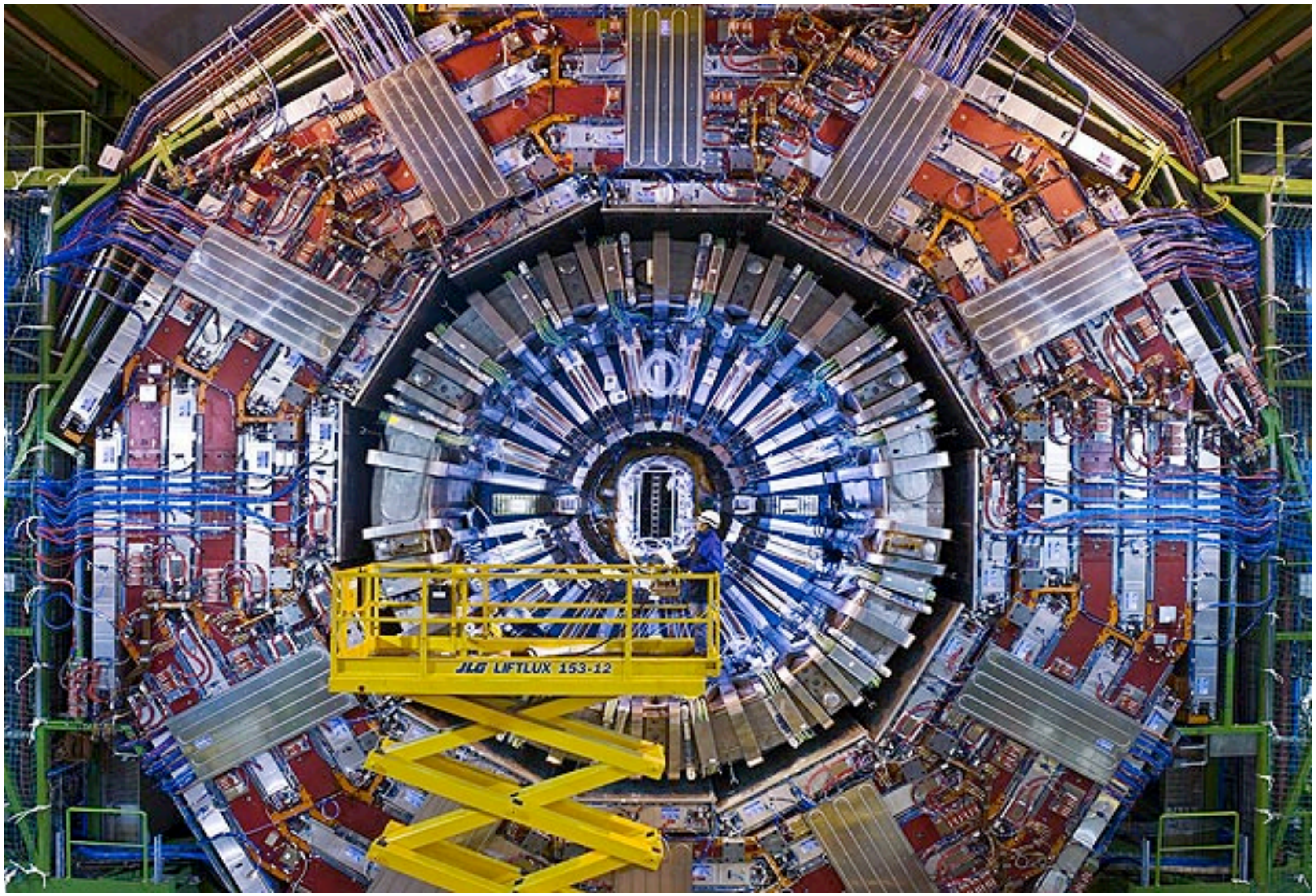
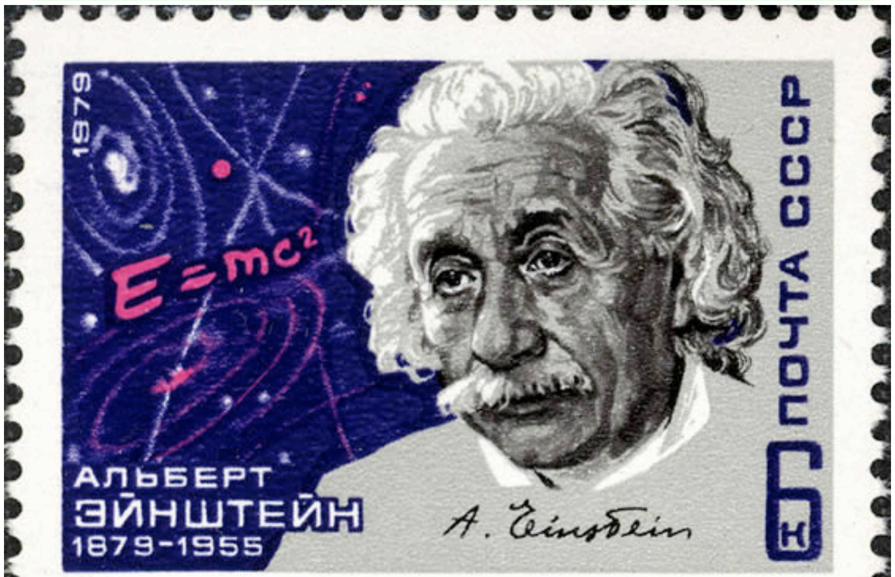
A View from a Particle Experimentalist



Photograph of the CMS (Compact Muon Solenoid)detector

Albert Einstein

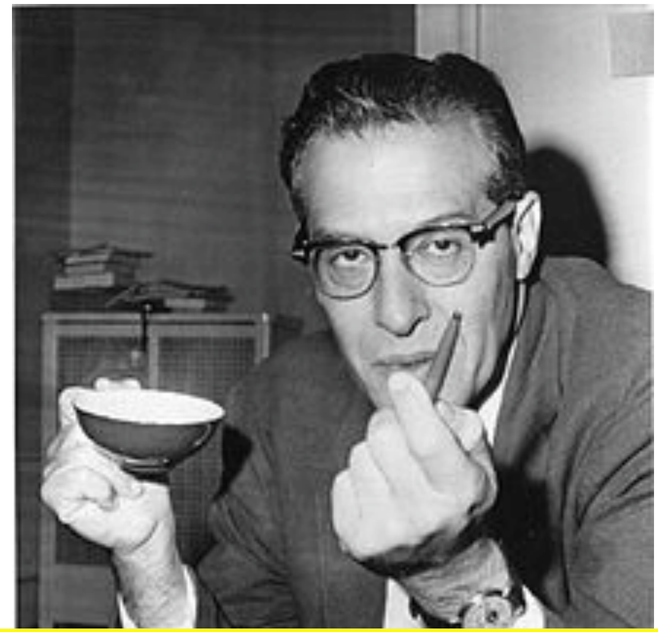
99th element of the periodic table named after him.



Russian stamp in honor of Einstein

- Brownian Motion
- Photoelectric Effect
- Special Theory of Relativity
- Matter- Energy Equivalence
- General Relativity
- 1921 Nobel Prize

