*Relaxed Bandwidth Sharing with*

# Space Division Multiplexing

*v guruprasad* (prasad)

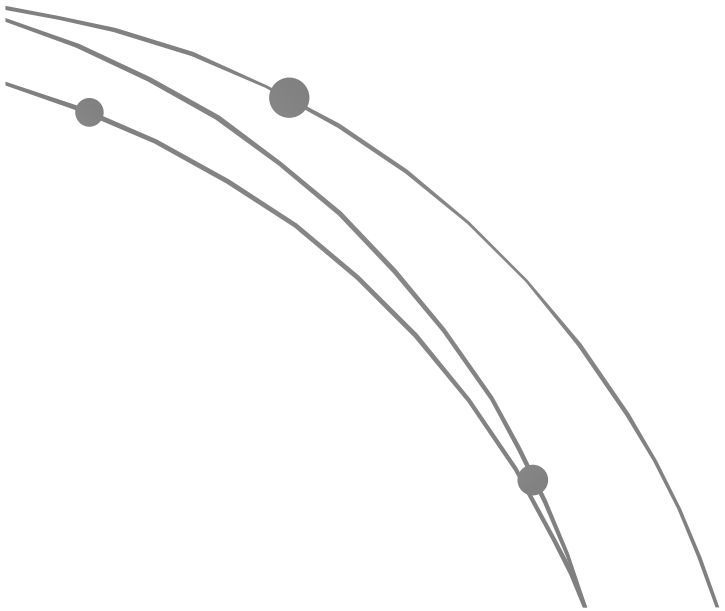
*2005.03.16*

www . inspiredresearch . com

*Relaxed Bandwidth Sharing with*

# ~~Space~~ Division Multiplexing

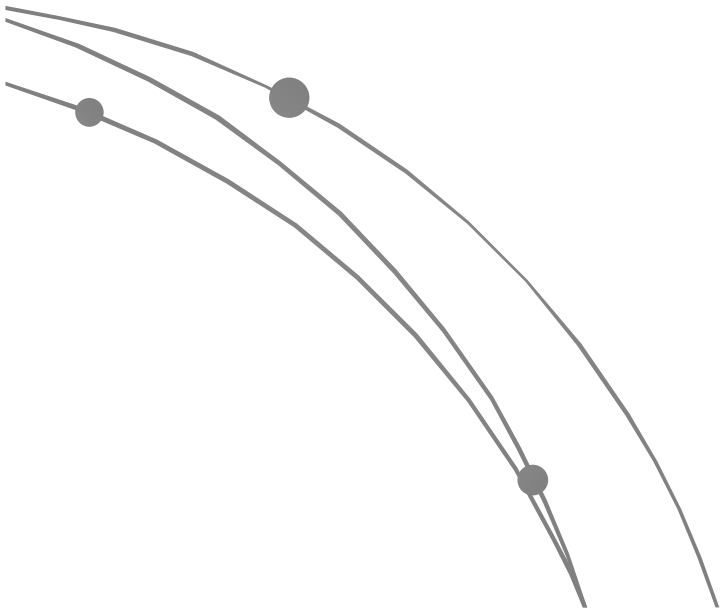
***Distance + angle***



*Relaxed Bandwidth Sharing with*

# ~~Space~~ Division Multiplexing

***Distance ~~+ angle~~ → directional antennae***

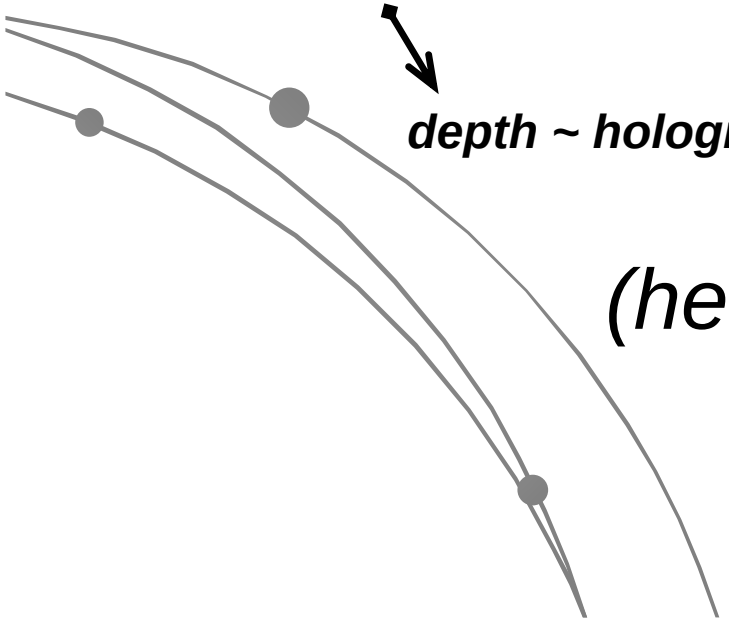


*Relaxed Bandwidth Sharing with*

# ~~Space~~ Division Multiplexing

***Distance*** ~~***+ angle***~~ → ***directional antennae***

↘ ***depth ~ holography***

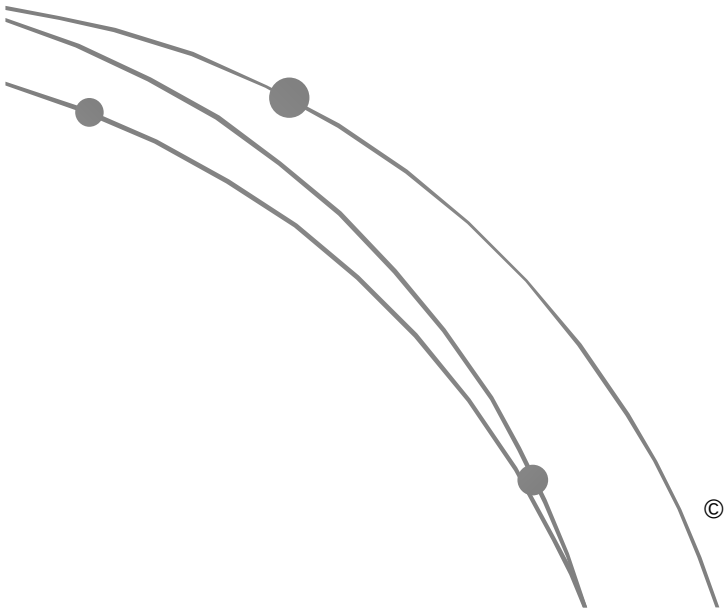


*(hence DDM, SDM)*

# *background*

*wave effect recognized from astrophysics*

*in 1995-1996 ~* ***informally*** *predicted cosmological acceleration (Λ)*



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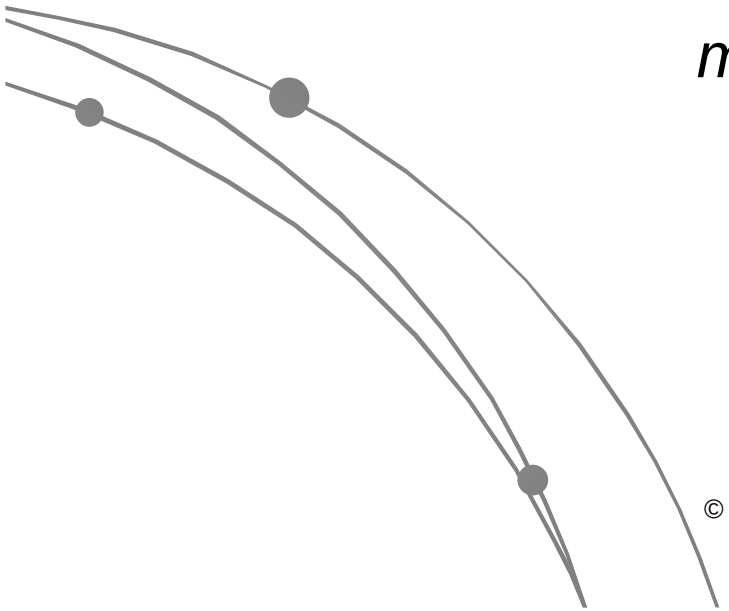
*under Bruce Elmegreen, IBM Research*
*many partial ALL POSITIVE results*
*ground to 15+ Gy*



# *background*

*wave effect recognized from astrophysics*

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*in 1995-1996 ~ predicted cosmological acceleration (Λ)*

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*under Bruce Elmegreen, IBM Research*
*many partial ALL POSITIVE results*
*ground to 15+ Gy*

*in 2004 ~ isolated wave effect + a systematic fallacy in calibration of space telescopes*

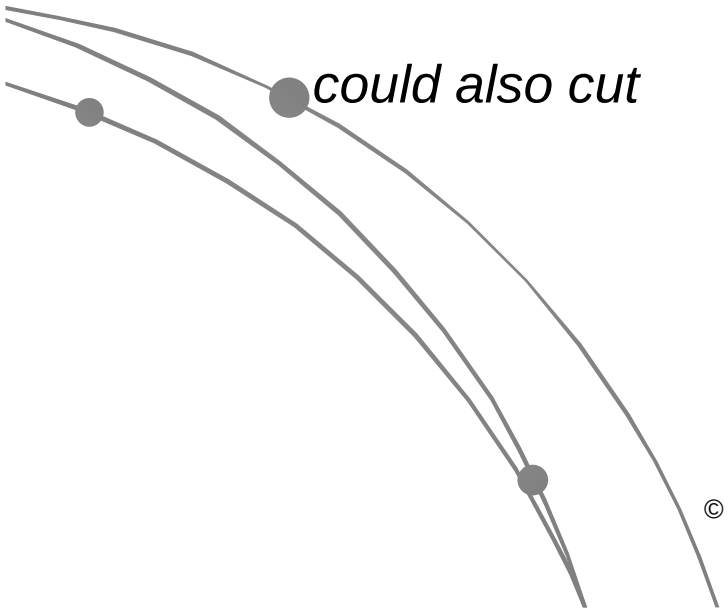
# *opportunity*

separation of signals by *source distance*

*fundamental* not using content, e.g. GPS
(*must* separate ***before*** demodulation *or* decoding)

*universal* orthogonal to FDM, TDM, CDMA

*could also cut* *noise & interference*



# *opportunity*

separation of signals by *source distance*

| | |
|---|---|
| *fundamental* | not using content, e.g. GPS |
| | (*must* separate ***before*** demodulation *or* decoding) |
| *universal* | orthogonal to FDM, TDM, CDMA |
| *could also cut* | *noise & interference* |

