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CfAI

Stereo-SCIDAR

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Optical turbulence profiling regimes:

- **SLODAR** at Paranal: aim is to profile the surface-layer of turbulence (up to ~200m) with very high resolution (~10-20m)

  - **Applications** - understand and estimate UT seeing
    - support GLAO / AOF

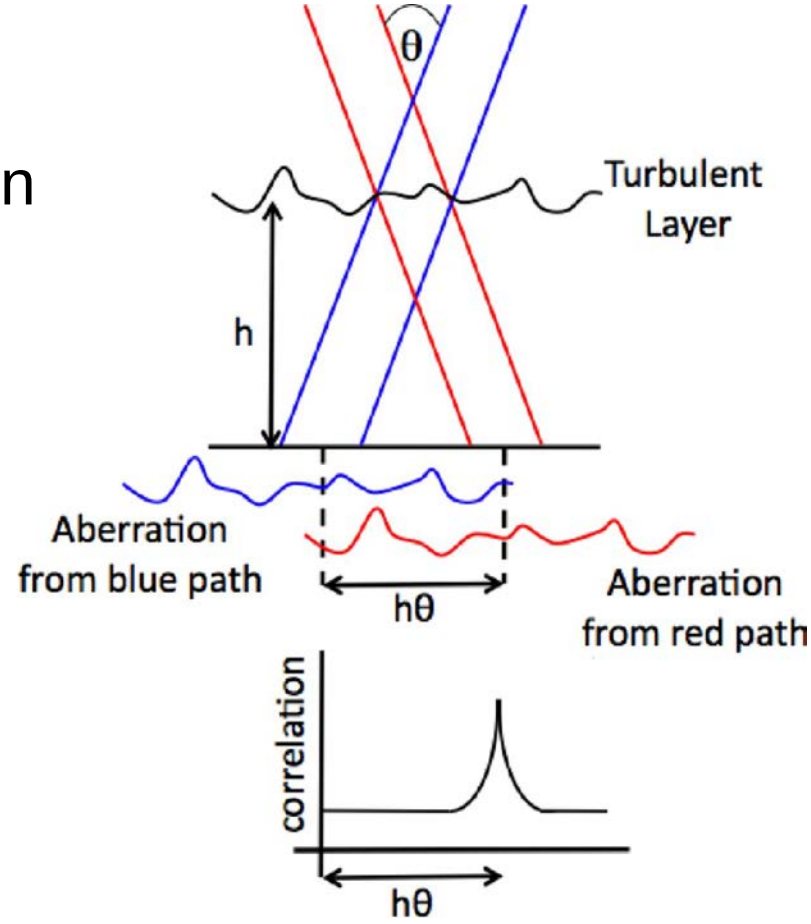
- **SCIDAR**: Profile the whole atmosphere up to ~20km
  - Lower resolution, but can be ~200m on 2m telescope
  - Very high sensitivity – detect weak turbulent layers
  - Measure layer velocities

  - **Applications** – model and support tomographic AO for large telescopes

- Requires a larger telescope, > ~1m (2m is much better)

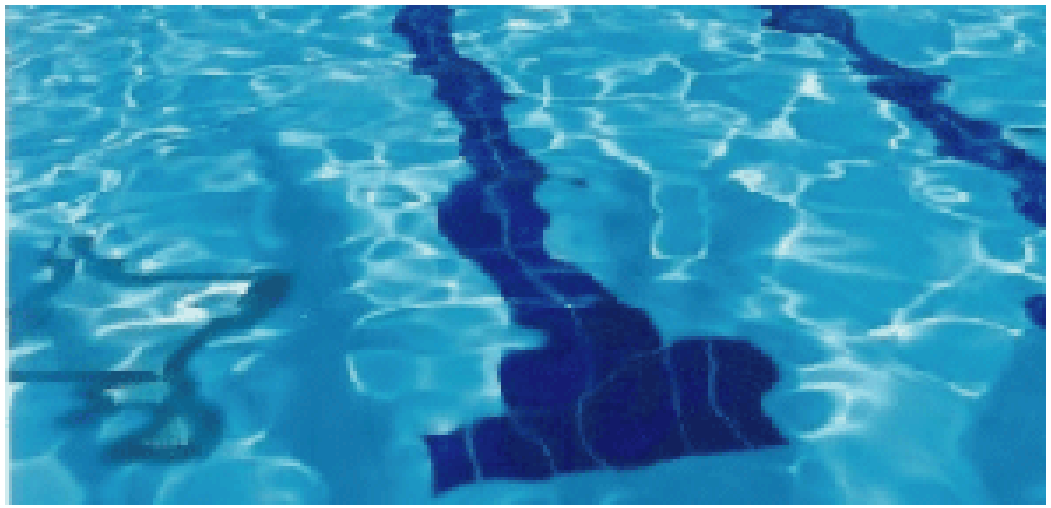
SCIDAR: Optical Turbulence Profile From Double Star Scintillation Patterns

- Triangulation method
- Peaks in cross-correlation pattern determine height and strength of turbulent layers

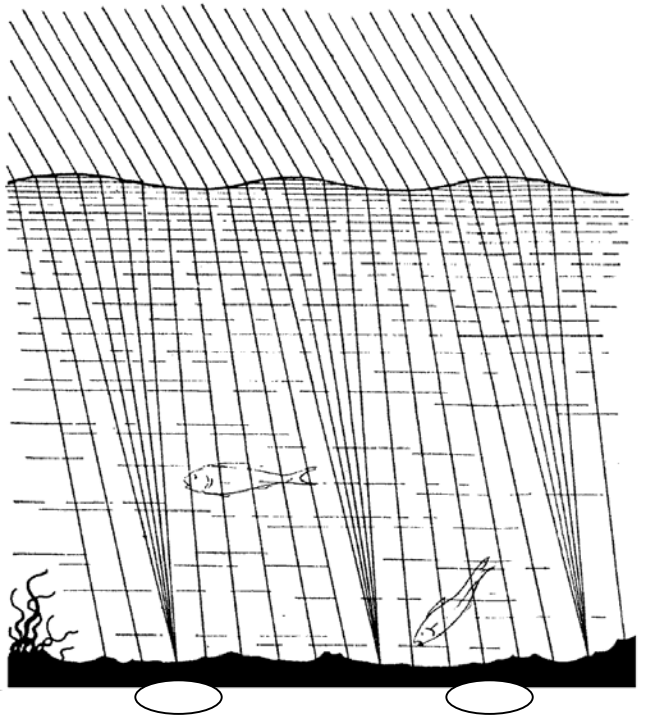


If a turbulent layer at height, h, is illuminated by two stars of angular separation, θ, then two copies of the aberration will be made on the ground separated by a distance hθ.

