Receiver Chain: Typical GAIN DRIFT, INSTABILITIES and their CAUSES

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Cagliari, 13th May 2011

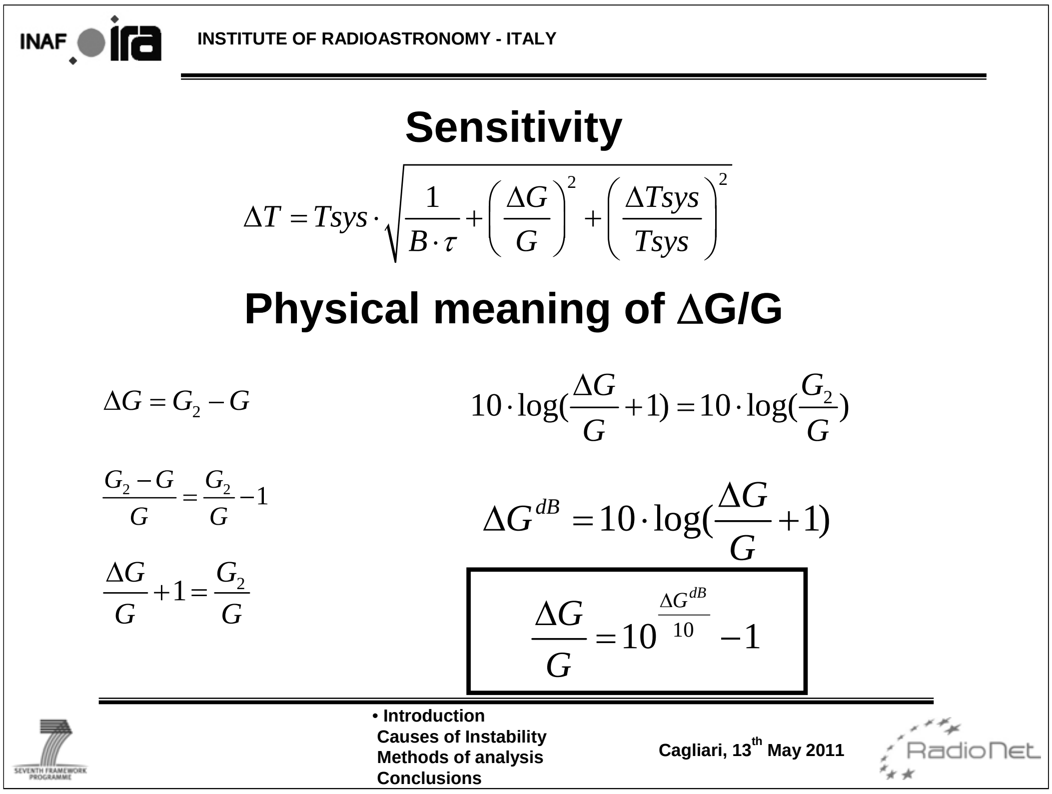
AGENDA

- **Introduction**

List of Causes of Instability

Methods of analysis and troubleshooting

Conclusions



Sensitivity

$$\Delta T = Tsys \cdot \sqrt{\frac{1}{B \cdot \tau} + \left(\frac{\Delta G}{G}\right)^2 + \left(\frac{\Delta Tsys}{Tsys}\right)^2}$$

Physical meaning of ΔG/G

$$\Delta G = G_2 - G$$

$$\frac{G_2 - G}{G} = \frac{G_2}{G} - 1$$

$$\frac{\Delta G}{G} + 1 = \frac{G_2}{G}$$

$$10 \cdot \log\left(\frac{\Delta G}{G} + 1\right) = 10 \cdot \log\left(\frac{G_2}{G}\right)$$

$$\Delta G^{dB} = 10 \cdot \log\left(\frac{\Delta G}{G} + 1\right)$$

$$\boxed{\frac{\Delta G}{G} = 10^{\frac{\Delta G^{dB}}{10}} - 1}$$

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In order to get the highest sensitivity , the term 1/(B*tau) should be the small as possible.

In most cases, DTsys/Tsys can be neglected.

