something something
theoretical Milky Way modeling
mumble mumble

AKA why use CPU-hours if I don't have to

Alex Pettitt — SEDIGISM — Sept 2021

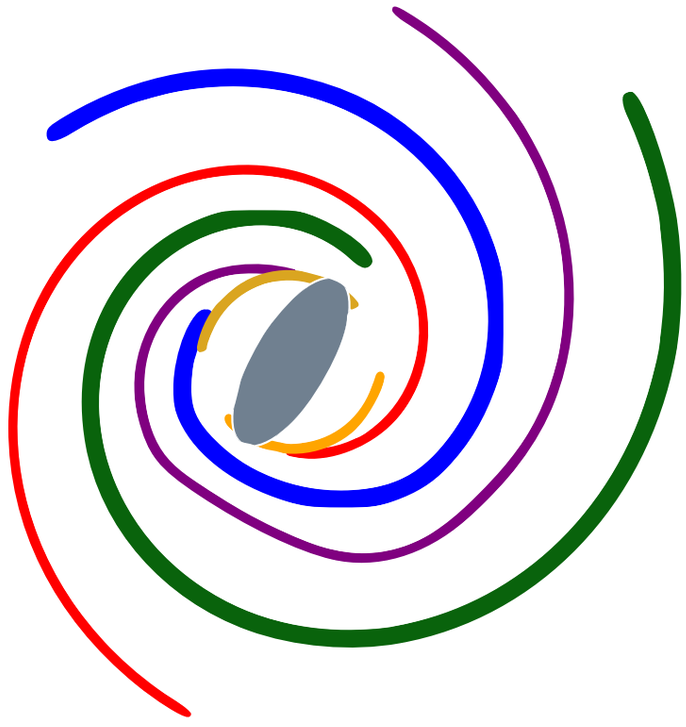
SACRAMENTO STATE

HOKKAIDO UNIVERSITY

科研費 KAKENHI

State of things

- Discerning the structure of the Milky Way is hard.



- Students have probably spent entire theses on this Q.

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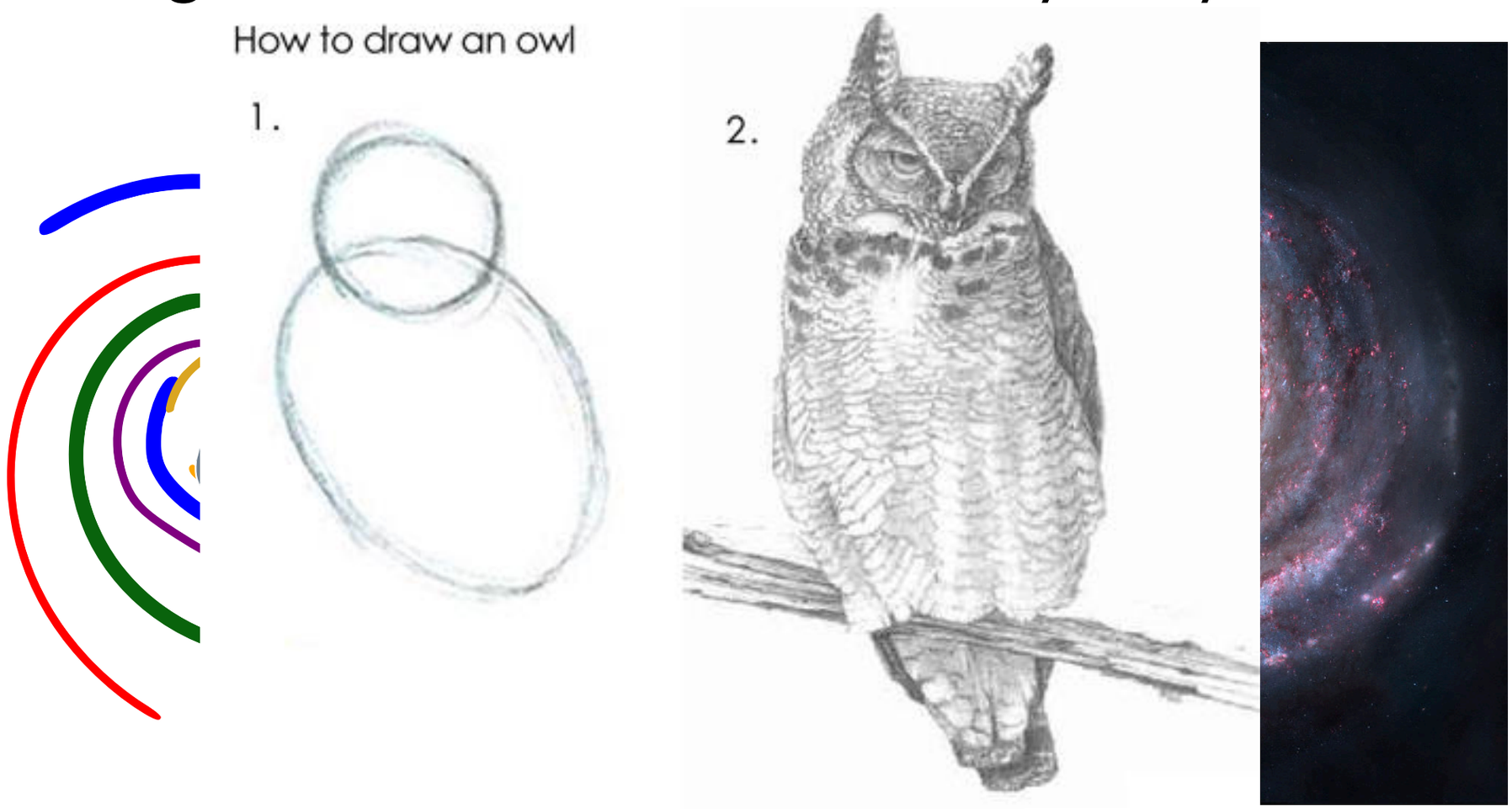
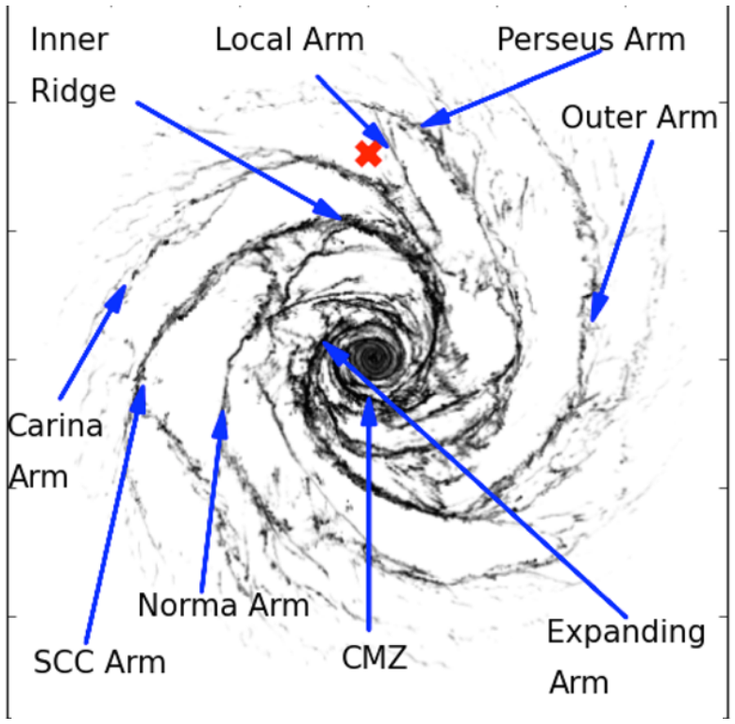