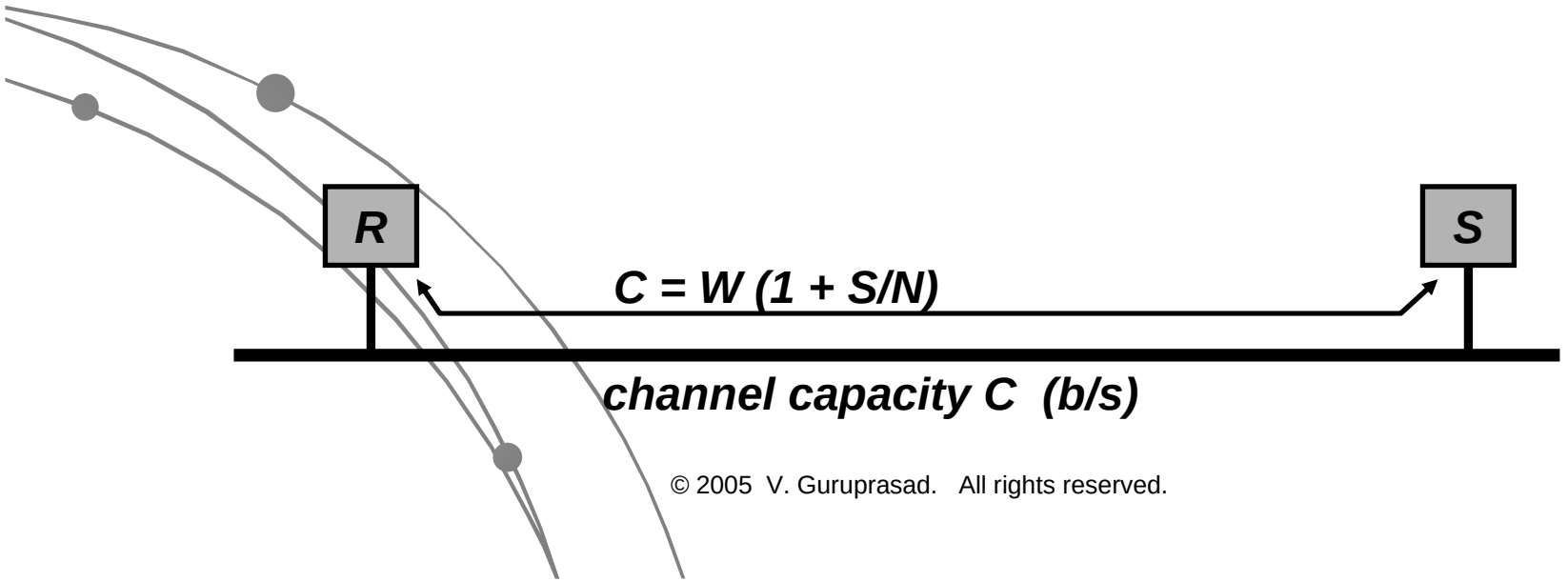
& would *multiply channel capacity*

# *beyond Shannon's limit*

*Shannon theory ~ time × bandwidth*

fundamental dimensions =
{ time, frequency, direction, polarization }

*each dimension <u>multiplies</u> capacity*



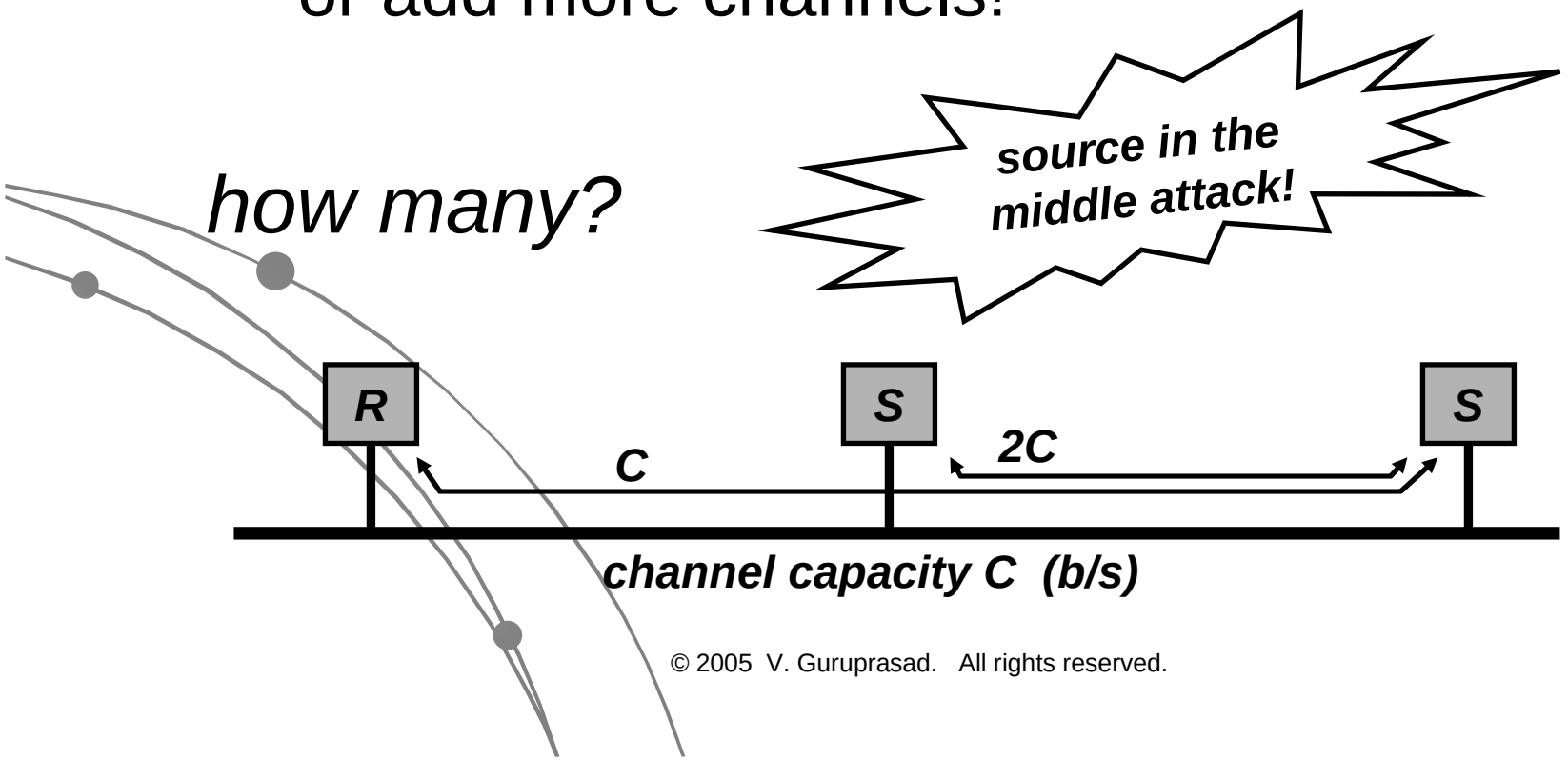
# *distance = new dimension*

*reuse full capacity for each source*

avoid partitioning by time, frequency, code

or add more channels!

*how many?*



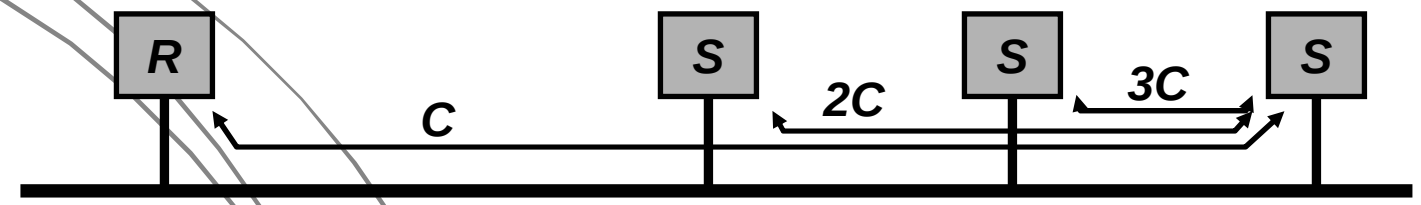
# *distance is a continuum*

*reuse full capacity for each source*

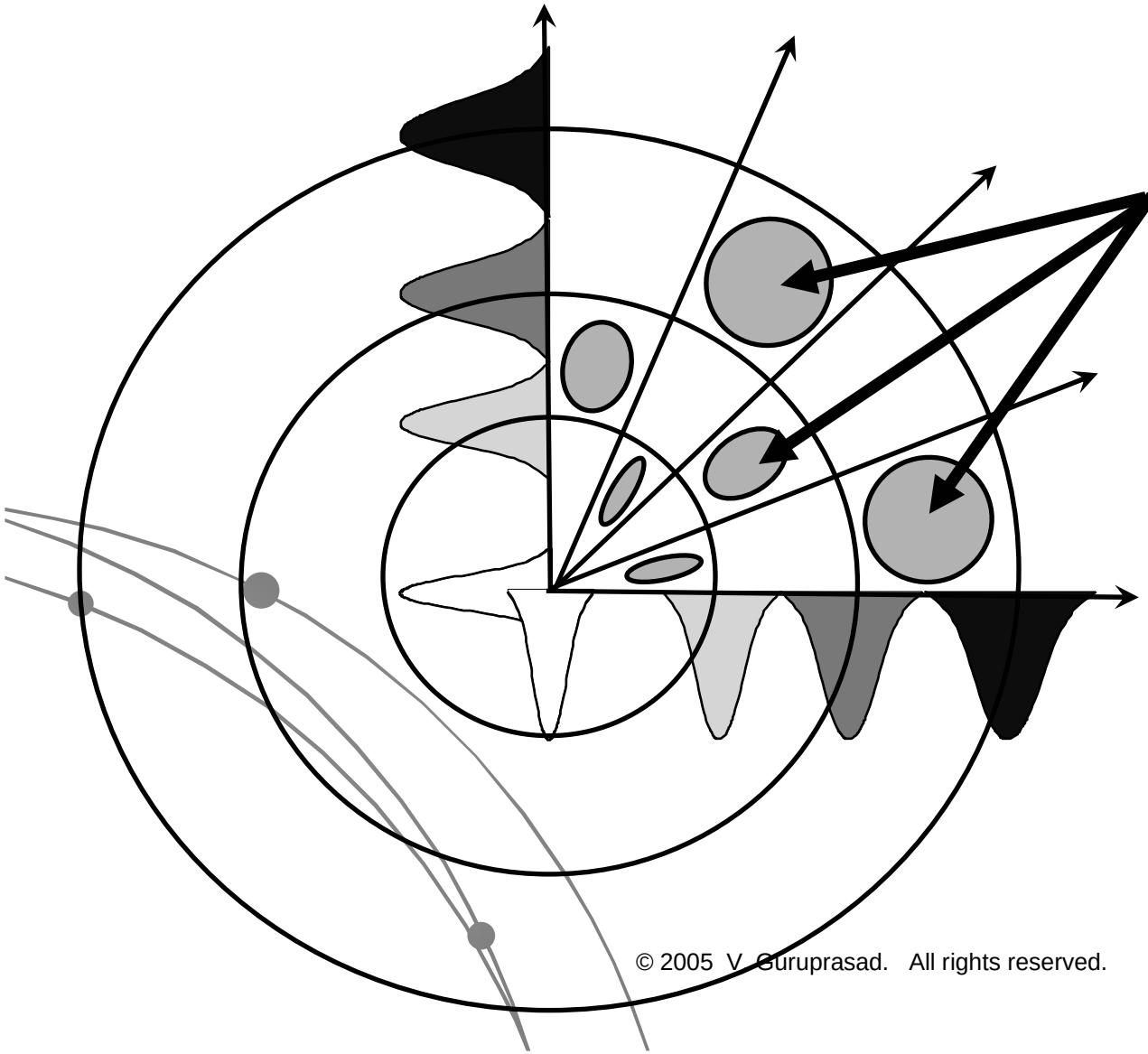
avoid partitioning by time, frequency, code

or just *keep adding* more channels!

