Dynamics at the bar-spiral interface

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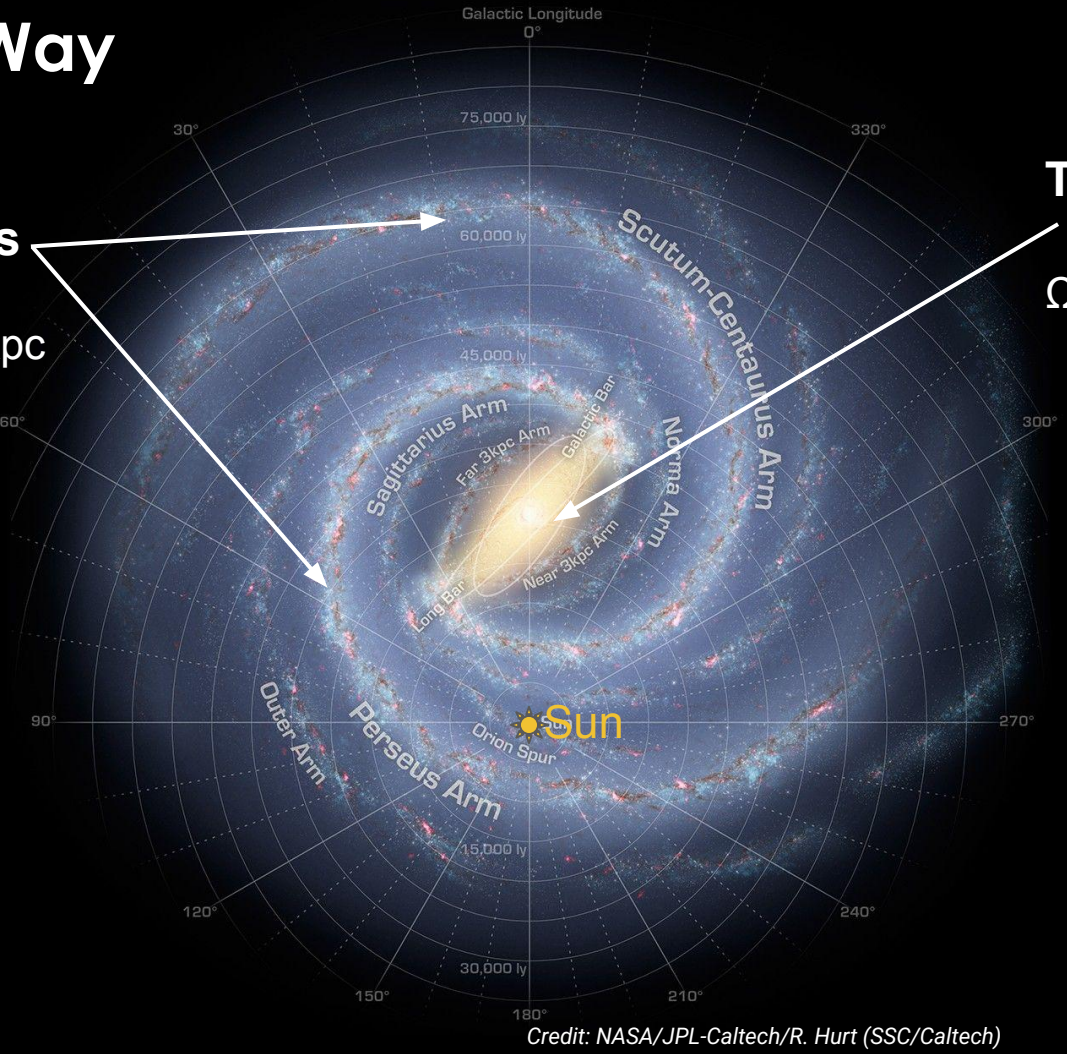
The Milky Way

2 main spiral arms
+ other arms
Ω_{spiral} ~ 10-35 km/s/kpc



The Galactic Bar
R_{bar} ~ 3-5 kpc
Ω_{bar} ~ 30-54 km/s/kpc

Credit: NASA/JPL-Caltech/R. Hurt (SSC/Caltech)

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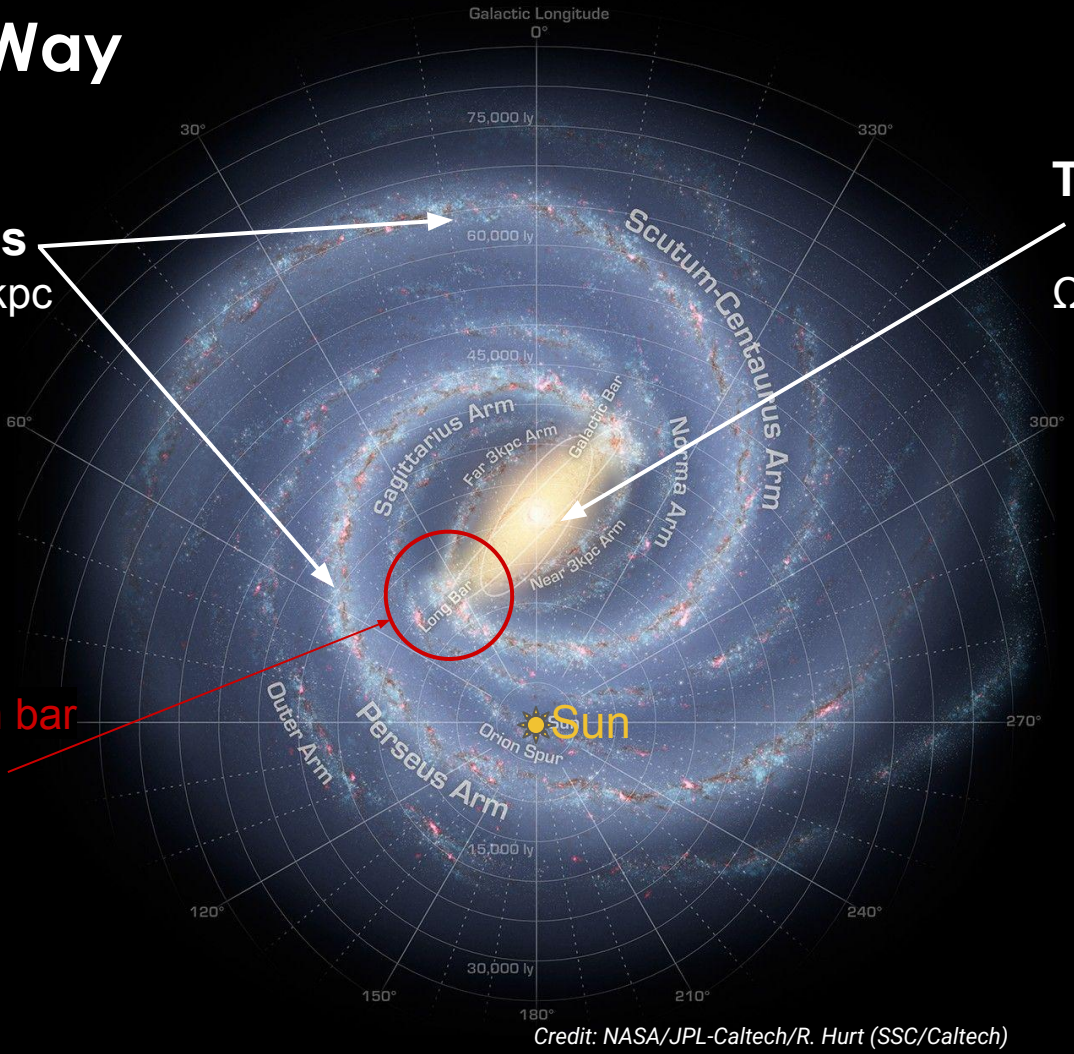
Connection between bar and spiral arm (Scutum-Centaurus)



