# Impact of Optical Coherence on Stellar Spectra

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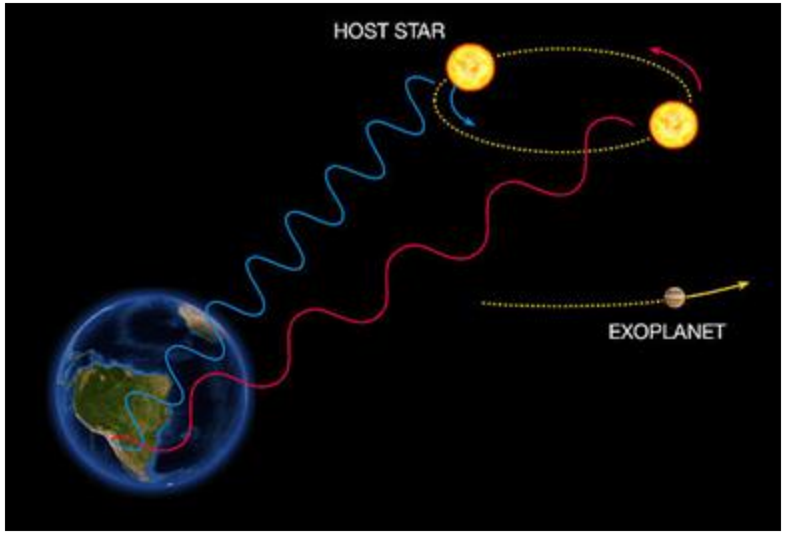
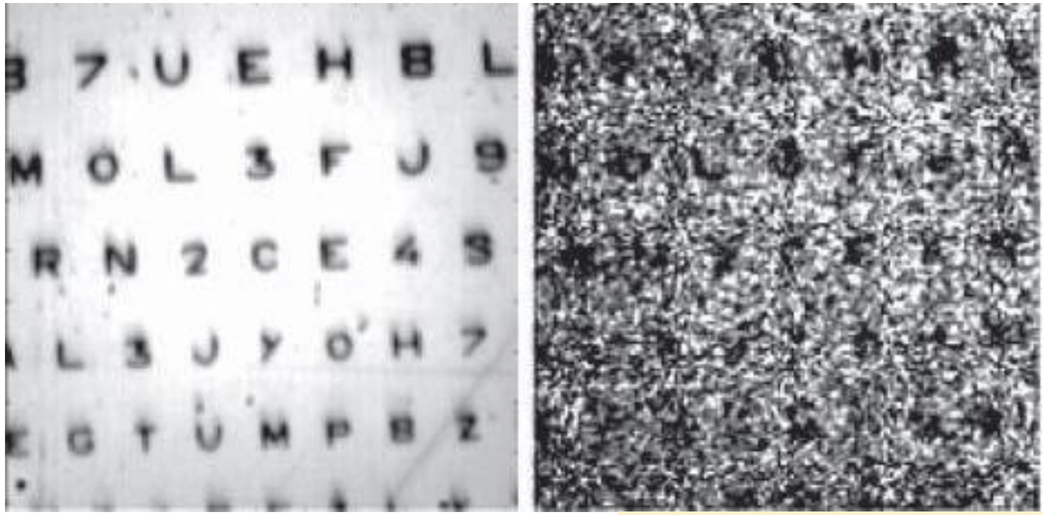
# Aim and Outline



[Goodman, 2015]

**Examples of causes for spectral shifts:**

- **Doppler effect**
- ….
- **Wolf effect**
  (or correlation-induced spectral changes)

**The sun as a good starting point:**

- Extrapolated to stars of the same type
- The only star we can spatially resolve
- Granulation with possible impact on coherence

**The challenge:** is to measure the spatial distribution of coherence of the radiation from the Sun, at granule-scale.

**Why?**

- To develop a more complete model of solar radiation
- To assess the relevance of observable solar spectra variations
- To assess the impact of the generalization of such analysis for stars of the same type