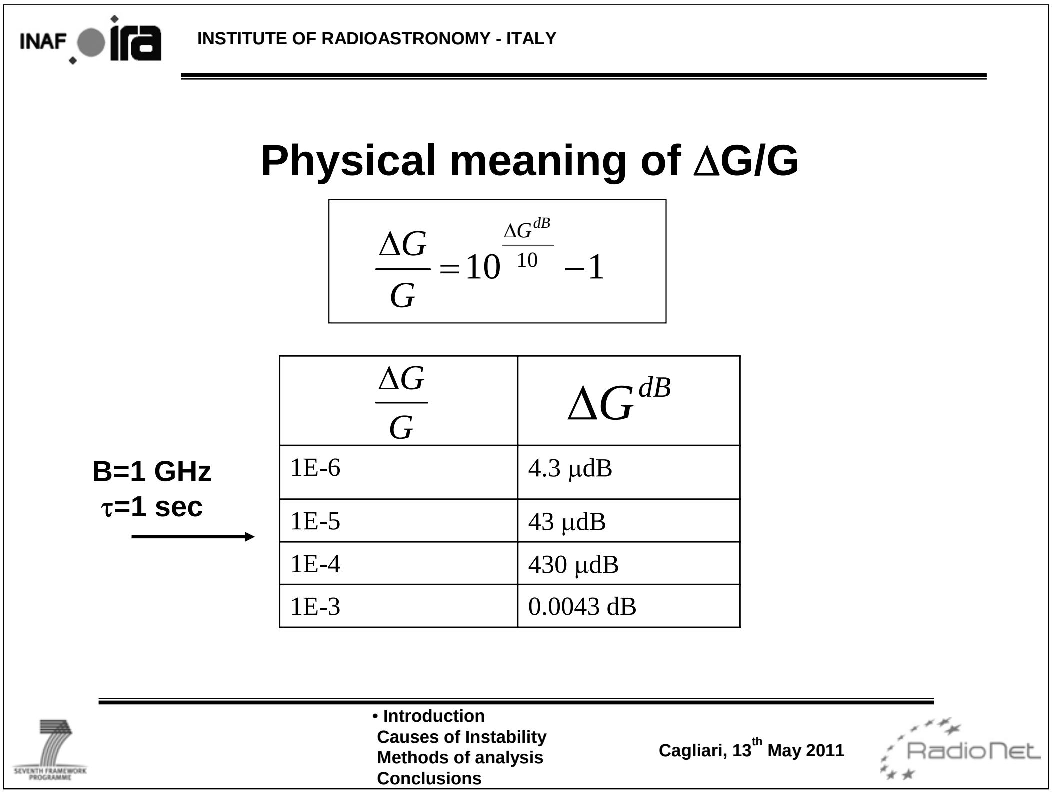
The term DG/G is the greatest disturbing term.

How we can reduce ΔG/G ?

Please, do not reduce DG/G by increasing G !!!

In order to better understand the meaning of the ratio the dB formatting is necessary.

DG/G (formatted as number) means DG (formatted in dB).