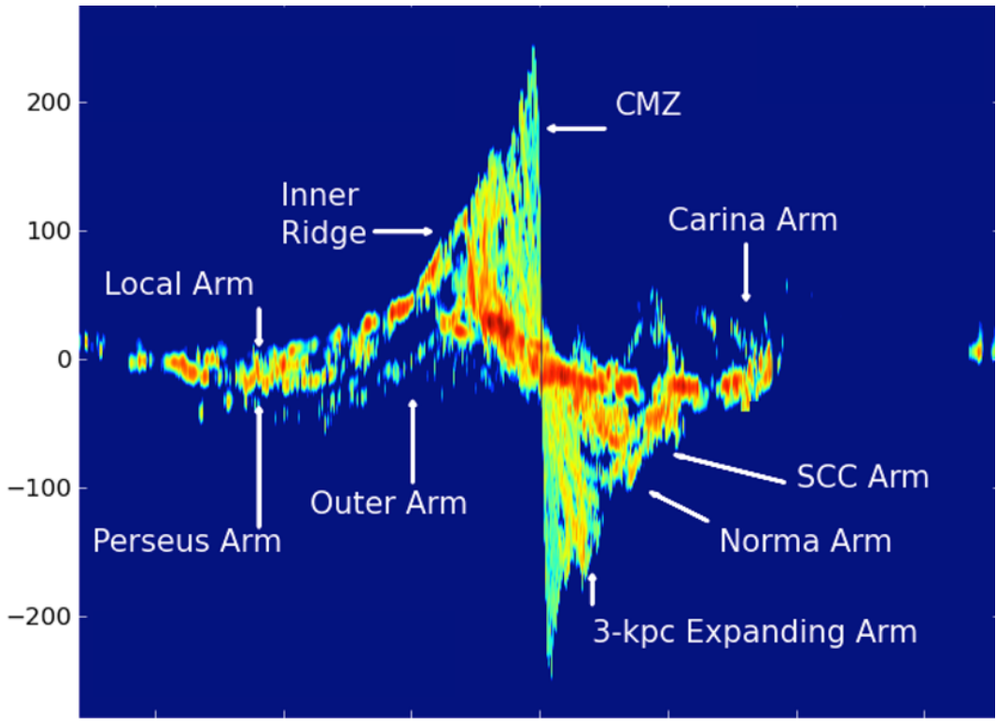
- Students have probably spent entire theses on this Q.

What I usually do

- A decent approach is make some model and compare it to the real thing.
- You can get a decent way to attacking this problem if you make some assumptions:

Hydro+gravity+chem



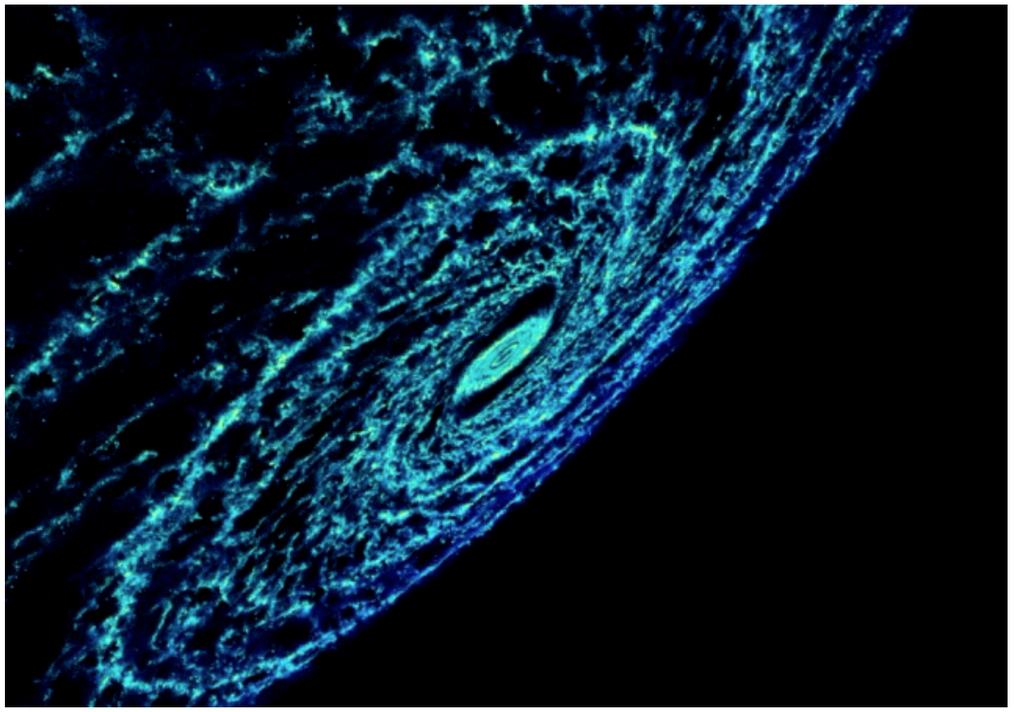


RT post-processing

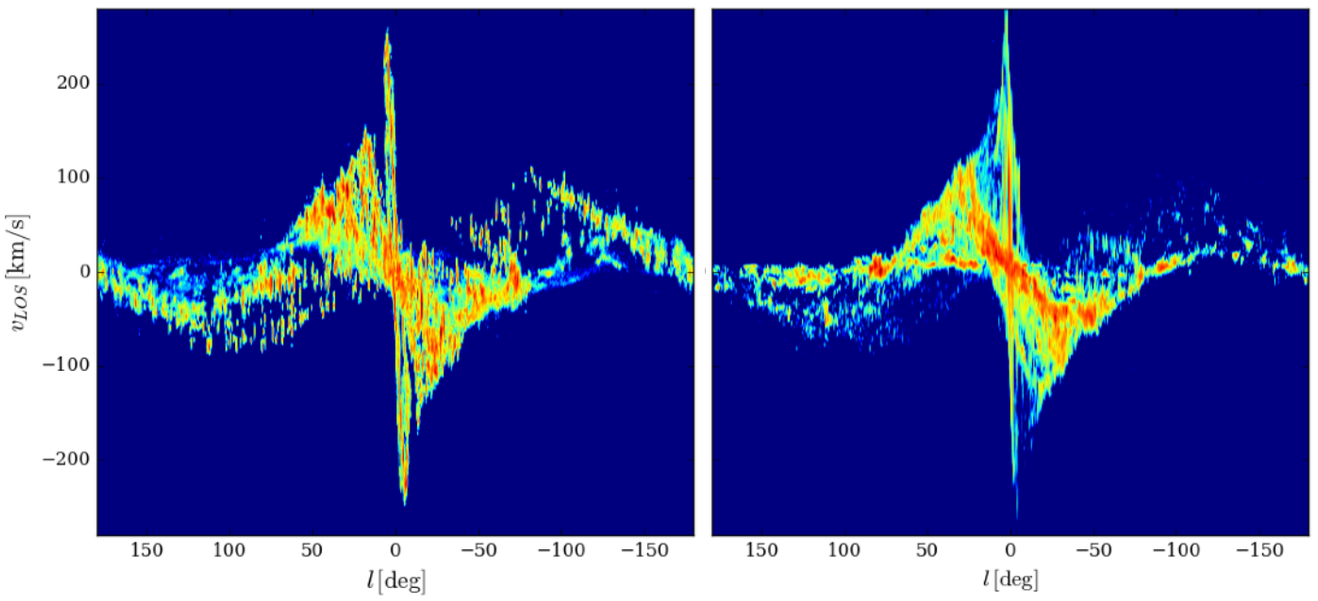
Pettitt et al. 2015. See also papers by Fux, Baba, Li, and many others

What I usually do

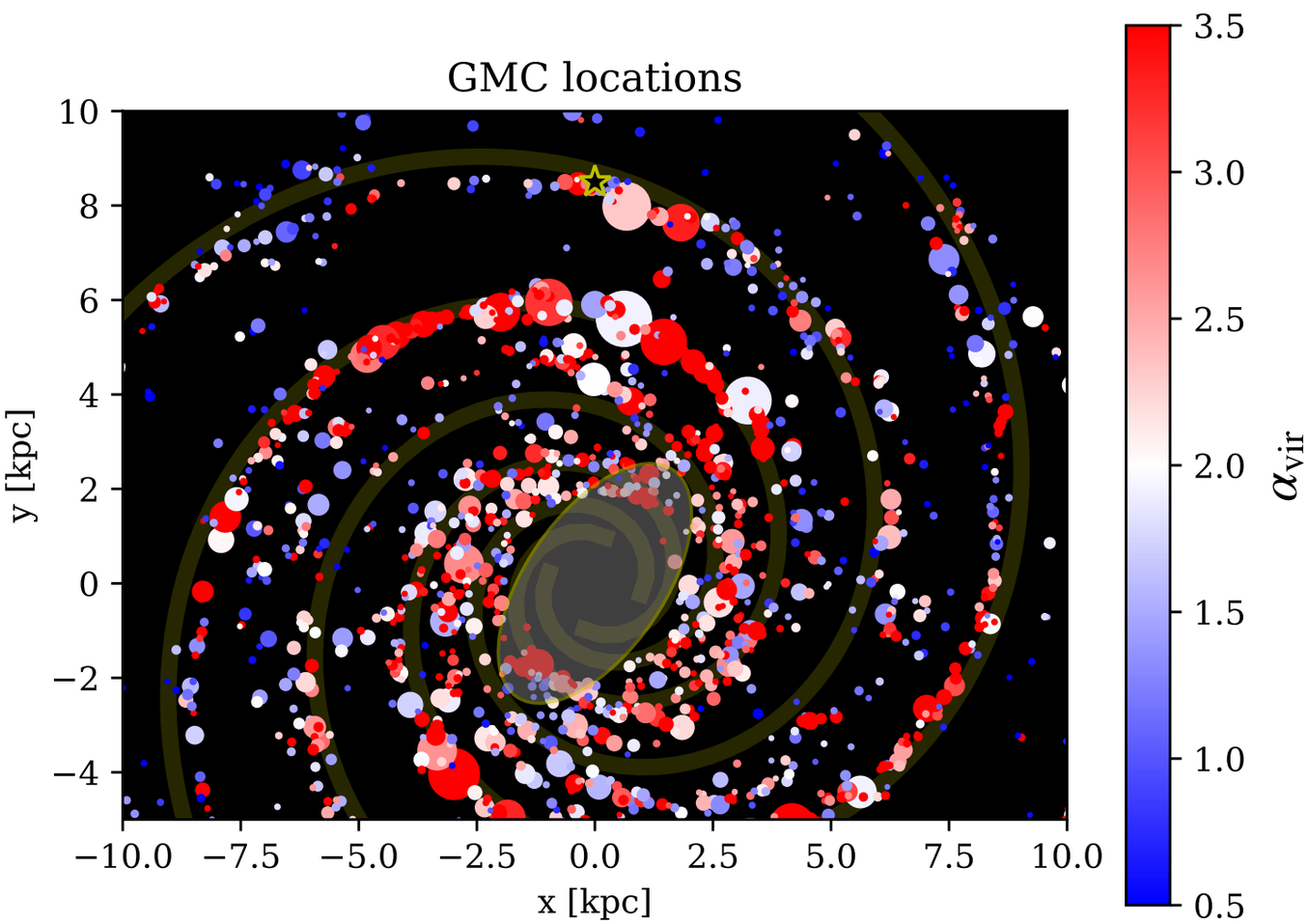
- But there is always more physics to add...



- Kitchen sink:
  numerical hydro, gravity, chemistry, cooling, supernova, B-fields, HII regions, CRs, radiative transfer, winds, satellite interactions...

