FAS010 - presentation/lecture

Astrophysical Turbulence

By Steve ~ From New Zealand - Not Australia!

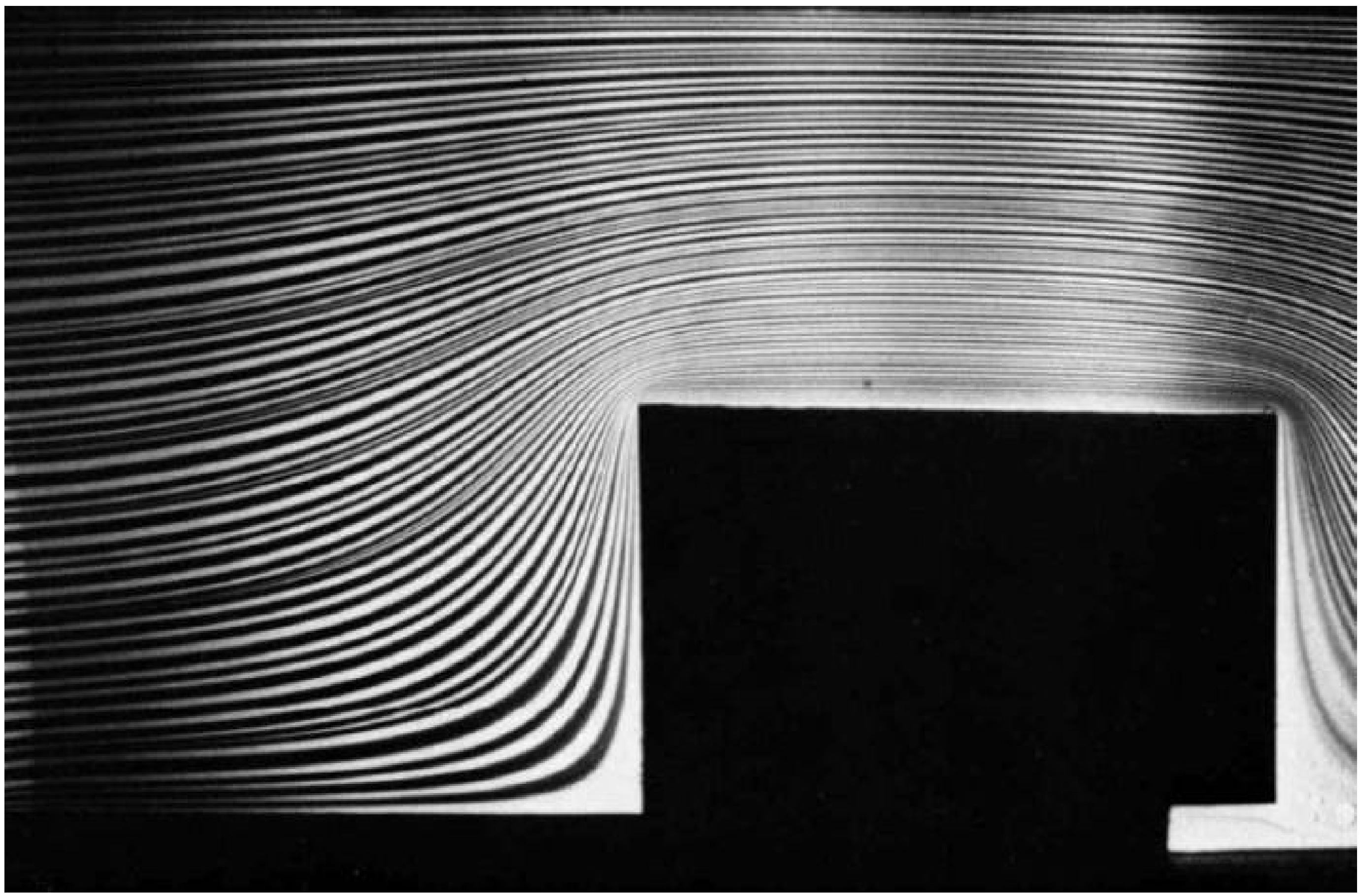
1. The characteristics of turbulence.

2. The structure of the ISM.

3. The relation and the implications.

1. Characteristics of turbulence

What is this "turbulence"?



