Exoplanets made in

I. Baraffe

Formation
Bate

Atmospheres
(1D RT/Chemistry)
Tremblin

Atmospheric
dynamics (GCM)
Mayne

Interior & evolution
(Planets & Stars)
Browning/Baraffe

Observations

Disc
Interferometry
Kraus

Debris discs &
Atmospheres
Direct imaging
Hinkley

Atmospheres
Transit
Sing

Instrumenta-
tion

PFI

ELT

THE
(£1M)
Naylor

Theory & Models
Planet formation: Disc Interferometry

People: Stefan Kraus
postdocs: A. Kreplin, J. Kluska
PhD: M. Wilson

- Infrared and mm-wave interferometry (VLTI, CHARA, ALMA)
  ➡️ resolve protoplanetary disc structures from sub-AU to few hundred AU

- Future (ERC Starting Grant):
  (Instrumentation work at CHARA array will enable first 6-telescope interferometry of YSO discs)
  ➡️ Time-resolved imaging of possibly planet-induced structures in the inner AU

- Planet Formation Imager
  PFI science working group (lead by Stefan Kraus)
  (talk by John Young)
Planetesimal accumulation near gaps

Figure 2. Rendered images of gas surface density for a disc containing a planet of mass of $333 \, M_\oplus$, with an initial value of $75 \, g \, cm^{-2}$ at $r_p$ (marked in the colour scale by a dashed line). The calculations are performed in three-dimensions, employing cartesian coordinates, but here have been mapped to cylindrical polar coordinates. Solid bodies are plotted as points over the gas distribution. Solid bodies of radius 10cm, 1m, and 10m are considered (as marked). The lower right panel illustrates the solid body distribution that evolves in the absence of gas. The degree of structure (i.e. number of visible spiral ridges) seen in the solid body distribution increases with their size as a result of less significant gas drag. For 10cm grains, the solids much more closely follow the gas structure than the 10m bodies, which more closely resemble the no gas case.

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Exoplanet direct imaging and debris disks

People: Sasha Hinkley
PhD: Elisabeth Matthews

• High resolution spectroscopy (SPHERE)
  ➤ Characterisation of young exoplanets & brown dwarfs
• Exoplanet & debris disk (Keck)
  ➤ Explore the relation between debris disks and presence of a planet

Future: Exoplanet atmospheric compositions with E-ELT 3-5 µm
Transiting Exoplanet Atmospheres

People: David Sing
Postdocs: T. Evans, T. Kataria, N. Nikolov
PhD: H. Wakeford, J. Spake

- Observations
  HST, GTC, NTT, WHT, VLT

- Observations meet modelling
  1D analytic
  3D Sparc/MIT + UK Met Office UM

Future: ExoMOS development

Detection Highlights

<table>
<thead>
<tr>
<th>Planet</th>
<th>Species Detected</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>WASP-12b</td>
<td>Haze</td>
<td>Sing, et al. 2013</td>
</tr>
<tr>
<td>WASP-31b</td>
<td>K, Haze &amp; Clouds</td>
<td>Sing, et al. 2015</td>
</tr>
<tr>
<td>XO-2b</td>
<td>Na &amp; K</td>
<td>Sing, et al. 2011, 2013</td>
</tr>
<tr>
<td>WASP-6b</td>
<td>Haze, K</td>
<td>Nikolov, et al. 2015</td>
</tr>
<tr>
<td>WASP-19b</td>
<td>H2O</td>
<td>Huitson, et al. 2013</td>
</tr>
</tbody>
</table>

much more soon…
Atmosphere models: static/dynamics

People: N. Mayne, I. Baraffe
Postdocs: P. Tremblin
PhD: B. Drummond, D. Amundsen
Met Off: J. Manners, C. Smith

• 1D RT + Convection + Chemistry (photochemistry, mixing) → B. Drummond
  ➫ Structure/spectra for exoplanets (irradiated or not) and brown dwarfs

• Atmospheric dynamics (N. Mayne)
  ➫ Hot Jupiter circulation and link with observations

Future: → Coupling with chemistry/cloud schemes
  → Solar system and Earth-like planets

Tools: ATMO (1D RT)
      UK Met Office GCM (3D deep non HSE + RT)

Facilities: DiRAC HPC facilities; University of Exeter and Met Office supercomputers

Evolutionary models for planets & stars

**People:** I. Baraffe. G. Chabrier

- 1D models for irradiated (transit) and non-irradiated (Dir. Imag.) planets
  - Transit data (Mass-Radius from NGTS, CHEOPS, PLATO, TESS) and DI data (L, colors, Teff) from SPHERE
  - Development of first principle EOS: New generation of planetary models are coming

⚠️ *Who sees a planet sees a star...*

- 1D models for planet host stars: MKG
  - Continued effort to improve the models *Baraffe et al. 2015*

![Graph](Quadruple young system LkCa (Torres et al. 2013).)
Convection, magnetism and rotation in stellar and planetary interiors

People: Matt Browning
Postdocs: Laura Currie, Lucia Duarte, Maria Weber
PhDs: Lewis Ireland, Felix Sainsbury-Martinez

- Global simulations of convection and magnetism
- More localised studies of heat and angular momentum transport
  ➡️ Relating simulations to MLT, incorporating into 1-D models
  ➡️ Misc. topics: instabilities, near-surface shear, magnet. buoyancy

Tools: Anelastic spherical harmonic (ASH, Rayleigh)
  Compressible spherical segments (CSS), f-plane (Dedalus)

Facilities: DiRAC HPC facilities and the University of Exeter’s supercomputer
2D/3D stellar models: fully compressible time implicit simulations

**People:** Isabelle Baraffe

Postdocs: Tom Goffrey, Jane Pratt, Chris Geroux

- Study of turbulent convection in stellar interior
- Overshooting/undershooting
- Rotation induced mixing and angular momentum transport

- ➡ Improvement of 1D formalisms
- ➡ Reduce uncertainties of 1D stellar models

**Tools:** Fully compressible time implicit code MUSIC

Spherical geometry, realistic EOS/opacities

**Facilities:** DiRAC HPC facilities and the University of Exeter’s supercomputer