*down to $\lambda_{max}$ ~ Rayleigh limit*



# *with angle, real SDM*



*fundamental cells using “DDM filters”*

~~***spread spectrum coding***~~

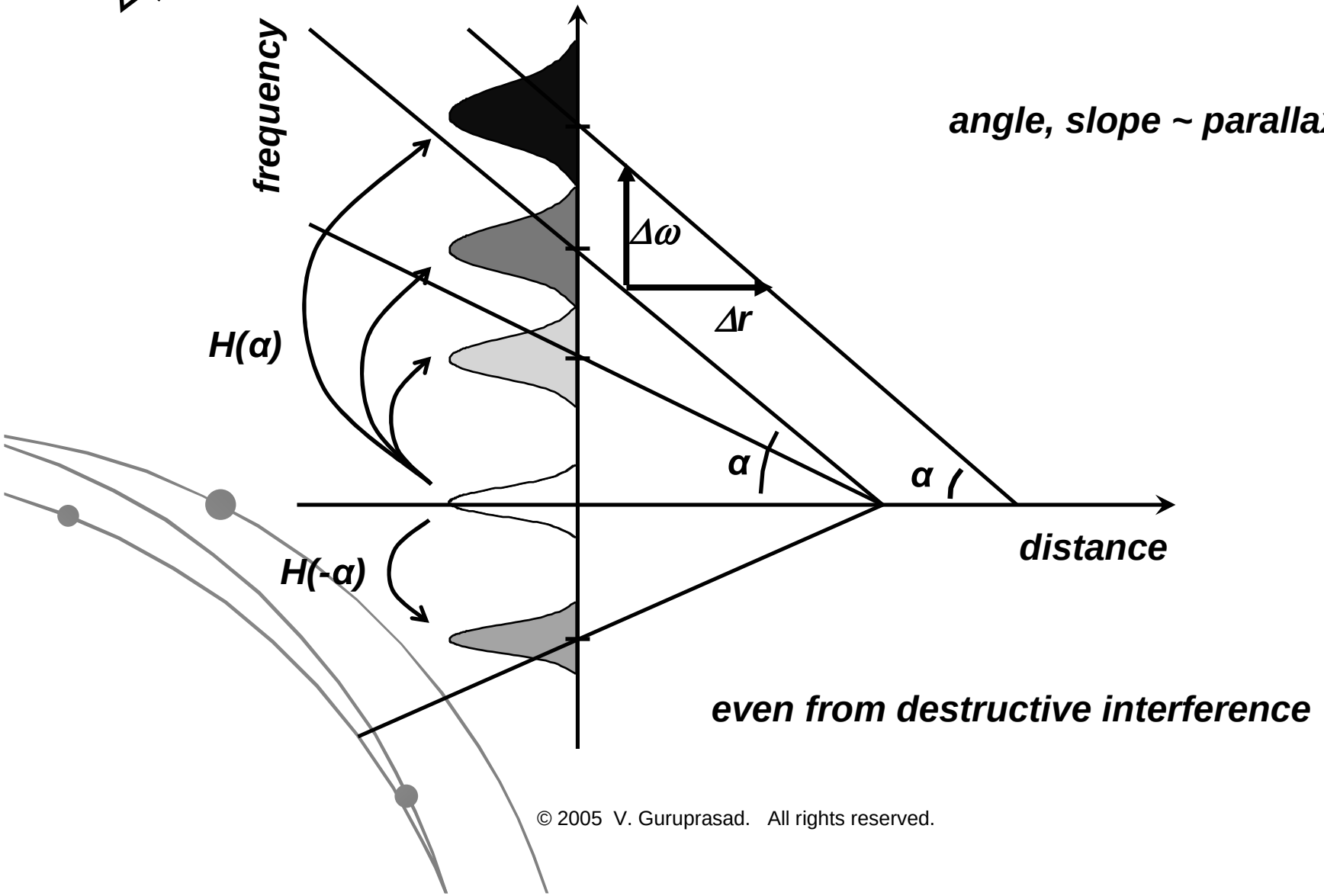
~~***modulation***~~

~~***time-slicing***~~

~~***polarization***~~

goal

# *"Hubble separation"*

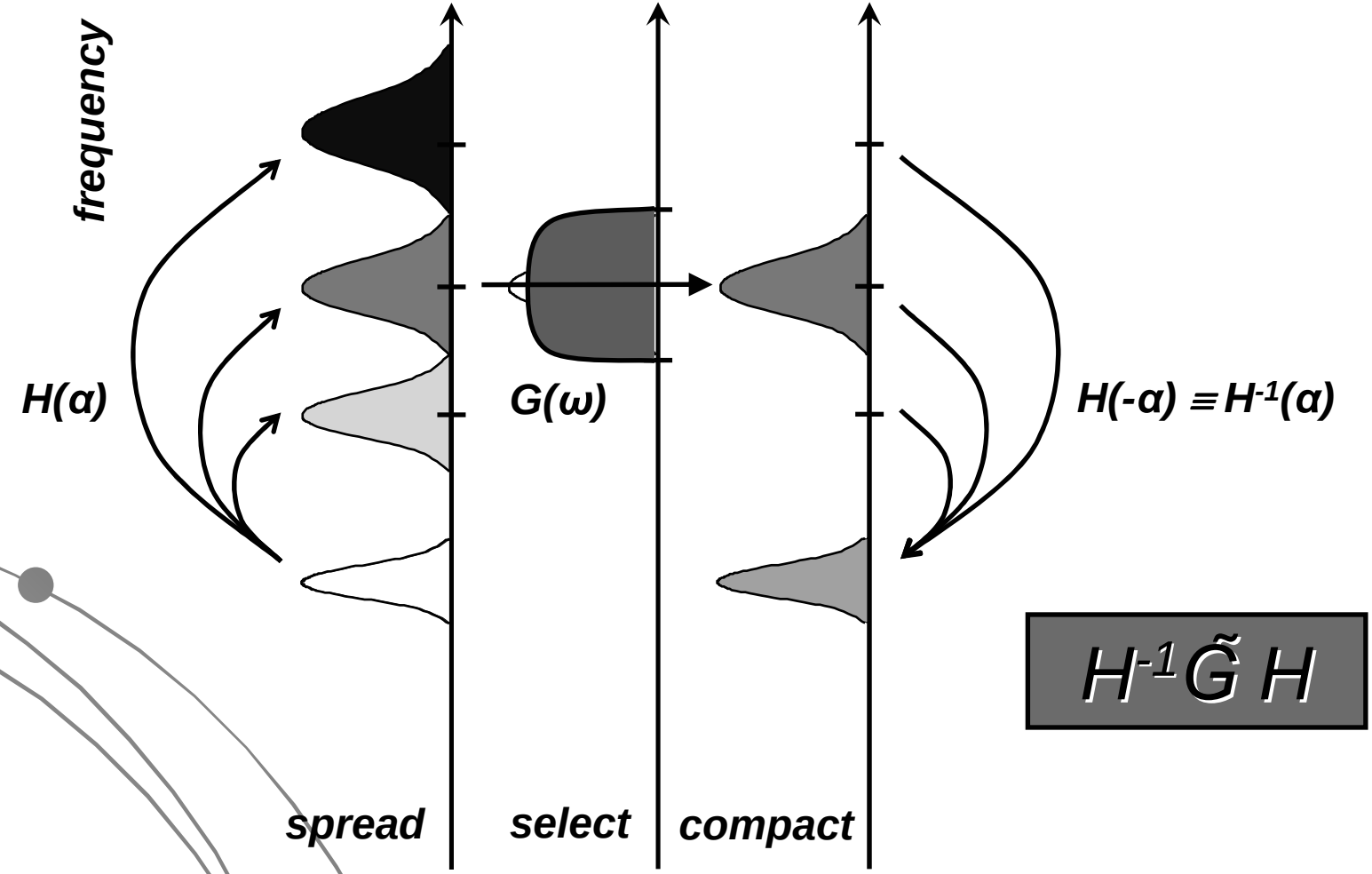



***angle, slope ~ parallax***

***even from destructive interference***

goal

# basic "DDM filter"




$H^{-1}\tilde{G}\,H$

# *cosmology is for dreamers*

cosmic $\alpha_0$ too small *and* non linear

$\approx 10^{-18}\ s^{-1}$ for the most distant galaxies

$\approx 10^{-41}\ s^{-1}$ at 1 AU ~ earth's orbit

$= 0$ at $r = 0$ – *Einstein-deSitter*

*no inverse for* $H^{-1}$

need larger, *receiver-controlled α*

# *a terrestrial occurrence*

*is mandated by solid state physics*

*gravitational compressive stress + tidal action*

*plasticity of all solids* *~ telescopes, clocks*

low stress limit creep rate ~ dislocation work function

$$\exp[\, k_B * 1\text{eV} / 300\text{K} \,] \sim O(10^{-18})\ \text{s}^{-1}$$

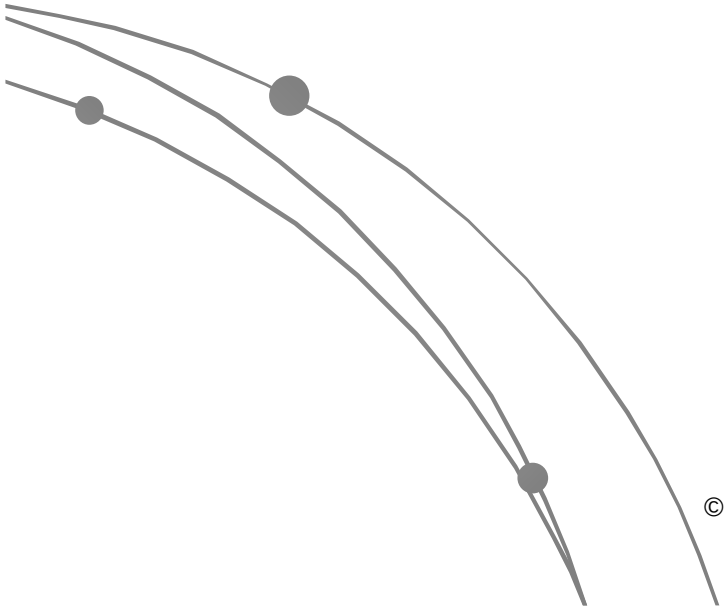
*extremely slow, weak*

half-life ~ age of solar system, universe

# *but exactly accounts for*

Hubble “flow” and acceleration (*no dark energy*)

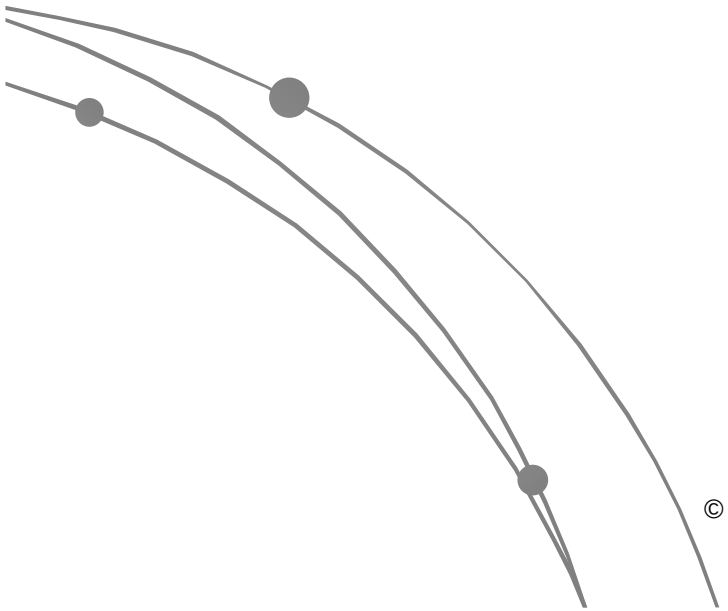
$10^{-18}$ $s^{-1}$ ≈ 70 km/s per Mpc (mega parsec)