1. Characteristics of turbulence

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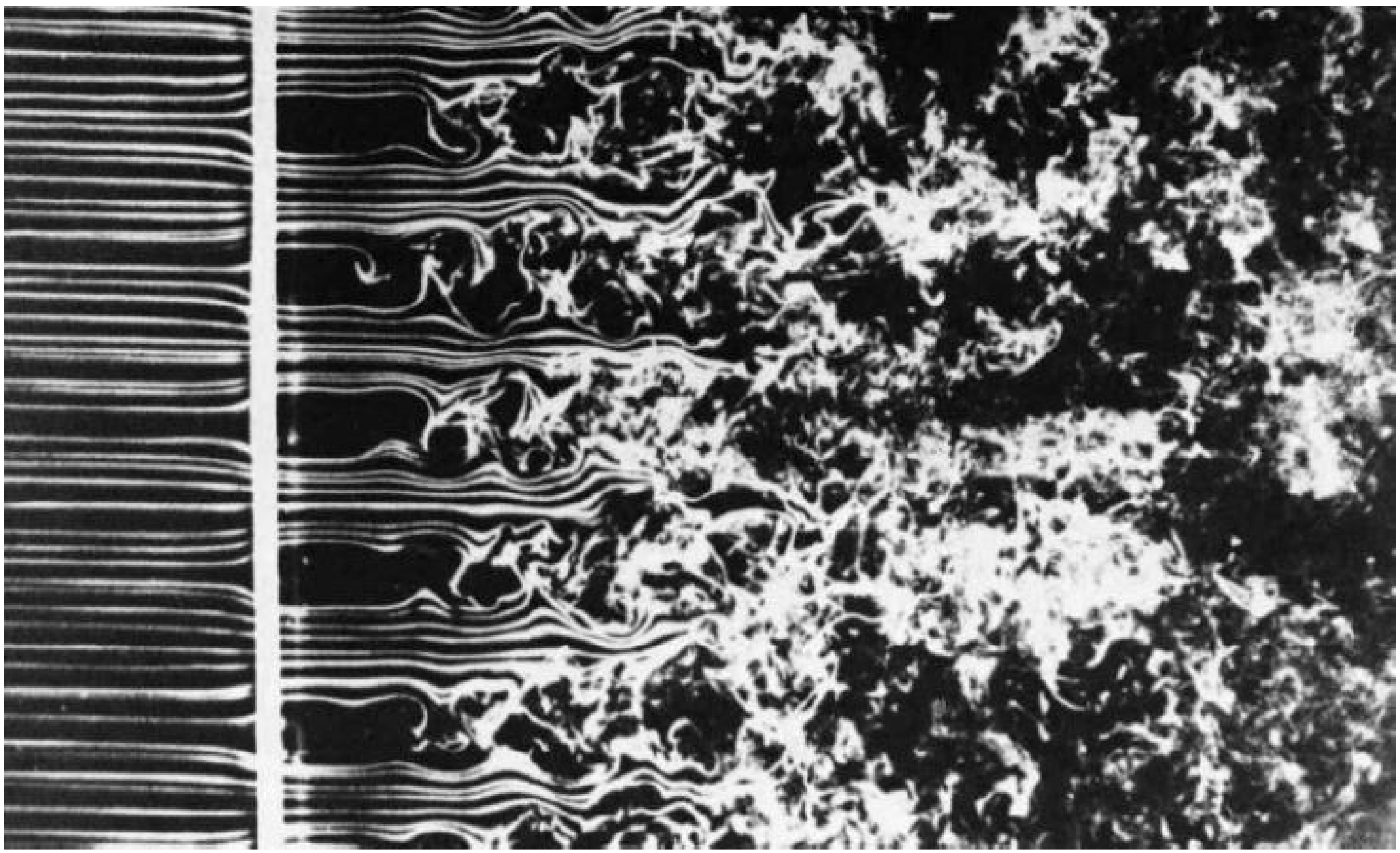


