Polar disc galaxy!

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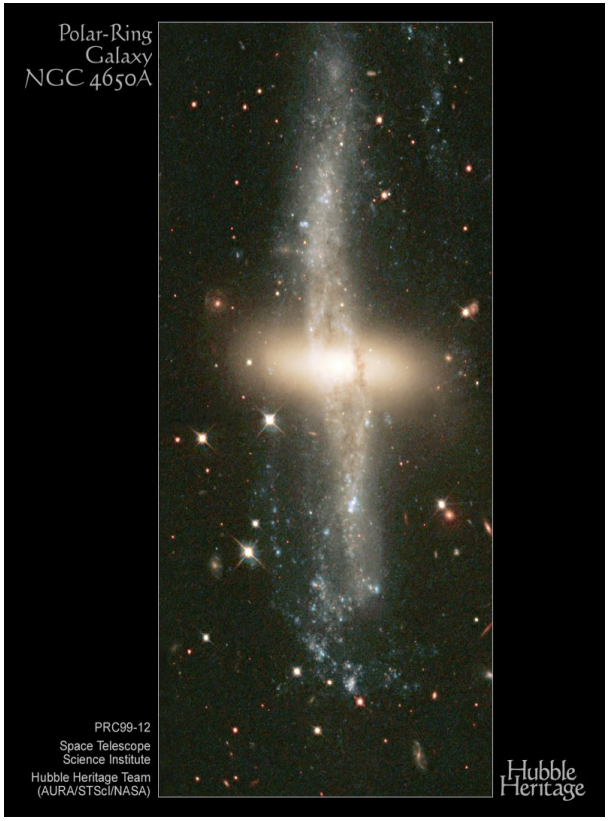
Brad Gibson, Chris Brook, Alexander Knebe, Rob Thacker, Tom Quinn, Fabio Governato, Patricia Tissera

See: Snaith et al. 2012, MNRAS, 425, 1967 ← most figures from here!
Brook et al. 2008, MNRAS, 689, 678

Introduction

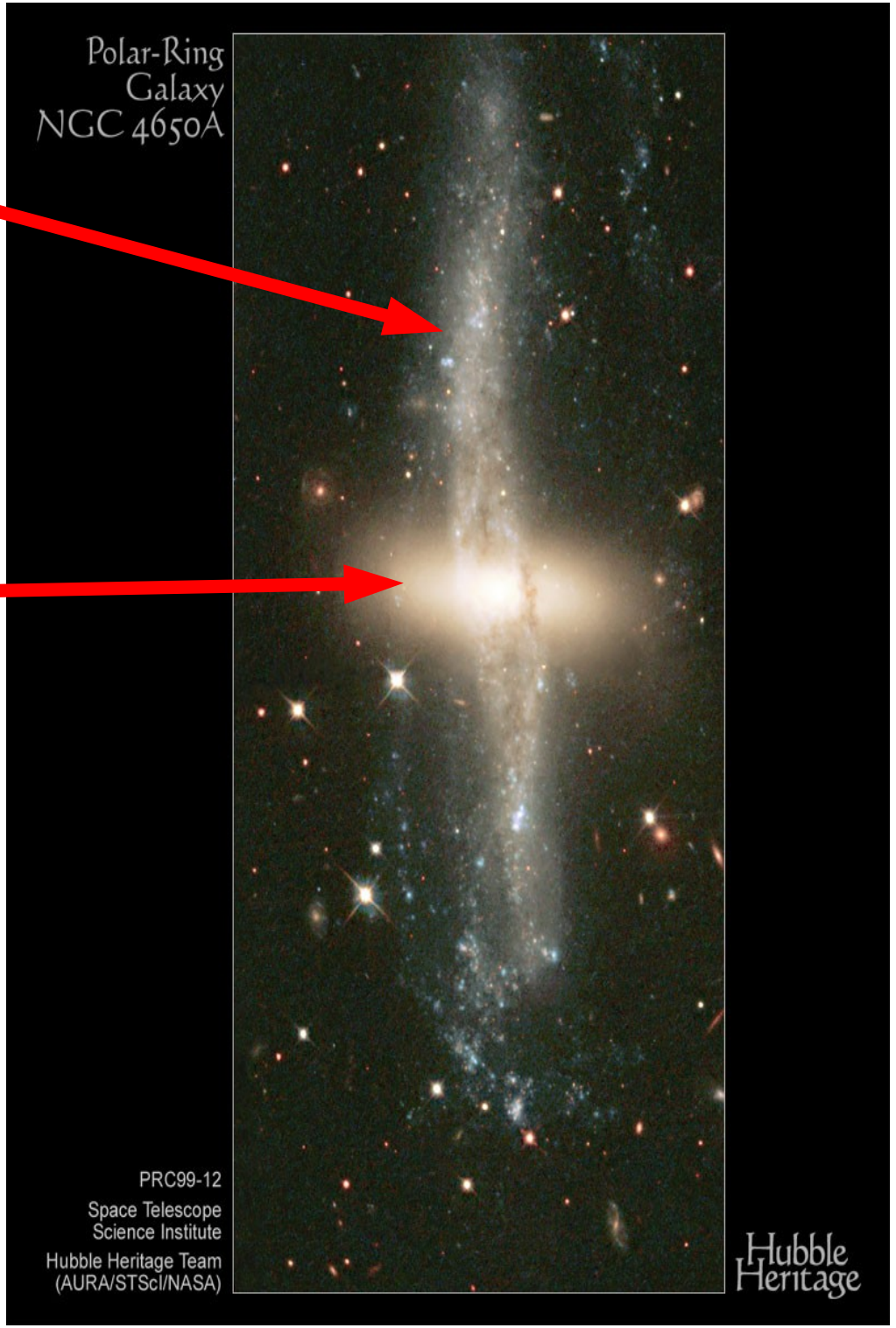
- Polar disc/ring galaxies have orthogonal structures (Whitmore et al 1990, Gallagher et al. 2002)
- Quiet odd!