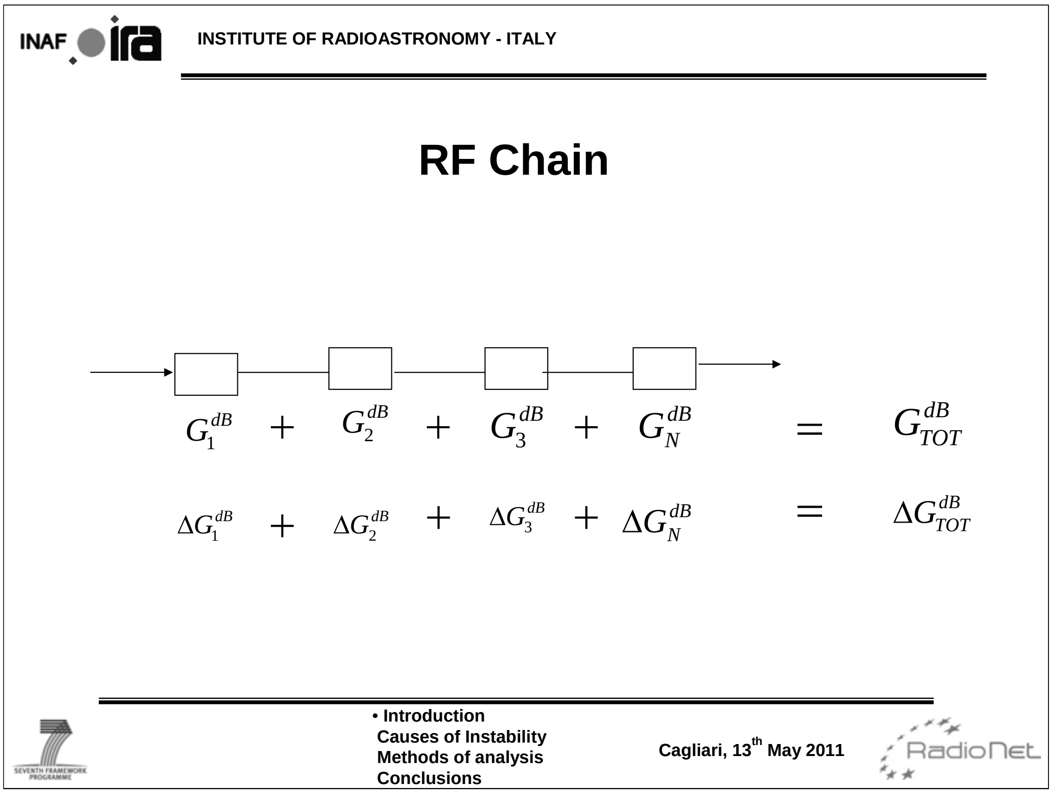
Physical meaning of ΔG/G

$$\frac{\Delta G}{G} = 10^{\frac{\Delta G^{dB}}{10}} - 1$$

B=1 GHz
τ=1 sec →

$\frac{\Delta G}{G}$	ΔG^{dB}
1E-6	4.3 μdB
1E-5	43 μdB
1E-4	430 μdB
1E-3	0.0043 dB

Some typical values of DG/G (num) and DG(dB).



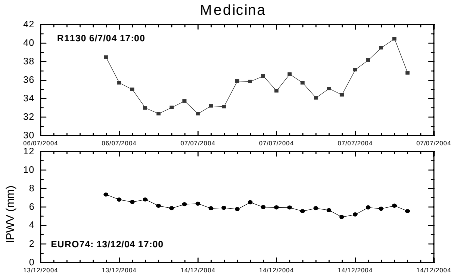
RF Chain

$$G_1^{dB} + G_2^{dB} + G_3^{dB} + G_N^{dB} = G_{TOT}^{dB}$$

$$\Delta G_1^{dB} + \Delta G_2^{dB} + \Delta G_3^{dB} + \Delta G_N^{dB} = \Delta G_{TOT}^{dB}$$

DG(dB) increase as G(dB) increase ,

Also, DG(dB) increase as the number of stages increase.