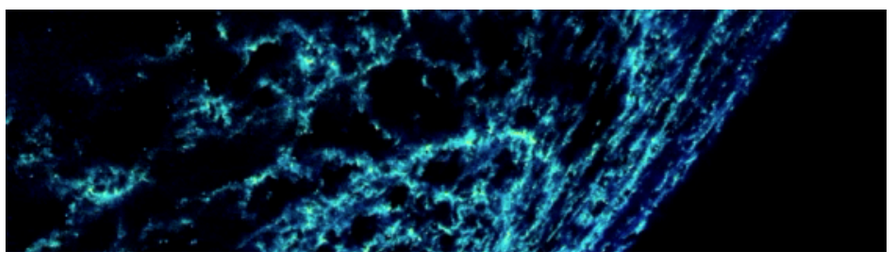


- Getting decent results (but uses old bar data).



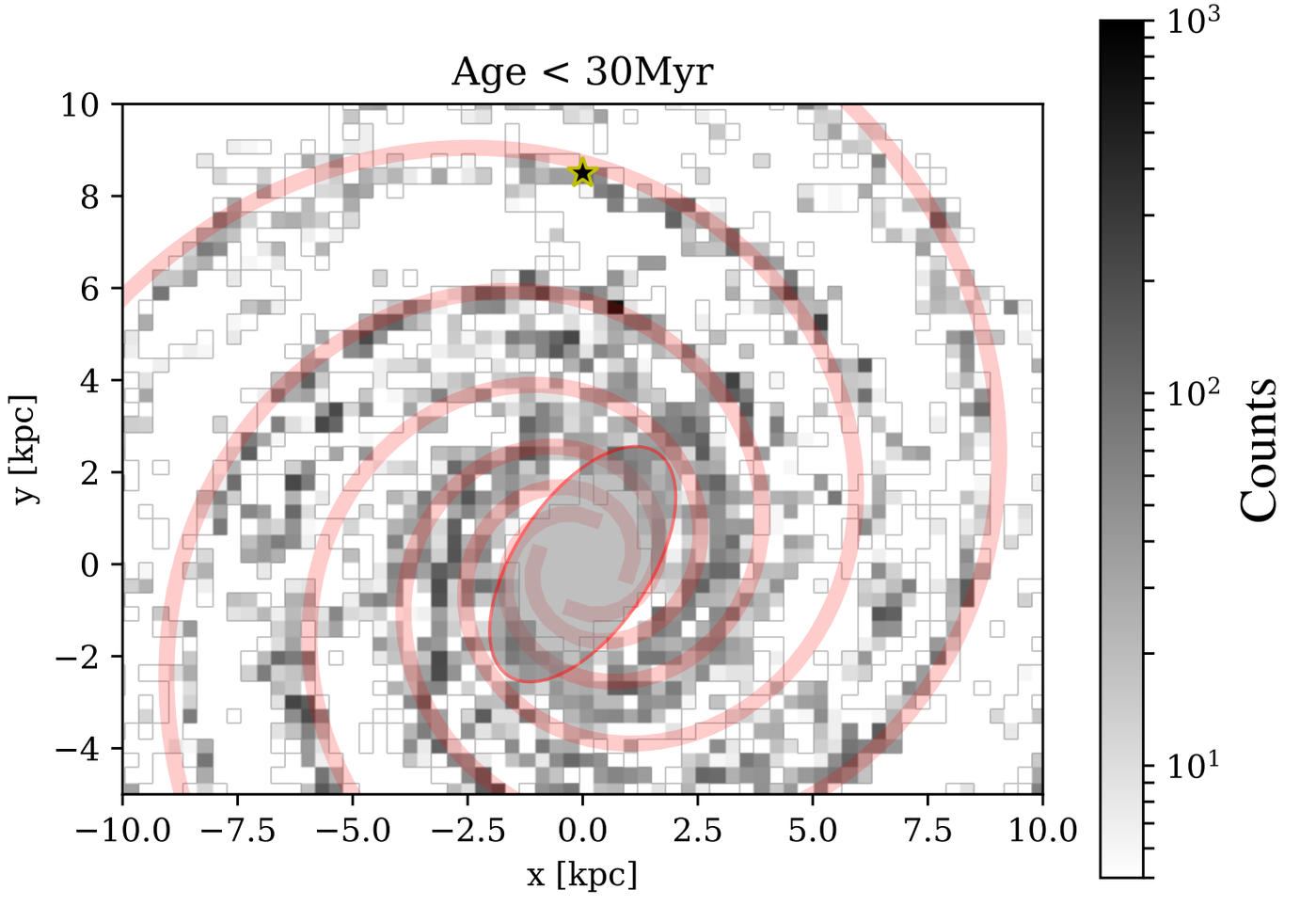
y do

to add...



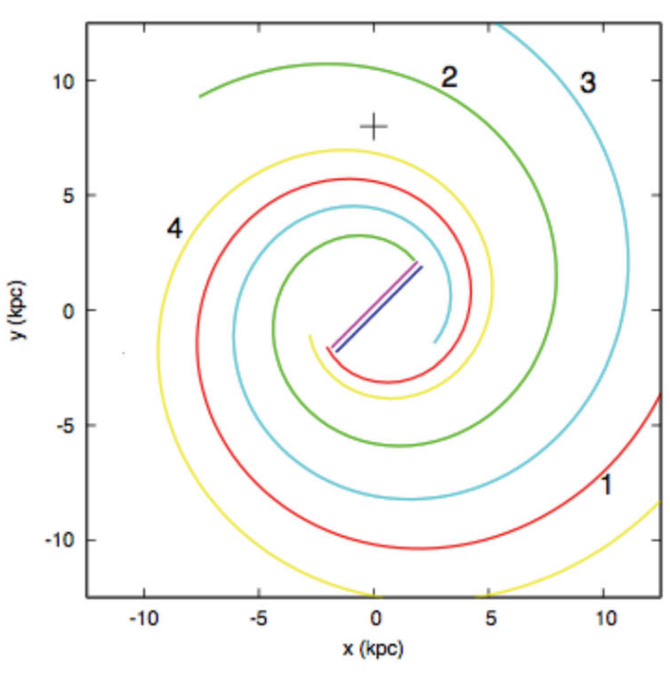
supernova, B-fields, HI regions, CRs, radiative transfer, winds, satellit interactions...