# *but exactly accounts for*

Hubble “flow” and acceleration (*no dark energy*)
NASA’s anomalous “accelerations” Pioneer 10/11, Galileo

in *all six deep space missions equipped for precision ranging*



# *but exactly accounts for*

| | |
|---|---|
| Hubble “flow” and acceleration | (*no dark energy*) |
| NASA’s anomalous “accelerations” | Pioneer 10/11, Galileo |
| 5× mismatch tidal coefficients | lab. & space (since ’70s) |
| past expansion of Earth puzzle | geology + paleontology ( ‘60s) |

[ Kurt Lambeck (1977), Paul Wesson (MS thesis, 1973) ]

# *better fit than any prior theory*

| | |
|---|---|
| Hubble “flow” and acceleration | *large scale, 15 Gy ≈ $10^{17}$ m* |
| NASA’s anomalous “accelerations” | *solar system, 1-40 AU ≈ $10^{12}$m* |
| 5× mismatch tidal coefficients | *lunar scale, ≈ 3.8 ×$10^{8}$ m* |
| past expansion of Earth puzzle | *plate tectonics ~ $10^{7}$ m* |

*perfect empirical fit on every measured scale*

(relativistic cosmology broken at both extremes!)

resolves long pending mysteries – but purely mundane

# *about cosmic microwaves…*

*astrophysics has MORE basic problems*

diffraction analysis limited to Fresnel

*also in quantum field theory*

questions current ideas of

CMB, dark matter, neutrinos

(recent – Jan 2005 – CMB data in favour)

# *earthly motivation*

the consistency must mean something … mundane!

some prior work on relativity

- formalism *ignores calibration referents*
- relativity *postulates completely derivable* from referents

usual premise of spectrometric stationarity

- central to all of quantum physics
- even in wavelet analysis, etc.

- but *no prior analysis of the distortion* → →

# *“new mundane physics”*

*directly from wave equation*

fundamental, very general

like Doppler, but *receiver-controlled*

*finally addresses*

spectrometric non-stationarity

ties empirical data together

# *remainder of this talk*

*physical concept & principle*

*“initial hype” results*

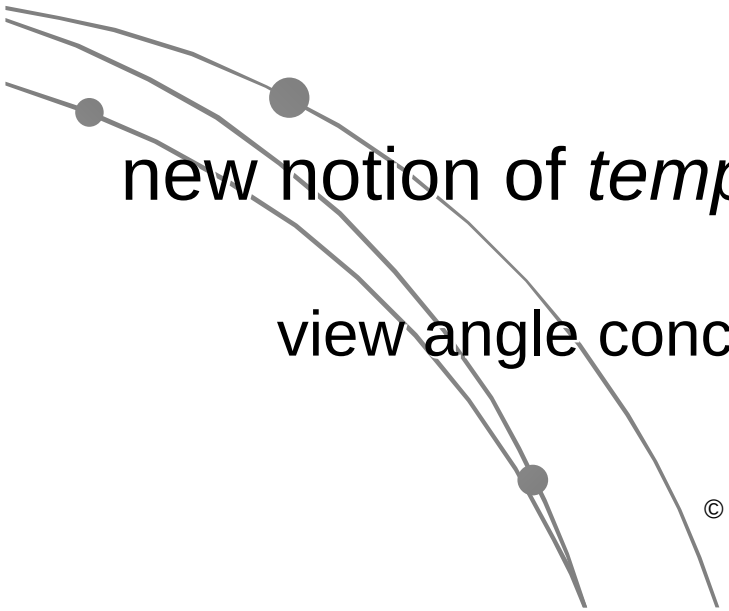
*prototype status & a couple of lessons*

# *distance information*

ordinary (spatial) parallax

view changes with angle ~ *spatial frequency*

information in wavefront curvature



new notion of *temporal parallax*

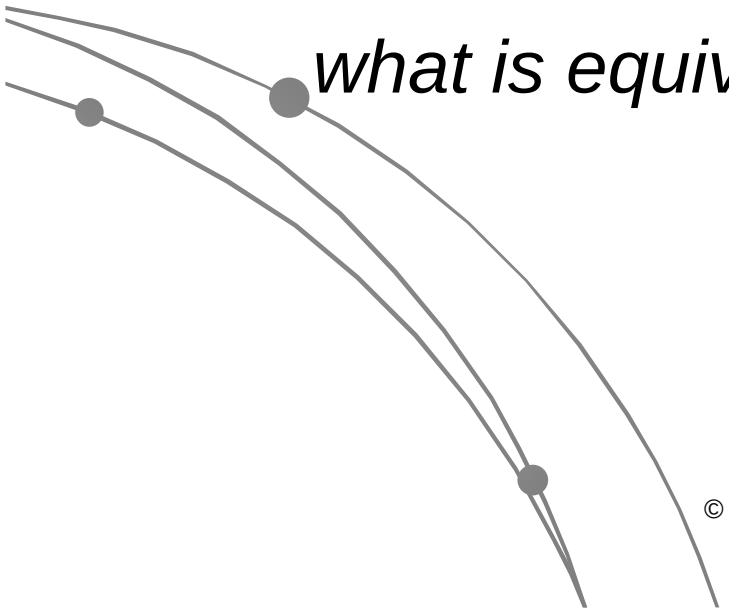
view angle concerns *temporal frequency*