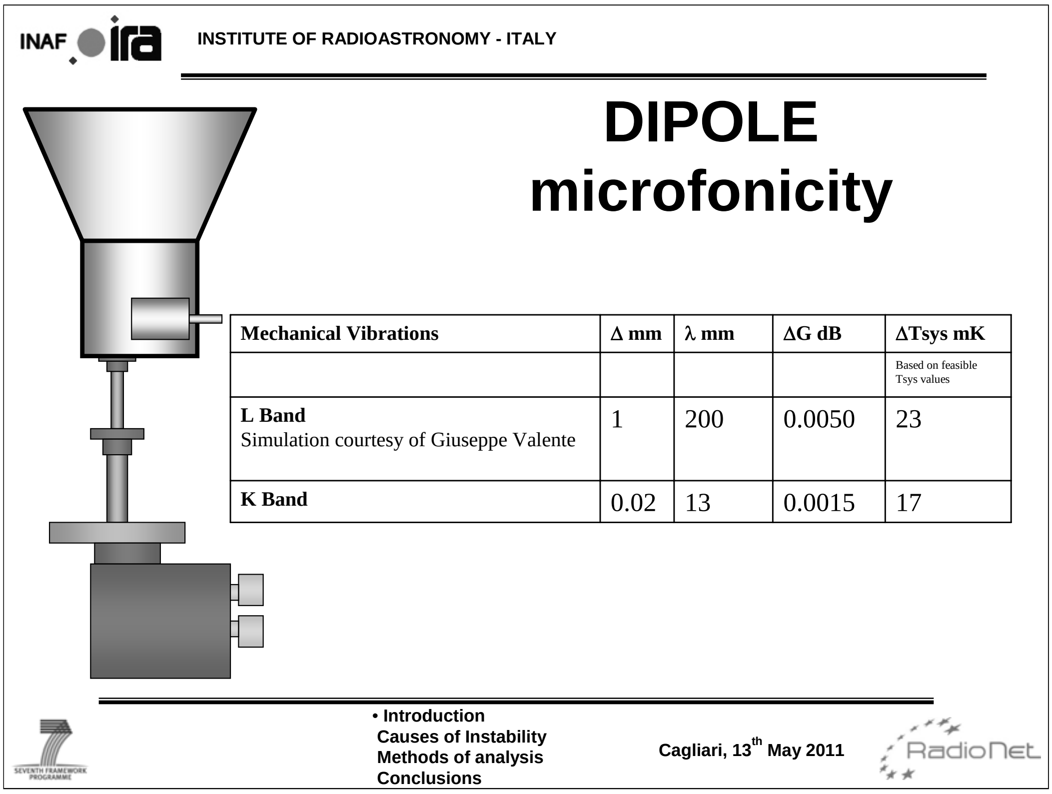
ATMOSPHERE

[Negusini M. and P. Tomasi (2005). Water vapour content and variations estimated at European VLBI sites. Proceedings of the 17th Working Meeting on European VLBI for Geodesy and Astrometry, Noto, 22-23 April 2005, pp. 84-89]

IPWV	**IPWV/hour**	**K/hour**	**mK/sec**
mm	**mm/h**	Based on Medicina RT F=22GHz, Tsys=50K, IPWV=20mm Looking the Zenith.	
5…35	0.5…3	0.8…4.8	0.2…1.3

Variations of airmass due to the Antenna Tracking	**mK/sec**
Te variations (1 sec)	2...10

The data are coming from experimental observations



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DIPOLE microfonicity

Mechanical Vibrations	Δ mm	λ mm	ΔG dB	ΔTsys mK
				Based on feasible Tsys values
L Band Simulation courtesy of Giuseppe Valente	1	200	0.0050	23
K Band	0.02	13	0.0015	17

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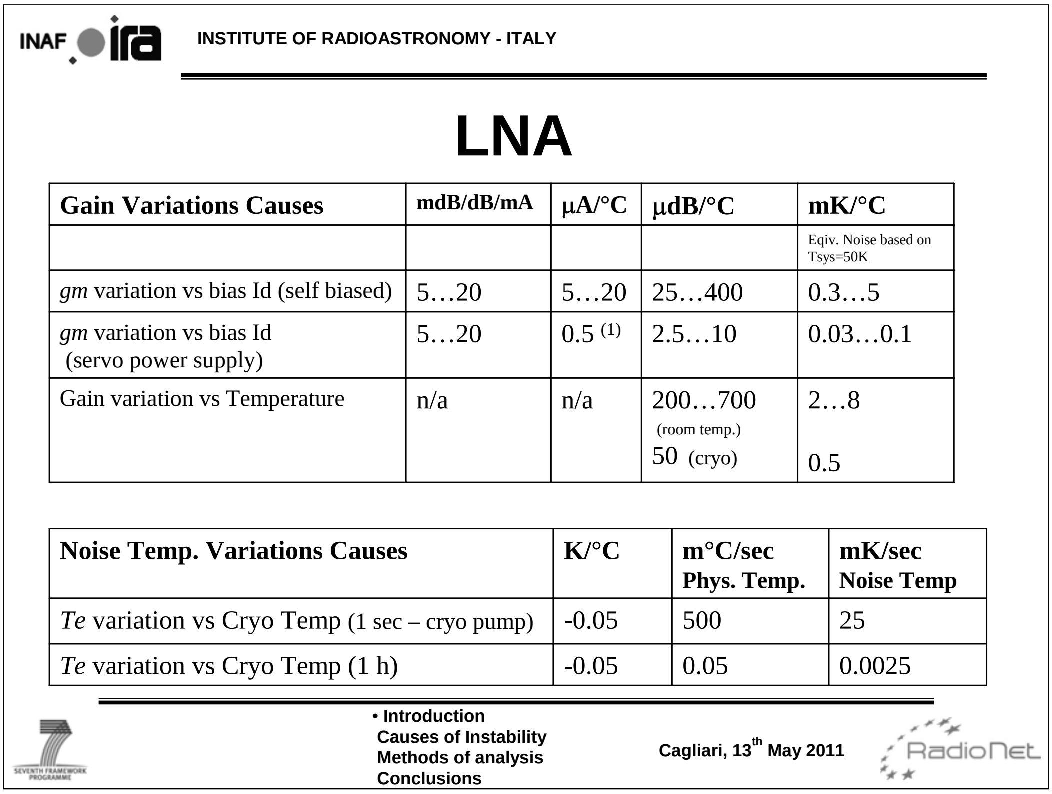
Many mechanical parts, even horn and dipole, are in touch with the cryo cold head.

