



FPIs and Bars

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3DNTT scientific meeting, April 2 2008, Meudon, France



Overview

Why are bars important for galaxy evolution ?

(~70% of all spirals, out to 9 Gyr, are barred)

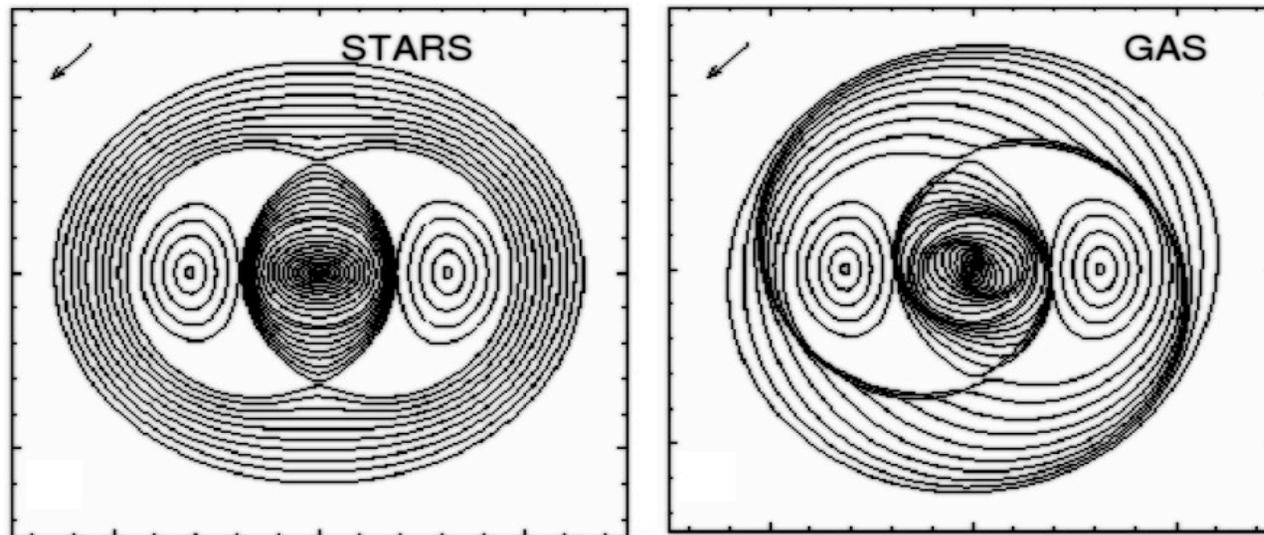
(Gas inflows, Starbursts, Nuclear disks/bars/rings, Pseudobulges, AGN)

- 1 Secular evolution
- 2 Resonance interaction
- 3 Angular momentum transfer
- 4 Pattern Speeds
- 5 Interplay with the DM halo vs. MOND
- 6 Feeding the central black hole
- 7 Feeding the central starburst
- 8 The 3DNTT connection



Bars and secular evolution

Dynamical instabilities are responsible for evolution
Bars form in a cold unstable disk and redistribute the ISM,
which in turn can destroy the bars.



Buta & Combes (1996)

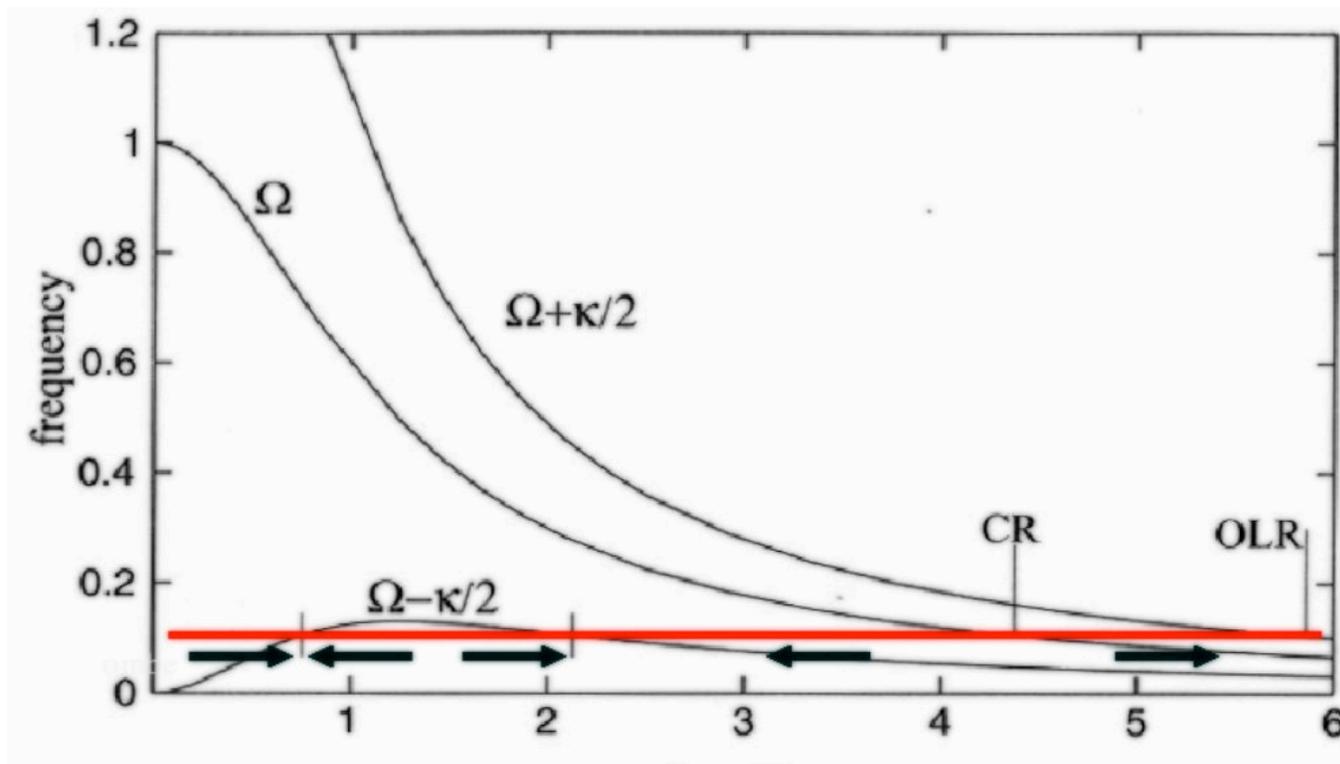
The ongoing debate is whether bar destruction efficient?

Or if bars can reform?



Resonance interaction in bars

The Milky Way has only rotated about 40 times (at the Sun's Galactocentric radius) \rightarrow Resonances are necessary to enhance the effects



Hernandez et al. 2005; Emsellem et al. 2006; Fathi et al. 2007;2008 etc.