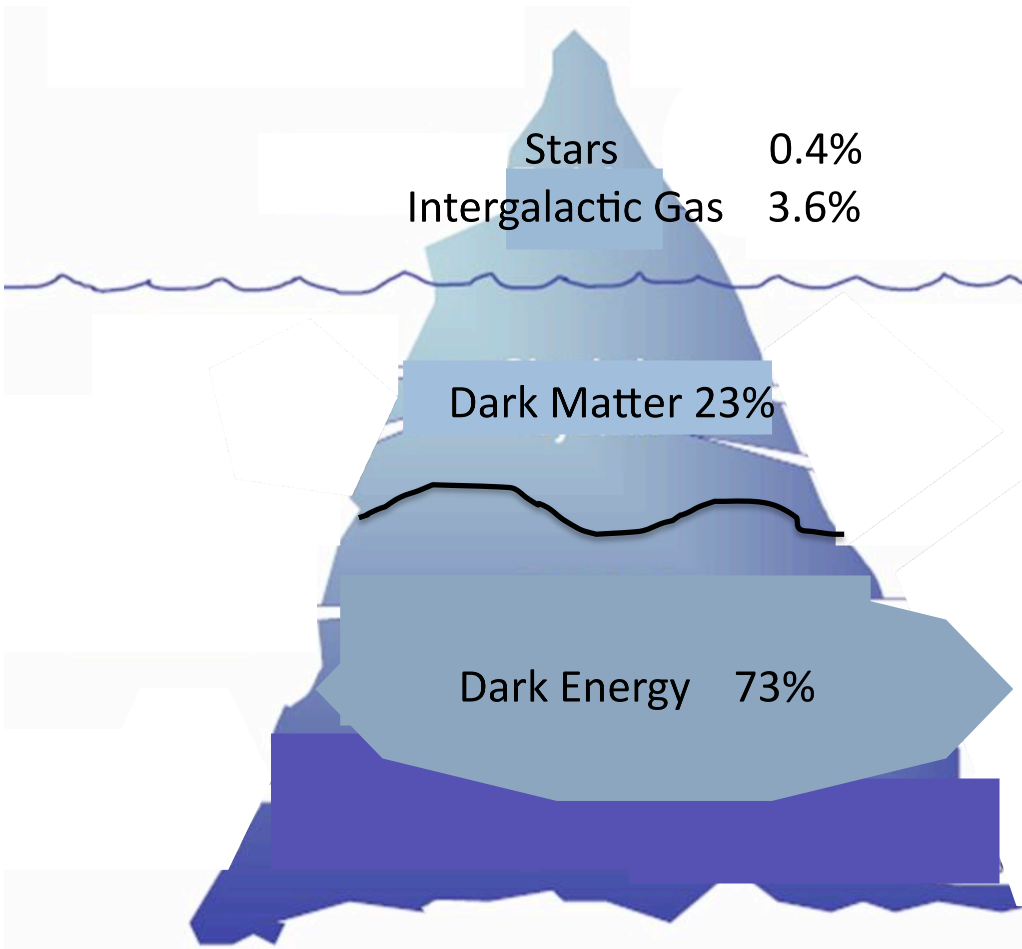
Julian Schwinger



My laboratory is a ball point pen!

- Quantum electrodynamics
- Renormalization
- Confinement
- Multiple Neutrinos
- Quantum Action Principle
- First Albert Einstein Award (1951)
- 1965 Nobel Prize

Neither guessed the Current Picture that we are the tip of an iceberg



Particle Physics - Astronomy

The physics of the elementary particle physics is deeply connected to the physics of the structure and evolution of the universe.

Particle accelerators can recreate the levels of energy that existed in instants after the big bang, making the kinds of collisions that characterized the whole universe at its birth.

Astronomical data from today's powerful instruments shed light on the fundamental nature of matter.

The fields have become much more interconnected.

Today I will talk about both fields

Neutrinos not obviously faster than speed of light! OPERA result is gone!

The news was delivered at the 25th International Conference on Neutrino Physics and Astrophysics in Kyoto, Japan last Friday.

$$\delta t = \frac{D}{v} - \frac{D}{c}$$

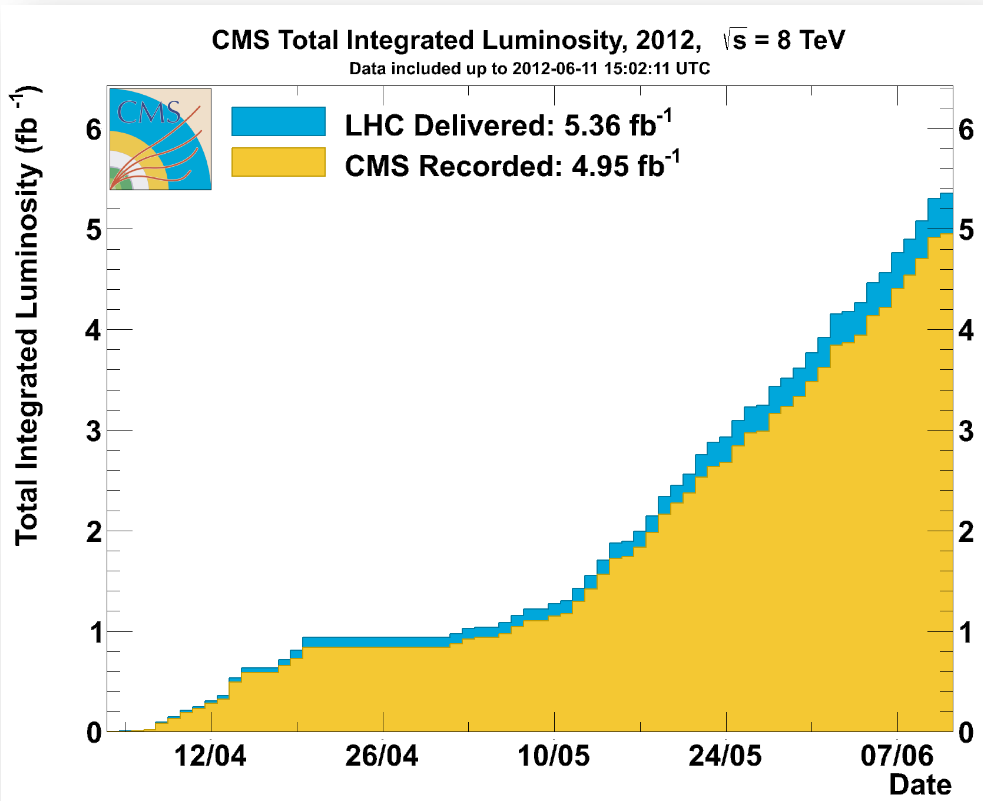
Neutrino 2012

Kyoto, June 8, 2012
Sergio Bertolucci
CERN

- **Borexino**: δt = 2.7 ± 1.2 (stat) ± 3(sys) ns
- **ICARUS:** δt = 5.1 ± 1.1(stat) ± 5.5(sys) ns
- **LVD:** δt = 2.9 ± 0.6(stat) ± 3(sys) ns
- **OPERA:** δt = 1.6 ± 1.1(stat) [+ 6.1, -3.7](sys) ns

LHC Running Very Well

> 5 fb^{-1} at $\sqrt{s}$ = 8 TeV



- Preparing many Higgs results
  - Open box on 15th. Expectations:
    - 4± 1 σ significance at ~125 GeV or exclude SM at all masses?

Lab Director wants 5σ from both experiments for both discovery and exclusion. This statement hides a lot of subtlety.

Is it adequate to have a combination of many channels with no visible signal in them or will there need a strong signal in one or more channels?

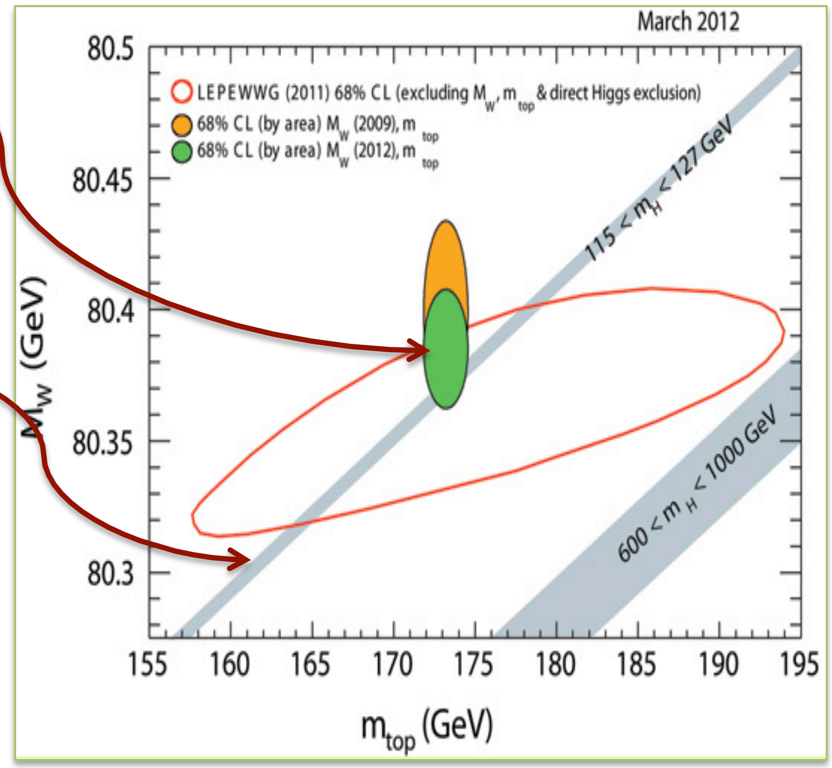
- We all aware that conservatism is important in a discovery!