# *semantics*

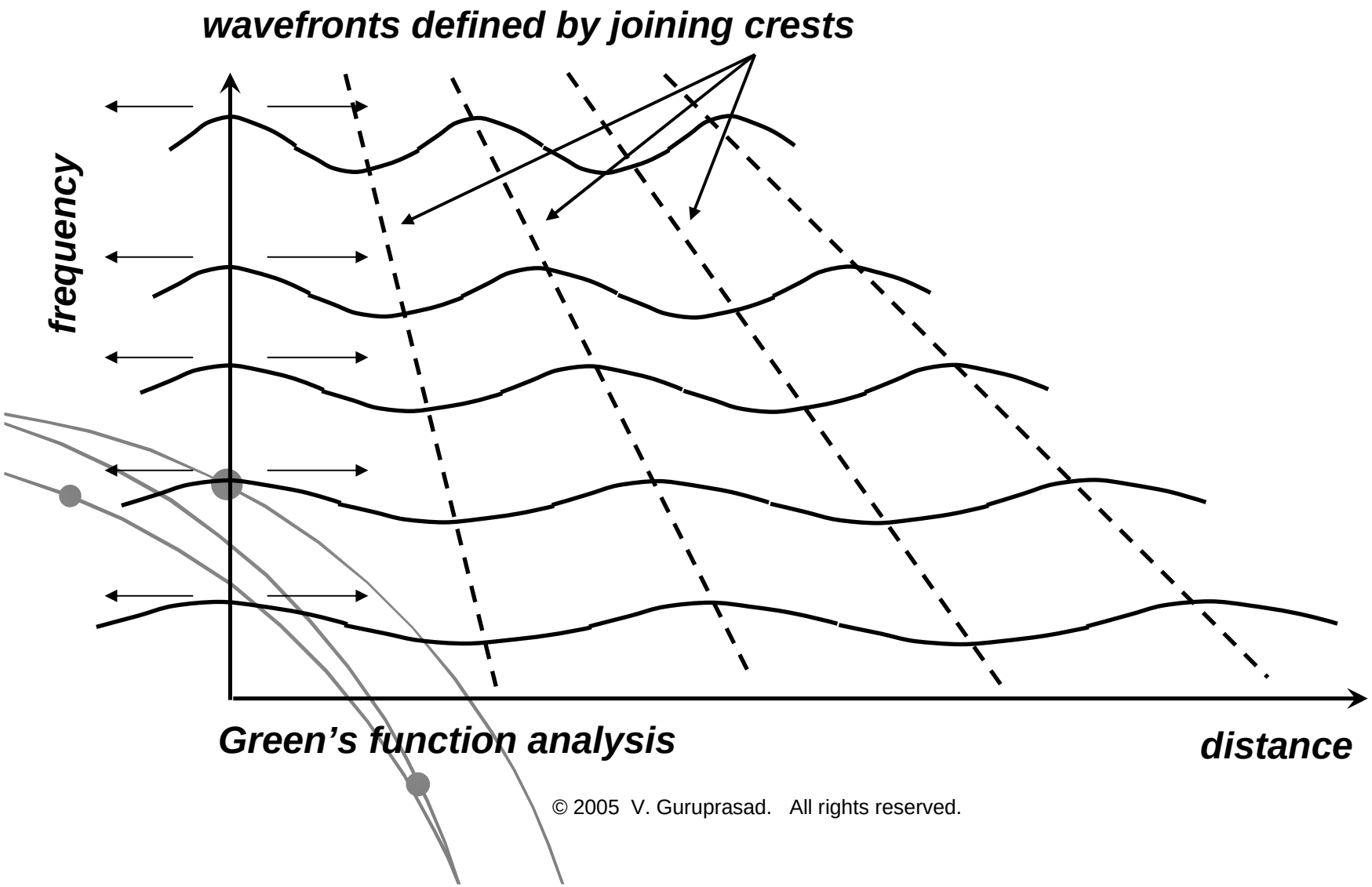
in *temporal frequency* domain,

*where is the wavefront curvature ?*

*what is equivalent to moving one's head ?*



# *temporal curvature of wavefronts*



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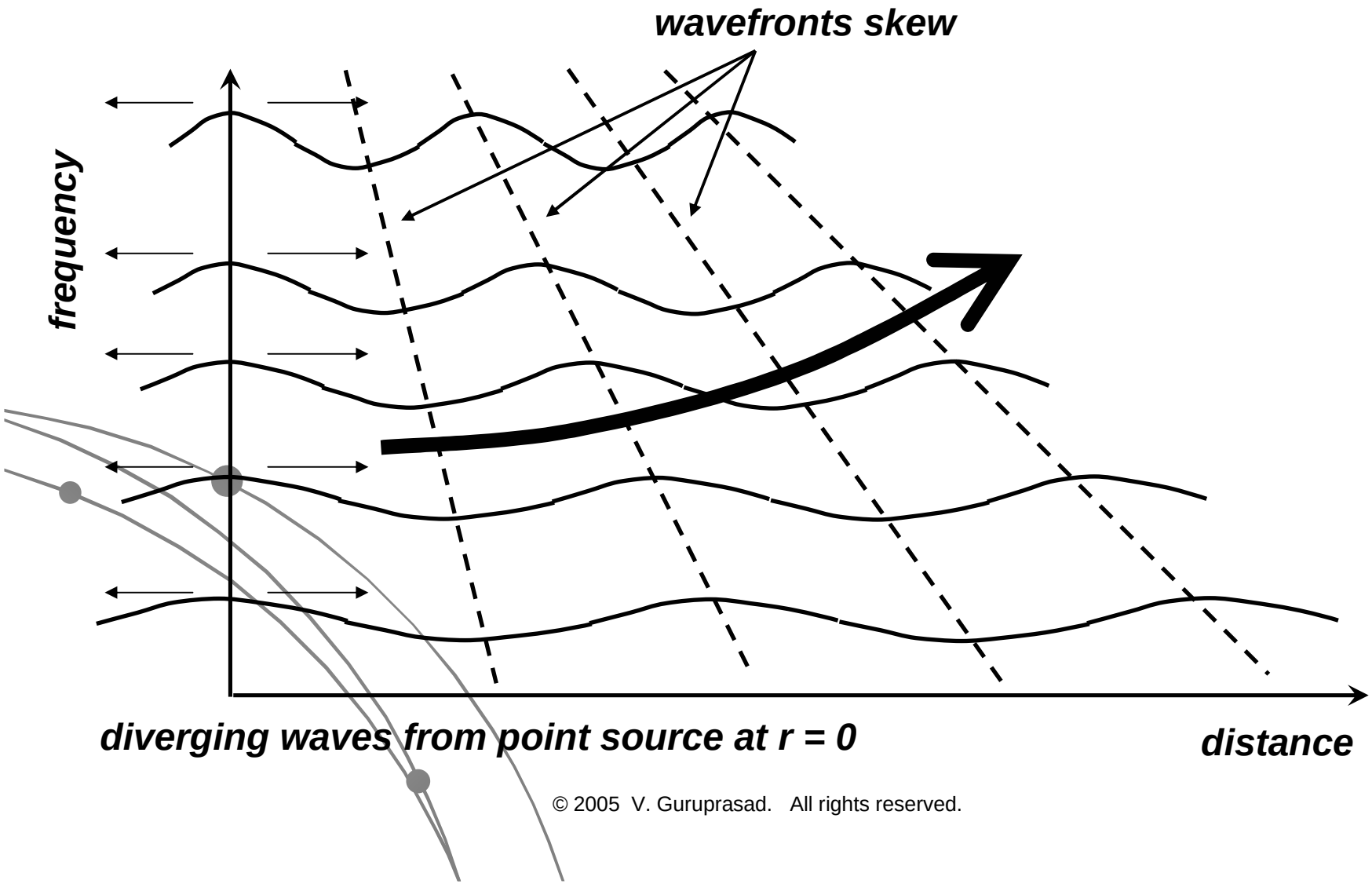


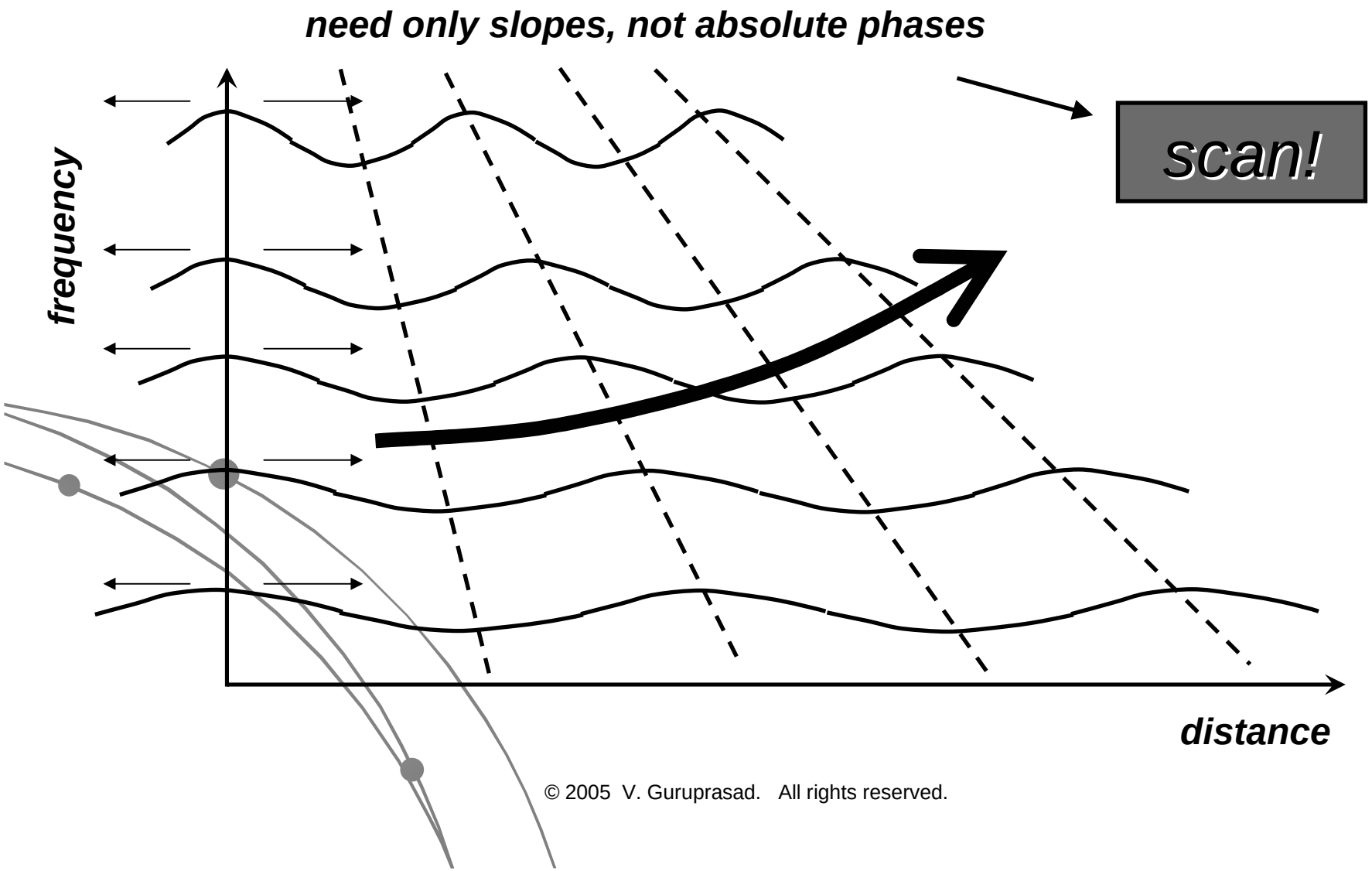
# *measuring phase*

*coherent reference ordinarily needed*

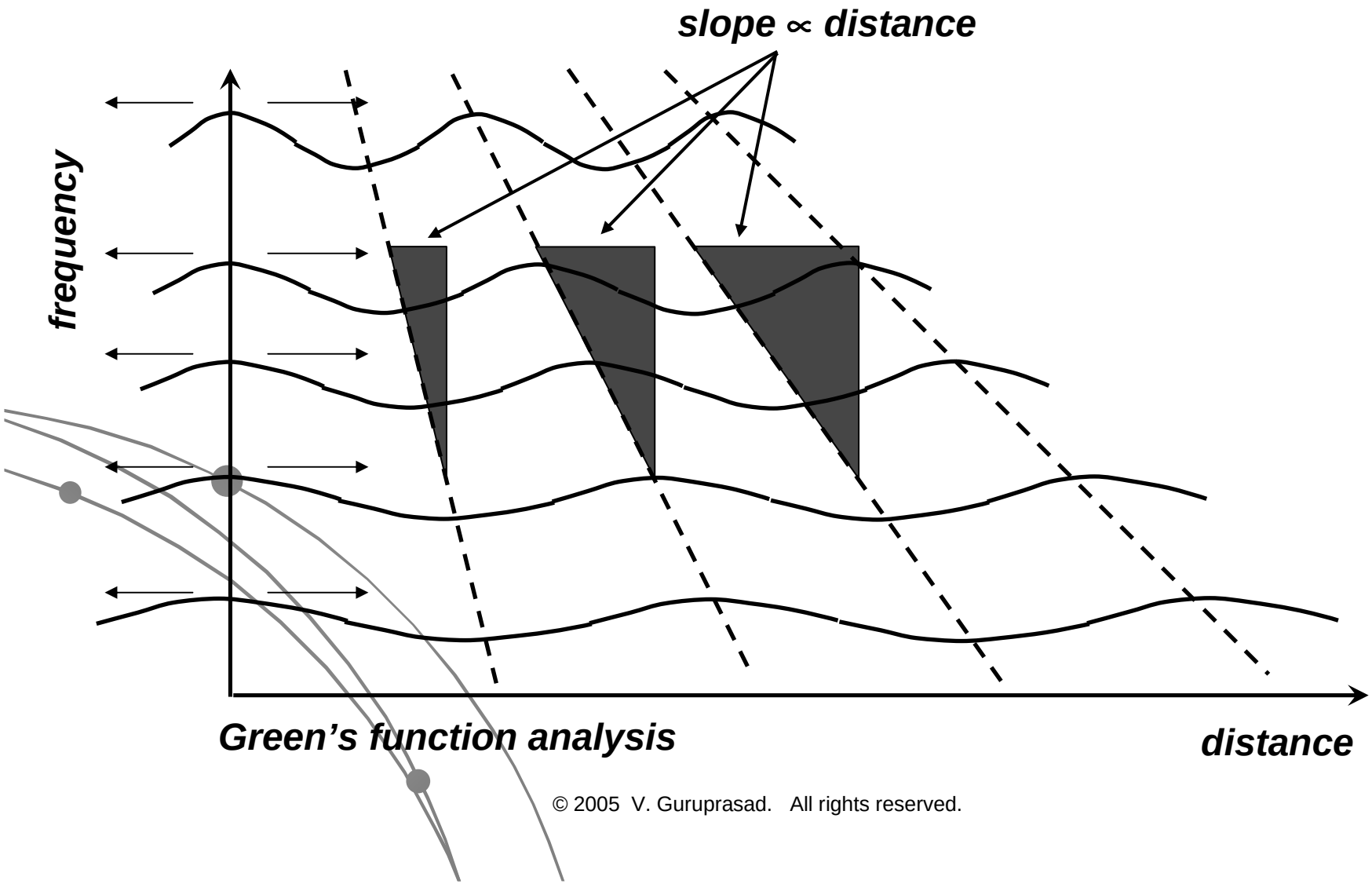
| | |
|---|---|
| 2 levels | digital holography |
| 1 frequency | holography & SAR |

