



Heidelberg Institute for
Theoretical Studies



Dark Matter Inferences From Rotation Curve Fitting

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AstroLunch Uniandes
2 de mayo de 2014

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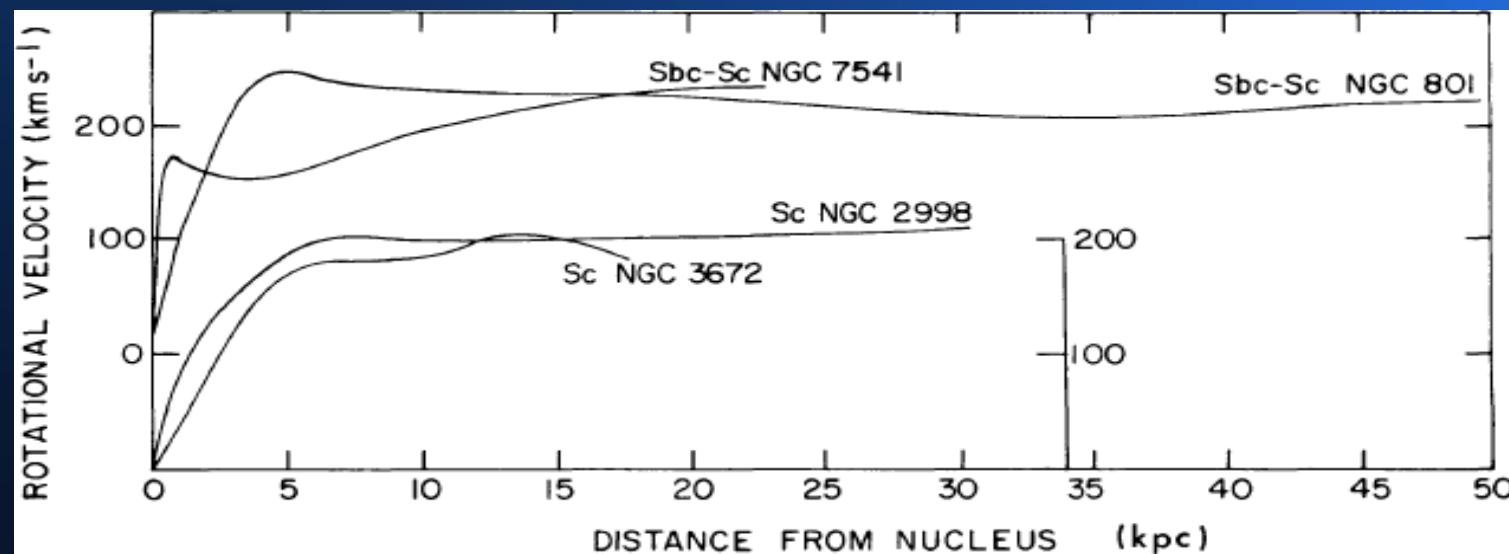
*Claudia Mendes de Oliveira (USP)



Introducción

Matéria oscura:

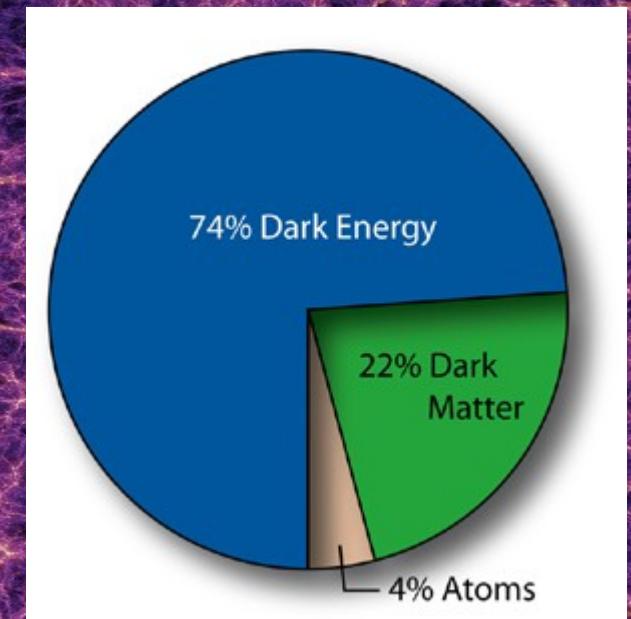
- Dispersión de velocidades en cúmulos de galaxias (Zwicky 30's)
- Curvas de rotación planas en galáxias espirales (Rubin 80's)



Introducción

Modelo de concordancia cósmica:

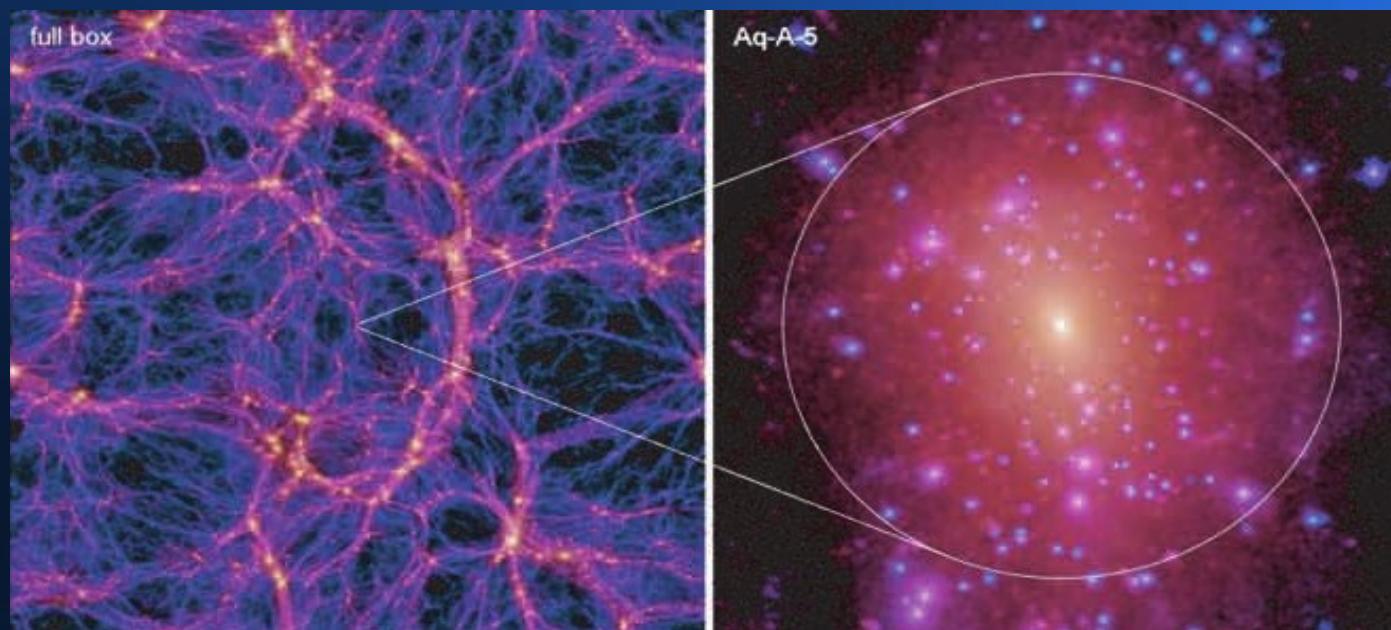
- Espectro de potencia de la CMB
- Lentes gravitacionales (cúmulos de galaxias)
- Oscilaciones Acústicas de los bariones (BAO)
- Supernovas Ia
- Simulaciones de formación de estructura



Introducción

Problemas de las simulaciones!

- Missing Satellites
- Too big to fail
- The cusp/core problem



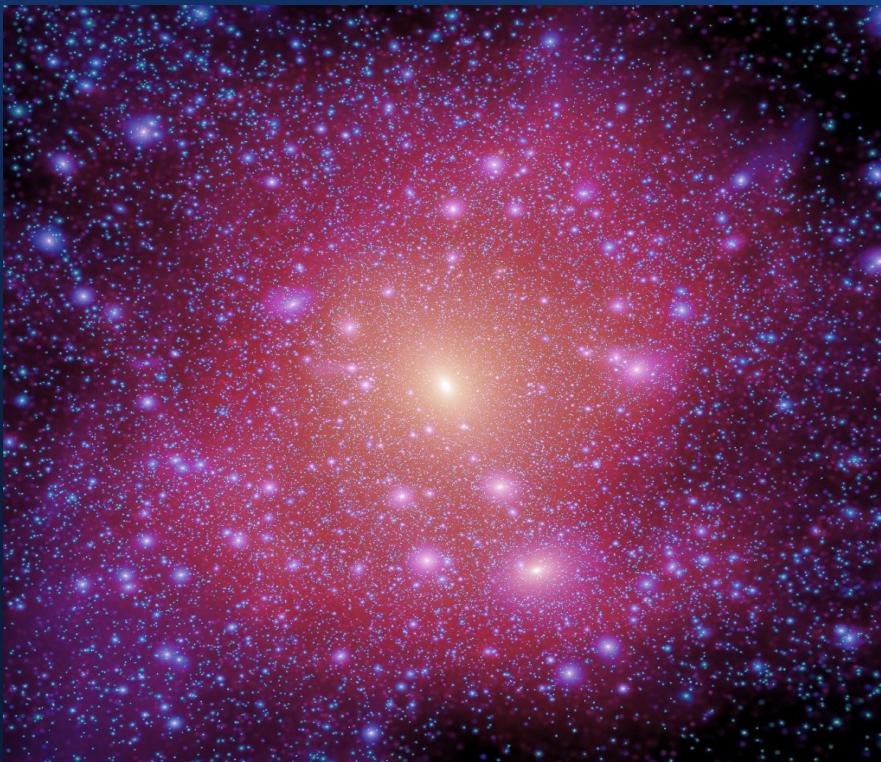
Simulación Aquarius (Springel et.al, 2008)

El problema cusp/core

- Simulaciones/ Λ CDM → Perfil de Navarro, Frenk White (NFW)

$$\rho_{inner} \propto r^{-1}$$

$$\rho(r) = \frac{\rho_0}{(r/R_0)[1 + (r/R_0)]^2}$$



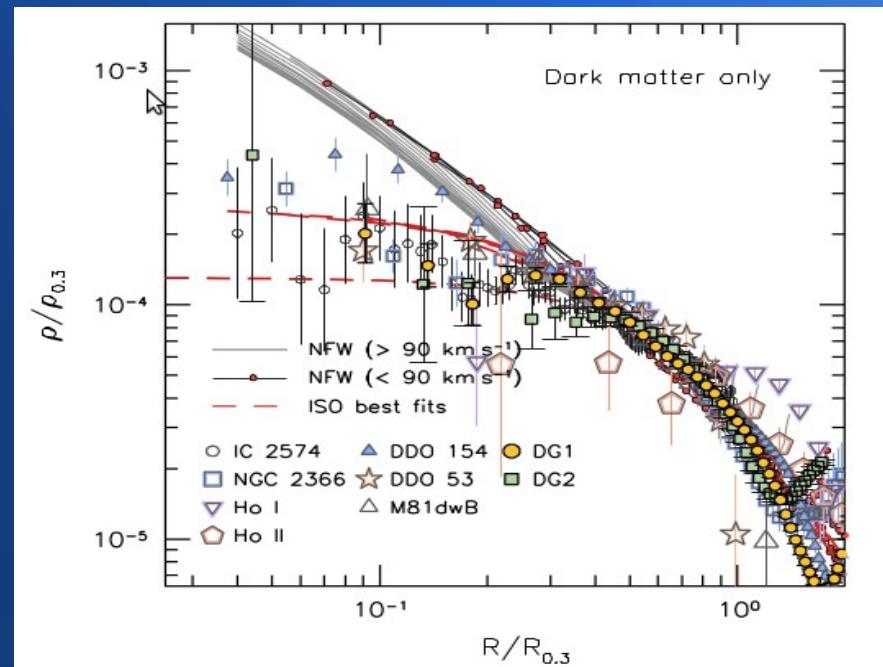
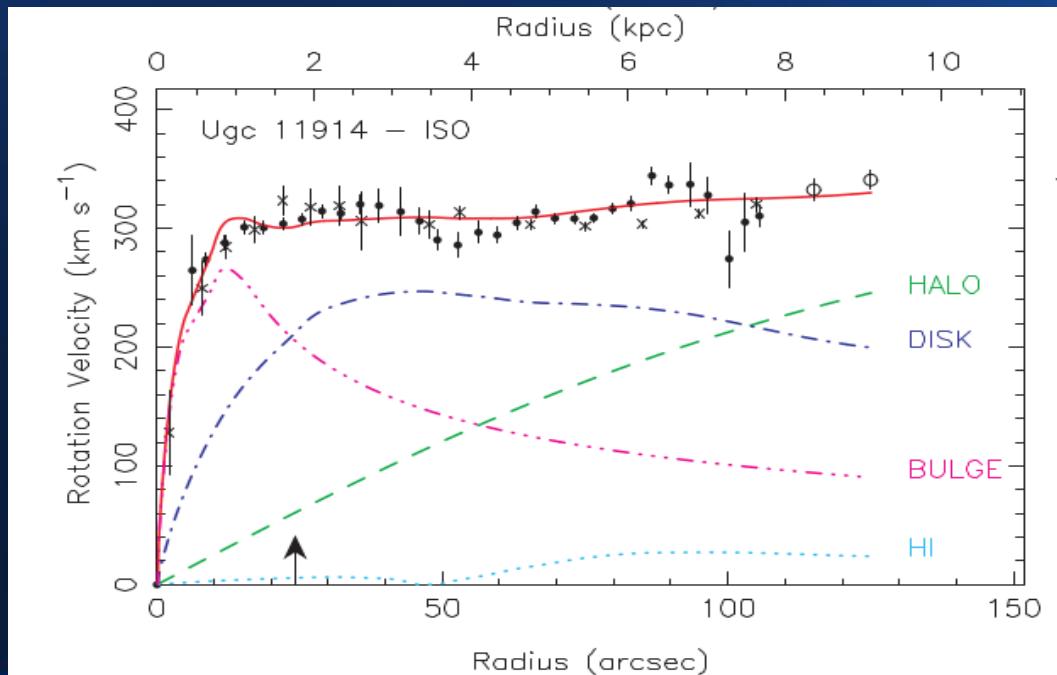
Simulación Aquarius (Springel et.al, 2008)

