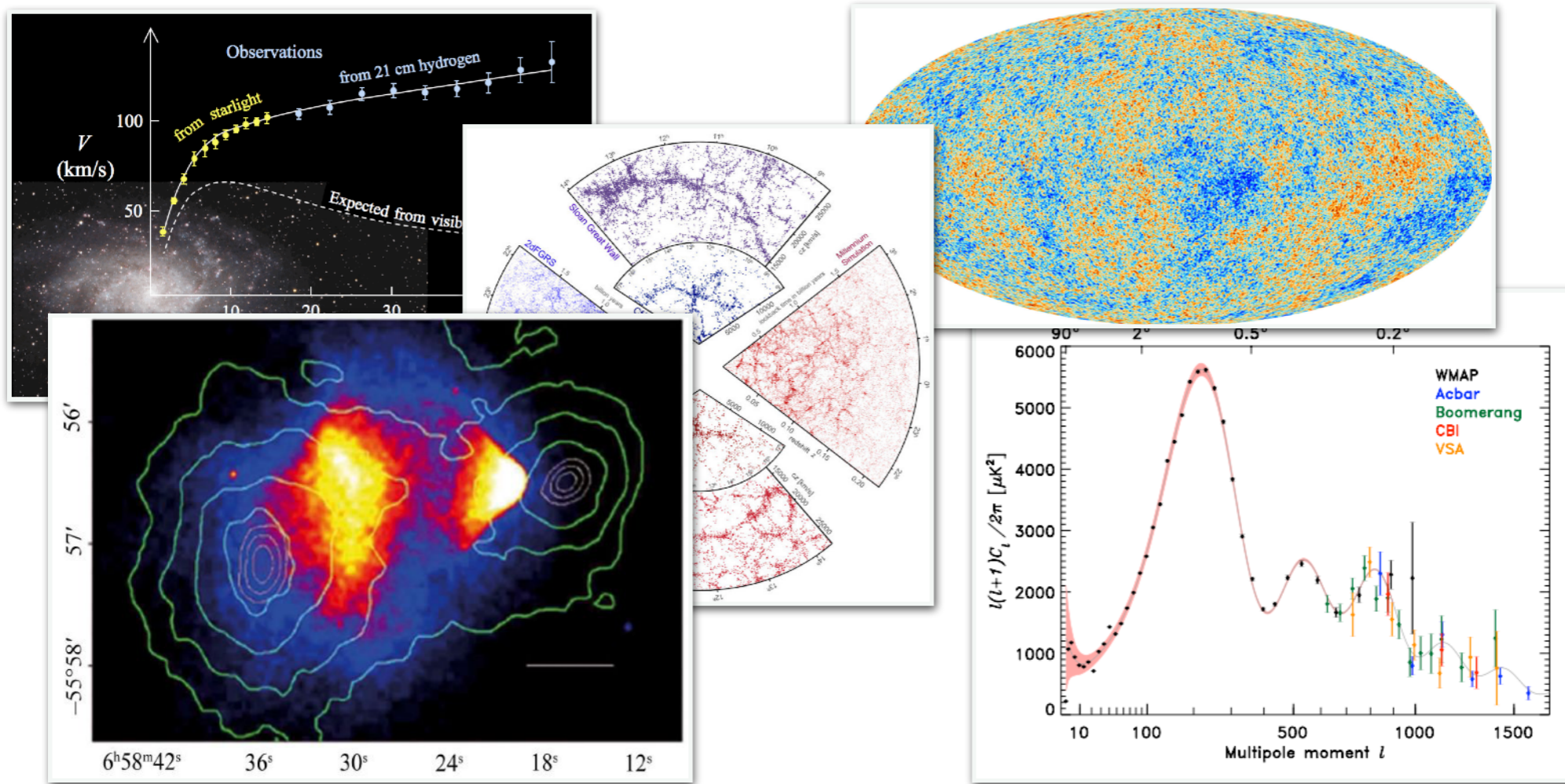


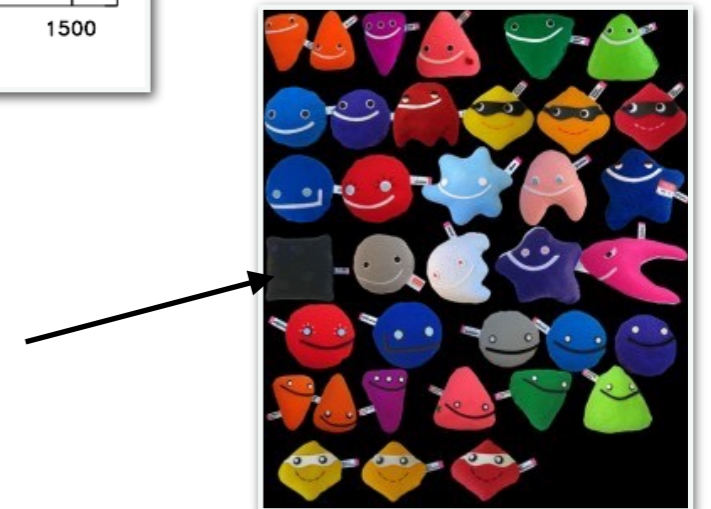
DARK MATTER

There is plenty of evidence on astrophysical and cosmological length scales that **DM exists**...