$$Re = \frac{u\ell}{\nu}$$

1. Characteristics of turbulence

3 dimensional structure

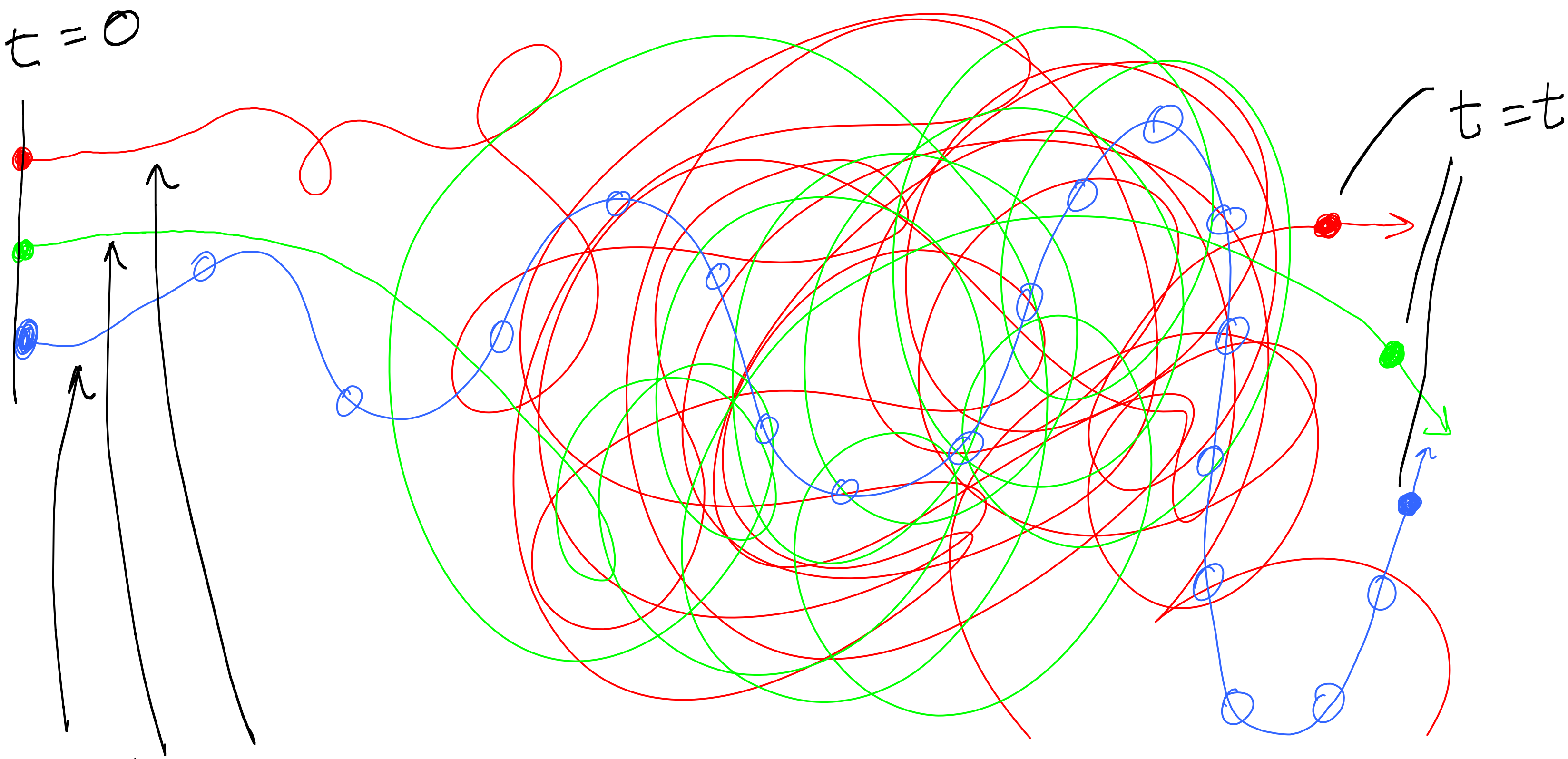
Chaotic

Self-similarity

↳ Scaling

1. Characteristics of turbulence

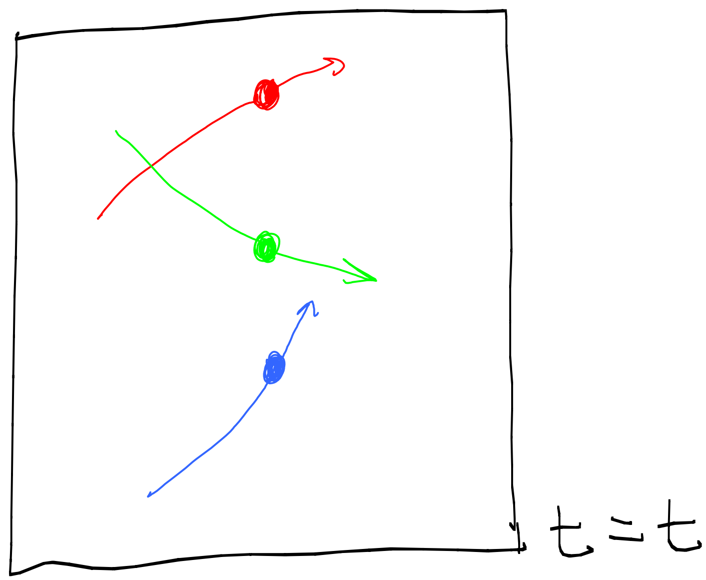
Example of a chaotic system



Motions governed by a differential equation!
(i.e. deterministic)