- But interesting!
- 1% S0 galaxies (Whitmore et al. 1990)
- Properties of each disc not dissimilar to ordinary discs (e.g. Schweizer et al. 1983, Cox et al. 2006)

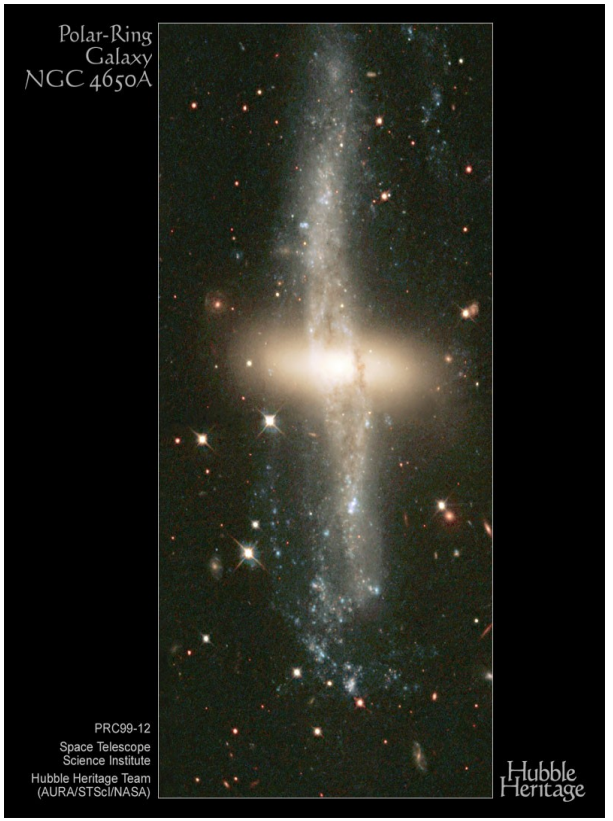
New Stars
(Polar disc)

Old Stars
(Old stellar disc)



Why do we care?

- Quiet odd. But interesting!
- Good test of galaxy formation theories
  - Gas accretion, mergers etc.
- Test shape of the inner dark halo (e.g. Combes & Arnaboldi 1996)
- Not that uncommon



Simulated Polar disc galaxy

- First presented in Brook et al. (2008)
  - Cosmological **SPH** simulation – GASOLINE, (Wadsley et al. 2004)
  - zoom
  - Only one galaxy
- Suggested it formed from a major merger followed by cold infall
- Brook et al. (2008) YOUTUBE video for the interested!

Defining the discs

- Age cuts:
  - Stellar disc is 4 Gyr < formation time < 6 Gyr
  - Polar disc formation time > 9 Gyr

- By z=0.17 the old stellar disc contains no gas

Dark Halo

- Iodice et al. (2003) – two orthogonal discs probe inner dark matter shape
  - From the LOS velocity

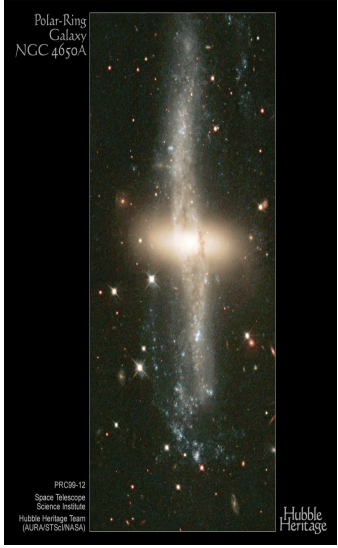
- Simulation can DIRECTLY measure the dark matter shape (e.g. Maccio et al. 2006) AND measure the LOS velocity (e.g. Brook et al. 2008)

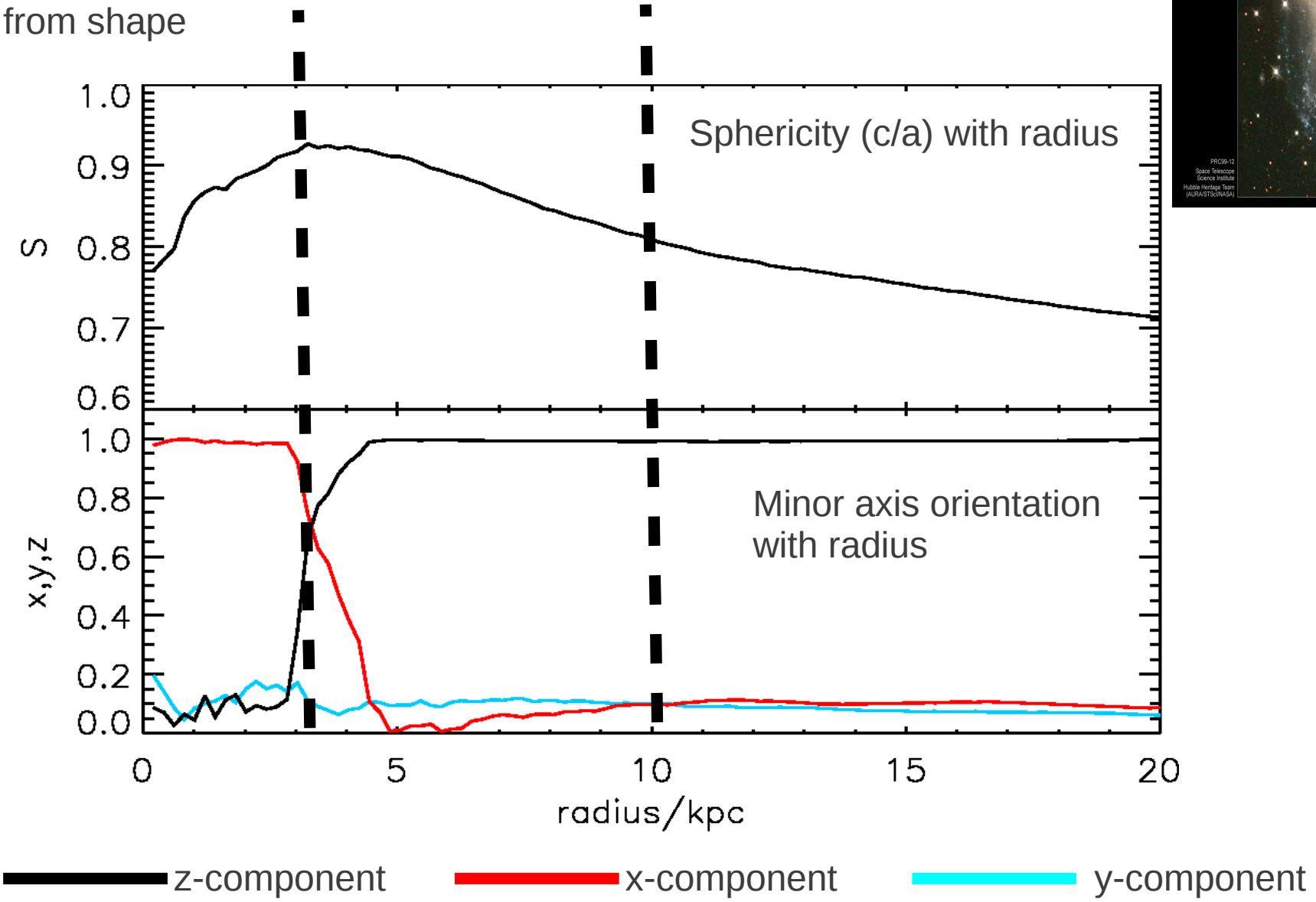
- Is this a good probe?

