Review of Day 2

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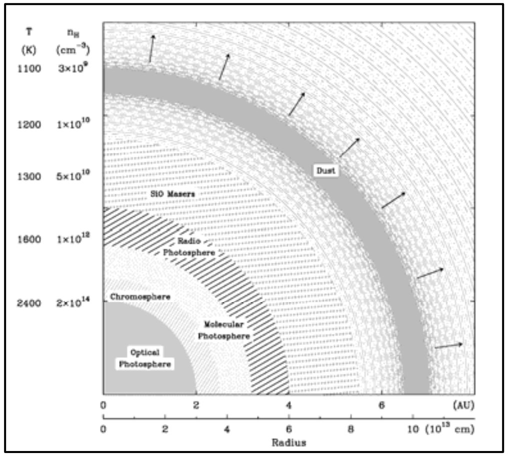
Measuring Stellar Diameters, Pulsation, Rotation (G. Perrin)

- Diameters:
  - An old game, but due to improving measurement accuracy, still producing interesting results, and challenging stellar models.
  - Measurements close to first vis null, most efficient. 0.5% accuracy demonstrated, 1000s of stars available => lots of good data to work with!
  - For many ("ordinary") stars simple, accurate, UD diameter measurements provide fundamental stellar properties that help understand their structure and evolution. Often need to include 1st order opacity effects: λ-dependent limb darkening.
  - For unusual stars (supergiants, Miras ...) there is even more richness, and measurements at many λs are needed (see B. Mennesson lecture later).



- Pulsation:
  - Large amplitude (~10s%) pulsators (i.e. Miras) **also** have complicated atmospheres, and need to disentangle “photospheric” diameter changes from time-varying opacity effects (e.g. R Leo). These measurements provide crucial constraints to dynamical models.
  - Cepheids are small, and require long baselines to be sensitive to (few %) diameter changes. These measurements allow to calibrate the P-L relation, and establish distances.
- Rotation:
  - 2nd order morphology.
  - Several stars have been measured to be non-spherical.
  - Probes interesting stellar physics (e.g. gravity darkening).

Astrometric Extra-Solar Planet Detection (D. Queloz)

- Astrometry: measure sky displacement of star due to orbiting planet.
- Signals (accuracy needed):
  - 0.5 mas for Jupiter-Sun at 10pc.
  - 10s umas for Hot Jupiters.
  - 1 umas for exo-Earths.
  - State of the art (Hipparcos): 1mas.
  - Need interferometry. Hot Jupiters possible from the ground (see also B. Lane lecture); space interferometers needed for exo-Earths.
- Technique: measure (relative) fringe positions, instead of their amplitudes.
- In combination with RV orbits yields the planet masses & allows to determine the true mass distribution of exo-planets, needed to test planet formation theories.
- Enables new discovery space, where many planets are predicted to exist.
- Instruments: PTI; VLTI/PRIMA, GRAVITY; KI; SIM (also GAIA - not an interferometer).

Synthesis Imaging (C. Chandler)

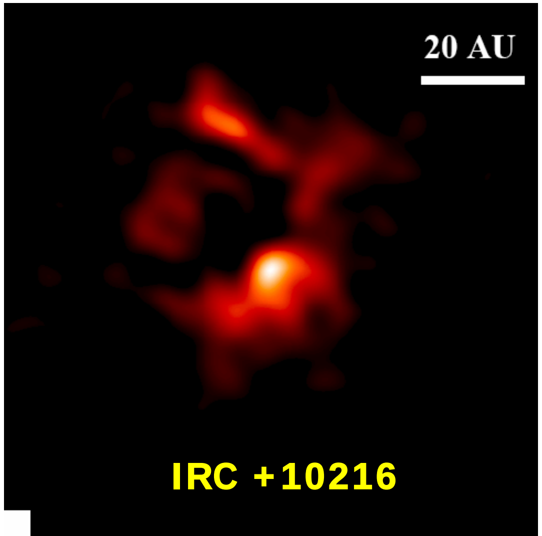
- Excellent tutorial on how synthesis imaging is done, including its limitations (min B & largest scales, max B & required resolution, holes in uv coverage - total flux & sidelobes - ...).
- This is, mostly, for the case the case that we have measurements of visibility amplitude and phase: i.e. how the Van Cittert-Zernike theorem is implemented in practice in radio interferometry.
- Perhaps we should all have the habit of attending the NRAO Summer School ....

Closure Phases (C. Haniff)

- Turbulence in the Earth's atmosphere corrupts the fringe phases, which give the astrophysical visibility fn. Phase (unlike radio).
- CP is the argument of the complex triple product: product of complex vis around a triangle of 3 telescopes that closes.
- In the CP, atmospheric terms cancel, yielding an astrophysically meaningful quantity.
- The bispectrum can be averaged coherently over many samples (not so the complex visibilities) and is robust to atmospheric biases => can be calibrated to higher precision than the visibility amplitudes.
- CP is non-zero or 180deg only if an object brightness that is non-point-symmetric.
- For strong CP signals to be detected, the object needs to be partially resolved on scales relevant to the asymmetric features. Also, CP ~ asymmetric fractional flux.
- CP is very useful:
  - Quick detector of potentially interesting morphology.
  - CP data provide powerful additional constraints to "parametric imaging" methods (model the vis amps and CPs).
  - CP can be input to modified aperture synthesis methods.

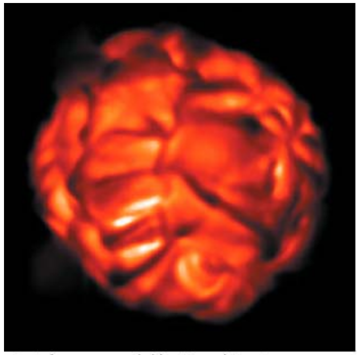
Science with Closure Phases (P. Tuthill)

- Showed many examples of CP astrophysics from real life.
- Aperture masking results dramatically illustrate the potential of the technique ... arrays with improved uv coverage are needed for imaging applications.
- Objects often need to be assumed to be morphologically simple (spherical cows) but are found to be very complex.
- Science areas: binaries, evolved stars (surfaces and dust), young star circumstellar disks, hot star environments, imaging stellar surfaces, jigh contrast binaries & exo-planetary companions.



Stellar Atmospheres & Surfaces (J. Aufdenberg)

- Dealing with stars in all their **reality** ...
  - The details of limb darkening and its λ-dependence.
  - Convection and surface granularity.
  - 3-D temperature structure.
  - Important even for stars with geometrically thin (0.1%) atmospheres, canbe probed interferometrically!
  - Most stars have thicker atmospheres (>5%) with lines and molecular bands => multi-λ observations are crucial, and using spherical models becomes more important.
  - Image stellar surfaces directly: a possibility for the future!



Betelgeuse model by Bernd Freytag