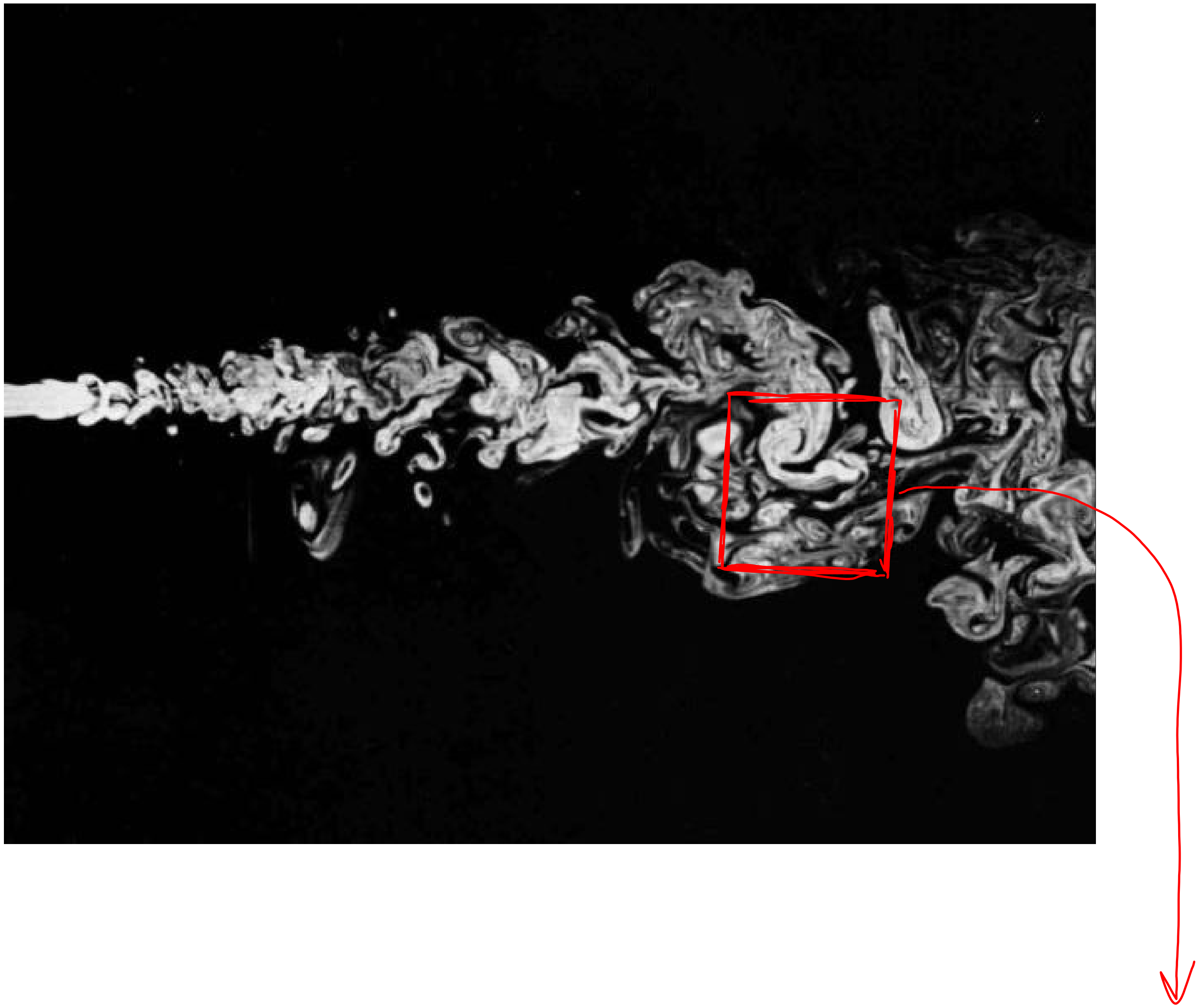
1. Characteristics of turbulence

Given the following state:

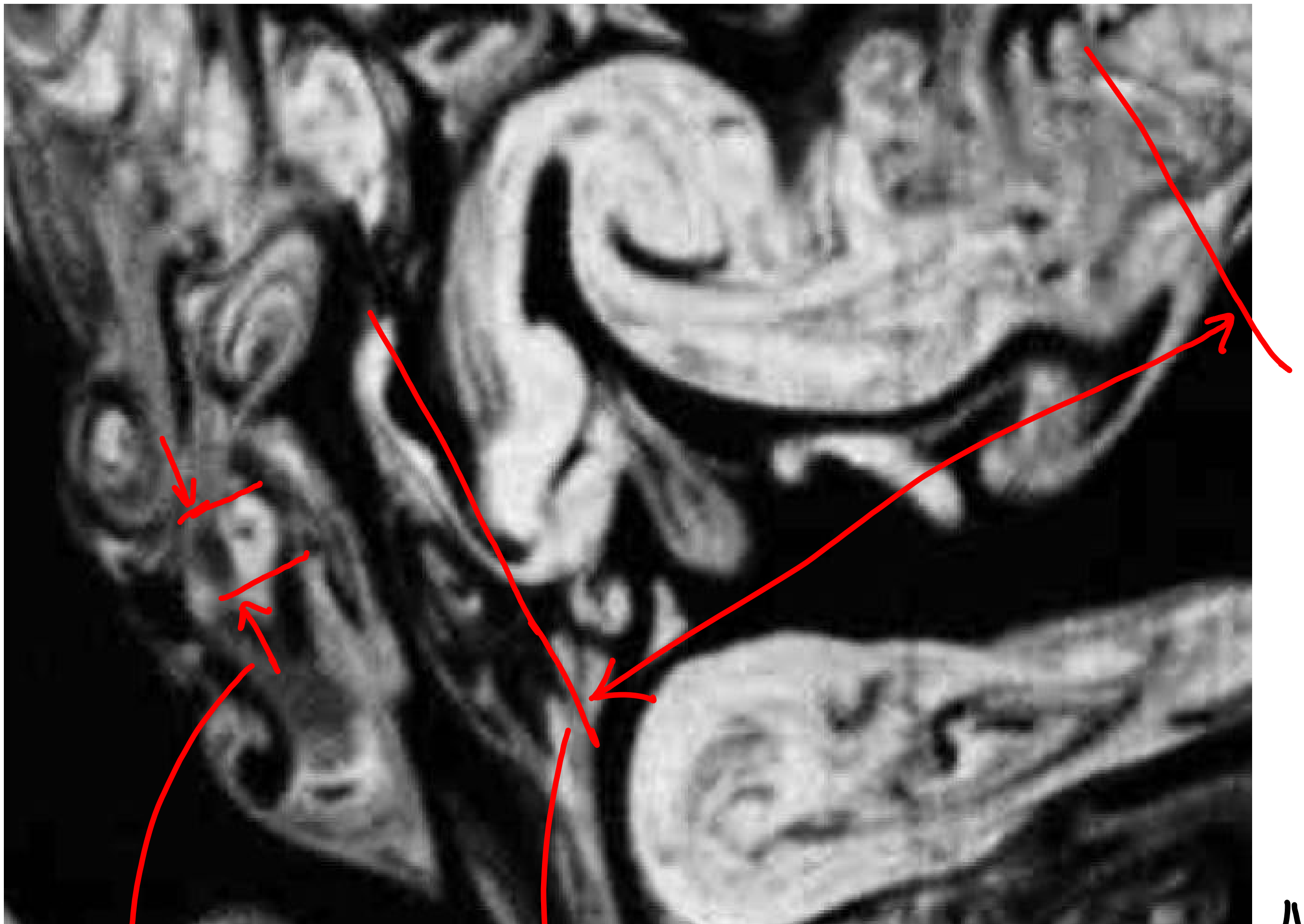


Could the previous map be recreated?