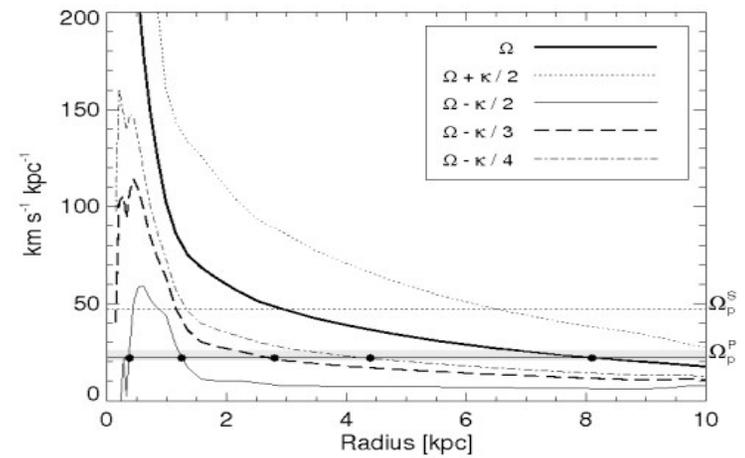
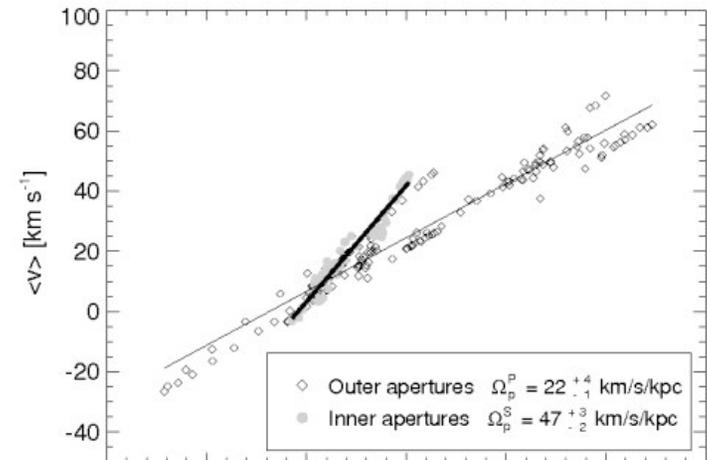
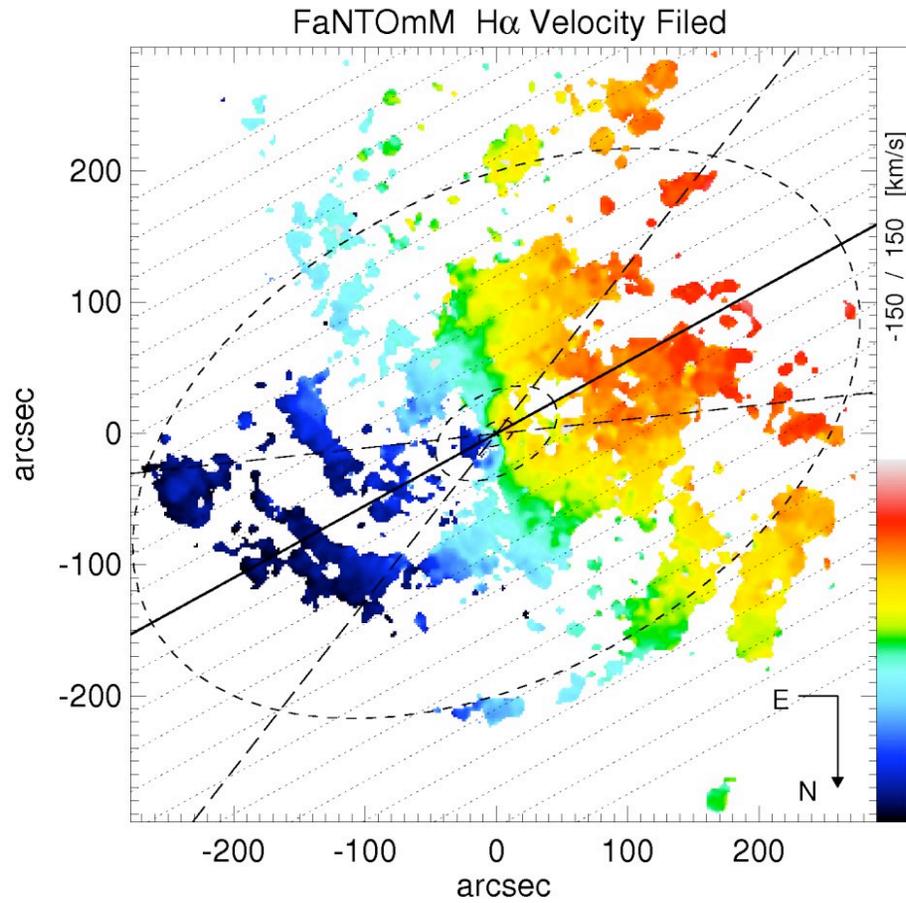
Resonant structure in NGC6946