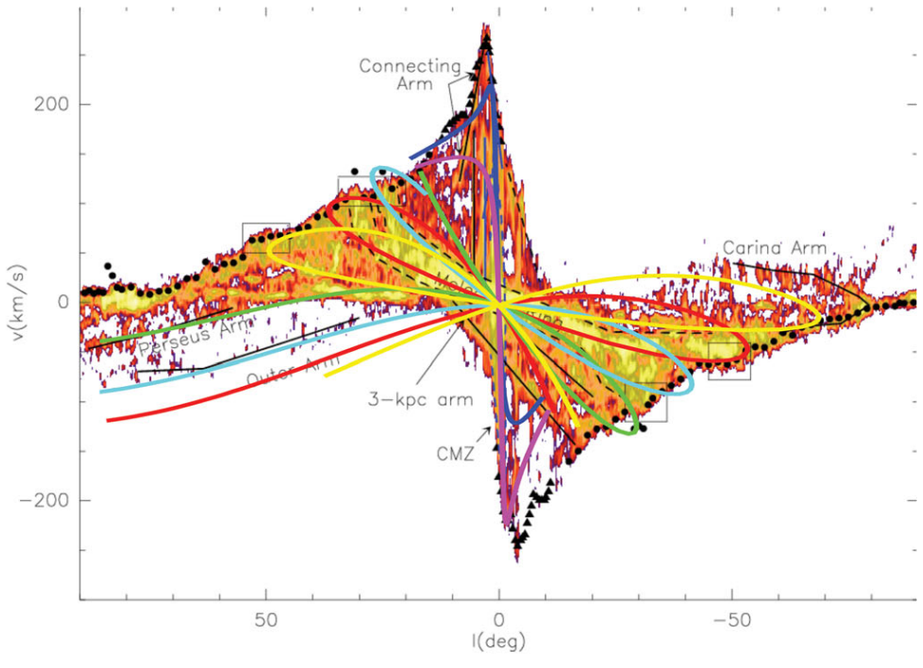
- Getting decent results (but uses old bar data)



Something simpler?

- This isn’t going to end well…
- Go analytic instead; e.g. Dobbs et al. 2012 (essentially how I made the arm tracks in Dario and James’ papers).





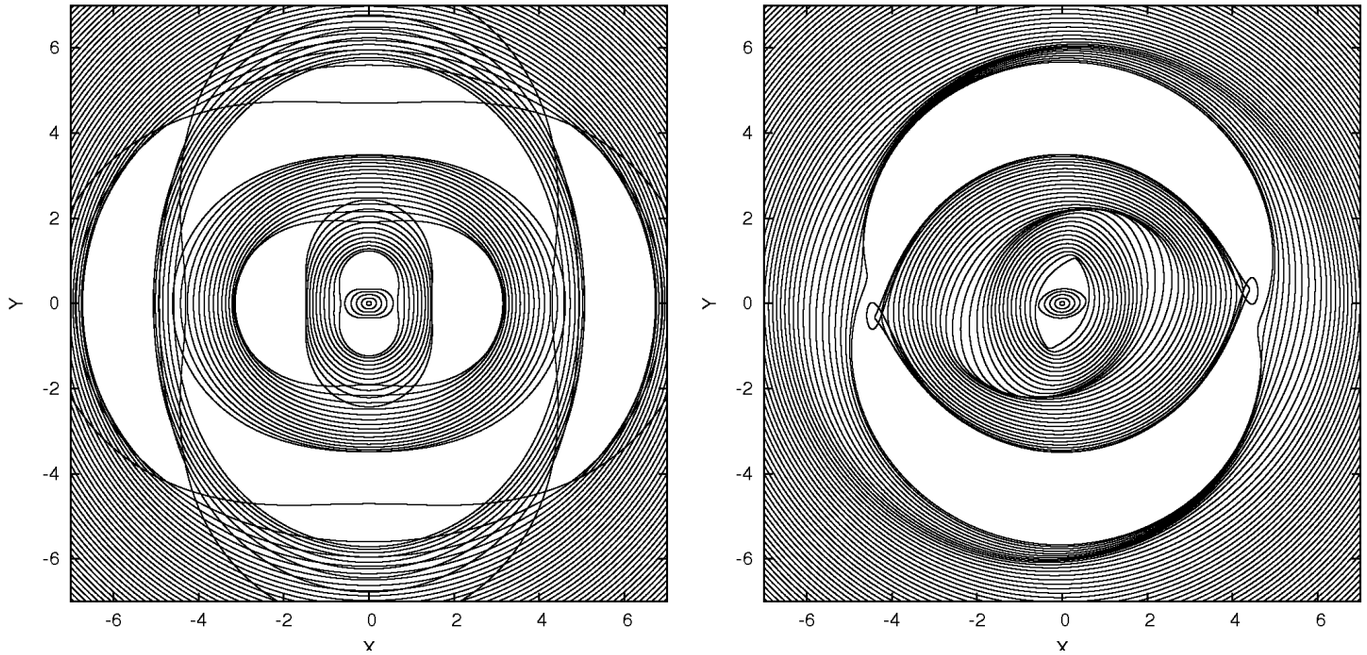
- Draw lines, fold in some smoothing with an assumed axisymmetric rotation curve.

Maybe a bit less simple than this

Orbital damping

- Wada (1994), Lindblad & Lindblad (1994), Pinol-Ferrer (2014).
- Approximate gas response as damped motion in the epicyclic approximation.
- Forcing directly influenced by pattern speed.

$$R_1(t) = Ae^{-\lambda t}\cos(\omega t + \alpha) + B\cos[2\left(\Omega_0 - \Omega_\mathrm{b}\right)\, t + \delta_0]$$