El problema cusp/core

- Ajuste de curvas de rotación → ~perfil de Esfera pseudo-isotérmica

$$\rho(r) = \frac{\rho_0}{[1 + (r/R_0)^2]^{3/2}}$$

$$\rho_{inner} \propto r^0$$



Spano et.al, 2008
Oh et.al, 2011

El problema cusp/core

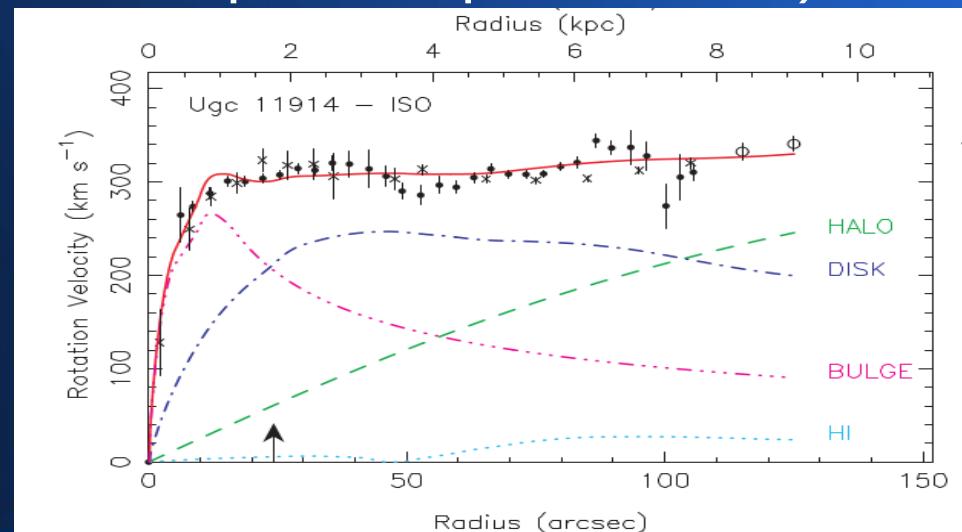
Simulaciones Vs Observaciones

- Errores sistemáticos? (Inclinación ; Beam Smearing ; Long slit errors Vs Mapas de Velocidade 2D)
- Falta de simetría en las distribuciones de luz/velocidad
- Triaxilidad de los halos?
- Física incompleta en las simulaciones?
- Interacción DM – Barions? (Stellar/AGN feedback)

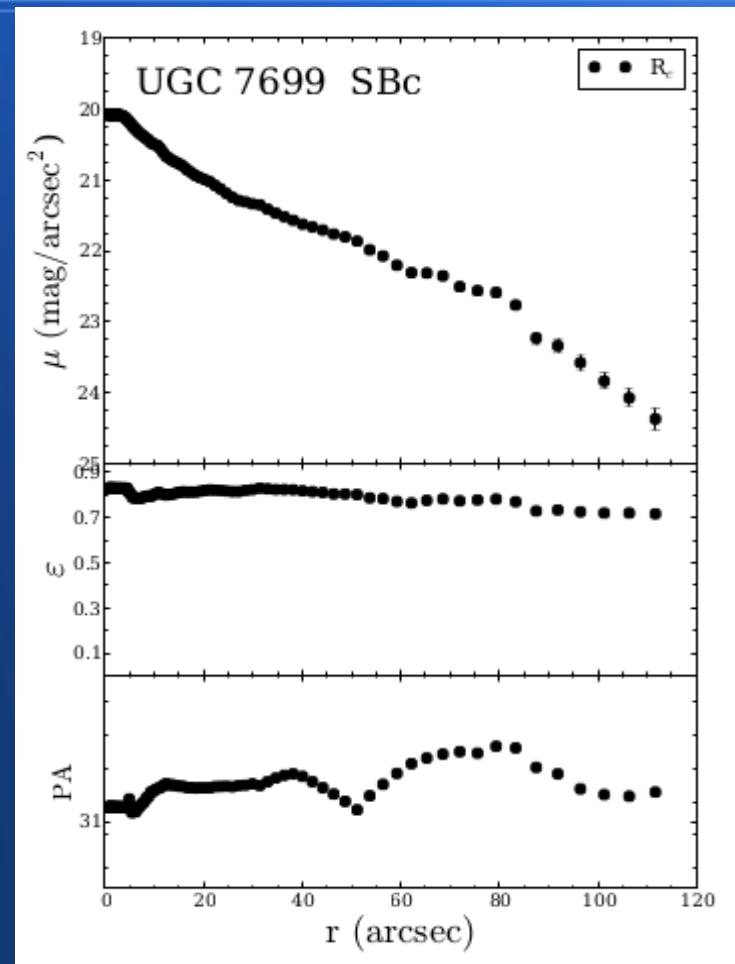
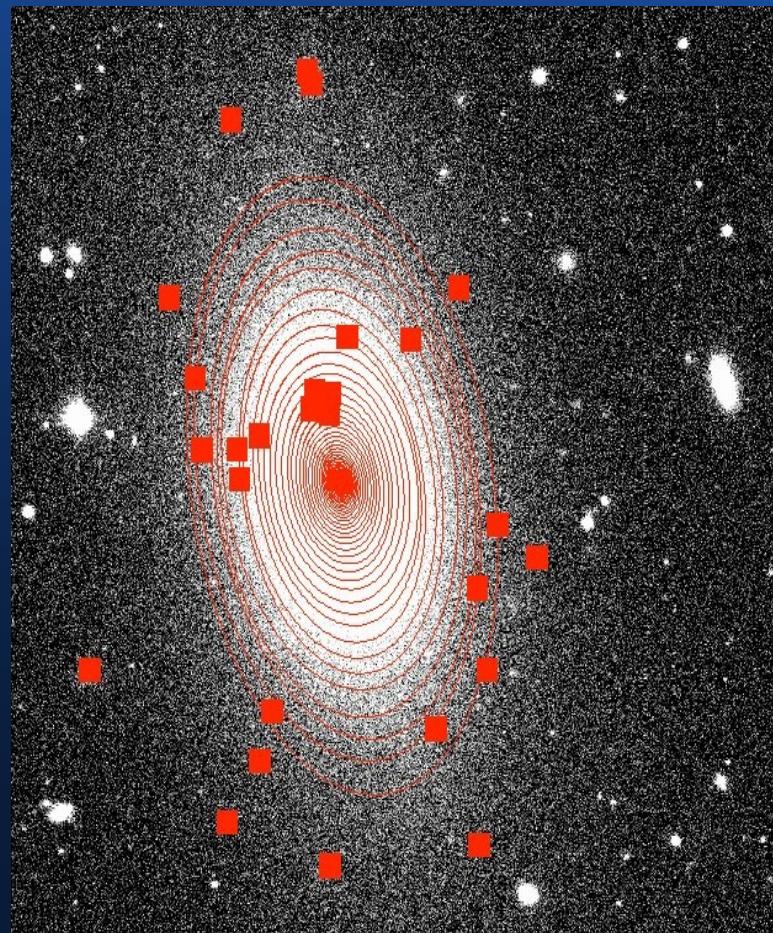
Ajuste de curvas de rotación

- Vel. de rotación es invertible al pot. gravitacional
- Sistema = suma de comp. geométricas axysimétricas
- $$V_c^2 = V_{bulge}^2 + V_{disc}^2 + V_{HI}^2 + V_{halo}^2$$
- Mismo centro para todas
- Equilibrio dinámico (disco soportado por rotación)
- Massa-Luminosidad

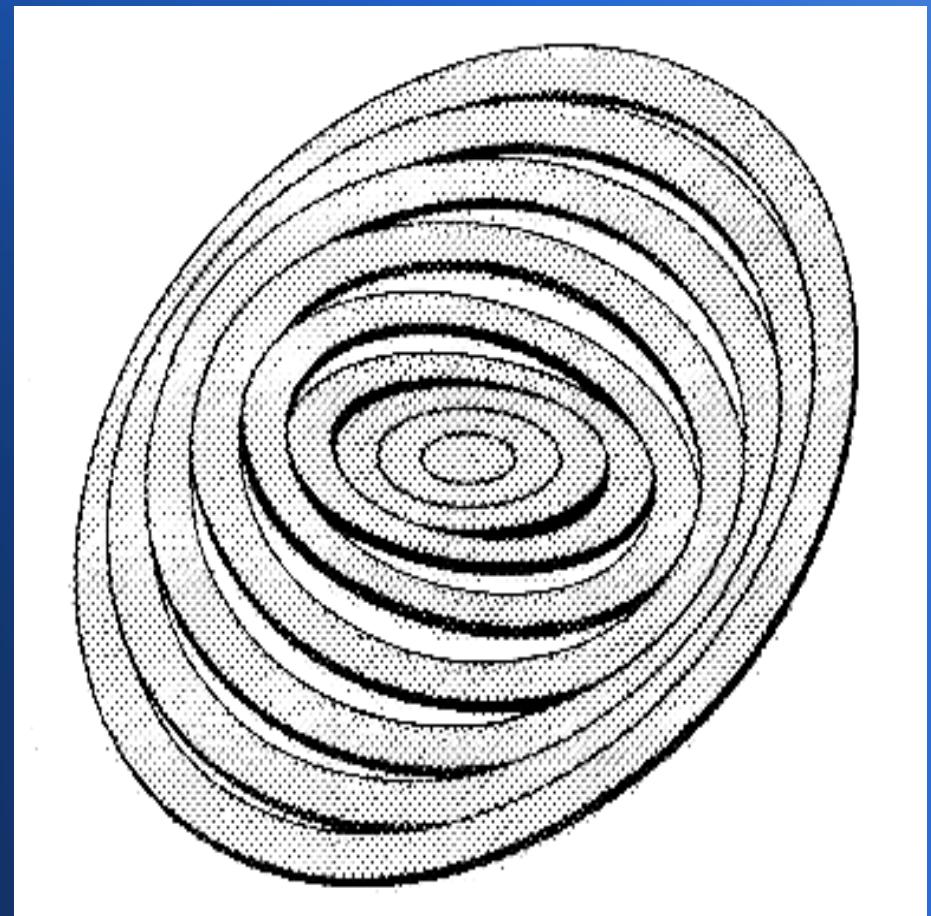
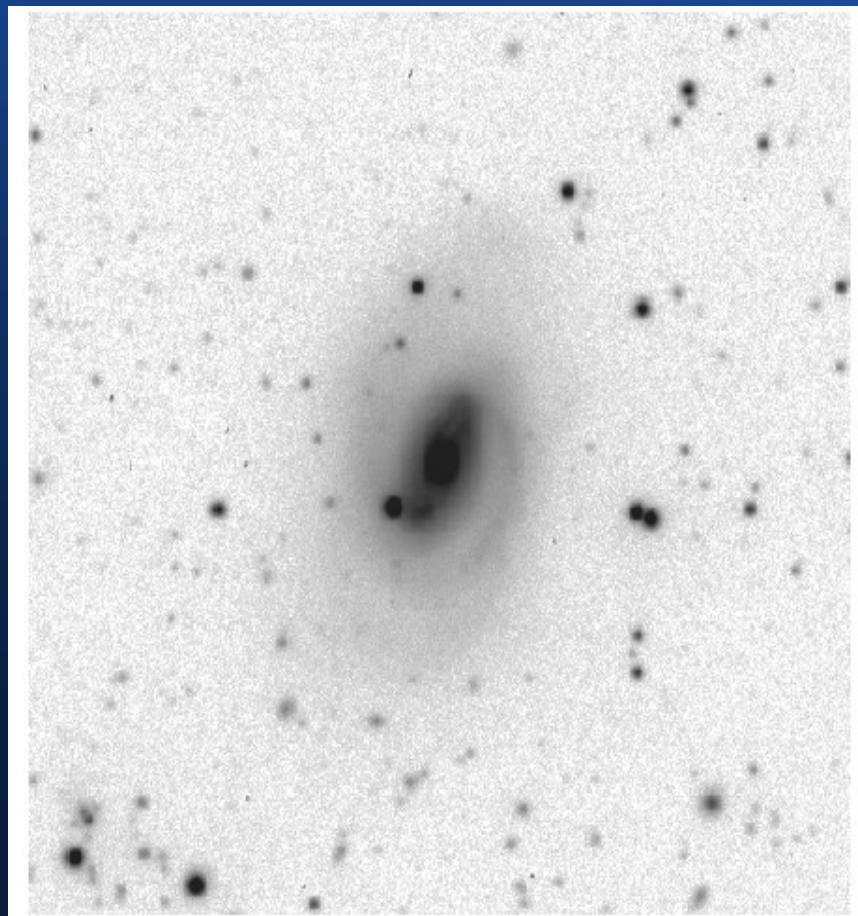
$$V_c(r) = \sqrt{-\nabla\phi \cdot r}$$