Image by Robert Gendler



Resonant structure in NGC6946



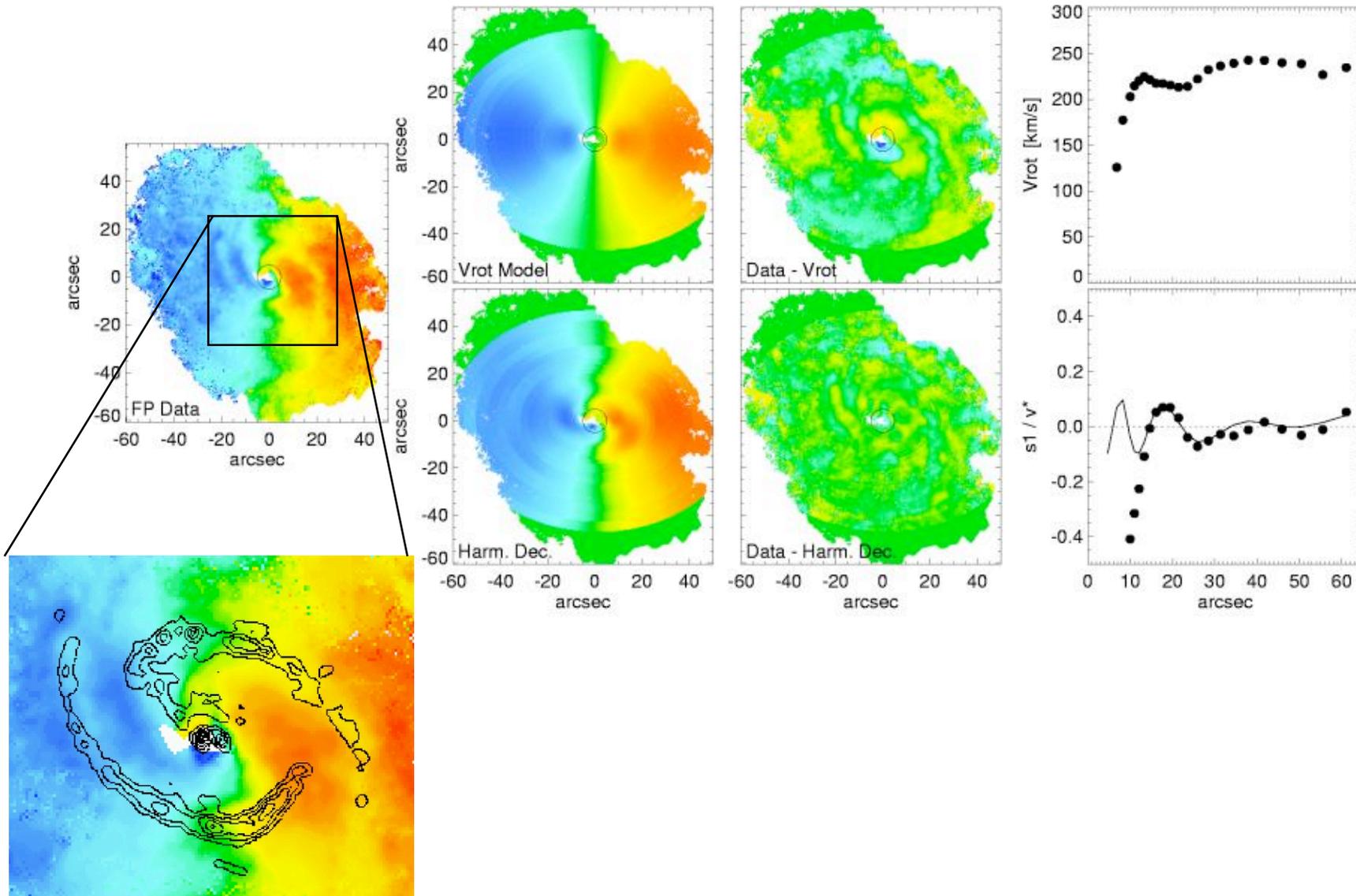


Angular momentum transfer in NGC1068



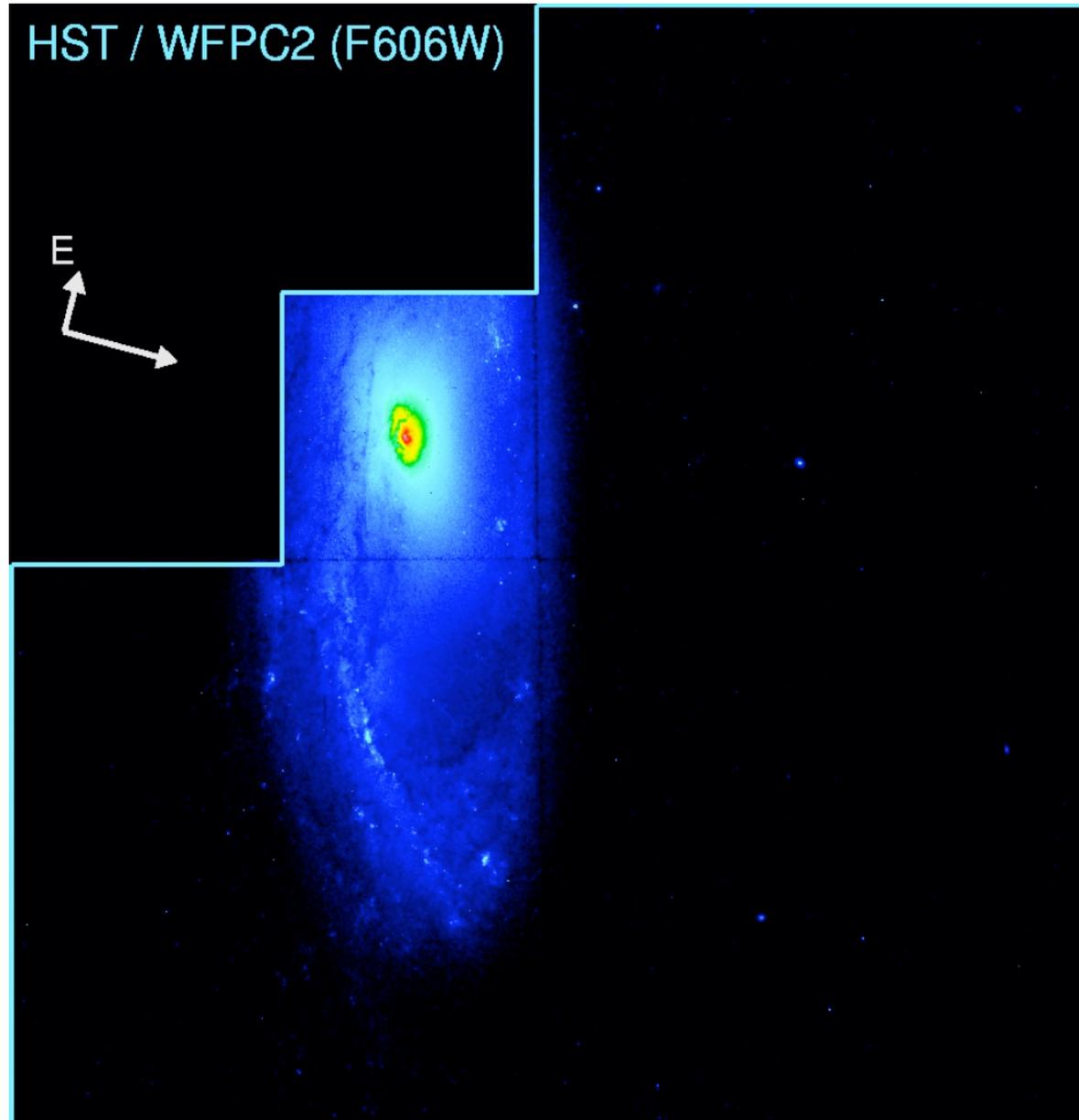
Image by Lai from the CFHT

Angular momentum transfer in NGC1068



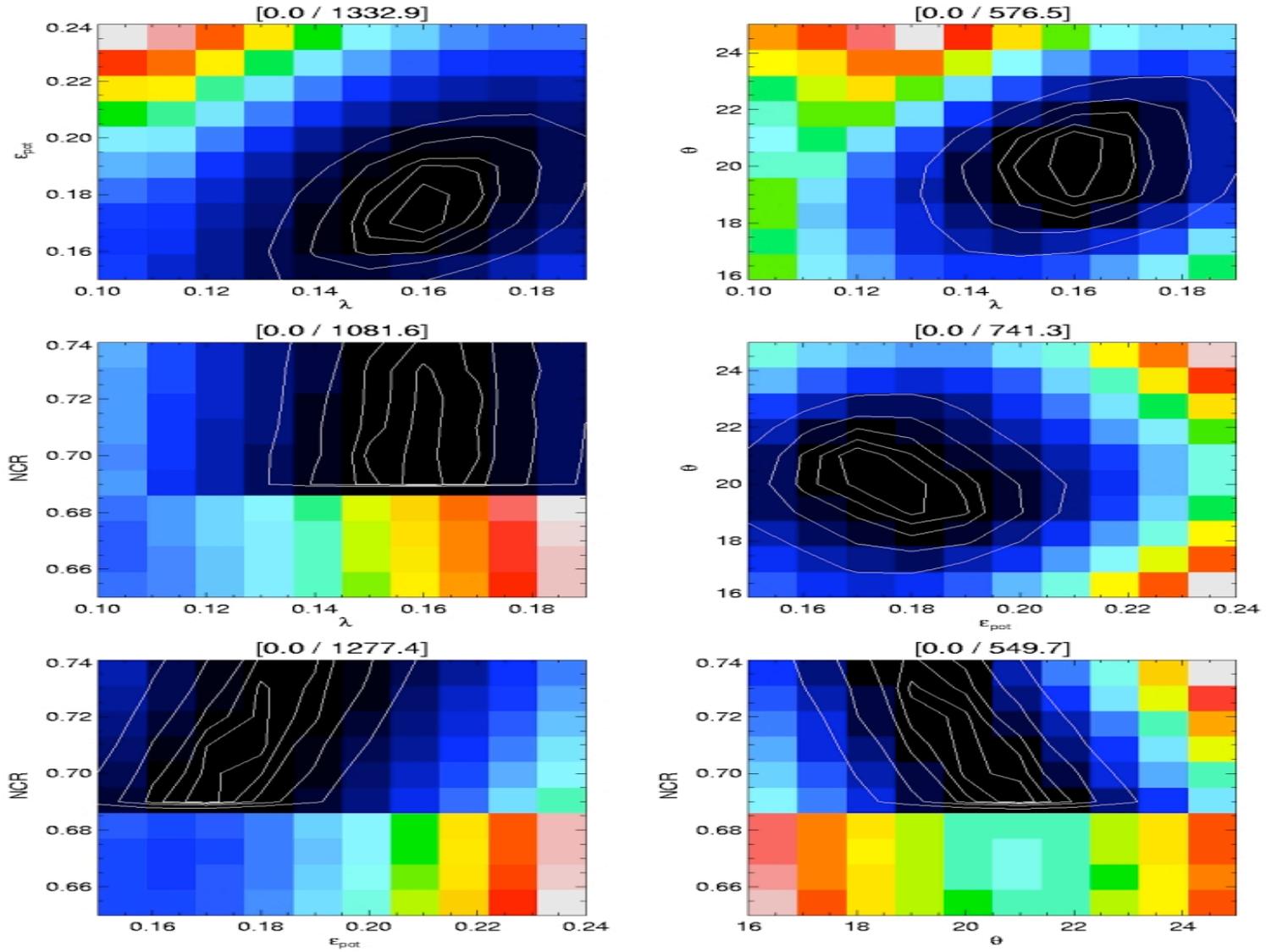