# Coherence Theory

Electromagnetic fields undergo random fluctuations (stochastic fields)

Correlation functions obey propagation laws

**Theory of Optical Coherence:**

statistical description of fluctuations of light

**Optical Quantities depend on correlation functions:**

**Intensity:** $I(\vec{r}) = \Gamma(\vec{r},\vec{r},\tau = 0)$

**Spectrum:** $S(\vec{r},\omega) = W(\vec{r},\vec{r},\omega)$

| **Time Domain** | **Frequency Domain** |
| --- | --- |

$V(t)$ FT forbidden $U(\omega)$

$$\boxed{\Gamma(\vec{r_1},\vec{r_2},\tau) = \langle V^*(\vec{r_1},t)V(\vec{r_2},t+\tau)\,\rangle} \xleftrightarrow{\text{Fourier Transform}} \boxed{W(\vec{r_1},\vec{r_2},\omega) = \langle U^*(\vec{r_1},\omega)U(\vec{r_2},\omega)\,\rangle}$$

normalizing

$\tau = 0$

$\vec{r_1} = \vec{r_2}, \tau = 0$

$\gamma(\vec{r_1},\vec{r_2},\tau)$ $J(\vec{r_1},\vec{r_2},0)$ $I(\vec{r},0)$ $\mu(\vec{r_1},\vec{r_2},\omega)$ $S(\vec{r},\omega)$

# Coherence Theory

In **coherence theory**, the spectrum of light **is not necessary invariant** and depends on **second-order correlations**

**1986** $\rightarrow$ 1st Paper questioning spectral invariance:

**Model:** Planar source

**Scaling law:** $\mu_Q(\vec{r_1}, \vec{r_2}, \omega) = h[k(\vec{r_2} - \vec{r_1})]$

**Emil Wolf**, University of Rochester & Institute of Optics (USA)

**1987** $\rightarrow$ 1st Paper on spectral shifts due to coherence:

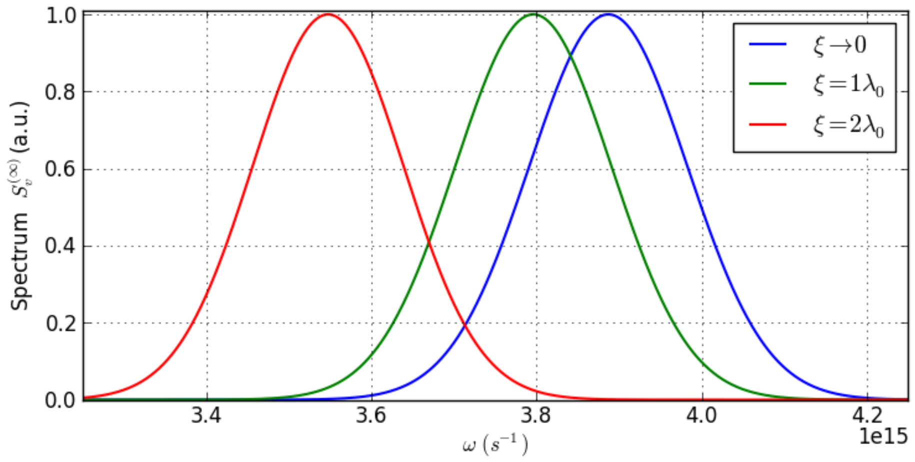
**Model:** 3D and isotropic source

$$s_V^{(\infty)}(\omega) \propto s_Q^{(\infty)}(\omega)\hat{\mu}_Q(k\vec{u}, \omega)$$