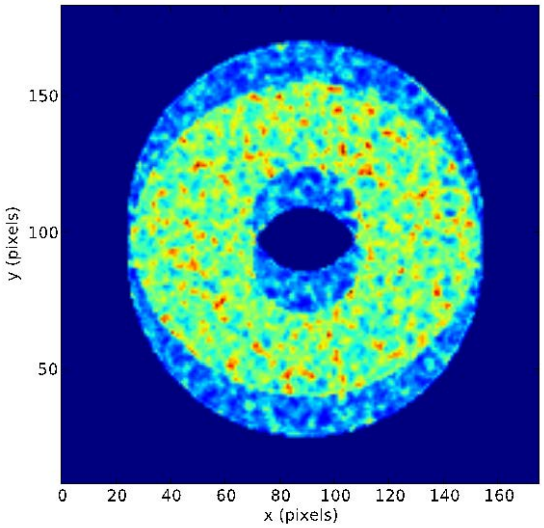
Scintillation (‘Flying Shadows’)



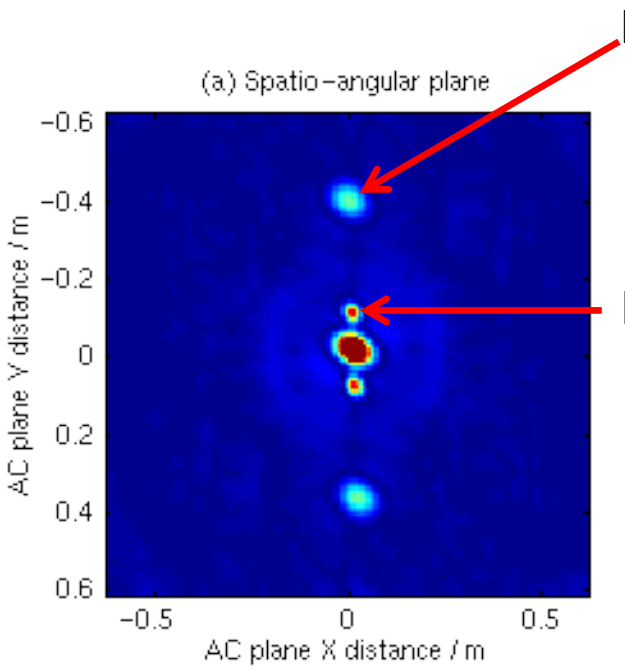
‘Shadow Patterns’ in Water



(Conventional) SCIDAR:
SCIntillation Detection And Ranging



Double Star Scintillation Pattern



High Layer

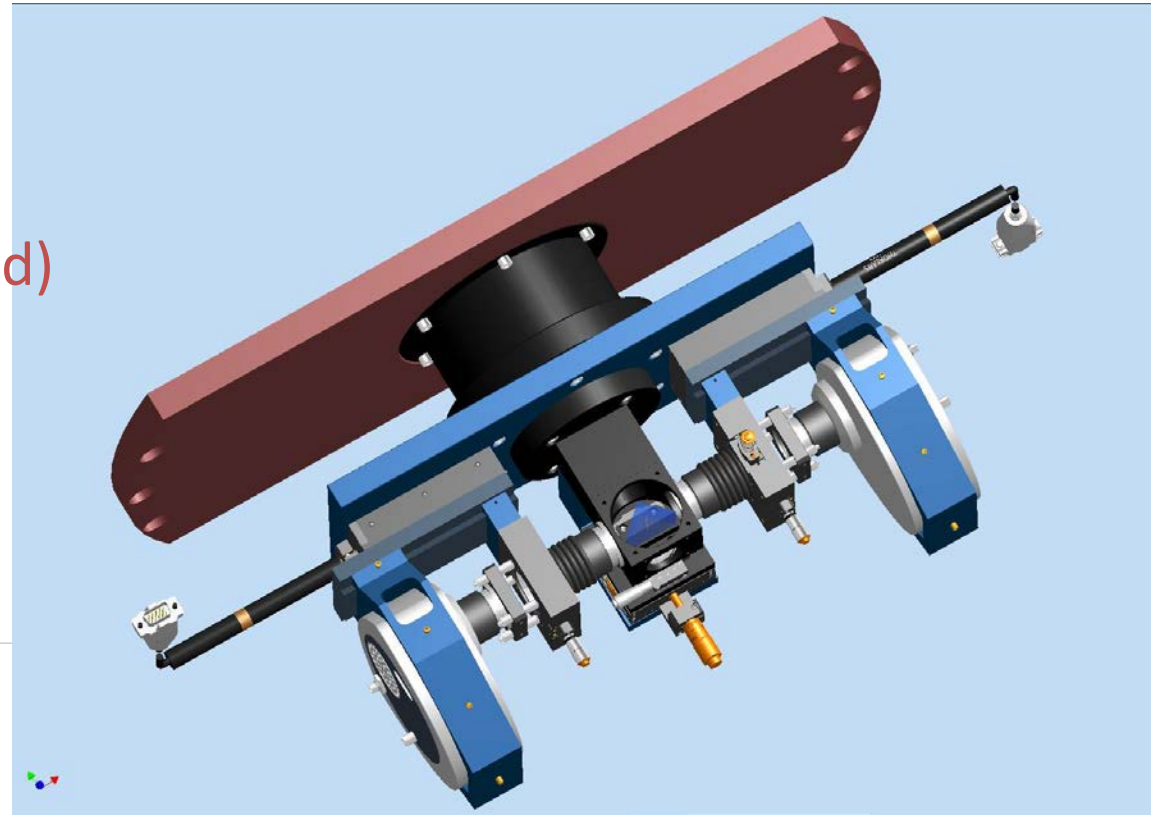
Low Layer

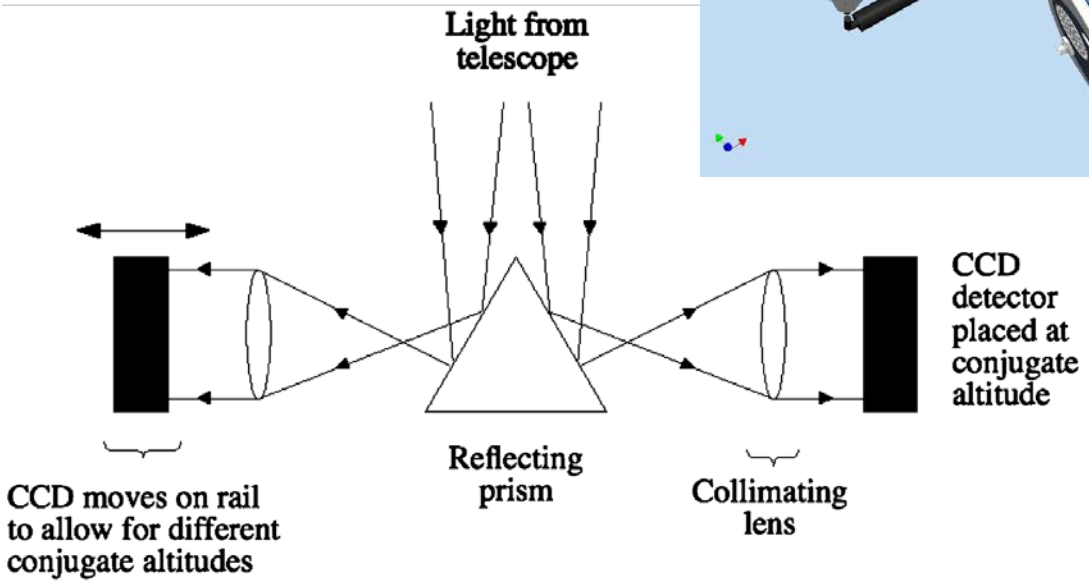
Image **Auto**-Correlation
(Time-Averaged)

