The Local Density of Dark Matter

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1.25* SHM give or take 25%

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OK, that's done…

What's the 3 and 6D Dimensional Distribution of Dark Matter and How does this alter Detection Scenarios and create new ones?

Collabs: Read, Garberi, Hahn, Bruch, Baudis

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What is the local dark matter density?

- In 1922, Sir James Jeans found there were “2 to 3 dark stars for every one we can see”
- In 1932 and again in 1960 ,Oort claimed as much dark matter in the disk as material seen
- Bahcall did it in the 1980s and 1990s, finding that there was half as much dark matter as material in the disk.

History of "The Dark Disk"

- Oort Found a local "baryonic density"
  - $0.038\ M_{sun}/pc^3$
  - unexplained density comparable to the observed
- typical modern value for baryons is 0.09 (gas is the greatest uncertainty), with a dark matter density that is 6-10 times smaller
- Baryonic number is uncertain, methods have systematics (many use the SHM as a prior), so constraints on DM densities are usually overstated.

“Dark Disk”, disk of normal dark matter

- I suggested a dark disk back in 1989
- Can’t be you idiot, there’s no dissipation!
- But, dynamical friction from the disk can cause satellites to spiral inward
- this works well at our distance in the galaxy, but the disk won’t extend all the way in, so the total disk mass won’t integrate to a lot, it all so “came from nearby” and doesn’t change the radially binned mass much
- getting to the Oort/Bahcall values seemed unlikely (would take a special “ring” of DM)

More lunancy

Letters to Nature

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Detectability of γ-rays from clumps of dark matter

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Top

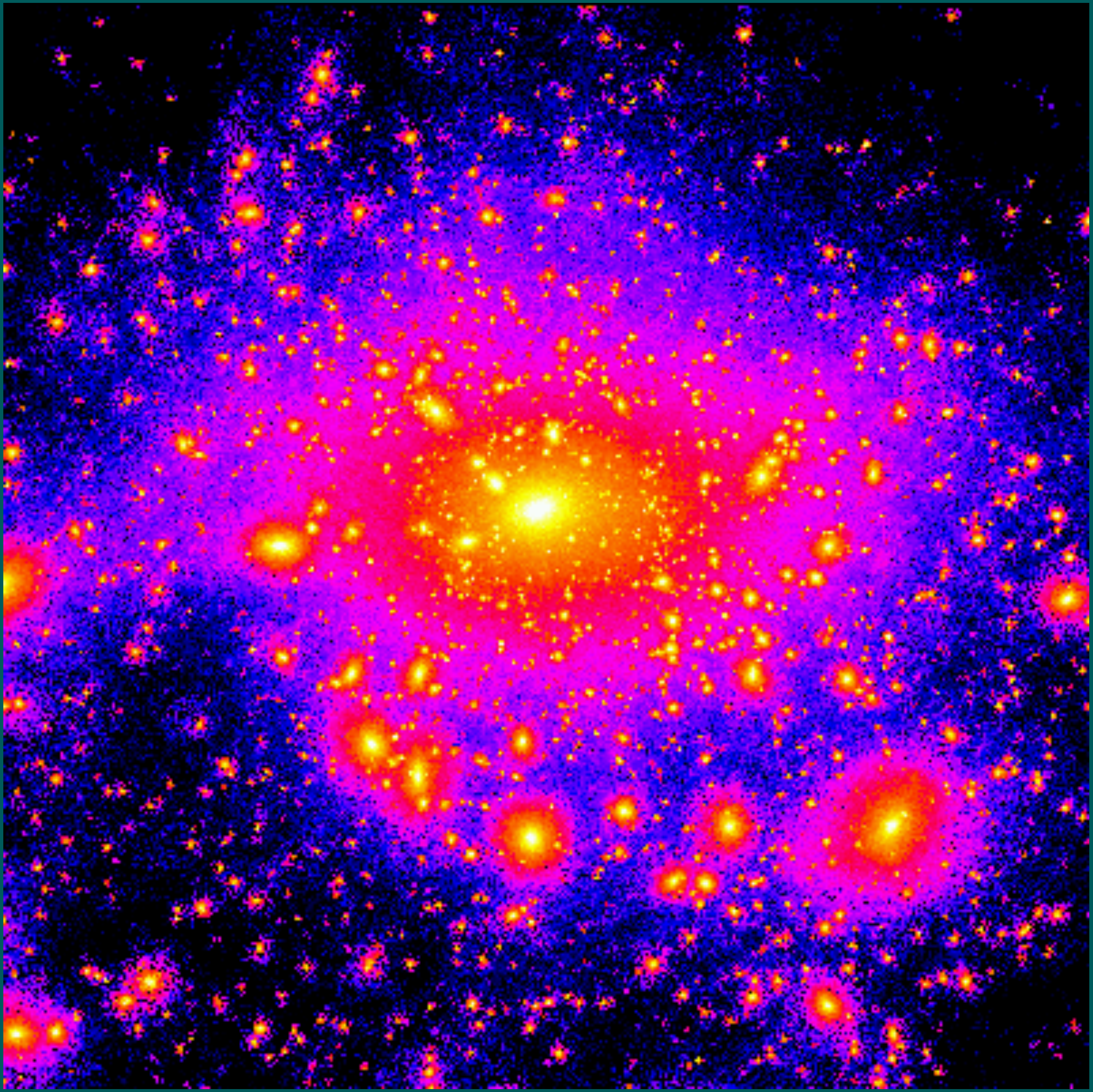
IF the dark matter in our Galaxy is made up of weakly interacting massive particles (WIMPs) with masses of the order of several GeV (for example, photinos or Higgsinos), γ-rays produced by their annihilation would in principle be observable[1,2]. But the expected flux[3] from a smoothly distributed dark matter halo[4,5] is much smaller than the observed diffuse background[6], and although narrow lines might be produced, their intensity would be much too low to see with the Gamma Ray Observatory (GRO)[3,7]. A complementary approach is to consider unique spatial signatures. Numerical simulations of galaxy formation[8] show that even in the central bulge of the Galaxy, the mean density of the dark matter could be equal to that of the stars. If this were so, GRO could see the Galactic Centre as a source of annihilating dark matter[1,3]. Other lumps formed as part of the hierarchical formation of the Galaxy could also produce sources that would be recognized by the shape of their continuum spectrum[2,3] and a line feature in sufficiently bright sources[3,7]. Even Geminga[9,10], the second strongest source of γ-rays at energies greater than 50 MeV, could be annihilating dark matter.

