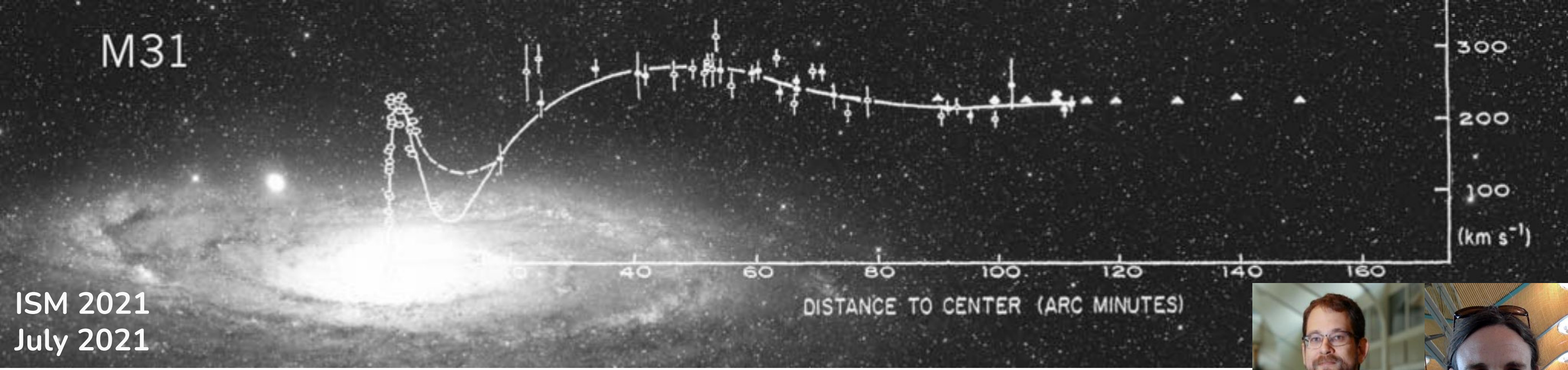
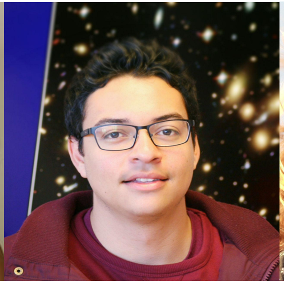


MEASURING ROTATION CURVES AND MASS PROFILES IN NEARBY GALAXIES


Adam Leroy
Annie Hughes

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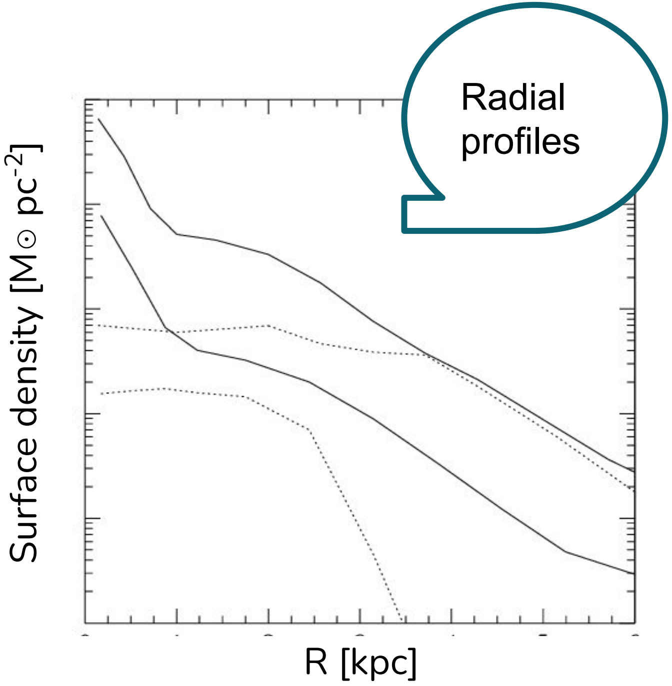
Main goals - part 1

- **Radial distribution of stars and cold gas in nearby disk galaxies**
  - Derive mass radial profiles from integrated intensity maps (Moment 0) for:
    - Stars from NIR data
    - Atomic gas from HI 21 cm line
    - Molecular gas from CO(2-1) line
- **Where does the transition from atomic (HI) to molecular (H_2) gas happen?**