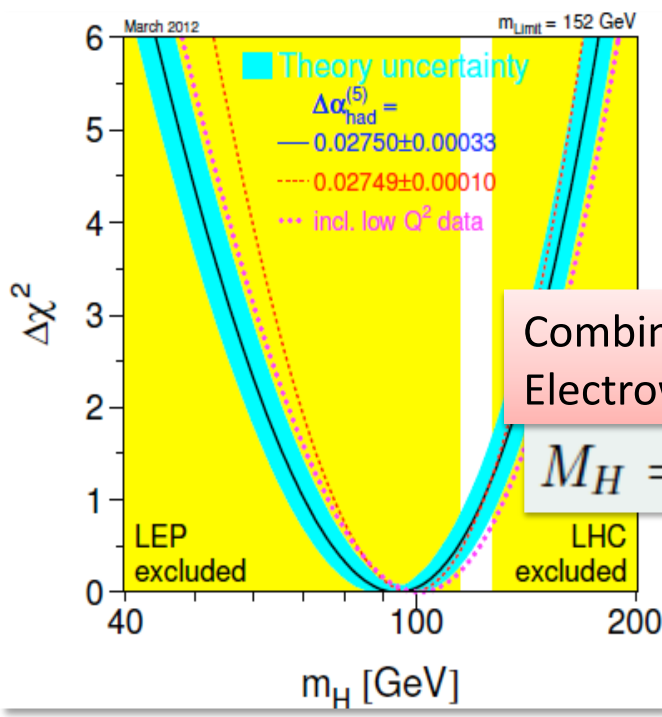
- **Recorded efficiency already a bit higher than 2011 despite facing the highest luminosity and pile-up ever encountered in a hadron collider**

SM Higgs in perspective

- Tevatron M_W *Tours de Force!!*
- Shifts for SM Higgs expectation

Colliders leave little space





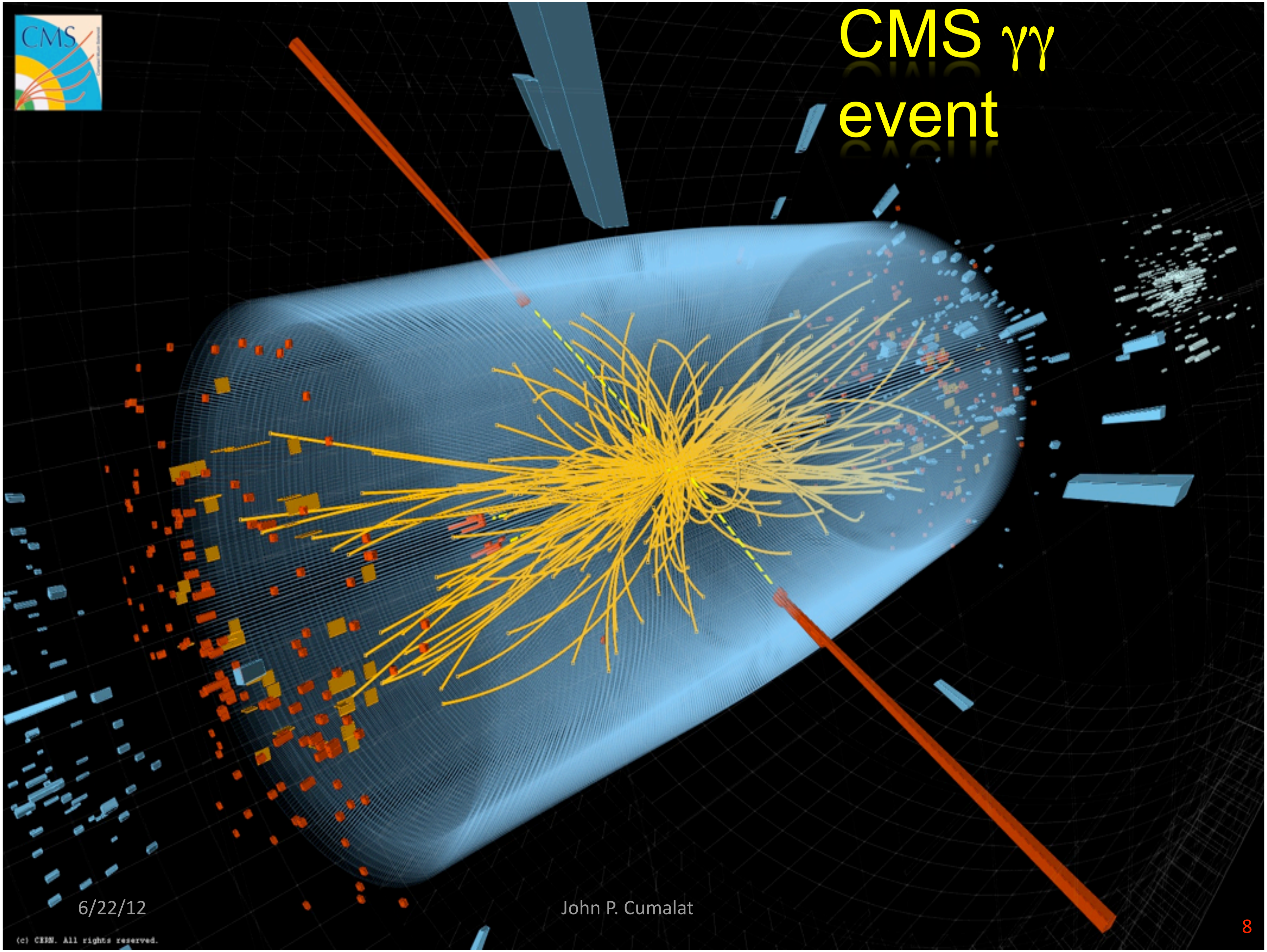
Combined precision
Electroweak data

$$M_H = 94^{+29}_{-24}$$

This is the main story of the past year

We eliminated >450 GeV of the mass range.

CMS $\gamma\gamma$ event



Higgs Updates since Feb 2012 papers

- Standard Model
  - H $\rightarrow \gamma\gamma$ been improved.
  - Associate production: WH $\rightarrow$ WWW(3l3ν), W$\tau\tau$
  - Added H $\rightarrow \tau\tau \rightarrow \mu\mu$, WH $\rightarrow$l$\nu\tau\tau\rightarrow$e$\mu\tau_h$,$\mu\mu\tau_h$ (+MET)
  - Added H$\rightarrow$ WW$\rightarrow$ lνjj
- Beyond the Standard Model
  - H $\rightarrow \gamma\gamma$ optimized for Fermiophobic Higgs
  - Charged Higgs: t$\rightarrow$ Hb
  - Doubly charged Higgs to dilepton
- Already more than doubled the data sample with the result to be announced at ICHEP in Melborne in July. ATLAS and CMS will need to agree on dominant channels and production mechanisms to establish the Higgs observation.

Illuminating Dark Matter

- Direct pair production at LHC
  - The dark matter goes undetected
  - Look for “nothing” plus a single photon or jet radiated off of an incoming quark from a proton

Great hope is that Dark Matter will be found via the observation of Supersymmetry (SUSY) at CERN. If the lightest SUSY particle is found, then its properties can be explored in the laboratory.

Simple SUSY models are now under pressure
    Limits > 1000 GeV for squarks and gluinos
But SUSY is not dead
    A 115-130 GeV Higgs is “tailor made” for SUSY
        More complicated (and interesting) “natural” SUSY models are plentiful.
        They involve more difficult searches for which it is hard to even get the data on tape!

Dark Matter

Cosmology supposes that roughly ¼ of our universe is made of Dark Matter, yet it has proven difficult to find.

Today, only limits on its existence, but a wide range of phase space and parameters has been ruled out.

DM is not needed to explain the movement of planets in our solar system, and apparently is not needed for other stars in the solar neighborhood.

Scientists reluctant to consider the alternatives to Dark Matter and accept the idea that Newtonian gravity does not apply everywhere.

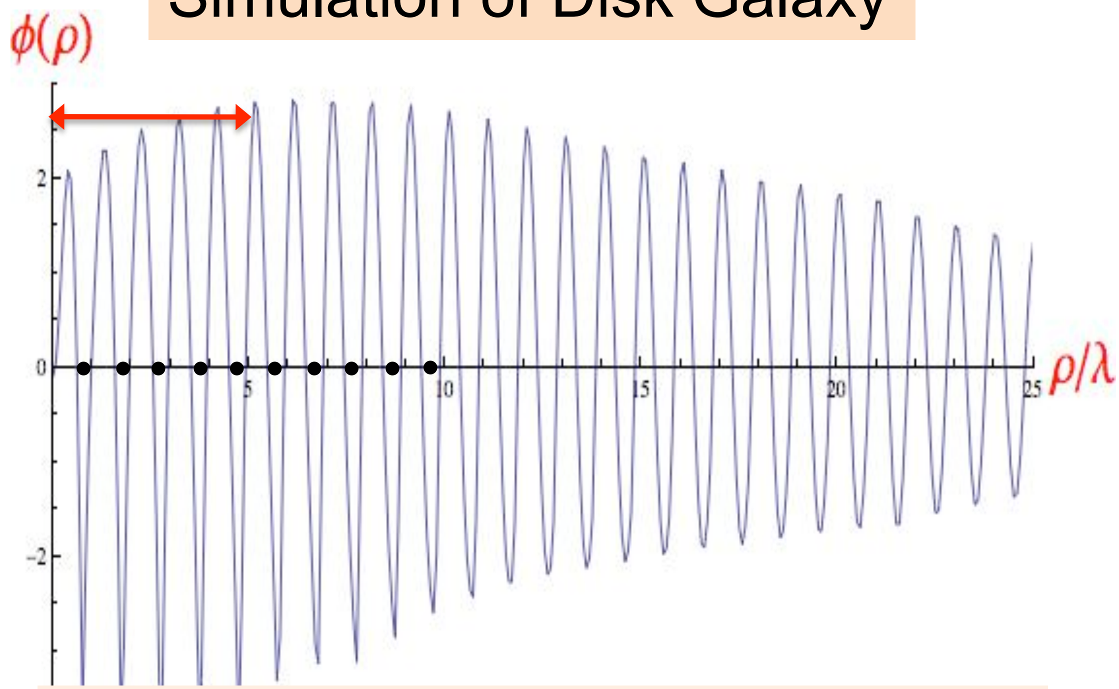
I've become interested in the Sinusoidal Potential as it has a number of attractive features that I'd like to show.