- **Conventional SCIDAR**: The scintillation patterns for the two stars are superposed on the detector
- Each turbulent layer produces **3 peaks** in the auto-correlation

‘Stereo – SCIDAR’

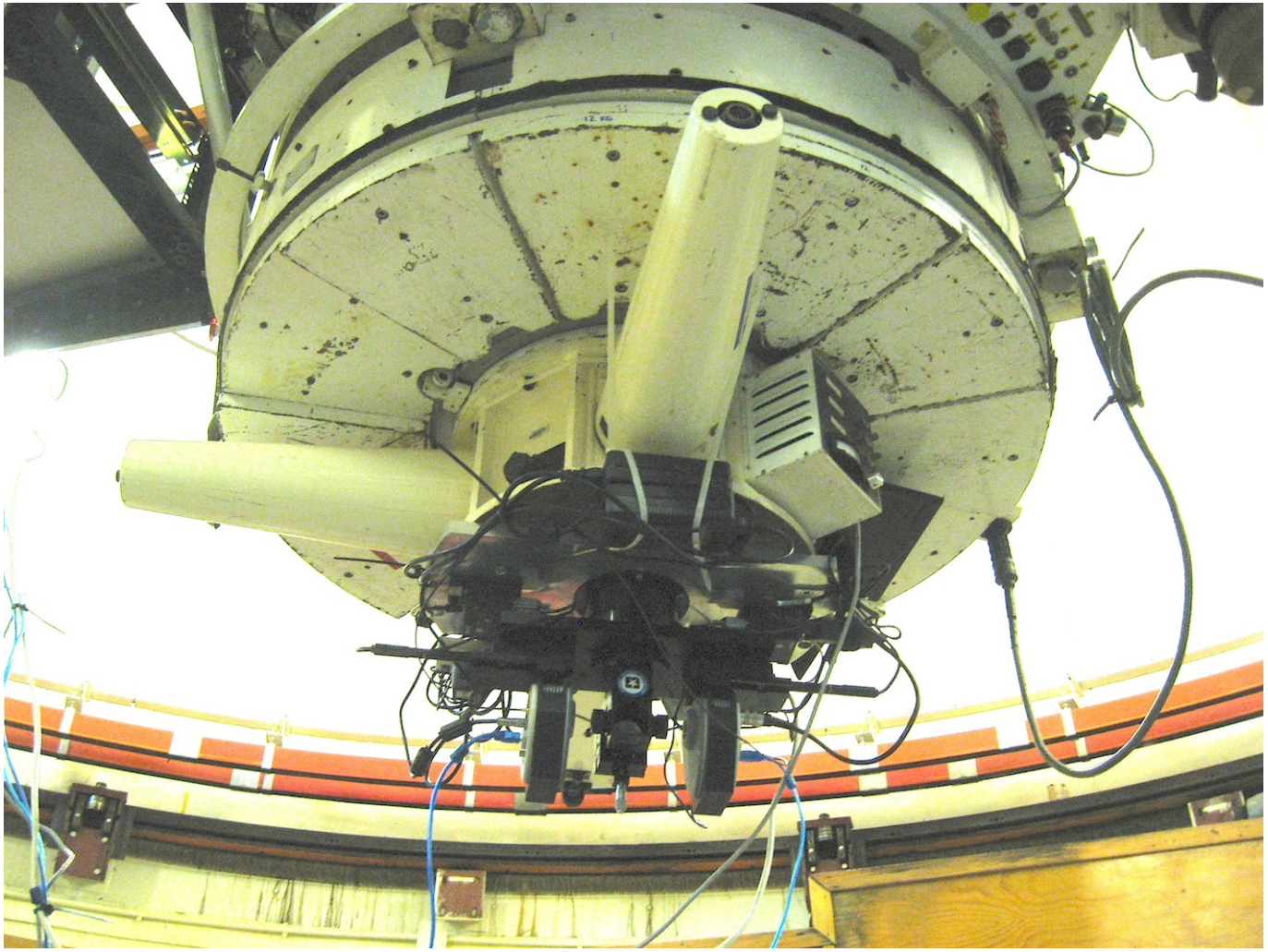
- Use separate (synchronized) cameras for each star



