GLOSSARY OF INTERFEROMETRIC TERMINOLOGY

A GLOSSARY OF INTERFEROMETRIC TERMINOLOGY

Pierre LENA
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- *Active optics*
  A device fully or partly restoring in real-time and at low frequencies (≤ 1 Hz) the coherence of a perturbed wavefront : useful for aberrations and image motion corrections.

- *Adaptive optics (AO)*
  A device fully or partly restoring in real-time and at high frequencies (100 Hz or more) the coherence of a perturbed wavefront : useful to correct atmospheric effects.

- *Aperture synthesis*
  Sequential or simultaneous measurement of coherence at several spatial frequencies of the source, by using different baselines **B.**

- *Array*
  A number (>2) of telescopes, either fixed or movable, providing a number of different or idential baselines (see redundancy).

- *Baseline*
  The physical separation of two telescopes in an interferometer (**B**).

- *Baseline, projected*
  Vector projection of the baseline on the sky plane. Equals **B**.cos *i* if *i* is zenithal distance of the source.

- *Calibrator*
  A source whose visibility is known when observed by the interferometer (usually a star). The best calibrators are point-like sources. Unfortunately, with visibility accuracy improvements in current interferometers (relative precision close to 10^{-3}) and sensitivity limitations, most of potential calibrators are slightly resolved by the interferometer, hence their exact intensity distribution requires to be known or assumed.

- *Chromatic*
  Means wavelength-dependent. The opposite is achromatic.

- *Coaxial recombination*
  See Pupil plane recombination.

- *Coherence*
  Characterizes the corrrelation between two electric fields of the radiation taken at different locations (spatial coherence) or times (temporal coherence), or both (spatio-temporal coherence).

- *Coherence, mutual degree of*
  A complex quantity measuring the coherence of the field between two points at two distinct instants : γ ($\mathbf{r}_1$, $\mathbf{r}_2$, t_2- t_1). Its modulus varies between 1 (full coherence) to 0 (full decorrelation).

pierre.lena@obspm.fr

- *Coherence time, atmosphere*
  Characteristic time (τ_0) during which the atmospheric induced phase shift induced by the atmospheric index of refraction inhomogeneities may be considered as constant. This time is wavelength dependent.

- *Coherence time, source*
  Characterisc time (τ_c) separating two instants at which the source electric field begins to be decorrelated. Related to the spectral bandwidth of the signal.

- *Coherence, area of*
  Characteristic area (A_c), normal to the wave vector **k**, over which electric fieds of radiation at two different points are strongly correlated.

- *Coherence, étendue*
  Etendue (or throughput) of a radiation beam within which the coherence is maintained. Its value is λ_o^2 for a quasi-monochromatic (λ_o) radiation.

- *Coherence, length (or transversal length)*
  Distance traveled by the wave during the coherence time, i.e. $c\tau_c$

- *Coherence, loss of*
  Degradation of the source/signal coherence by various phase perturbations of the wavefront

- *Coherence, spatial*
  Measures the correlation of the electric fields of the radiation at two different points in space, at the same instant

- *Coherence, temporal*
  Measures the correlation of the radiation at two different instants, at the same point in space

- *Coherence, volume*
  Volume within which the radiation at two different points is coherent with itself. Product of area A_c by length $c\tau_c$

- *Correlation*
  Mathematical operator acting upon two identical (auto-correlation) or different (cross-correlation) functions of one or several variables. The function obtained by the action of the correlation operator presents several « mean » characteristics of the initial function(s). By Fourier transform of the correlation, one gets the power spectral density, also called power spectrum (Wiener-Khintchine theorem) of the initial function(s). Correlation functions can be deterministic or stochastic. Correlation can also be defined for distributions.

- *Delay line*
  Optical device, usually made of translatable mirrors, able to impose a variable and known phase shift (or time delay) to a beam of radiation. Fully achromatic when used in vacuum. Can also be made of single mode optical fibers.

- *Differential refraction*
  Atmospheric differential bending of rays, versus wavelength, for a source at non-zero zenithal distance *i*. Can be corrected by an optical device, tunable versus *i*.

- *Double Fourier (spatial and spectral)*
  In an interferometer working in a large spectral band and in the Pupil recombination mode (see this entry), fringe scanning provides a signal which contains both the spatial (visibility of fringes) and spectral (fringes frequency) information on the source.

- *Dual-beam (or dual-feed)*
  Interferometer configuration where the recombined focus allows to simultaneously measure visibilities (fringes) on two nearby (on the ground) or nearly arbitrarily located (in space) sources.

