Dynamos

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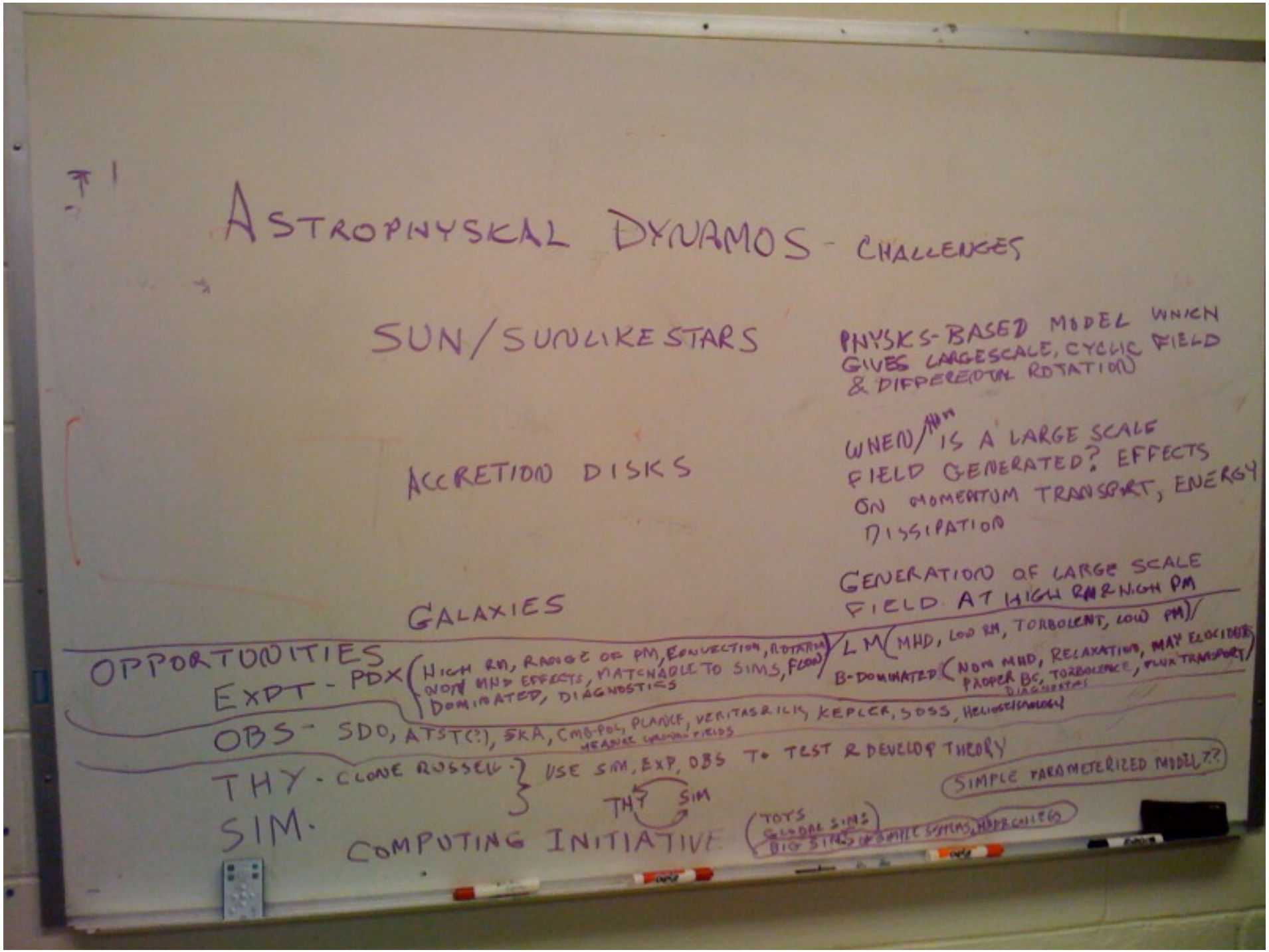
ASTROPHYSICAL DYNAMOS - CHALLENGES
SUN/SUNLIKE STARS
PHYSICS-BASED MODEL WHICH GIVES LARGESCALE, CYCLIC FIELD & DIFFERENTIAL ROTATION
ACCRETION DISKS
WHEN/HOW IS A LARGE SCALE FIELD GENERATED? EFFECTS ON MOMENTUM TRANSPORT, ENERGY DISSIPATION
GALAXIES
GENERATION OF LARGE SCALE FIELD AT HIGH Rm & HIGH Pm
OPPORTUNITIES
EXPT - PDX (HIGH Rm, RANGE OF Pm, EQUATION, ROTATION, NON MHD EFFECTS, MATCHABLE TO SIMS, FLOW DOMINATED, DIAGNOSTICS)
L M (MHD, LOW Rm, TORBOLENT, LOW Pm)
B-DOMINATED (NON MHD, RELAXATION, MAY ELOCITIES PROPER BC, TORBOLENCE, FLUX TRANSPORT)
OBS - SDO, ATST(?), SKA, CMB-POL, PLANCK, VERITAS, ILC, KEPLER, SDSS, HELIOSEISMOLOGY
THY - CLONE RUSSELL
SIM.
USE SIM, EXP, OBS TO TEST & DEVELOP THEORY
THY SIM
COMPUTING INITIATIVE (TOYS GLOBAL SIMS BIG SIMS OF SMALL SYSTEMS, HYPERCODES)
SIMPLE PARAMETERIZED MODEL??