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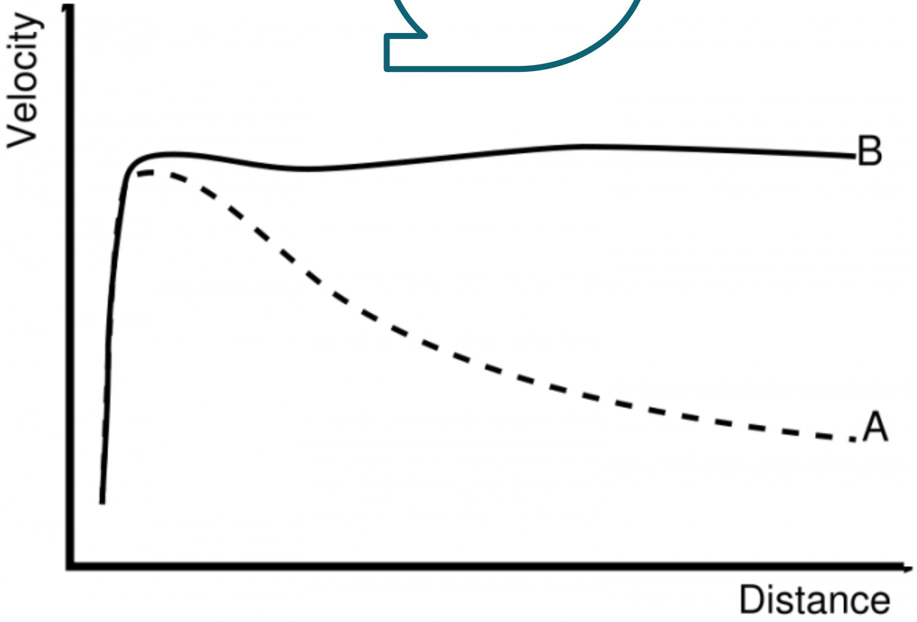
Main goals - part 2

- **Extract the gas kinematics**
  - Extract rotation curves from the recessional velocity maps for:
    - Atomic gas using HI 21 cm line
    - Molecular gas using CO(2-1) line
- **Additionally**
  - Learn and develop tools to achieve our goals (see the Summary slide)
    - python, astropy, SpectralCube, numpy

Rotation curve



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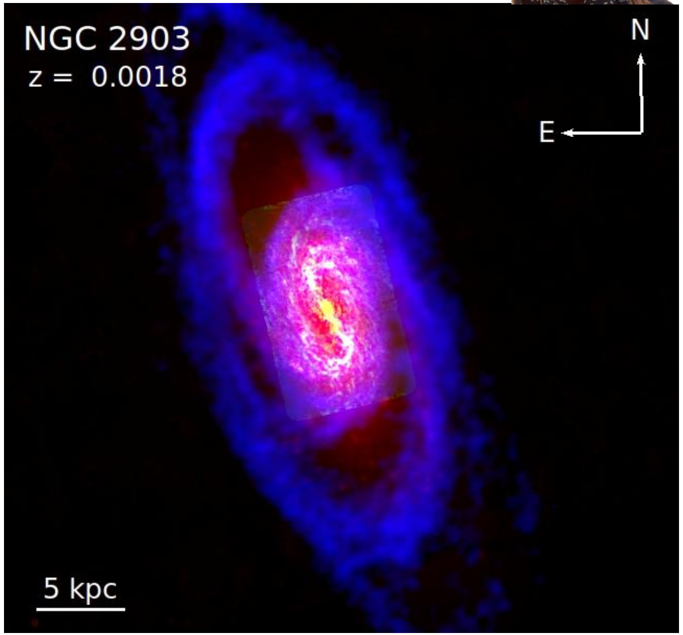
Data description - emission maps and velocity fields

1. Integrated HI map (Moment 0) & velocity field (Moment 1):
   - Observed in VLA-THINGS survey (Walter et al. 2008)
   - Moment 0/ 1 units: Jy $beam^{-1}$ m s^{-1} / m s^{-1}
2. CO(2 $\rightarrow$ 1) Integrated intensity map (Moment 0) & Velocity field (Moment 1):
   - Measured by PHANGS-ALMA survey (Leroy et al. 2021)
   - Moment 0/ 1 units: K km s^{-1} / km s^{-1}
3. WISE W1 filter 3.4μm (Wright et al. 2010) and Spitzer IRAC 3.6 μm band (Sheth et al. 2010) Near-IR emission images
   - Data unit: MJy sr^{-1}



Color composite image of NGC 2903 (Red: Spitzer IRAC 3.6 μm , Green: CO Moment 0 , Blue: HI Moment 0)