*must be independent of signal phase*

# *measuring temporal curvature*



# *measuring temporal curvature*



# *so the trick is*

*measure against RATE of dial turning*

*transforms phase slope → frequency shift*

$$\Delta\omega = d\varphi / dt$$

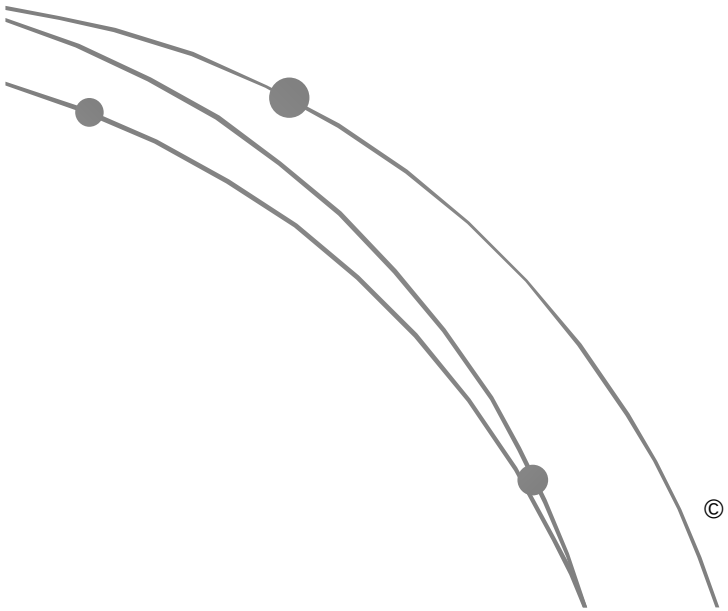
*dial turn rate ~ temporal parallax*

*temporal equivalent of viewing angle*

# *wave theoretic analysis*

*from wave equation*

total phase $\varphi = k\, r - \omega\, t$



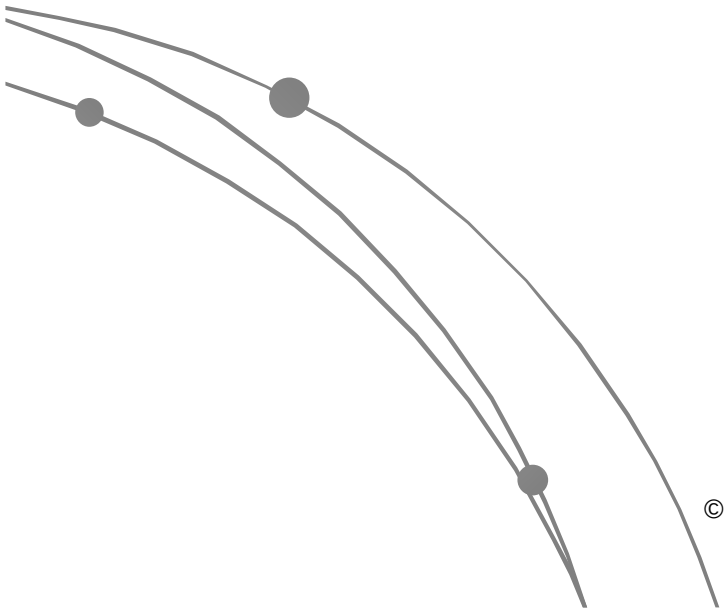
# *wave theoretic analysis*

*from wave equation*

total phase $\varphi = k\, r - \omega\, t$

$\rightarrow$ $\Delta\varphi = k\,.\,\Delta r + \Delta k\,.\,r - \Delta\,(\omega\, t)$

*last term (time part) = signal*



# *wave theoretic analysis*

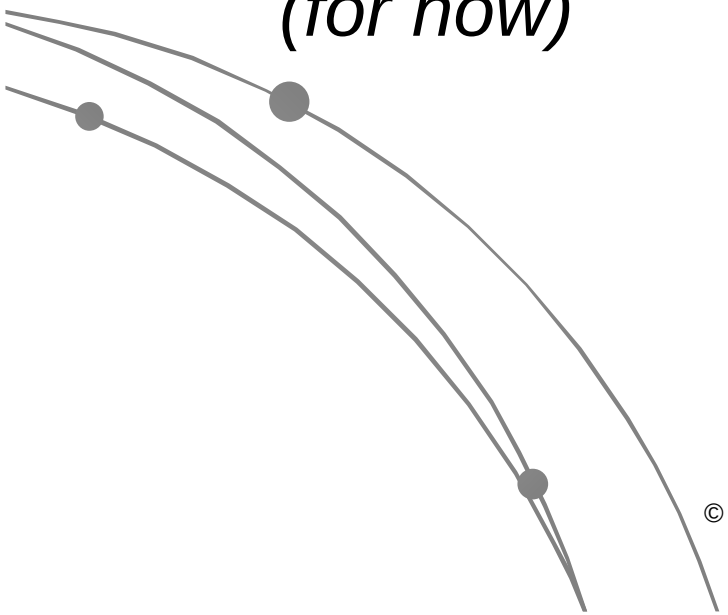
*from wave equation*

total phase $\varphi = k\, r - \omega\, t$

$\Delta\varphi = k\, .\, \Delta r + \Delta k\, .\, r - \Delta(\omega\, t)$

ignore signal part $\Delta\varphi = k\, .\, \Delta r + \Delta k\, .\, r$

*(for now)*



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$\Delta\varphi = k \,.\, \Delta r + \Delta k \,.\, r - \Delta(\omega\, t)$

$\Delta\varphi = k \,.\, \Delta r + \Delta k \,.\, r$

---

*space part 1st term* $\Delta\varphi = k \,.\, \Delta r$

fixed frequency holography, SAR

# *wave theoretic analysis*

*from wave equation*

total phase $\varphi = k\, r - \omega\, t$

$\Delta\varphi = k\, \Delta r + \Delta k\, .\, r - \Delta(\omega\, t)$

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*space part 1st term* $\Delta\varphi = k\, \Delta r$

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# *wave theoretic analysis*

*from wave equation*

total phase $\varphi = k\, r - \omega\, t$

$\Delta\varphi = k\, \Delta r + \Delta k\, .\, r - \Delta(\omega\, t)$

$\Delta\varphi = k\, \Delta r + \Delta k\, .\, r$

---

*space part 2nd term* $\Delta\varphi = \Delta k\, .\, r$

fixed distance ~ *source*

# *wave theoretic analysis*

*from wave equation*

total phase

$$\varphi = k\, r - \omega\, t$$

$$\Delta\varphi = k\, \Delta r + \Delta k\, .\, r - \Delta(\omega\, t)$$

$$\Delta\varphi = k\, \Delta r + \Delta k\, .\, r$$

---

*no more terms left*

→ fundamental in terms of phase information

# *resulting wave effect*

discrete $\Delta k$ pulse radar → *limited by aliasing*

*continuous scanning* $\Delta\omega = d\varphi / dt = r \,.\, dk / dt$

*Doppler-like ~ proportional*

$z = \Delta\omega / \omega = \beta\, r / c$ *where* $\beta = k^{-1}(dk / dt)$

*measured "z" in astrophysics –* well beyond **7**

# *realization*

| *Receiver type* | *time-varying* |
| --- | --- |
| *diffractive optics* | grating intervals |
| *resonant or tuned systems* | tuning element |
| *digital signal processing* | sampling interval |

# *grating approach*

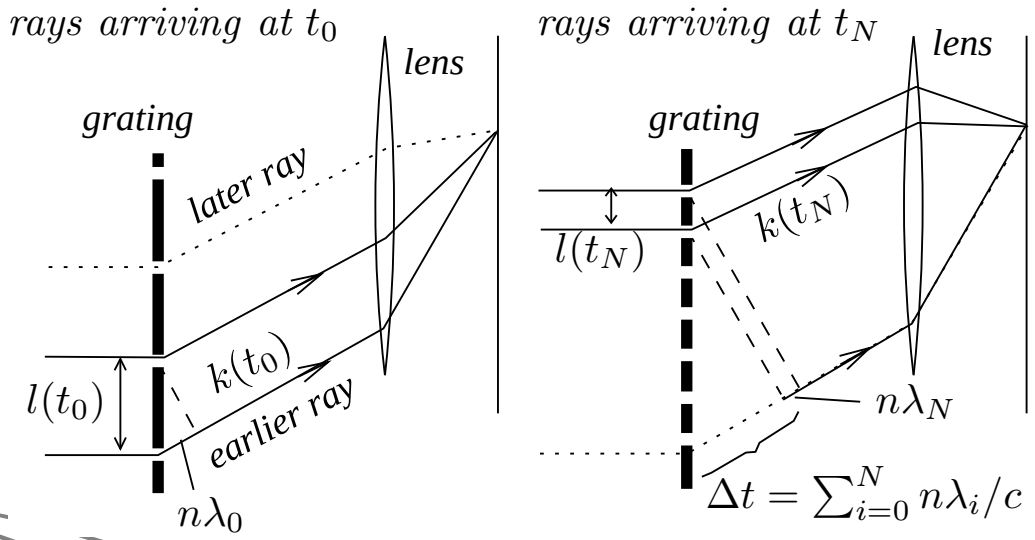
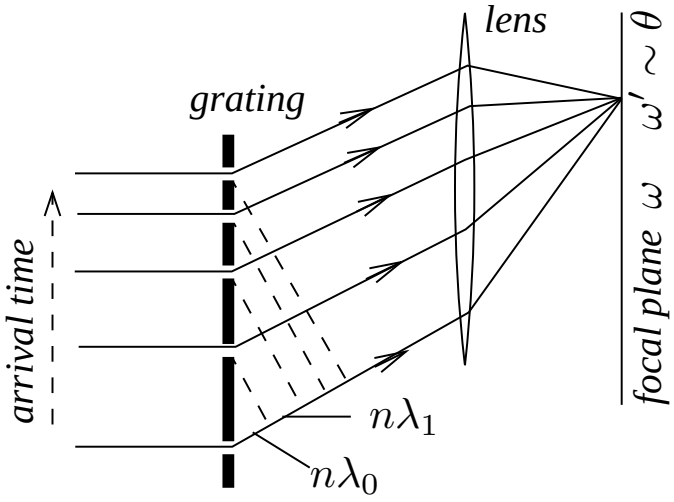



***Fig. 3 of paper***

***Fig. 4 of paper***



# sampling approach

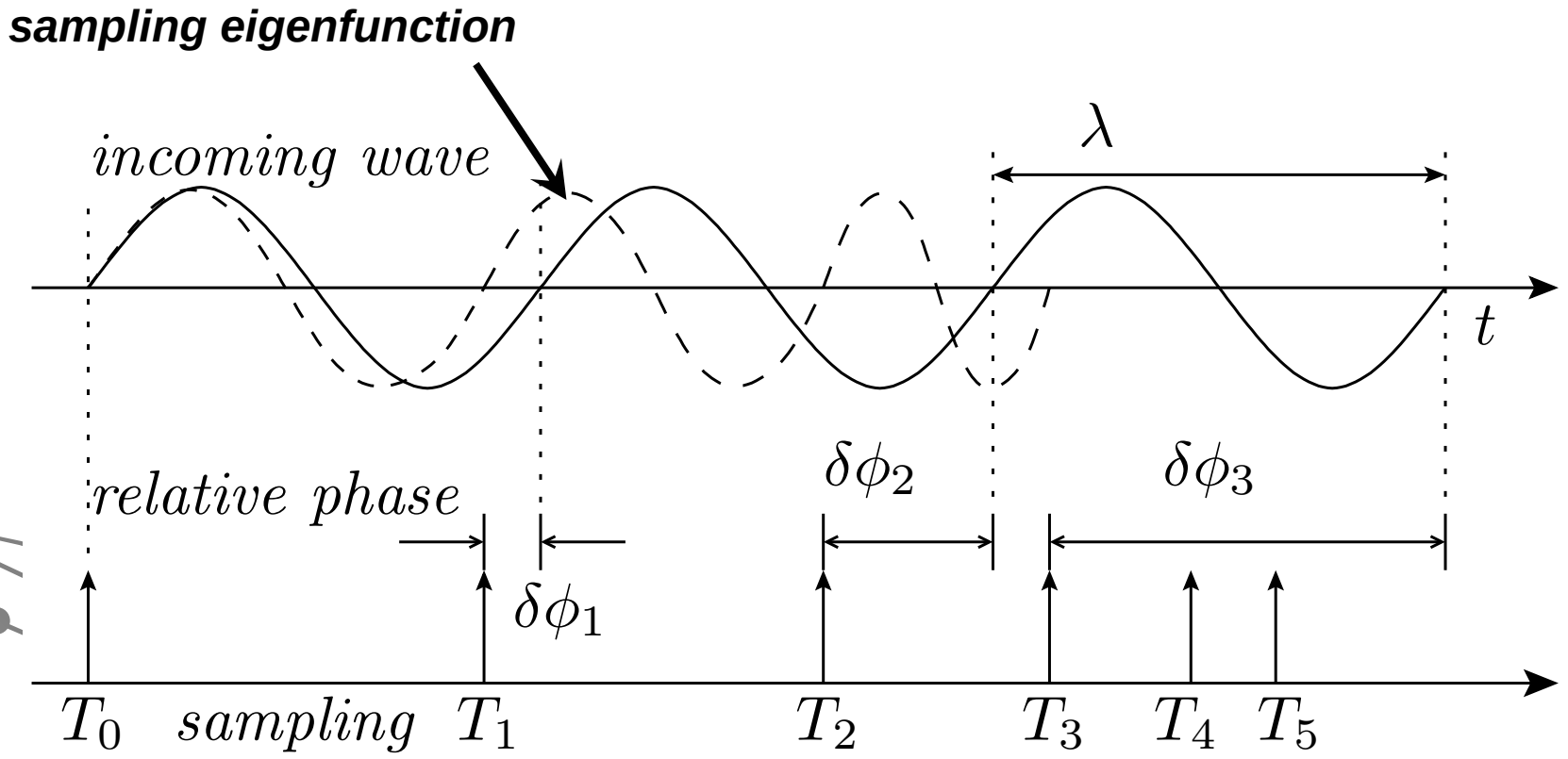
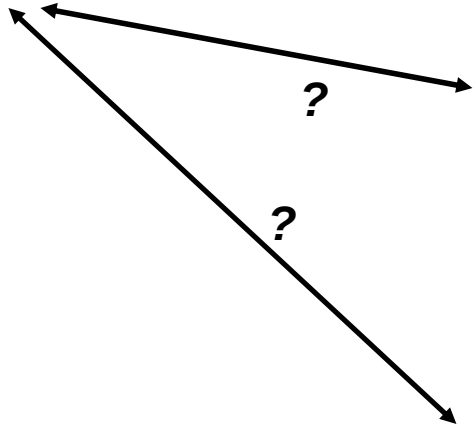