Dark Halo

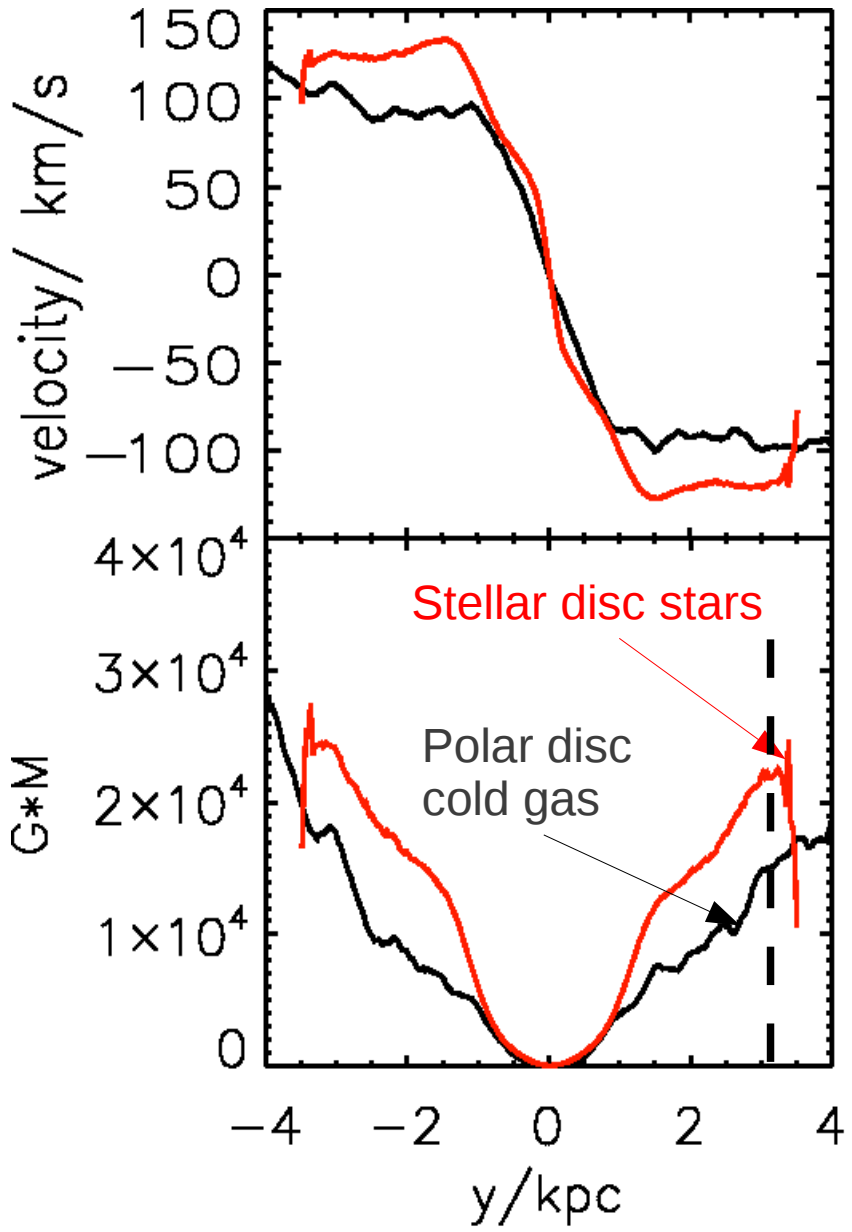
Fit ellipse from shape tensor

a>b>c





Dark Halo

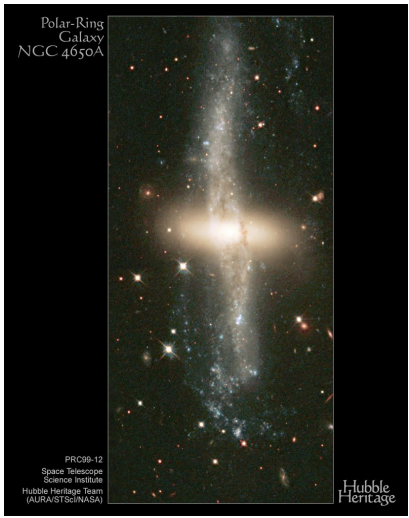


$$M(<r) = v^2_{circ}\, r/G$$

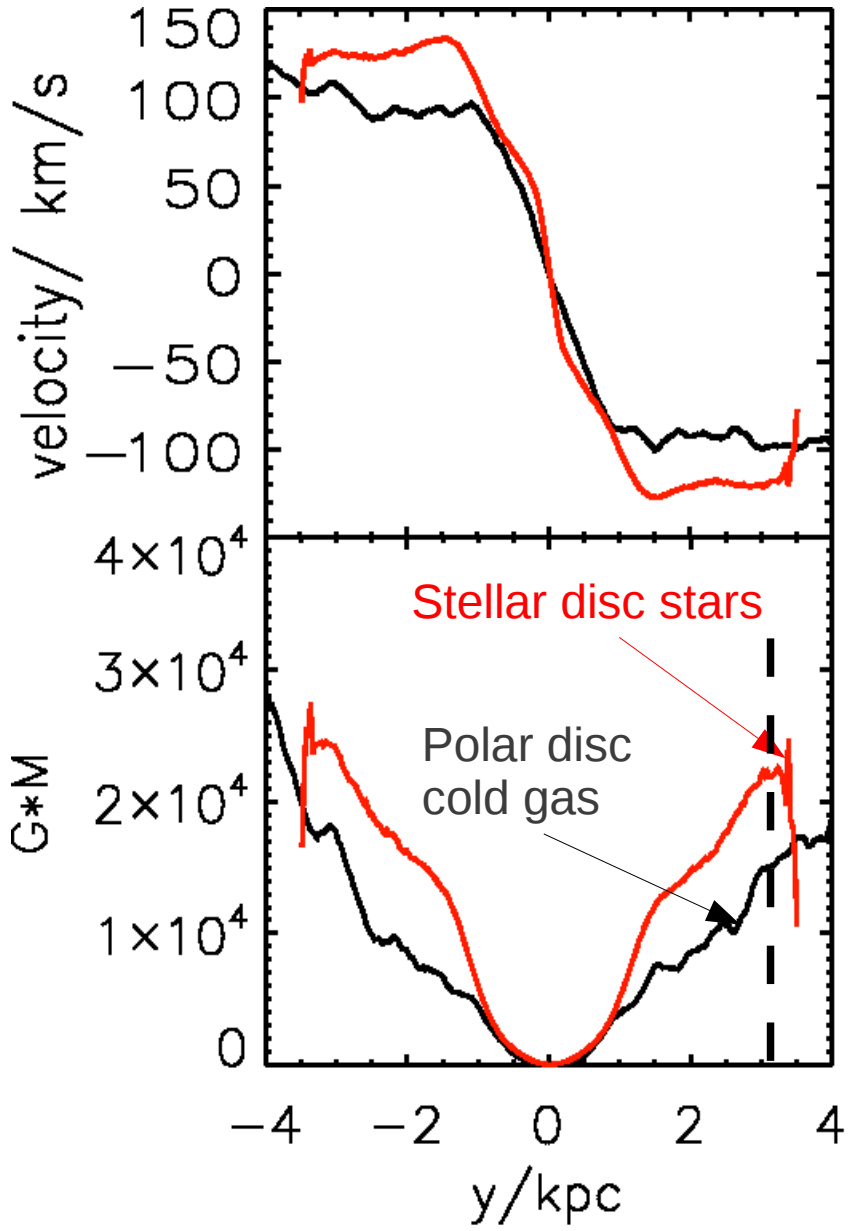
measure

Cube root of the mass measurements

Axial ratio = 0.9 ==> Matches direct measurement