Angular momentum transfer in NGC5448



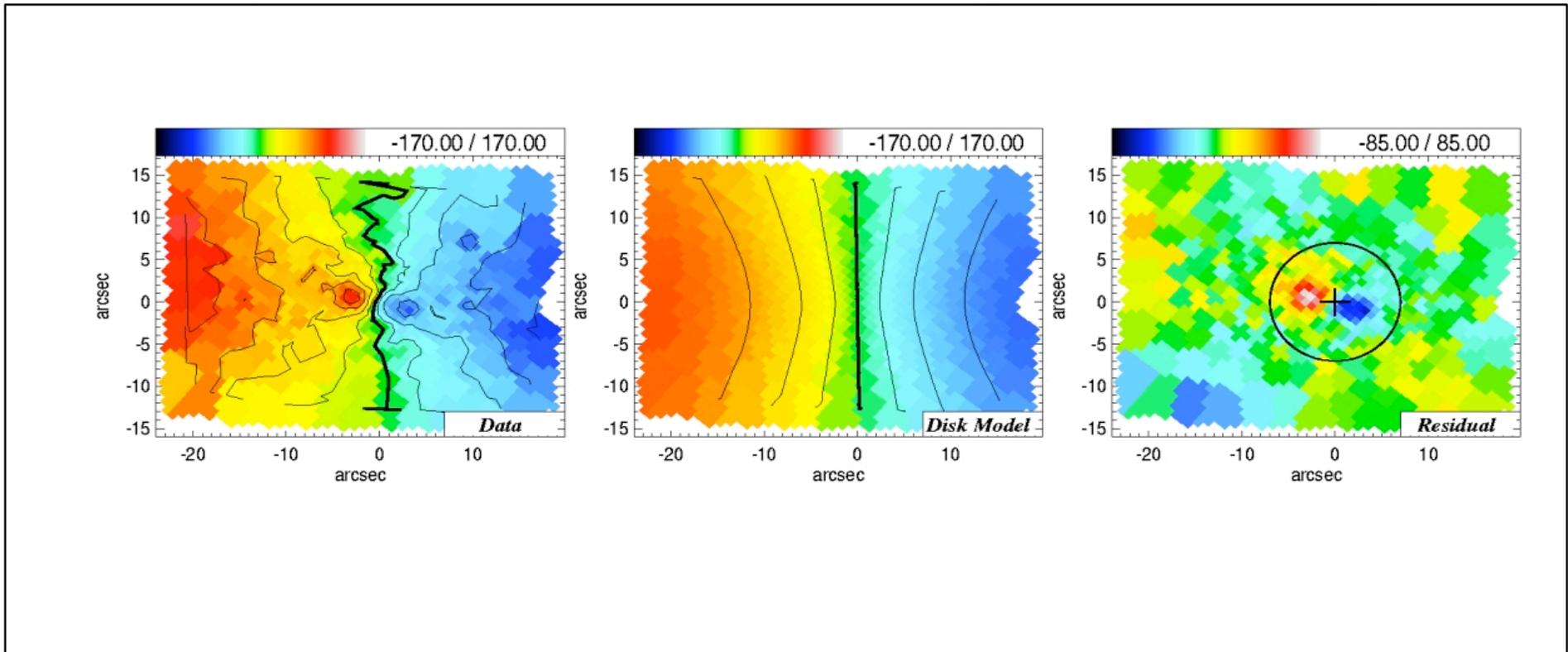
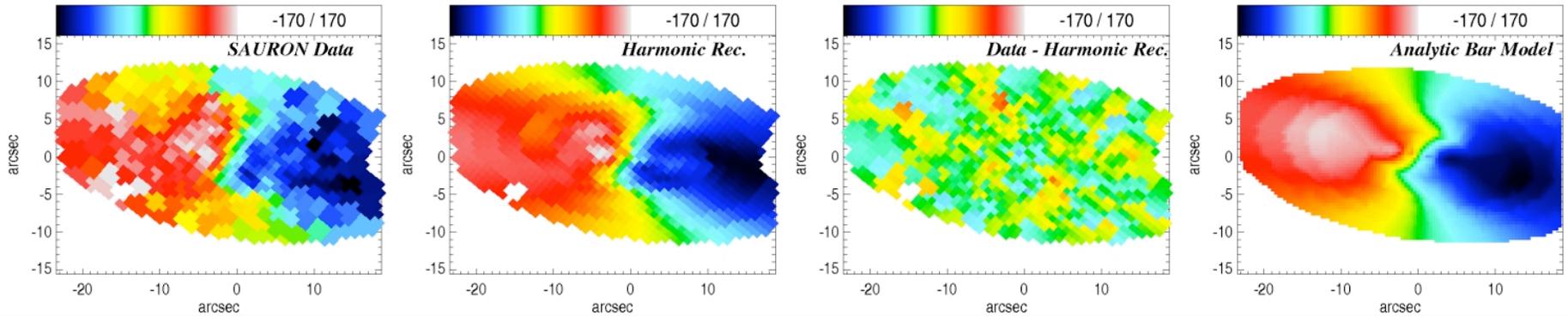


Angular momentum transfer in NGC5448





Angular momentum transfer in NGC5448





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Evolution of Structure in Late-type Spiral Galaxies