Ellipse fitting



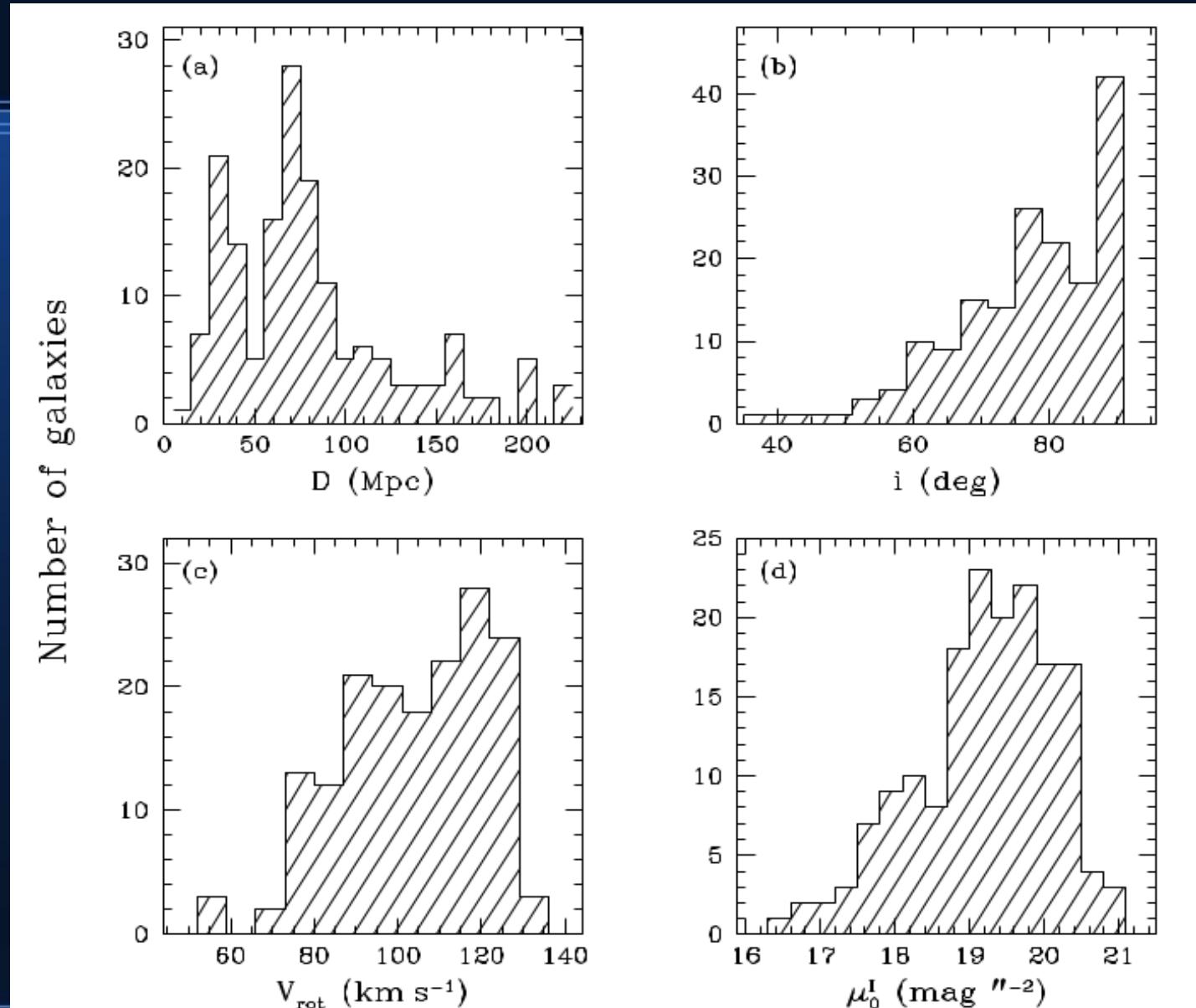
Ellipse fitting



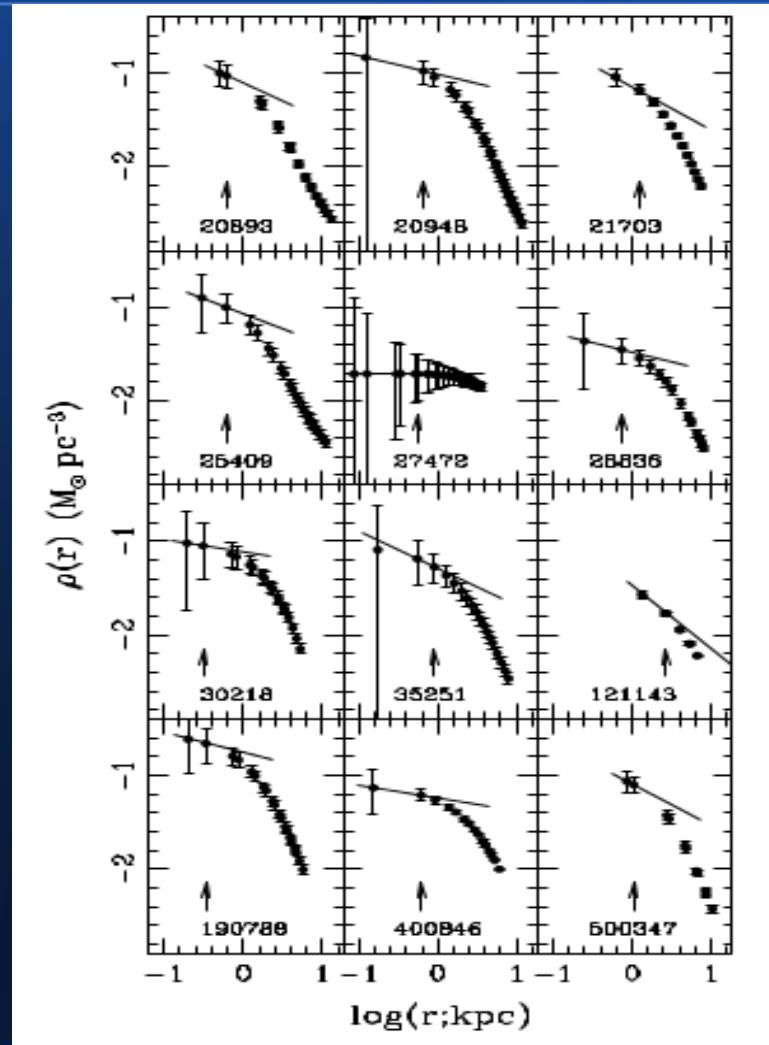
Muestra de galaxias utilizadas

- Low Surface Brightnes (LSB) y Espirales enanas son preferidas
- Sin embargo hay ejemplos de Espirales normales (Salucci, 2001; Spano, 2008) y galáxias con Bulbos (Kassin, 2006; Barnes, 2004)