Our pilot target: NGC 3621

Morphology: SA(s)d

Inclination angle: 66°

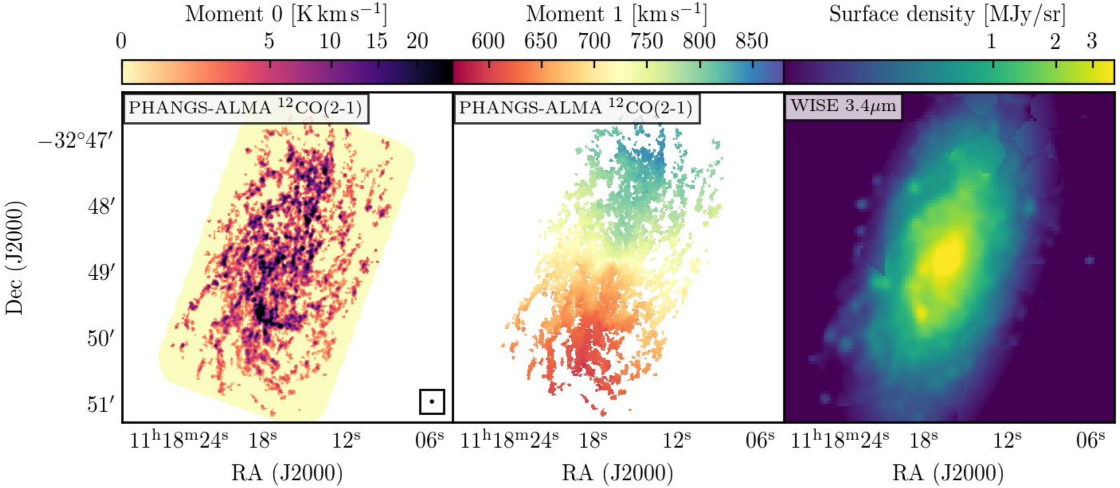
Position angle (PA): 344°

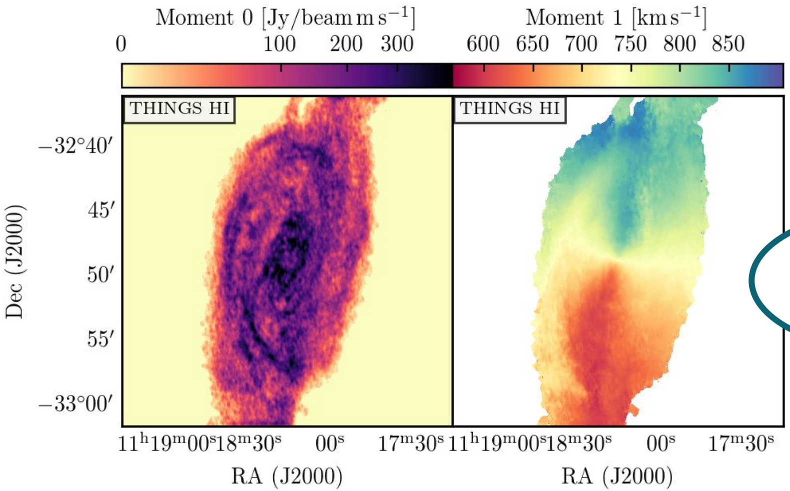
Distance: 7.3 Mpc

Systemic velocity: 724 km/s

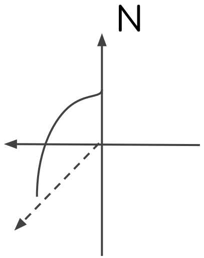
Other galaxies in the sample:

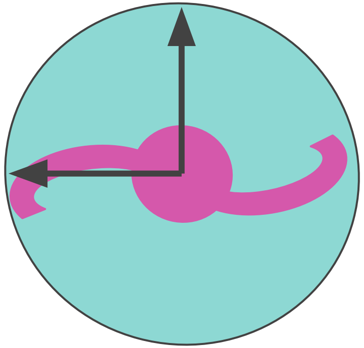
NGC 2903, NGC 3198, NGC 3521, NGC 3627, NGC 7793

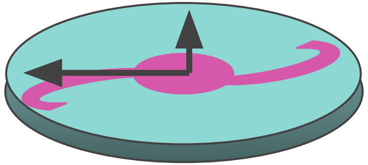


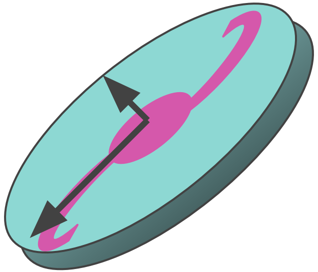


Galaxy inclination and position angle





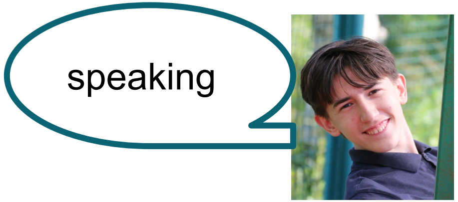




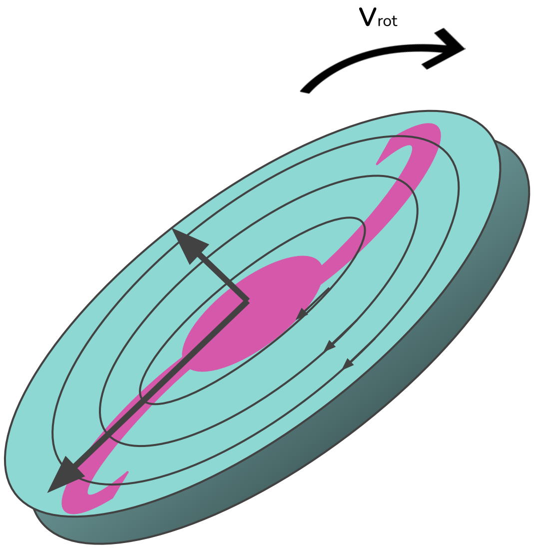
$i = 0^\circ$
PA = ?

