High-resolution solar magnetography from space: beyond Solar-B

"From the viewpoint of theory & modeling"

Karel Schrijver

Evolution of the scientific method:

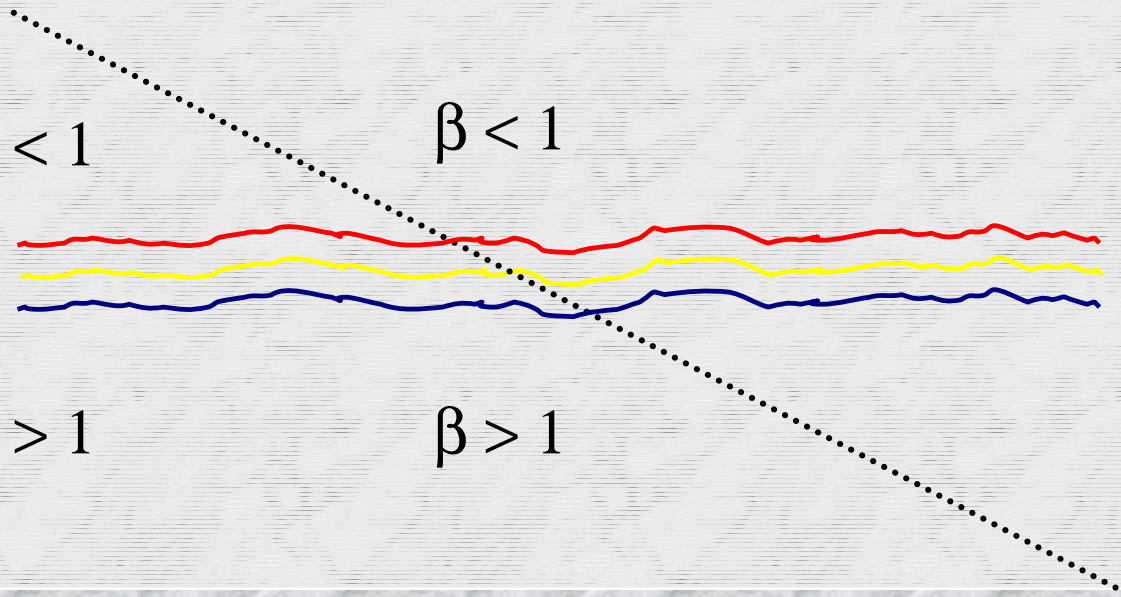
- Galilei: “measurements are essential”
- Descartes: “study processes in isolation”
- …: “study the connected system”

Heard during this meeting:
(With a much deeper meaning than it may seem to have)

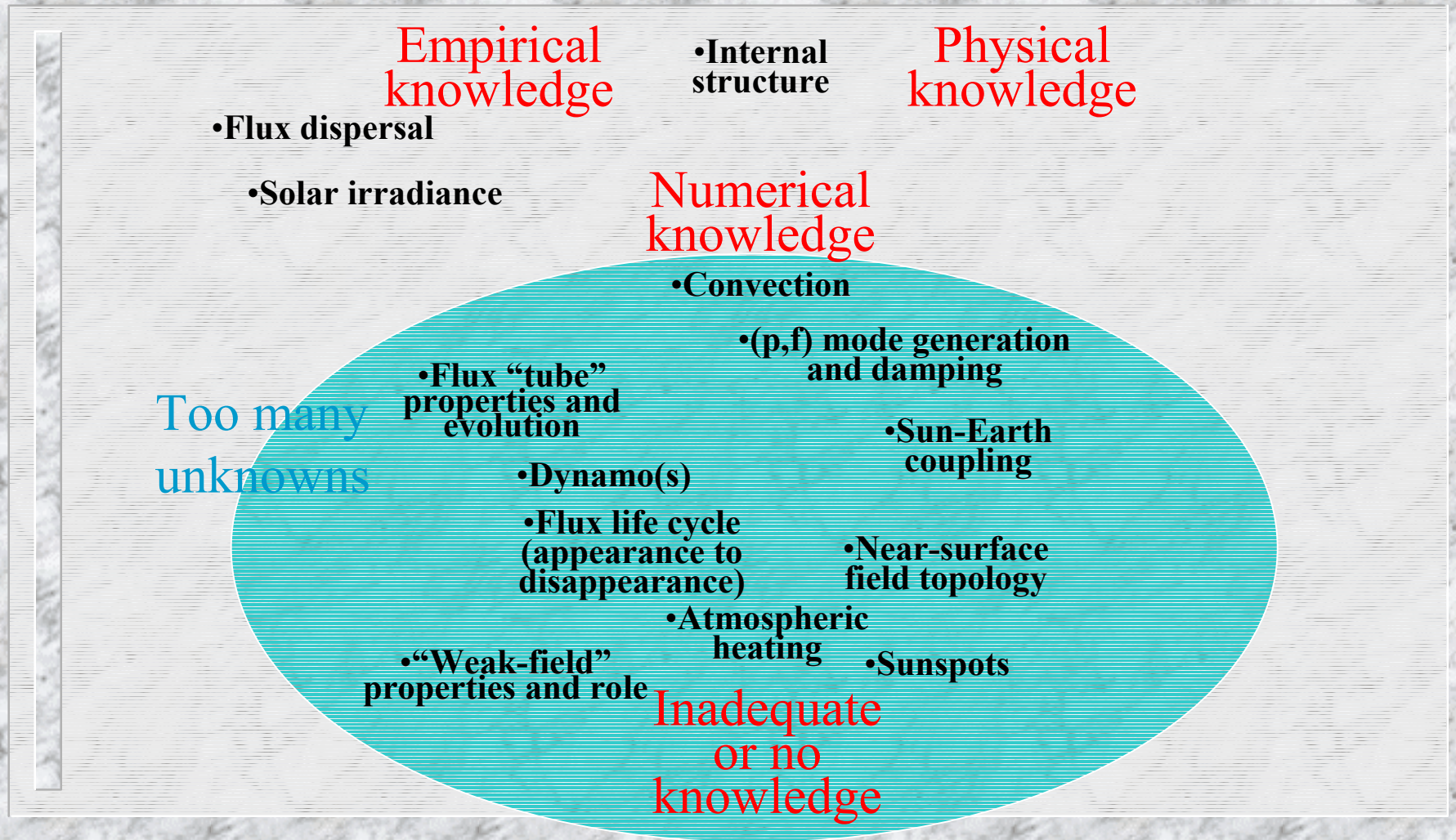
- "Where? How many? Who cares?"
- "The slit is always in the wrong place.''
- "The network forms islands of stability"
- "Why is there a penumbra at all?"
- "You have to give up a lot of physics."
- "You have to throw something away to make a computation."
- "You can make an almost perfect fit, but I don't think it means anything."
- "*Supposed* to be? I'm talking about what it *is*!"
- "[Doing the best you can] isn't good enough; you have to do the *right* thing!"
- "In some sense, in some way, it must always be a flux rope."
- "Is it spaghetti or an octopus?"