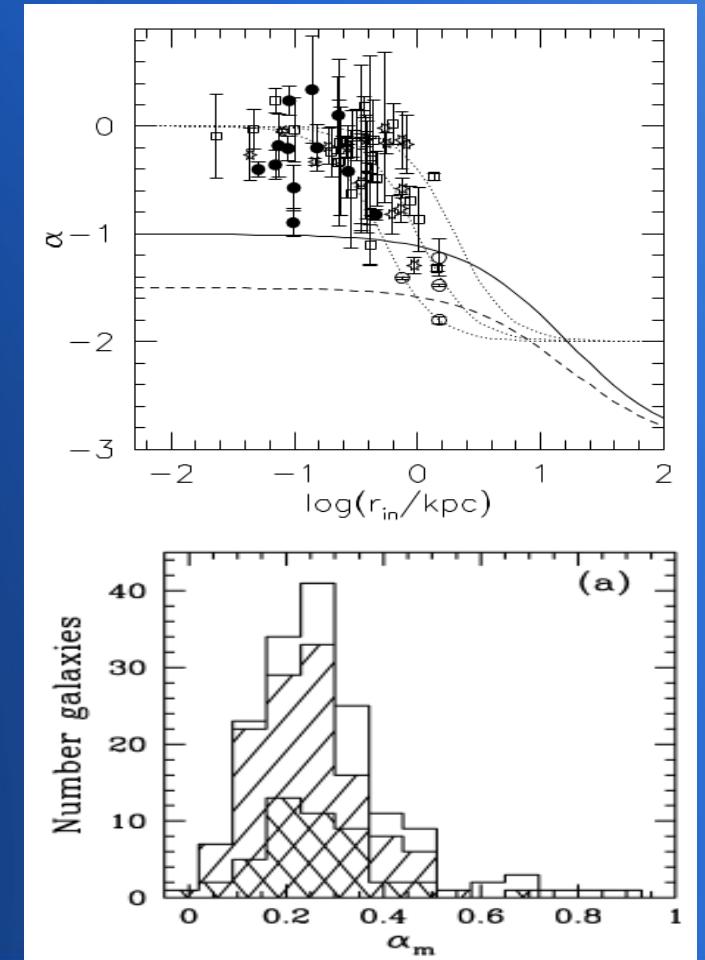
Distribución de propiedades



Pendiente del perfil de densidad en la región central

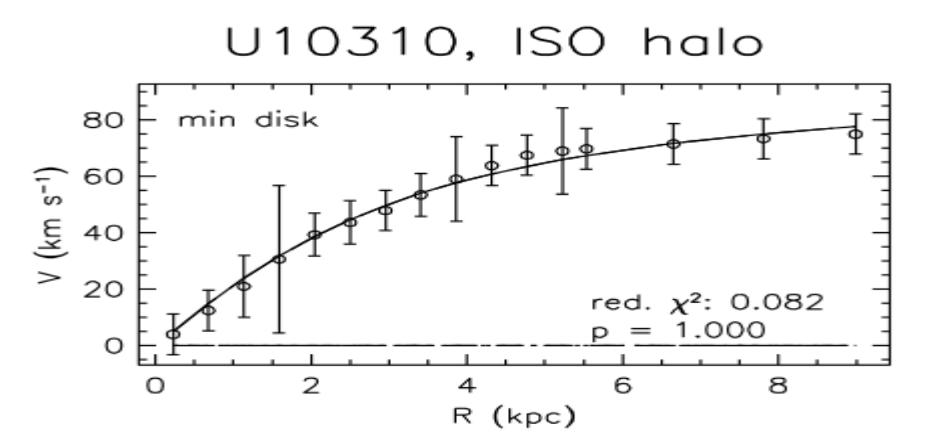
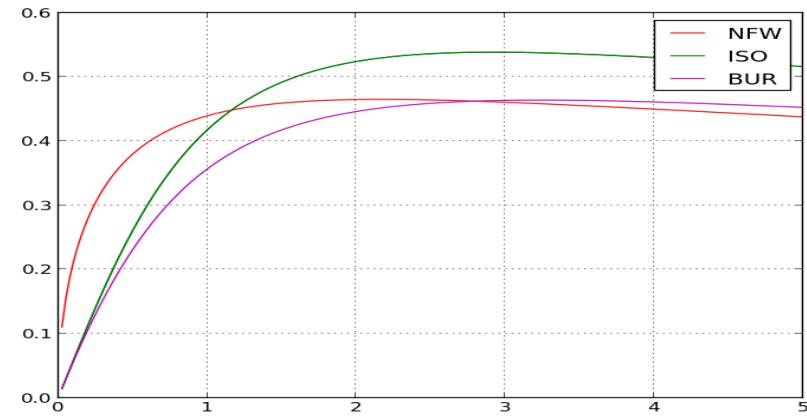
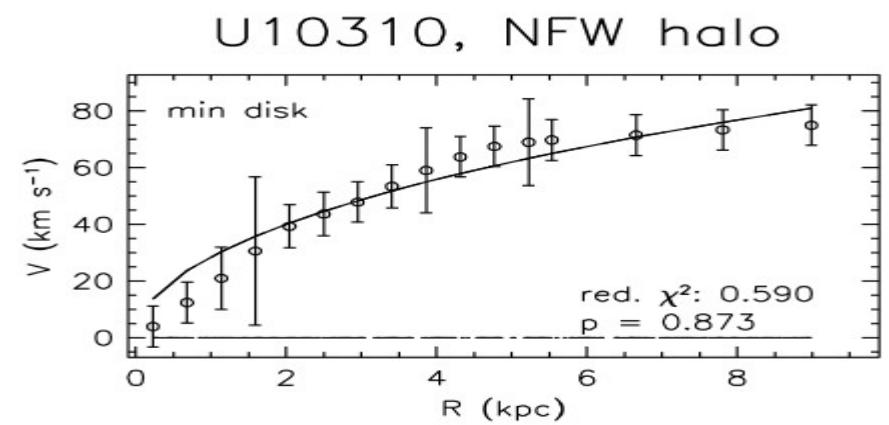
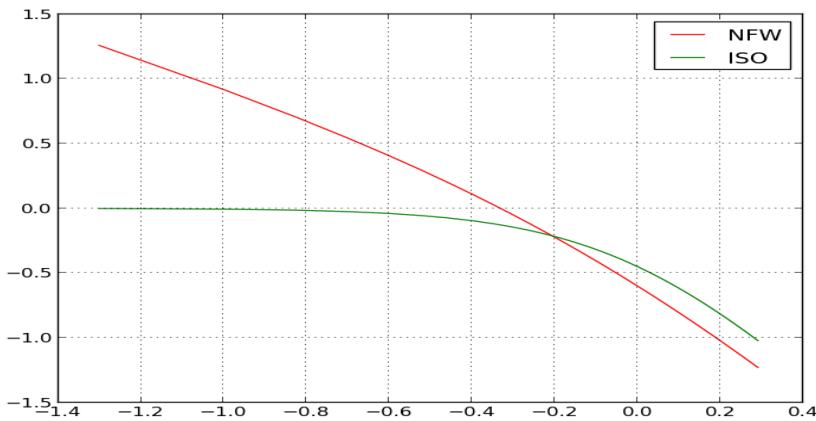


$$4\pi G \rho(r) = 2 \frac{v}{r} \frac{\partial v}{\partial r} + \left(\frac{v}{r} \right)^2$$

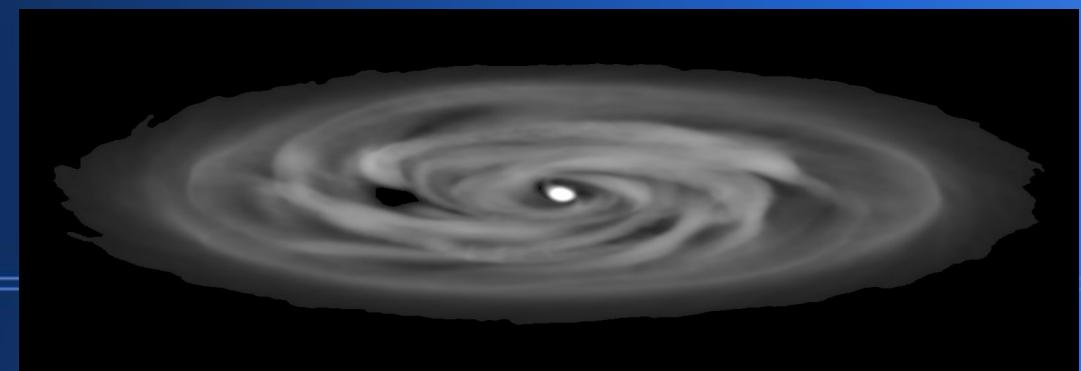
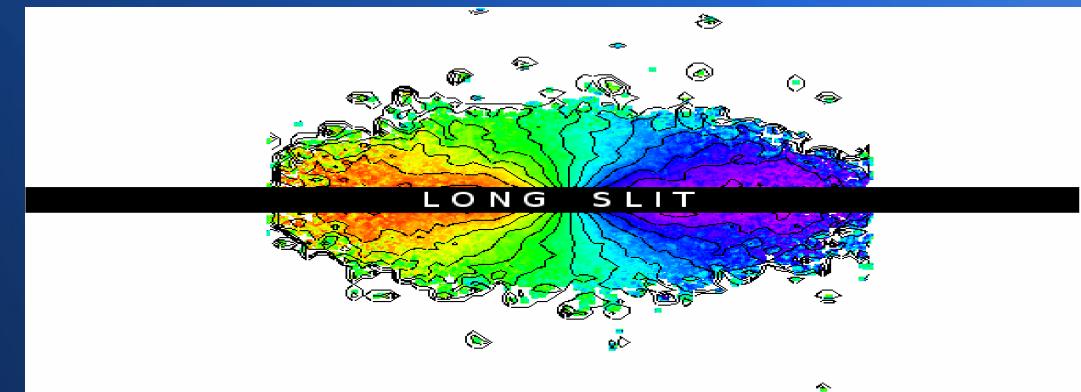
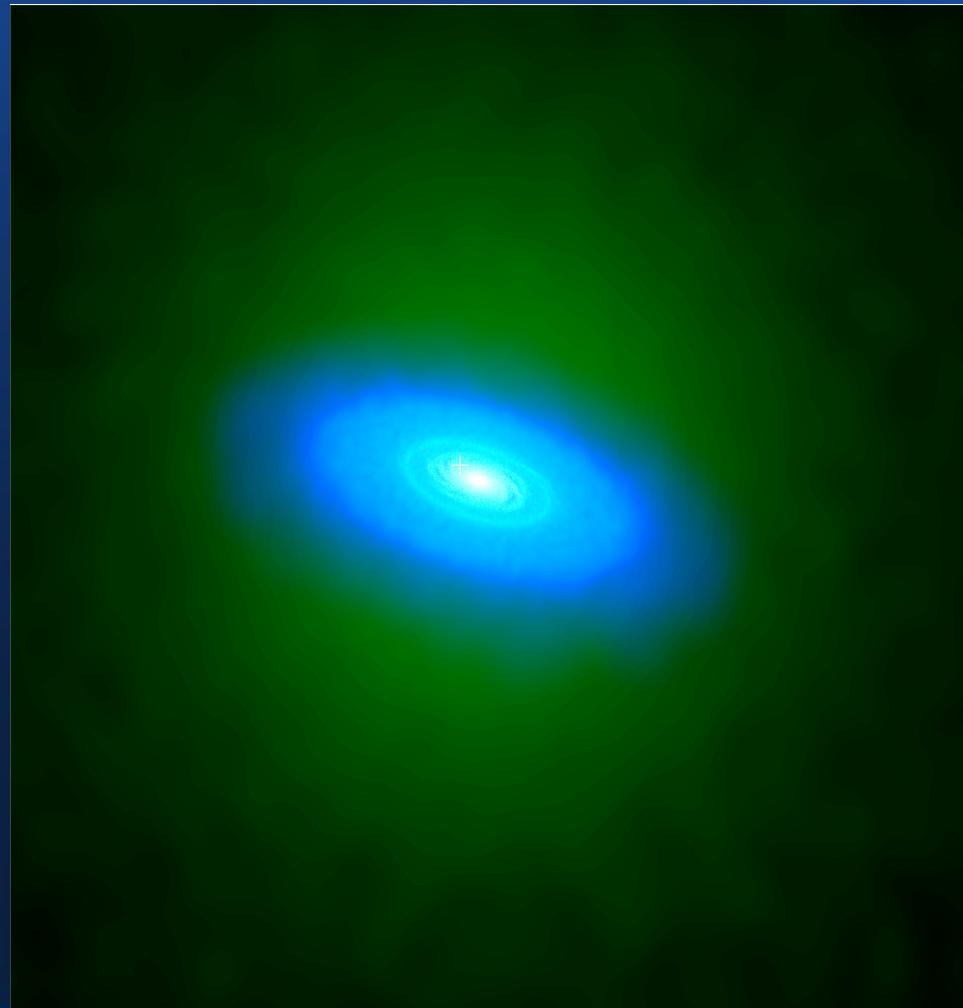


Spekkens et.al, 2005
de Blok & Bosma 2002

Cusps Vs Cores



Estrategia: Observaciones Simuladas



Simulaciones

Galaxy parameters

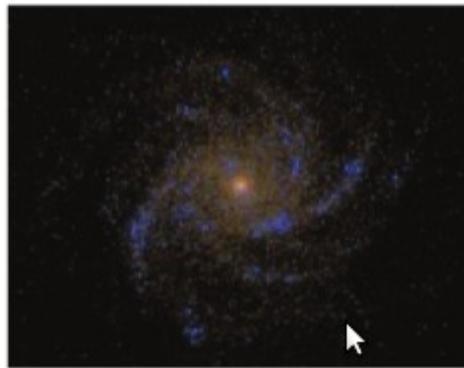
Model	Mtot ($10^{10} M_{\odot}$)	M _★ ($10^{10} M_{\odot}$)	h ₀ (kpc)	z ₀ (kpc)	M _{gas} ($10^{10} M_{\odot}$)	h _{gas} (kpc)	f _{bulge}	V _{rot} (km/s)	c
Sbc+	92.8	7.5	7.0	0.9	8.1	21	0.1	210	12
Sbc	81.2	4.9	5.5	0.7	5.4	16.5	0.1	195	11
Sbc-	36.0	2.4	4.0	0.5	2.6	12.0	0.1	155	8
G3	116	5.0	2.8	0.4	1.2	8.4	0.14	192	6
G2	51.0	1.5	1.9	0.4	0.5	5.7	0.08	139	9
G1	20.0	0.5	1.5	0.3	0.2	4.5	0.04	103	12
G0	5.1	0.1	1.1	0.2	0.1	3.3	0.01	67	14

- Código SPH GADGET3 (Springel, 2005)
- Propiedades de las Sbc: Roberts & Haynes, 1994; de Jong 1996; Broeils & Van Woerden, 1994
- Propiedades de las G's: Shen 2003; Bell 2003

Simulaciones

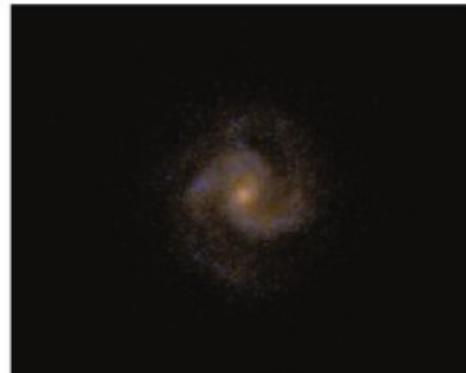
Galaxy

0°

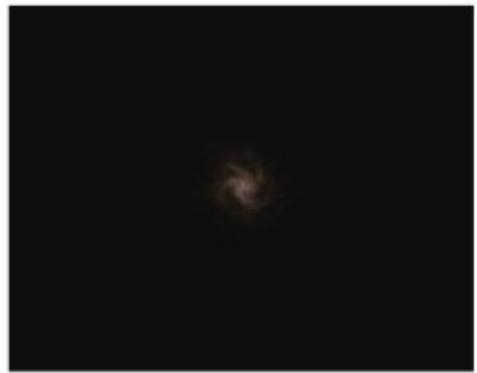


Sbc+

G3

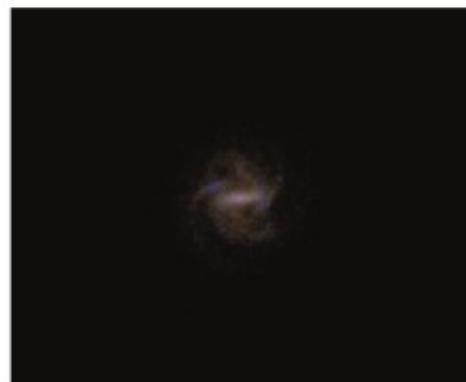


G1

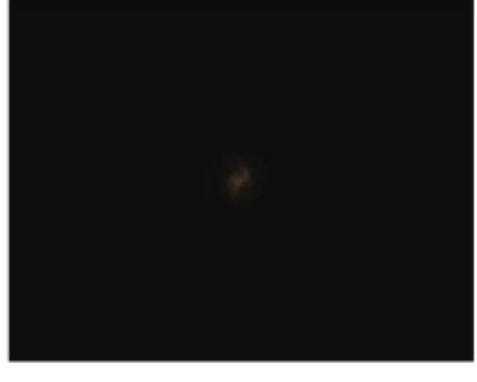


Sbc

G2



G0



Sbc-



Jonsson, 2010

Imágenes artificiales con SUNRISE

(Jonsson, 2006; Jonsson et.al, 2010)