II. Pattern Speeds From the Tremaine-Weinberg Method on $H\alpha$ Velocity Fields[★]

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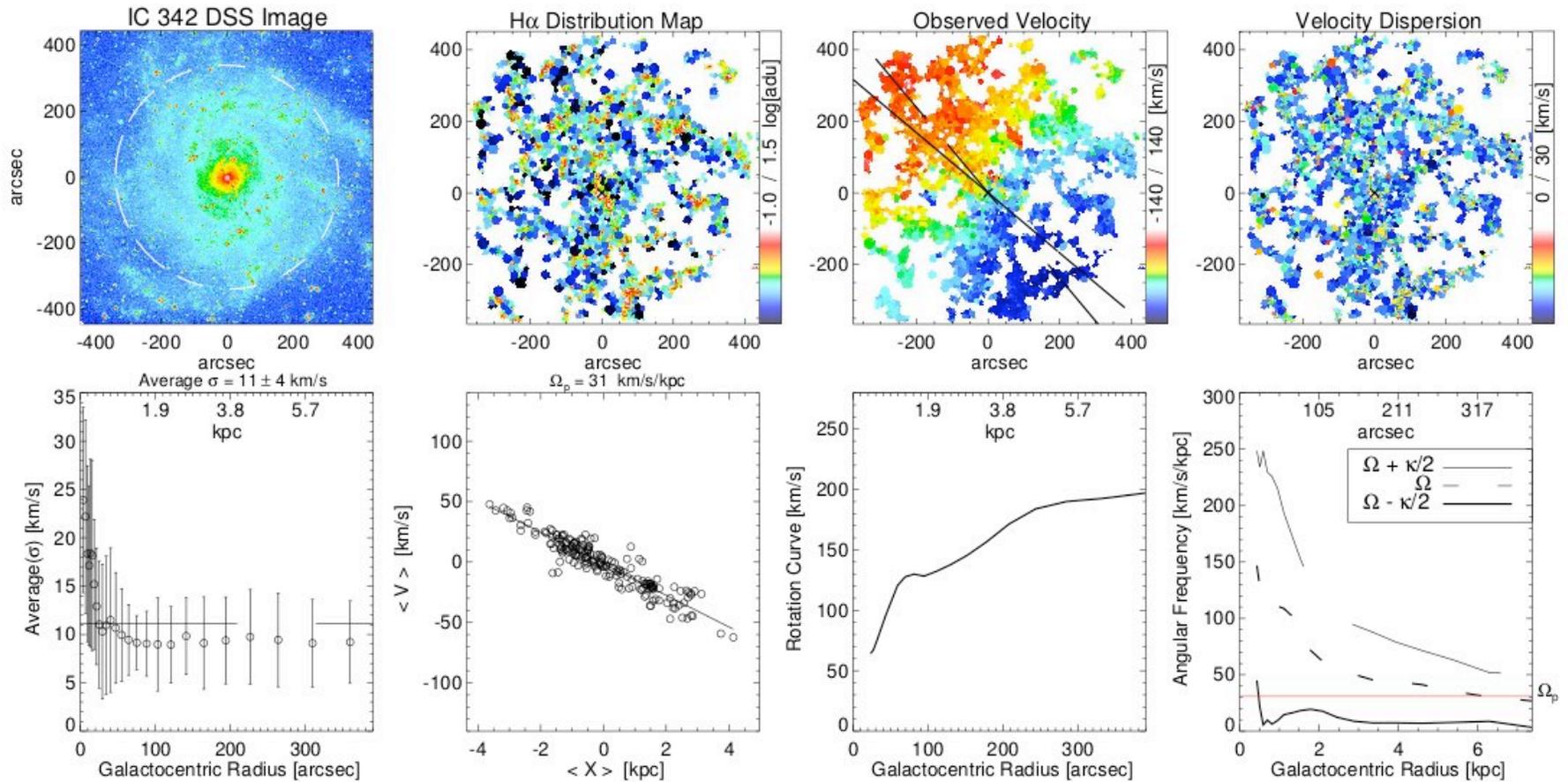
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Submitted