⇒ Qualitatively convergent picture!

... most likely it is a particle DM



NUMERICAL TOOL STUDYING DM PRODUCTION

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Dark matter Relic Abundance beyond Kinetic Equilibrium

Authors: Tobias Binder, Torsten Bringmann, Michael Gustafsson and Andrzej Hryczuk

DRAKE is a numerical precision tool for predicting the dark matter relic abundance also in situations where the standard assumption of kinetic equilibrium during the freeze-out process may not be satisfied. The code comes with a set of three dedicated Boltzmann equation solvers that implement, respectively, the traditionally adopted equation for the dark matter number density, fluid-like equations that couple the evolution of number density and velocity dispersion, and a full numerical evolution of the phase-space distribution. The code is written in Wolfram Language and includes a Mathematica notebook example program, a template script for terminal usage with the free Wolfram Engine, as well as several concrete example models. DRAKE is a free software licensed under GPL3.

If you use DRAKE for your scientific publications, please cite

- **DRAKE: Dark matter Relic Abundance beyond Kinetic Equilibrium**, Tobias Binder, Torsten Bringmann, Michael Gustafsson and Andrzej Hryczuk, [arXiv:2103.01944]

Currently, an user guide can be found in the Appendix A of this reference. Please cite also quoted other works applying for specific cases.

v1.0 « [Click here to download DRAKE](#)

(March 3, 2021)

<https://drake.hepforge.org>

Applications:

DM relic density for
any (user defined) model*

Interplay between chemical and
kinetic decoupling

Prediction for the DM
phase space distribution

Late kinetic decoupling
and impact on cosmology

see e.g., 1202.5456

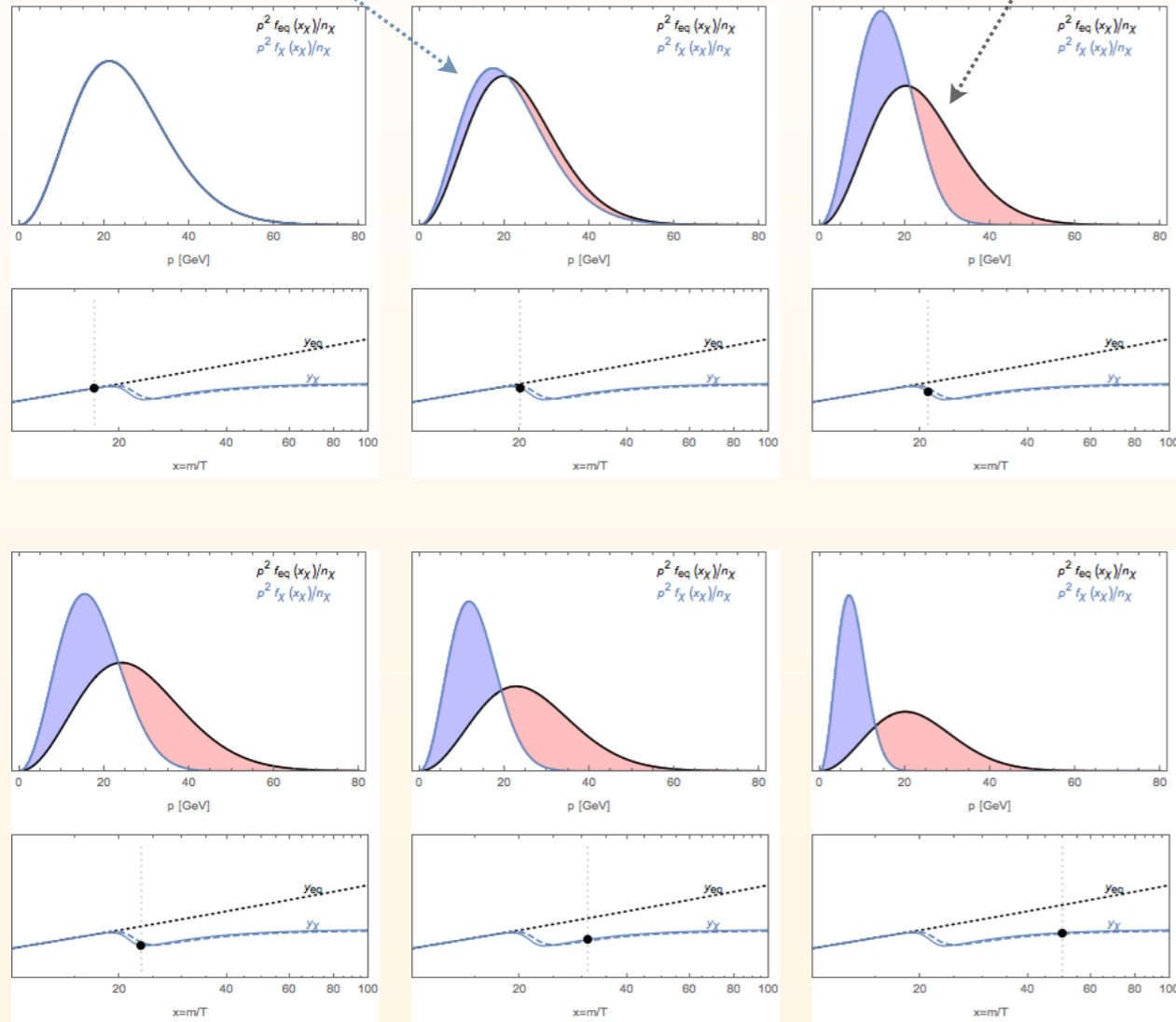
...