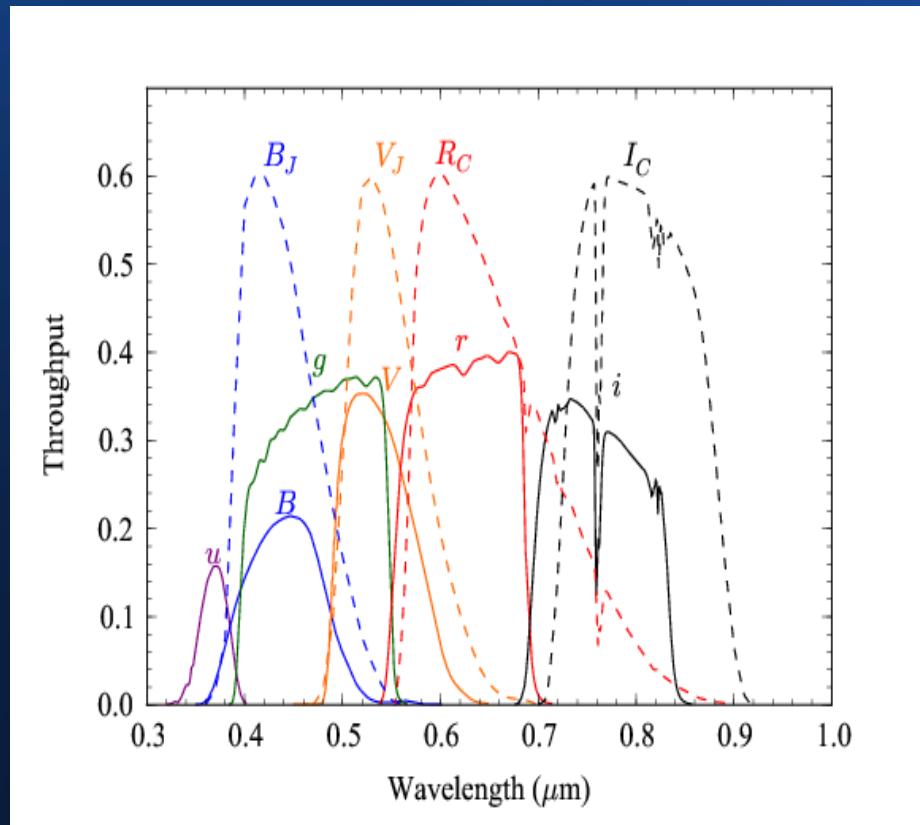
Imágenes artificiales con SUNRISE

- 1. Calcular la retícula para los cálculos de TF
- 2. Asignar edades y metalicidades a las estrellas
- 3. Calcular SED's atenuadas por la nube protoplanetaria
- 4. Efectuar cálculos de TF a través del medio interestelar
- 5. Cálculo iterativo de la temperatura del polvo
- 6. SED emergente de la galaxia para un ángulo de observación
- 7. Imágenes artificiales: Filtros (telescopio), pixel size, distancia

Imágenes artificiales con SUNRISE



Imágenes artificiales con SUNRISE



- **SDSS:**
- Pixel = 0.4"
- PSF + Ruido gaussiano típicos
- **SPITZER** 3.6 micrones:
- Pixel = 1.2"
- PSF+ruido típicos

Observaciones artificiales en HI

- Emisión en un canal:

$$\frac{\eta \cdot M_{part}}{4\pi D^2} \cdot \frac{\int_{v_{ch}-\frac{\Delta v}{2}}^{v_{ch}+\frac{\Delta v}{2}} gauss(v, v_{part}, \sigma) dv}{\Delta v}$$

- La contribución de una partícula de gas a un pixel cae con la distancia proyectada entre ellos

- **THINGS Survey :**

- Pixel = 1.5"
- Separación de canales: 5.2 [km/s]
- Beam gaussiano 12"
- No se aplicó ruido

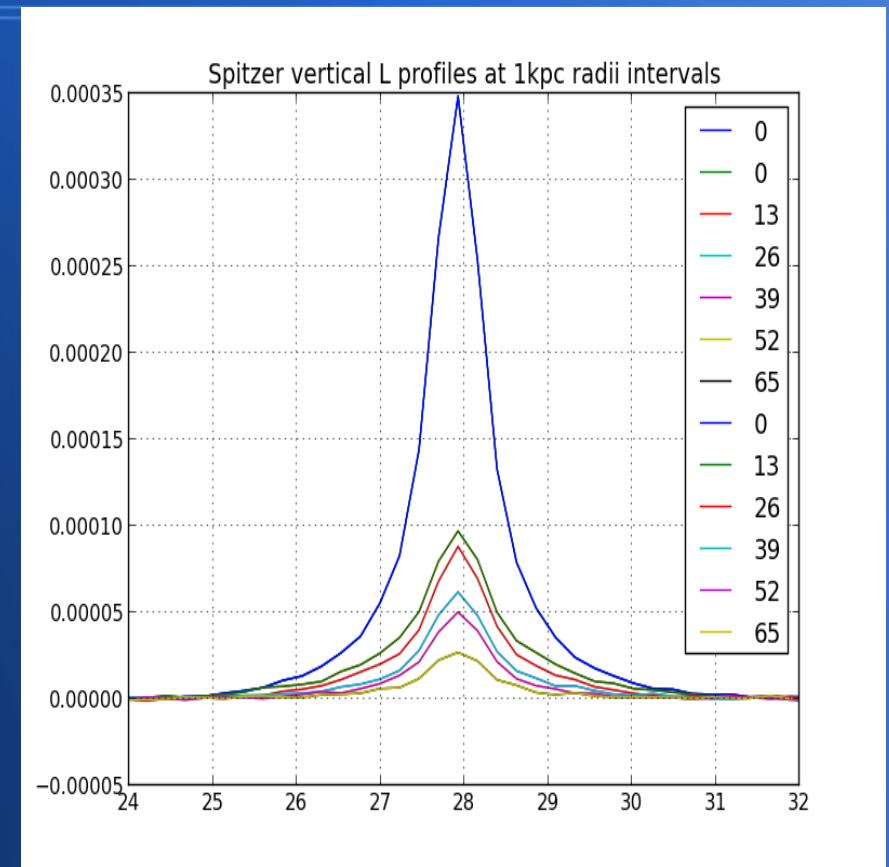
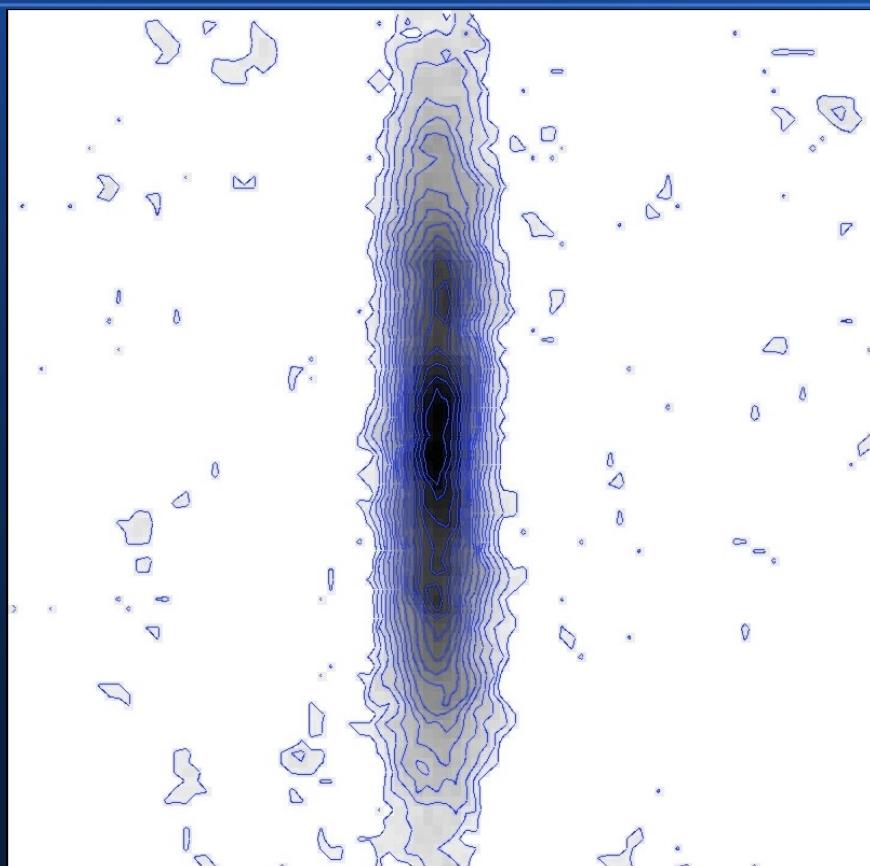
4.2. Integrated HI Maps

$$I_{HI} = \sum_i S_i \times \Delta v,$$

4.3. Velocity Fields

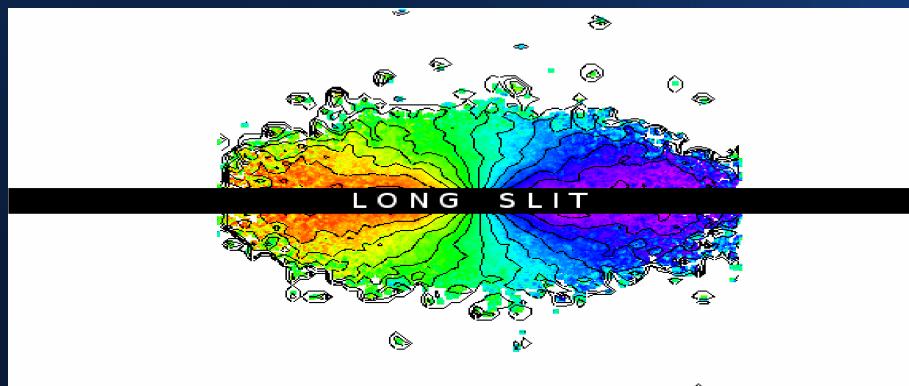
$$\langle \mathbf{v} \rangle = \frac{\sum_i S_i \times \mathbf{v}}{\sum_i S_i},$$

Observaciones artificiales en HI



Observaciones artificiales en Halpha

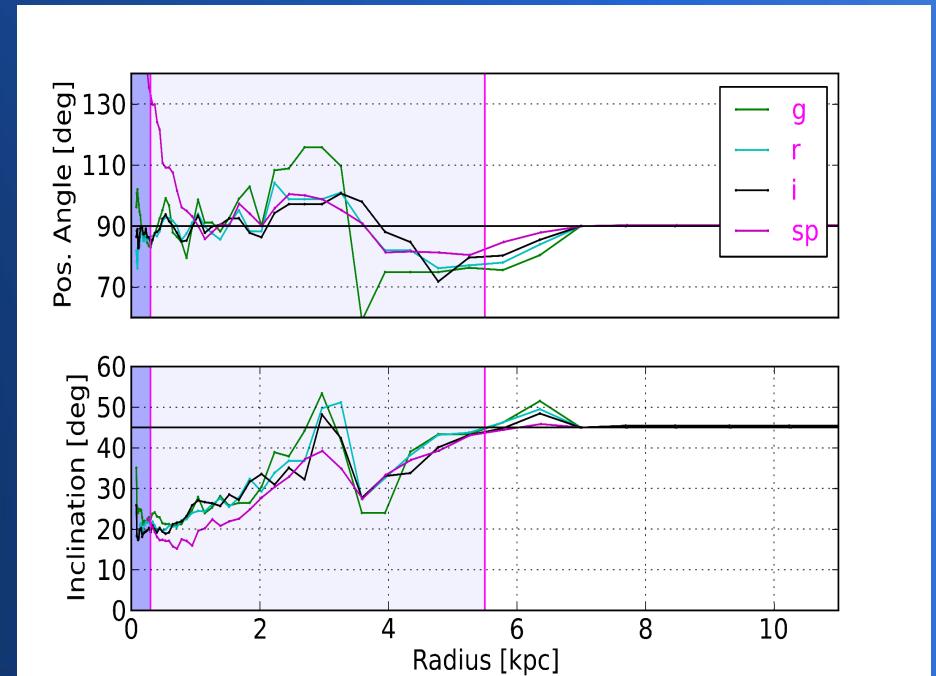
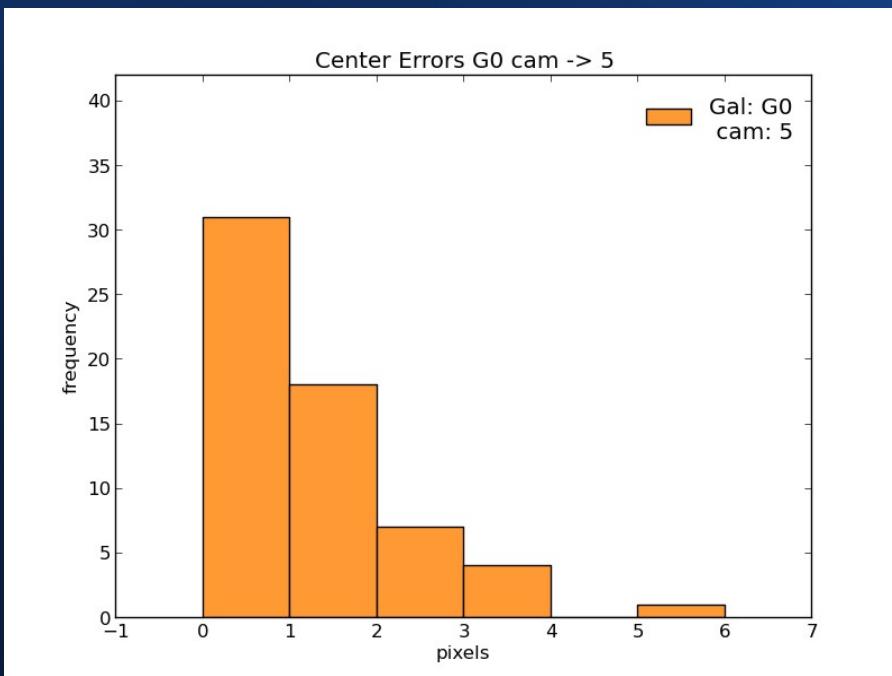
- Una diferencia fundamental entre HI y Halpha es su distribución espacial.
- Modelamos Halpha como gas con formación estelar activa