***Fig. 5 of paper***

# *time-varying eigenfunctions*

$$\exp[\, kr \pm \omega t / a(t) \,] \equiv \exp[\, a(r)\, kr \pm \omega t \,]$$




$$\alpha = \beta / c$$

$$\beta = k^{-1}(dk / dt)$$

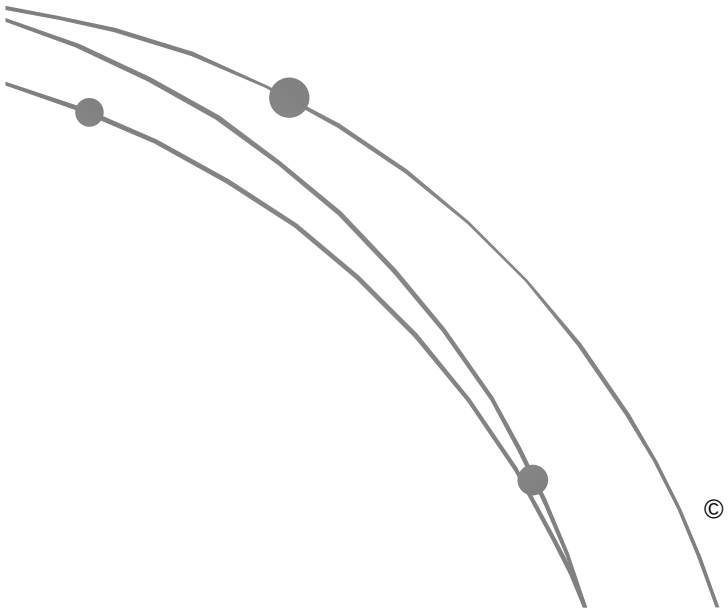
# *time-varying eigenfunctions*

exp[ $kr \pm \omega t / a(t)$ ] ≡ exp[ $a(r)\, kr \pm \omega t$ ]

L. Parker's 1966 PhD thesis in cosmology

*a ~ relativistic scale factor*

$$\beta = a^{-1}(da / dt)$$



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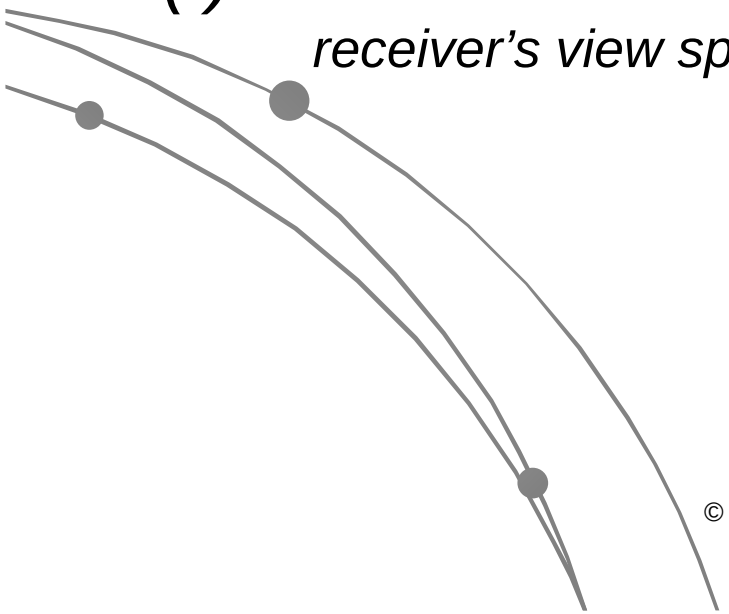
*a(t) ~ receiver's* scale of frequencies

*receiver's view spatially distorted as* a(r)



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*a ~ relativistic scale factor*

$$\beta = a^{-1}(da / dt)$$

*a(t) ~ receiver's* scale of frequencies

*receiver's view spatially distorted as* a(r)