The cold head produces mechanical vibrations, which are propagate along the metals and may resonate where metal cantilever are encountered.

May be the case of the dipole, which often is made by a thick and heavy cylinder , connected by a thin rod.



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LNA

Gain Variations Causes	**mdB/dB/mA**	**μA/°C**	**μdB/°C**	**mK/°C**
				Eqiv. Noise based on Tsys=50K
gm variation vs bias Id (self biased)	5…20	5…20	25…400	0.3…5
gm variation vs bias Id (servo power supply)	5…20	0.5 (1)	2.5…10	0.03…0.1
Gain variation vs Temperature	n/a	n/a	200…700 (room temp.) 50 (cryo)	2…8 0.5

Noise Temp. Variations Causes	**K/°C**	**m°C/sec Phys. Temp.**	**mK/sec Noise Temp**
Te variation vs Cryo Temp (1 sec – cryo pump)	-0.05	500	25
Te variation vs Cryo Temp (1 h)	-0.05	0.05	0.0025

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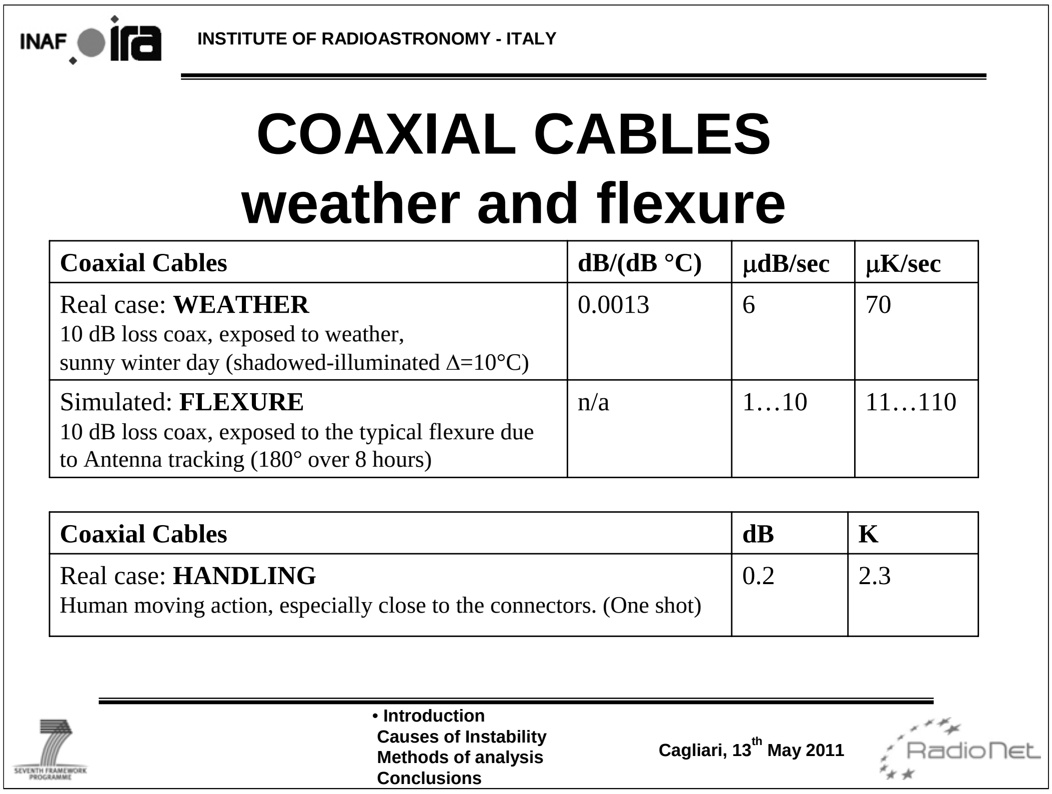
The data are coming from experimental observations of the behavior of the LNA