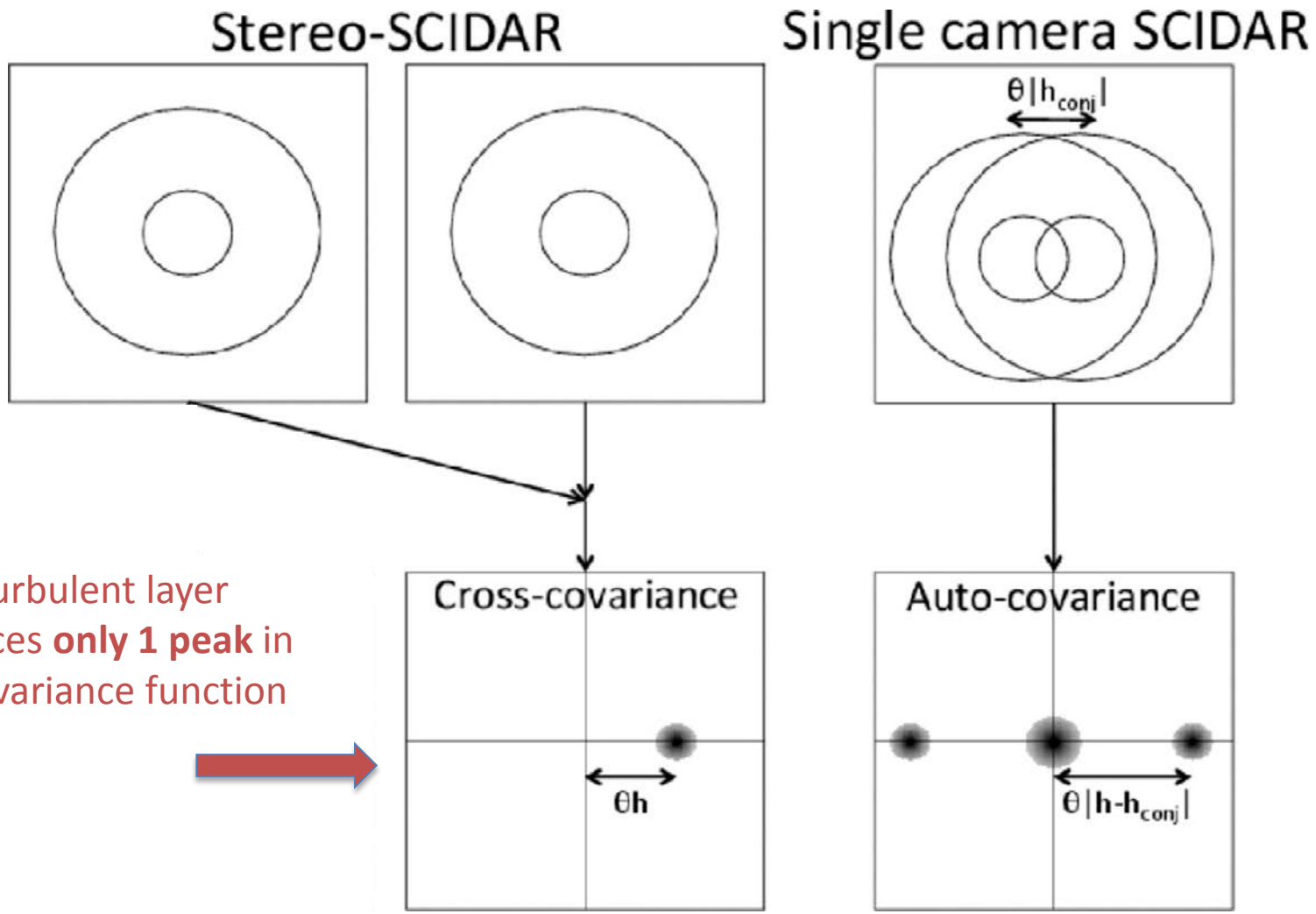


Stereo –SCIDAR on JKT, La Palma

Supports Canary AO demonstrator on WHT

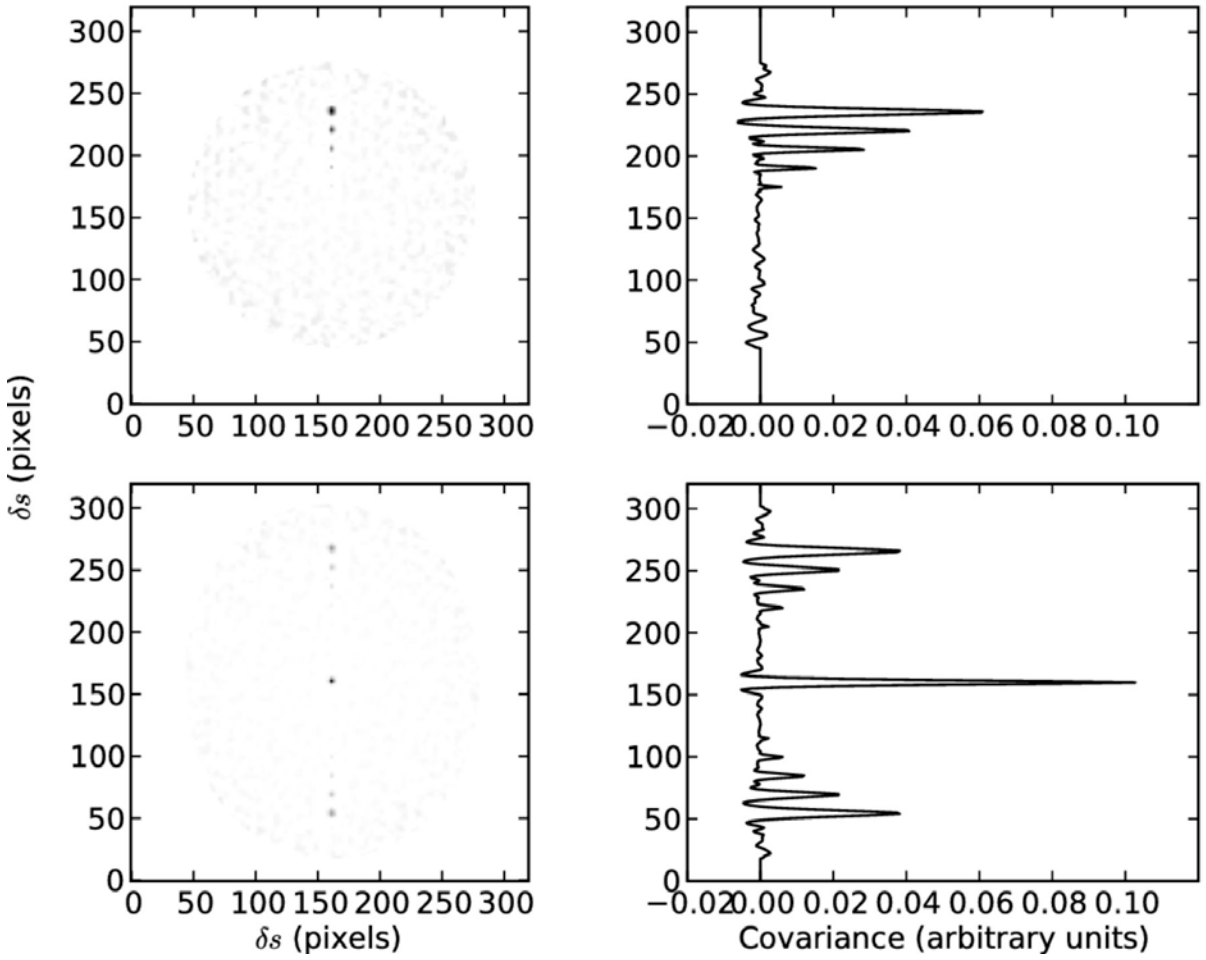


Covariance Response Functions – Conventional and Stereo SCIDAR



Each turbulent layer produces **only 1 peak** in the covariance function