Sinusoidal Potential

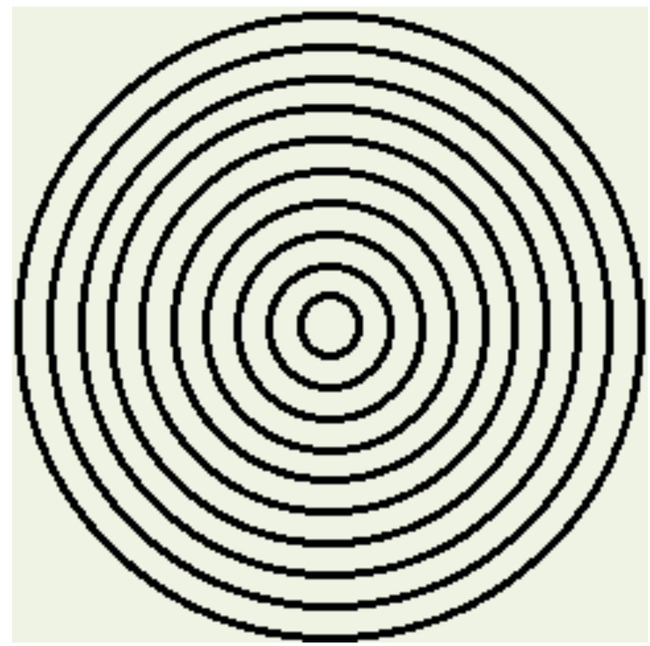
$$\Phi = -\frac{GM}{r}\cos(k_0 r)$$

Recovers Newton with small enough k_0

Simulation of Disk Galaxy



The Sinusoidal Potential as a function of ρ/λ_0. Made with 21 rings of material (stars and gas) with each ring having a radius larger than the previous ring by the universal length. Note the build up in the strength of the potential and the slow fall-off in radius. The 25 λ_0 limit in ρ/λ_0 corresponds to 10 kpc.



Sinusoidal Potential

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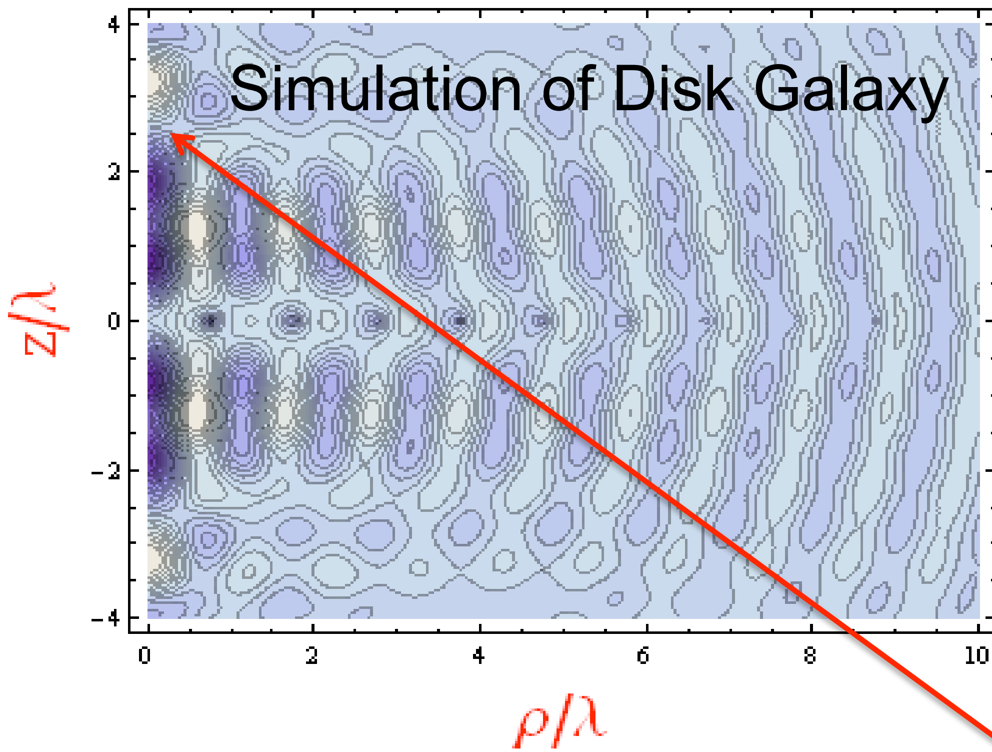
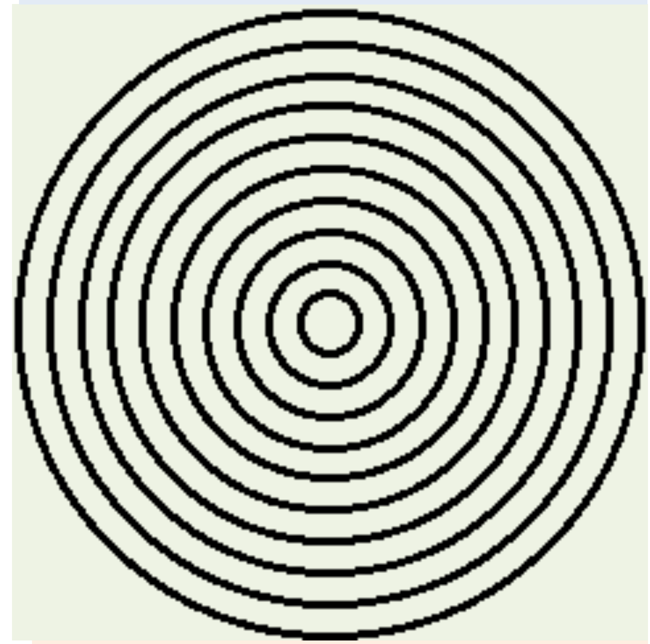




Top View of Dust and Stars in the thin disk

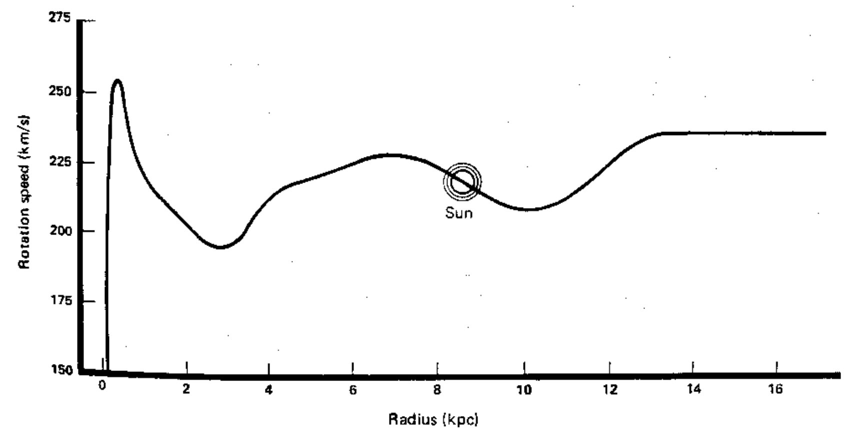
Contour plot of Sinusoidal potential in cylindrical geometry – dark is potential minima.