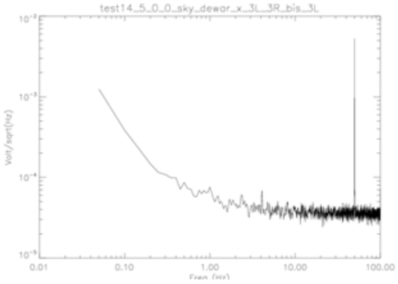
COAXIAL CABLES
weather and flexure

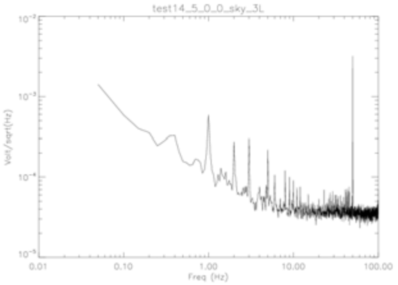
Coaxial Cables	dB/(dB °C)	μdB/sec	μK/sec
Real case: **WEATHER** 10 dB loss coax, exposed to weather, sunny winter day (shadowed-illuminated Δ=10°C)	0.0013	6	70
Simulated: **FLEXURE** 10 dB loss coax, exposed to the typical flexure due to Antenna tracking (180° over 8 hours)	n/a	1…10	11…110

Coaxial Cables	dB	K
Real case: **HANDLING** Human moving action, especially close to the connectors. (One shot)	0.2	2.3

Detectors

Square Law Detectors	dB/°C	μdB/sec	μK/sec
		Based on a variation of 1°C/hour	Based on Tsys=50K
Instrument grade (Wiltron), biased, 40 GHz, Schottky or Tunnel?	0.005	1.4	16
Spacek Lab , Zero bias, Schottky, 50 GHz	0.05	14	160