Astrophysical Challenges

- Develop a model of the solar dynamo that captures the essential features: the *large scale* toroidal & poloidal fields & their cyclic behavior, and the correct differential rotation.
- Develop models for dynamos in accretion disks that predicts when a *large scale* field can grow, how the field affects momentum transport, and how energy is dissipated.
- Develop models for galactic dynamos that explain how a *large scale* field is generated at the high Rm and Pm characteristic of galaxies.

Current Tools

- Liquid metal & magnetically dominated plasma experiments, MRI experiments.
- Helioseismic probes of solar rotation, photospheric field measurements, observations of disk & jet plasma, coarse galactic B maps.
- Theory & simulation of small scale dynamos in most regimes, global models w. simple parameterization of small scales, theories for large scale dynamos.

Opportunities

These opportunities might usefully be combined through a center, possibly in partnership with other areas such as angular momentum transport or turbulence.

Opportunities: Experiment

- Flow dominated plasma dynamos for a range of collisionalities, Pm, Rm, flow properties.
- Transport, relaxation, boundary conditions, physics beyond MHD, in magnetically dominated experiments.
- Low Pm MHD dynamos in liquid metal experiments.
- Liquid metal & plasma MRI experiments

Opportunities: Observation

- Measure solar coronal field, vector photospheric field, magnetic activity on a large sample of stars, solar interior rotation & flow (SDO, ATST, Kepler, SDSS).
- Magnetic field diagnostics in accretion disks & jets.
- Detailed mapping of Milky Way magnetic field, nearby galaxies, galaxies over cosmic time (SKA, CMBPol,..).

Opportunities: Theory & Simulation

- Develop theory for growth of a large scale field, dynamos in low collisionality systems, and low Pm systems. Understand what saturates the small scale field predicted to grow rapidly at high Pm, Rm.
- Major computing initiative to use simulations to test and develop theory, and simulate existing & future experiments.
- Model observational signatures of dynamos.
- Explore low order/simply parameterized models that capture the essential physics & are astrophysically useful.

Challenge 1	Existing Research Capabilities	Gaps	Opportunities
How do large scale fields, possibly cyclic, arise in astronomical systems?	Moderate scale, observational probes, & simulations, liquid metal & magnetically dominated expts.	Theory of large scale field generation confirmed by computation or experiment.	Experiments on dynamos in flow dominated plasma, MRI in liquid metals & plasmas, extended data base of solar, stellar, galactic B observations. Computing initiative to increase synergism between theory, simulation, experiment, observation.

Challenge 2	Existing Research Capabilities	Gaps	Opportunities
How do dynamos operate in low collisionality systems where anisotropic viscosity, pressure, & 2-fluid effects may be important?	Observations of hot accretion disk & jet plasma, experiments on flux transport & conversion in magnetically dominated systems, theory of MRI.	Experiments on flow dominated plasma, theory and simulation of field growth in collisionless plasmas.	Flow dominated plasma dynamo experiment, components of dynamos in magnetically dominated experiment. Develop theory for low collisionality dynamos. Computing initiative to maximize synergism between theory, simulation, experiment, observation. Develop & implement observational diagnostics of low collisionality dynamos.

Note the strong overlap of opportunities for both challenges. Dynamo studies might be usefully combined under the umbrella of a national center/consortium.