFs

Christine Koepferl
Why do we need Synthetic Observations?
Radiative Transfer Modelling

Simulate
perform ...
HD output
toy model

Compensate
distance
units
extinction
resolution
convolution
noise

Realistic Synthetic Observations
extract ...
image
SED
flux
visualise
3 color
movies

Real Observations (e.g. FITS)
add to ...
REALITY CHECK

... combined with real background
Applications | all over Astronomy

compare

→ simulations with real observations
→ see if simulation can reproduce observational features

test

→ observational techniques which extract properties
→ mass, SFR, ...
→ structure finding ...

develop

→ new (better) techniques
→ new (better) simulations
Applicable for Problems all over Astronomy

**Young Stellar Objects**
Koepferl, Robitaille, Morales, Johnston 2015

**Protoplanetary Discs**
Ercolano, Koepferl, Owen, Robitaille 2015

**Filaments**
Roccatagliata et al. 2015

**Star-Forming Regions**
Koepferl et al. 2017abc

**Galaxies**
Koepferl & Robitaille 2017
Synthetic observations of star formation and the interstellar medium

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Abstract

Synthetic observations are playing an increasingly important role across astrophysics, both for interpreting real observations and also for making meaningful predictions from models. In this review, we provide an overview of methods and tools used for generating, manipulating and analysing synthetic observations and their application to problems involving star formation and the interstellar medium. We also discuss some possible directions for future research using synthetic observations.
Producing Synthetic Observations
Insights from Synthetic Star-forming Regions

I. Reliable Mock Observations from SPH Simulations

Koeperfl, Robitaille, Dale, Biscani 2017a  arXiv:1603.02270

Data release on zenodo.org
New images available for classification. See the Blog entry on Simulated Bubbles for details.

What do you see in this image? Make classifications using the sets of tools below, and if multiple objects appear in the same image mark each bubble, bow shock + driving star, etc. If you find that there’s nothing worth marking, simply click ‘Done’ to complete the classification and view other images.

- **Bubble**
- **Bow Shock**
- **Bow Shock Driving Star**
- **Yellowball**
- **Other Objects**

**NEED SOME HELP WITH THIS TASK?**
- Hide previous marks

**Done**
Testing SF Rate Tracers
RATES

CHILD-BIRTH RATE

\[ \text{RATE} = \frac{\# \text{ BABIES}}{\text{time}} \]
RATES

CHILD-BIRTH RATE

\[
\text{RATE} = \frac{\# \text{ BABIES}}{\text{time}}
\]

STAR-FORMATION RATE

\[
\text{RATE} = \frac{\# \text{ STARS}}{\text{time}}
\]
RATES

CHILD-BIRTH

\[ \text{RATE} = \frac{\# \text{ BABIES}}{\text{time}} \]

STAR-FORMATION RATE

\[ \text{RATE} = f \frac{L(\text{BAND})}{\text{ergs/s}} \]
RATES

Child-Birth Rate

\[ \text{Rate} = \frac{\# \text{ Babies}}{\text{Time}} \]

Star-Formation Rate

\[ \text{Rate} = \frac{L(\text{Band})}{\text{ergs/s}} \]
RATES

Child-Birth Rate

Rate = \frac{\# \text{ Babies}}{\text{Time}}

Star-Formation Rate

Rate = f \frac{L(Band)}{\text{ergs/s}}
RATES

CHILD-BIRTH RATE

\[
\text{RATE} = \frac{\# \text{ BABIES}}{\text{time}}
\]

STAR-FORMATION RATE

\[
\text{RATE} \approx \frac{\# \text{STARS}}{\text{time}}
\]
WHERE IS THE PHYSICS?

CHILD-BIRTH RATE

\[
\text{RATE} = \frac{\# \text{ BABIES}}{\text{time}}
\]

STAR-FORMATION RATE

\[
\text{RATE} \approx \frac{\# \text{STARS}}{\text{time}}
\]

SYNTHETIC OBSERVATIONS CAN HELP
for local scales ...

\[ \frac{SFR}{M_\odot/yr} = f \frac{L_{band}}{\text{ergs/s}} \]
Insights from Synthetic Star-forming Regions

IV. Analysis of Synthetic Point-source Catalogs (TBD)

Koepferl, Dale & Halder in prep.

DIRECT METHOD

[Graph showing number of stars over time (Myr), with results from analysis and observations from Koepferl et al. 2017c]

[Image of a happy face superimposed on a star-forming region]
Testing Gas/Dust Properties
Insights from Synthetic Star-forming Regions

II. Verifying Dust Surface Density, Dust Temperature & Gas Mass Measurements with Modified Blackbody Fitting

Koopferl, Robitaille, Dale 2017b  arXiv:1606.08435

Data release on zenodo.org

Use PPMAP+
Marsh et al. 2015

![Graphs and images showing data analysis results.](image-url)
Modified $B_\nu$ Fitting | total $M_{\text{gas}}$

$\Sigma_{\text{obs}} \sim \Sigma \rho \kappa_\nu B_\nu (T_{\text{dust}})$

Koepeferl, Robitaille, Dale 2017b

CM3 O3 D2

- simulation
- synthetic observation
- $\chi^2$ correction

Gas Mass ($M_\odot$)

real time (Myr)

intrinsic values
R3 measured values
R3 measured values ($\chi^2 < 5$)
R2 measured values
R2 measured values ($\chi^2 < 5$)
Testing Column Density PDFs

Previous Studies: Schneider et al. (2011, 2013, 2015), Lombardi et al. 2015, Alves et al. 2017, Kainulainen et al. (2013) and many, many others
Insights from Synthetic Star-forming Regions

V. Analysis of Synthetic N-PDFs (TBD)

Koopferl & Dale in prep.

工作进行中

CLOUD 1

\[ \Sigma_{\text{gas}} \times 100 \]

CLOUD 2

\[ \frac{N_{\text{gas (H or H2)}}}{m(\text{H or H2})} \times 100 \]

CLOUD 3

\[ A_V \times 1.086 \times \kappa_V \]

YSOs / Sinks
Insights from Synthetic Star-forming Regions

V. Analysis of Synthetic N-PDFs (TBD)

Koopferl & Dale in prep.

work in progress
LAST-CLOSED CONTOUR

Alves, Lombardi, Lada A&A (2017; Fig. 1)
Insights from Synthetic Star-forming Regions
V. Analysis of Synthetic N-PDFs (TBD)

Koopferl & Dale in prep.

work in progress
Insights from Synthetic Star-forming Regions

V. Analysis of Synthetic N-PDFs (TBD)

Koopferl & Dale in prep.

work in progress
Insights from Synthetic Star-forming Regions
V. Analysis of Synthetic N-PDFs (TBD)

Koopferl & Dale in prep.

SAME CLOUD!!!
Just different orientations
Insights from Synthetic Star-forming Regions

V. Analysis of Synthetic N-PDFs (TBD)

Koopferl & Dale in prep.

work in progress
Insights from Synthetic Star-forming Regions
SF Properties Measurements

(l) Indirect SFR
Koepferl et al. 2017a, 2017c

(l) Direct SFR
Koepferl et al. 2017a, 2017c

$\Sigma_{\text{dust/gas}}$ & $T_{\text{dust}}$
Koepferl et al. 2017a, 2017b

$M_{\text{gas}}$
Koepferl et al. 2017a, 2017b

N-PDFs
Koepferl & Dale in prep.

The Flux Compensator
Koepferl & Robitaille 2017
https://github.com/koepferl/FluxCompensator