Dark Halo



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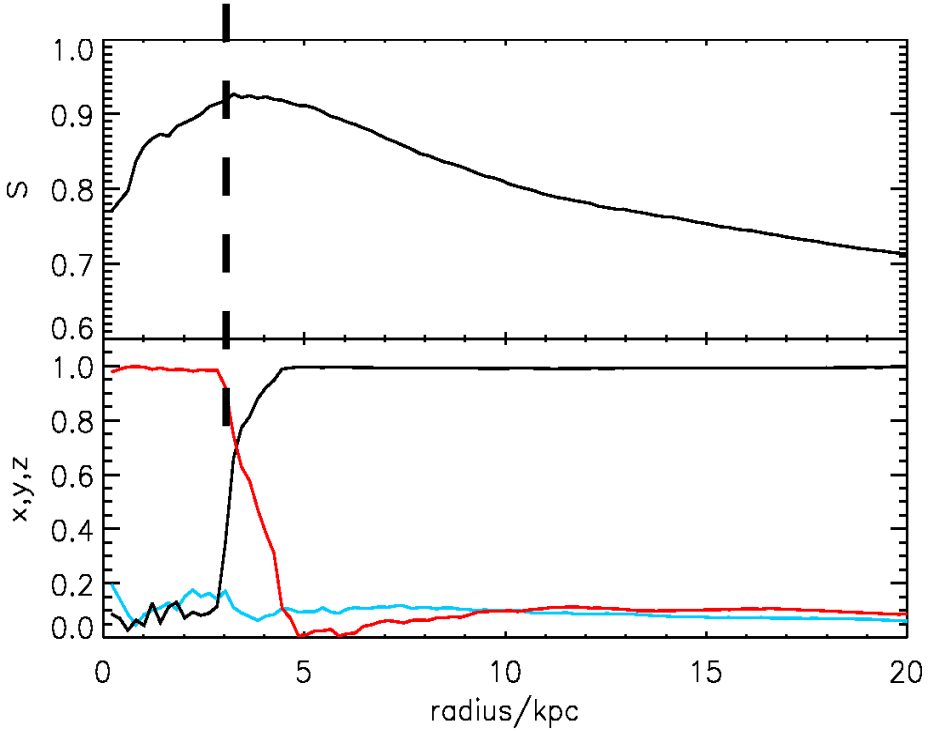
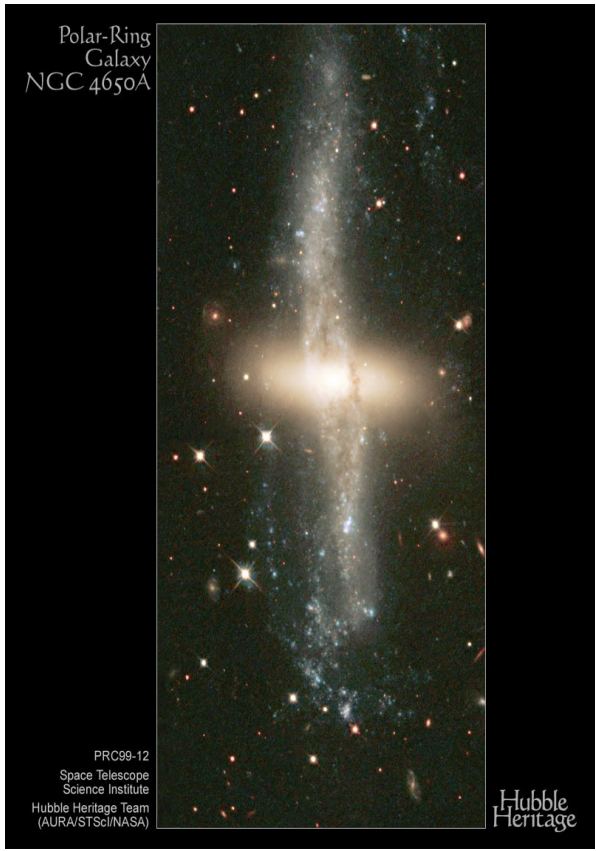


Evolution

- Simulation!
- Follow the angular momentum through time
- How does it evolve?
- Look at the angular momentum of:
  - the gas,
  - the stars,