- *Fiber, optical*
  A waveguide, usually made of glass, carrying optical radiation. Fibers can be mono-mode, i.e. carrying a single spatial mode (fully coherent) of the radiation, hence carrying its phase, or multi-mode, where phase information of the transported signal is lost between fiber input and output.

- *Field-of-view, interferometer*
  Angular domain on the sky within which the spatial information coming from the source and analyzed by the interferometer can be retrieved at its output

- *Field-of-view, single telescope*
  Angular domain on the sky within which the spatial information coming from the source is available in the telescope focal plane, i.e. in the focal image

- *Fizeau, combination mode*
  Design of an interferometer such that the individual apertures/telescopes focus the radiation they receive on a common focal point

- *Fried's parameter r_o*
  Characteristic size of the domain of an atmospherically perturbed wavefront over which the initial coherence is conserved despite the crossing of an inhomogeneous Earth's atmosphere. Is wavelength dependent.

- *Fringe contrast*
  See Fringe visibility

- *Fringes, dispersed*
  An arrangement at the common focal plane of an interferometer, working in the Image mode (see this entry). One dimension(e.g. x) of the focal plane is used for for fringe modulation, the other for spectral dispersion. Hence visibilities can be measured at a number of differnt wavelengths simultaneously.

- *Fringe frequency*
  When the phase difference between the two beams recombined at an interferometer focus is varied linearly with time, intensity at output varies sinusoidally at this frequency. Causes of fringe scanning may be Earth rotation or delay line motion.

- *Fringe phase*
  The relative phase of the fringe pattern with respect to an absolute reference (defined by the interferometer metrology) or to a relative one (the fringe pattern of another source).

- *Fringe tracking*
  Fringe stabilization obtained by an optical device (fast delay line) maintaining the fringes at a fixed phase at the interferometer focus, therefore correcting for Earth rotation and piston noise with a priori prediction or servo-control, or both.

- *Fringe visibility (or contrast)*
  Complex quantity, the module of which is the normalized contrast of a set of interference fringes; its phase is the fringes phase. Is a measure of the spatio-temporal coherence of the two interfering beams. Contrast is more qualitative, while the visibility is quantitative. Visibility amplitude varies from 0 (incoherence) to 1 (full coherence).

- *Fringes*
  One (sinusoidal or somewhat periodic) of the possible aspects of the signal at the output of an interferometer. Fringes can be observable in time (scanning mode) or on an image at the comon focus of the interferometer.

- *Group delay*
  When the radiation has passed through a dispersive medium (e.g. atmosphere, optical fibers) with unequal paths for the two interfering beams, the central fringe position is defined by the group velocity of the radiationin the dispersive medium.

- *Hufnagel, profile*
  Standard variance of the Earth's atmosphere index of refraction random fluctuations versus height, in the simple case of a fully developed Kolmogorov turbulence. This variance is high near ground, decreases with height and increases again at the tropause to practically cancel above it. Used in zero-order simulations of atmospheric behaviour, but can be refined for a given astronomical site.

- *Image plane combination*
  A way to combine beams at the common focus of an interferometer, where images given byt the individual telescopes are coherently superimposed. Is also called multi-axial combination.

- *Interferometer*
  Imaging system where the spatial frequency coverage of the entrance pupil, at a given instant, is quite limited (bandpass filter) : hence the image bears little resemblance with the object, unless aperture synthesis is used. Boundary between « interferometer » and « telescope » is not well defined. In an interferometer, the entrance pupil is not simply connected : it is made of individual, well separated apertures.

- *Isoplanatic angle*
  Defines a cone of directions, from the ground to the sky, within which the transmitted radiation from a celestial source suffers identical phase shift. The associated property is isoplanetism. Opposite is anisoplanatism.

- *Karhunen-Loeve, polynomials*
  Complete base of polynomials to develop in series a stochastic perturbation, e.g. the phase of a wavefront vs. the point of the wavefront at a given time.

- *Kolmogorov turbulence*
  A particular distribution of turbulence, where energy is injected at a given (large) scale, cascade to smaller cales to be finlly dissipated. Average power spectral density of the kinetic energy of the fluid vs. position is then given by a power-law (-11/3).

- *Metrology*
  Ensemble of sub-systems, ususally based on lasers, which, in an interferometer, allow to measure the optical paths of the radiation within the interferometer (e.g. from primary mirrors of each telescope to the common interferometric focus) at an accuracy significantly better than the wavelength of the radiation.

- *Michelson, combination mode*
  Design of an interferometer such that the individual apertures/telescopes produce afocal beams which after cophasing are recombined before the interferometer output.

- *Mode filtering*
  Selecting one or several spatial modes in a radiation beam with an optical device. A pin-hole, a single mode optical fiber can achieve this.