Also work by Hernandez et al. 2005 and Hernandez et al. In preparation

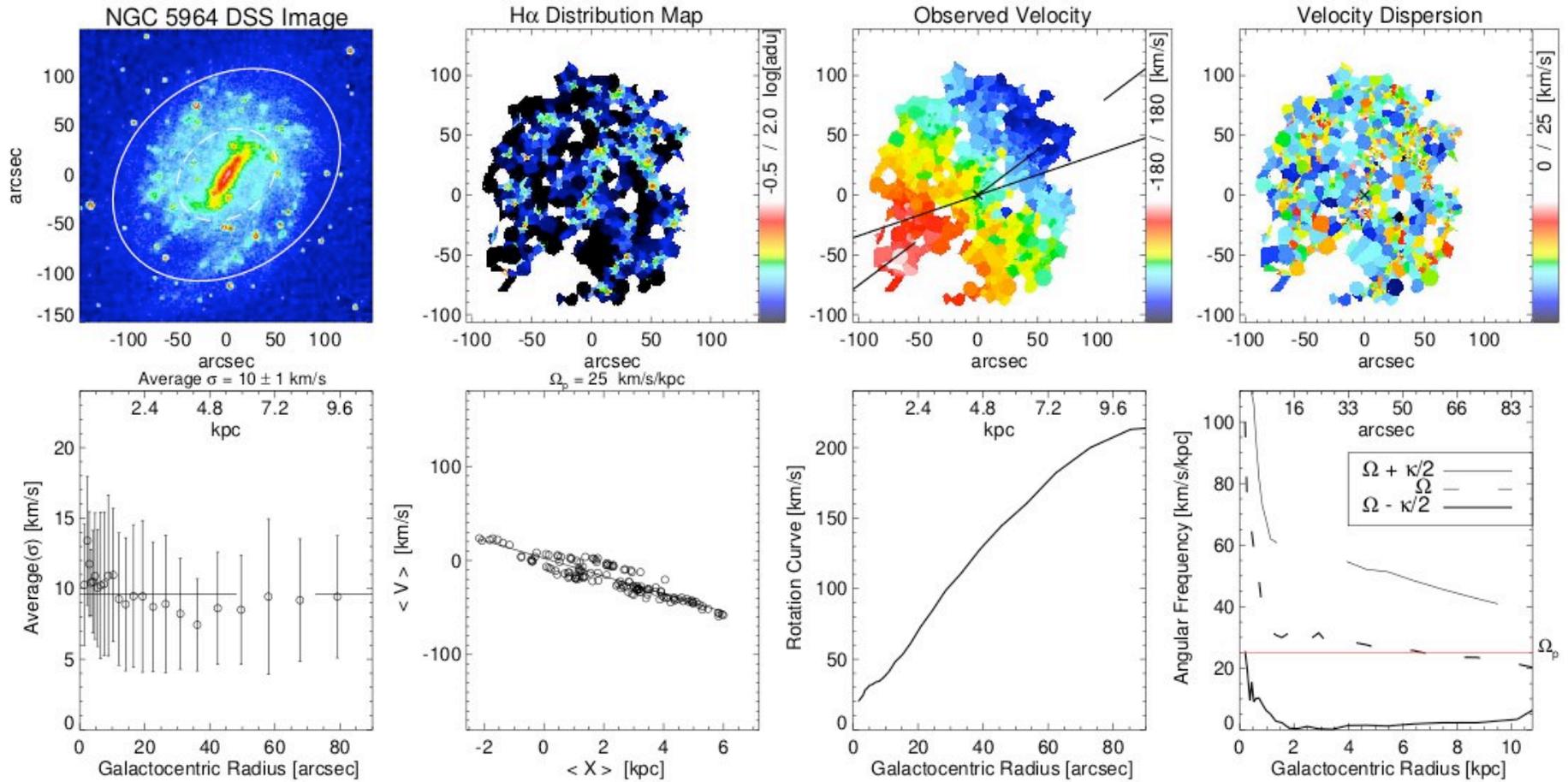


Pattern speed(s) in Bars



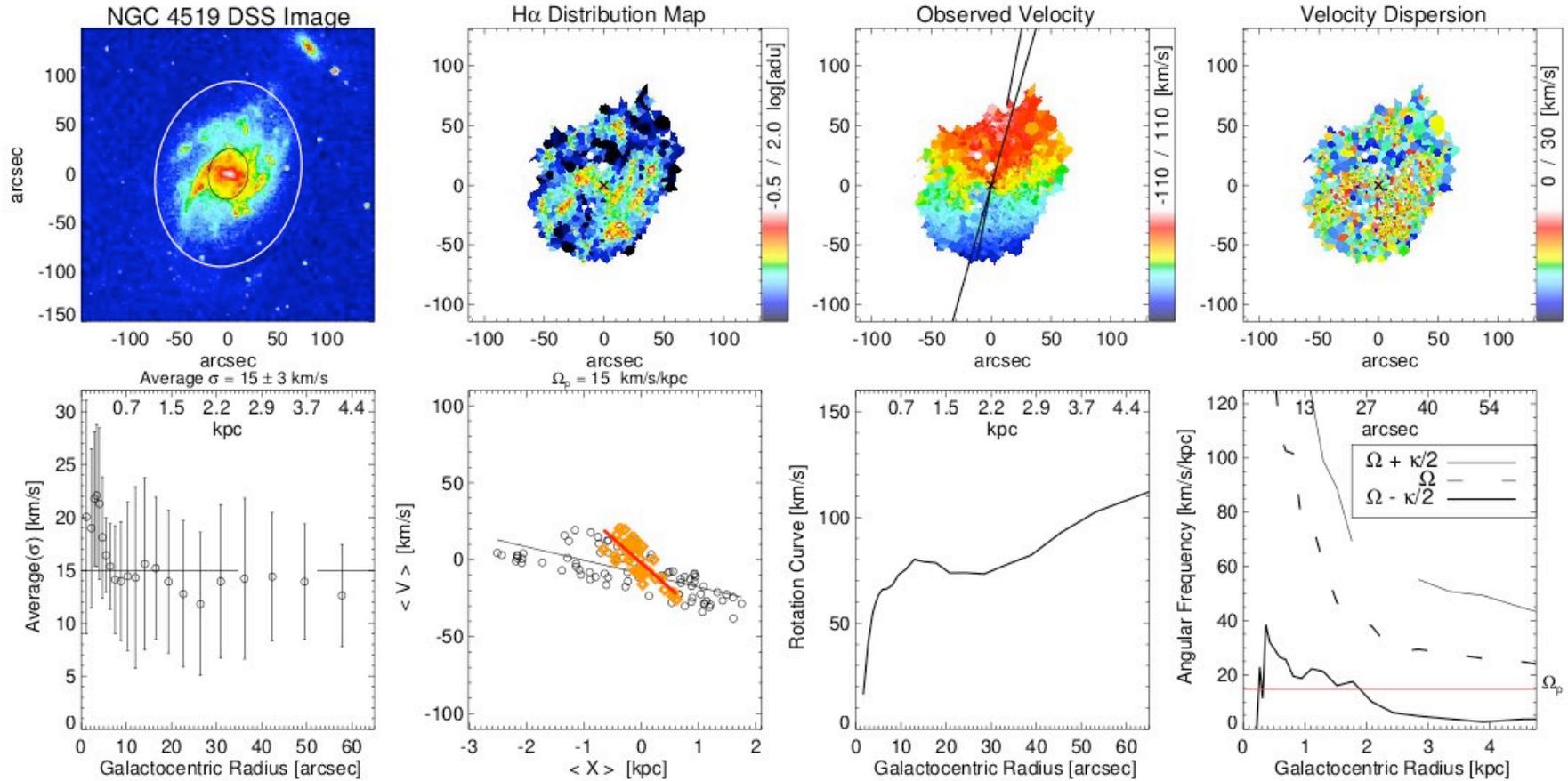


Pattern speed(s) in Bars





Pattern speed(s) in Bars





Pattern speed(s) in Bars

Numerical simulations

Object	Ω_p km s ⁻¹ kpc ⁻¹	Structure	CR kpc	ILR kpc
IC 342	31 ⁺⁵ ₋₁	Main Bar	6.5	...
NGC 2403	22 ⁺⁶ ₋₁	Main Bar	6.0	...
NGC 4294	44 ⁺³ ₋₁₀	Main Bar	1.9	...
NGC 4519	15 ⁺³ ₋₂	Spiral/Oval	> 5	2.0
	45	Bar	2.0	...
NGC 5371	14 ⁺⁵ ₋₁	Spiral Arms	17	...
NGC 5921	14 ⁺² ₋₂	Spiral/Bar	8.0	...
NGC 5964	25 ⁺¹ ₋₅	Spiral/Bar	6.5	...
NGC 6946	25 ⁺⁶ ₋₆	Spiral/Oval	8.0	1.7
	46	Bar	1.5	...
NGC 7479	16 ⁺³ ₋₂	Main Bar	15.0	...
NGC 7741	18 ⁺¹³ ₋₂	Main Bar	6.5	1.3

Study	Ω_p km s ⁻¹ kpc ⁻¹	Comments
DS	30 - 10	Rapid decrease in first 100 time steps
ES	25	Primary bar in double barred systems
HSA	≈ 70	Static dark matter halo after 6 Gyr
IB	30 - 20	Between 0 and 5 Gyr
LA	28 - 7	Decreasing by ≈ 0.5 km s ⁻¹ kpc ⁻¹ Gyr ⁻¹
MV	25 - 5	Between 1 and 12 Gyr
OND	19 - 7	High- and low-resolution simulations
SD	30 - 10	Between 2 and 12 Gyr
TC07	≈ 25	MOND between 1 and 7 Gyr
TC07	30 - 25	Static dark matter halo
TC07	27 - 10	Live halo between 1 and 7 Gyr
TC08	≈ 20	Gaseous bar in MOND between 1 and 8 Gyr
TC08	22 - 14	Gaseous bar in dark matter between 1 and 8 Gyr
VK	40 - 20	Between 0.5 and 1.5 Gyr
WK	19 - 5	Both for Hernquist and NFW halos

Table 5. Predicted Ω_p s from numerical simulations from DS (Debattista & Sellwood 2000); ES (Englmaier & Shlosman 2004); HSA (Heller et al. 2007); IB (Berentzen et al. 2007); LA (Athanasoula 2003); MV (Martinez-Valpuesta et al. 2006); OND (O'Neill & Dubinski 2003); SD (Sellwood & Debattista 2006); TC07 (Tiret & Combes 2007); TC08 (Tiret & Combes 2008); VK (Valenzuela & Klypin 2003); WK (Weinberg & Katz 2007). Note that Ω_p is decreasing with time.