Is a Dark Disk Likely?

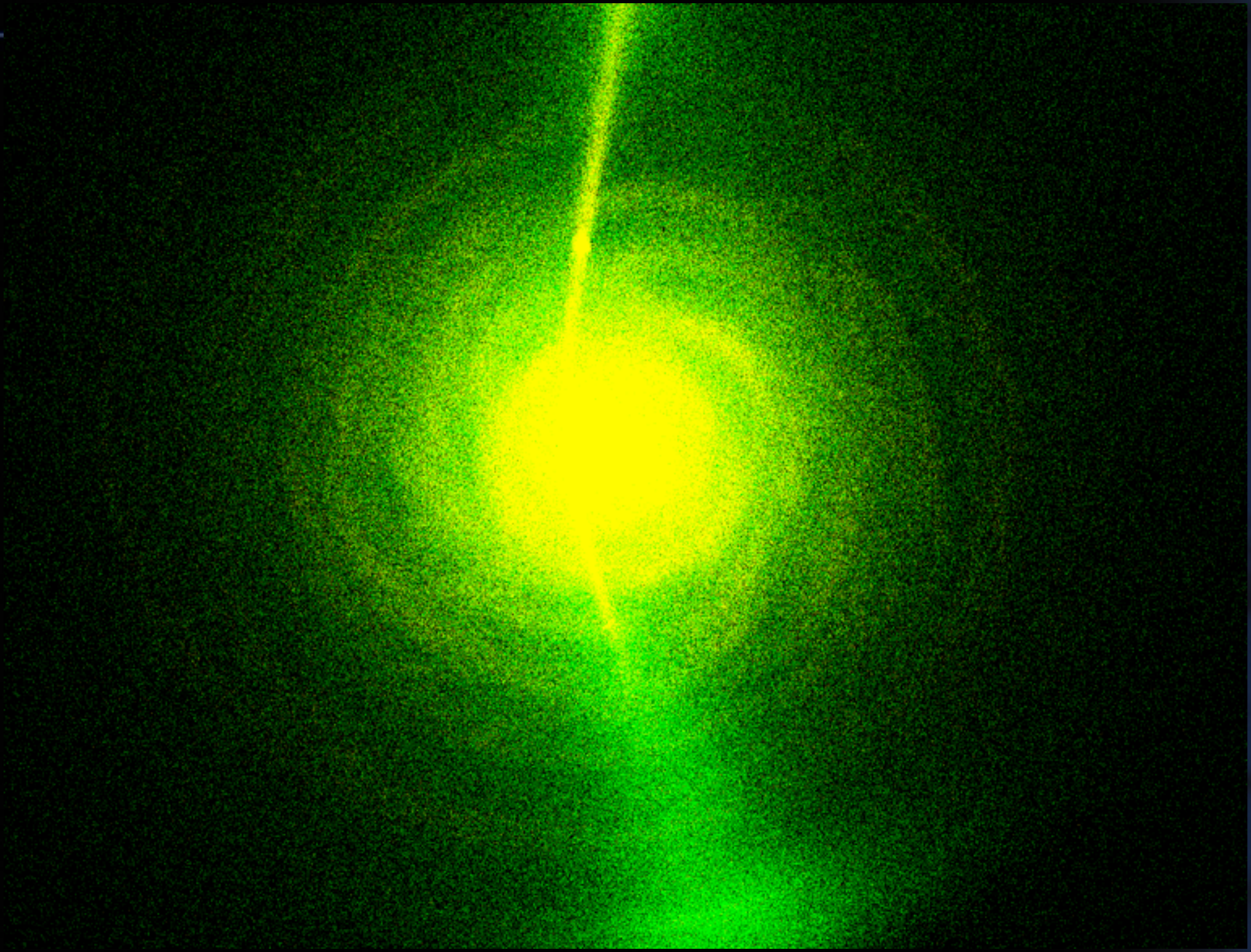
- "Controlled simulations, a disk + satellites: dark discs should have local densities 0.25-1 x local dark matter halo
- Ab initio cosmological sims, dark disks were 0.5-2 x local dark halo. Not ideal sims for DM disk, extremely weak baryonic disks (only a few percent of the correct density at the solar radius) EVERY COSMOLOGICAL SIM WITH A GAS/STAR DISK HAS A DARK DISK
- Highlights the difficulty of finding anything in a large simulation, you can answer questions but "exploration" is difficult