- *Mode, spatial*
  Any propagating wave can be considered as an (eventually infinite) superposition of propagation modes, each one made of spatially coherent radiation.

- *Modulation transfer function (MTF)*
  A normalized function, which for imaging systems describes the filtering properties of the system, versus spatial frequency (u,v). It always has a cut-off maximum frequency. Can be deterministic or stochastic (e.g. for the atmospheric MTF).

- *Multiaxial recombination*
  See Image plane recombination.

- *Noise*
  Any phenomenon introducing uncertainity in the determination of the observable provided by an instrument. Can in some cases be part of the observable itself (signal photon noise).

- *Noise, atmospheric*
  Rather broad term, designating all atmospheric effects, time-dependent, perturbating the signal from a source observed through it.

- *Noise, background*
  Noise (additive) adding to the signal and caused by the simultaneous reception, on the detector, of radiation emitted by the atmosphere, the instrument itself or other causes.

- *Noise, phase*
  Random fluctuation of the fringes phase with time, due to random optical path variations in the atmosphere.

- *Noise, quantum*
  Intrinsic fluctuation (additive) of the signal with time, as soon as the quantum nature of light-matteer interaction is present.

- *Noise, scintillation*
  Mutiplicative noise, caused by random transmission variations of the atmosphere.

- *Noise, signal*
  See Noise, quantum.

- *Noise, speckle*
  Random fluctuations of the light intensity within an image, caused by loss of coherence of the radiation after being transmitted by an inhomogeneous atmosphere, or scattered by a random medium (surface or volume).

- *Noise, thermal*
  A particular type of background noise, associated with the thermal emission of matter : e.g. thermal noise due to atmospheric emission, to dioptric or catadioptric materials in the optics. Is particularly important for wavelengths close to or above the Planck's curve (for the considered temperature) maximum.

- *Noll, coefficients*
  When a standard (Kolmogorov) atmospheric random phase perturbation of a wavefront is represented on the basis of Zernike polynomials, their coefficients are random. Noll's values are the rms values of these coefficients.

- *Nulling*
  A method for improving the contrast between a bright source (star) and its immediate neigbourhood (e.g. planet). it is therefore an extension of the classical concept of coronography. It aims at configurating the interferometer in order to produce a null

(destructive interference) at the place where the bright star contribution will be in the common focal plane, and a maximum transmission (constructive interference) at the planet location (e.g. interferometric configurations known as Angel's cross, Mariotti or Lawrance design).

- *Optical path*
  The effective length traveled by a ray in a medium, given by the integral, along the path *l*, of the product *n. dl*, where *n* is the (usually chromatic) index of refraction.

- *Phase*
  May designate the phase of the radiation itself (electric or magnetic field), or the phase of the (eventually quasi-) periodic signal at the output of an interferometer.

- *Phase closure*
  Remarquable additive property of the interferometer output phases if 3 or more baselines are simultaneously used : the phase addition of the interferometric signals cancels the atmospherically induced phase shifts.

- *Phase variance*
  When phase noise is present, variance of the instantaneous phase.

- *Phase, differential*
  Difference of interferometric phases observed between one source and a reference metrology beam from the instrument itself, or two sources in different directions (dual beam operation), or one single source at two different wavelengths.

- *Piston*
  Atmospheric effect creating a net phase difference, randomly variable, between the signals received by the two separated telescopes of an interferometer. It displaces randomly the fringe pattern, creating phase noise. Piston is almost achromatic and is not corrected by adaptive optics. The zero-order term in Zernike polynomials.

- *Point spread function (PSF)*
  Distribution of radiation intensity observed in the focal plane of an optical instrument, when observing a point-like source at a given wavelength. Can be deterministic or stochastic. Forms a Fourier pair with the MTF.

- *Pupil (entrance)*
  The physical contour forming a surface and delimitating the rays accepted by an optical instrument.

- *Pupil, densified*
  A peculiar way of recombining afocal beams in a Michelson-type interferometer, where the exit pupil is no longer homothetic to the entrance pupil. Produces intensity concentration in the final interference pattern, at the expense of field-of-view.

- *Pupil plane recombination*
  A way to recombine beams at the exit of an interferometer : wavefronts are coherently superimposed by beam splitting (division).

- *Quasi-monochromatic radiation*
  Radiation with a dominant wavelength λ_o and a spectrum entirely contained in a narrow spectral range $\Delta\lambda_o$ near λ_o ($\Delta\lambda_o \ll \lambda_o$).

- *Redundancy*
  Characterizes an optical device where the same spatial frequency (or narrow frequency range) is transmitted by several (two or more) baselines over the pupil : e.g. a 3 telescopes (T_1, T_2, T_3) linear interferometer with 2 equal baselines ($\mathbf{B}_{1\,2}=\mathbf{B}_{2\,3}$).