Ring Structure naturally yields bulge at center

Use Virial Theorem to Recover Flat Rotation Curves

$$\phi(r) = -(\frac{GM}{r})\cos(\frac{2\pi r}{\lambda_0})$$

$$g_r \approx -(\frac{2\pi GM}{r\lambda_0})\sin(\frac{2\pi r}{\lambda_0})$$



Slowly weakening field (instead of $1/r^2$) is what is needed to obtain flat rotation curves

$$\boxed{2\langle T\rangle = -\left\langle \frac{\partial\phi}{\partial r}\bullet r\right\rangle = \frac{2\pi}{\lambda_0}GmM_{eff}\left\langle \sin\left(\frac{2\pi r}{\lambda_0}\right)\right\rangle}$$

$$\text{Note: } 2\langle T\rangle \neq \langle V\rangle$$

Butler Burton’s HI layer of Milky Way

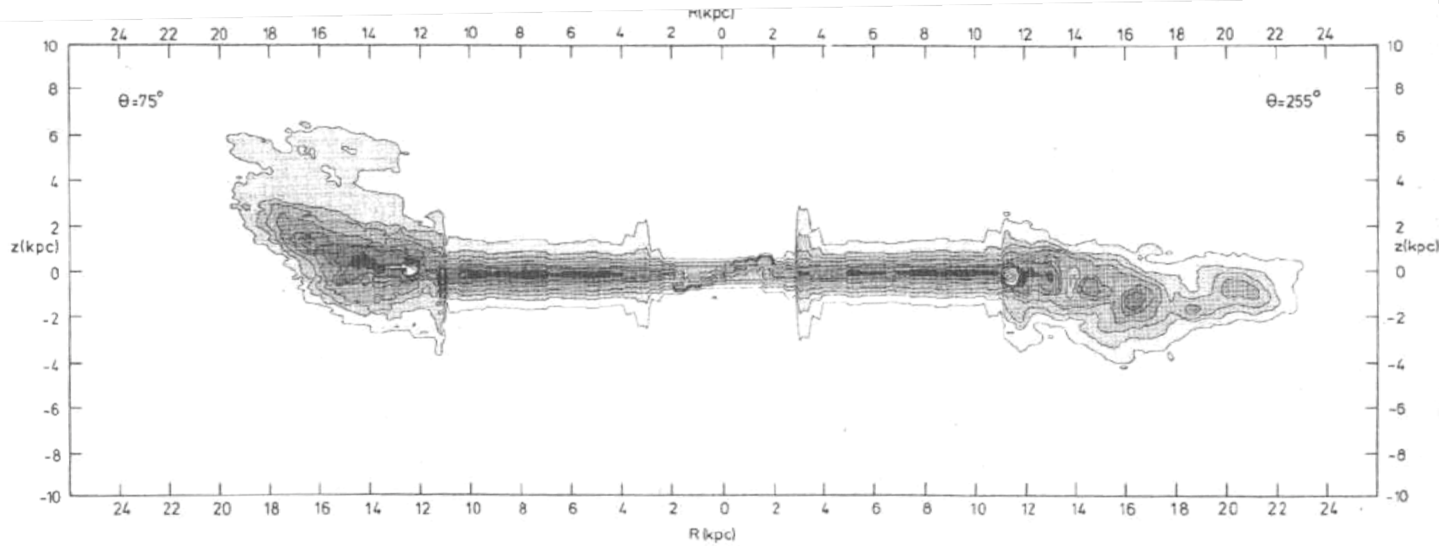
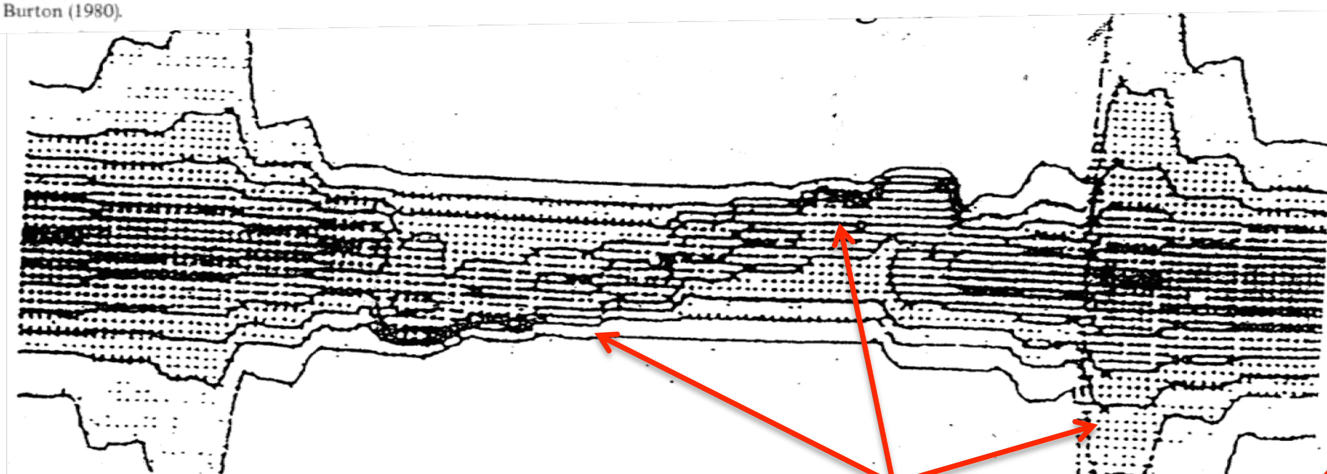


Fig. 7.23. Schematic, but not arbitrary, representation of the HI layer of our Galaxy. The cross section represents a cut through the Galactic center perpendicular to $b = 0°$ in a sheet sampling strong deviations from a flat layer. The representation at $R > 11$ kpc is from R, z maps, like the ones in Figure 7.21, at $\Theta = 90°$ and $270°$. Over the range $2 < R < 10$ kpc, the parameters of the layer are those given by Lockman (1984) for the subcentral-point region; at $R < 2$ kpc, they are those given by Liszt and Burton (1980).

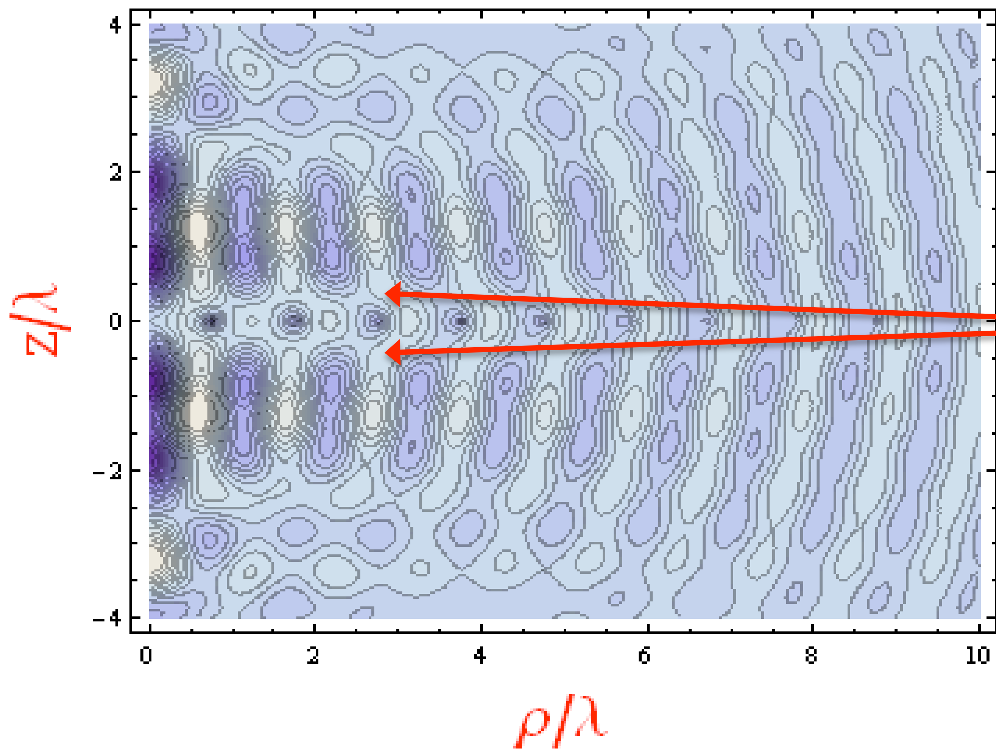


Expanded View of Central Region

Pick λ_o=400pc

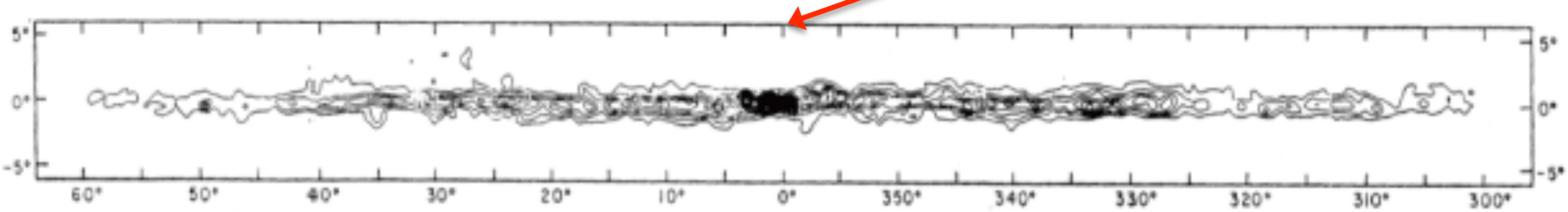
Butler Burton has stated that the “central wiggles are real”. Note he assumed a distance from the sun to the galactic center of R_0 =10kpc. The step structure is equal to R_0/20

Sinusoidal Potential Z versus r dependence



Provides a natural explanation for the extreme disk – at a distance of +/- ¼ λ or +/- 100 pc

Note: There are two dense bands of CO contours from Tom Dame et al (1987). These bands are probably related to stall points in the z-motion of matter in the extreme disk.