1. Characteristics of turbulence



1. Characteristics of turbulence



½ thumb

6 thumbs ~ An order of magnitude different

1. Characteristics of turbulence

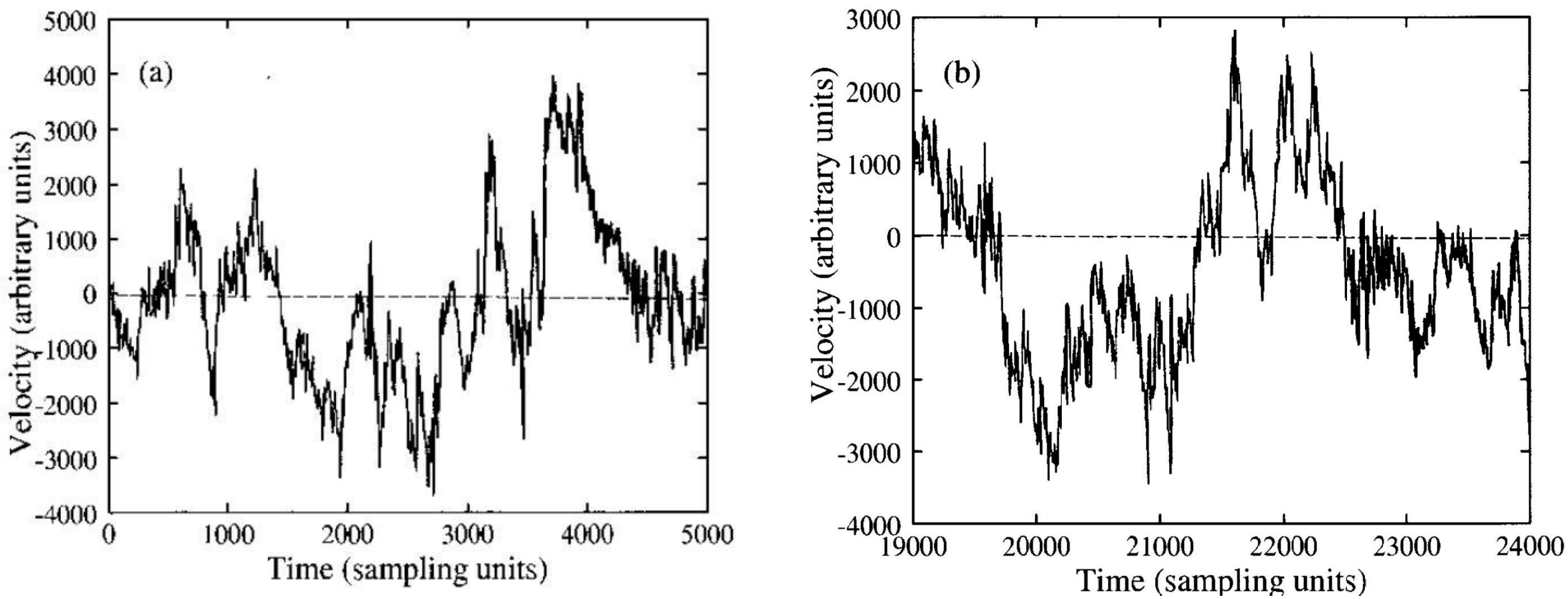
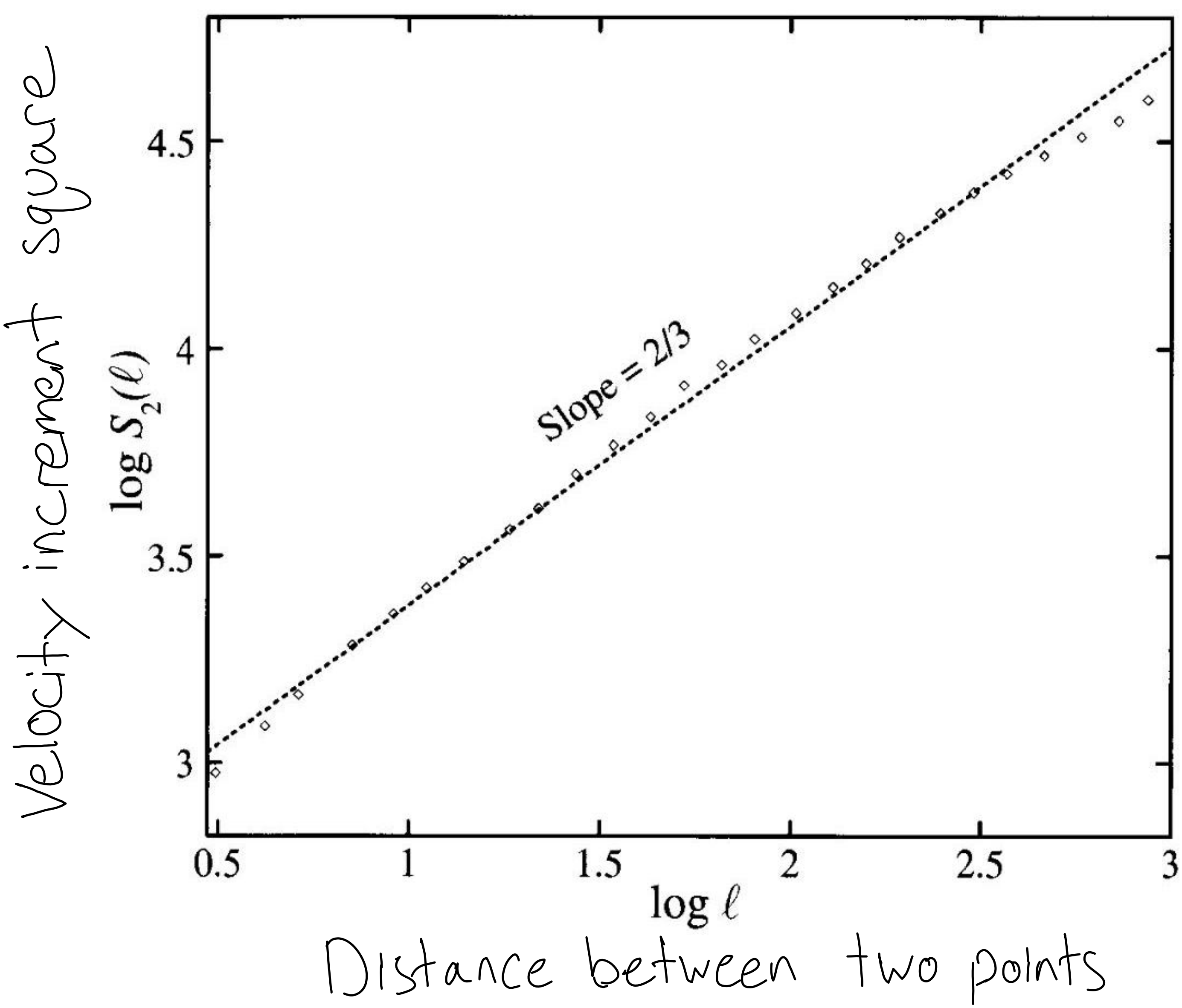