SPECTRUM ANALYSYS

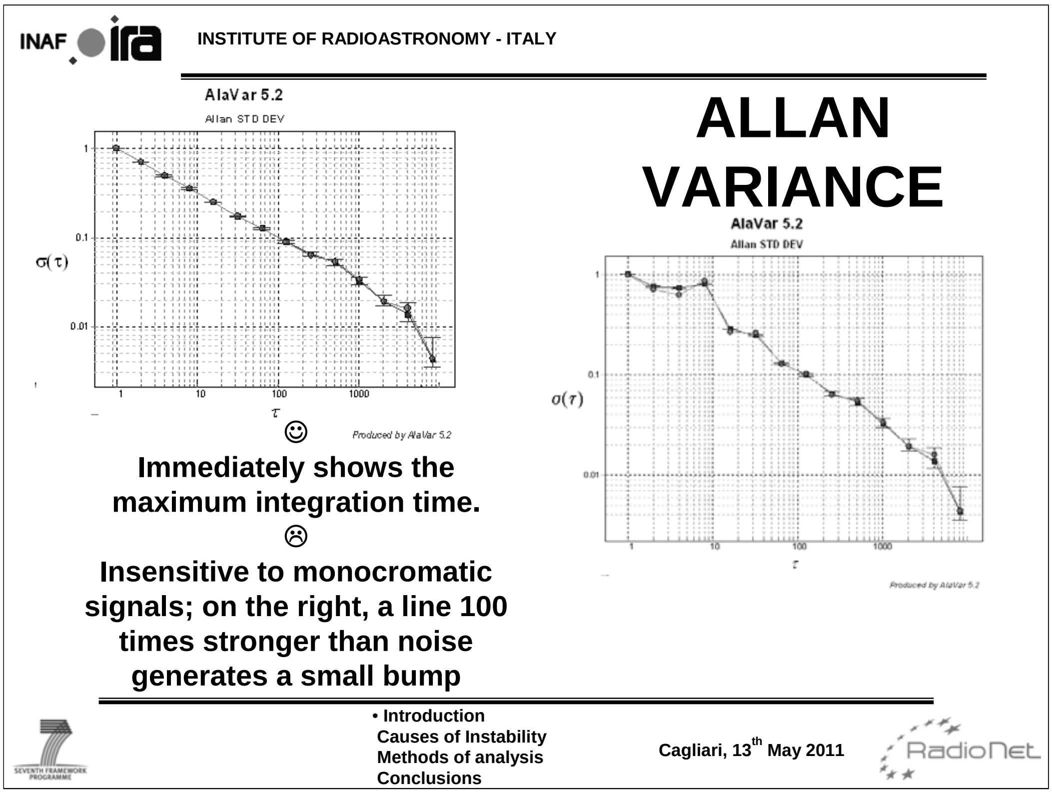
☺

Sensitive to spectral lines
Cryo generator (1Hz)
Mains (50 Hz)

☹

The knee depends on bandwidth also.

Insensitive to “jumps”



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ALLAN VARIANCE

☺

Immediately shows the maximum integration time.

☹

Insensitive to monocromatic signals; on the right, a line 100 times stronger than noise generates a small bump

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AVar is a powerful method used to calculate the maximum integration time.

But it’s little sensitive to non-noise data such periodic signals.

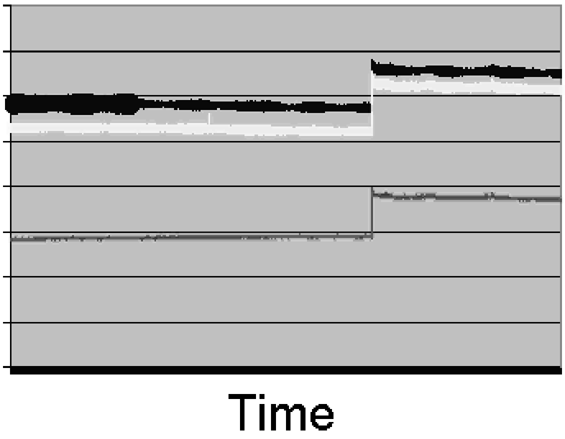
ALLAN VARIANCE
as well as
NOISE SPECTRUM
are both needed

… but they aren’t enough…

AVAR and NOISE SPECTRUM are sensitive to static and continuum conditions.

Level steps, or pulse occurring rarely , as well hysteresis behaviours needs other troubleshooting methods.

Oscilloscope



The time domain analysis better shows steps rather than freq. domain or AVar.

The dear old oscilloscope has been substituted by a

LabView code.

Method and picture Courtesy of Andrea Maccaferri

CONCLUSIONS

Summary of Instabilities

Summary of Drift and Instabilities (assuming presence of mechanical vibrations)	**mK/sec**
Due to variations of IPWV	0.2…1.3
Air mass variations due to Antenna Trackingv	2…10
Due to Dipole vibrations (1Hz cryo)	20
Due to LNA Gain variations (worst case)	2…13
Due to LNA Gain variations (typ. cryo)	0.5
Due to LNA Phys. Temp. changes (1 Hz cryo)	25
Due to cables flexure	Negligible
Due to cables handling	> 2000
Due to square law detector	0.2

- **Drift phenomena occurring on the atmosphere cannot be corrected by observing techniques.**
  Partially FALSE

- **Instability occurring between mirror and LNA cannot be corrected by observing techniques:**
  TRUE

- **Instability occurring between LNA and Backend may be corrected:**
  TRUE, (but not every time done).

Instabilities occurring between the mirror and the plane of injection of noise cannot be corrected in any way.

Vibrations of the plastic cover of the horns are a typical example.

As well as vibrations of dipoles and connectors

When the Antenna is observing in SINGLE-DISH mode, the vibrations occurring between the mirror and the plane of noise injection, will get worse the confusion limit of the whole Radiotelescope.