*receiver's decomposition is mathematical*

*fundamental* : not a postulate or result of physics

*a(r) ≡ a(t)* from the wave equation

# *principle of receiver decomposition*

*choice belongs to receiver*

receiver sums successive λ's

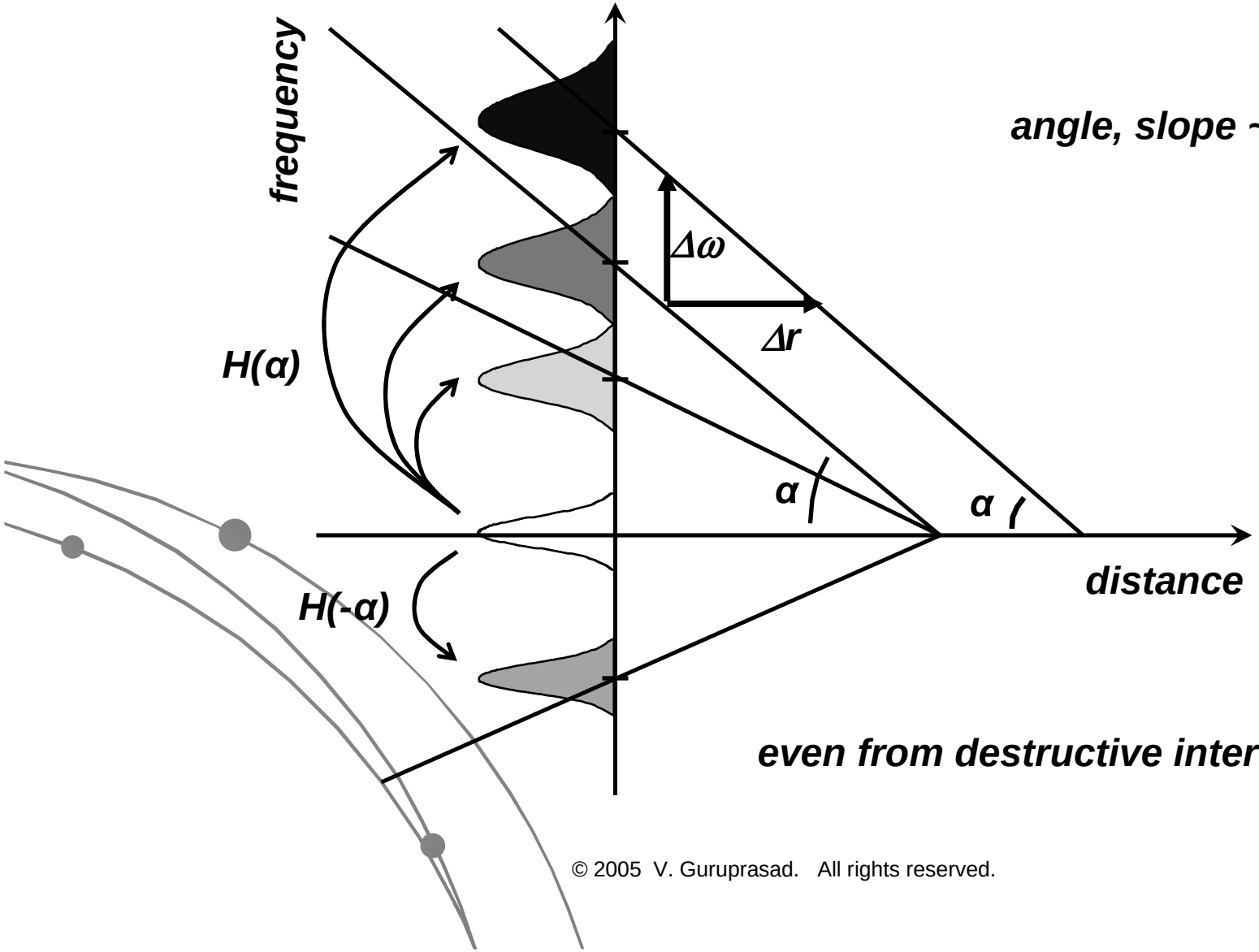
"Parker" if λ's vary

*requires real signals –* $\Delta\omega \neq 0$

like the natural occurrence…

*fundamentally changes photon theories*

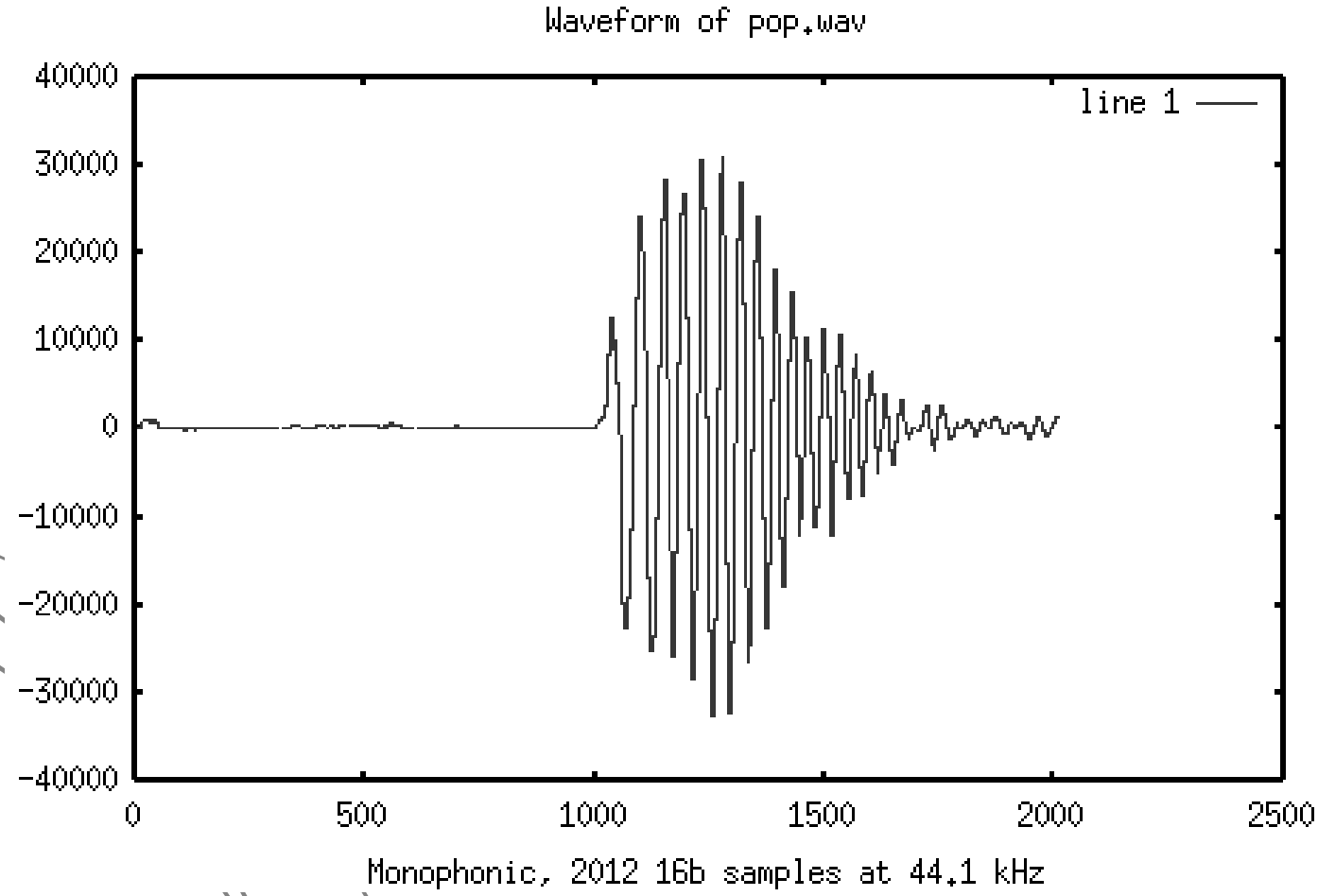
# *thus temporal parallax*



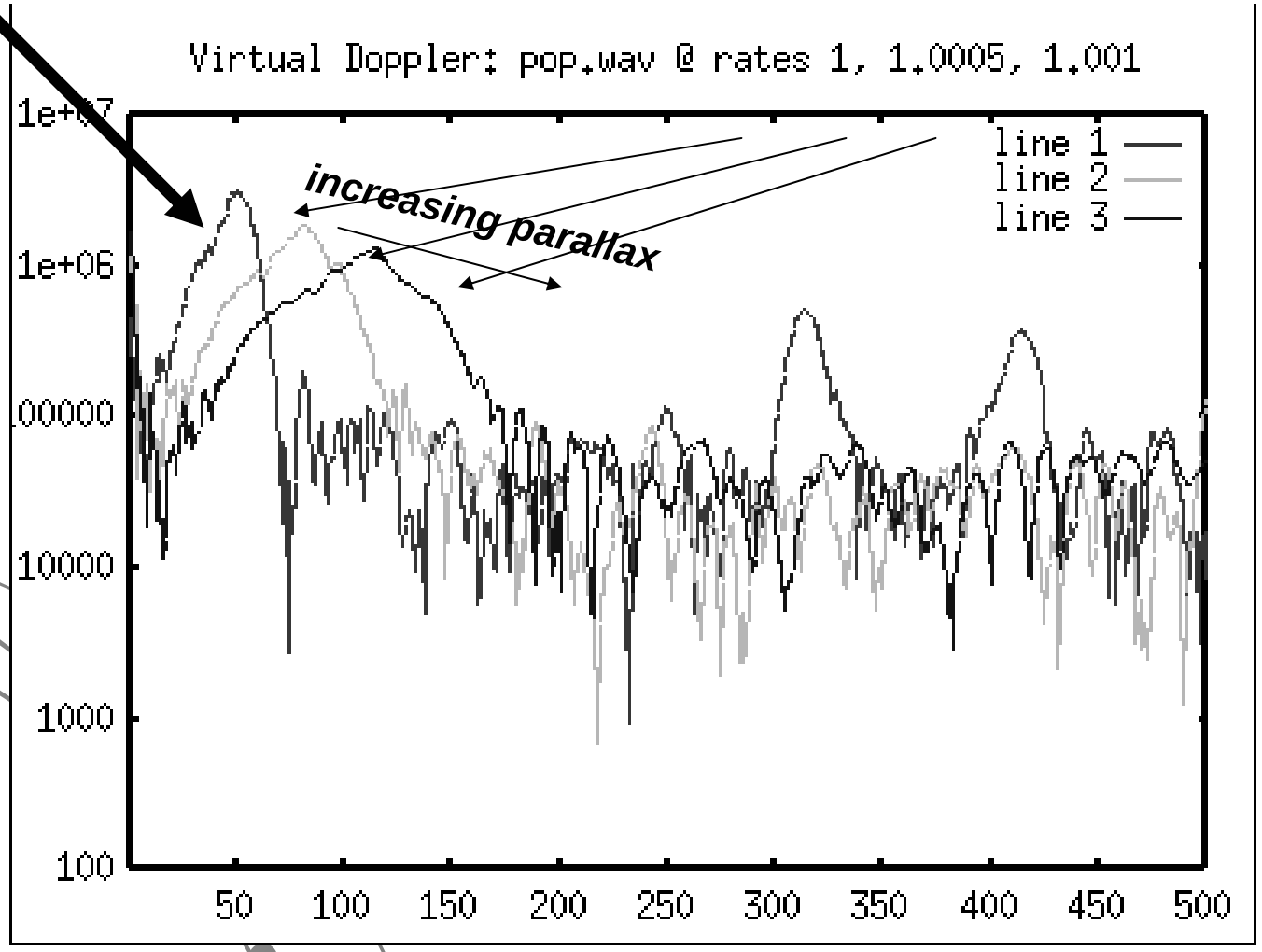

***angle, slope ~ parallax***

***even from destructive interference***

# *initial example (from paper)*



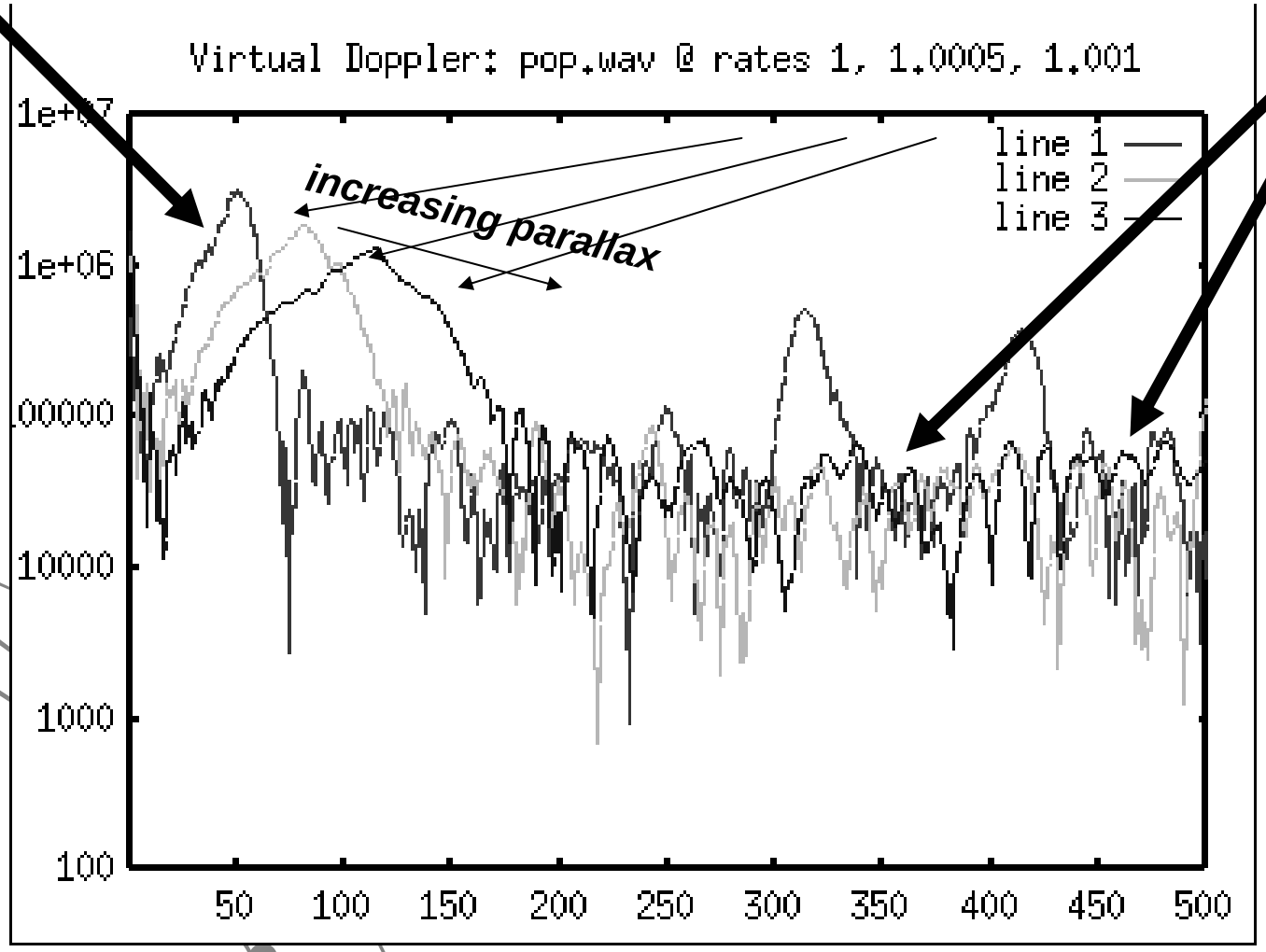
# its “Parker spectra”



# *its “Parker spectra”*

***original wave***

***interpolation loss***



# *java prototype*

## *simple design console*

test of “DDM filters” — $H^{-1}\tilde{G}\,H$ operators

Remez algorithm — filter design ($\tilde{G}$ )

test of assumptions

## *envisage easily portable*

to Software-Defined Radio, MAC layers

# *lessons from simulation*

*orthogonality ≠ Fourier*

applying *H* to generated sinusoids gives scarily bad results
*must simulate source with* $\Delta\omega > 0$ ("Parker" orthogonality)

*ω-scanning mixes with signal*

current area of work – should be easy to solve

*"textbook DSP" is deceptive*

may be necessary to use spatial spread ~ grating approach

*must* really really *try with* real *data*

other audio samples not so lucky ~ back to the drawing board!

# *known limits*

## *no fundamental limits*

the Big Bang corresponds to $z = \infty$

$\alpha > 0$

## *technology limits*

limits of sampling, DSP – e.g. simulation woes

must use RF – *IF separation will be poor*

phase distortions in antenna, processing

angular resolution of phased arrays

filtering limits – stop-band rejection (*G*)

# *conclusion – or beginning?*

*a new basic wave effect shown*

with commensurate broad implications

*must try with real data*

*unless totally mistaken…*