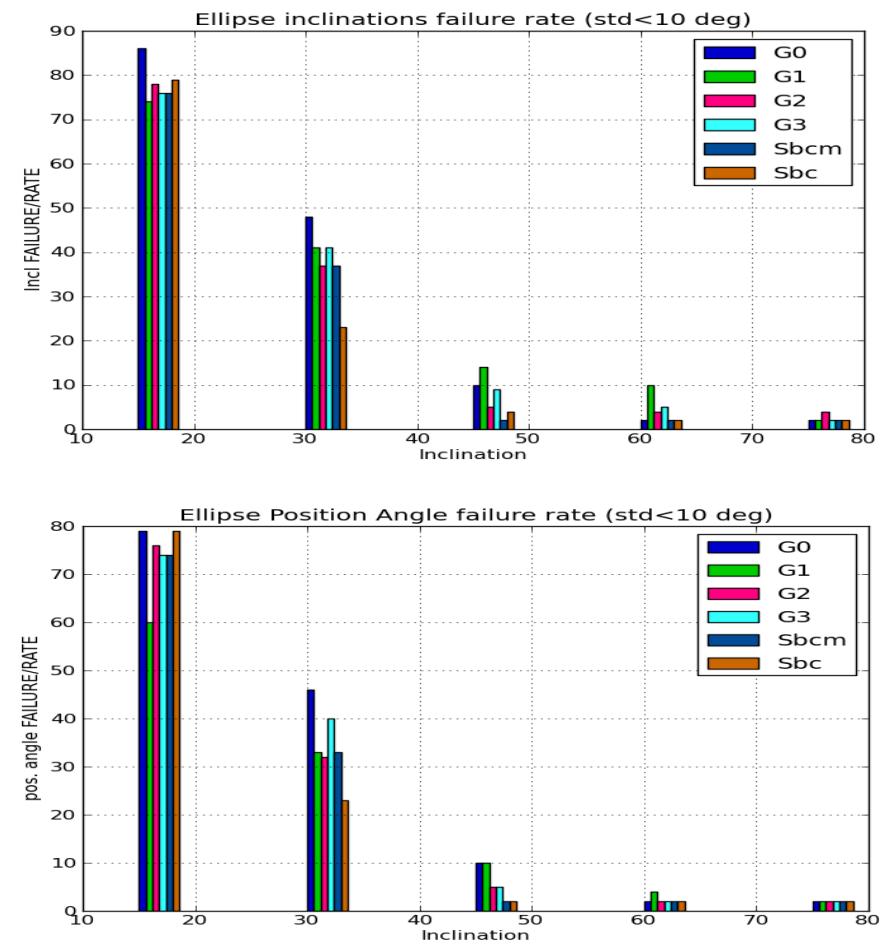
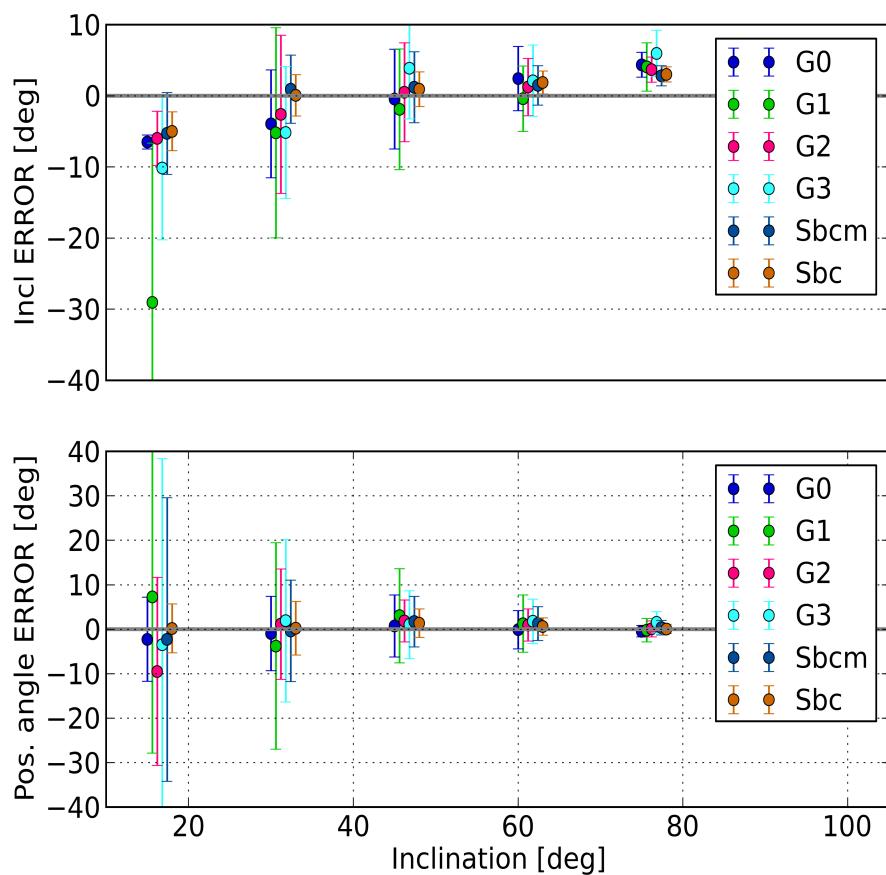
- **Valores más comunes en la literatura:**
- Pixel = 0.7"
- Separación de canales: 15 [km/s]
- Beam gaussiano 2"
- No se aplicó ruido
- Foalding and binning para el caso long-slit

Análisis: Ajuste de isofotas

- Estimativa del centro: pixel más brillante y valor medio de Isofotas Vs Verdadero Centro del potencial gravitacional:
- Parámetros geométricos

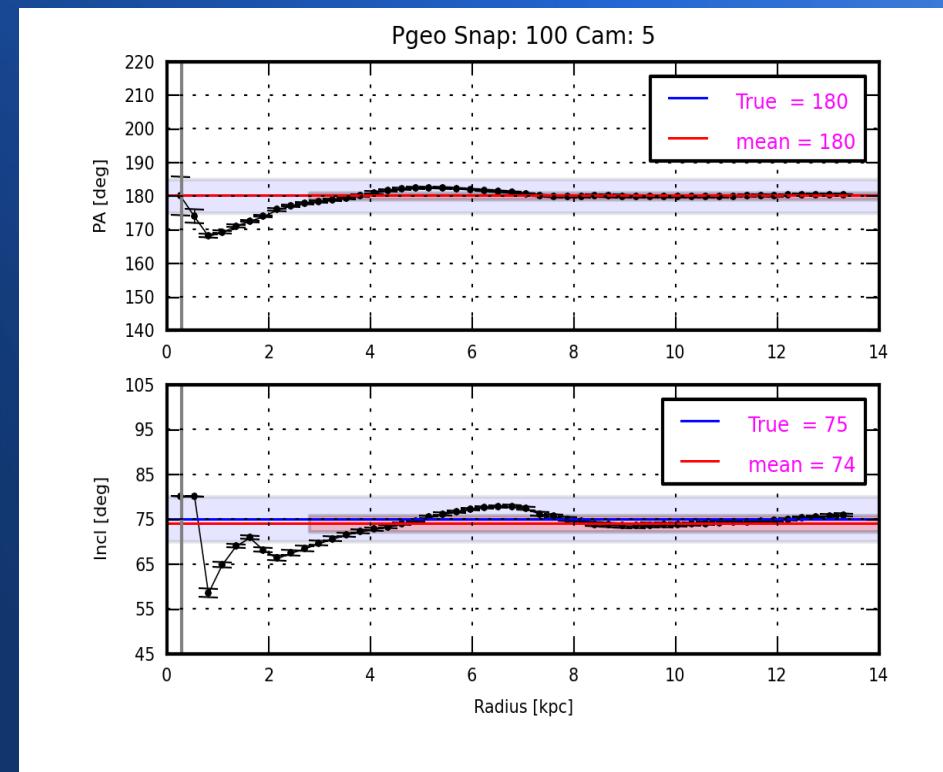
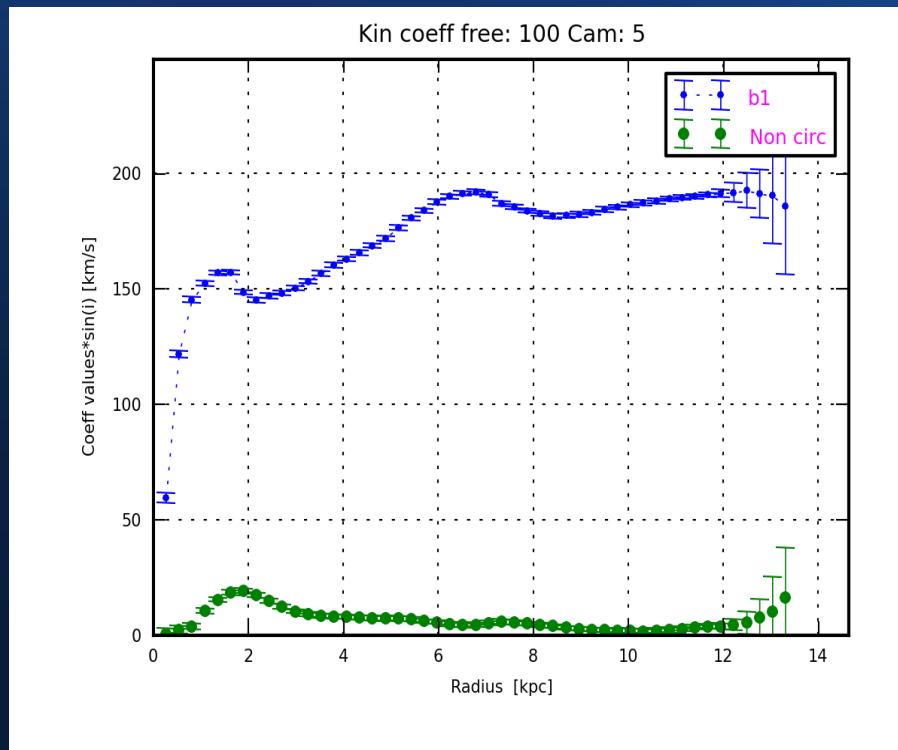