Additional supporting evidence

Dan Clemens investigating CO velocity residuals using a Fourier analysis. Finds an unexplained $R_0/20$ length.

Matese and Whitmore (1997) have found the perihelia of long-period comets are influenced by the galactic tidal force to a large extent. This surprise is removed if tidal force is 120x larger than expected and is what is found with Sinusoidal Potential.

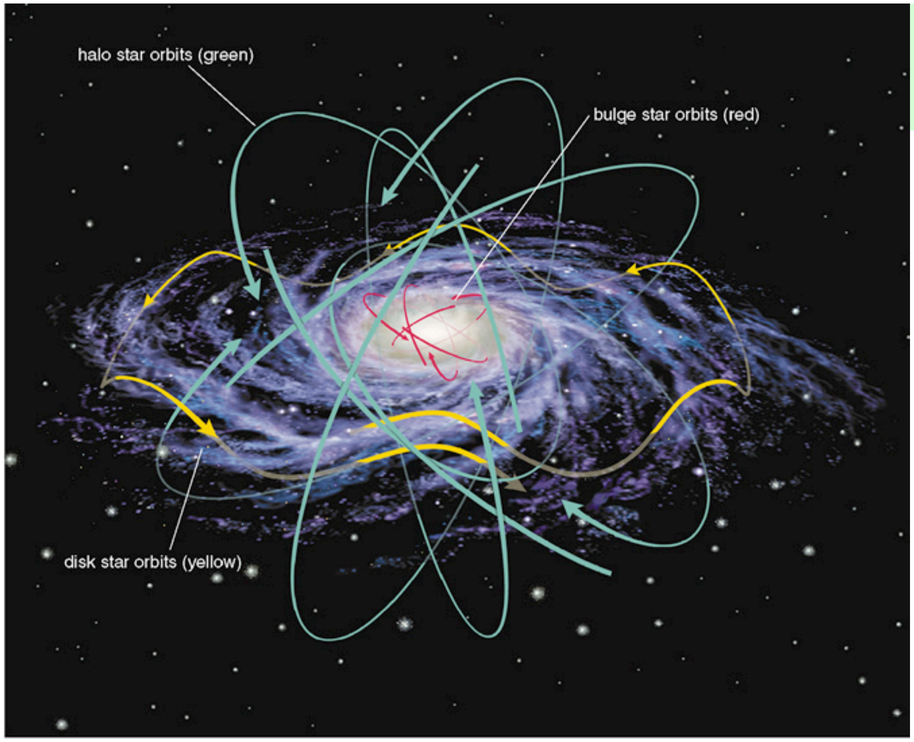
These tides give an epicyclic period about 30 times less than the rotational period. Thus, period of radial oscillations of the sun (in a record groove) is about 8 Myr compared to the 240 Myr for the Galactic period.

As stars and gas oscillate in the record groove they spend the most time at stall points before reversing their direction in the groove. Stall points are the regions to find stars forming. Search for location of methanol masers.

Milky Way: Periods at Solar Circle

	Conventional Poisson's Eq.	Sinusoidal Helmholtz's Eq.
Orbital	240 Myears	240 Myears
Radial	170 Myears	8 Myears
Z	62 Myears	240 Myears

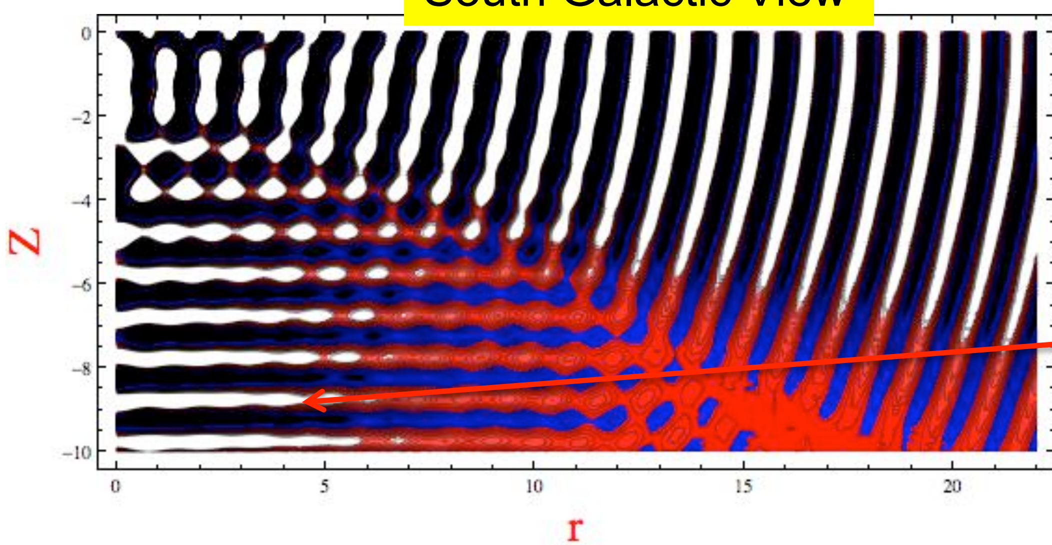
Info: C.W. Allen *Astrophysical Quantities, 3rd Edition.*



Stellar Orbits in Galaxy

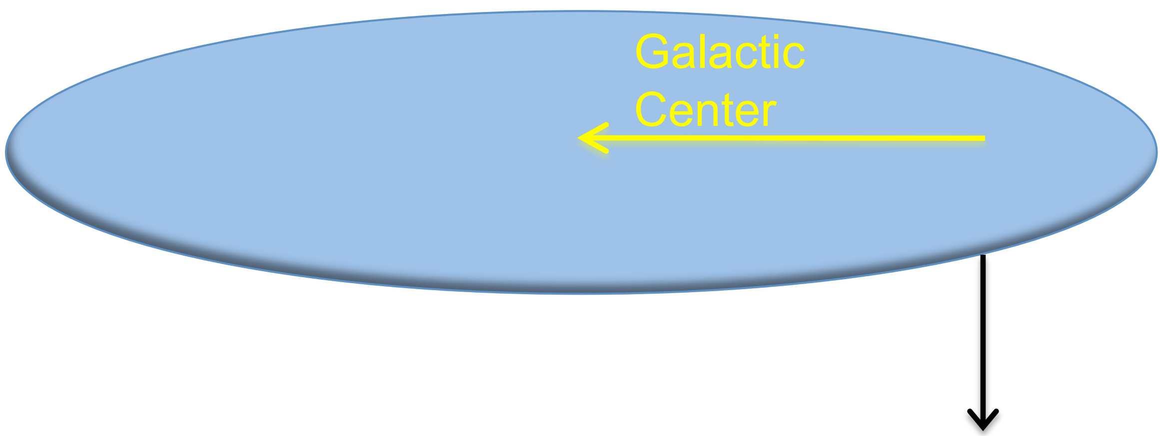
- Stars in the disk all orbit the Galactic center:
  - in the same direction
  - they "bobble" up and down
    - this is due to gravitational pull from the disk?
    - this gives the disk its thickness?
- Stars in the bulge and halo all orbit the Galactic center:
  - in different directions
  - In the Sinusoidal Potential they can rotate around the z axis