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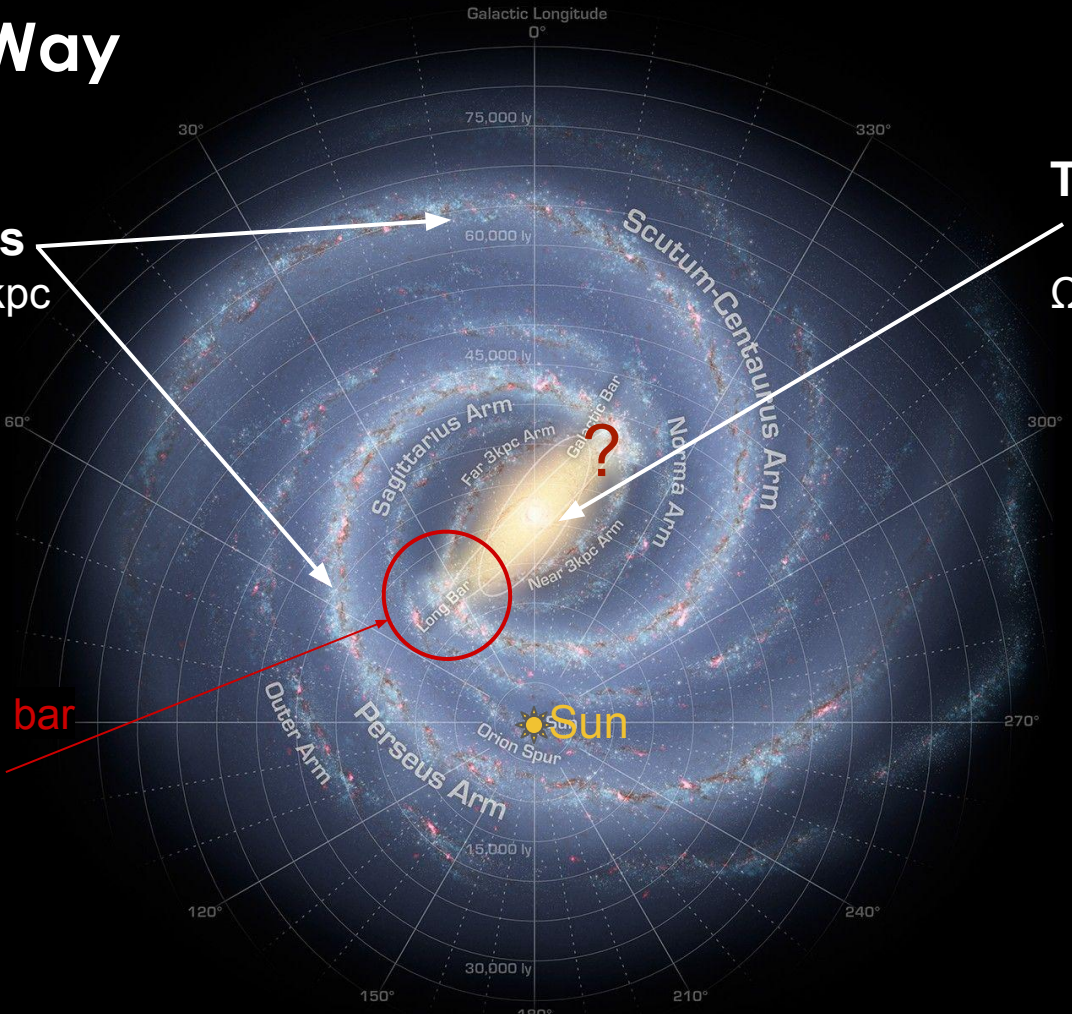


Credit: NASA/JPL-Caltech/R. Hurt (SSC/Caltech)

Bar-spiral interaction

spirals are bar-driven

$\Omega_{spiral} = \Omega_{bar} \rightarrow$ few interaction

spirals are not (directly) driven by the bar

$\Omega_{spiral} \neq \Omega_{bar} \rightarrow$ interaction !