If it's within the uncertainty, should you care?

- As a "disk" component, the velocity structure is different
  - different signal in lab detectors
  - easier to capture by Sun and Earth, can boost the signal from the center of the Sun almost 100x, the Earth 10,000x



A merger for a thick disk



Merger/thick

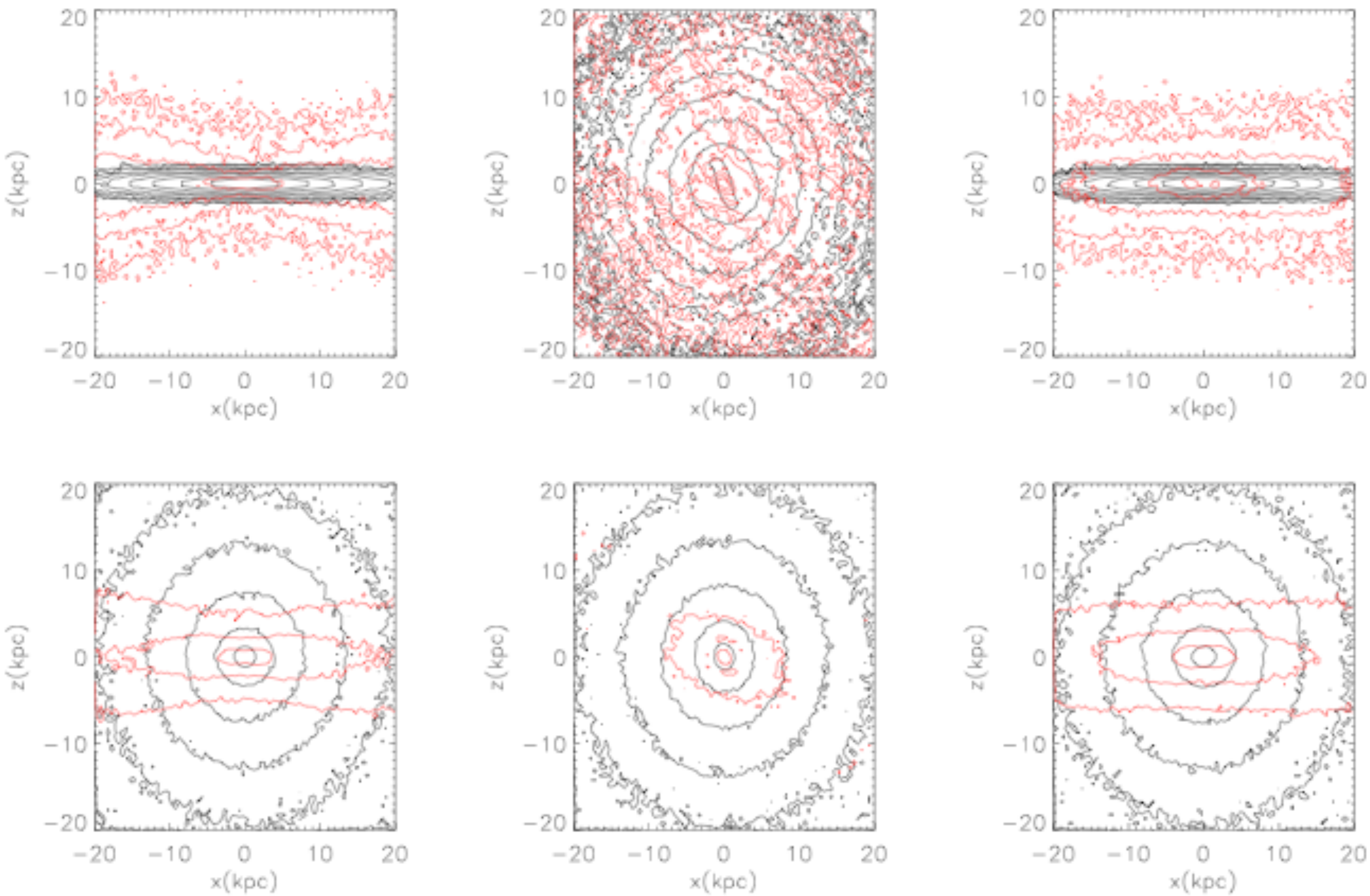


FIG. 1.— Projections for the stars (top) and dark matter (bottom) for the dSphO1 simulation. The black lines show the underlying host galaxy, the red the material from the infalling satellite after 10 Gyrs.

What you see (JustinRead recent review)

b) A new compilation of Σ_b

Component	$\Sigma_i [M_\odot pc^{-2}]$	Reference
Σ_{HI}	12.0 ± 4.0	Kalberla & Dedes (2008)
Σ_{H_2}	3.0 ± 1.5	Flynn et al. (2006)
$\Sigma_{\mathrm{Warm\ gas}}$	2.0 ± 1	Flynn et al. (2006)
Σ_*	30 ± 1	Bovy et al. (2012)
$\Sigma_\bullet$	7.2 ± 0.7	Flynn et al. (2006)
Σ_b	54.2 ± 4.9	This compilation

- Dominated by systematics, beware of "enthusiasm dominated" error

3D density

- The column $$\Sigma_b = 55\,\mathrm{M_\odot\,pc^{-2}}$$
- translates to $$\rho_b = 0.0914\,\mathrm{M_\odot\,pc^{-3}}$$

Column/local densities of mass

- Most methods have major problems with hidden assumptions (See Garberi et al 2011 tests of them on Nbody models)
- Enthusiasm for false high accuracy “1.5 sigma results” (yes, an oxymoron)
  - one shows a Dark Disk at that level
  - another says it’s hard to squeeze
  - either are still fine at a couple sigma and that’s the statistical not systematic error

Directions.

- Accreted Thick Stellar Disk is an extremely popular idea. The DM thick disk is always denser than the accreted stellar thick disk
- If the thick disk were accreted, there would be a huge Dark Disk, but so large that you'd expect a lot of heated stars to make up a thick disk:)
- This is an area where massive amounts of data will be taken in the next years and we might really know something then.

From 1D Spherical Halo to 3D space, now 6D phase space

- The Dark disk is more important for its velocity distribution function
- Much has also been written about “heavy tails” on the velocity distribution function owing to infall
- But, let’s look at what how the 6D evolution goes

Cold Dark Matter

- Cold Dark Matter is very cold indeed! It can be thought of as 3D sheets in a 6D phase space. It's evolution is Hamiltonian, so it obeys Liouvilles Theorem => it remains layers in 3D planes in the 6D phase space

