No, Eric, not the “answers” you were asking for in your keynote talk!

Modeling the dynamo(s)
Measuring activity
Observing the dynamo(s)
Consequences of the dynamo(s)
Continuity of records
Forecasting the dynamo(s)
Sun and Earth’s climate
Wishful thinking
Statistical & transdisciplinary science
The future
Dealing with 2000 refereed publications each year ...
• “healthy balance between purists/explain observed features” (Priest)

• “We have in the Sun two dynamos: small-scale and large-scale.” (Brun) Do these operate independently? How could that be?

• Meridional flow appears critical: cycle length, cycle overlaps (or spacing), ... Yet it is the result of a near-balance of two (or four [Karak]) strong effects (e.g., Brun). Can we expect to model it well enough? Or is it (for now) to be measured as input to dynamo models? Does the flow vary stochastically (Karak) or is there a feedback from the field?

• Turbulent pumping may dominate in large-scale advection (meridional conveyor belt) and in diffusive transport (Nandi on Dikpati vs. Choudhuri). How do we quantify its workings in a system in which convective downdrafts span all scales (Nordlund/Stein)?
Modeling the dynamo(s) - 2

- Do we learn the right lessons from dynamo models running in a closed box? Is helicity conservation (now or at higher Rm) a killer (“catastrophic quenching”) unless we include atmosphere/asterosphere in the model? Is hemispheric (diffusive) coupling an acceptable way out? (“bi-helical field”, Brandenburg; Candelaresi: “Small-scale helicity is counterproductive, and should be got rid of!”)

- Why is there no obvious transition between fully convective and partially convective stars? (Giampapa; Schmitt; cycle on Prox Cen and on dM3.5+dM3.5 binary Gl 375 - Mauas) Are we missing the lesson? (Brun on tachocline; Browning on cool dwarfs)

- What does it take to model a fibrillar dynamo which the Sun appears to be showing us? (Guerrero) “One thing we really don’t know is how to create small fibrils.” (Munoz)
Measuring activity

- Sunspot numbers do not (yet) provide a uniform historical record (Svalgaard). Ionospheric/dD variations reach back to 1780s. Can we use, e.g., GCR-induced $^{10}\text{Be}$ isotopes for this, with all its complexity (heliospheric field, geomagnetic field, atmospheric/climatic effects, limited number of core samples, ...)?

- Is surface activity a direct/monotonic/unambiguous measure of the internal dynamo? What should we be measuring to make that the case? Can we differentiate a shallow dynamo (Brandenburg) from a deep-seated or volume-filling one (Brun, Browning)?

- What could we measure to determine where the alpha effect(s) operate(s)? (Nandi) Context: “The big question is how you get poloidal field back from the toroidal field” (Choudhuri)
Observing the dynamo(s) [& components]

• “We only have one Sun, but we can observe many stars.” (Thompson) “It is appalling when you see the number of stars monitored long enough to see coronal cycles (2; Schmitt) “I have not heard the words ‘solar twins’ in this meeting.” (Linsky) “The minimum behavior of the Sun is the minimum behavior of stars at large.” (Schmitt, Poppenhaeger)

• Do “flat-activity stars”, the least active stars, and the Sun in 2009 or in its Maunder Minimum exhibit (the same) near-surface dynamo action? How should we study this “magnetic chaff” (Browning) as input/validation to shallow/local/turbulent dynamo models?

• Is there reason to expect that meridional return flow can be measured (within or below the convective envelope makes a big difference to dynamo modelers)? (Thompson/Hill)

• What does it mean that the solar dynamo is “a limit cycle rather than a saddle-point bifurcation”? (DeRosa) Do such measurements guide dynamo modelers? Is there hope to do so for other stars? Is quadrupole-dipole-quadrupole change (Tlatov) part of this discussion?

• Do ephemeral regions really have a tilt (Joy’s law) opposite to that of active regions? (Tlatov, vs. KHarvey, Hagenaar)
Consequences of the dynamo(s)

• Internal: Low-l helioseismology shows cycle-dependent frequency shifts, including a quasi bi-annual oscillation (Elsworth). Attributable to pulses/nests/complexes of activity and their associated “rushes to the pole”? “Multiple cycles can be led by fluctuations in emerging flux.” (Isik)

• Coronal: MHD modeling (Linker), EUV irradiance modeling (Haberreiter), and tomography (Vasquez) need up-to-date descriptions of the global surface magnetic field. Does it suffice to have front-side magnetographs only? Will Orbiter help (enough)? (Korhonen on Kepler data: “every rotation is different”; Valio: each planetary occultation sees a somewhat difference ‘spot-scape’ even at <2d orbital period)

• Heliospheric: What happens to the heliosphere if there is only a ‘quiet-Sun’ network on the Sun? (Cliver: solar-wind floor; Gibson: “porcupine Sun”)

• Systemic: How Cartesian are we allowed to think: may we separate dynamo, flux emergence, flux dispersal (Isik), coronal heating, heliosphere (Linker), ...?
Continuity of records

• “It matters a lot how long a data set you analyze.” (Van Driel) I am eagerly looking forward to IAU 1000!