Pattern speeds
=
determining factors of
bar-spiral interaction

Bar-spiral interaction

spirals are bar-driven

$\Omega_{spiral} = \Omega_{bar} \rightarrow$ few interaction

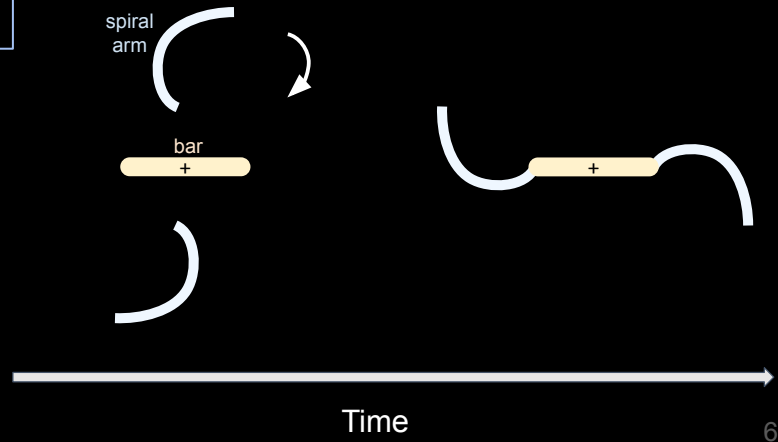
bar and spiral move together

Pattern speeds
=
determining factors of bar-spiral interaction

spirals are not (directly) driven by the bar

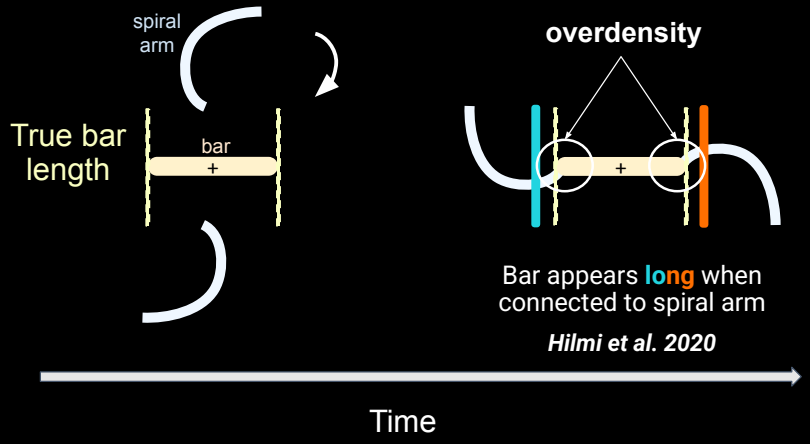
$\Omega_{spiral} \neq \Omega_{bar} \rightarrow$ interaction !

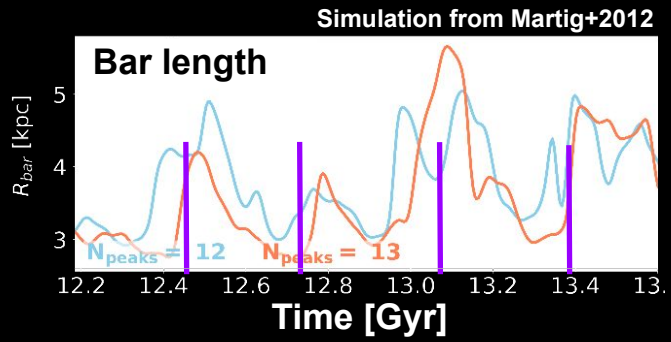
Regular overlaps of the tips of the bar with spiral arms