Covariance Response Functions: Stereo-SCIDAR and Conventional SCIDAR

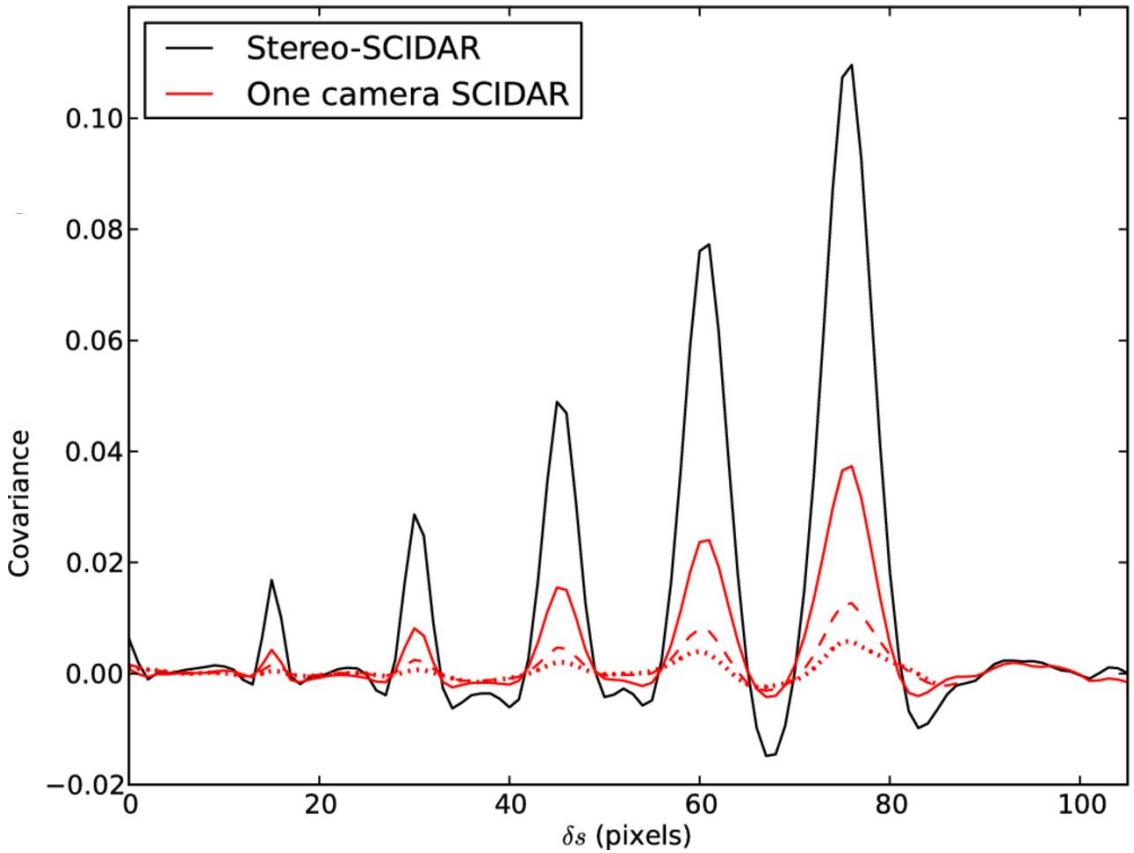


Stereo-SCIDAR

Conventional SCIDAR

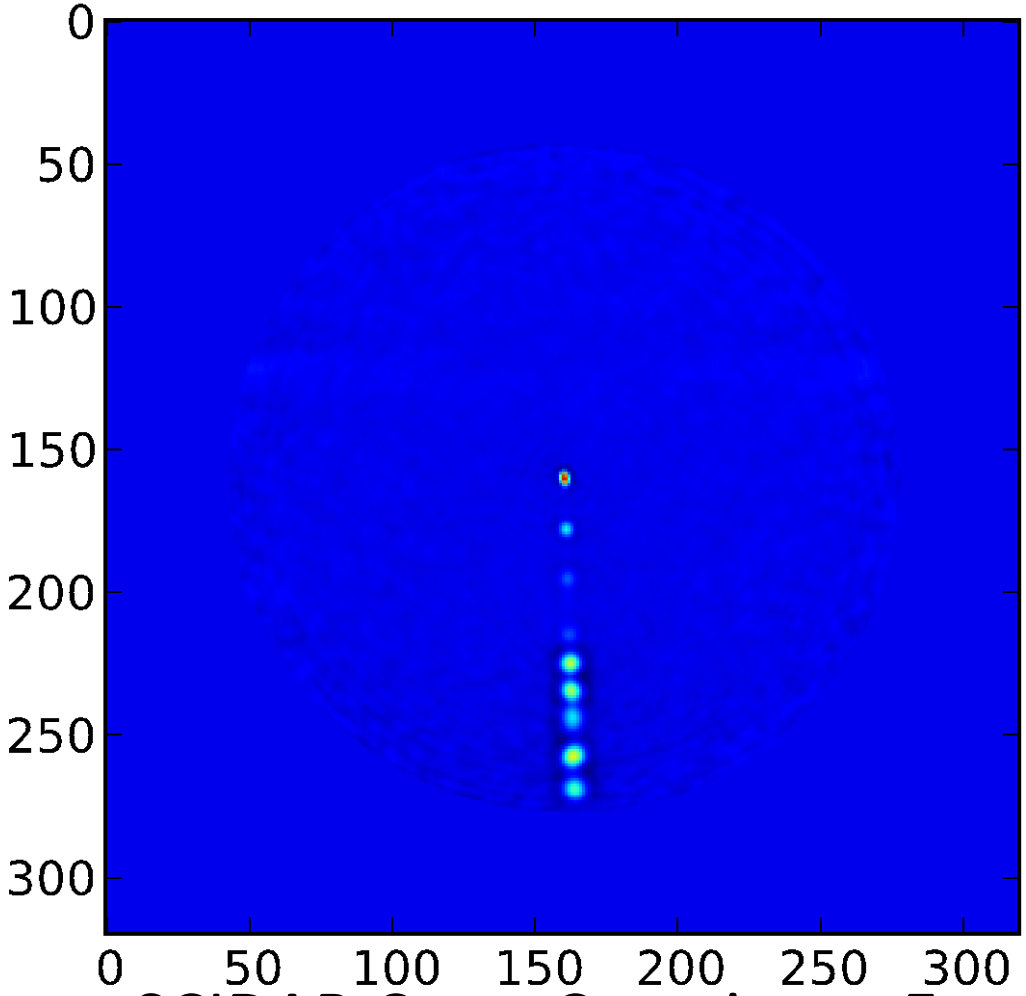
6 layers of equal strength, 2 km intervals between 0 and 10 km