• Magnetograms: since 1974. But the various data sets show substantial inconsistencies in scalings and nonlinearities (talk to Linker to hear about those problems). How do we make the existing record uniform? How do we plan for a consistent set of observables? There are parallel lessons here to Svalgaard’s discussion of “k-factors” in the sunspot records: dependent on instrument, site, observer’s experience (or tedium) ... which he calibrated by an indirect metric: diurnal magnetic declination variations from ionospheric effects. But how dependent is that on the quadrupolar/dipolar structure of the Sun’s field and associated IMF? (Tlatov, Usoskin)

• Records of Halpha (Tlatov) from 1887; eclipse recordings (de Toma) from 1869 (http://mlso.hao.ucar.edu/mlso_eclipse_archive.html); green-line since 1930’s (Schmitt); Ap since 1806-1830s (Bothmer); aurorae >1000AD, sunspots >-100BC (Vaquero)

• 10,000 y of $^{10}$Be records ... but there is a long chain of physical processes from there to the dynamo!

• Stars: 40 y of photometry; 110 y of plates.

• “All relevant observations should be maintained and extended.” (Echer) Is TSI the right thing to measure going forward? Or is it SSI? (Linsky’s “panchromatic”; Haberreiter; Mendoza: differential forcing) Or is it HMF? As to “extended”: also into the past!
Forecasting the dynamo(s)

- “Predicting cycle 24 has been tough” (Priest) Is the dynamo predicable at all? (Nandi) “No two self-respecting dynamo theorists agree on how grand minima occur” (Choudhuri) Which analogy with weather is really applicable: we can (sort of) forecast a few days (not even a full turnover on global scales) but we cannot forecast a full year (driver cycle)? Is forecasting easier if we extend the ‘training set’? (Tlatov; de Toma)

- What do we do with Penn and Livingston’s threat of the vanishing spottedness of the Sun by 2020?

- “We need to develop an assimilative dynamo model.” (Nandi) What would we need to observe to drive that? How long will it take to get those observables?
Sun and Earth’s climates(!)

- Sunspot records are not uniform; recent “grand maximum” is not as strong as we thought: “There is no more modern grand maximum” (Svalgaard).
- Magnetic network never disappears: floor to TSI modulation by faculae (Schrijver, Schmitt: “Baseline activity of a G star is that of the Sun in 2009.”). What does that mean for the heliosphere? (Cliver, Luhmann) Models by Voegler & Shuessler; Bercik et al.; ...
- No significant change in TSI from 1996 to 2008 (Schmutz). ? “The ionosphere has collapsed” in the 2008-2009 minimum (Guhathakurtha)
- From TSI to SSI: irradiance modeling requires improved (dynamic!) atmospheric modeling and (dynamic!) radiative transfer modeling (Haberreiter)
- Open field, to GCR modulation, to surface field distribution is a very uncertain chain. Can it be made more reliable? (Usoskin?, Svalgaard?) If the Rss is ~1.8 in minima and ~2.5 in (recent) maxima, this affects our understanding of B_{Sun}(GCR). (Luhmann; Haberreiter: “The modulation potential is important for EUV irradiance modeling.”) Pseudo-streamers (may?) behave differently from streamers (Luhmann: “We can’t dismiss them in anything we do!” & “Recent minimum is like a maximum but with weaker field.”; Gibson: “a new kind of slow solar wind.”) How does that impact our interpretation and use of $^{10}$Be records (with modulation functions sometimes going to [near] 0; Cliver)? What about “breathing heliosphere?” (Linsky)
- What are the implications for existing climate models?
Wishful thinking

• “The whole atmosphere varies with the cycle” (Priest). Yet we measure activity of Sun and stars with sets of widely different diagnostics (e.g., “be careful with generic ‘X-rays’ - at high energies defining the pass bands is essential for intercomparisons” Thompson). Should we be pursuing obtaining the same observables for Sun and stars? How about “pan-chromatic” data sets (Linsky; Schmitt: “Stellar activity is a multi-wavelength endeavor.”)?

• The “golden index” (Echer, Batista, Saar: “you have to be very careful interpreting an index” - on the S-index and its sensitivity to metallicity and gravity + “Is R’HK working correctly as a diagnostic at low activity?”; Van Driel: “The cycles are not steady; they are cycles that evolve”; Mauas: Halpha and Ca II H+K measured simultaneously show much scatter)
• The use of knowledge from multiple disciplines is not just useful; it appears essential to our endeavors under the focus of this meeting (from solar/stellar dynamo work to atomic modeling for Ni I lines and the solar O abundance; Linsky/Vieytes)

• Given that knowledge exists from other fields relevant to any one we happen to work in, we should not pick and chose: comprehensive testing and identification of what works and what does not should be routine.

• How do we best foster transdisciplinary science given the unnatural fences set up by funding Agencies? (Luhmann: “Need for textbooks and solar physics educators ...”; Guhathakurtha +:“You can think of heliophysics as an environmental science”)

• Well on the road to statistical studies for Sun (Hurlburt), perhaps on the trail of heliospheric studies (Luhmann) But: funding for interdisciplinary research is still difficult (although very much improved within the branches of heliophysics; not (yet) when reaching out to climate or stellar studies. But: making coordinated use of the “heliosphysics system observatory” still difficult (Gibson).
The future ...

- It is said that the present is pregnant with the future. **Voltaire**
- The future will be shaped in the arena of human activity, by those willing to commit their minds and their bodies to the task. **Robert Kennedy**
- The direction in which education starts a man will determine his future in life. **Plato**
- The future will be better tomorrow. **Dan Quayle**
- The Sun: Are we entering a Maunder Minimum????
- And us: The future does not just happen - we can shape it. What do you think we should envision (require?) as part of our future?