The bar-spiral interface in simulations

Bar-spiral overlap ↔ longer bar length

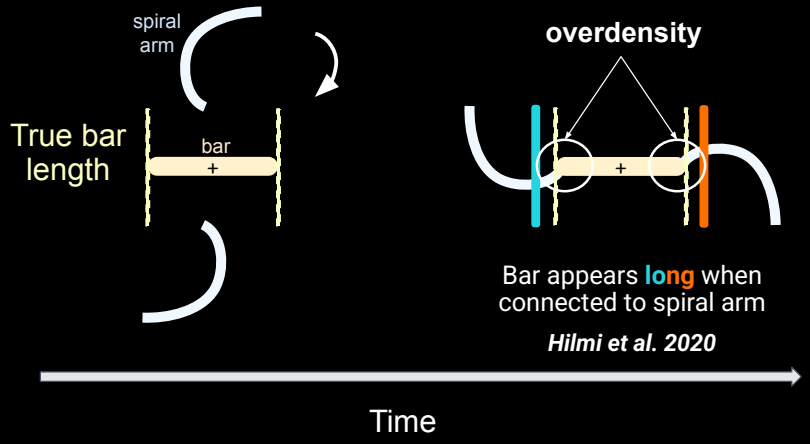


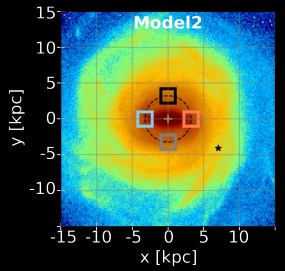


adapted from Marques+2025

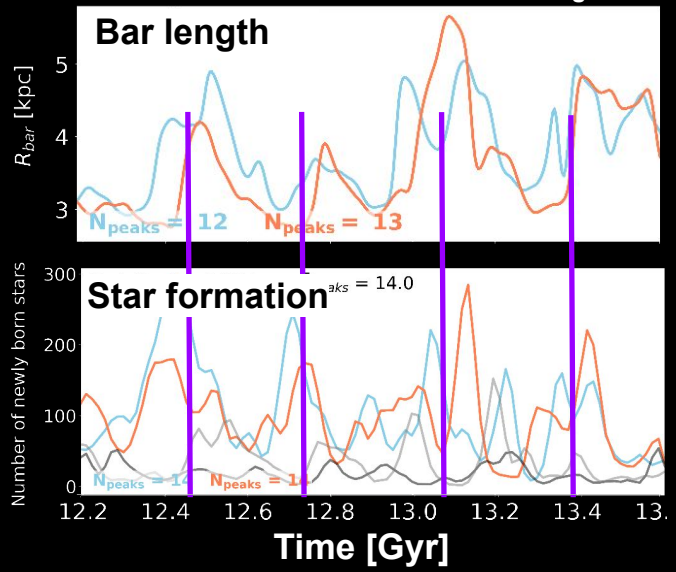
The bar-spiral interface in simulations

Bar-spiral overlap ↔ longer bar length
peaks in star formation





Simulation from Martig+2012



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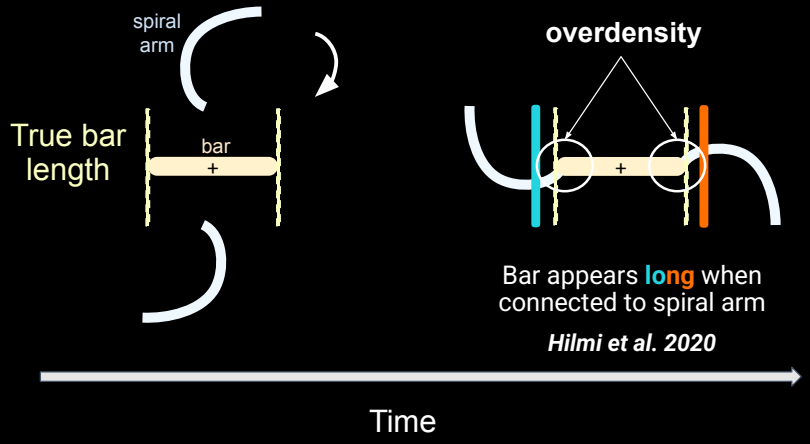
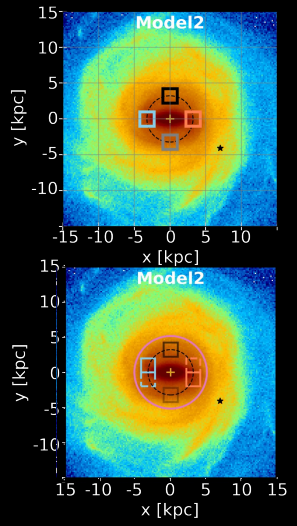
The bar-spiral interface in simulations

Bar-spiral overlap ↔ longer bar length
peaks in star formation
stronger radial migration





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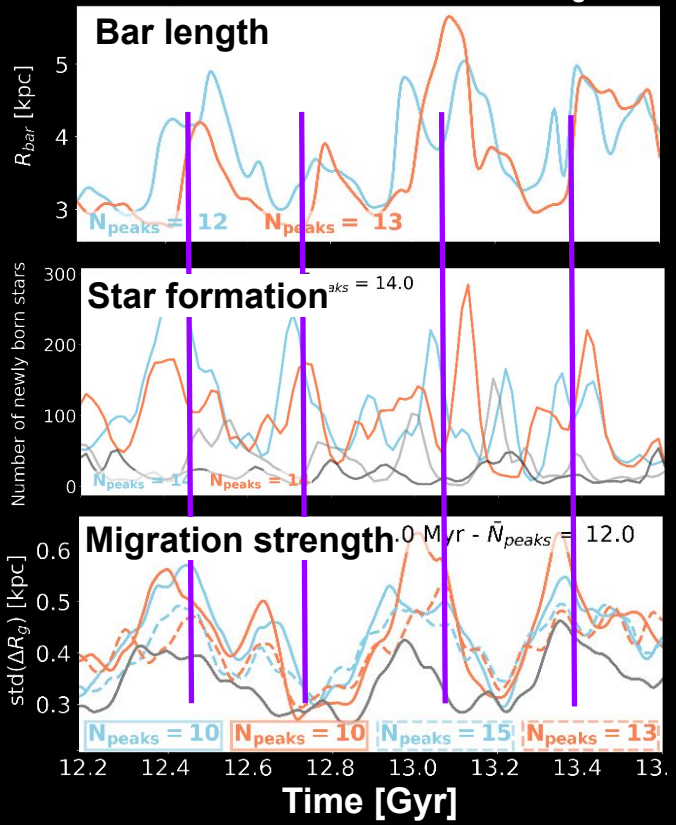

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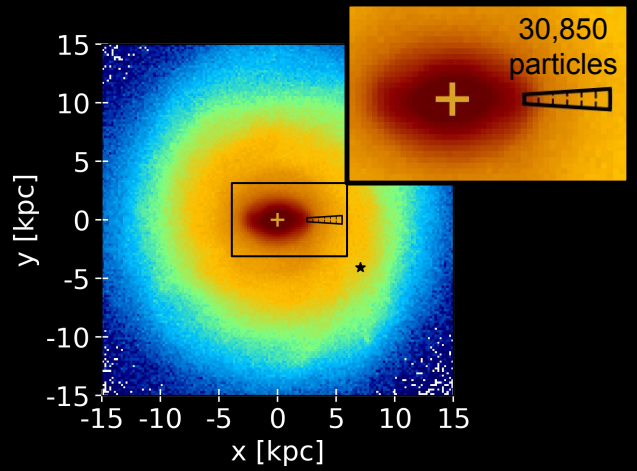
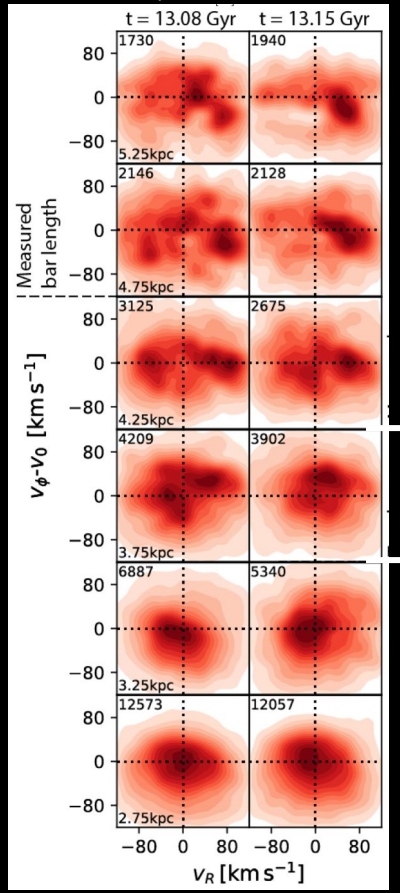
Clumps in the velocity space around the bar ends that are connected to spiral arms



Hilmi et al. 2020 (simulation from NIHAO-UHD)



R_{GC}

even more clumps, from different spiral modes?