Tremaine-Weinberg & pattern speed(s)

- Deriving Pattern Speed from different disk sections could alone exhibit the presence of multiple patterns.
- In 30% we have confirmed the direct resonant interaction or interplay by non-linear mode coupling between the spiral arms and the main bar.
- One third of our 10 late-type spirals show clear evidence for an ILR. In all three galaxies thickening of the gas in the central region could build the bulge-like component in late-type spirals.
- Comparing the kinematically derived corotation radii for the bars with the bar radii independently derived from the morphology is consistent with predictions from numerical simulations.



Interplay with DM halo

Numerous mass models by

Carignan et al.

Amram et al.

etc.

+ recent MOND model by Tiret & Combes

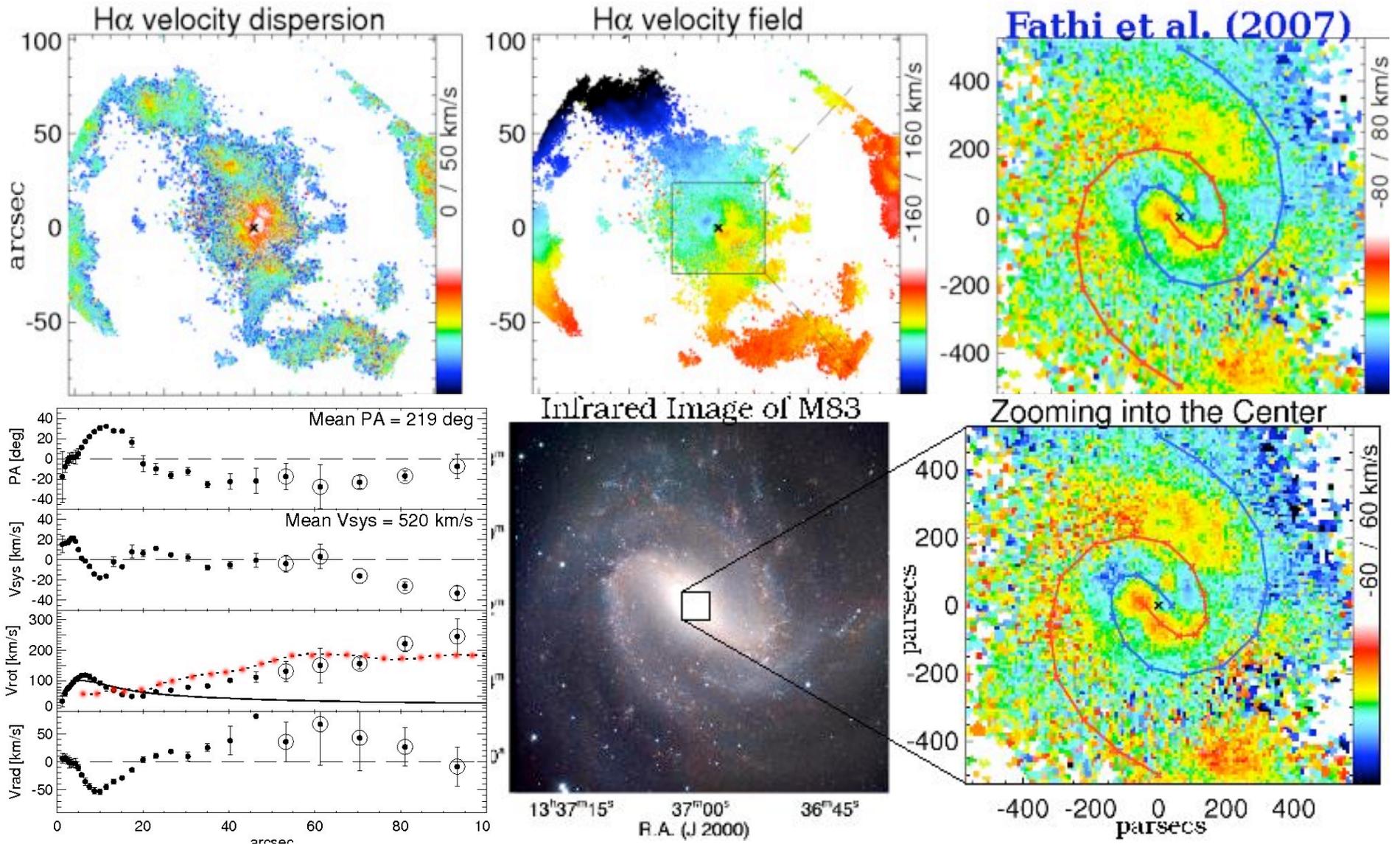


Feeding the nuclear starburst in M83



Infrared Image of Spiral Galaxy Messier 83
(NTT/SOFI + Danish 1.54-m/DFOSC)