EXAMPLE FROM DRAKE v1.0

blue - full solution for f_{DM} at T_{DM}

$m_{DM} = 58 \text{ GeV}$

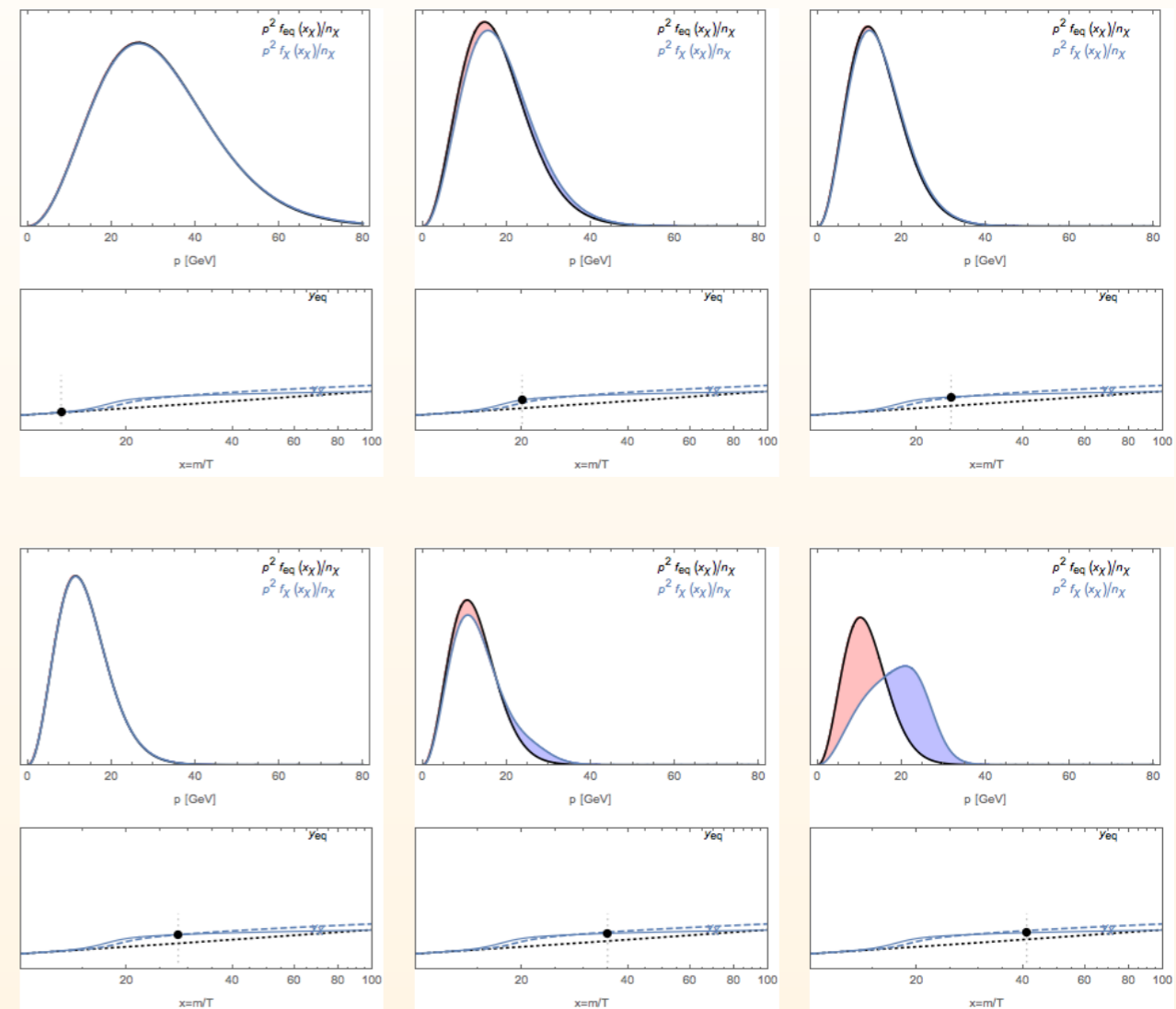
black - equilibrium at T_{DM}



significant deviation from equilibrium shape **already around freeze-out**

→ effect on relic density largest, both from different T and f_{DM}

$m_{DM} = 62.5 \text{ GeV}$



large deviations **only at later times**, around freeze-out not far from eq. shape

→ effect on relic density ~only from different T