Measured R_{bar}

extra clump, from "spiral" orbits

True R_{bar}

one clump, from x1 orbits

The bar-spiral interface in simulations

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Clumps in the velocity space around the bar ends that are connected to spiral arms

Divergence of the Tremaine-Weinberg method
to measure bar and spiral pattern speed

TW : integrate the continuity equation $\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \boldsymbol{v}) = 0$ → isolate Ω_{bar}
→ apply for different ℓ bins

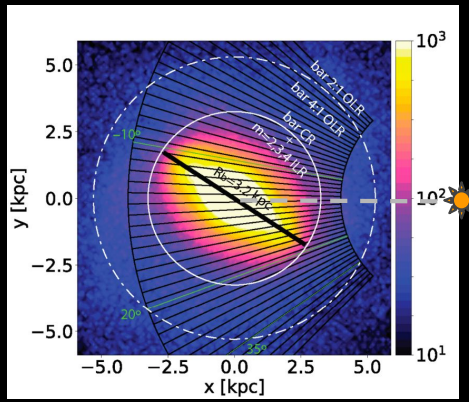
Valid if :

(1) the pattern is steady

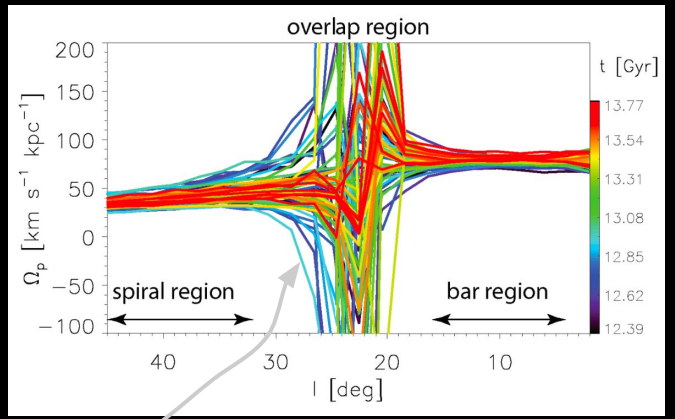
(2) the integration encompasses the entirety of the non-axisymmetry → *careful with the derivation*

(3) there is a single pattern speed broken there

from Hilmi et al. 2020



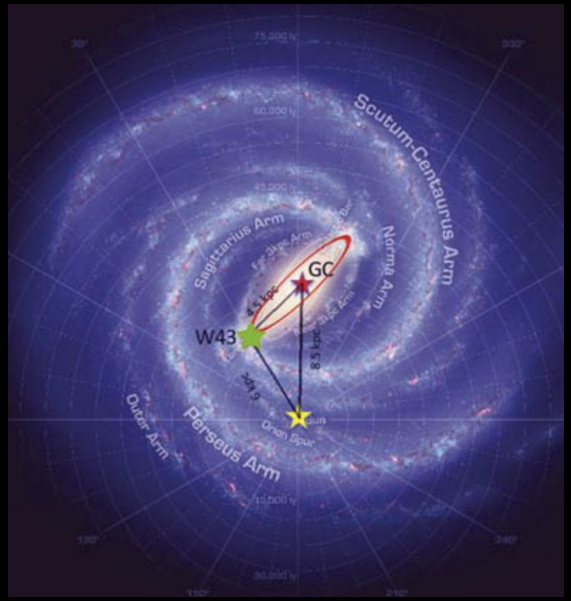
Sun



The bar-spiral interface in observations?

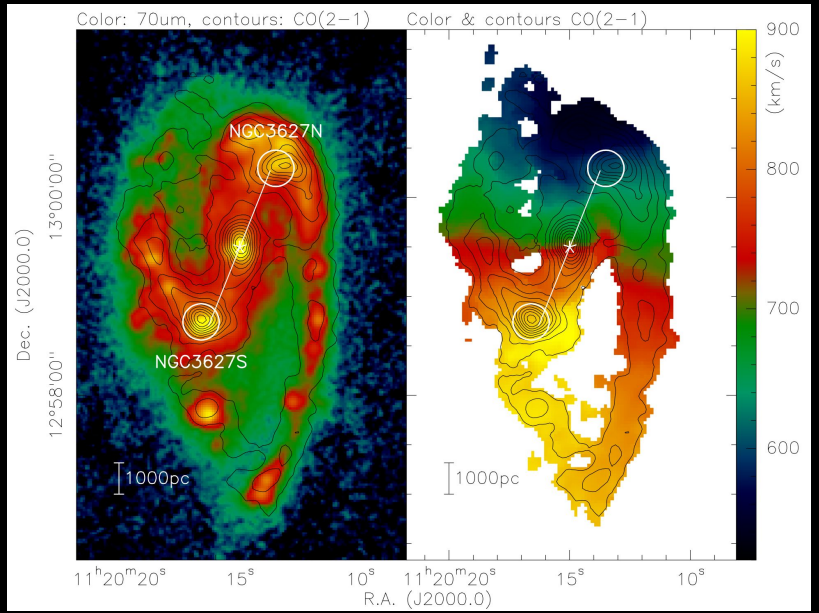
Mostly gas…

W43 “mini-starburst” : highest SFE in the MW, right at bar-spiral interface



Nguyễn Lương et al. 2011

extragalactic : NGC 3627



Beuther et al. 2017

The bar-spiral interface in the MaNGA survey

one of my current research projects with Amelia Fraser-McKelvie

Do we find SFR enhancement at the end of (observed) bars connected to spiral arms?