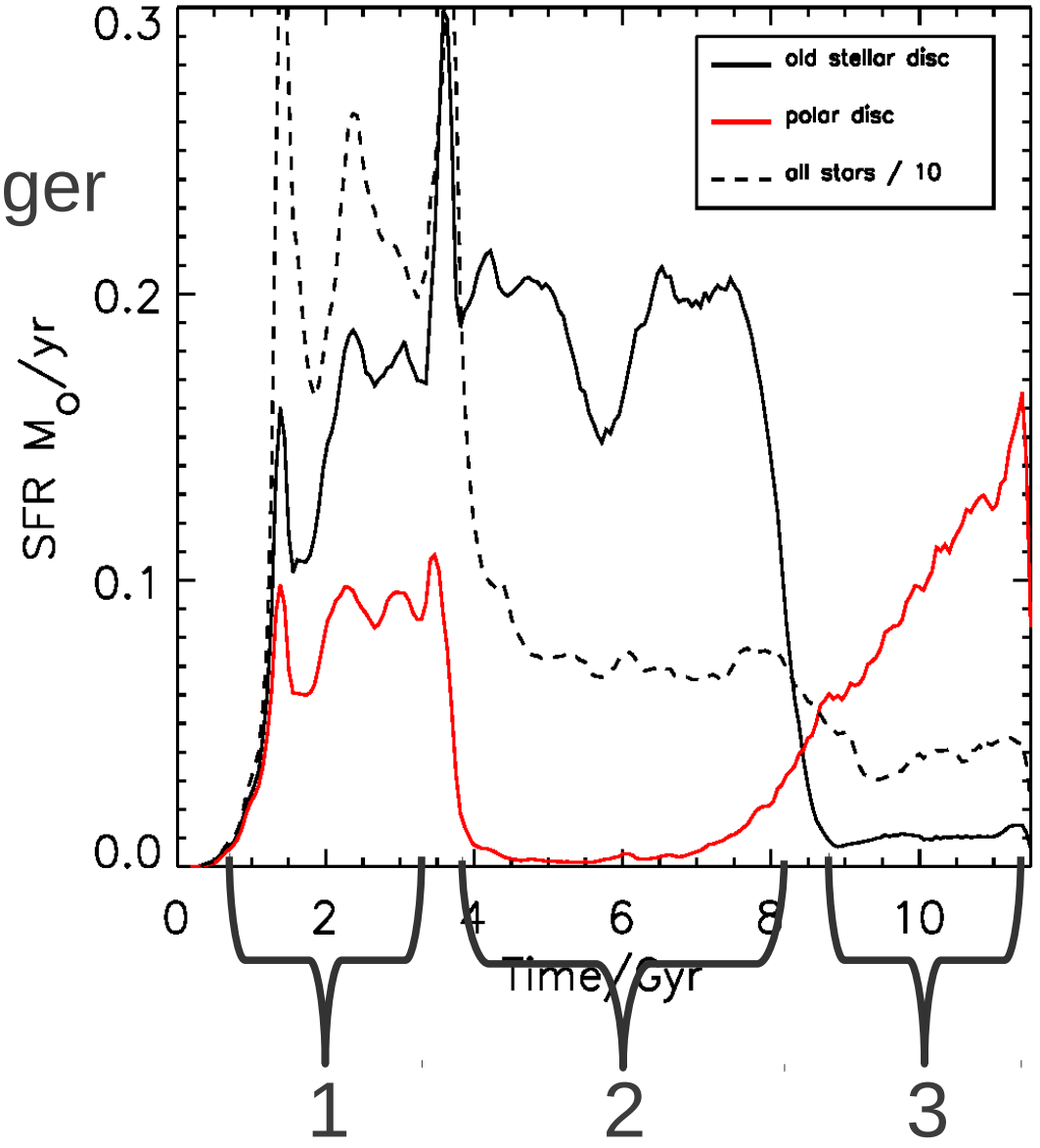


Evolution

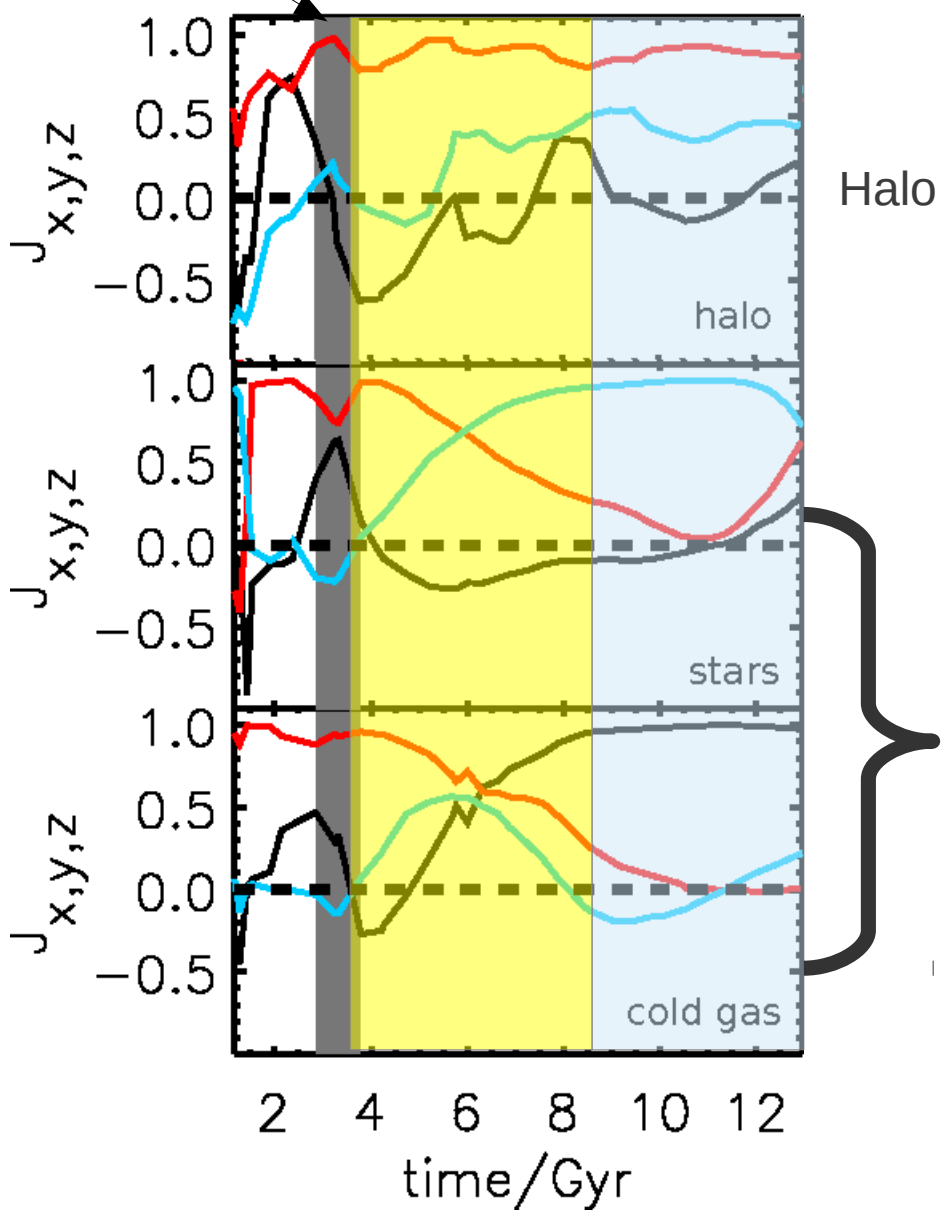
- 3 eras
  1) Before last major merger
  2) Old stellar disc
  3) Polar disc