Feeding the nuclear starburst in M83



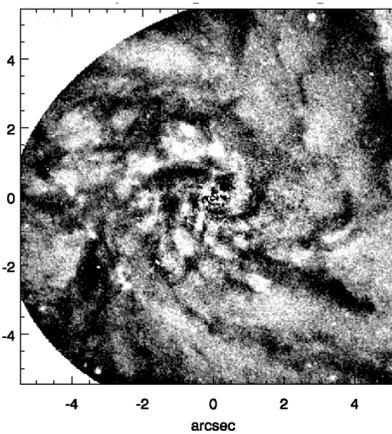
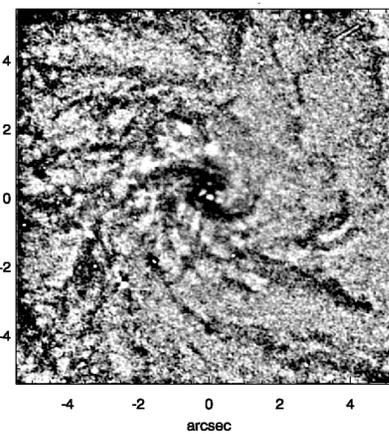
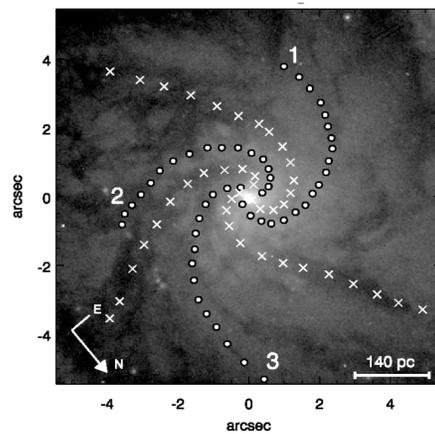
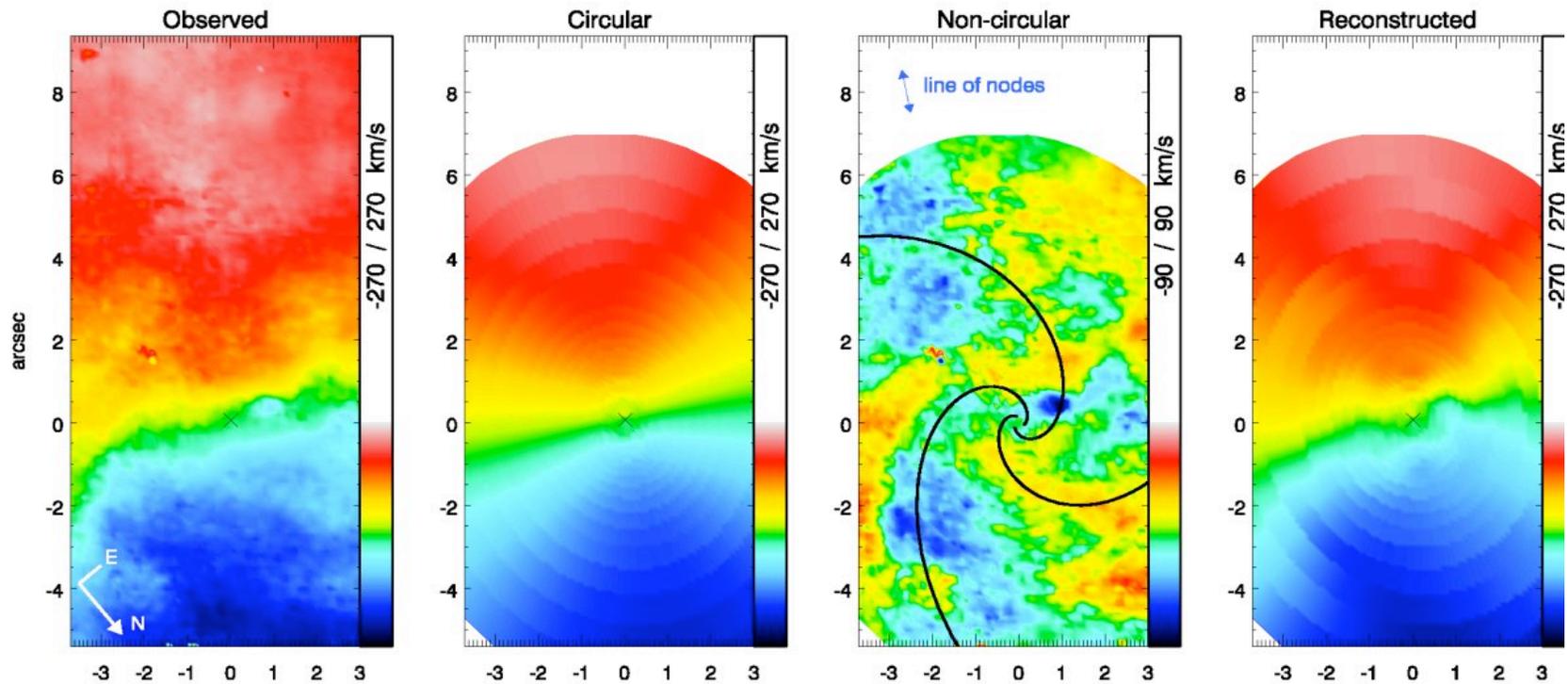


Feeding the central black hole in NGC1097

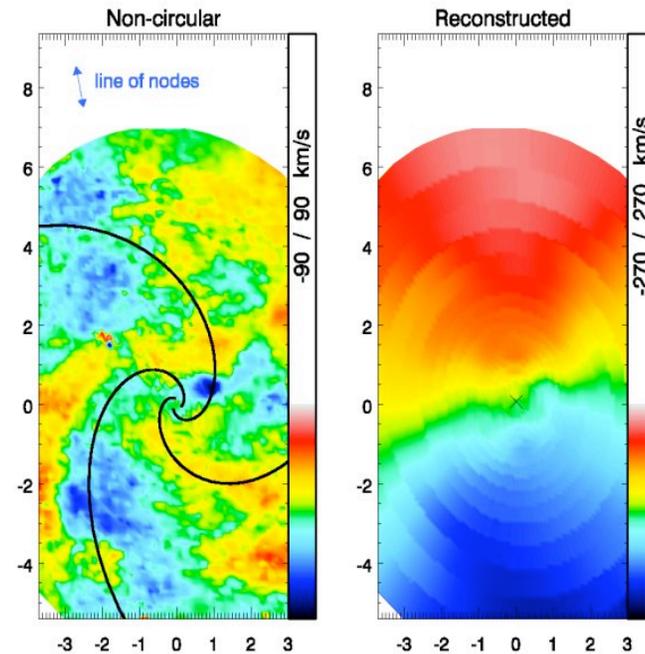
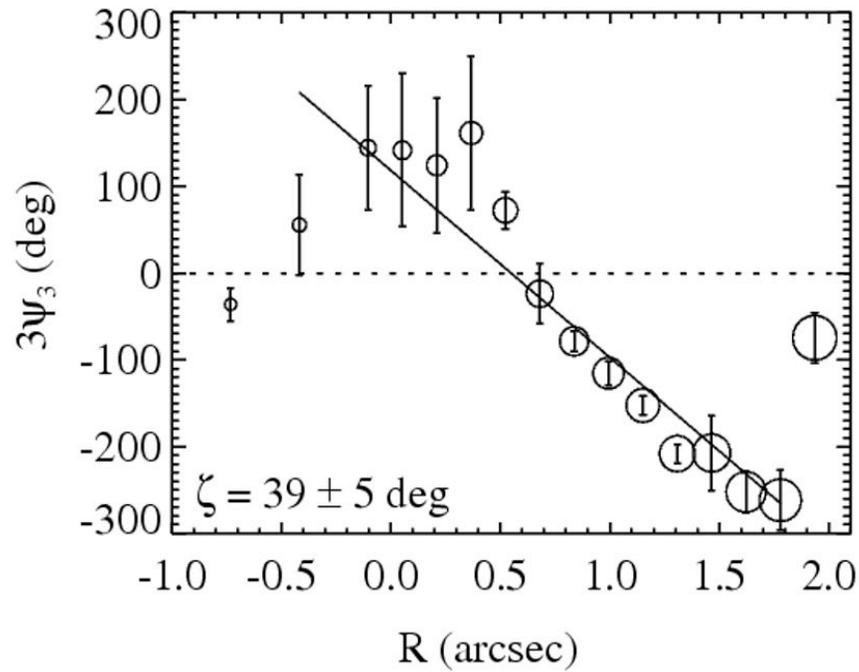


Spiral Galaxy NGC 1097
(VLT MELIPAL + VIMOS)

Feeding the central black hole in NGC1097



Feeding the central black hole in NGC1097





Crucial pieces still unknown

The 3DNTT connection

Are bars a recent phenomenon and how do they differ from their parent disks or the AGN?

- Key objects in the Southern Hemisphere (e.g., NGC1097, M83 etc.)
- Stellar populations within bars ($R > 4000$)
- Stellar bars ($R > 4000$)
- Substructure along bars ($R > 10\ 000$)
- Bars in low-SB and dwarf galaxies ($R > 10\ 000$)
- Bars at High- z
- Tunable-Filter mode to compare the energetics involved

The objects as well as target lines fit well within the science cases discussed by Michel, Roberto, Lourdes, Matthew, etc. ...