Scales of turbulence, outer, inner

Charcteristic lengths above which (outer L_o) or below which (inner l_o) the rotational structure of the flow in the atmosphere vanishes. These scales delimitate the spatial frequency range (in the atmospheric turbulence spectrum) contributing to the wavefront propagation alteration.

- *Sky background*
  Irradiance produced by the emission of the Earth's atmosphere (thermal or fluorescence), adding to the signal and producing thermal or quantum noise (see Background noise).

- *Source, extended or resolved*
  A source having an angular size larger than the resolution of the observing system.

- *Source, incoherent*
  A source where individual emitting area emit radiation with random relative phases.

- *Source, point (or point-like, or unresolved)*
  A source having a size significantly smaller than the resolution of the observing system. Care should be exercized , since even a quite unresolved source will have a visibility departing from unity, even only by a few percents.

- *Spatial filtering*
  Reduction of the spatial frequency content of the radiation received from a source, produced by an optical system (telecope or interferometer) or by other causes (e.g. atmospheric propagation). Can be deterministic or stochastic.

- *Strehl ratio S*
  The peak intensity in an actual image, normalized to the peak of the perfect, diffraction-limited image the same instrument would ideally give. $0 \leq S \leq 1$. Efficiency of adaptive optics is measured by the increase of S it can produce. S also measures the fraction of the radiation which is coherent (contained in the coherent core of the image).

- *Taylor, hypothesis*
  Assumes atmospheric turbulence to be « frozen » and carried by the wind, at least in each independent horizontal layer contributing to image degradation. This is usually valid as the characteristic atmospheric time τ_0 is much smaller than the characteristic time of evolution of turbulent eddies.

- *Telescope*
  Imaging system where the spatial frequency coverage of the entrance pupil, at a given instant, is quite extended (low-pass filter) : hence the image bears great resemblance with the object. Boundary between « interferometer » and « telescope » is not well defined. In a telescope, the entrance pupil is entirely connected, or at most affected by small gaps (e.g. spider arms, secondary mirror, gaps between primary mirror segements if any).

- *Tip-tilt*
  The overall inclination of the wavefront, caused by atmosphere or other causes and characteriez by two angles (« tip » and « tilt »). It produces image motion in the focal plane of a telescope. in the pupil plane recombination mode, it suppresses the flat state of interference over the pupil surface. Is usually corrected in real time by an active optical device. In the Zernike polynomial development, tip-tilt is a low-order aberration coming immediatly after piston.

- *u-v plane*
  As the image is a two-dimensional intensity distribution, its Fourier transform is also two-dimensional. Its variable is the spatial frequency vector, hence having two coordinates, classically called u and v. The u-v plane is therefore the spatial frequency plane.

- *Vignetting*
  Effect of instrument throughput reduction at the edge of its field, due to partial obstruction of the radiation by optical surfaces within the instrument. The vignetted fields surrounds the full illumination field.

- *Visibility*
  A normalized complex quantity **V**. Its modulus measures the contrast of interference fringes. $0 \leq$ modulus $\mathbf{V} \leq 1$. Its phase measures the fringes phase, relative to an other phase (e.g. the phase of fringes from another source, or from the interferometer internal metrology system).

- *Visibility losses*
  Reduction of the source visibility by losses of coherence affecting the radiation coherence outside (atmosphere) or within (optical surfaces, polarisation) the instrument. Visibility losses need to be calibrated using known external calibrators (see this entry).

- *Visibility, instrumental*
  The visibility which would result from the observation of a point-like source, the visibility of which being unity. The instrumental visibility measures the coherence losses.

- *Zernike, polynomials*
  A convenient set of polynomials, defined within a circular area and orthogonal. They are used in developed series to represent the wavefront local phase perturbation over a pupil. higher order abberrations correspond to the higher order polynomials.

- *Zernike-van Cittert, theorem*
  A basic theorem in optics, stating the reciprocal correspondance of the irradiance of a source and the mutual degree of coherence of the quasi-monochromatic radiation on a surface illuminated by this source. This correspondance is a two-dimensional Fourier transform. Basic for interferometry, as the measurement of coherence carreid on Earth leads to informations on the source irradiance spatial strucure.

- *Zero Optical Path Difference (OPD)*
  A position in space, at the interferometer output, from which the optical paths are equal to the source through either of the two interfering beams (including instrument effect, delay lines, atmospheric piston). The OPD point would constanly move if not servoed inposition by various optical devices (delay lines, piston compensation, etc.).

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