South Galactic View

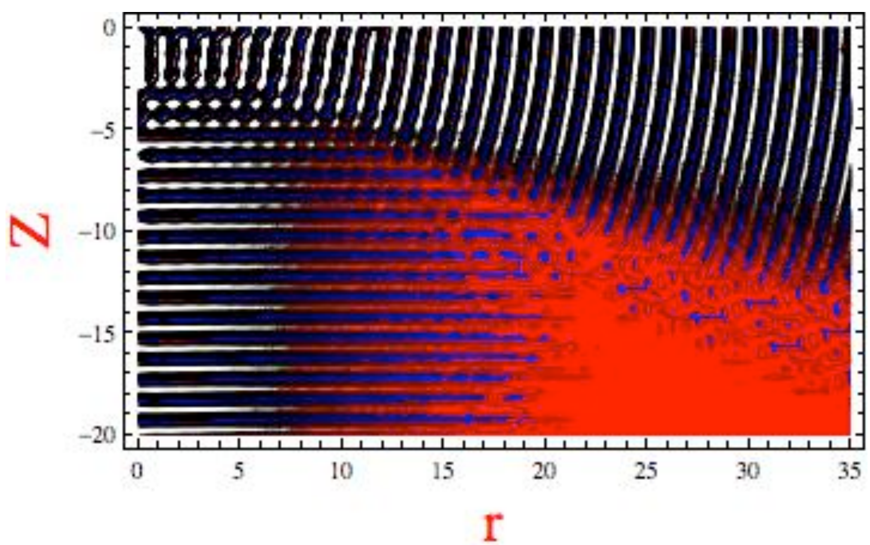


In plot color white is potential minima

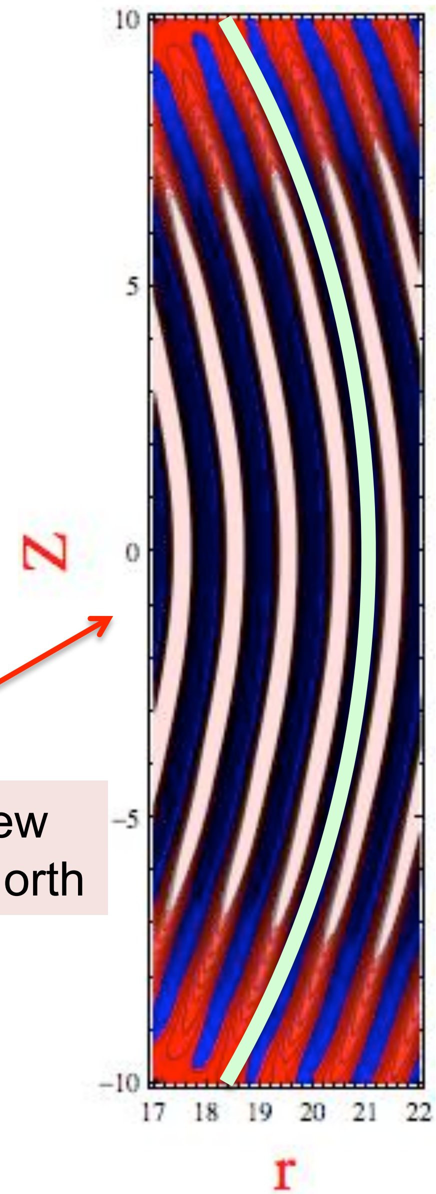
A Natural Explanation for Thin and Thick Disks?



South
Pole



Zoomed view
Including North

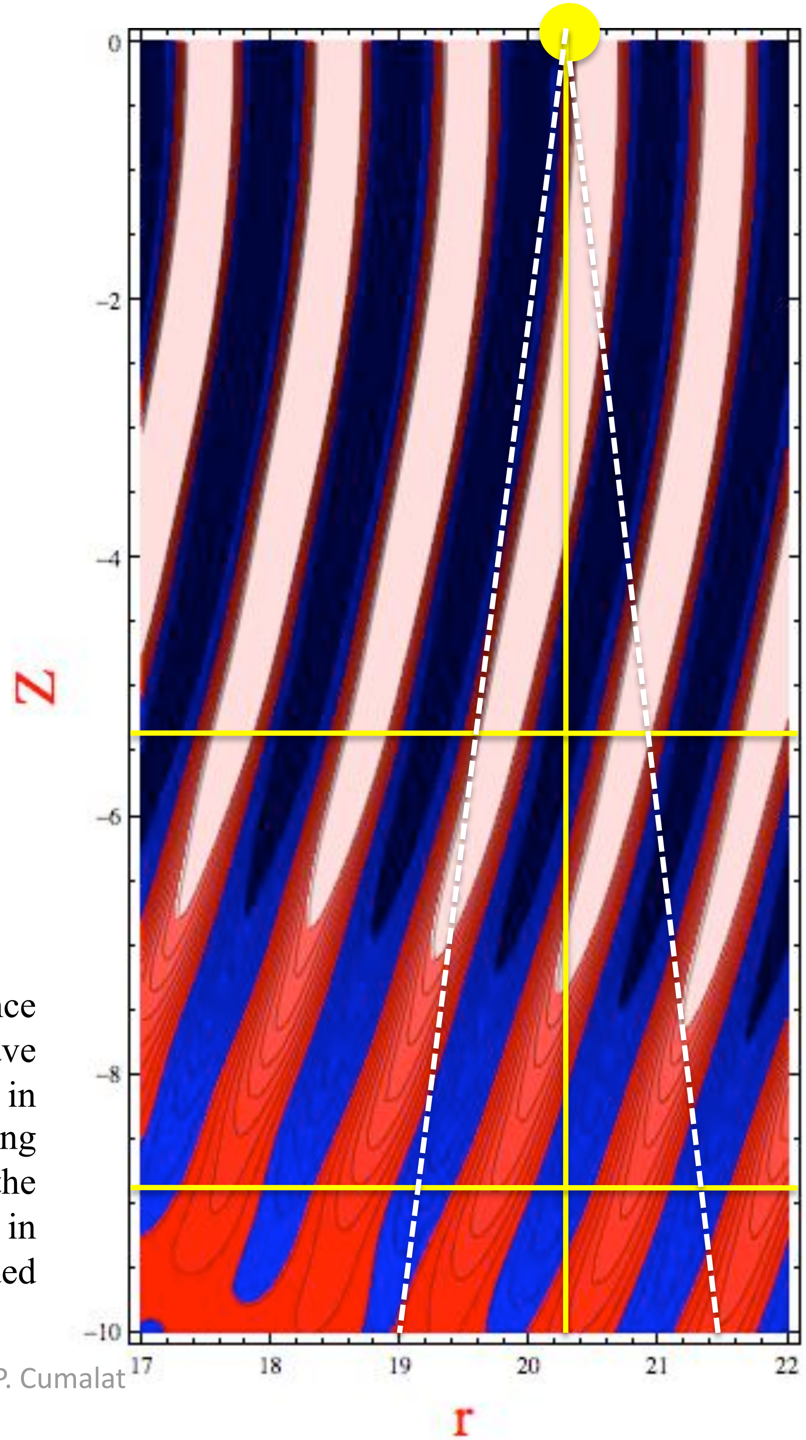


Sun is located at 20.25 λ

Stars are free to move in a record groove. Groove of Sun extends out to a z of 5.45 λ (2.18 kpc) and next groove is out to a z of 8.85 λ (3.5 kpc).

Presumably, these stars orbit around the galactic center.

Two papers from the same group have explored the evidence for DM. Moni-Bidin, Carraro, Méndez, and Smith 2012 have compiled full 6-parameter kinematics for 400 red giant stars in the direction of the South Galactic Pole. Preliminary reading of their plots is the conventional thin and thick stars near the sun can be separated into stars in the solar record groove and in one a distance λ_0 further out. The authors have kindly provided us data on individual stars for a detailed analysis.



Mean Velocity of red giant stars as a function of distance from the Galactic plane

Data from Moni-Bidin, Carraro, Méndez, and Smith 2012

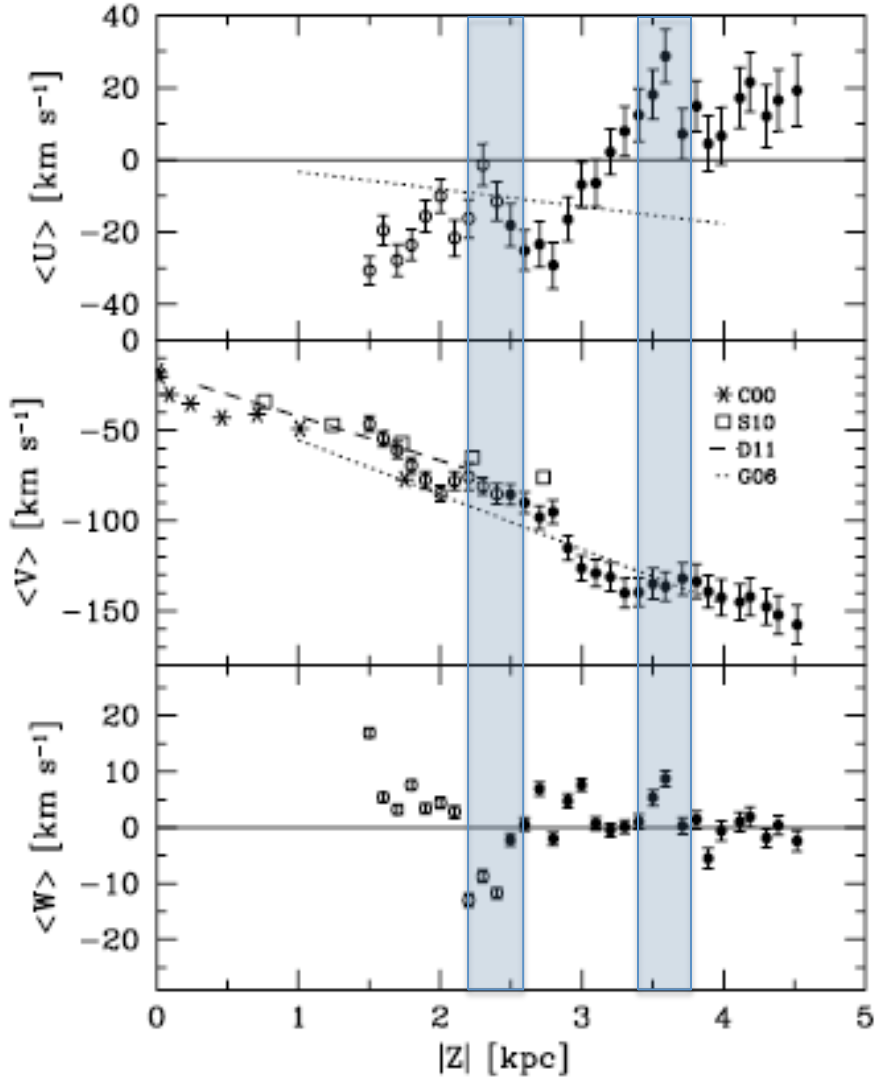


Figure 4. Trend of mean velocity components (from top to bottom: radial, rotational, and vertical component) as a function of distance from the Galactic plane. Empty dots are used for the bins contaminated by the thin disk, where the measurements are less reliable. Results of previous investigations are also indicated: Girard et al. (2006, G06), Casetti-Dinescu et al. (2011, D11), Chiba & Beers (2000, C00), and Spagna et al. (2010, S10).