Measured spectrum in the far-field

Source spectrum

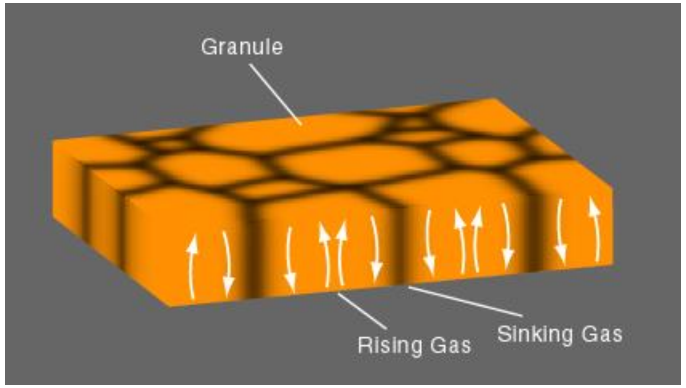
Source correlations

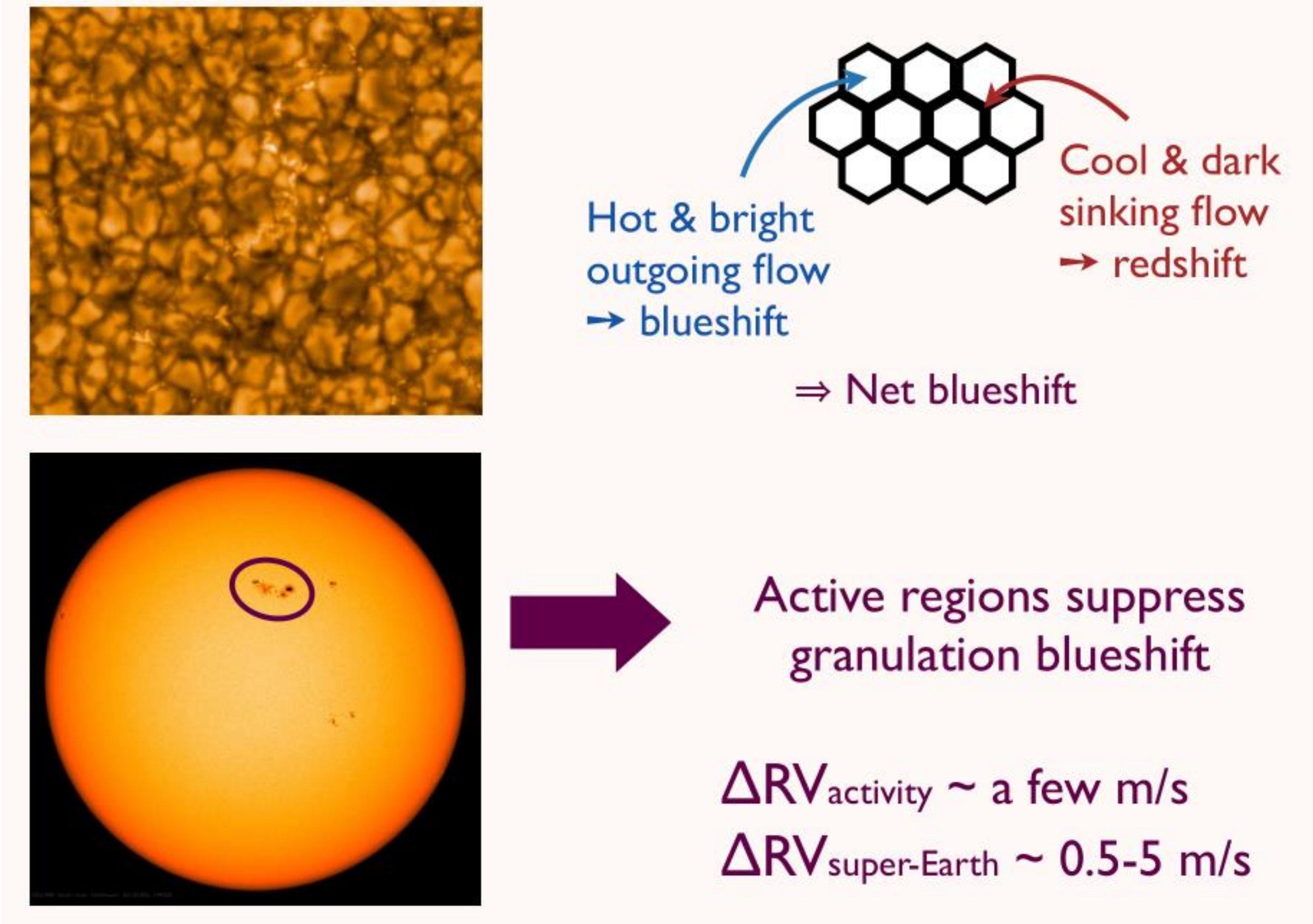



Can these correlation-induced spectral changes be present in astronomical spectra, in particular, in the solar spectrum?

# Solar Granulation

- **Granule:** Small region of hot rising material
- **Intergranular space:** Thin region of cooler falling material
- **Granular cell** = Granule + Intergranular space → convective cell
    - ~ 1000km
    - lifetime ~ 10 minutes