Fig. 3.1. One second of a signal recorded by a hot-wire (sampled at 5 kHz) in the S1 wind tunnel of ONERA (a); same signal, about four seconds later (b). Courtesy Y. Gagne and E. Hopfinger.

1. Characteristics of turbulence



$\Rightarrow \sigma^2 \propto \ell^{2/3}$

or $\sigma \propto \ell^{1/3}$

2. Structure of the ISM

All the gassy stuff in here

2. Structure of the ISM

The traditional three phase model at quasi-static equilibrium

1	2	3
"Cold"	"Warm"	"Hot"
$T < 300K$	$T \sim 1 \cdot 10^4 K$	$T \sim 1 \cdot 10^6 K$

2. Structure of the ISM

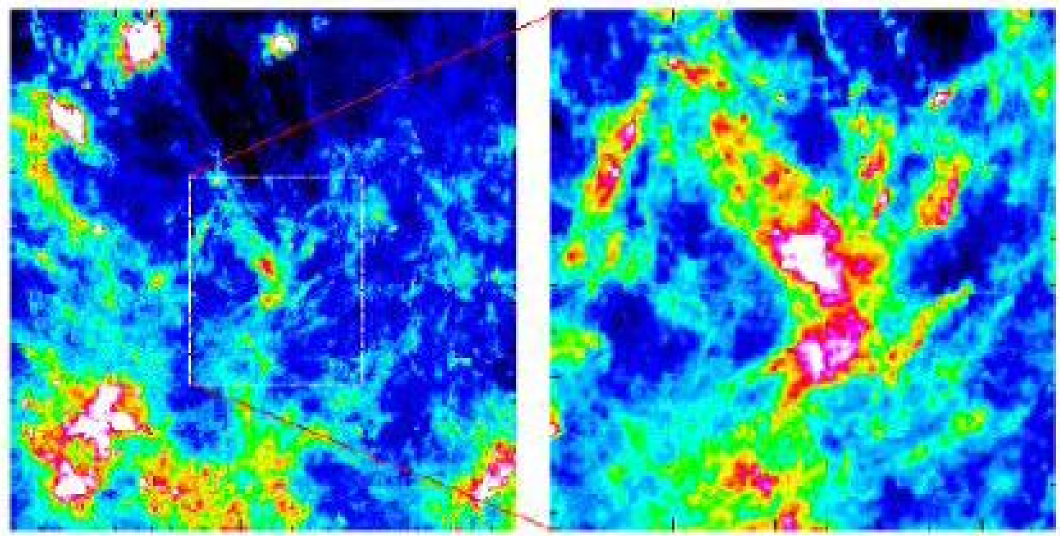


Figure 1. *Left:* IRAS 100 μm map of the Taurus molecular cloud complex, traced by the dust emission. The square is $\sim$ 4000 pc^2. *Right* Zoom of the central region (the square is now $\sim$ 400 pc^2).

Confusing self similar appearence!

But over what scale?