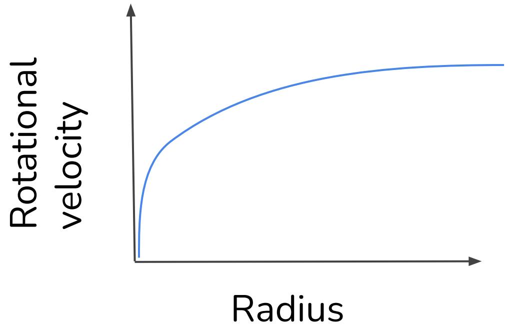
$i = \sim 45^\circ$
PA = 90°

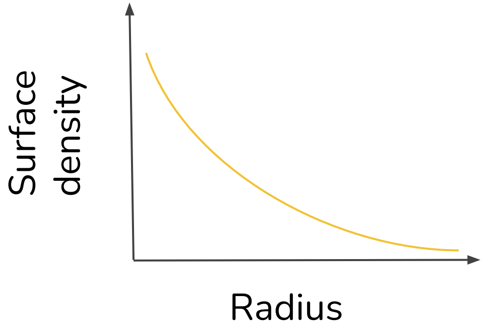
$i = \sim 45^\circ$
PA = ~135°

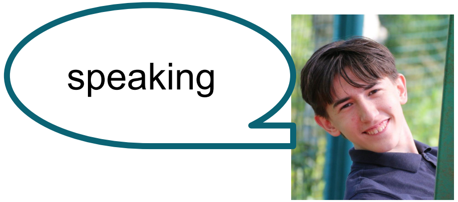


Slicing spinning frisbees





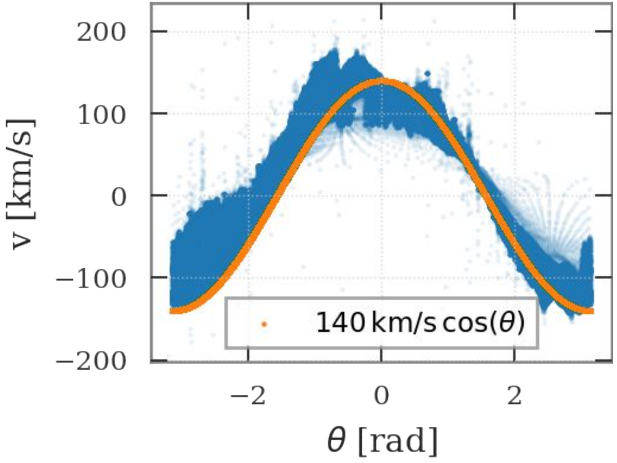


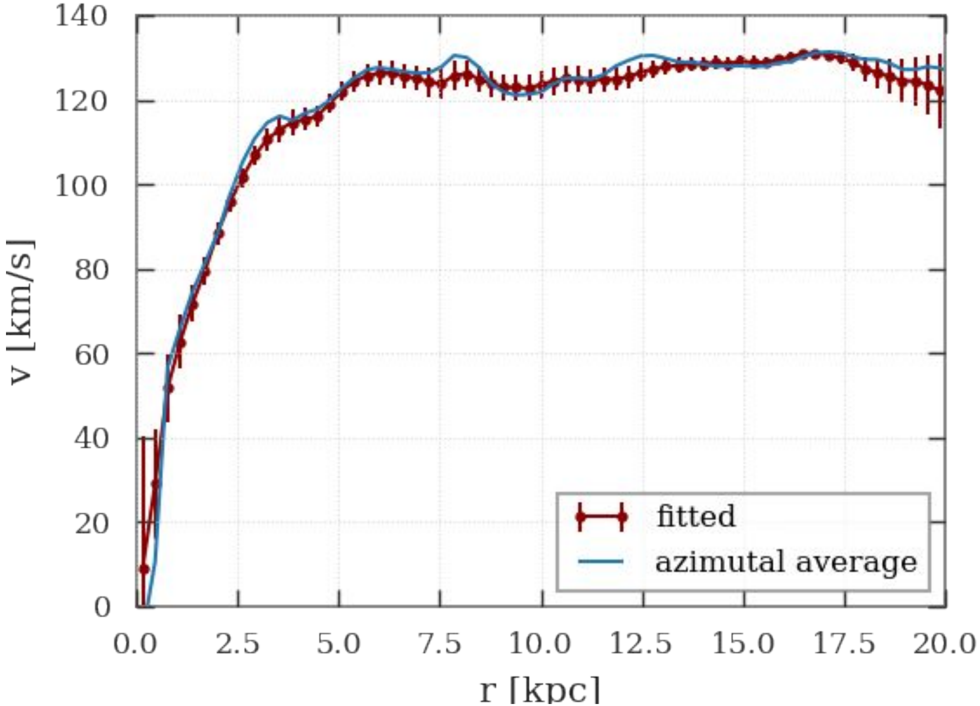


Extracting rotation curves

In every radial bin:

- Averaging V / cos(θ)
- Fitting a “frisbee” model: $v = V_0 \cos(\theta)$





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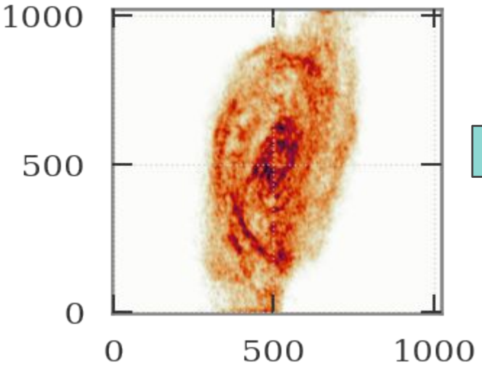
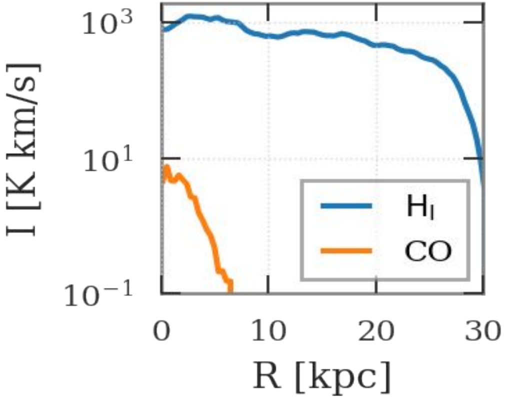
Extracting the mass radial profile

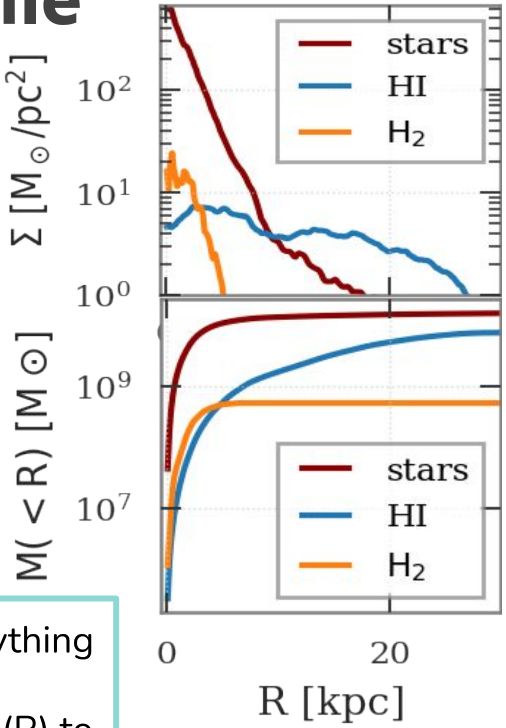
Intensity map



Intensity profiles

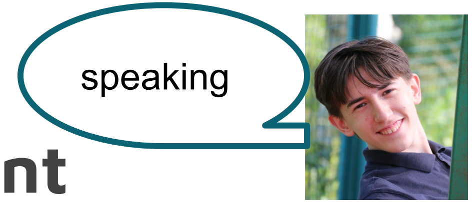


Mass profiles

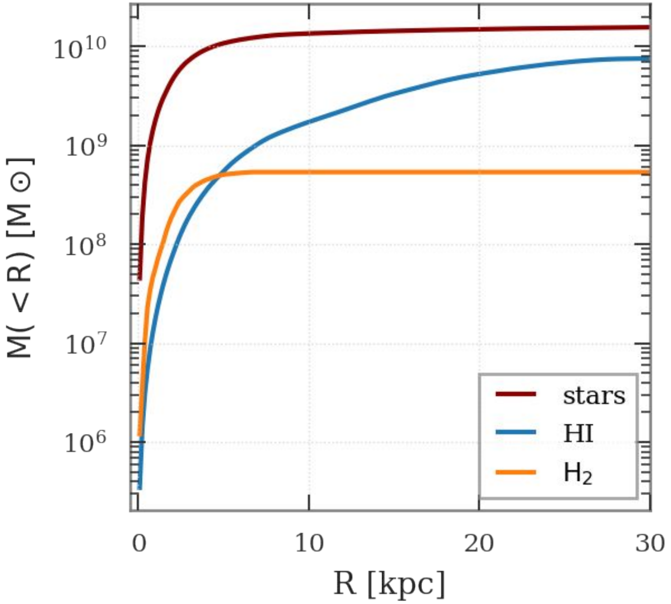


1. {RA,DEC}->{R, theta}
2. Radial binning
3. Computing average intensity in each bin
4. Converting to same intensity units