- Dark Mater Caustics have been considered before,

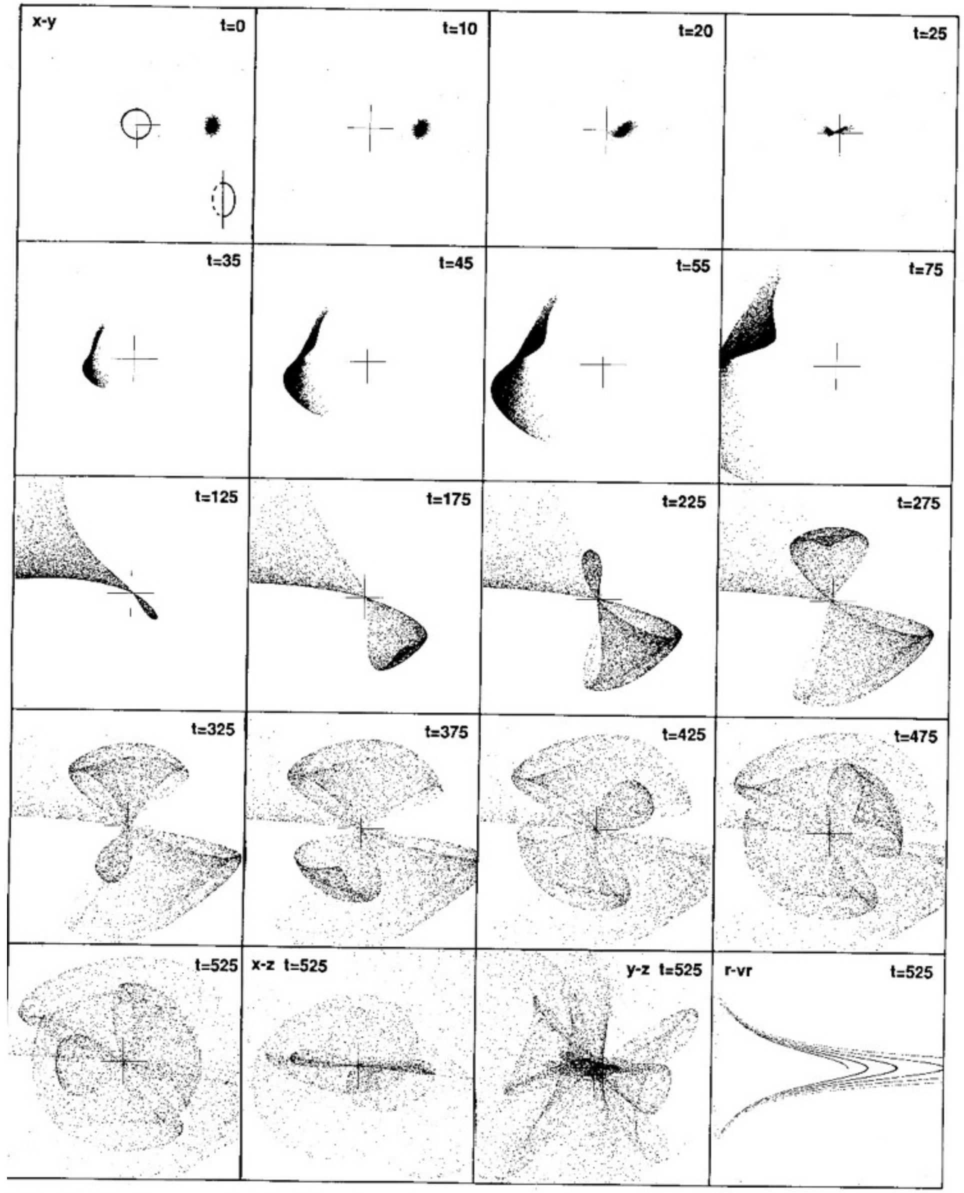
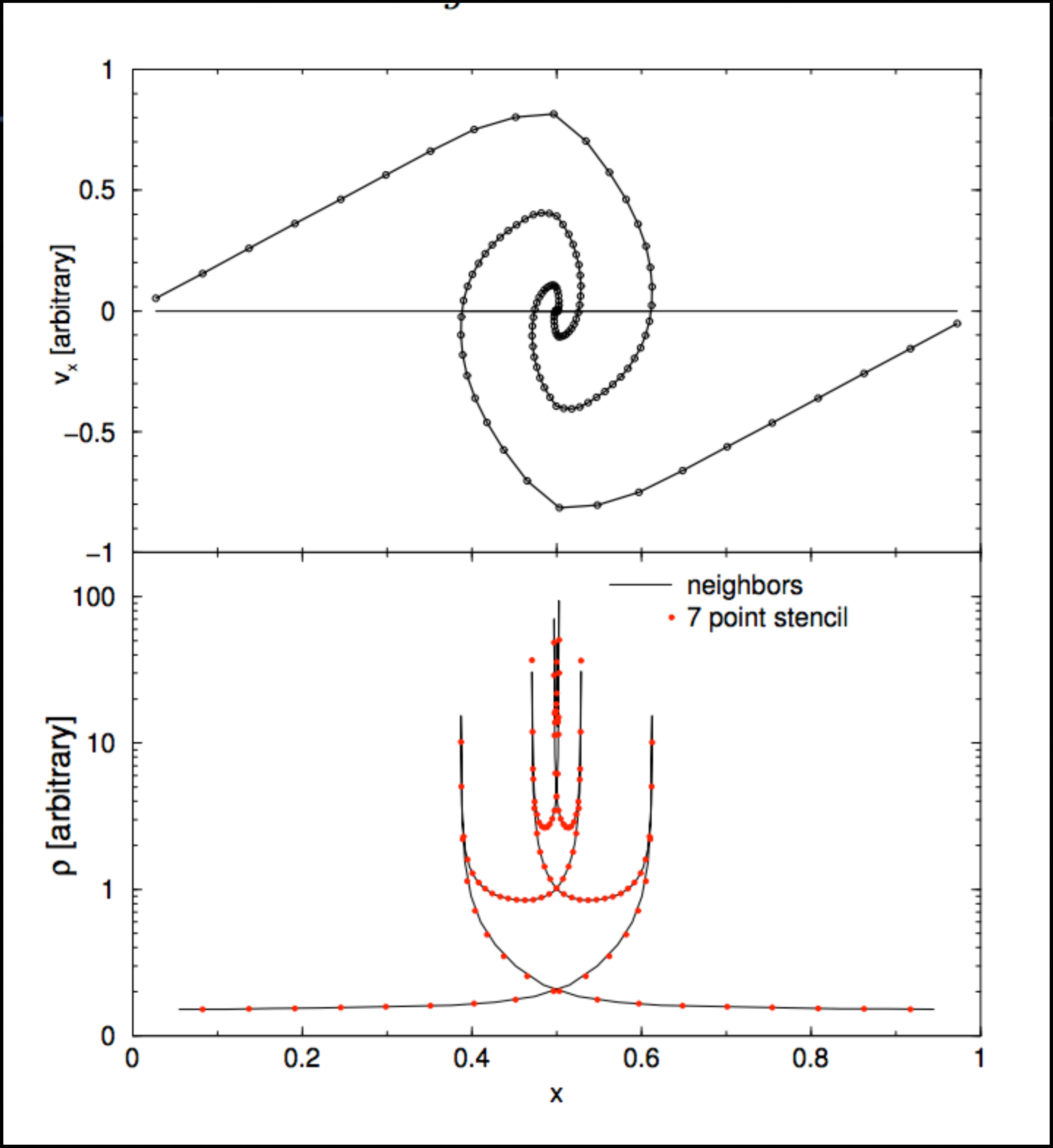