Análisis: Ajuste de isofotas



Análisis: Mapas de Velocidad con Kinometry

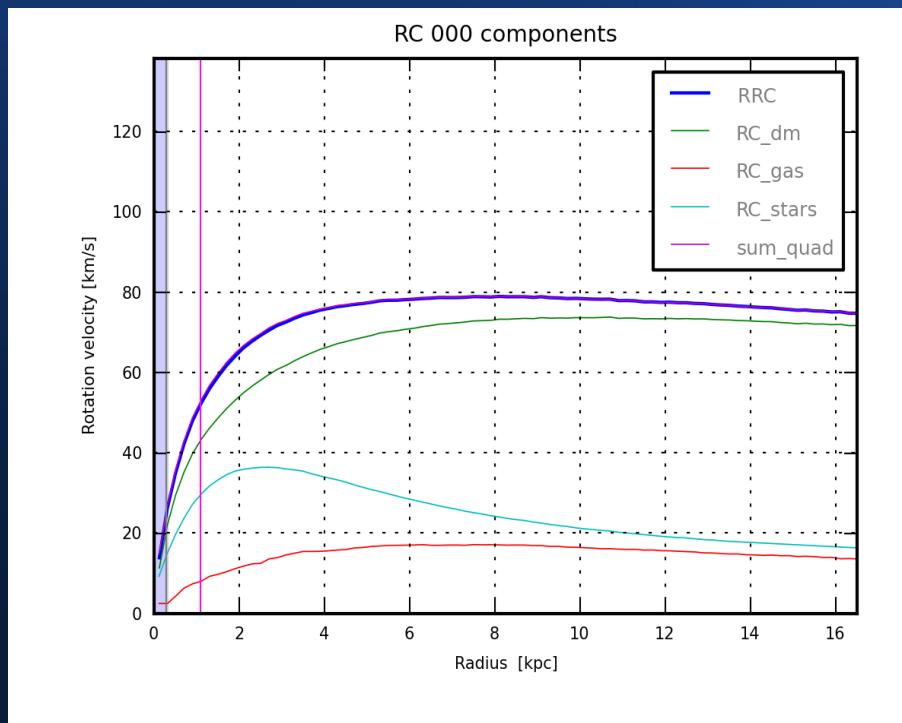
$$V_{los} = V_{sys} + V_{circ} \sin(i) \cos(\theta) + V_{exp} \sin(i) \sin(\theta)$$



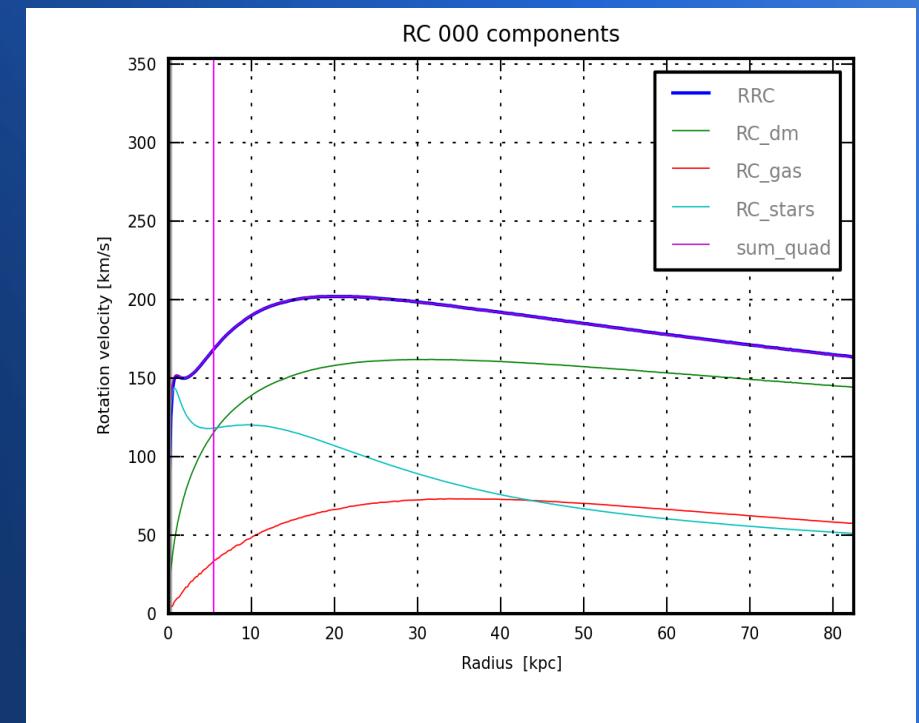
Comparación de las curvas de rotación

$$V = \sqrt{-\nabla\phi \cdot r} = \sqrt{-a_r \cdot r}$$

• G0

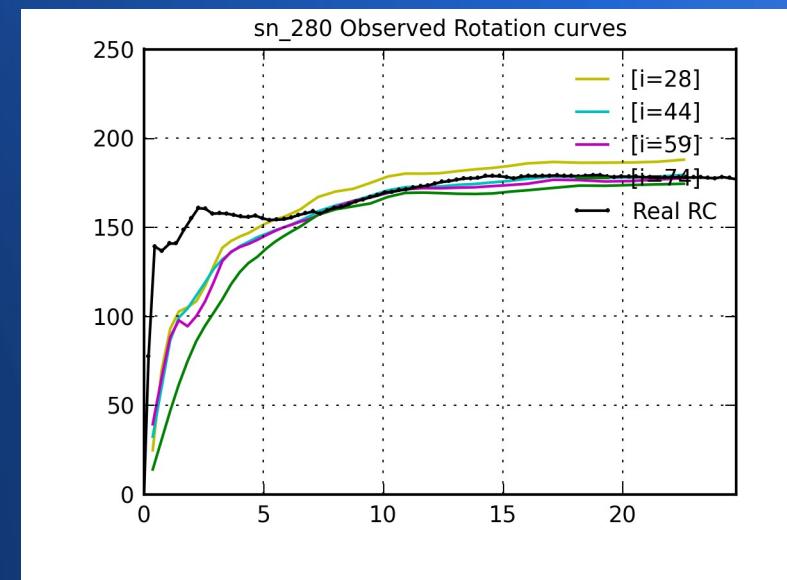
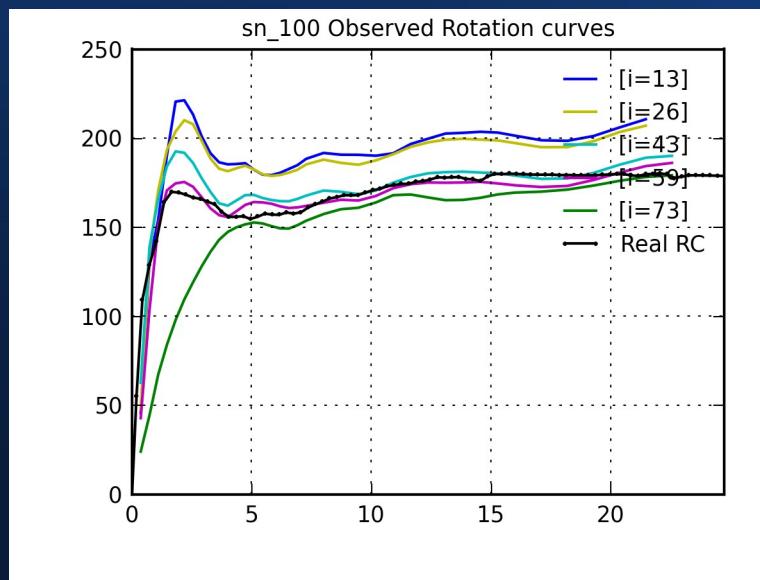


• Sbcm



Comparación de las curvas de rotación HI

- Disk Thickening?? Efecto de la barra??
- G3. Snapshot 100 (10 Mpc)
- G3. Snapshot 280

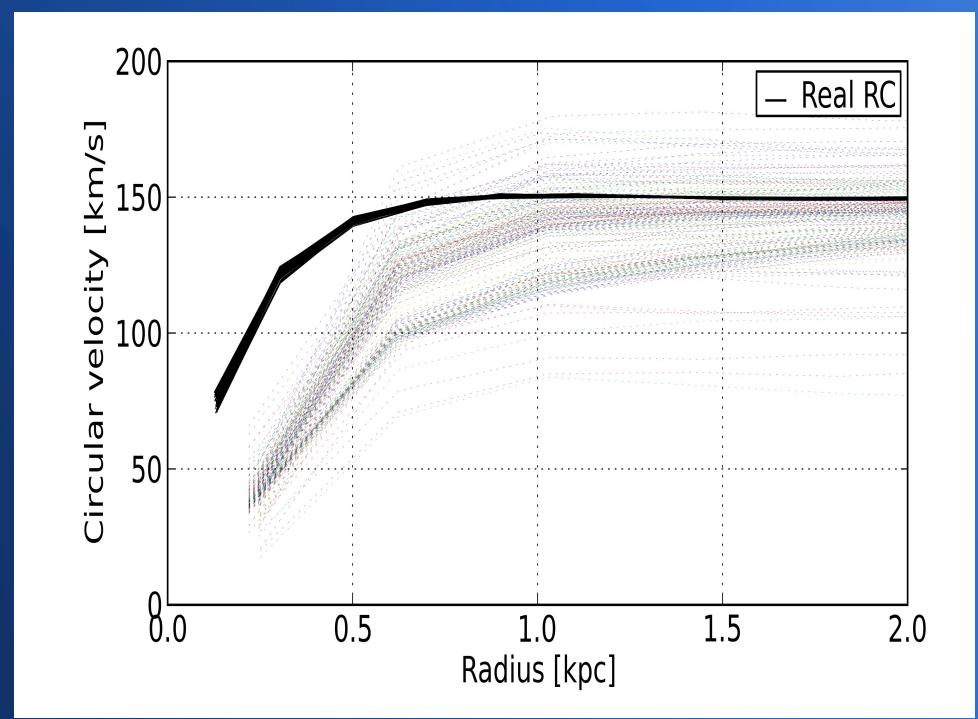
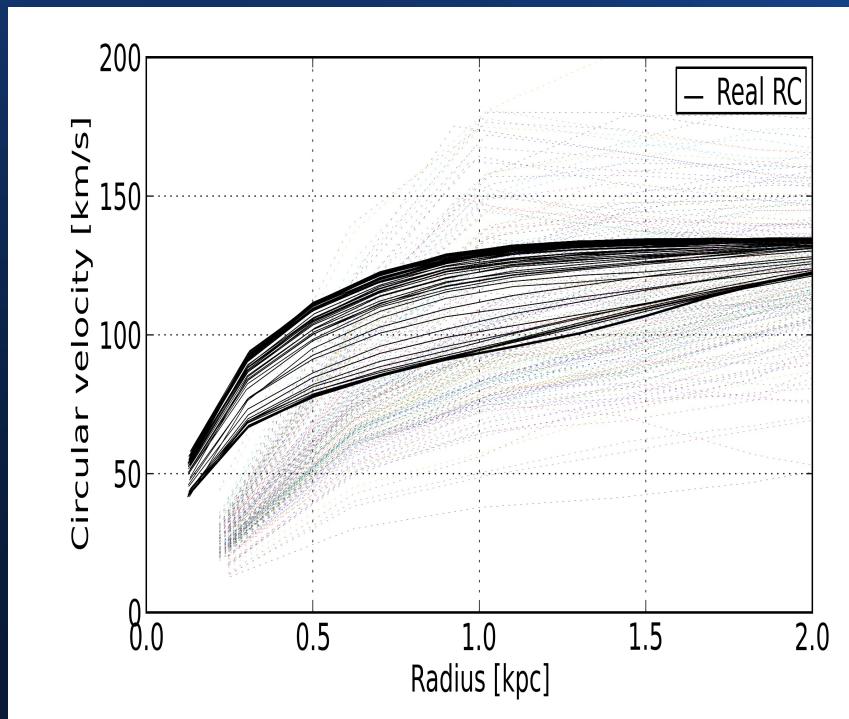


Comparación de las curvas de rotación Halpha

- Real RC Vs RC Observada: No coinciden!!!