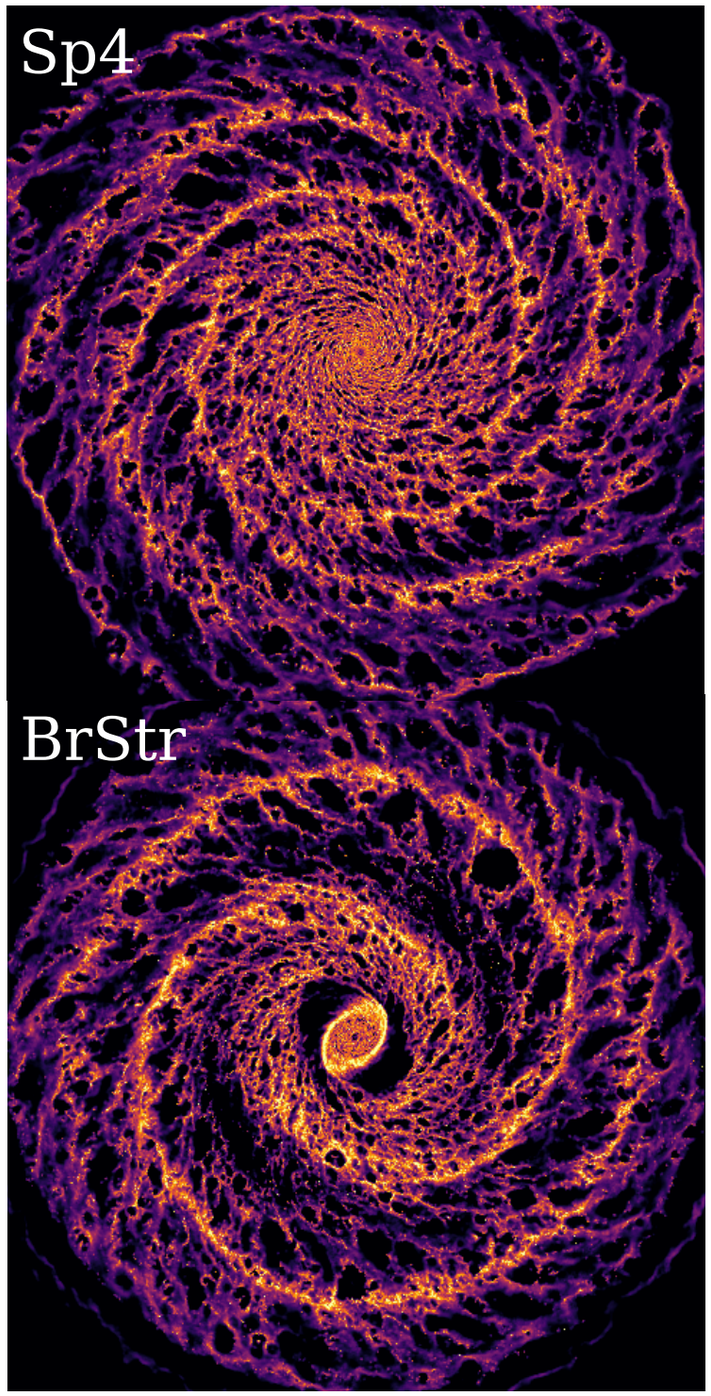


E.g. Dobbs & Baba (2014)
left: stellar orbit in bar without damping
right: gas orbits using method of K. Wada

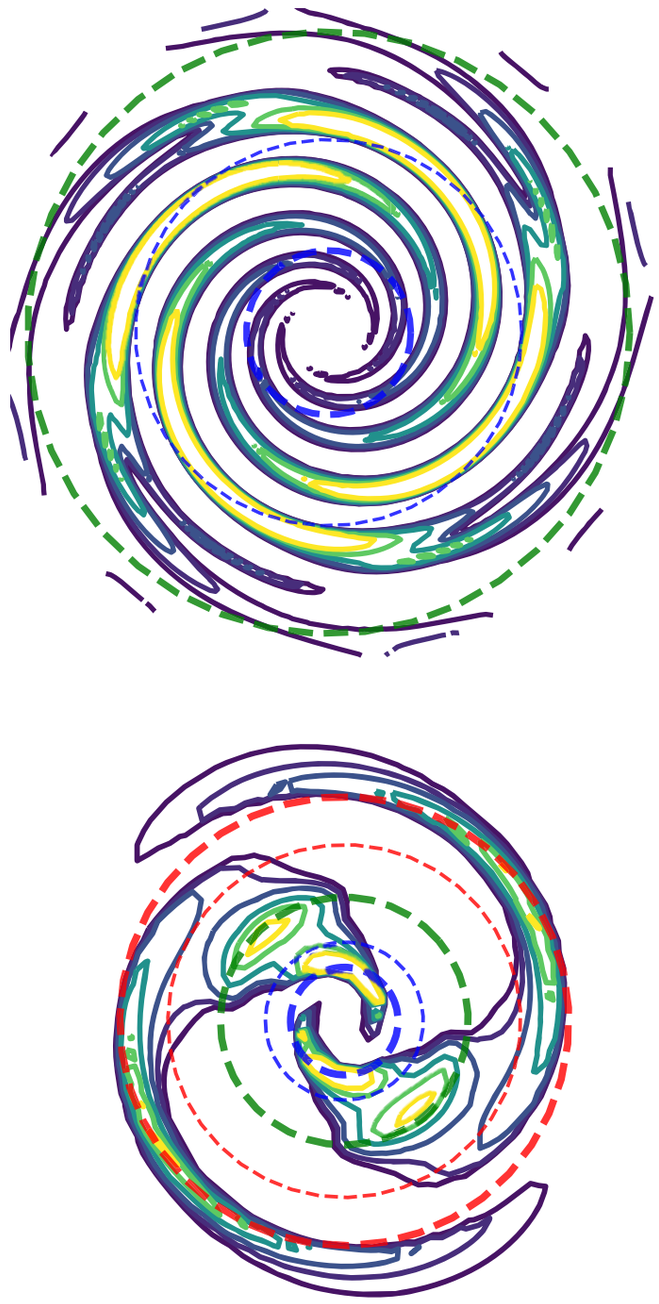
Previous usage

- I used this in Pettitt et al. (2020) to convince a referee of something.
- Orbits are trivially converted into an over density, matched the simulation response pretty well!
- Velocities should be easy too...

Simulation



Analytic calculation



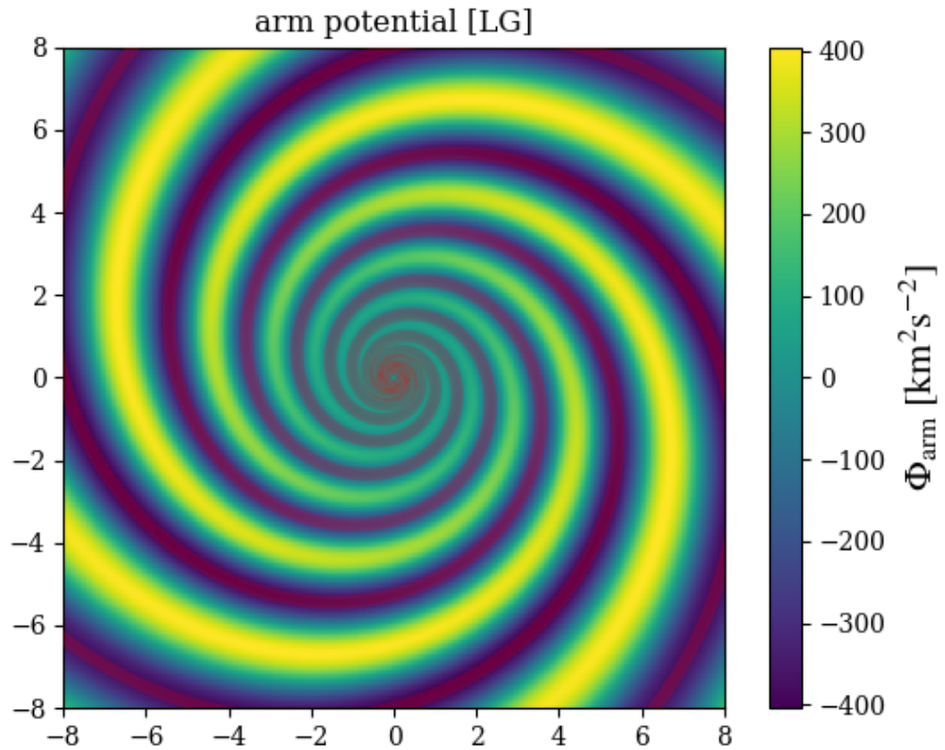
How does it work?