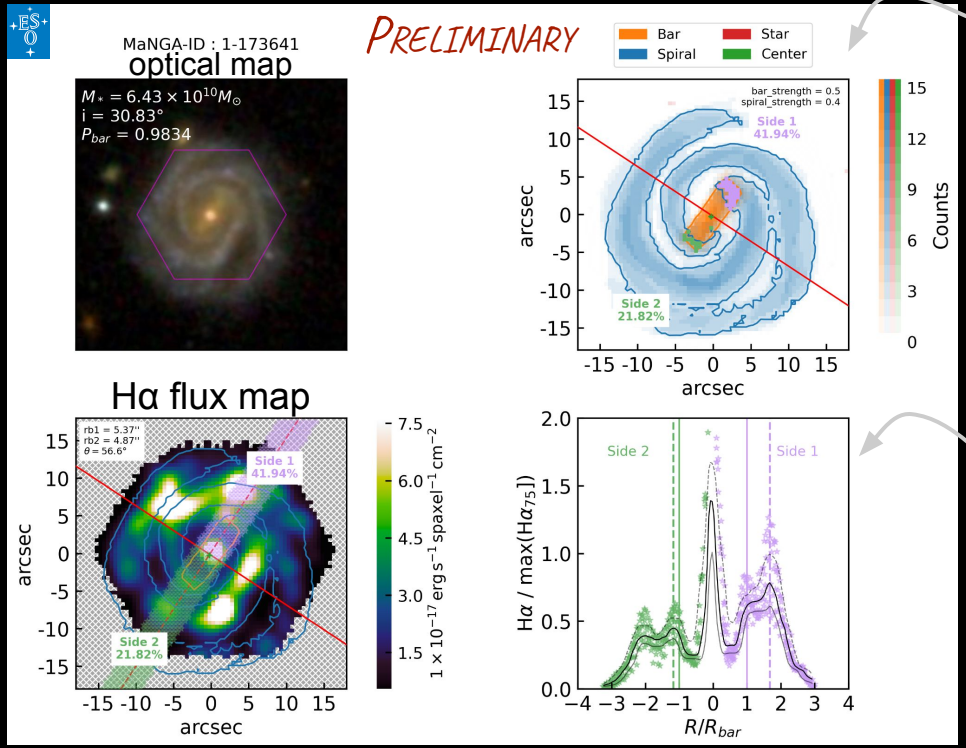
Bundy+2015

IFU spectroscopy
with ~ 1 kpc resolution

> 100 of face-on barred spiral galaxies

preliminary result

hints of SF enhancement at the edges of bar more strongly connected to spirals



Galaxy Zoo:3D environmental masks
Masters+2021

Hα profile along the bar

S3 / 4MIDABLE-LR selection function (SFn)

S3 ESN + Dyn + Chem : Uniform target distribution

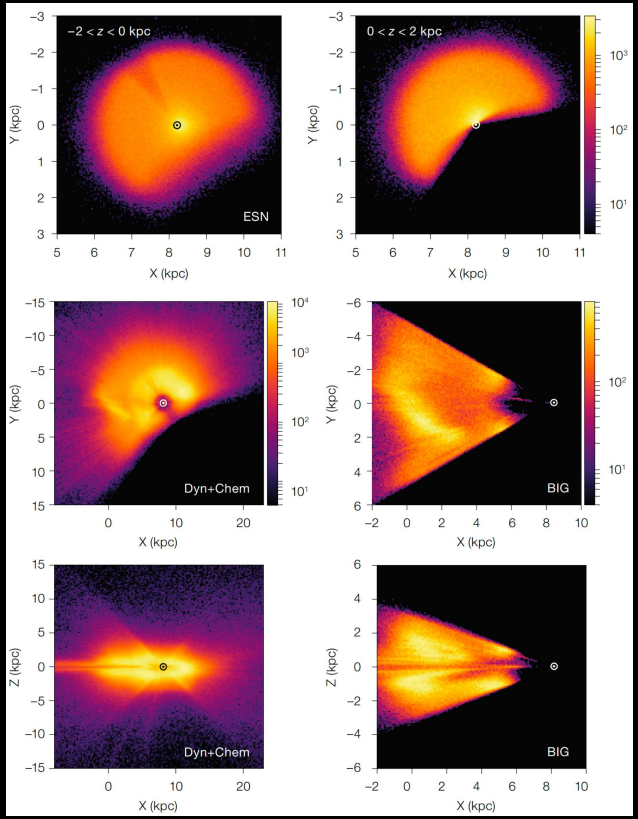
along given line of sight, keep density of targets constant

$N_{obs} \propto d^2$

😕 smoothes out density structures (e.g. spirals…)