FIG. 2.—Model 2: radial encounter of an inclined disk companion of mass $m_c = 0.01$ and scale length $a = 0.3$ with a spherical Plummer primary. The inclination the disk was 45° with respect to the $x - y$ plane as indicated by the outline in the bottom right of the $t = 0$ panel. Bottom four frames show the three spatial ɔjections and the phase space density (radial velocity vs. radius) at the final time $t = 525$. All other figure parameters are as in Fig. 1.

Caustics

- These have been considered coming from disrupted dwarfs
- But, the annihilation signal isn’t changed much by them
- Indeed, the signal was stronger from the dwarf before it disrupted



1
0.5
0
−0.5
−1
v_x [arbitrary]
neighbors
7 point stencil
100
10
1
0
ρ [arbitrary]
0
0.2
0.4
0.6
0.8
1
x

Back to the "Sheets"

- The local distribution of DM is dominated by about 10,000 sheets (the top 100 are a large fraction even)
- Makes the velocity distribution function spikey (come back and we'll talk about this when you are detecting a million DM particles/day:)
- Doesn't do anything for annihilation signal either

Think about traveling "on a sheet"

- Most of phase space is empty, but consider a star that lands on a sheet. It has the same 6D phase space coordinates as the local DM sheet and will travel with it. It sees a local distribution that is cold and accretes like mad
- There are a Billion halo stars, each a lottery ticket to land on a stripe
- We are calculating how the accretion evolves through the turning points to see if we can get a dark burner or two

Conclusions

- Don't consider the 3D or 6D distribution of dark matter to be so well understood. The issue is not whether the SHM is 10% high or low.

- I'm convinced that we probably haven't found the mechanism that will detect the DM. There will be more mechanisms…