Radial

Rotational

Vertical

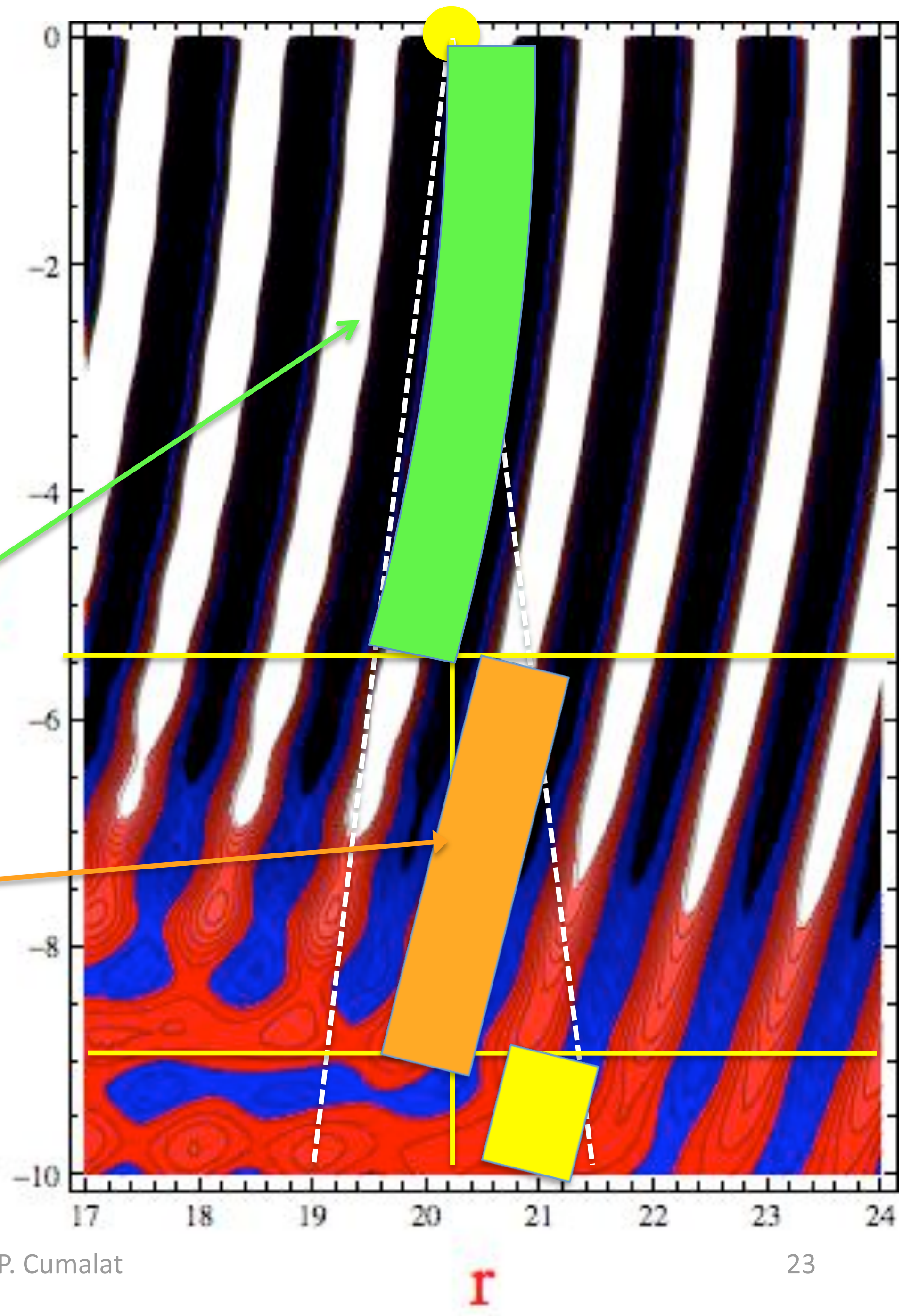
Sun is located at 20.25 λ

Stars are free to move in a record groove. Thin disk extends out to about 5.45 λ (2.18 kpc) and thick disk is out to 9 λ (3.6 kpc).

Thin Disk= thin shell

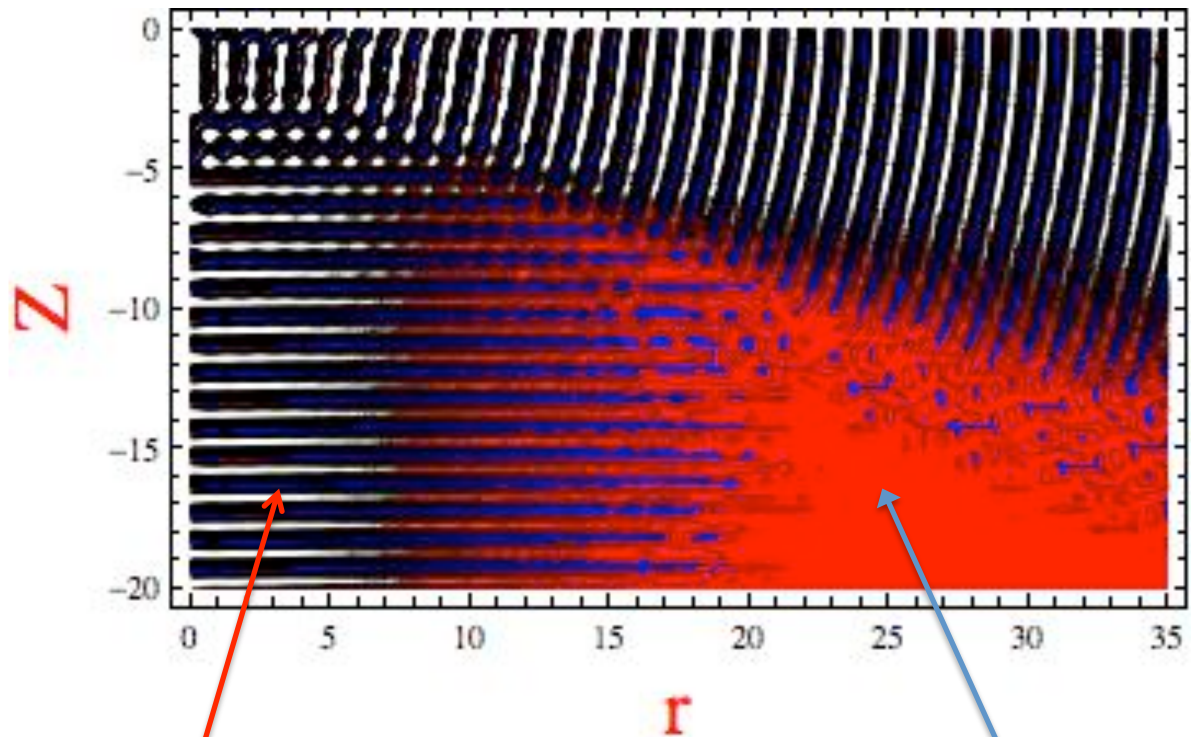
Thick Disk = next groove

Presumably, the stars orbit around the galactic center.



Recent VPOS results
Vast POlar Structure

(Pawlowski, Pflamm-Altenburg, and Kroupa 2012) the distribution of satellite galaxies, globular clusters, and streams orbiting the Milky Way were examined and the group finds they lie in a vast polar structure. Dark matter models predict the satellites should be distributed in a more-or-less spherical pattern.



Strong minima and maxima in the polar region

Potential about 0, neither attractive or repulsive

Summary

The Standard Model Higgs should be found or excluded by end of summer.

SUSY is being squeezed.

Sinusoidal Potential is an interesting model to pursue and test. Seems to naturally explain many of the broad structures of our Galaxy. (Bulge, extreme disk, maybe thin + thick disk, and flat rotation curves, orbits, vast polar region, etc.)

Would be nice to try out the potential in some of the larger simulations as a replacement for Newton.

Ideas for Sinusoidal Potential?

Not getting any younger!