Covariance Response Functions: Stereo-SCIDAR and Conventional SCIDAR



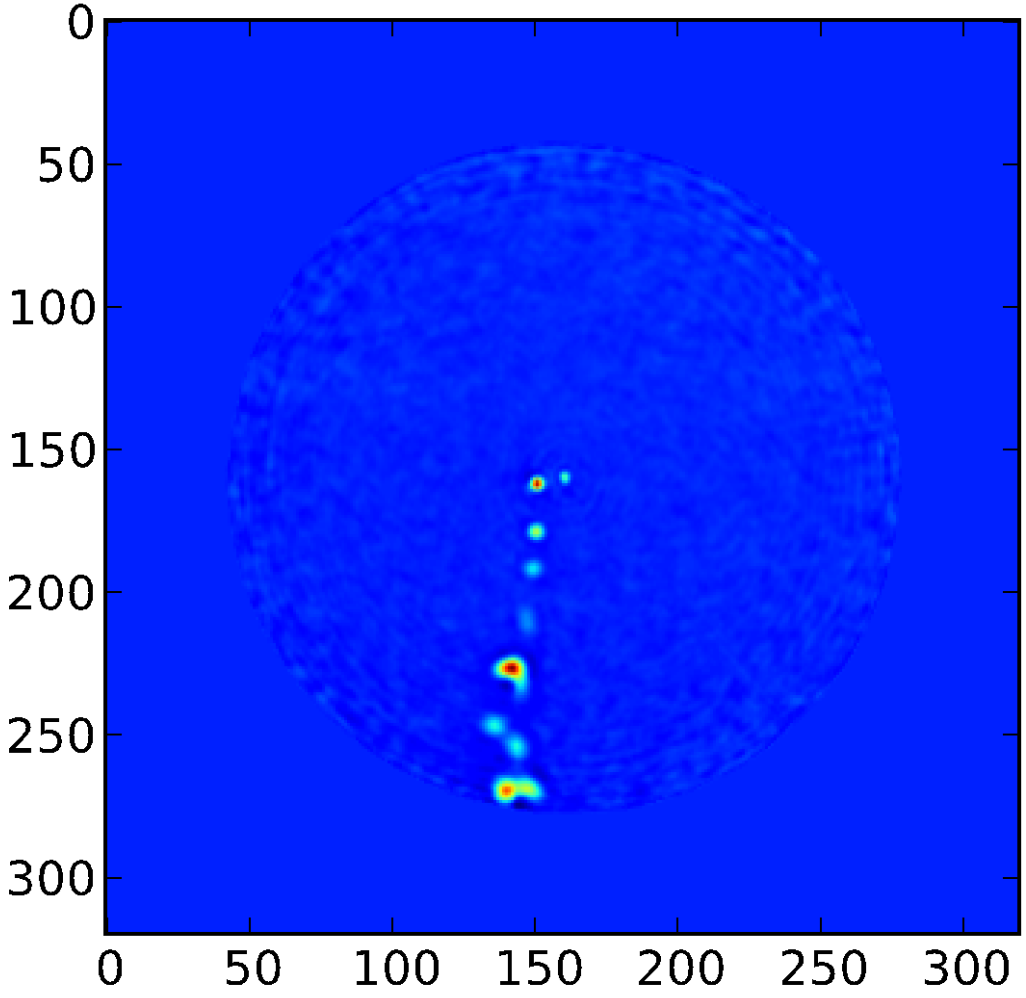
Solid lines: Target stars have the equal magnitude
Broken line: 2 magnitude difference (m1 = 4, m2 = 6)
Dotted line: 3 magnitude difference (m1 = 4, m2 = 7).

Turbulence (Wind) Velocity Measurements



Stereo-SCIDAR Cross Covariance Example

Nordic 2.5m Telescope, La Palma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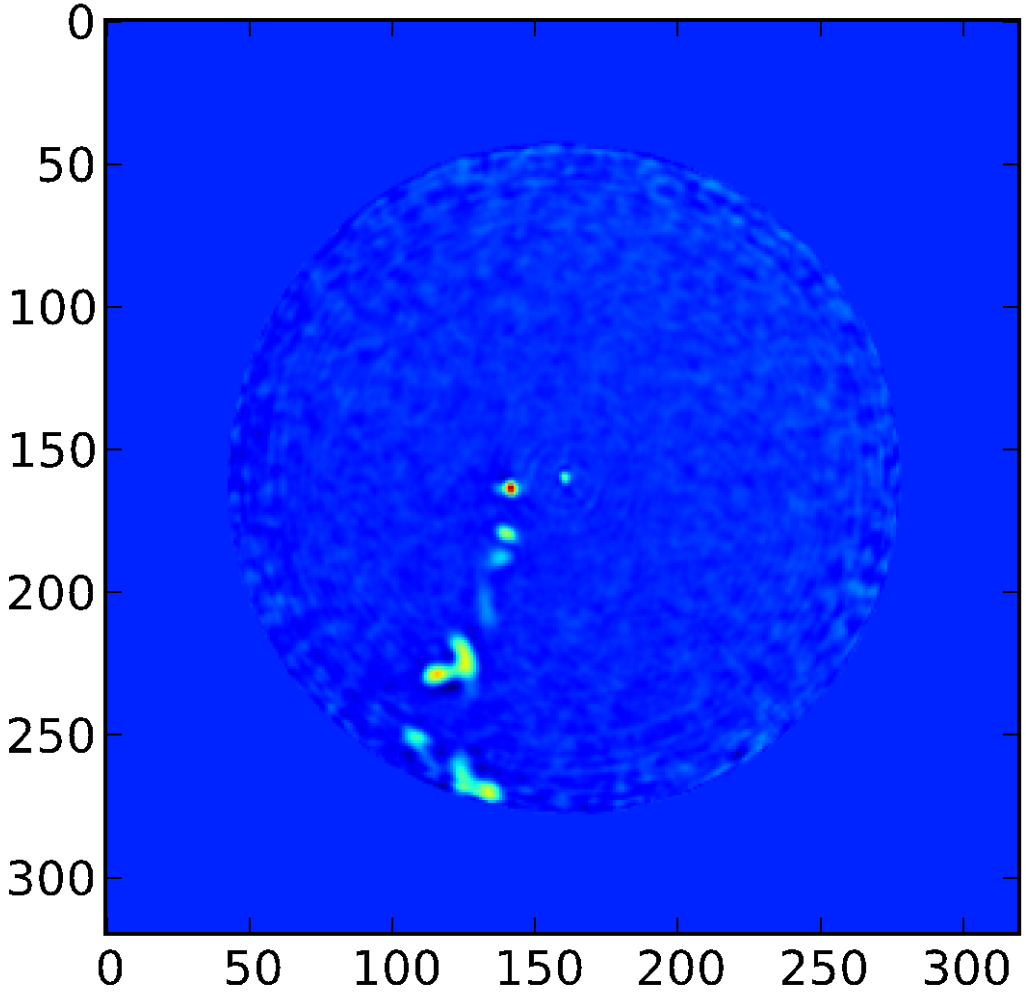
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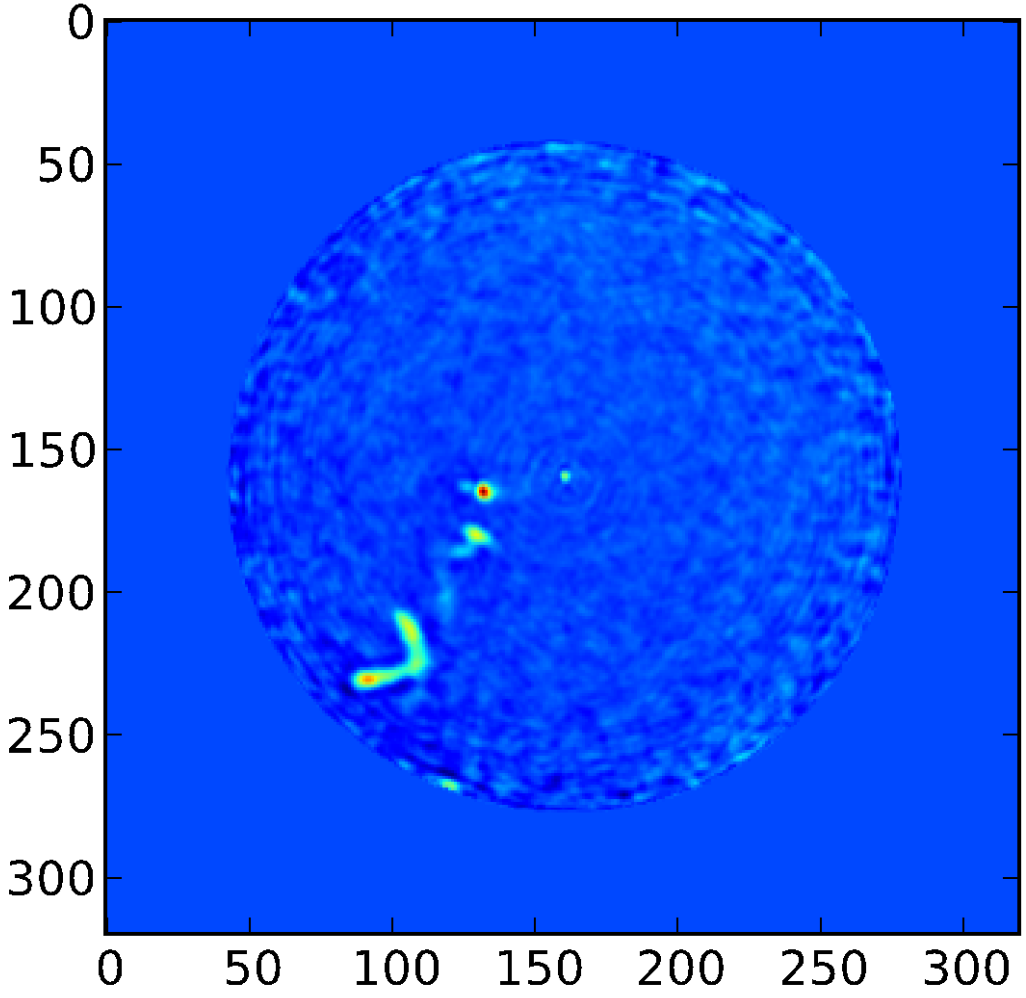
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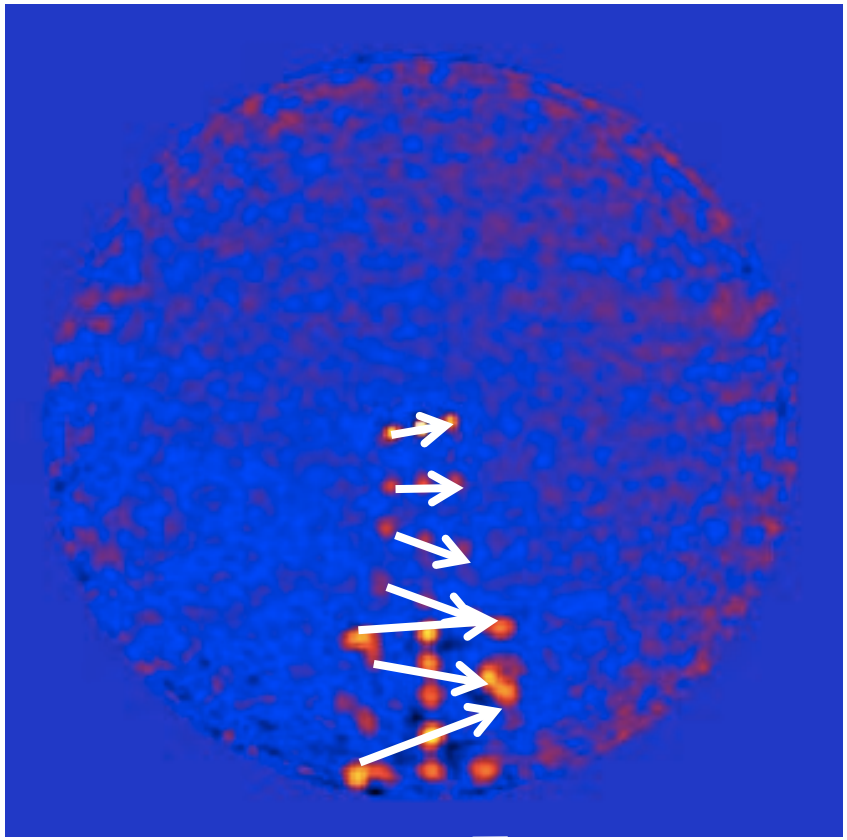
Wind Velocity Profile