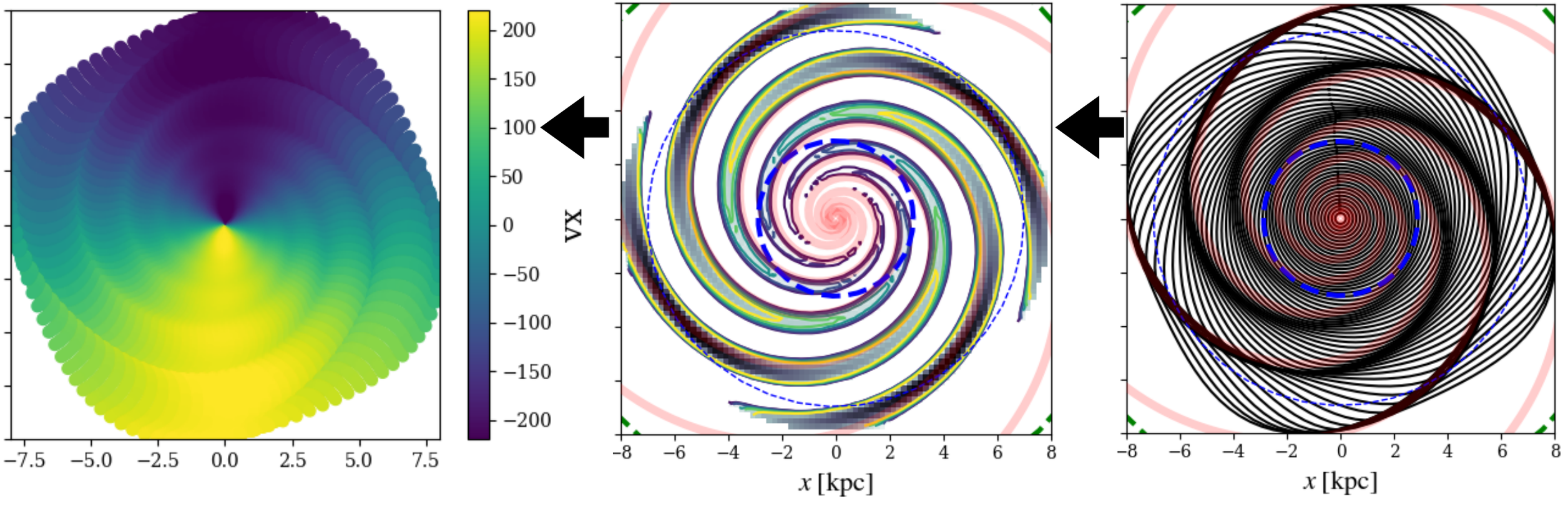
1. Take some assumed potential.

2. Calculate orbital response under epicycle approx.

3. Calculate over-density from continuity equation.

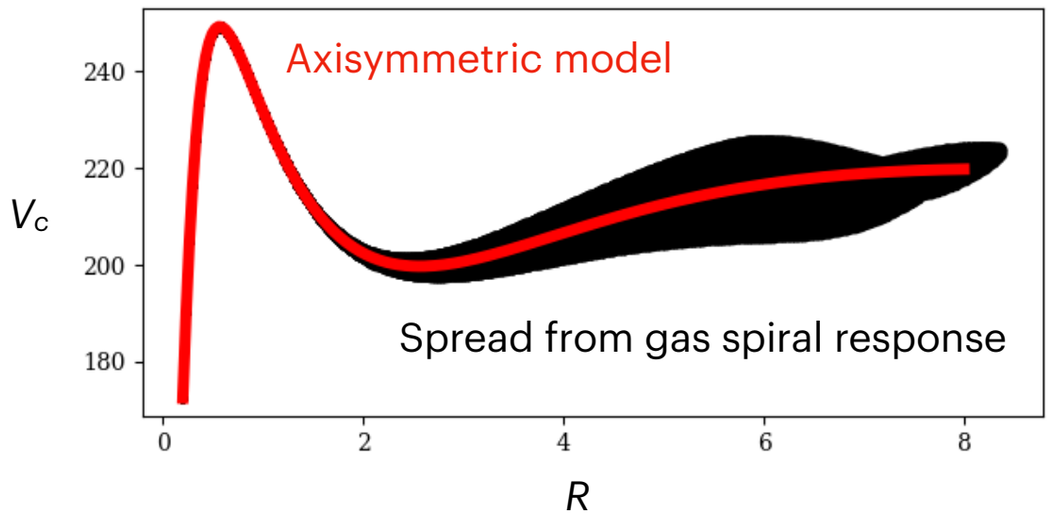
4. Velocities can be calculated from orbits.