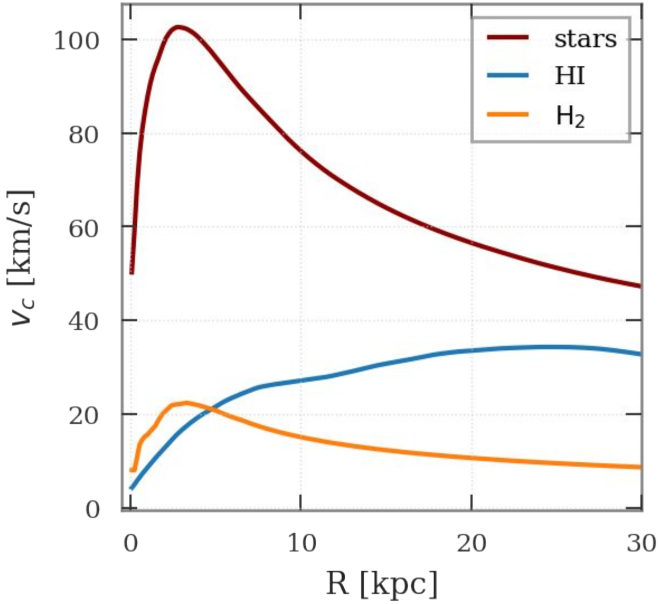
1. Converting everything to $M_\odot$ / pc^2
2. Integrating the $\sum(R)$ to get enclosed mass profiles



Deriving rotation curves of different components

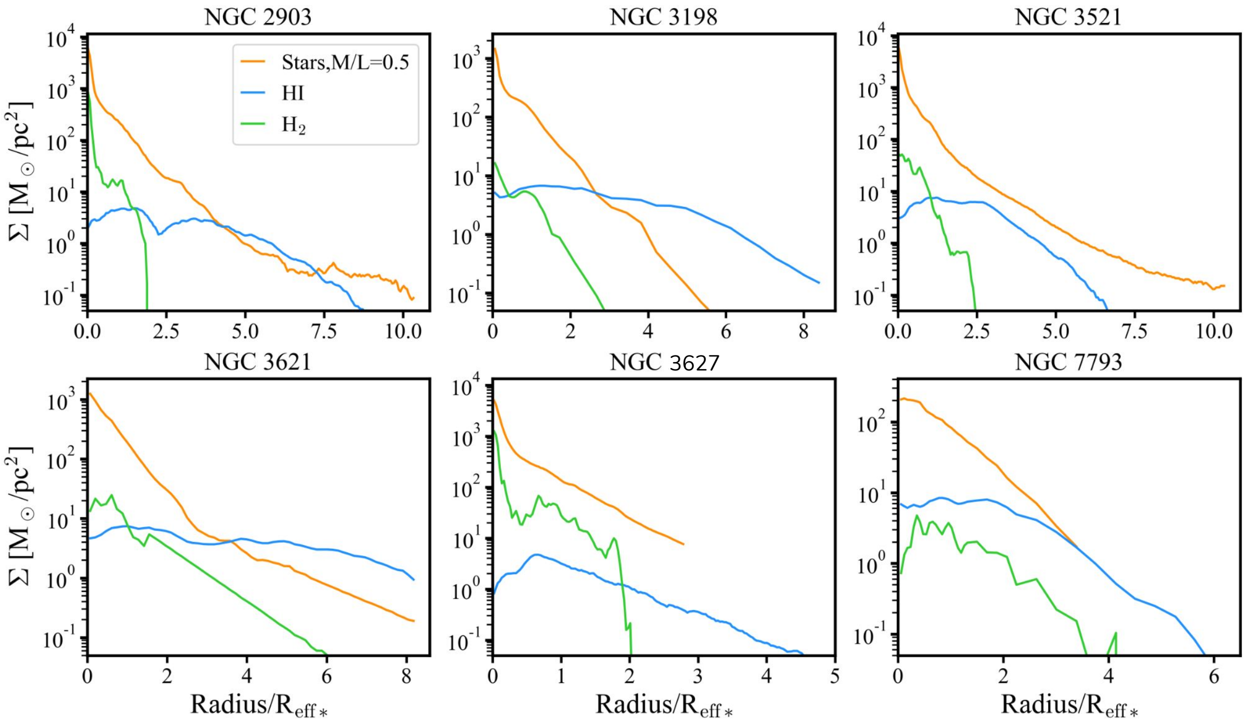


$$V_{\rm circ}(R) = \sqrt{\frac{GM(<R)}{R}}$$



Results: mass profiles

- Depletion of HI near the centre
- Half of the galaxies show a typical transition radius (HI→ H_2) ~ R_e