No starbursts near the polar disc – e.g. Spavone et al. 2010/2011

Gas in old disc not renewed after ~10 Gyr



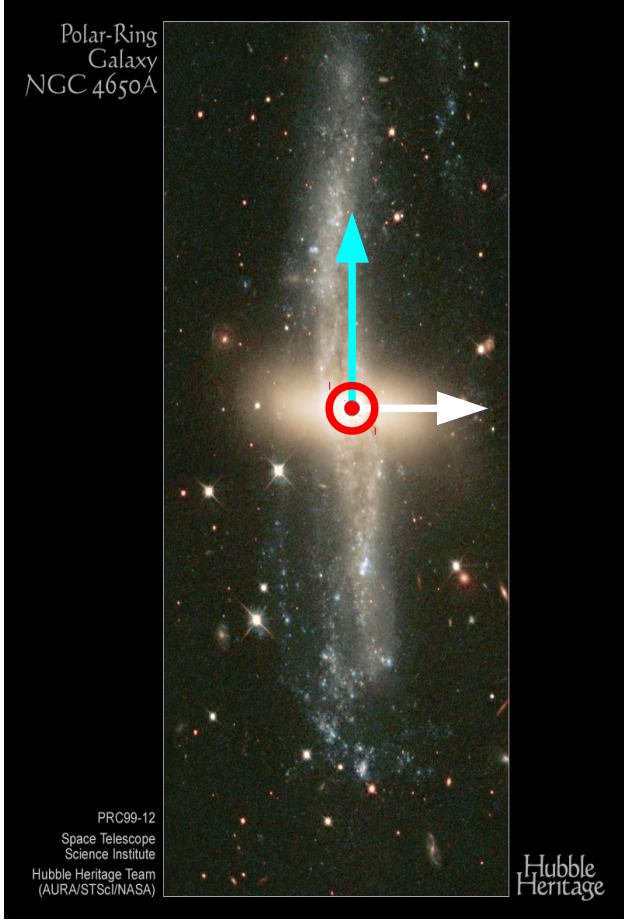
Evolution



Halo establishes early

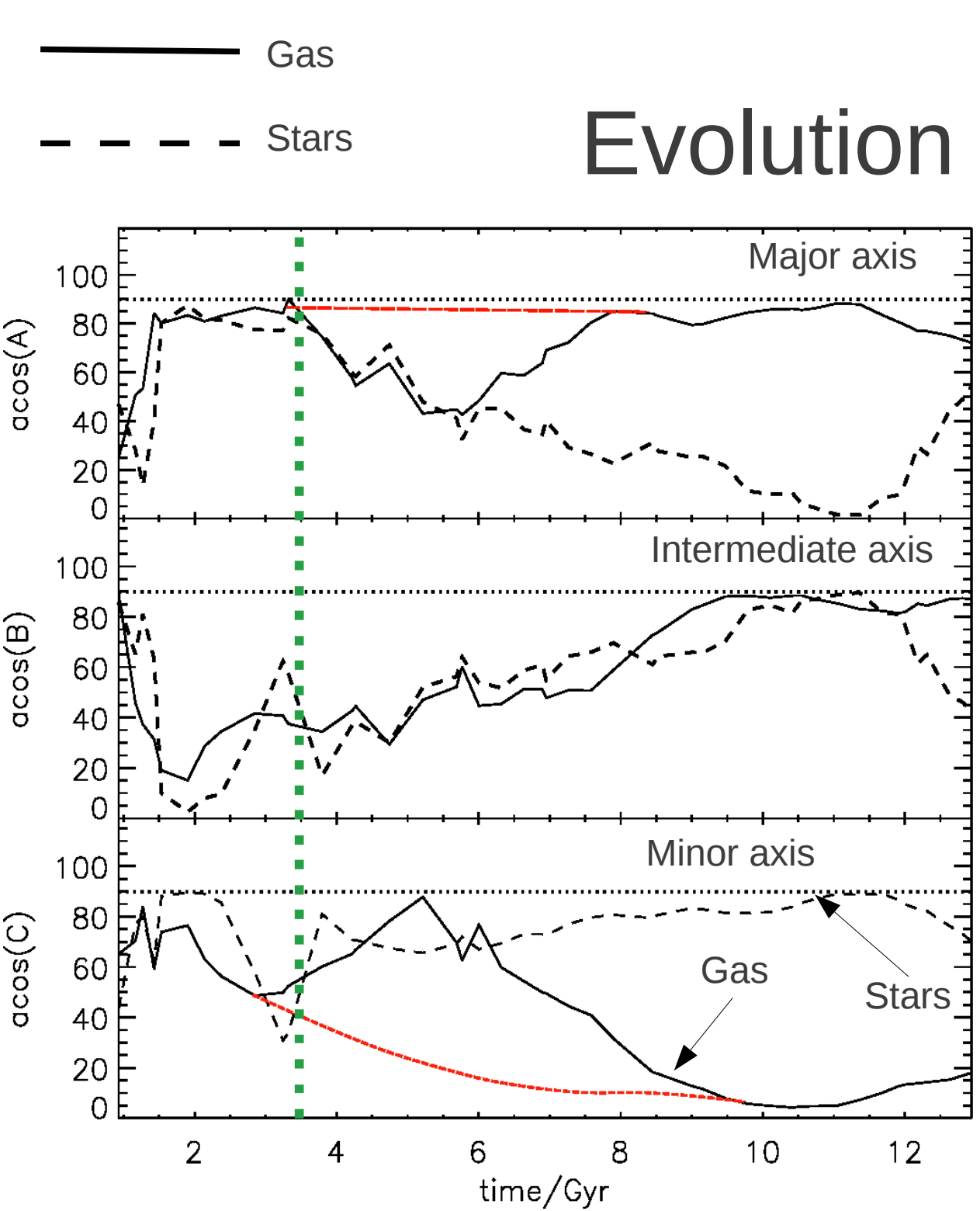
Long term re-orientation

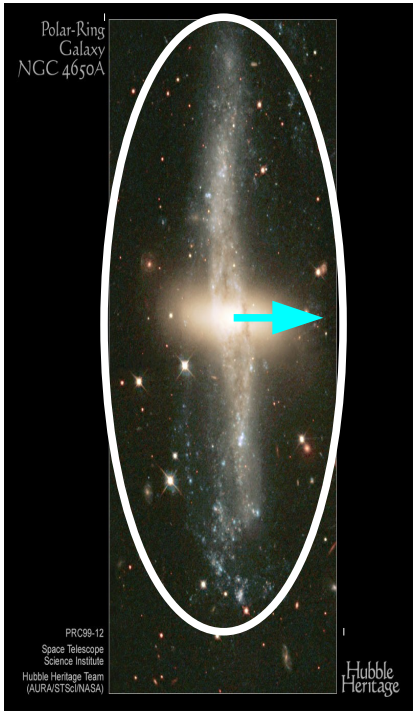
Apparently initialised by the major merger