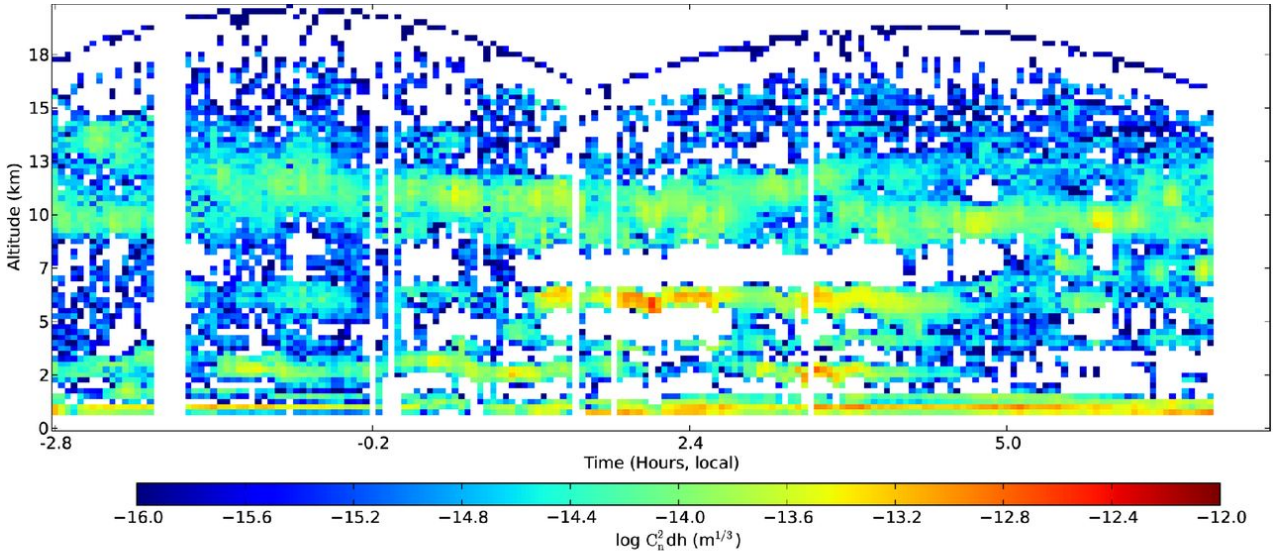
- Cross correlations only contain one set of peaks.
- Geometric wind profile algorithm rather than wavelet analysis
- Stationary central peak corresponds to dome seeing (dt +ve and –ve to avoid confusion with other peaks)