2. Structure of the ISM

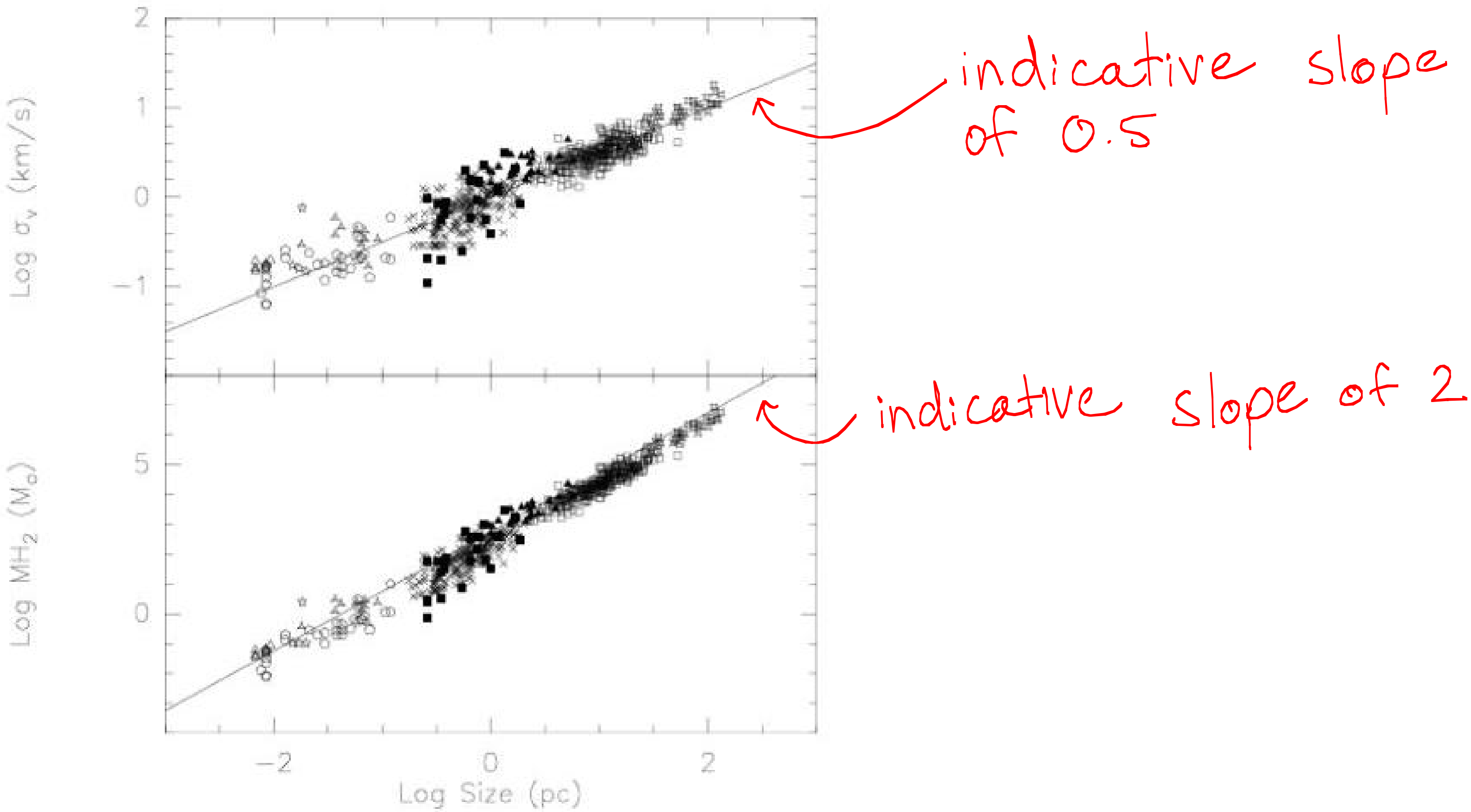


Figure 2. *Top:* Size-linewidth relation taken from various sources: Dam86: Dame et al. (1986); Sol87: Solomon et al. (1987); Heit98: Heithausen et al. (1998); MBM85: Magnani et al. (1985); Will94: Williams et al. (1994); Fal92: Falgarone et al. (1992); W95: Wang et al. (1995); Ward94: Ward-Thompson et al. (1994); Lem95: Lemme et al. (1995). An indicative line of slope 0.5 is drawn. *Bottom:* Mass-size relation deduced from the previous one, assuming that the structures are virialised. The line drawn has a slope of 2.

2. Structure of the ISM

Scaling laws:

$\sigma \propto R^q$

Several authors have identified

$$q = \frac{1}{2} \text{ to } \frac{1}{3}$$

2. Structure of the ISM

If we assume virialisation on all scales:

$$M \propto R^D$$

Where $D \sim 5/3$ to $6/3$

(Compare to graph!)