😀 probes disc homogeneously

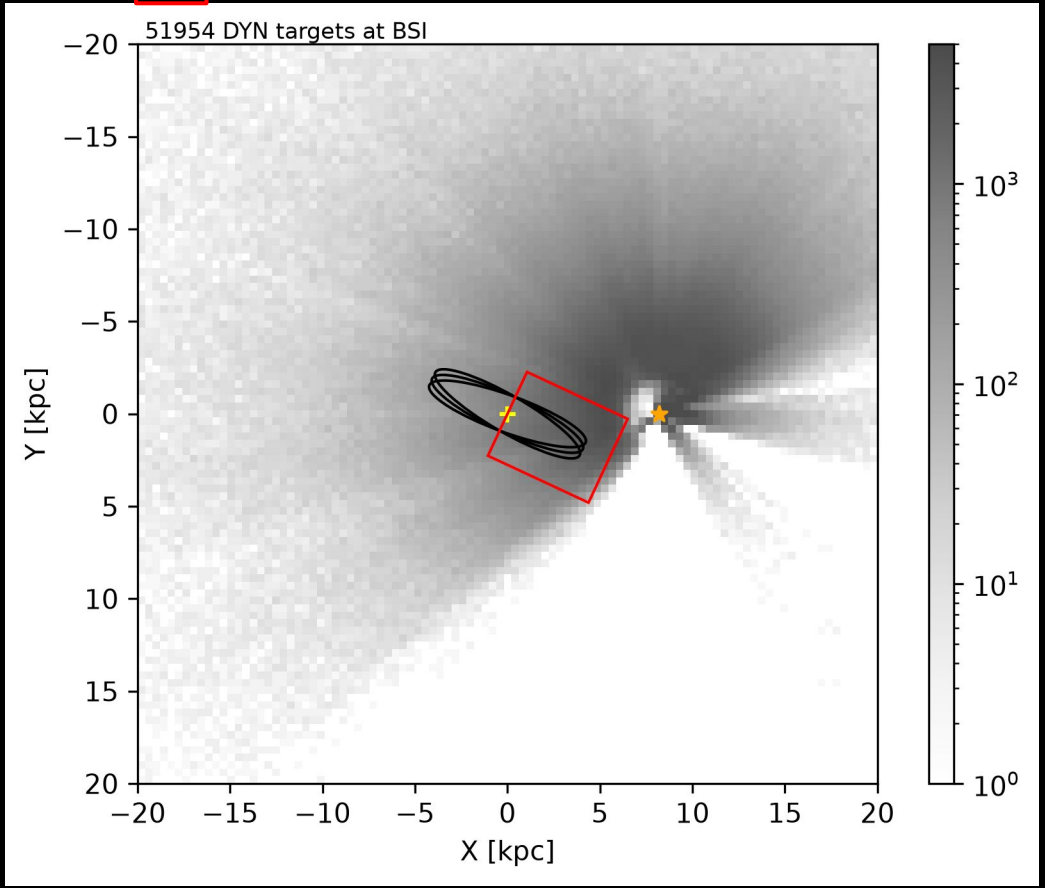
including the
bar-spiral interface…



Chiappini et al. 2019

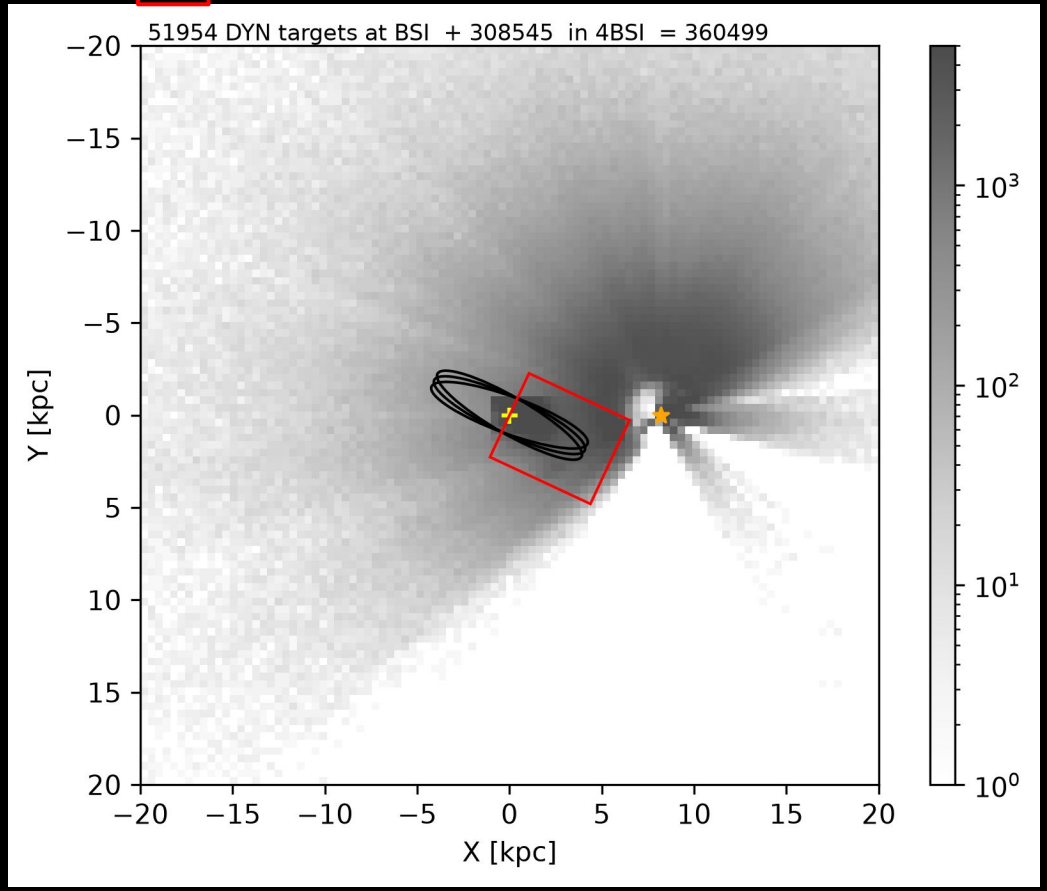
S3 / 4MIDABLE-LR : Dyn

at BSI : 52,000 targets (80% of Dyn)

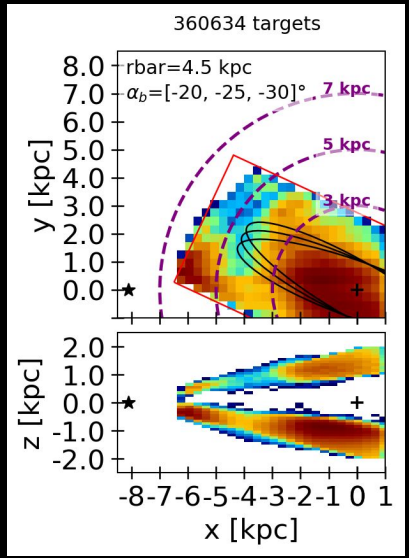


Dyn + Dynamics at the Bar-Spiral Interface (4BSI)

at BSI : 52,000 targets (80% of Dyn) → 360,000 targets (4BSI)



Supplementary targets
Dynamics at the Bar-Spiral Interface (4BSI)



increase the number statistics of S3 (~target density X7) at the bar-spiral interface to resolve resonant structures