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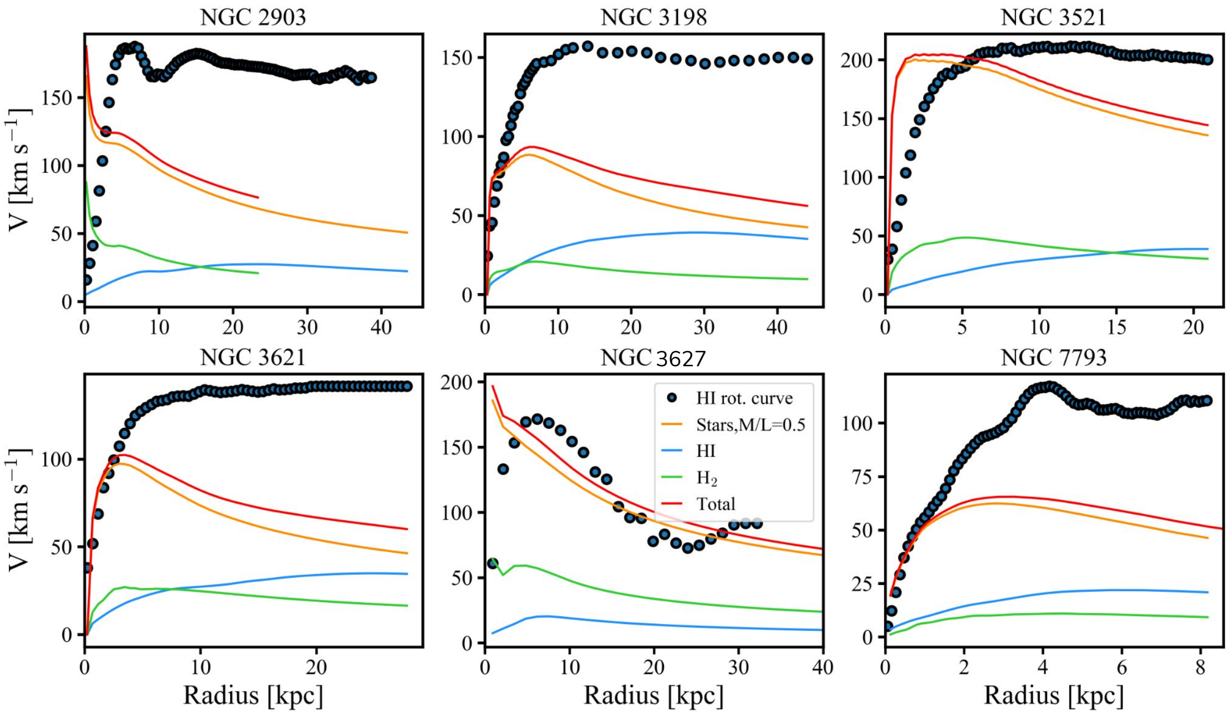
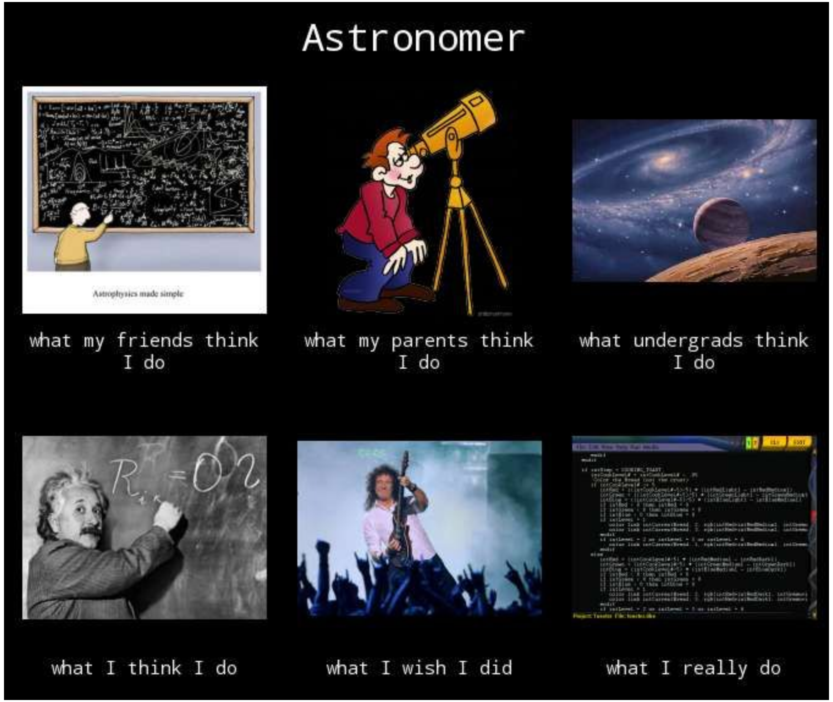
Results: rotation curves