z-component x-component y-component

Evolution





- Alignment of angular momentum with dark halo
- No difference in the intermediate axis direction
- Restoration of the cold gas for major axis?
- Roll from intermediate axis to minor axis for cold gas – stars disrupted.

Formation?

- **Merger :** Specific collision parameters produce polar rings/discs (Bekki 1997, 1998, Bournaud & Combes 2003)

- **Accretion :** Near miss satellite is stripped of gas.
  - More robust than merger scenario
  - (Schweiser et al. 1983, Reshetnikov & Sotnikova 1997, Bournaud & Combes 2003, Combes 2006)

- **Infall :** Gas falls into galaxies along preferential direction inclined to stars.
  - (Keres et al. 2005, Maccio et al. 2006, Brook et al. 2008, Combes 2006, Bournaud & Combes 2003).

Formation

- Maccio et al. (2006) model currently favoured for many galaxies.
  - Polar discs massive! Approx mass of old stars
  - No starbursts (e.g. Spavone et al. 2010/2011)
  - **BUT** Different galaxies favour different scenarios.
  - All right somewhere? But Maccio et al. (2006) here!

Formation

- 2 mechanisms to form the polar structure.
  - Cold flow from large scale structure changes direction
  - Old stars realign and gas flow is unchanged

Formation

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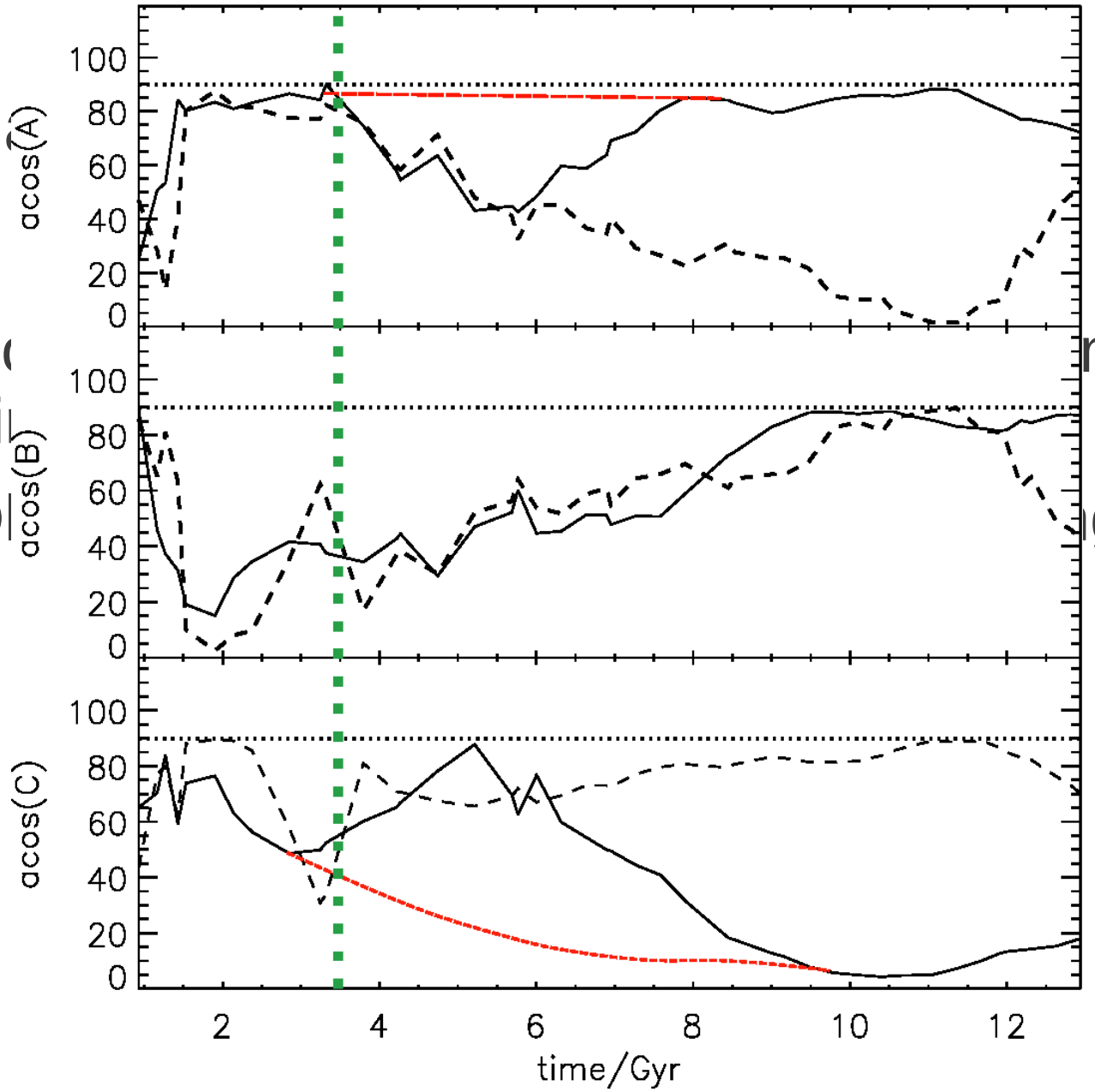
  - O ged