To simplify or not to simplify?

- Basic problem: *disjoint interfaces in non-linear, non-local, non-stationary system*



Status of our knowledge



“Weak-field” properties & role; Dynamo

- Is “weak” field really weak?
- Is “weak field” locally generated or a decay product of the global dynamo?
- If “weak field” is generated locally, how does it interact with the global dynamo?
- Does “weak field” contribute significantly to atmospheric heating (and dynamics); does it dominate that?
- What are the properties (pdf, …) of emerging bipoles?

Flux-”tube” & sunspot properties, evolution; Convection & (p,f)-mode generation, damping

- How does flux manage to emerge strong and coherently?
- How do flux concentrations form (advection/collapse); and (how) do flux concentrations end (“dissolve” or cancel [retracted or expelled])”? (‘atomic’ vs. ‘fluid’ approximation)
- How does field pick up high and low frequency stresses?
- How does field affect convection and the generation of “seismic events”?
- Why does generation of acoustic power appear to be linear in velocity?
- How does magneto-convective interaction determine dispersal of flux?
- What is the subsurface structure of flux “tubes”?
- When and how do pores (spots?) form well after emergence?

Near-surface field topology

- Why is there no signature of a “magnetic canopy” over quiet Sun?
- What is the field geometry & dynamics in the “carpet”?
- How is the field structured in and over spot penumbrae?
- Is flux indeed commonly retracted? Is it ever expelled from inside the Sun, or “clipped” in the atmosphere?
- How important are substantial field distortions by waves (mmf, Ellerman bombs, …)?
- What are the properties and role of magnetic null points, both at the canopy and higher in the corona?

Atmospheric heating

- Which mechanism dominates where?
- How does magneto-convective coupling lead to atmospheric heating?
- What field structures can lead to atmospheric heating?
- Why aren't coronal loops braided and twisted more?
- Are corona and chromosphere really heated along different field lines? What does that mean for mechanisms involved?
- Are very small scale "eddies" and "seismic events" the significant drivers?
- Is convection-driven, "weak-field" reconnection important?

Sun-Earth coupling

- Living With A Star: strategic “systems approach”
- SEC missions: dedicated to specific scientific problems, or problems that require dedicated, substantial resources.

Observational needs from theory perspective (I)

- List of unknowns and uncertainties merits a mission dedicated to the interface between solar interior and magnetosphere: understanding that domain appears to be crucial to understanding of the rest of the solar atmosphere.
- “The kind of complexity we are facing really requires multi-wavelength, multi-instrument observations”
- Primary objective: ~ “study the dynamic connections between photosphere and corona”
- The photospheric field in not force-free. Hence, multiple-height probing of the domain from the deep photosphere to the “top” of the chromosphere is needed.

Observational needs from theory perspective (II)

- High resolution (angular and temporal) to validate magneto-convective coupling (< 20 km, < (« ?) 2 sec).
- (Vector-) Magnetographic coverage from deep photosphere (including Wilson depressions) to top of chromosphere to study *field geometry* and *currents*.
- Need to detect (transverse, longitudinal, torsional) waves
- Field of view > a few supergranules
- Continuity > several days
- Local-area seismology for pre-emergence and post-retraction sub-surface imaging
- Context: larger area magnetic field, chromospheric and coronal spectrography and/or narrow-band imaging.

Modeling needs from observational perspective

- Develop reliable diagnostics for line-profile & polarization diagnostics, with physically consistent [ρ, T, **B, v**](*x,y,z,t),* including Hα.
- Demonstrate that [ρ, T, **B, v**](*x,y,z,t)* can be successfully recovered (prerequisite for mission definition).
- Establish observables to distinguish reconnection and heating models.
- Develop *nonlinear* force-free field extrapolation methods (using vector-magnetographic boundary conditions as well as coronal loop structures) as "library tools." Particular care should be given to unstable and metastable cases, and understanding of (intrinsic?) non-uniqueness.
- Learn about force-free field geometry and dynamics (including nulls, separators, separatrices, …).
- Learn to use statistical approaches in comparing forward modeling with numerical models.

This presentation can be found at:

- http://www.lmsal.com/~schryver/Public/homepage/talks/BeyondSolarB.ppt