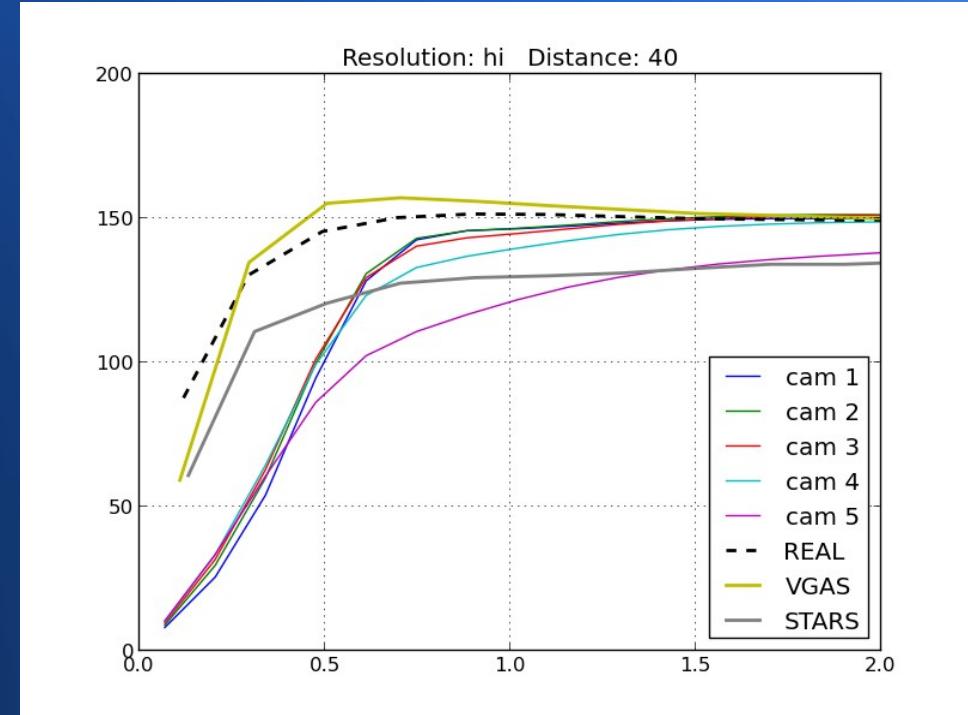
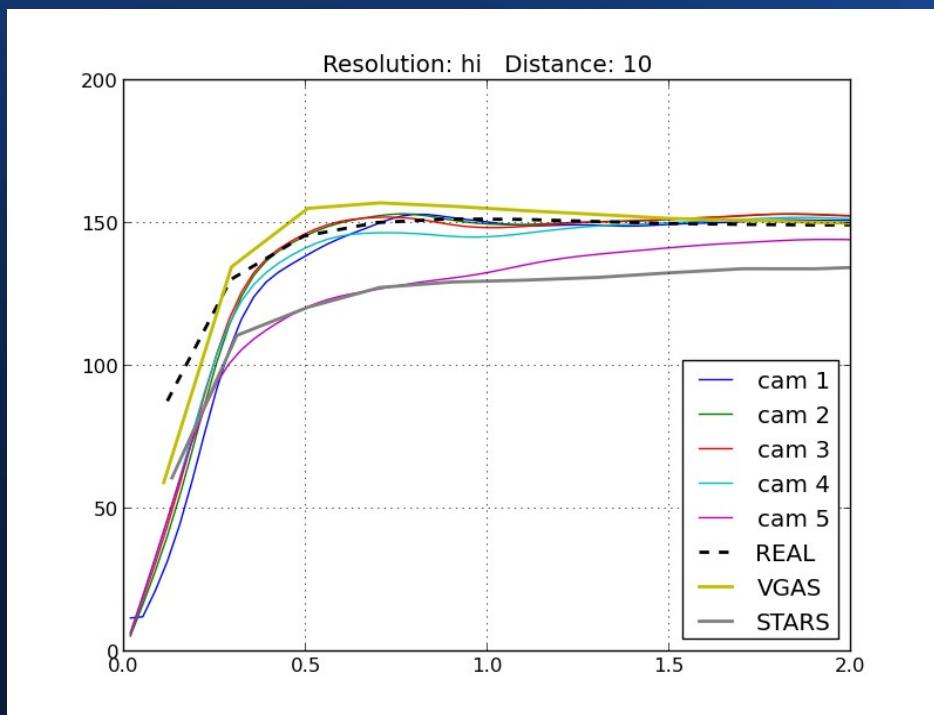
- **G2 (40 Mpc)**

- **Sbcm (40 Mpc)**



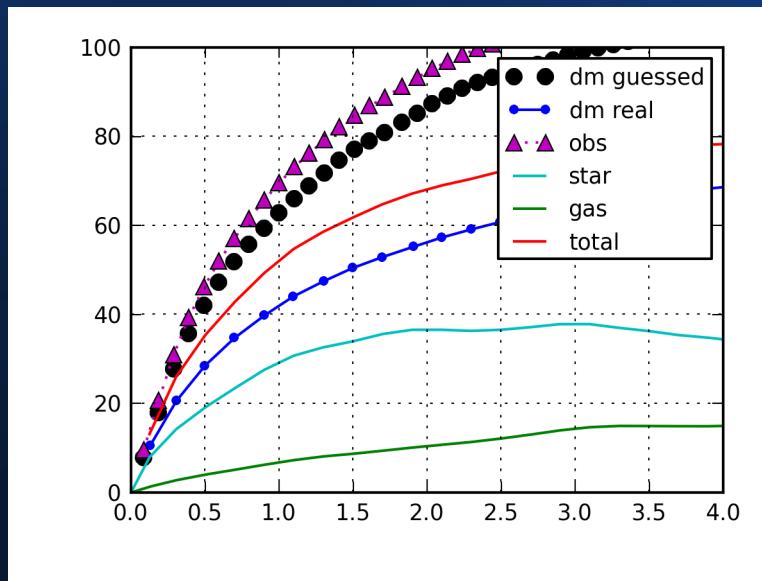
Comparación de las curvas de rotación Halpha

Dependencia con la distancia: Beam Smearing!!!

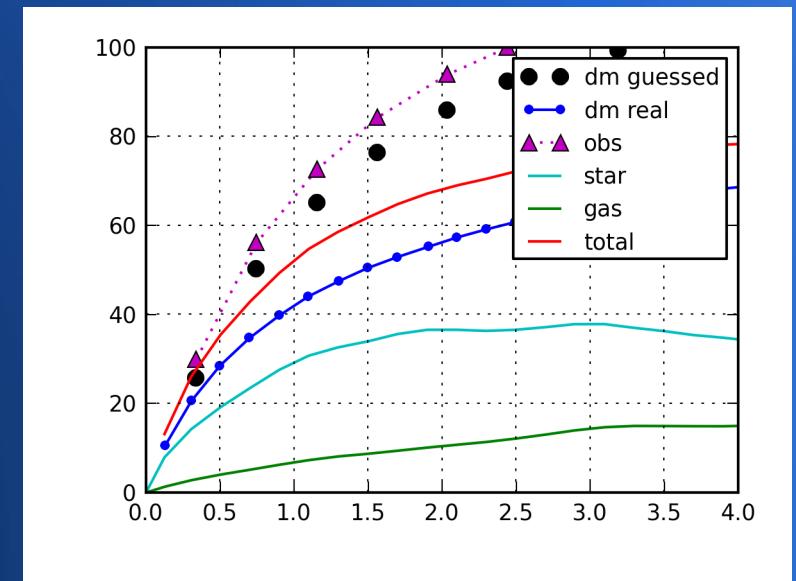


Comparación de las curvas de rotación

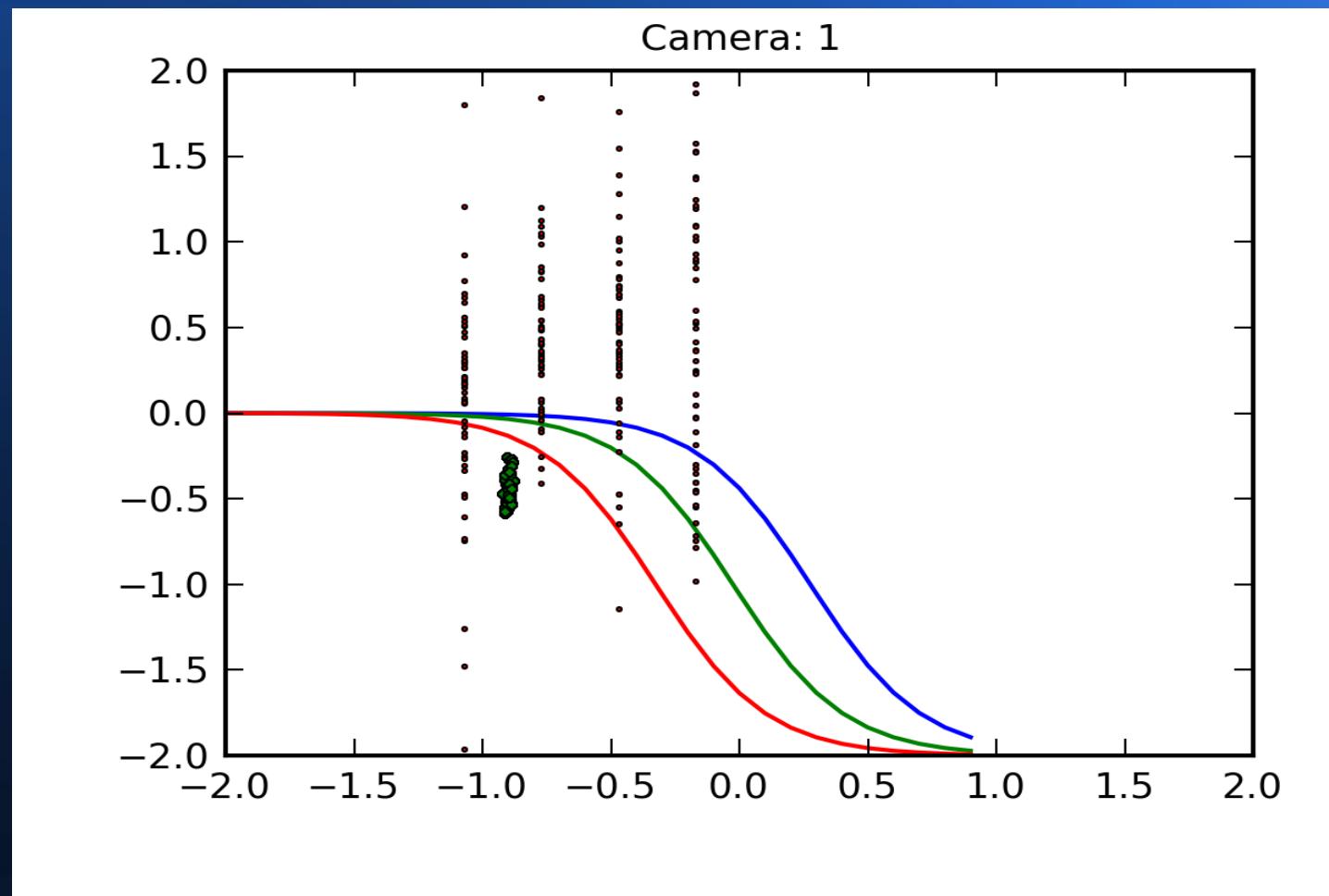
- G0 (10 Mpc)



- G0 (40 Mpc)

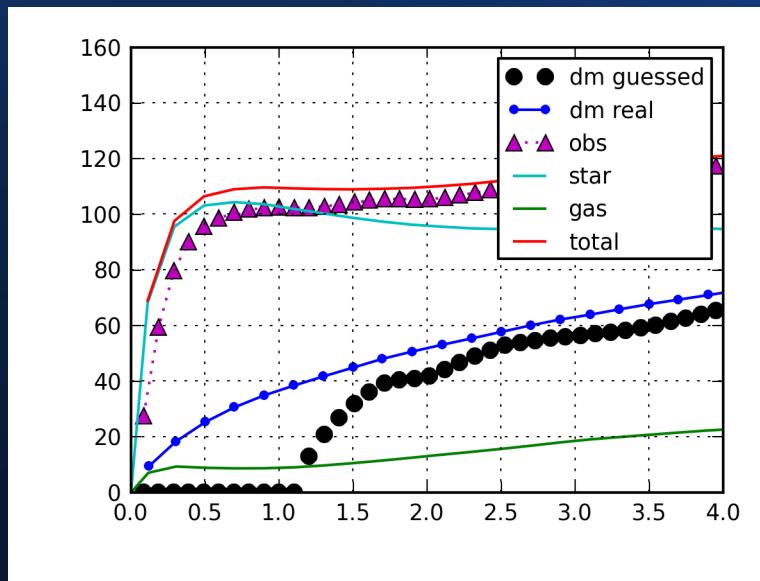


Pendiente del perfil de densidad en la región central

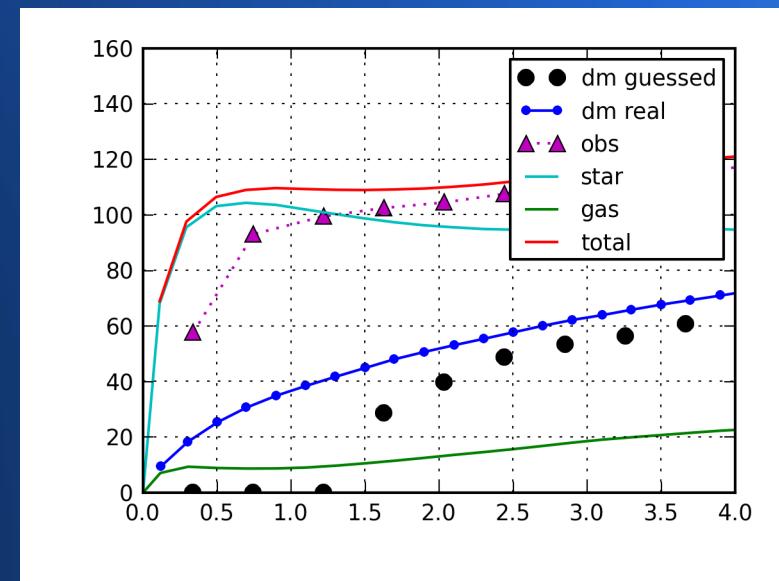


Comparación de las curvas de rotación

- Sbcm (10 Mpc)



- Sbcm (40 Mpc)





A vibrant, colorful illustration featuring a rainbow arching across the top left, a large yellow star with a face on a green planet, a blue planet with a yellow spiral, a pink mountain with a yellow star, and a small green plant in the foreground.

¡Gracias!