- Overestimated stellar rotation velocities in most galaxies
- Room for small changes due to M/L
- Need dark matter to explain flat rotation curves



Summary

- Use of multi-wavelength data set:
    - IRAC-WISE 3.6 microns
    - THINGS HI 21 cm
    - PHANGS-ALMA CO(2-1)
- Doing lots of coding
- Deriving:
    - Surface density profiles for each component
    - Enclosed mass profiles
    - Rotation curve from velocity maps
    - Rotation curve from mass profiles

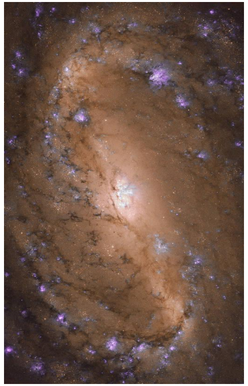


Backup slide #1: parameters of galaxies

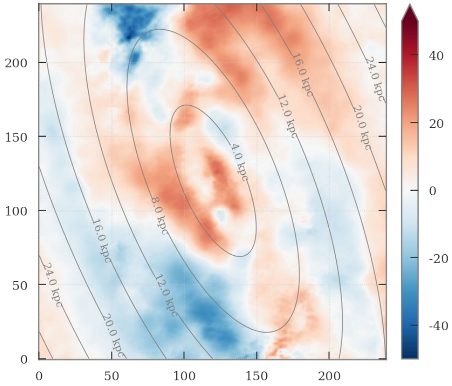
	i (deg)	PA (deg)	Distance (Mpc)	Systemic velocity (km/s)	R_eff (kpc)	bulge?
NGC3621	66	344	7.1	724	3.5	No
NGC2903	204	67	10.0	547	4.2	Yes
NGC3198	73	33	13.8	663	5.3	No
NGC3521	69	343	13.2	798	5.8	Yes
NGC3627	57	173	11.3	715	16.8	Yes
NGC7793	50	290	3.6	222	2.2	Yes

Backup slide #2: next steps

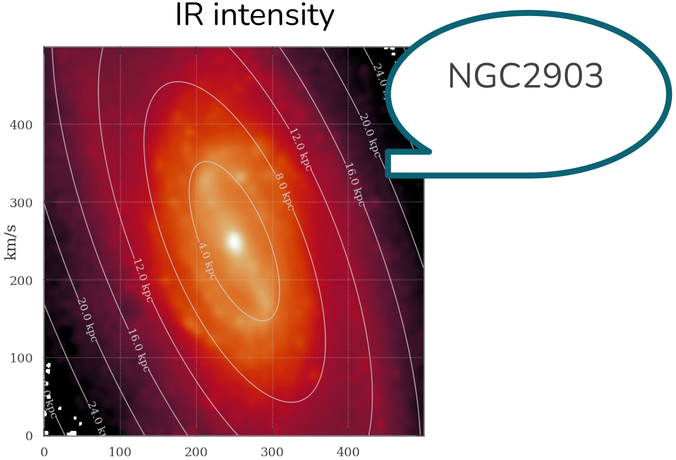
- Fit dark matter haloes and improve potential of the discs
- Testing different theoretical models to:
  - Describe the partitioning of cold gas into HI and H2 components in the ISM (e.g. the BR, GK and KMT mode).
- Study the effects of the bar on the velocity field



Residial velocity



IR intensity



Backup slide #3: intensity to mass conversion

1. IR intensity to stellar mass, ~330 for WISE data, ~350 for IRAC1, M/L ~ 0.5

$$\frac{\Sigma_\star}{1\ \mathrm{M_\odot\ pc^{-2}}} \approx 330 \left(\frac{\Upsilon_\star^{3.4}}{0.5}\right) \left(\frac{I_{3.4\mu\mathrm{m}}}{1\ \mathrm{MJy\ sr^{-1}}}\right) \cos i$$

2. 21cm intensity to hydrogen number density

$$N_{\mathrm{HI}} = 1.82 \times 10^{18} \int \left[\frac{T_{\mathrm{b}}(v)}{\mathrm{K}}\right] d\left(\frac{v}{\mathrm{km\,s^{-1}}}\right)\ \mathrm{cm^{-2}}$$

3. CO(2-1) intensity to H_2 surface density

$$\Sigma_{\mathrm{mol}} = \alpha_{\mathrm{CO}}^{1-0}\ R_{21}^{-1}\ I_{\mathrm{CO(2-1)}}\ \cos i\ .$$

$$\alpha_{\mathrm{CO}}^{1-0} = 4.35\ \mathrm{M_\odot\ pc^{-2}\ (K\ km\ s^{-1})^{-1}} \qquad R_{21} = 0.65$$

Milky Way

Backup slide #4: Central-peaking circular velocity curve in bulge potential