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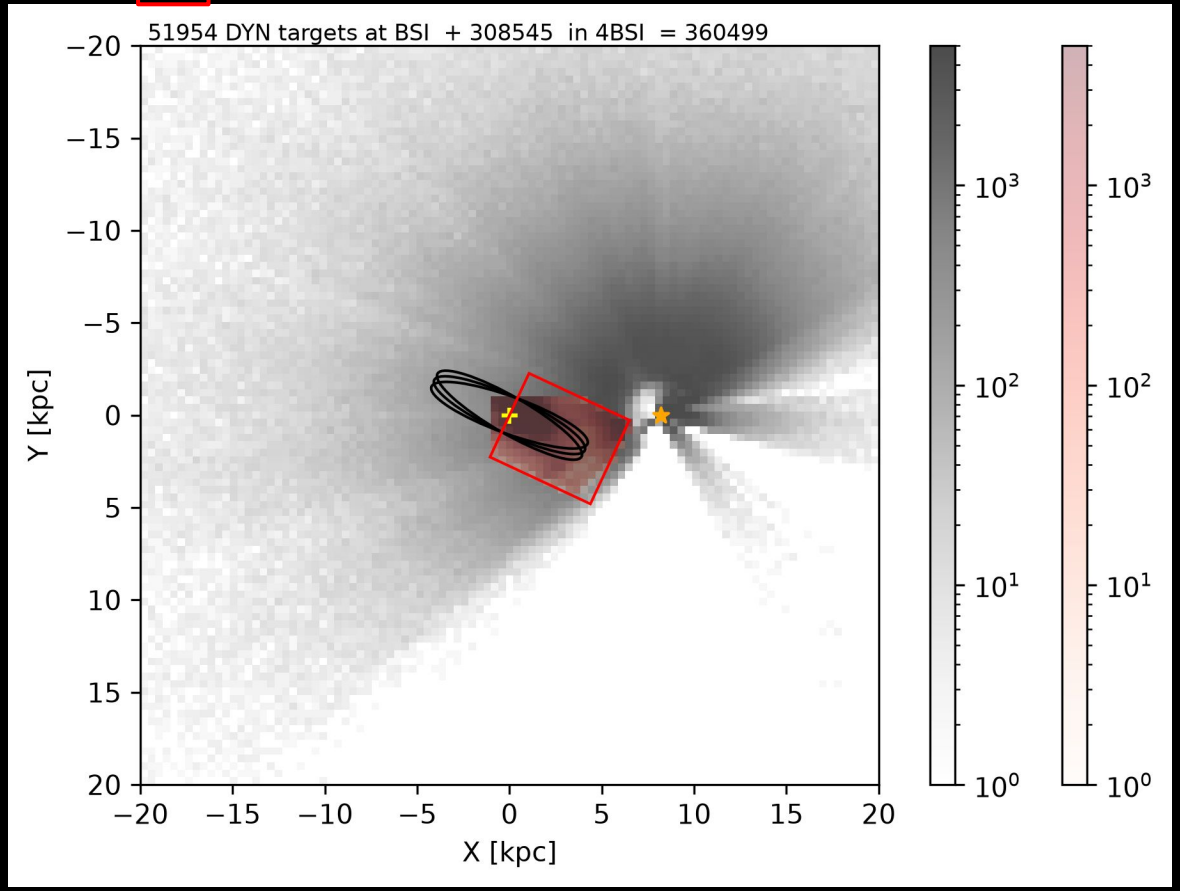

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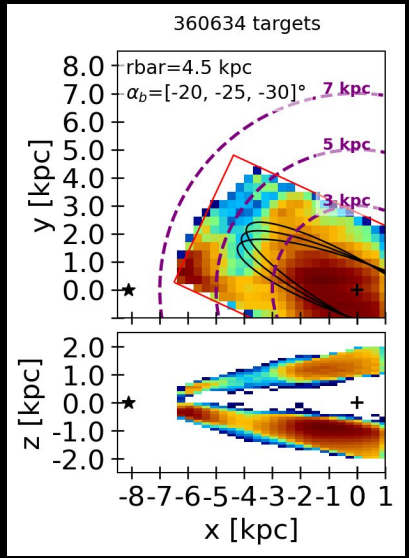

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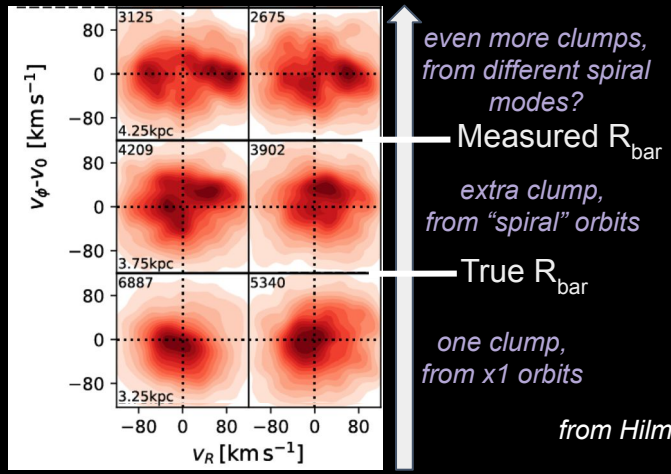
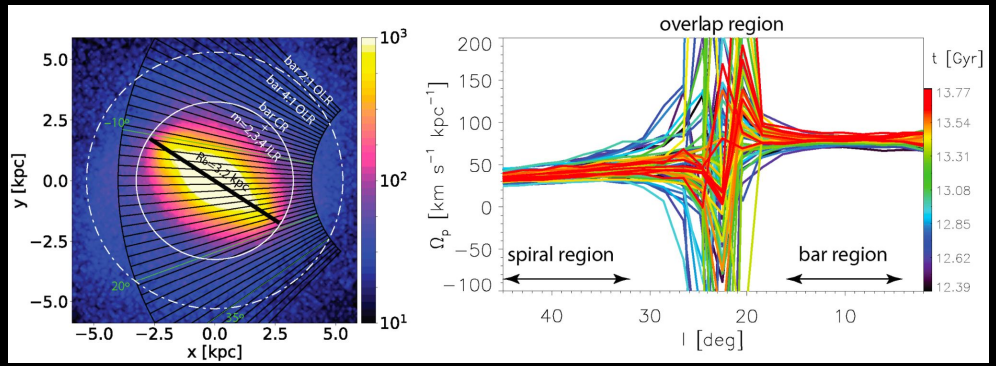
Retrieving dynamics

- Combining 4MOST (heliocentric) radial velocities + Gaia proper motions
  - galactocentric Vr and Vphi

→ apply TW to find both pattern speeds + define the width of bar-spiral interface
→ explore velocity space





from Hilmi et al. 2020

\+ identifying current migrators? esp. if we can get [Fe/H] and age

Conclusion

- Bar and spiral pattern speeds are different in the MW → they must be interacting

- Observational data at the bar-spiral interface are lacking
  - especially in terms MW stellar targets
  - obs of gas in the MW and external galaxies hint at enhanced SFR at BSI

- Yet simulations show many interesting processes in this region, which reveal the structure of the Galaxy and influence its evolution
  - bar-spiral regular overlaps cause the bar to appear longer
    peaks in SF
    peaks in migration strength
  - bar-spiral connection leaves signatures in the velocity space
  - TW method diverges at the bar-spiral interface

- Dynamics at the Bar-Spiral Interface (4BSI)
  - supplementary target program
  - increase target density at the BSI, compared to S3-4MIDABLE-LR Dyn
  - allows to resolve density structures in the velocity space