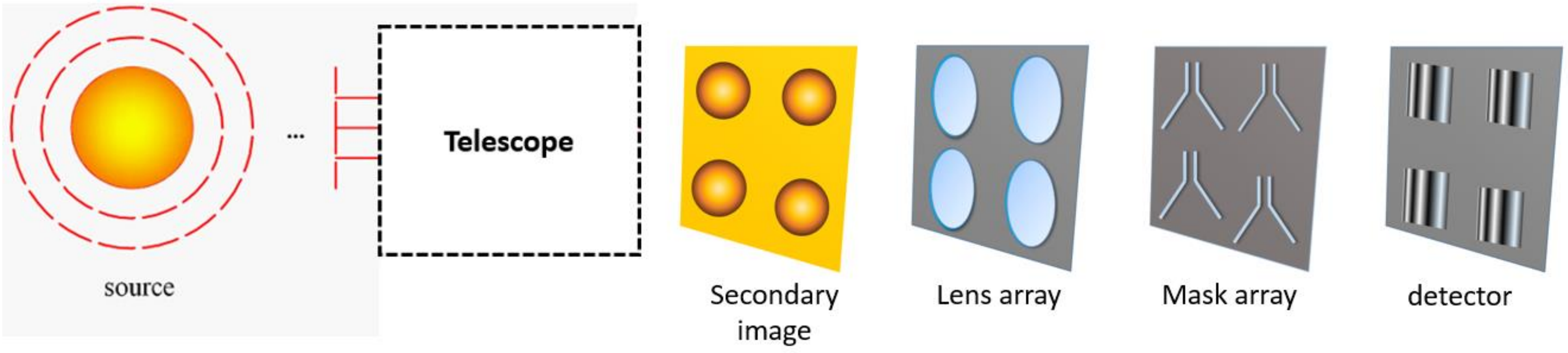


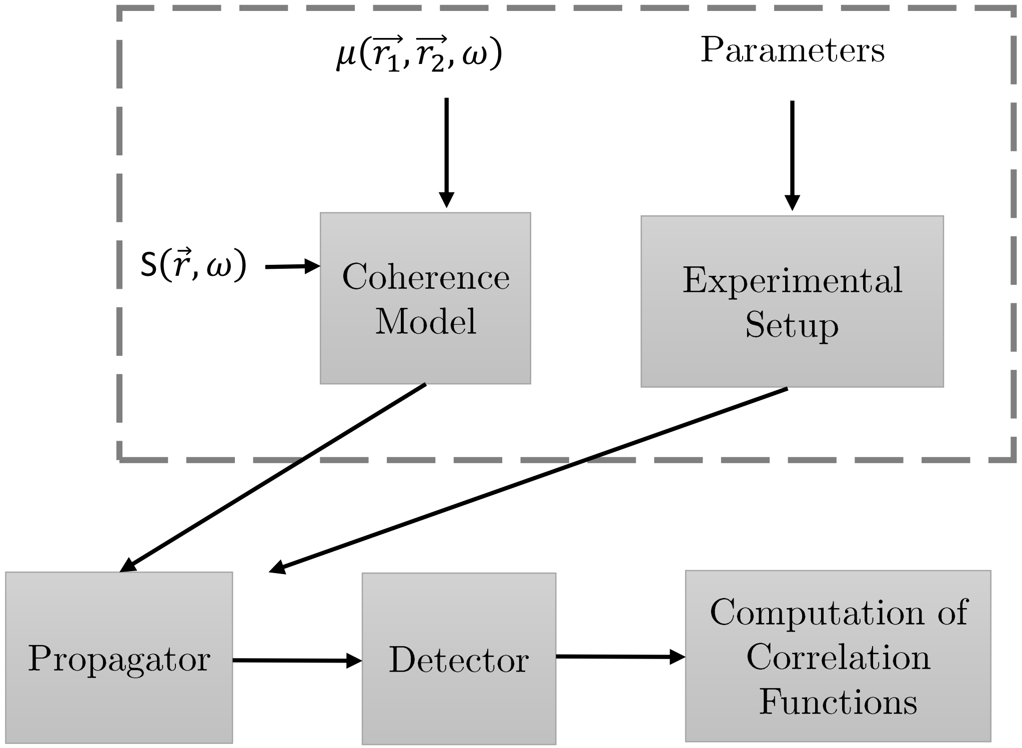

[Haywood, 2015]

The goal is to design an instrument to measure the CSDC of solar granular cells

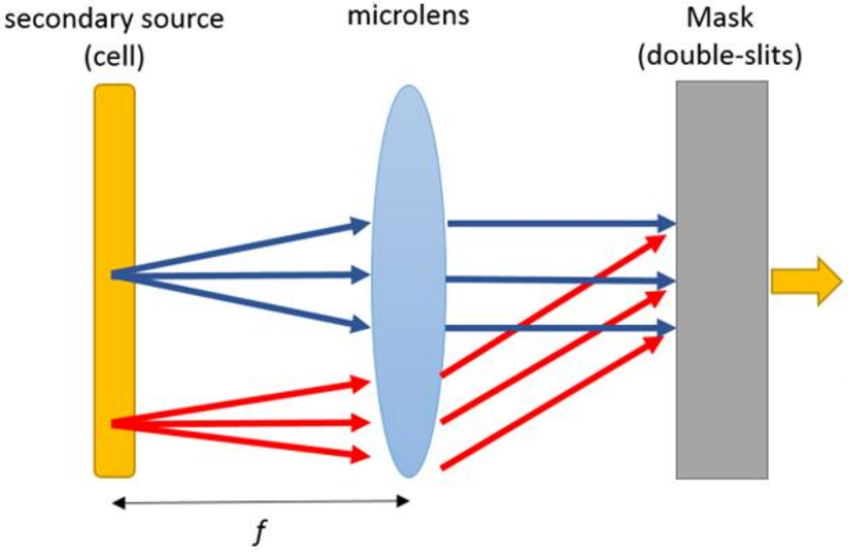
# Instrument Concept

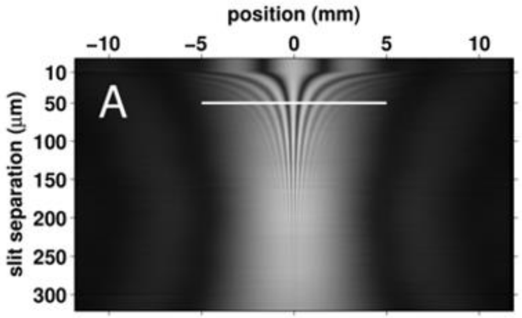



## Simulation




## For each channel:




Compute $\mu(\vec{r_1}, \vec{r_2}, \omega)$

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**Thank you!**