3. The relation and the implications

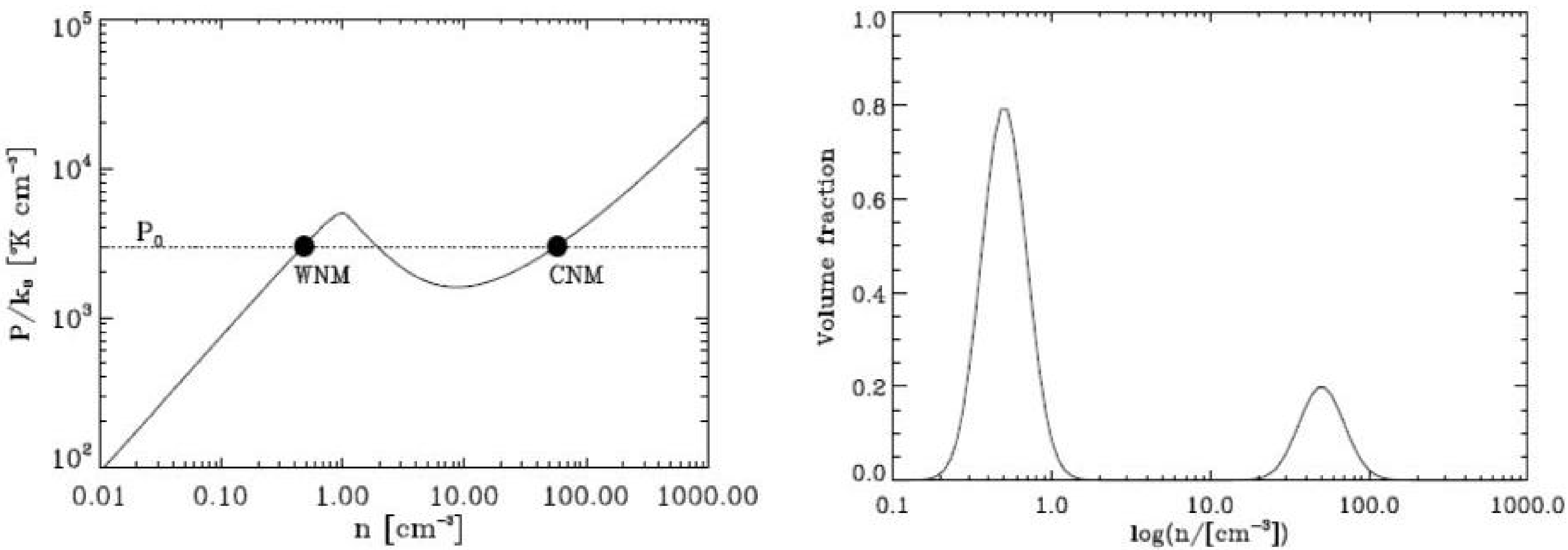


Fig. 1. *Left panel:* Thermal pressure corresponding to thermal equilibrium between heating and cooling for the atomic ISM. Figure from Vázquez-Semadeni et al. (2007), using the (errata-free) fit to the cooling function by Koyama & Inutsuka (2002). The horizontal dotted line indicates a mean pressure P_0 that allows the medium to spontaneously segregate into a diffuse, warm phase and a cold, dense one, indicated by the heavy dots. *Right panel:* Schematic illustration of the density probability density function (PDF) for the two-phase model. The vertical axis is in arbitrary, non-normalized units, and the relative amplitude of the peaks is meant to simply illustrate the fact that most of the volume is occupied by the WNM.

3. The relation and the implications

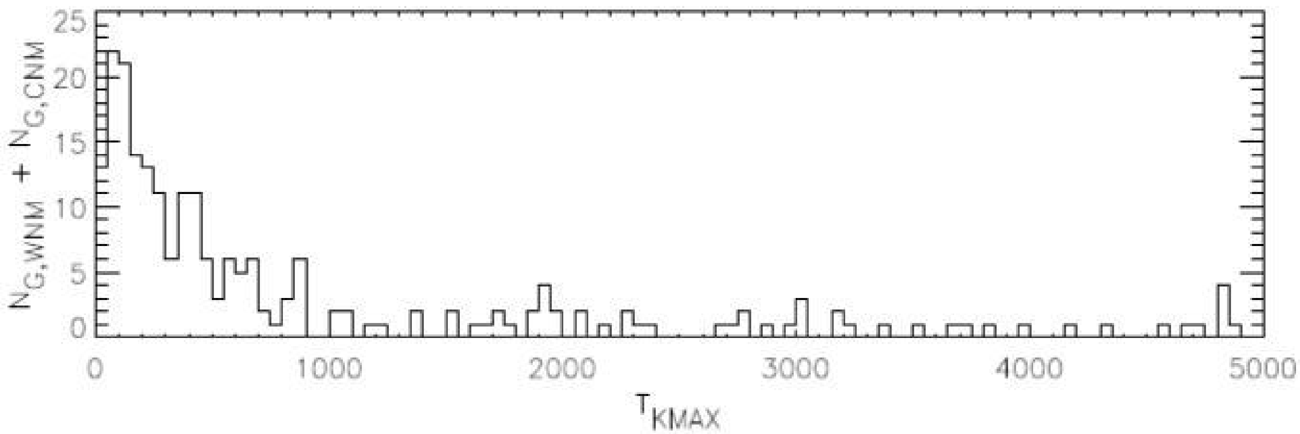


Fig. 3.— Histograms of upper-limit kinetic temperatures T_{kmax} and spin temperatures T_s for the combined set of WNM and CNM components for sources having $b| > 10°$. N_G is the number of Gaussian components; $N(HI)_{20}$ is the column density in units of 10^{20} cm^{-2}. For WNM components, spin temperatures are lower limits.

3. The relation and the implications

Turbulence experiments $\sigma \propto \ell^{1/3}$

ISM Velocity disperssion $\sigma \propto R^{q}$

$(q = \frac{1}{2} \sim \frac{1}{3})$

3. The relation and the implications

How much of the self-similar nature of the ISM is attributable to turbulence?

How much of the ISM's structure and behaviour in total is dependent on the chaotic pressure and velocity fluctuations presented?