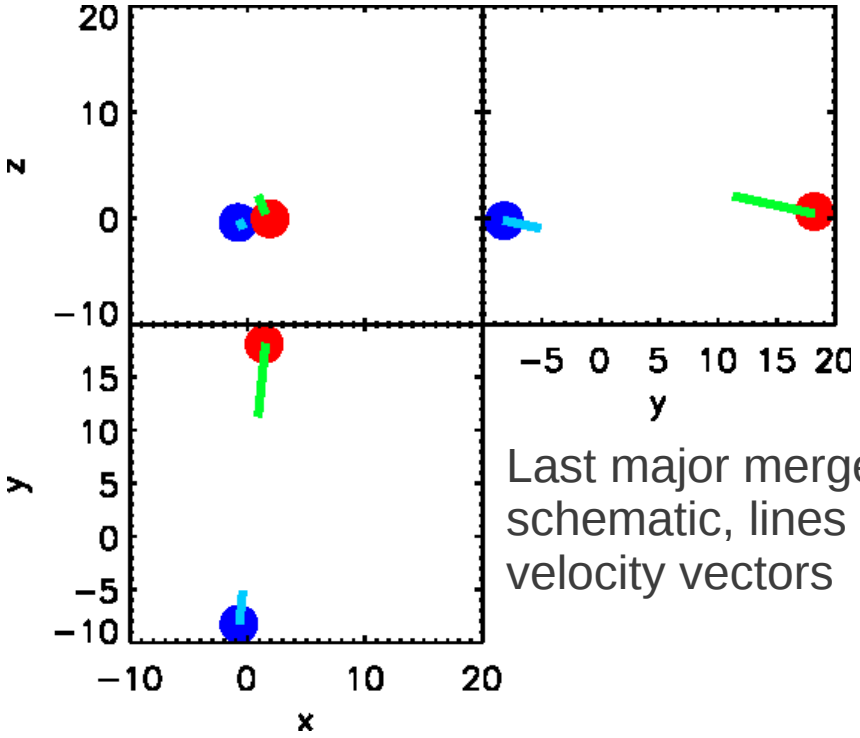


Formation

- Trace the gas from the two discs
- Same origin?
- Yes!
- Except, gas aligns as it flows into the halo
  - Funnelling?

Formation

- Angular momentum of the last major merger?
- Mass ratio ~ 1:2



Last major merger schematic, lines show velocity vectors

- At 90 degrees to infalling gas!
- Suggests realignment!

Forthcoming

- Idealised simulation of gas accretion with angular momentum 90 degrees to in-situ stars
- Forms gaseous polar structure
- But gas funnelled into inner region!
- In spherical halo infalling gas pushed the disc into alignment with filament, destroying the polar structure
- Further work.

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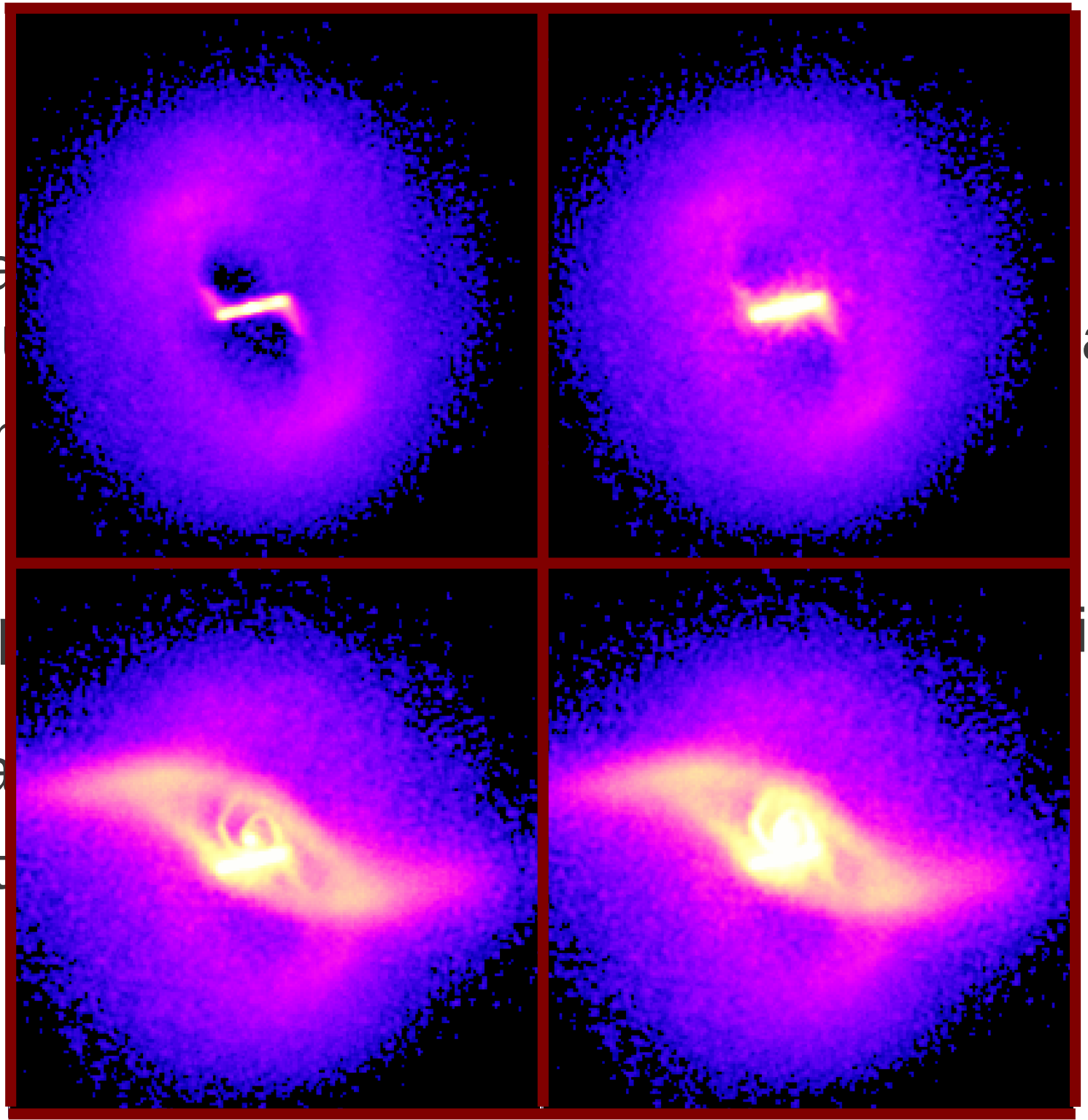

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Conclusions

- LOS velocity is a good method of finding the shape of the inner dark halo.
- Polar disc galaxy formed from a major merger followed by a resumption of gas infall.
- Its not easy to disentangle exactly what causes what.
- Matches observations!
- Only one object!
- http://www.youtube.com/watch?v=c-H3WzaewdY