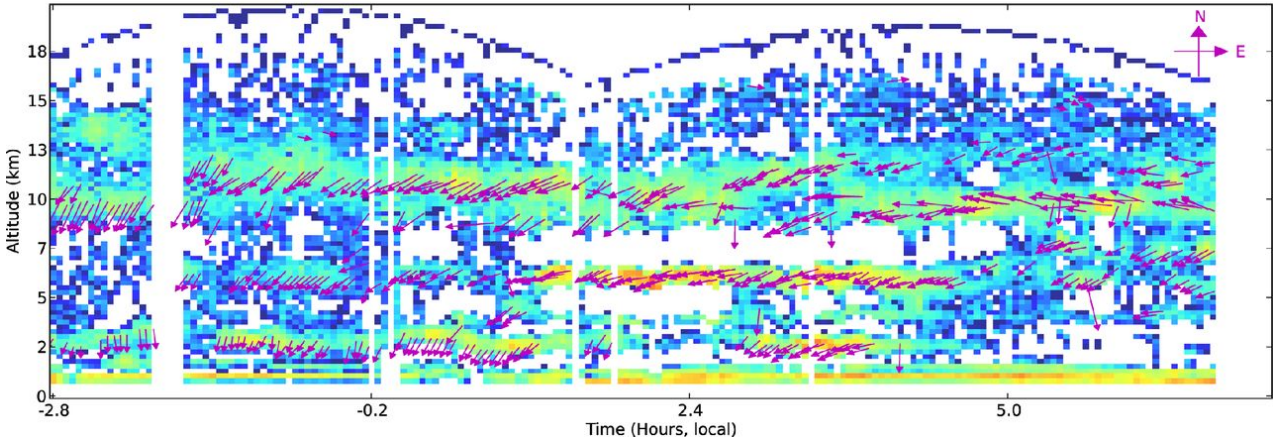


Wind profile 25/09/12, NOT 2.5 m, 9 Layers
Sum of Cross correlations for three time steps

Example S-SCIDAR Turbulence Profile Sequence

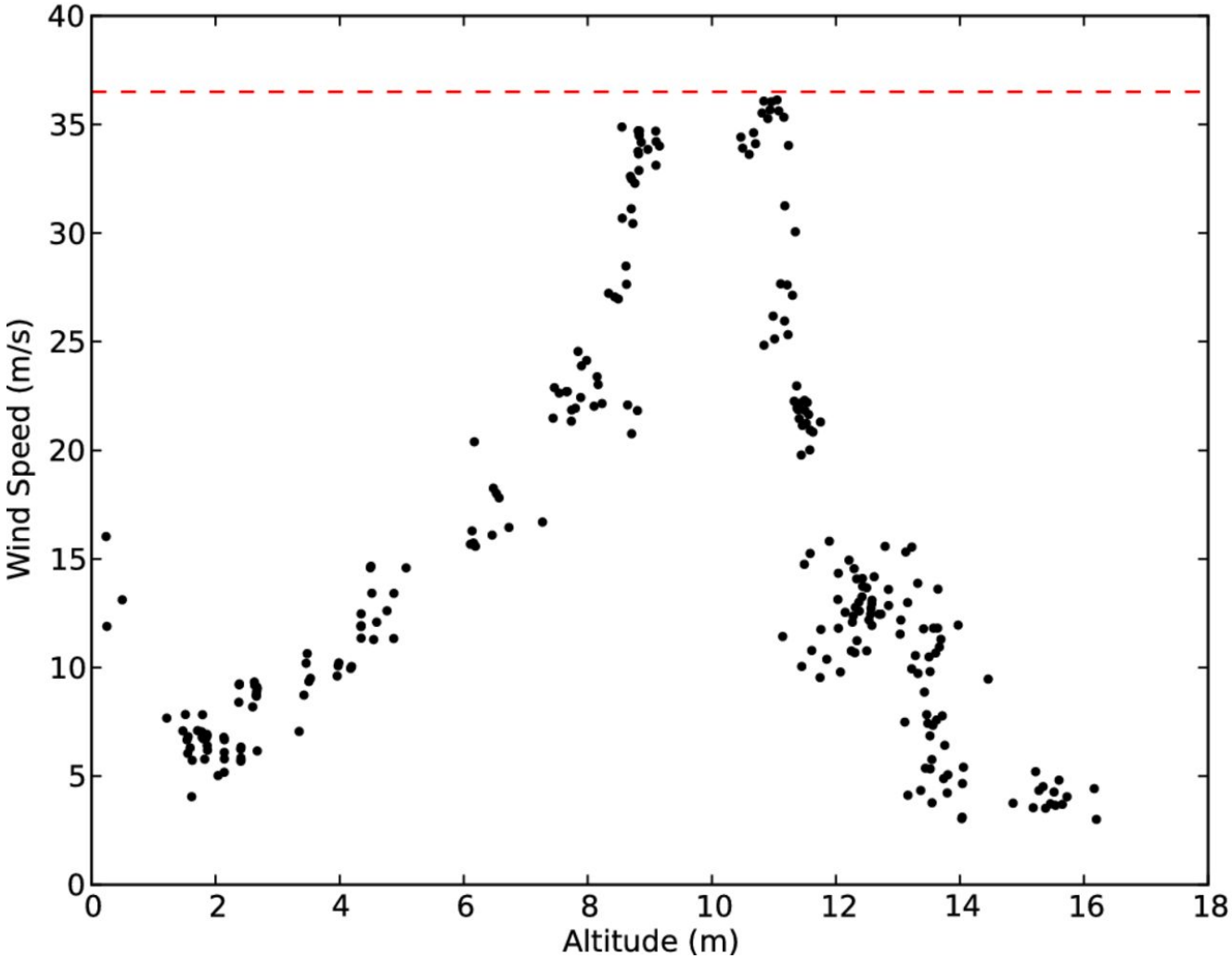
JKT, La Palma, 2013 September 15.





Example Distribution of Wind Speed with Altitude

Stereo-SCIDAR on JKT, La Palma, 2013 September 13



Stereo-SCIDAR Advantages

- **SNR improved** for turbulence profiling by factor of 2-20, c.f. conventional SCIDAR (target dependent):
    - Detect weaker layers
    - More accurate determination of layer strengths
    - Improve resolution in altitude:
        - ~ 200m resolution possible on 2m telescope

- **Turbulence velocity** measurements are very sensitive, robust and greatly simplified.

- **Dynamic re-conjugation** is possible – may improve layer altitude accuracy even more (but strong ground-layer is a problem)

- **More target** double stars available (can tolerate bigger magnitude difference) …

Stereo-SCIDAR: Application at Paranal ?

- Possible Auxiliary Telescope instrument
- Precedent - IAC `Cute-SCIDAR' deployed on AT (2007)
- Aim for minimal support requirements, 'point-and-shoot' instrument

- Could operate on ~6 nights per month (when ATs are not in use for interferometry)
- Acquire statistical turbulence profile data relevant to Paranal and Armazones:
  - Turbulence strength and velocity up to ~20km
  - High vertical resolution, high sensitivity