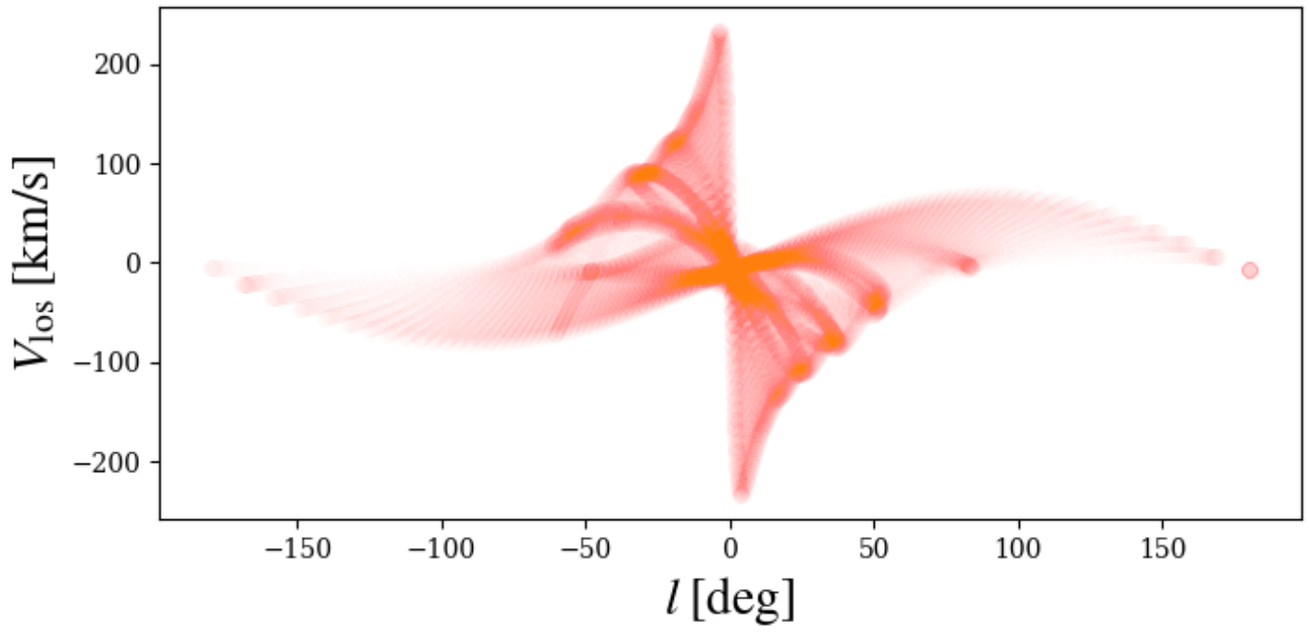


How does it work?

- Can then simply bin things up and calculate a synthetic gas response!



- Gives you the terminal velocity curve, and over-densities throughout the entire disc.



- Plan to apply to SEDIGISM and some other surveys in a meta-analysis.

What's the catch?

- Has a lot of things going for it:

Made in minutes!

Can apply to anything you can write a potential for.

Can alter strengths, pattern speeds, and predict actual velocity response.

- But some caveats:

There are two damping parameters. One is not really important, the other is basically a proxy for sound speed and surface density.

^can constrain via a small number of hydro sims?

Can't handle strong shocks as epicyclic approx. breaks down.

^not a huge issue if you only care about general global response

But your title was about “numerical sims”

- Side note:
  I still do simulations :/

BESPOKE

- **BESPOKE** project = Better Extragalactic Simulation Physics On Known Examples.
- Wide simulation survey tailored to well observed local galaxies, starting with NGC 5055, 6946, 7331.

Pettitt, Benincasa, Wadsley, Iles, Keller — coming very soon!

But your

- Side note:
  I still do sim

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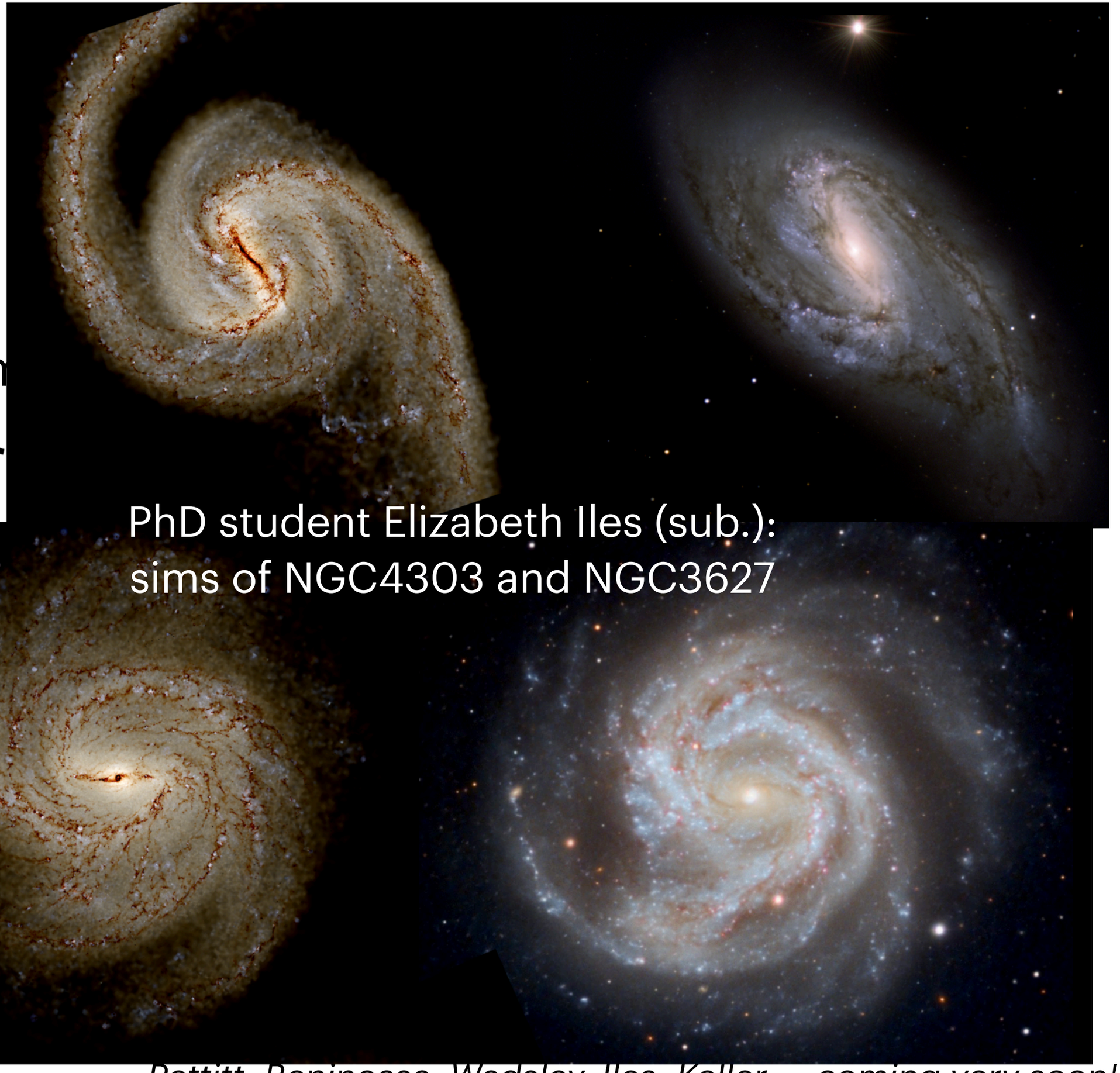

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Conclusions

- Modeling the MW is hard, and not getting any easier.
- How far can we get without full sims?
- Pretty far! Plan on applying a method of damped orbital response to SEDIGISM and friends.
- Work is still fairly early stages, no paper draft yet to speak of.
- Shameless plug of continuing simulation efforts.